SECRET

S.D. 686

Copy Nº 369

THE SECOND WORLD WAR

1939–1945

ROYAL AIR FORCE

SIGNALS

VOLUME VII

RADIO COUNTER-MEASURES

Promulgated for the information and guidance of all concerned.

By Command of the Air Council,

J. H. Barnes.

ISSUED BY THE AIR MINISTRY (A.H.B.)

1950

SECRET

Preface

During the First World War, 1914–1918, the function of the signals services of the Royal Flying Corps and the Royal Air Force was that which the word implied—the provision and maintenance of telecommunications.[1] In the period between the two world wars the art of wireless direction-finding developed, and Signals became responsible for radio aids to air navigation. During the Second World War the employment of new radio techniques enlarged still further the province of Royal Air Force Signals until communications were eventually only one of the many distinct yet interwoven commitments in the sphere of electronics. Amongst them was that of radio counter-measures.

The Second World War demonstrated amply that the use of radio by the air force of one belligerent could often be neutralised, or in some instances turned to some disadvantage by the employment of an appropriate radio counter-operation by the other. Sometimes a further process followed in which a radio means of combating the first counter-measure was evolved, leading to a prolonged battle of scientific and technical wits on both sides, to which the term "radio warfare" has been applied. The operations have been known individually as radio counter-measures.[2]

Part I of this volume gives an account of defensive counter-measures—those put into effect primarily to assist in the air defence of the United Kingdom in conjunction with Fighter Command. In this phase of the narrative, radio counter-measures grow from small beginnings to the status of a distinct department of Signals. The evolution of offensive radio counter-measures—those used in support of the air offensive against Germany, mainly by Bomber Command, forms the subject of Part II of the narrative. Then follows in Part III an account of radio counter-measures in a few of the important Allied landings in enemy-occupied territory, involving all arms, and commonly termed "Combined Operations". These were an occasion for the planned exploitation of certain radio counter-measure techniques under special circumstances, and are accordingly thought worthy of separate treatment.

This volume is devoted largely to the activities of No. 80 Wing and No. 100 Group in association with Fighter Command and Bomber Command, but it by no means exhausts the story of radio counter-measures. In the maritime theatre the aircraft of Coastal Command found themselves dependent to some extent on A.S.V. radar equipment in their search for U-boats. It was therefore the Germans who primarily sought to neutralise the advantages of radio in this sphere, with the Royal Air Force endeavouring to retain its advantage. An account of the radio war in Coastal Command will be found in Volume VI, Radio in Maritime Warfare, where by reason of its connexion with anti-U-boat tactics and the developments in A.S.V. equipment, it is more appropriately placed.

[1] There were isolated instances of wireless jamming, such as against Naval vessels in the Battle of Jutland and against German Zeppelins.

[2] Radio operations and counter-measures were of such wide scope that inevitably, large numbers of code words were introduced. A glossary of these terms is given at Appendix No. 18.

It is the intention in this narrative to record only those events which contributed something substantially new to the evolution of radio counter-measures as a technique; where certain campaigns and important operations have been mentioned only shortly, no reflection should be inferred of the value, magnitude or success of radio counter-measure services in them. There was naturally much repetition in type of operation from time to time and from place to place, any differences being mainly in organisation. The United Kingdom had most of the resources for research, design, development, trial and production, in addition to having almost continuous priority. Most of this narrative concerns, therefore, operations based in England, but radio counter-measures in oversea theatres also contributed towards technical and operational progress.

RADIO COUNTER-MEASURES

Contents

Appendices

1. *Knickebein.*
2. Wireless Investigation Aircraft Units.
3. German Medium Frequency Navigational Aids and Counter-measures applied.
4. Operations Room—Organisation and Procedure.
5. Typical R.C.M. Night Operation 8/9 May 1942.
6. No. 80 Wing Liaison Section at Headquarters Fighter Command.
7. Wartime Control of Radio Transmissions.
8. Ruffians and the " X " *Gerät.*
9. Benito and the " Y " *Gerät.*
10. Organisation of No. 80 Wing Outstations.
11. R.C.M. Equipment.
12. Radio Counter-measures against Big Ben.
13. Monitoring.
14. Summary of Post-war Reports on German Air Defences.
15. C.A.S. Appreciation on Effect of Window on the Conduct of Bombing Operations.
16. Bomber Command Policy Letter explaining Restricted Use of Radar Devices.
17. Radio Counter-measures Plan for Operation "Anvil "/" Dragoon ".
18. Glossary of Terms.

Diagrams

PART I

DEFENSIVE RADIO COUNTER-MEASURES

PART I

INTRODUCTION

During the early months of 1939 the Air Defence Sub-committee of the Committee of Imperial Defence sought to ensure that all scientific and technical resources in the country were put to use for air defence in the forthcoming war, and as a result of their deliberations a radio counter-measure was taken. Before hostilities began on 3 September 1939 preparations were complete for denying to the enemy the assistance of the British Broadcasting Corporation transmissions both for use as radio aids to navigation in the form of medium frequency direction-finding beacons and as instruments for spurious propaganda.[1]

As the war progressed attention was drawn more and more towards the possibilities of defensive radio counter-measures against the German night offensive. Accumulating evidence showed how greatly the German Air Force relied upon radio aids to navigation. In so far, therefore, as they were soon found to be vulnerable to the new radio counter-measures technique, these radio navigational aids promised to become the enemy's Achilles' heel, and the counter-measures were brought to play with ever increasing effort and effect. Indeed, until the Royal Air Force night-fighter defence system began to be fully effective in May 1941, this new artifice remained a primary weapon of air defence.

Apart from the R.C.M. activity on the B.B.C. system already mentioned, the early months of the war saw the collection of information as to the precise extent to which the German Air Force was dependent upon radio aids to navigation, and in what form the latter were provided. Information drawn from papers salvaged from crashed enemy aircraft, from interrogation of prisoners, and from other sources indicated that the Germans had a navigational aid which made use of narrow radio beams on a high frequency, and that this would probably be used to enable their bombers to attack targets in the United Kingdom by night and under conditions of bad visibility by day. It was realised that the use of narrow radio beams intersecting over selected targets would prove an invaluable aid to enemy aircraft. The Prime Minister therefore instructed that a special investigation to determine details of the enemy system should be carried out. This work was delegated by the Secretary of State for Air to the Assistant Chief of the Air Staff (Radio). At a meeting of the Night Interception Committee on 16 June 1940 certain recommendations were made which resulted in the formation of a ground watching organisation, and in a decision to employ aircraft specially equipped for investigating beams. At a further meeting on the following day it was decided that, as the crews of the recently disbanded Blind Approach Training and Development Unit (B.A.T.D.U.) were the only personnel sufficiently trained in beam flying capable of carrying out such an investigation, this unit should be re-formed. The new unit became the Wireless Intelligence and Development Unit, and later, No. 109 Squadron. Steps were also taken to evolve a suitable counter-measure system.

As the enemy had already an extensive system of medium frequency beacons and a medium frequency direction-finding network to assist his bomber crews

[1] Air Defence Sub-Committee (A.D.C.) Minutes and Memoranda, 1939.

in their navigation, there was obviously a wide field for radio counter-measures. It was apparent therefore that it was most advisable for this work to be co-ordinated under a single control. The control was at first given to Headquarters, Fighter Command, where full information on movements of enemy aircraft approaching the United Kingdom was available. Later, a radio counter-measure section was formed in the Directorate of Signals at the Air Ministry, followed by the formation of No. 80 Wing at Radlett, Hertfordshire, to which formation the control of all operations associated with the countering of enemy radio navigational and bombing aids was transferred. It was also necessary to establish liaison officers in the Operations Room, Headquarters, Fighter Command, to pass essential information to No. 80 Wing.

Radio counter-measures in the early stages of the war were of an entirely defensive nature, but as the tide turned, they began to take their place in the offensive and eventually justified the formation of a R.C.M. Group known as "No. 100 (Bomber Support) Group." No. 80 Wing was embodied in this Group and whilst retained primarily in its defensive role to the end of the war in Europe, it also took its share in the air offensive by providing certain ground radio counter-measures as distinct from airborne counter-measures. As the war progressed the enemy continually introduced new and various radio aids to navigation and blind bombing; consequently the counter-measures employed were many. The extent and periods of their operational use were, of course, dependent on the intensity with which the enemy exercised his various radio aids to navigation. It is this factor which has determined the form of Part I of this volume which describes in phases the defensive radio counter-measures undertaken.

CHAPTER 1

RADIO COUNTER-MEASURES, SEPTEMBER, 1939, TO SEPTEMBER 1940

At the beginning of the War the German Air Force placed great reliance on radio beams and radio beacons as navigational aids for their bomber aircraft. It was therefore important to prevent the use of such aids by hostile aircraft flying over the United Kingdom.

Knickebein

The information obtained from various sources during 1940 disclosed that the enemy had a navigational system consisting of narrow beams on the 30 megacycles per second frequency band which could be directed to intersect over a predetermined target and used for accurate bombing at night or in conditions of bad visibility.[1] As this frequency band was covered by the blind approach receiver with which all German bomber aircraft were fitted, the system could be used by the entire bomber force. The aid was called *Knickebein* and the code name Headache was given to the Royal Air Force's collective counter-measures against it. At the time, two *Knickebein* stations were believed to exist, one at Kleve (near the Dutch/German frontier) and the other at Bredstedt.

Although according to scientific theory it was then believed that these signals, because of their high frequency, could not be heard on the ground in the United Kingdom except under freak conditions of propagation, arrangements were nevertheless made for listening watches to be kept not only in aircraft but at certain ground stations along the south coast of England.[2] Later, when it was found that the scientists' theory was not borne out in practice, the listening network was extended further inland, and an extensive system of ground watching was set up over the southern half of England, some of the receivers at first being mounted on 300-foot towers. The existence of a beam laid over this country was first established on the night of 22/23 June 1940, during a flight by an aircraft of the re-formed Blind Approach Training and Development Unit,[3] and on the night of 24/25 June 1940, one of the tower listening stations reported that beam type signals were being heard on a frequency of 31·5 megacycles per second.

Concurrently with the provision of listening facilities, action was taken to provide counter-measures against the use of the beams. In the absence of suitable jamming transmitters it was decided as an emergency measure to utilise a number of electro-medical (diathermy) apparatuses as jammers.[4] Two of these sets were modified to cover the 30 megacycles per second frequency band as crude jammers without keying facilities. They were installed in vehicles with receivers for intercepting the beam signals and sent to Wyton in Huntingdon and to Boscombe Down in Wiltshire, whence they could be

[1] Appendix No. 1 for details of the German radio beam system.
[2] Air Ministry (A.M.) A.I.1 (*e*) Meeting, 9 August 1940.
[3] Appendix No. 2.
[4] Air Ministry A.I.2 (*e*) Reports, 26 June and 28 June 1940.

quickly despatched to any specified target area. Telephone tie-lines were provided to the Filter Room of Headquarters, Fighter Command, where the reports from the listening stations were received by a small body of experts specially formed for this purpose.

Meanwhile a 50-watt beam approach beacon had been hastily modified so that in conjunction with a receiver, it could emit a synchronised signal as a more suitable form of interference. By the use of this equipment it was hoped to distort the equi-signal path of the German radio beam in order that the enemy aircraft would be diverted from their course without realising it. The equipment was first set up at Wyton but was moved in a few days to a more suitable site in Norfolk. This emergency equipment was, however, not used operationally, as up to the end of June there was no evidence from the tracks of aircraft that the enemy was using beams to assist his attacks,[1] and it was considered very undesirable at this stage to disclose to the enemy by jamming that his system had been discovered.

In the meantime, reception tests of transmissions from the two diathermy sets at Wyton and Boscombe Down had revealed that their unmodulated signals were unlikely to give the desired range and jamming effect. More diathermy sets of different patterns were therefore obtained from hospitals, and twelve of the most suitable were selected and modified to act as radio transmitters with audio modulation. The sets were installed in selected police stations on the east and south of England to form a jamming screen, their switching on and off being in the hands of the police on instructions from the Control at Headquarters, Fighter Command. A number of sets were eventually provided with crystals in order to maintain a constant frequency. In addition to the rebuilt diathermy sets, five fixed beam approach beacons at airfields and three portable ones were taken over and adapted for jamming. These equipments were much superior to the rebuilt diathermy sets, since not only was their power greater, being of the order of 0·5 kilowatt, but the transmitters were already fitted with good quality audio frequency modulation.

The Deviator Method of Interference

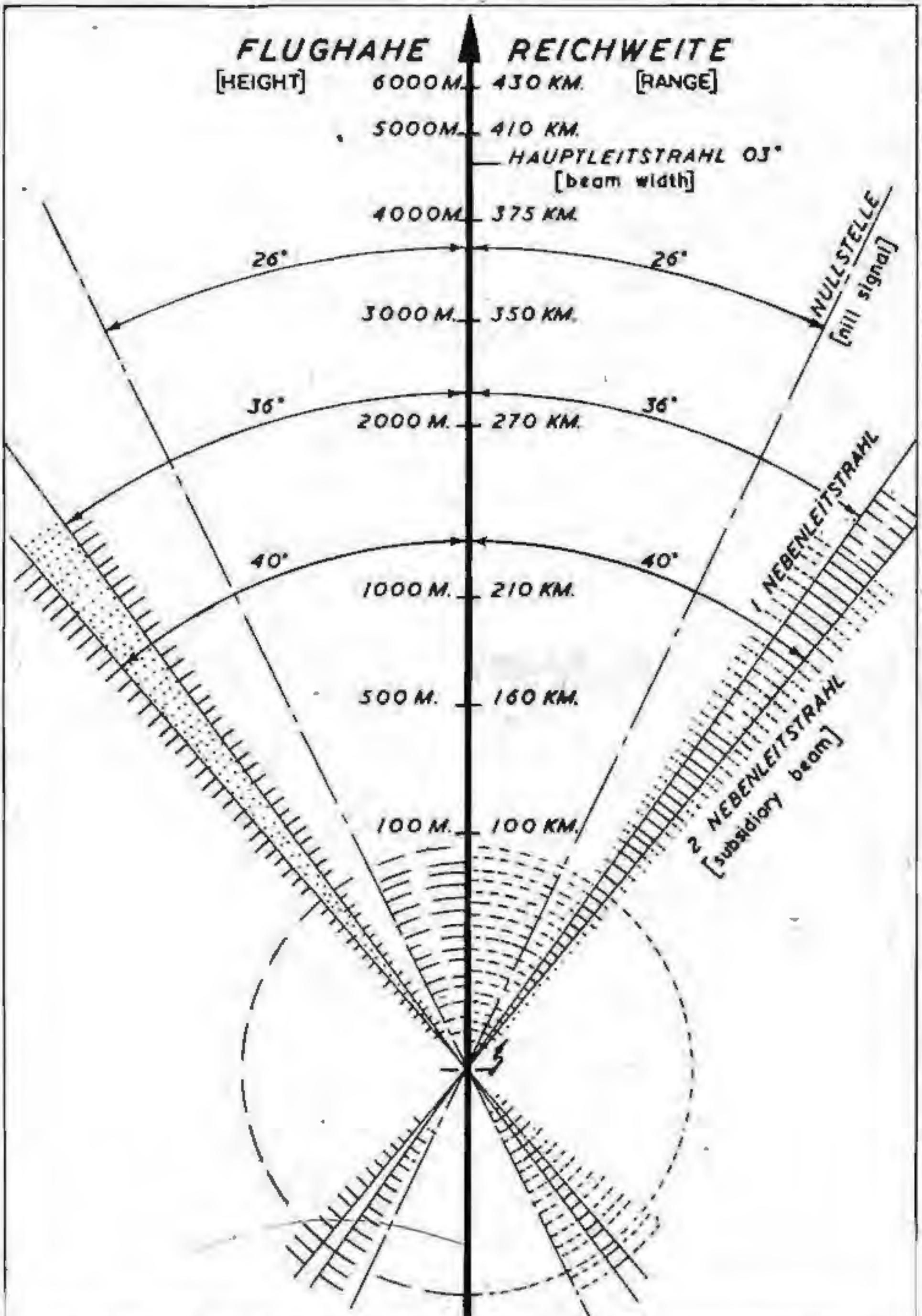
The first of the portable beam approach beacons was adapted so that it could be used as a synchronised transmitter to replace the low power beacon with which the early experiments to produce interference had been made. The method consisted of passing a received signal to a transmitter through a device which enabled the transmitter to be "keyed" in synchronism with the received signal. For synchronising purposes two receiving stations were provided, one about 50 miles north and one 50 miles south of the transmitter site at Harlestone, near Norwich. Alternative sites were thus available for picking up the enemy's signal, depending on the direction or setting of his beam.

While the arrangements for countering the beams were being prepared, an analysis was being made of the signals intercepted by aircraft of the re-formed B.A.T.D. Unit and of observations from the monitoring ground receivers. It was found that the beams originated in the Kleve district (in Western Germany near the Dutch frontier) but that the characteristic dot/dash signals received at the various ground stations were not always in the usual sequence. A theoretical diagram of an aerial array which could produce such an effect

[1] Director of Signals (D. of S.) Conference, 25 June 1940.

SECRET

DIAGRAM 1



COPY OF ENEMY KNICKEBEIN DOCUMENT CAPTURED JULY 1940

SECRET

by a combination of lobes of radiation had been produced, when a captured enemy document was obtained giving a description and methods of use of the *Knickebein* Long Range Beacon together with a diagram of the "beam" pattern.[1] The theoretical diagram was found to agree very closely with this. The diagram showed that there was a main beam with two subsidiary beams on either side, the dot/dash characteristics being reversed in the case of the first subsidiary beam on each side.[2] It was immediately realised that with a knowledge of the angular position of the side beams with respect to the main beam, if sufficient ground observations could be obtained (and by this time it had been found that reliable signals could be obtained at ground level), it should be possible to estimate the setting of the main beam.

A copy of the German beam pattern diagram was made on tracing cloth. This was placed on a map with the centre of the diagram on the site of the *Knickebein* and rotated until the characteristics obtained at the various ground stations fitted those of the diagram ; the direction of the main beam was thus determined and an immediate indication obtained from the map of the cities or towns over which the beam passed. The process was repeated for a second *Knickebein*, the intersection of the two beams then indicating the target area. This method of determining the target was found to be fairly reliable. The information was passed to the Duty Air Commodore at Fighter Command as soon as the target was determined and, at times, proved of great value.

During the last week of August two more *Knickebein* stations were identified by aircraft of the B.A.T.D. Unit, one near Dieppe and the other near Cherbourg. Both of these transmitted on a frequency of 30 megacycles per second. Information was also received of another *Knickebein* at Stavanger. Heavy raids over Britain were made in August, and from the tracks of the aircraft plotted by the Royal Air Force Home Chain radar stations, it appeared that the Kleve and Dieppe *Knickebein* were usually employed by the *Luftwaffe* for the attacks on London, while Dieppe and Cherbourg *Knickebein* were used for attacks on the Midlands and Portsmouth.

Flight tests were made during enemy raids to test the efficiency of the British jammers. On some flights it was found that the frequency of the jammers was not exactly the same as that of the enemy signal and was inclined to wander, with the result that the *Knickebein* signals could be received clear of jamming. When, however, the frequency of the jammer was identical, the enemy beam was blotted out in the neighbourhood of the jammer. In order to ensure that the frequency of the jammer remained exactly the same as that of the enemy signal, the jamming transmitters were modified to enable the frequency to be crystal-controlled.

Flight tests were also carried out on the so-called Deviator system, mentioned above, which had been used whenever the Kleve *Knickebein* was active. These tests did not give any conclusive evidence of a shift of beam, but the equi-signal zone was found to be masked. In view of these results and of the difficulties of production on a large scale, it was decided to abandon the scheme of synchronised jamming, and concentrate on the easier and more effective unsynchronised methods. It was evident that to ensure complete jamming of the signals over that part of the country covered by *Knickebein* signals, a greater concentration of transmitters with higher power was required, and that

[1] R.A.F. Wireless Intelligence Summary No. 6, A.I.1 (*e*) of 2 May 1940 includes an account of this. [2] Diagram 1.

additional listening stations on the South Coast were necessary in view of the newly installed *Knickebein* which had become active in Northern France.

Medium Frequency Beacons

At the outbreak of war, preparations were already complete for synchronisation of a number of transmissions of each British Broadcasting Corporation (B.B.C.) programme, so dispersed as to make it impossible for the German Air Force to use them as medium frequency beacons for navigation by means of aircraft direction-finding loops. At the same time it had been arranged to prevent intrusions by enemy propagandist announcers into the B.B.C. programme, by filling all gaps between items and by having the B.B.C. announcer state his name before making his announcement in order to familiarise the public with his voice and mannerisms. This pre-war plan was put into effect upon the outbreak of war and was the first radio counter-measure to be used.[1]

It was well known before the war that the enemy favoured the use of radio aids to navigation and that throughout Germany there existed a vast network of M.F. radio beacons. After the enemy occupation of France and the Low Countries in 1940, he expanded this network to form an elaborate system throughout these countries to assist the navigation of his aircraft in attacks upon the United Kingdom. The Air Officer Commanding-in-Chief, Fighter Command, stressed that the radio beacons were being used to assist German Air Force aircrews to navigate to their targets, and he urged as an immediate operational requirement the provision of a suitable counter-measure. In spite of the usually accepted theory that " night effect " rendered M.F. beacons useless for accurate navigation at night, it was decided to undertake counter-measures. Information eventually obtained from prisoners justified the wisdom of this decision.

In order to render the beacons less useful to the enemy, a system of masking was put into operation. At intervals throughout the country were sited a number of transmitters, the frequency of which could be changed rapidly. These were designed to re-radiate the enemy beacon signals and so render them unsuitable for direction-finding purposes over the United Kingdom. The enemy signal was used to trigger the counter-measure transmitters. This system was one previously devised by the Radio Branch of the Post Office Engineering Department to guard against the use of illicit radio beacons in this country by enemy aircraft.[2] The equipment was given the name Meacon (masking beacon). The meaconing principle was more subtle than plain jamming, as, being a re-radiation of the original beacon signal, there was no frequency difference and no difference in keying, but simply a different point of radiation. Thus the presence of meaconing could not readily be detected in an aircraft fitted with normal receiver equipment, and false bearings were obtained without any but the most experienced operators realising that counter-measures were being applied.

A comprehensive scheme for the provision of Meacons was drawn up by the Air Ministry in conjunction with the G.P.O., so that effective cover could be given to the whole country, and the installation work was pushed on with all speed. The first Meacons were ready for service during July, 1940, and by the end of August of that year fifteen sets of equipment at five different sites were in use operationally to mask enemy beacons. These sites were at Flimwell,

[1] Appendix No. 7, War-Time Control of Radio Transmissions.
[2] Post Office Engineering Department Radio Reports Nos. 597, 598 and 599. Also Post Office Instruction G.B.1, *et seq.* " The G.B. Scheme."

Harpenden, Templecombe, Henfield and Petersfield originally, but were later increased in number.

The successful operation of Meacons was not only dependent on the skilled manipulation of the equipment employed, but relied to a major degree on a precise knowledge of the German "systems" of call signs and frequencies allocated to his beacons, together with their radiated powers and localities. It will be seen that the supply of rapid information as to when "systems" were changed, played a very important part throughout the war in the application and control of meaconing.[1] Not all the German M.F. beacons were meaconed. Aircrews in Bomber Command made extensive use of enemy beacons during their sorties, so certain beacons were left unmasked during the time they were required. To prevent this being realised by the enemy the beacons selected for this purpose were changed from day to day.

As a supplement to the Meacon scheme during its build-up period, arrangements were made to use as jammers about a hundred T.77 transmitters which were already installed for ordinary communication purposes at Royal Air Force stations throughout the United Kingdom. Thus the country could be covered with jammers arranged in groups, each group being capable of dealing with the enemy beacons likely to be used in its area by enemy aircraft. The need for application of the scheme did not, however, arise. Consideration was also given to the use of high power B.B.C. transmitters to jam the whole band of frequencies used by the enemy beacon system. It was determined that ten transmitters would be required, the frequency of each transmitter being made to vary over a band of 30 to 40 kilocycles. Unless these had been operated in synchronised groups of at least three transmitters, however, the aid provided to the enemy by the use of the B.B.C. stations as beacons would have probably outweighed any advantage to be derived from their use as jammers.

By the end of this phase there were certain indications suggesting that the enemy realised that counter-measures were in operation and that all was not well with his aircrews when using radio beacons over England. The evidence was as follows :—

(*a*) The enemy frequently reduced the power of his beacons to such an extent that the received signal could not be used to drive the Meacon transmitter. With this reduced power, however, the beacon was probably of little value to enemy aircraft over this country and could only be used for "homing".

(*b*) The beacons were no longer used by the enemy on a fixed methodical system. Changes of frequency and call-sign were made at irregular times—a system which added to the difficulties of his aircrews.

(*c*) Enemy aircraft had been heard to report that their D.F. sets were out of order.

(*d*) Royal Air Force interception stations, listening to enemy radio transmissions, reported a marked increase in the number of enemy aircraft requesting D.F. fixes while over the centre of England from stations of the *Luftwaffe* safety service organisation, a procedure not usually hitherto employed owing to the danger of their transmissions disclosing the position of the aircraft calling.[2]

---

[1] Appendix No. 3, German medium frequency navigational aids and counter-measures applied.

[2] This led to the meaconing of enemy aircraft D.F. signals.

It was believed that pulse transmissions were used by the enemy during the invasions of Norway and Holland, but although there was no evidence of these being used as navigational aids over this country, precautions were nevertheless taken. Certain transmitters were earmarked to act as jammers, a frequency band of 3 to 6 megacycles per second being covered.

Controlling Authorities

With the increasing availability of equipment and an increasing number of jamming stations, it was necessary to decide in whom the control of radio counter-measures should be vested. On 25 July, 1940, A.C.A.S.(R) presided over a meeting which considered whether this control should be exercised by Headquarters, Fighter Command, by the "Y" Service, or by an entirely separate organisation.[1] As it was agreed that the useful application of these measures could only be achieved by a controller having a complete knowledge of enemy aircraft movements, the early control was placed in the hands of Fighter Command. It was soon apparent, however, that radio counter-measures would be required on an ever-increasing scale, involving a very much greater organisation than had been originally envisaged, and requiring more independent control.

[1] Minutes of Assistant Chief of Air Staff, A.C.A.S. (R) Meeting on 25 July 1948.

CHAPTER 2

RADIO COUNTER-MEASURES, SEPTEMBER 1940 TO MAY 1941

Formation of No. 80 Wing

The decision having been taken by Air Ministry that the control of radio counter-measures should be undertaken by an organisation other than Headquarters, Fighter Command, arrangements were made for the establishment of No. 80 (Signals) Wing to act under the direct operational control of Air Ministry. After a transitional period at " Radium " (alternative Headquarters, Fighter Command), No. 80 Wing opened at Aldenham Lodge Hotel, Radlett, Hertfordshire, on 14 October 1940. This location was chosen by reason of its proximity to the main London–Birmingham G.P.O. trunk cable which facilitated considerably the difficult problem of communications to many remote outstations. It was also within easy access of Air Ministry and of Headquarters, Fighter Command at Stanmore. The establishment included a Central Operations Room which received reports from Watcher Stations, Intelligence, and other sources, and issued operational instructions to the various types of jammer outstations.[1] Headquarters, No. 80 Wing worked throughout in close co-operation with Headquarters, Fighter Command by means of liaison officers who, in addition to Home Security duties (closing down of B.B.C. stations and other M.F. transmitters), were responsible for keeping Headquarters, No. 80 Wing informed by telephone of movements of enemy aircraft during their attacks on this country. This was done by passing a running commentary of the information available in the Operations Room at Fighter Command.[2]

By September 1940 the Germans had developed the narrow beam *Knickebein* system by the installation of additional transmitters on the north coast of France, making a total of five stations, and had used these during attacks on this country. Preliminary radio counter-measures had been taken against them but it was soon realised that considerable expansion of these counter-measures was necessary to meet the new threat. A scheme to reduce the value of the enemy medium frequency beacon system as a navigational aid had also been instituted and was in process of development.

The phase from September 1940 to May 1941 covers the period of greatest intensity of enemy night attacks on the United Kingdom, decreasing only when a considerable portion of the German Air Force was transferred to the Eastern Front for the attack on Russia during mid-1941. During this phase several additional radio navigational aids were brought into operation by the enemy. These included two new narrow beam systems employing the " X " *Gerät* and " Y " *Gerät* which were capable of being used for blind bombing of individual targets, the accuracy being very much greater than that possible with the *Knickebein* system. More *Knickebein* installations were erected, so sited as to increase the area of the United Kingdom over which good beam

[1] The Operations Room organisation, layout and procedure are described in Appendix No. 4.

[2] Details of the work undertaken by these officers are given in Appendices Nos. 6 and 7.

intersections could be obtained by making full use of the coastline of Northern France and Holland. A total of nine *Knickebein* stations was now available and the frequencies used were 30, 31·5 and 33·3 megacycles per second.[1]

Aspirin

During this period a number of transmitters, some of high power, for which contracts had been placed during the previous period June to September 1940, became available as jammers. Some of these were sited on the approach lanes to the various vital target areas such as London, the main Midland industrial centres, Liverpool, South Wales and Bristol, in order to render the beam signals unusable during approach to the target. Other transmitters were placed near the east and south coasts so that not only were the ports protected but the area inland was covered by beam jamming signals. The code name Aspirin was given to these jammers of *Knickebein*.

As the installation of good quality jamming transmitters progressed, the modified diathermy sets which had filled the gap while better transmitters were being obtained, were gradually withdrawn from Police Stations and, after rebuilding, were installed on certain of the newly-established jamming sites.

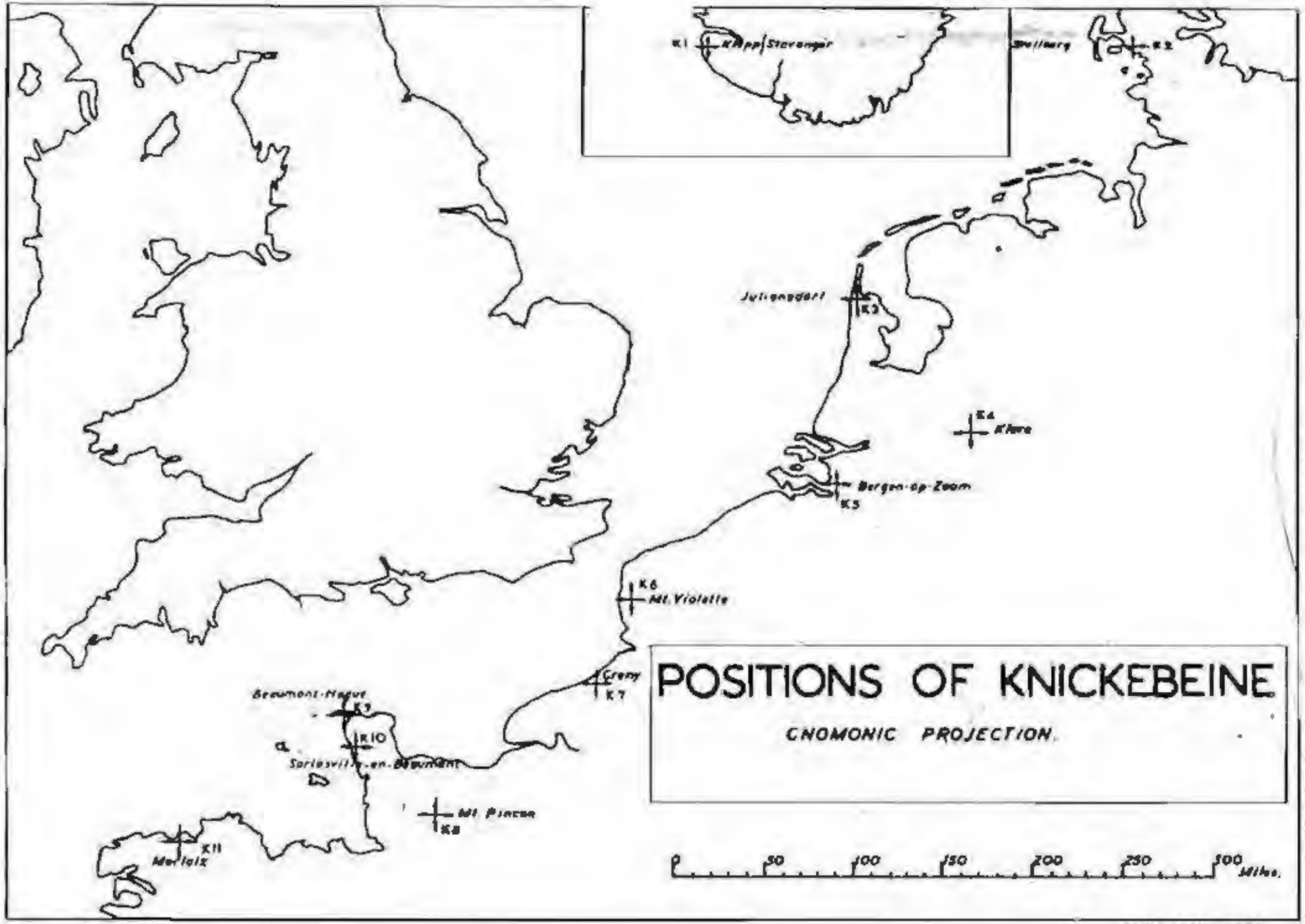
In order to maintain at a high level the efficiency of the transmitters as jammers, it was essential for the frequency to be kept as closely as possible to that of the enemy signal. It was necessary also that changes of characteristic of the beam signal, signifying a change of setting of the beam, were observed as soon as possible. To enable both of these functions to be carried out, each jamming station was equipped with a receiver so that it could be self-monitoring, all jammers being switched off for ten minutes at predetermined times to allow readings to be obtained. The time was subsequently reduced to five minutes as it was realised that the enemy could make use of this period of freedom from jamming to check his position. This interval was eventually cut out altogether when special monitor stations with directional aerials became available.

Direct evidence that the enemy was now realising that counter-measures were being applied to *Knickebein* was given by an occurrence on the night of 24/25 September 1940 when, during an attack on London, the first recorded instance of an interchange of frequencies between two *Knickebein* was made.[2] This change was unquestionably an attempt to obtain relief from our counter-measures. At a later date statements by prisoners were received indicating a general mistrust of *Knickebein*, which they had found to be variable or unreliable over the United Kingdom.[3] One statement which referred to the September period indicated that it was known in Germany that *Knickebein* had been countered by producing effects which " obliterate the weak beams and turn aside [*sic*] the strong beams from the target."

By January 1941 it was apparent that the enemy's scientific experts were at last beginning to believe their pilots' reports that *Knickebein* over this country was unreliable. An interesting report was received describing a lecture given by an engineer to a number of experienced German pilots.[4] The pilots were told that the area of disturbance of the beams was purely local, and that if on reaching the disturbed area they continued on their course they would

[1] Diagram 2. [2] Daily Operations Reports R.C.M./15, 25 September 1940.
[3] A.D.I. (K) Reports Nos. 24/41 and 44/41 (Air Ministry). [4] *Ibid.*, No. 31/41.

DIAGRAM 2



SECRET

eventually pick up the beam again. The report concluded by stating that the audience did not seem to be at all impressed by the advice given to them. Since the results of one of the periodical tests, carried out on a particular night by an investigation aircraft at operational height using a German radio receiver, had shown decisively that the beam had been well covered by the jammers over the whole of its length except during the "shut down" period mentioned above, it was probable that the enemy lecturer had arrived at a wrong conclusion.

Anticipated Enemy Methods of Evading Counter-Measures

It was to be expected, judging from the number of reports from prisoners received during January 1941 and from Royal Air Force air tests, that since *Knickebein* was now of little use to German pilots over this country, the enemy would endeavour to introduce some new method of overcoming our counter-measures. The most likely methods that the Germans might adopt were considered to be :—

(*a*) A change of radio frequency, *i.e.*, frequencies other than 30, 31·5 and 33·3 megacycles per second, which had been used up to this time.

(*b*) A change of modulation frequency.

(*c*) The adoption of frequency modulation.

The first of these was considered to be the most probable, although it would entail a general modification to the German blind-landing receiving equipment used for the reception of *Knickebein*.

The high-power jammers mentioned above were already able to meet the first contingency. Modifications to the small transmitters were put in hand so that these jammers could be adjusted to any radio frequency in the band and to changes in the audio modulation frequency. Provisioning action was also taken for a number of modulation units covering a wider band of audio frequencies to meet the second contingency. The third alternative, a change to frequency modulation, was thought to be very much less probable. Nevertheless, consideration was given to meeting this more remote contingency should it occur, by an addition to the jamming transmitters known as a "wobbulator".

Up to the end of this phase, however, there were no indications of any major change in the technique of the *Knickebein* system. Nevertheless, one important change which did occur was in connection with the times of operating. At first the *Knickebein* stations were switched on for long periods before an attack, sometimes during daylight, while the beam was adjusted to the correct target setting. The enemy must have realised that this was giving away useful information since he progressively cut down the periods of transmission before an attack until, finally, those *Knickebeine* which were to be used during an attack were not switched on until the aircraft had crossed the English coast. This procedure called for a high standard of efficiency in all the sections of the counter-measure organisation. It also rendered difficult, and often impossible, the prediction of the target from the beam intersection, as it was necessary to switch on the jammers immediately the enemy signal became active.

Ruffians and the "X" *Gerät*

In the middle of August 1940, "Y" interception stations on the Kent coast reported[1] a new signal with beam type characteristics on a frequency

[1] R.A.F. Wireless Intelligence Report A.I.1 (*e*), No. 8.

of 74 megacycles per second. There was insufficient data to establish the signal definitely, and as the frequency was not covered by any known German radio receiver, the report was treated with reserve. By the end of the month, however, further signals in this frequency band had been recorded, and later, from ground D.F. stations and investigations carried out in aircraft, beams were established which appeared to originate in the Calais and Le Havre areas and also from Cherbourg. The signal characteristics differed from *Knickebein* transmissions in radio frequency, modulation frequency, and rate of keying, but they were sufficiently similar in principle to suggest that they might be employed in some kind of routeing system, possibly for surface craft.

By September 1940 considerably more information concerning the new beams had been obtained from Intelligence sources and from further investigation flights. It then appeared that these beams were connected with the "X" *Gerät*, which was a new system of blind bombing for use by aircraft of a specialist enemy squadron.[1] It was indicated that the systems had an accuracy of the order of 10 to 20 yards over London. It was established that the system consisted of fine (narrow) and coarse (wide) approach beams, and fine and coarse cross beams originating in the Cherbourg and Calais areas respectively.[2] By a process of deduction, the Air Scientific Intelligence Section of the Air Ministry showed that the time of flight between two fine cross beams, directed across the fine approach beams, would give the ground speed of the aircraft along the line of approach, and this in conjunction with the position of the second fine cross beam relative to the target would be sufficient to give the correct instant of bomb release at a given height. These deductions were later proved to be correct, so that if the expected accuracy were attained, here was a system of blind bombing which was an even greater threat than *Knickebein*.

Proof that the threat was an extremely serious one was produced later by the Air Warfare Analysis Section of the Air Ministry.[3] This Department carried out an investigation after an attack on Birmingham by the specialist *Luftwaffe* Squadron *II KG.100*, on the night of 26/27 October 1940. By correlating the bomb plots with the direction of the beams it was shown that as regards "line" in particular, the accuracy of the system was of an extremely high order.

Counter-Measures against the "X" *Gerät*

Immediate steps were taken to provide a radio counter-measure to this new system to which the code word Ruffian had been given, but a search throughout the country failed to produce any suitable transmitters with the requisite frequency coverage of 65 to 75 megacycles per second. A number of tests were made in an attempt to increase the frequency range of existing transmitters, but the output power after modification was too low for these to be effective as jammers. Eventually a Gun-Laying pulse transmitter, Type G.L./T Mark 1, was converted, first into a pulsing jammer, and later with greater effect, into a continuous wave transmitter with grid modulation. An emergency transmitter was also produced at short notice by the Royal Navy Signals

[1] A.S.I. Interim Reports Nos. 1 and 2. [2] Appendix No. 6.
[3] Air Warfare Analysis Section, Air Ministry (A.W.A.) Report No. BC/2, 15 November 1940.

School, Portsmouth to cover the frequency band with alternative audio modulation frequencies, since the enemy signal had been variously reported as 900 to 1,000 and 1,500 cycles per second. This transmitter was keyed at 120 per minute—the rate of the enemy signal.

Installation of Bromide Transmitters

The transmitters used for this counter-measure were known by the code name Bromide. The first of these—the converted G.L. transmitter—was installed at Hagley near Birmingham, and the R.N. Signal School transmitter was sited on high ground at Birdlip in Gloucestershire. The sites were chosen to cover the approach route from Cherbourg to the Midlands, this area having been subjected to attacks by enemy aircraft using the new radio beam system. Both transmitters were brought into operation during the first week of November 1940.

A supply of Gun-Laying pulse transmitters was obtained from the War Office and their installation was carried out with the utmost speed immediately they were delivered by the firm making the modifications. The number of jammers covering the Midlands was augmented, while other jammers to protect Liverpool and Manchester were provided by the middle of November. This was followed by the installation of transmitters to screen London. In all cases the jamming transmitters were sited to be adjacent to the line from Cherbourg to the target areas since it had been established that the Cherbourg beam was always used for the approach to the target. It had not been expected, however, that in the early stage the jammers would have any marked effect owing to the number of frequencies used simultaneously by the enemy in this system and the limited number of jammers available; also the personnel available for operating the jammers were unskilled in the handling of the complicated equipment with the precision and speed necessary for its efficient use. The monitoring of the jammers to ensure that these were on the exact frequency of the enemy signal also proved to be a difficult problem.

Capture of Crew from the German Squadron *II K.G.100*

A fortunate incident in mid-November, 1940 resulted in the capture of a crew, less the Observer who was killed in the crash, from an aircraft of the specialist German "pathfinder" Unit *II KG.100*, which alone at that time used the "X" *Gerät* system. This capture was the direct result of one of No. 80 Wing's counter-measures, the meaconing of enemy beacons. The Navigator stated that he was completely lost owing to wide divergence in readings between his master compass and D.F. repeater compass.[1] This difference he concluded later, quite correctly, was due to a masking station reproducing the characteristic signal of the German Air Force M.F. beacon which he had been using.

A fairly comprehensive description of the apparatus and the method of its use was obtained from the crew, but efforts to salve the aircraft, which had come down in the sea, were unavailing.[2] Later several pieces of apparatus connected with the "X" *Gerät* were fortunately recovered. These included two receivers and a "clock" for computing the ground speed. In spite of

---

[1] A.D.I. (K) Report No. 908/40.

[2] No. 80 Wing Report No. 1, 8 December 1940, Appendix "A."

damage due to submersion in the sea some valuable information was obtained.[1] One of the results of the examination showed that the receivers were fitted with narrow band audio filters designed to operate on a frequency of 2 kilocycles per second, with a tolerance of ± 50 cycles per second. This discovery entailed a change in the audio modulation of the Bromide transmitters. Moreover it was necessary to keep an accurate check on the modulation during operations to ensure that it did not wander outside the close limits necessary for the jamming to be effective.

Installation of Additional Listening Stations

As the installation of Bromide transmitters progressed, observations were continued from ground listening stations and from aircraft. Listening stations were set up in the Bournemouth area since the approach beams from the Cherbourg group of transmitters passed over the district and early warning of an attack could thus be obtained. Mobile receivers were also used in this area, specified routes being patrolled where Ruffian signals were heard. The routes used by the vehicles were calibrated, and as soon as the operator was able to report an equi-signal, the exact position of the vehicle was telephoned from the nearest telephone box to the main Bournemouth station and passed to the Operations Room at Headquarters, No. 80 Wing. At a later stage, in order to save time, radio telephone links were used between the vehicles and the local listening station. It was not, however, always possible to differentiate at this time between the main beams and the large number of subsidiary beams. An example of this occurred on the night of 24 November 1940 when the main Ruffian beam was directed on Bristol. One of the subsidiary beams covered the Bournemouth area and gave the impression that Coventry was likely to be the target that night.

A considerable amount of flying for determining the direction and frequencies of the beams was a regular feature of the daily operations.[2] These flights were made by No. 109 Squadron, which had been formed from the original B.A.T.D.U., renamed in October 1940 the Wireless Intelligence Development Flight. They were often made in bad weather, entailing a high standard of flying and navigation, and were invaluable in obtaining the desired information.

Analysis of the Ruffian System

By the end of 1940 an analysis of the reports from ground listening stations and from flights had enabled a picture of the Ruffian beam systems to be obtained and a Beam Predictor devised.[3] This could not, however, be as simple as that provided for *Knickebein* owing to the number of subsidiary beams; it was first necessary to find the rough position of the coarse approach beam in order to determine which of the many fine beams on a particular frequency was the one used for the target approach. An added complication was the fact that although in its simplest form five separate beam systems (one coarse and one fine approach, one coarse and two fine cross) were needed, a total of seven transmitters was sometimes used. These were distributed as follows :—

Approach : One course, two fine.
Cross : One coarse, three fine.

---

[1] A description of this instrument and the method of use is given in Appendix No. 8.
[2] Appendix No. 2.
[3] No. 80 Wing Report No. 15.

The beams additional to those necessary in the simplest form of the system were used to duplicate the fine beams, probably in case of electrical failure or as a safeguard against jamming. Determination of the frequency used for the approach beam was aided by the discovery at this period that the Germans used frequencies in the band 66·5 to 71·1 megacycles per second for approach beams and 71·5 to 75 megacycles per second for cross beams. In the middle of January 1941 two more Ruffian transmitters became operational from the Morlaix area between Cherbourg and Brest, and were used for *Luftwaffe* attacks on the West Country and South Wales. The approach to the target was made along the beams from these transmitters, the Cherbourg beams being used as cross beams.

With the successful operation of the first batch of seventeen Bromide transmitters at widely spaced points over the country, and with improvements in the manipulation of the equipment, there were indications that the Germans were reacting to the interference that was being caused to the Ruffian system. The system was no longer set up in the afternoon preceding a night raid, or, if it were so aligned, both the frequencies and the settings employed were different from those which were used later. During operations certain of the beams had super-imposed on them at regular intervals a morse letter, evidently to assist aircrews in identification of the correct beams.

After a lull of some weeks, attacks by enemy aircraft using the Ruffian system were renewed in February with significant changes in an attempt to avoid counter-measures. All the transmitters available to the enemy at the three sites were switched on during operations so that nine frequencies were active simultaneously, rapid changes of frequency being made to certain of the "fine" beams during attacks. It was found also that instead of the frequencies being spaced 0·5 megacycle per second apart and divided between the sites in two well defined bands, frequencies approximately 0·25 megacycle per second apart were being radiated. These were distributed at random between the three sites and identification was thus made more difficult. Identification letters continued to be superimposed on the beam signals, but they were not altered when a frequency was changed.

Target Prediction

Prediction of target settings became almost impossible in the time available, as the Cherbourg beams were used for either approach or cross beams, and as the pattern of beams from the Cherbourg transmitters was such that while certain of these might have been used as cross beams for attacks in the West, subsidiary beams could have been interpreted as being used as approach beams to the Midlands. This may well have been another deliberate action by the enemy to confuse. In order to overcome these difficulties, the Morlaix and Cherbourg beams were jammed by the Bromides in Devon, in the Bristol area, and in Wiltshire, while the Calais beams were jammed by the London group of stations. Jamming was supplemented by the Midland and Northern Bromides.

Close co-operation between all jammer and watcher stations was necessary to overcome the advantage the enemy was seeking to obtain by changes of frequency. Changes appeared to be made at the times at which the leading aircraft of the German specialist squadron (*II K.G.100*) made their final approach to the target.[1] By means of a special landline communication system

[1] Appendix No. 8.

from Headquarters, No. 80 Wing, to certain selected watcher and Bromide stations, it was usually possible to follow any such change of frequency within three or four minutes.

During June 1941 the Morlaix transmitters were used less frequently by the enemy, and ceased radiating altogether on the 21 June 1941. Frequency changes continued to be made on the Cherbourg and Calais transmitters, three changes on one transmitter being recorded on several occasions. At this time the enemy appeared to realise that by retaining the same recognition letter after a change of frequency he was giving a useful lead as to which station had changed frequency. As he changed the frequency and identification letter of the various transmitters at different times, however, it was still possible for particular transmissions to be recognised.

Effect of Bromides

A further report on the Ruffian system by the Air Warfare Analysis Section (A.W.A.S.) of the Air Ministry was issued in February 1941 in which it was shown by the same system of analysis as that previously used that the accuracy since 15 November 1940 had deteriorated materially.[1] Evidence that this deterioration had been caused by radio counter-measures was obtained from the crew of a *II K.G.100* aircraft which crashed on 13 March 1941.[2] It was stated by them that by November 1940 it had been definitely assumed that the interference to the beams had been caused by counter-measures. The interference to the pilot (approach) beams was described as very serious in December and January, and again when disturbances on the cross beams first began to be experienced. The later statement is interesting in that it was not until about the middle of January that sufficient transmitters became available for jamming the cross beams in addition to those for the approach beams. Further support to the evidence that radio counter-measures against the Ruffians were effective was given by a detailed analysis by the Air Warfare Analysis Section of an attack on St. Athan airfield in Glamorgan on 28/29 April 1941.[3] On this night the cross beams were adequately jammed, but owing to the small number of transmitters in the West Country it was not possible to give full coverage to the approach beams. The result was that the enemy was able to make an attack which was extremely accurate in line but had an error of one mile in range. Although up to the end of May 1941 and later, Ruffian transmissions continued to be made, there was a steady decline in the use of the system by the *Luftwaffe* Unit *K.G.100*. This may have been due to the enemy's preoccupation with the Eastern Front, but the evidence points to a growing lack of confidence in the system.

Bombing of Ruffian Transmitters

In addition to interference with the enemy beam system by radio counter-measures, consideration was also given to destroying the enemy transmitters by bombing. Although the exact position of the beam transmitters had been established, it was realised that their destruction would, for two reasons, present a difficult task. Firstly, the targets were neither conspicuous nor particularly large; and, secondly, by reason of the value the Germans attributed to the installations, the defensive measures were on a heavy scale. It was known,

[1] A.W.A. Report No. BC/G/2, February 1941. [2] A.D.I. (K) Report No. 341, 1941.
[3] A.W.A. Report No. BC/G/5, May 1941.

however, that they were experiencing considerable difficulty in obtaining spares for Ruffian equipment. It was to be expected therefore that bombing attacks resulting in even minor damage to the transmitters would cause considerable embarrassment and interfere to a large extent with the use of the Ruffian system.

In November 1940 it was decided to begin offensive action against the beam transmitters in the Cherbourg area. Attacks were to be carried out by aircraft of the Wireless Intelligence and Development Unit (later No. 109 Squadron) which had been engaged for some weeks on the investigation of the Ruffian system. Close collaboration was maintained with the Telecommunications Research Establishment (T.R.E.) on the production of a suitable technique for attacking, and the following methods were proposed as practicable :—[1]

(*a*) Use of enemy beam for direction, and the cone of silence for range.

(*b*) Use of enemy beam for direction in conjunction with a landmark to fix range.

(*c*) Use of two beams in conjunction with marker bombs to given an aiming point.

(*d*) Use of enemy beam for direction, with C.H.L. Station for range.

(*e*) Use of C.H.L. Station for direction and range.

(*f*) Use of a Royal Air Force radio beam for direction and C.H.L. for range.

(*g*) Use of a Royal Air Force radio beam for range and German beam for direction.

(*h*) Use of two Royal Air Force beams.

It was realised that attacks could only be sustained by adopting a wide variety of methods of approach since each of the courses noted above had certain inherent limitations, *e.g.* :—

(*a*) The use of the enemy beam for line or range could be easily countered by local jamming or by the temporary switching off of the transmissions.

(*b*) Beams set up from this country were susceptible to enemy jamming, and attacks dependent upon fixing a position from the ground must pre-suppose favourable weather conditions.

Clearly no method could be relied upon exclusively, so that it was decided to proceed with the development of each scheme individually, and to begin with methods (*a*) and (*b*) mentioned above.

Use of Enemy Beam in Conjunction with Cone of Silence

The pilot was to fly down the enemy beam until he heard the cone of silence which was assumed to be vertically over the target. Thereafter he turned at a known rate until flying on a reciprocal course and parallel to the beam for a certain time. He then turned again at a known rate through 180°, flew down the beam and released his stick of bombs at a calculated time.

Use of Enemy Beam for Direction in Conjunction with Landmarks to fix Range

The pilot approached along the enemy beam, identified some definite landmark lying along the line of approach, and calculated his range from there to

[1] No. 80 Wing File S.3018/1/Sigs., Encl. 13A.

the known target. This method, provided good weather conditions prevailed, was considered particularly suitable for attacks on the Cherbourg Peninsula, easily identified from the air by its distinctive coastline.

The offensive commenced on the night 13/14 November 1940, when two Whitley aircraft attempted an attack on the transmitters in the Cherbourg Peninsula during a large-scale enemy raid on Coventry. Coincident with the bombing, both *Knickebein* and Ruffian transmitters temporarily ceased transmission and later evidence proved that at least one had received a direct hit. This flight also provided valuable evidence as to the scale of the enemy defences. Considerable anti-aircraft fire was encountered and two parallel lines of balloons were observed. The latter had been placed to one side of the transmitters presumably in order that their wire cables should not interfere with the beam transmissions. Royal Air Force attacks continued throughout November and it was soon clear that the enemy was aware of the attacker's intention to fly down the beam and would, therefore, be lying in wait. Consequently, every effort was made to avoid routine procedure, each programme being carefully worked out to provide variation in the time of attack, height and direction of approach, by making use of the subsidiary beams. Defensive measures by the enemy had been steadily intensified, and the use of searchlights and anti-aircraft guns capable of being turned with the beam was suspected. Although no direct hits could be proved there was evidence that the enemy was considerably embarrassed by these attentions.

Attacks during the first three months were made by Whitley aircraft, but in February 1941 the establishment of No. 109 Squadron was increased to include a striking flight of 4 + 2 Wellington aircraft for this specific purpose. Meanwhile T.R.E. had been actively pursuing the development of more accurate methods of attack (some of which have already been noted) and the training of crews under operational conditions in readiness for the time when new methods became available continued steadily. In April 1941 a new radar ranging device was brought into operational use during two attacks, and although it proved difficult to assess results it was considered that the system was a promising one. It is interesting to note that both this ranging technique and the use of beams from this country were at a later stage of development employed in attacks against the two German battleships and cruiser in Brest Harbour (Operation "Trinity").[1]

In May 1941 calculations were made by A.W.A.S. to determine the exact position of the Ruffian transmitters at Morlaix; results agreed with a position previously suggested by the Scientific Analysis Section of Headquarters, No. 80 Wing, and were later confirmed by photographic reconnaissance. Attacks were made on 6 and 11 May, and although the precise degree of success could not be assessed, one of the transmitters was not heard again for six days after the second attack.

During the summer of 1941 Ruffian activity declined to a very low level, and offensive action against the transmitters ceased at the end of June. Throughout the period of operations attacks had been made on more than fifty occasions. Although no major destruction had been effected, numerous hits were scored in the target area, many large fires started, and considerable damage done to power supplies, stores and defensive positions.

---

[1] This technique was the forerunner of Oboe.

Benito and the " Y " *Gerät*

New signals with a curious dash characteristic were heard during November 1940 in the 40 megacycles per second frequency band.[1]

Investigation of these signals by ground and air observations showed that the rate of " keying " was 180 per minute, which was much higher than that connected with *Knickebein* or Ruffian beams, and that there appeared to be two sources in Northern France, one in the Poix area. It was also observed that messages were being passed to aircraft by radio telephony on frequencies in the same band.[2] One such message instructed an aircraft to drop its bombs as the weather was getting bad. It also added, " We are accompanying you " and " Follow the beam from the emergency aerodrome." Messages on another occasion stated that the beam was being turned and continued : " Turn round and make a new approach "—and " Measurements impossible, carry out task on your own." A bearing taken on the beam signals at the time of the messages gave a line through Poix near Amiens. Later the " Y " service heard two signals on different frequencies in the same band with the same modulation frequency which appeared to be interlocked, one of these being from an aircraft. It was apparent that this could only have been achieved by one station relaying the modulation of the other. The data obtained from observations gave direct support to Air Scientific Intelligence reports issued on 17 July 1940 and on 12 January 1941 that the Germans were developing a system known as *Wotan* for making a distance measurement along a beam, which involved a measurement of phase angle between outgoing and incoming modulations, and that this system had been used for bombing.[3]

Preliminary Analysis of Benito

In the first weeks of January 1941 considerable progress was made in the investigation[4] of the new system to which the code name Benito had been given, but the working principles employed in the system had not yet been fully established. The accuracy of the range measurement had been determined to be of the order of 90 yards ; no figure had been arrived at for the accuracy of the azimuth as the details of the beam were not known. It was evident that the beam differed from that used in the *Knickebein* and Ruffian systems since all reports had stated that the signal changed from dots to dashes or vice versa without passing through an equi-signal. It had been established that Benito systems had been set up at Cassel, 15 miles south of Dunkirk, at Beaumont in the Cherbourg Peninsula and in the Poix area near Amiens. It had also been determined that bombing attacks had been carried out by the German Air Force Unit *II K.G.26*, which was stationed at Poix, and that this squadron was similar to *II K.G.100* which had specialised in the use of the Ruffian system for its attacks.

Counter-measures—Domino

In view of the high degree of accuracy which could be obtained by the ranging system it was decided that the first counter-measures should operate against this. The type of counter-measure designed by the Telecommunications Research Establishment (T.R.E.) was a form of Meacon in which the enemy

[1] Appendix No. 9.
[2] No. 80 Wing Monthly Reports Nos. 13 and 14.
[3] A.S.I. Reports Nos. 7 and 10.
[4] Telecommunications Research Establishment Report (R.C.M. Section) No. 5/2.

aircraft ranging signal (which was a re-radiation of the enemy ground signal) was picked up on a broad band receiver and the received modulation superimposed on the output of a medium power transmitter tuned to the radio frequency of the German ground range station. Thus the range indications at the enemy ground stations would be confused.

The first installation of this counter-measure, to which the code name Domino was given,[1] was set up to protect London from enemy aircraft working in conjunction with the Benito station at Cassel. Use was made of the B.B.C. television sound transmitter at Alexandra Palace in North London. The receiver with its associated relays was at a B.B.C. station nearby, as a high-fidelity cable was available to Alexandra Palace for passing the various tones to the transmitter. The receiving equipment was later moved to a higher site at Parliament Hill as it was found that receiving conditions were not good at the B.B.C. station. The equipment was ready for operational use by the middle of February 1941. By the end of February 1941 a second Domino installation had been completed on Beacon Hill near Boscombe Down about eight miles north of Salisbury, thus making both the Cherbourg and Cassel controls subject to counter-measures simultaneously. Plans were also put in hand to install additional transmitters at the two Domino sites, and to open up a new site further west to give protection to South Wales and the West Country.

During the month of February 1941 the enemy made the mistake of using the Benito system on a small scale over this country, presumably to test the principle under operational conditions. On some occasions the fact that aircraft of *II K.G.26* were the only aircraft engaged during the period of the operation enabled good indications to be obtained of the tracks followed by the aircraft and of the bomb plots. These showed that the system was capable of enabling aircraft to bomb with remarkable accuracy and to obtain great precision in grouping.

Observation of Benito Signals

Investigations continued to be made on the beam signals by ground and air observations, but although a certain amount of knowledge was obtained, the exact method of operation still remained obscure. As early as February 1941 there were indications from the messages passed by the enemy ground stations to the aircraft that the system was not working smoothly. For instance, out of a possible 89 aircraft in action, 27 were told to carry on and undertake their tasks independently of ground control, 44 were not heard to receive a bombing signal, and only 18 were given the " bomb drop " signal. There was, however, no definite evidence that this was due to counter-measures, mainly because it had been found impossible to gauge the accuracy of the bombing owing to the difficulty of differentiation between the tracks and bomb plots of *II K.G.26* aircraft using the Benito system and those of other aircraft taking part in attacks on the same target.

Effect of Domino

Enemy attacks using the Benito system became heavier in March, and out of 36 aircraft working within the range of their ground stations, 18 received bombiug signals. Two incidents occurred early in the month to show that the effect of Royal Air Force counter-measures was being felt. During an attack on

[1] Appendix No. 9 for details.

London on 9 March 1941 a change of air and ground ranging frequencies was made during the course of the operation. These changes were at once followed by the two Domino stations. The second incident took place on 11 March 1941, when a bombing attack was made on the Domino station at Beacon Hill and the station suffered a near miss. As a result the Beacon Hill Domino was not working on the following night when nine enemy aircraft operated with the Cassel control and eight with the Beaumont control. The Cassel aircraft were covered by the Alexandra Palace Domino, while the Beaumont aircraft were uncovered. None of the Cassel aircraft received the bombing signals, whereas most of the Beaumont aircraft appeared to perform their task satisfactorily.

Attacks by Benito-controlled aircraft continued to be made during April and May on a relatively large scale, up to twenty aircraft being used on occasions. These attacks were distributed widely over the country and Domino action was taken whenever possible. It was difficult to determine to what extent Domino action had affected the accuracy of the system, but it was significant that only on two occasions did more than 25 per cent. of the aircraft taking part in any one operation receive the "bomb drop" signal. Information was received, however, from interrogation[1] of the crews of three aircraft of *II K.G.26* brought down on the night of 3/4 May 1941 that the whole of their unit were losing confidence in the "Y" *Gerät* system owing to the troubles which were being experienced. These troubles were attributed by them to British jamming and had become progressively worse since March.

The "Y" *Gerät*

From one of these crashed enemy aircraft a complete "Y" *Gerät* apparatus was recovered in a damaged condition. It was thus possible to determine the principle on which the Benito beam operated. A detailed examination was made by the Royal Aircraft Establishment (R.A.E.) which confirmed that the equipment consisted of two parts which were independent of each other—a "Course" panel and a "Range" or "Distance" panel.[2] It also showed that the "Course" panel included a mechanical analyser for interpreting the characteristics of the "beam," and that this was maintained in synchronism by means of a magnetic clutch which was controlled by signals from the ground "beam" transmitter.[3] Tests carried out on this equipment showed that it was very susceptible to jamming which would prevent the synchronising device from operating and would produce erratic indications of the "Course" indicator. Preparations were therefore made for the jamming of the Benito beam signals under the code word Benjamin.

Elektra

Intermittent dot/dash signals were heard in August 1940 indicating that the enemy was using a beam system on a medium frequency of 481 kilocycles per second. The signals were "keyed" at the same rate of 60 per minute as *Knickebein* but the transmission was unmodulated. It was determined in September 1940, from ground observations and from flight tests by the Wireless Intelligence and Development Unit, that the enemy system consisted of a fan of beams spaced approximately five degrees apart which covered the whole of

[1] A.I.1 (K) Report No. 240/41 and A.I.1 (K) Special Report to A.C.A.S. (I), 10 May 1941
[2] Royal Aircraft Establishment Report (E.A. 33/8 Dept.) No. W.T. 18.
[3] More details are given in Appendix No. 9.

the United Kingdom. The source appeared to be south of Sylt or near Bredstedt. The width of the beams was found to be about 1,000 yards as measured at the coast.

It was thought that this system had been provided for use by reconnaissance aircraft over the North Sea or for surface craft to overcome the difficulty, due to propagation, of using beams on the higher frequencies at low height. It was later found from captured documents and maps that the system was known by the enemy as *Elektra*[1] and that the transmitter was positioned at St. Peters, near Busum in Schleswig. It was for use as a long distance navigational aid, and it had been used by aircraft in convoy raiding at a range of 1,500 miles. It had also been used in conjunction with a *Knickebein* beam to obtain a cross fix for an attack on London, the correct cut being obtained by counting the number of *Elektra* beams crossed. The system could be adjusted to give eitber of two alternative settings of beams.

In December 1940 a second *Elektra* came into operation from a site near Bayeux in Normandy, with beams spaced approximately 10° apart instead of 5°. This station was sited so that the fan of beams covered the country from the south, thus giving, in conjunction with the St. Peters *Elektra* a complete lattice over the United Kingdom. It was soon proved that the system was vulnerable to the same radio counter-measure which had been adopted for masking the enemy radio beacons, and Meaconing action was immediately applied. Tests carried out by No. 109 Squadron showed that this action rendered the system unusable over the whole country.

Enemy Medium Frequency Beacons

The development of the Meacon scheme for masking enemy radio beacons continued during the phase described in this chapter. By October 1940 ten sites with a total of 30 transmitters were in operation, and by the end of the phase this number had increased to sixteen sites making a total of 60 transmitters. More evidence of the success of this counter-measure was obtained from prisoners, some of whom had been brought down in this country solely due to false bearings caused by meaconing. Further changes were therefore made by the enemy in an attempt to overcome the effects of meaconing. The power of some of the beacons was increased and civil broadcast transmitters were used as beacons, recognition letters being keyed by them either superimposed on the programme or on an unmodulated carrier. Moreover, changes in the enemy " systems " of callsign and frequency allocation were frequently being made, necessitating the breaking down of the new enemy system before meaconing could be applied. One broadcast transmitter which continued radiating after normal programme times without modulation but with a recognition letter was the station at La Coruna in Spain. This was undoubtedly used as a beacon by the Germans.

German Safety Service System as an Alternative Radio Aid

The enemy found it increasingly difficult at this time to obtain reliable fixes in aircraft by taking bearings on beacons when over the United Kingdom, and began to use the German safety service system for this purpose. This consisted of a number of ground D.F. stations which through central control

[1] Descriptive diagrams of the principles of the system as determined from an analysis of the signals are given in Diagram No. 3.

FIGS. 1a,b,c & 2a.

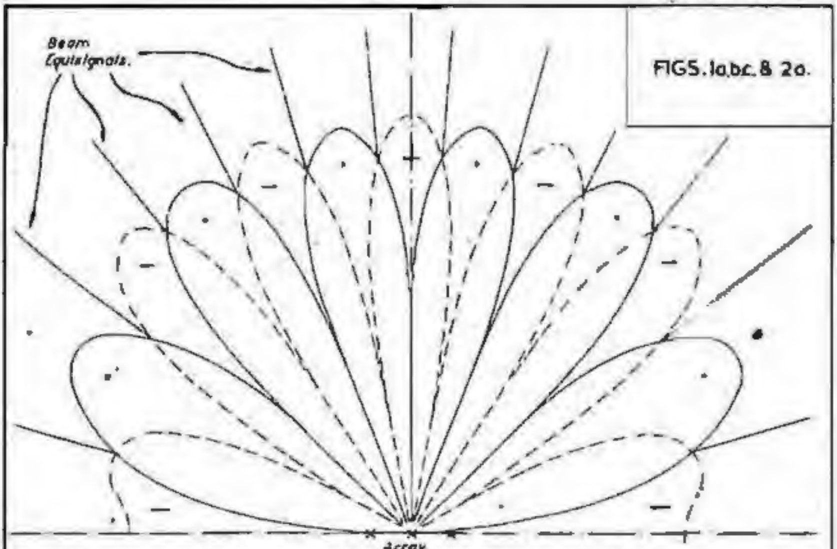


FIG. 1(a) DISPLACED POLAR DIAGRAMS { DOTS ——— DASHES - - - -

Cutting to produce the equisignals of a symmetrical pattern.

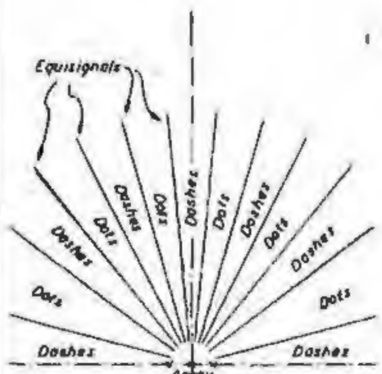


FIG. 1(b) SYMMETRICAL PATTERN

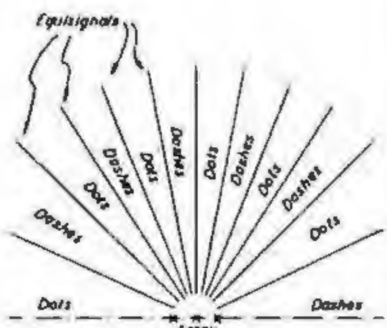


FIG. 1(c) CENTRAL PATTERN

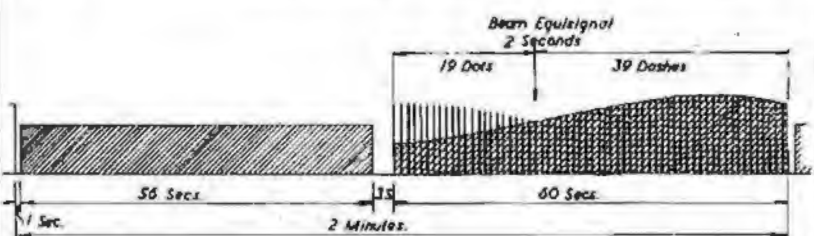


FIG. 2(a) 'SONNE' CYCLE

PATTERNS OF ELEKTRA AND DIAGRAM OF SONNE CYCLE

stations "fixed" the position of the aircraft on request and passed the position back to the aircraft. When it was realised that this system was being used to give "fixes" over this country, meaconing of the aircraft transmission was instituted with the intention of preventing the ground medium frequency D.F. system from obtaining the true bearing of the aircraft. By January 1941, aircraft meaconing was being carried out from three sites, and by the end of May 1941 a fourth site was included in the scheme.

"Fixes" had formerly been taken and passed to the aircraft usually in a few seconds and never in a greater interval than a minute or so, but after meaconing was introduced the information was frequently not passed for much longer. The time required grew to a period of 10 or 15 minutes and the "fix" given was often as much as 100 miles away from the plot of the same aircraft obtained from the Fighter Command Plotting Table. The German reaction to aircraft meaconing consisted of a reduction of power of the aircraft transmitter so that the signal received by the Meacon receiver would not be strong enough to drive the Meacon transmitter. This method worked however to the disadvantage of the enemy since it resulted in too weak a signal being received from the aircraft for successful direction-finding. An alternative frequency was eventually brought into use by the Germans, but by that time sufficient aircraft Meacon installations were available to cover the new frequency.

Starfish

By November 1940 it was realised that the beneficial effect being obtained from R.C.M. action against the German beam systems was to some extent being vitiated by the "visual beacon" effect produced by large fires in the target area.[1] This became particularly noticeable during an attack on Birmingham on the night of 26/27 October. On that occasion the main body of the German bomber force was preceded by a number of pathfinder aircraft of *K.G.100* whose task it was to start a fire in the target area and to report on the effect of counter-measures upon the *Knickebein* in use on the particular target. The pathfinders succeeded in setting a gasometer on fire which could not be extinguished before arrival of the main bomber force. These pathfinders reported that the *Knickebein* director beam was apparently being deflected some distance to one side of the target. The main enemy force was told therefore not to bomb on the *Knickebein* but to continue toward the target area until within sight of the fire. The blaze was then to be used as the aiming point. No. 80 Wing on that occasion reported that had they been able to light a decoy fire in the area over which the *Knickebein* beams were alleged to be intersecting, it was probable that some at least of the bombs would have been dropped away from the real target. Thus was conceived a decoy fire scheme, operated under executive control of Colonel J. Turner, and in close association with related radio counter-measures of No. 80 Wing.

Decoy fires (called later Starfish) were accordingly laid in open country in the neighbourhood of large Midland towns which were at that time the subject of heavy bombing attacks.[2] Although these sites were constructed and manned by Colonel Turner's personnel, the central control of fires was vested in Headquarters, No. 80 Wing, which was considered to be in the best position to

[1] From minutes of Air Ministry meeting on 23 November 1940. No. 80 Wing File S.3035/Sigs., Part I

[2] A.H.B. monograph "Deception and Decoy," by Colonel Sir John Turner. Also A.M. File C.S. 7888, 5 January 1941.

correlate the various factors governing the choice of the best site for fires at any time, as well as for deciding the best moment for lighting them.

The choice of the place and time to light Starfish was a matter requiring considerable forethought and judgment. The lighting of a decoy fire, for example, in open country on a moonlight night would probably fail to deceive, except perhaps in the presence of some other factor such as a ground mist. The line of approach of the raid was important, since it was inadvisable to allow the bombers to pass over the real target area when attacking the decoy. For this reason Starfish were prepared on several sides of each target area in order to provide against the raid approaching it by an indirect route. Care was taken not to light Starfish on both sides of the real target for fear of the Germans attacking the midpoint between the fires.

Liaison was maintained with Colonel Turner's department by the attachment of one of its officers to Headquarters, No. 80 Wing ; liaison was also maintained with Headquarters, Fighter Command and Home Security, and with the Directorate of Signals, Air Ministry. High priority landline communication was established from the sites to local Starfish control centres and thence to Headquarters, No. 80 Wing. In the event of landline failure, local controls were authorised to act autonomously. Close liaison was essential between the Operations Room at Headquarters, No. 80 Wing and the local Starfish control centre during an attack, so that the position and size of fires caused by bombing could be correlated with a decoy to give the best effect. It was found that if a fire caused by bombing could be extinguished rapidly, then a decoy on the line of approach was frequently successful in drawing a large proportion of the bombing effort, since the enemy leading aircraft reported the fires as having been produced by them, and succeeding aircraft naturally bombed the decoy.

Three types of fires were used, employing respectively diesel oil, paraffin and baskets of scrap wood, and known as Full, Medium and Short Starfish, the different types used depending on the size and type of fire it was decided to imitate. Fires were lit either by hand or by electricity, the latter more speedy method being more generally employed. Certain difficulties arose, however, in the electrically controlled sites due to the accidental firing of Starfish sites during lightning storms.

Effects of Starfish

The first Starfish were used during an attack on Bristol on 2/3 December 1940, the two sites fired receiving a total of 66 H.E. bombs. Thereafter Starfish played an important part in the defensive campaign, sometimes attracting as much as 75 per cent. of the total enemy effort. Evidence obtained from prisoners showed that though in many cases they were aware that decoy fires existed, their ideas as to the position and location of these fires were erroneous. Liaison was maintained with the Air Warfare Analysis Section and many test flights were made by No. 109 Squadron to observe the effect of various types of fire from the air.[1] For this purpose the experimental site was established at Winterslow. At a later stage it was decided to augment the normal decoy fires by the addition of certain "strategic" Starfish. These full-size fires were located in open country and were used when enemy aircraft had become lost

[1] No. 80 Wing File S.3035/Sigs., Encl. 26A—Minutes of Conference at Radlett, 27 February 1941.

owing to radio counter-measures and weather conditions, as an inducement for them to drop their bomb loads where they would do least harm.

An example of the value of decoy fires used in conjunction with radio counter-measures was provided by attacks on the night of 8/9 May 1941. On this night the Ruffian beams were set for an attack on the Rolls Royce works at Derby. Owing possibly to counter-measures the leading enemy squadron, *II K.G.100*, failed to find Derby and bombed Nottingham in error,[1] where some small fires were still burning from a previous attack. As a result, Nottingham was subjected to attack by the main force of bombers. It appeared, however, that it was the enemy's intention that successive waves of bombers should attack Nottingham after the completion of the Derby attack. As a result of the original error, this second attack was made on open country in the Vale of Belvoir over an area situated in approximately the same position relative to Nottingham as Nottingham is to Derby. It is interesting to record that the German official communique subsequently claimed to have destroyed the Rolls Royce works at Derby, when, in fact, not a single bomb fell on Derby on this occasion. The number of bombs which fell in the Vale of Belvoir was 230 high explosive, 1 oil bomb and 5 groups of incendiary bombs, and the casualties were two chickens. During this attack the weather was clear, visibility exceptionally good with light wind.

In the early stages a decoy fire was never lit if by so doing its identity was likely to be revealed. During the "Baedeker" raids against the English cathedral cities in 1942 this policy was modified, enabling a fuller use of Starfish to be made by disregarding to some extent prevailing weather conditions.[2] This modification was based on the fact that at the time the *Luftwaffe* was employing large numbers of "freshmen" crews who, by reason of their lack of experience, would be less likely to recognise a decoy fire as such.

A further modification was made in 1944 during the final phase of enemy bomber activity against this country.[3] As a result of a new Pathfinder Force technique adopted by the German Air Force, which now employed large numbers of target indicator flares, arrangements were made to provide a small fire (12-16 baskets) directly target indicator flares or incendiaries were dropped over or near Starfish sites. Instructions to fire these "minor" Starfish which were arranged on all sites south of a line Kings Lynn, Bletchley, St. David's Head, were given from Headquarters, No. 80 Wing, although in the case of certain sites around London and Southampton, control was delegated to the N.C.O. in charge of the site.

Development of the Operations Room at No. 80 Wing Headquarters

The establishment in September 1940 of Headquarters, No. 80 Wing as a R.C.M. Control Centre, controlling a steadily increasing number of outstations, necessitated from its inception a carefully planned Operations Room.[4] By this means incoming intelligence from Watcher Sites, "Y" Service, Fighter Command, and other sources could be filtered and co-ordinated, a complete picture of enemy operational activity maintained, and control instructions issued to sites with the minimum of delay.

[1] A.W.A. Report No. BC/G/10, June 1941.
[2] No. 80 Wing File S.3035/Sigs., Part III, Encl. 24A.
[3] *Ibid.*, Encl. 50B, Conference—Colonel Turner's Department.
[4] Full details of the Operations Room organisation and procedure are given at Appendix No. 4.

Commitments during the very early stages consisted simply of meaconing enemy beacons and jamming the *Knickebein* beams by Aspirin action; the Operations Room was therefore divided into Headache and Meacon Control Sections. Under the Commanding Officer, a Duty Wing Commander was in control of operations assisted by a Scientific Analyst, an Operations Officer and two Junior Officers in charge of the Clerks (Special Duties) manning the Control Sections. Close liaison was maintained with the No. 80 Wing Liaison Officer at Headquarters, Fighter Command.[1] Communications were effected in every case by landline over the G.P.O. network.

Headache Control was responsible for the reception, logging, and charting of listening reports from Aspirin outstations; the display of this information with the beam settings determined from them and appropriate counter-measures taken, on an Aspirin map; the logging and charting of reports on the Ruffian beams (then under preliminary investigation); and, finally, under direction from the Duty Wing Commander, the briefing (by tie-line) of aircrews engaged on investigational flights and the preparation of preliminary flight reports. Meacon Control was responsible for all R.C.M. against enemy medium frequency aids. The information was obtained from the " Y " Service, the instructions passed to Meacon sites, and all enemy beacon and counter-measure activity was displayed on a large-scale map.

During the winter of 1940, the operational commitments of No. 80 Wing showed a rapid increase. Jamming of Ruffian beams (Bromide) was commenced, high power Aspirin stations had been established, Starfish had come into operation, and counter-measures against the new Benito beam and range system were being planned.[2] The duties of Meacon Control grew rapidly as more and more sites came into operation, and meaconing of aircraft asking for fixes had been instituted. This increase in commitments necessitated a corresponding expansion of the Operations Room. The basic organisation remained the same, whilst Meacon Control was moved to an adjoining room, and a new Starfish Section manned by one officer was incorporated in the main Operations Room. Headache Control was now divided into sub-sections dealing first with incoming information and the display of reports of enemy signal activity, and, secondly, with outgoing orders to Aspirin and Bromide stations. A further sub-section dealt with orders and the display for Benjamin (Benito) beam jamming. Benito range jamming (Domino) was in the first instance under the direct control of the Duty Wing Commander, the site thereafter acting autonomously.

As has been stated above, information from Headquarters, Fighter Command had hitherto been received via the No. 80 Wing Liaison Officers in telephone communication with the Operations Office at Headquarters No. 80 Wing. As a result of the greatly increased pressure of work it became impossible for the Operations Officer to maintain the close liaison necessary, and to overcome this difficulty a plotting table was installed in the Operations Room, on which tracks of enemy aircraft activity passed from Headquarters, Fighter Command were continuously recorded. Reference to this plotting table gave all the latest information available concerning enemy air activity, and more detailed plots could be obtained on any tracks which appeared of particular interest, especially those which showed evidence of beam flying.

---

[1] Appendix No. 6. [2] Appendix No. 9.

N°80 WING AREA HEADQUARTERS AND AREAS

In the event of the destruction of Headquarters, No. 80 Wing at Radlet by bombing, or in case an invasion rendered this Operations Room inoperative, arrangements were made for an alternative Headquarters and Operations Room at Worcester, and a detailed scheme for the evacuation there was prepared. This place was selected as there existed already a comprehensive network of telephone lines which had been prepared for another emergency scheme ("Black Move"). The emergency Operations Room was not fitted out, but arrangements were made for telephone circuits to be provided on an emergency basis and made available for switching within 24 hours. The need for an alternative Headquarters became more unlikely as the war progressed and the facilities were withdrawn in July 1943.

Organisation of Outstations

The organisation of Headquarters, No. 80 Wing as an R.C.M. Centre controlling a large number of small outstations, often situated in remote country districts, presented many difficulties.[1] For security reasons the generally-accepted Service method of attaching small detachments to nearby "parent" stations for administration, barrack and clothing services was undesirable and it was therefore necessary to devise an organisation capable of fulfilling, in addition to technical supervision, all administrative and provisioning duties for outstations over a very wide area of the British Isles.

Only about a dozen of the larger sites had resident officers, and a relatively large staff of visiting technical officers had to be maintained at Headquarters. During the early stages individual officers were appointed for the supervision of stations classified under their different functions, *e.g.*, Aspirin, Bromide and Meacons. Administrative and equipment staffs at Headquarters were on a small scale and for this reason visiting technical officers were frequently called upon to undertake duties of this nature, particularly with regard to technical and barrack equipment.

In April 1941 it was decided that the area to be administered had become too large for satisfactory control to be effected from one central Headquarters, and administration was accordingly decentralised and an Area Organisation formed. Six Area Headquarters were set up, the areas being as follows :—[2]

(*a*) South Eastern Area .. Headquarters—Windlesham (Bagshot).
(*b*) Southern Area .. Headquarters—Ashmansworth (Newbury).
(*c*) South Western Area .. Headquarters—Fairmile (Honiton).
(*d*) Eastern Area .. Headquarters—Braintree.
(*e*) Midland Area .. Headquarters—Hagley (Birmingham).
(*f*) Northern Area .. Headquarters—Marske (Redcar).

Siting, installation and the opening of new outstations was in all cases the duty of Wing Headquarters, no station being handed over to an area until it was fully established.

One officer, assisted by a Warrant Officer or Senior N.C.O., was appointed to each area to be responsible for visiting all stations in his area, regardless of the type of equipment. Where this was of a special type, assistance was given by specialist officers from Wing Headquarters. His duties included also many normal administrative functions which later grew in volume as the general organisation of the Wing became stabilised.

---

[1] Appendix No. 10. [2] Diagram 4.

CHAPTER 3

RADIO COUNTER-MEASURES, MAY 1941 TO NOVEMBER 1942

The end of the phase already described which concluded in May 1941 saw a reduction of the bombing offensive against the United Kingdom owing to the transfer of the major part of the main German bombing force to the Eastern Front. It also marked the close of the first round of the battle of wits between the enemy's radio experts and those responsible for Royal Air Force radio counter-measures. It was not expected, however, that the Germans would accept a situation in which the value of their aids was seriously reduced by radio counter-measures. Precautions were therefore taken by modifications to jamming transmitters and by the provision of additional sites and jamming equipment.

It had been expected that with the longer hours of darkness there would be a renewal of the bombing offensive in the autumn of 1941, but this did not occur. Bombing attacks continued on a very small scale until April 1942, when *Luftwaffe* attacks on English cathedral cities were begun. During this month the Ruffian system of blind bombing was again used operationally after a lapse of nine months, and some enemy daylight attacks under conditions of cloud cover were carried out.

In order to overcome the difficulty of keeping jamming transmitters continuously in a state of readiness (*i.e.* warmed up) to cover the possibility of attacks in daylight by the use of the various navigational or bombing aids, arrangements were made for weather information (cloud, height, cover, etc.) to be passed by the Meteorological Section at Headquarters, Fighter Command to the Operations Room at Headquarters, No. 80 Wing at frequent intervals. If these reports showed that conditions were favourable for an attack in a particular area, the jamming transmitters necessary to protect that area were brought to a state of readiness, so that if enemy signals were then heard the jammers would be able immediately to radiate.

Knickebein

The precautions taken to meet the expected changes to the *Knickebein* system have been stated and information obtained from prisoners of war and captured enemy documents indicated that the first of these, a change of radio frequency, was likely to materialise.[1] In addition, the number of *Knickebein* stations was to be increased to twelve. The information also showed that a new radio receiver, the *E.Bl.3*, was being produced to replace the *E.Bl.1*, which had been used by the German Air Force for *Knickebein* and blind approach landing. The *E.Bl.3* receiver was stated to be capable of being used on any one of 34 " spot " frequencies between 30 and 33·3 megacycles per second and to be more selective and sensitive than the *E.Bl.1*. The latter receiver was used only on any two of the three frequencies, 30, 31·5 and 33·3 megacycles per second, the selection of frequency being made by a two-way switch.

[1] A.D.I. (K) Report No. 269/41 and A.D.I. (K) Special Report to A.C.A.S. (I) 23 May 1941.

An appreciation was prepared from the information available by Headquarters, No. 80 Wing, for the Director of Signals, Air Ministry, and a radio counter-measures plan drawn up to combat this extension of the enemy radio bombing aid.[1] The plan called for the provision of two more listening stations on the East Coast and for modifications to the aerial systems of the existing South Coast stations. It also called for the provision of a total of 66 jamming transmitters, of which 32 were already available, and for four new jamming sites. These details were based on the probability of an enemy beam range of 450 miles being obtained by high-flying aircraft with the more sensitive receiver.

The implementation of the plan, which was based on the worst possible set of conditions that could arise, was carried out with all speed so that by the end of November 1941 all the additional Aspirin transmitters had been installed. D.F. facilities were also supplied to the listening stations so that rapid identification of signals could be obtained. The B.B.C. vision transmitter and aerial system of the Television Station at Alexandra Palace, North London, which was being held in readiness for Army purposes in the band 33·8–28 megacycles per second, was modified to provide a high-efficiency *Knickebein* jammer to protect the London area.[2] The modifications allowed rapid frequency changes to be made over 34 channels in the frequency band 33–33·3 megacycles per second, adjacent channels being separated by 0·1 megacycles. Sixteen channels could be radiated simultaneously and different audio-modulation frequencies could be applied.[3]

In September 1941 the first transmissions from *Knickebein* on frequencies other than 30, 31·5 and 33·3 megacycles per second were recorded, confirming prisoners' reports. These transmissions continued daily and many changes of frequency were made. It was thought that these were for training as no aircraft operations coincided with the transmissions. Further confirmation[4] of the development of the *Knickebein* programme was obtained on 12 October 1941 when the first *Do. 217* aircraft to be captured forced landed at Lydd, Kent, and a model of the new German *E.Bl.3 Knickebein* and blind landing receiver was obtained intact. It is interesting to record that, as in the case of the aircraft carrying the "Y" *Gerät*, the capture of this aircraft was also due entirely to successful Meacon action.[5]

An examination[6] of the new *E.Bl.3* receiver showed that it was capable of continuously variable tuning over the range of frequencies 30 to 33·3 magacycles per second and that the revolving drum scale was graduated with 34 lines, confirming that it could be set to 34 "spot" frequencies. The receiver had greater selectivity, but the audio filter was the same as that in the *E.Bl.1* so that no change of audio modulation of the Aspirin transmitters was required. One disadvantage of the new receiver was apparent in that the quick change of frequency, obtained in the *E.Bl.1* by the two-way switch, was no longer possible with the continuously variable tuning. This indicated that the *Knickebein* system of intersecting beams used in conjunction with the new receiver could not have the same accuracy as with the *E.Bl.1*

[1] AHB/IIE/177, "No. 80 Wing Historical Report, 1940–1945," Appendix "N" gives this Appreciation in full.
[2] No. 80 Wing File S.3001/8/Sigs. Encls. 2A, 3A, 5A.
[3] *See* Appendix No. 13 on Monitoring.
[4] A.D.I. (K) Report No. 491/41
[5] This is discussed later in this Chapter.
[6] R.A.E. Report No. E.A.41/3, 10 November 1941.

receiver. Although from April 1942 until the end of this phase in November 1942 many attacks were carried out, *Knickebein* transmitters were seldom switched on by the enemy, and then often only as "spoof." For instance, during attacks on eastern or north-eastern targets, two *Knickebein* stations were set up to intersect over a southern target.

Ruffian

Although the Ruffian system was not used operationally after June 1941 until April 1942, the enemy transmitters continued to radiate for periods both during the day and at night. Recognition letters were "keyed" and frequency changes were made during operations but there was little doubt that the transmissions were made in an attempt to mislead.

Two new aerial arrays at the Cherbourg site were discovered by the Photographic Interpretation Unit (P.I.U.), and transmissions were intercepted from these.[1] It was thought at the time that these additions had been made so that two independent systems could operate simultaneously if desired, by using some of the Cherbourg transmitters in conjunction with the Calais transmitters and the others with those at Morlaix. This was later found not to be the case, as further photographs by P.I.U. showed that the arrays furthest from the main group had been removed from both the Calais and the Cherbourg sites.[2] It became evident that the reason for erecting the aerial arrays of each group very close together was to enable the aircraft to maintain course with as little deviation as possible when transferring from a beam on one frequency to that on another.

In October 1941, information was obtained from a prisoner that a "dog whistle" frequency was likely to be used.[3] This obviously meant supersonic modulation. The reference to it was made in connection with the new *Knickebein* receiver *E.Bl.3*, but as one of these had been examined and there was no trace of this provision, it was assumed that it was intended to employ the new type of modulation with the Ruffian system. Provision was made for Royal Air Force listening stations to be provided with means for checking if supersonic modulations were being used both on Ruffian and *Knickebein* frequencies. A number of jamming transmitters were fitted with additional modulation units so that frequencies up to 15 kilocycles per second could be covered either with supersonic modulation only, or with normal and supersonic modulation simultaneously.

During the afternoon of 3 April 1942 a single enemy aircraft dropped bombs close to the Bristol Aircraft Factory. An analysis of the bomb plots made by the Air Warfare Analysis Section[4] showed that a line drawn through the stick passed very near the site of the Cherbourg Ruffian transmitters. Since they were radiating at the time, it was possible that the aircraft involved belonged to the German specialist squadron *II K.G. 100.* On the following day a daylight attack under cloud cover was made on the Brockworth airfield by three aircraft. These were definitely established as being from *II K.G. 100.*[5] A number of other attacks were made during April, but in two cases only were there

[1] C.I.U. Photographic Sortie T/297, No. 667, 20 July 1941.
[2] C.I.U. Photographic Sortie T/685, No. 610, 27 September 1941.
[3] A.I.1. (K) Report S.R.A. 2249, 15 October 1941.
[4] A.W.A.S. letter B.9 of 14 April 1942.
[5] A.W.A.S. drawing No. 132, 11 April 1942.

indications that the Ruffian system had been used with success. These were on the nights of 21/22 and 22/23 April, when three sticks of bombs were dropped on the torpedo filling factory at Holton Heath near Wareham, Dorset, without, however, causing any damage of a military character.[1] The accuracy obtained may be judged by the fact that the three sticks overlaid each other and that one stick dropped on the first night was released at 10,000 ft. through 10/10ths cloud and rain.

A survey of the bomb plots by the Air Warfare Analysis Section revealed great accuracy in line but error in range, indicating that the more remote Calais cross beams were more adequately covered by jamming stations than the approach beams. Adequate cover of the approach beams used against targets in this area was difficult as the distance from the transmitters to the target was only 70 miles, and the strength of the enemy signal was therefore great.* No special features were noticed in the transmission, except that the Calais beams were used for the approach on one occasion.

The Ruffian system was used for operations only seven times during May, but on the night of 23/24 May 1942 the first definite indications of dual modulation were observed, the frequency of the second modulation being of the order of 15 kilocycles per second.[2] The additional modulation was used on one or two frequencies on subsequent operations, but owing to the preparations which had been made, this was jammed immediately it became active. It was noticed that the frequencies with dual modulation did not key recognition letters. On several occasions before 23 May recognition letters were not received on certain frequencies; it was possible that the additional modulation had been superimposed on these frequencies without being observed. The dual modulation was never observed on "coarse" beams. In August 1942 and subsequently, signals with the same characteristics and in the same frequency band as the Ruffians were heard from the St. Valerie area. It was thought that these might have been from an additional site to be used in conjunction with the Morlaix site, one transmission from which had been heard during October. No developments, however, occurred and no photographs were obtained.

In spite of the elaborate changes made by the enemy in re-siting the transmitters and in providing additional modulation, little use was made of the revised system. It was used four times only in June 1942 and once only in July and September; no further signals were heard after the middle of Nnvember. It may have been, therefore, that the readiness with which the Royal Air Force radio counter-measures acted against the additional modulation had convinced the Germans that it was useless to continue. Photographs taken subsequently by the Photographic Interpretation Unit showed that all the aerial arrays had been dismantled.[3]

Benjamin

The capture of a "Y" *Gerät* and its examination in May 1941 had resulted in a decision to jam the Benito beam signals in such a manner as to cause erratic indications of the "Course" indicator in the enemy aircraft. It had been concluded that the required jamming signal should consist of a dash equivalent to the enemy dash, but at a slightly different keying rate from that of the

[1] No. 80 Wing Monthly Report No. 29.
[2] No. 80 Wing Signal RX.457, 24 May 1942.
[3] C.I.U. Letters M.D.M./S.2130/1/Ops. 681, 27 March 1944; *ibid*, 856, 16 May 1944; and report G.2011, 10 March 1944.

Benito beam. It was decided, therefore, to implement immediately a programme of jammers mainly by utilising from a readily available source a number of low-power transmitters estimated to be effective for the particular type of jamming proposed. By September 1941 a total of thirty Benjamin jammers had been completed, covering the Cassel, Mont de Boursin, Poix, St. Valery, Cherbourg and Commana beams respectively.[1] Although during the period under review Benito beams were radiated, it was difficult to associate them with the few aircraft attacks on the United Kingdom as enemy tracks did not suggest beam flying.

Domino

The existing Domino stations were at all times ready for operation, but, in view of decreased enemy activity, as stated above, there was little need for them. Eventually, although the enemy had increased the number of his Benito stations in France, in view of the extremely large numbers of Domino stations with highly trained crews which would be required, it was decided to rely on Benjamin and the jamming of the associated communication channels.

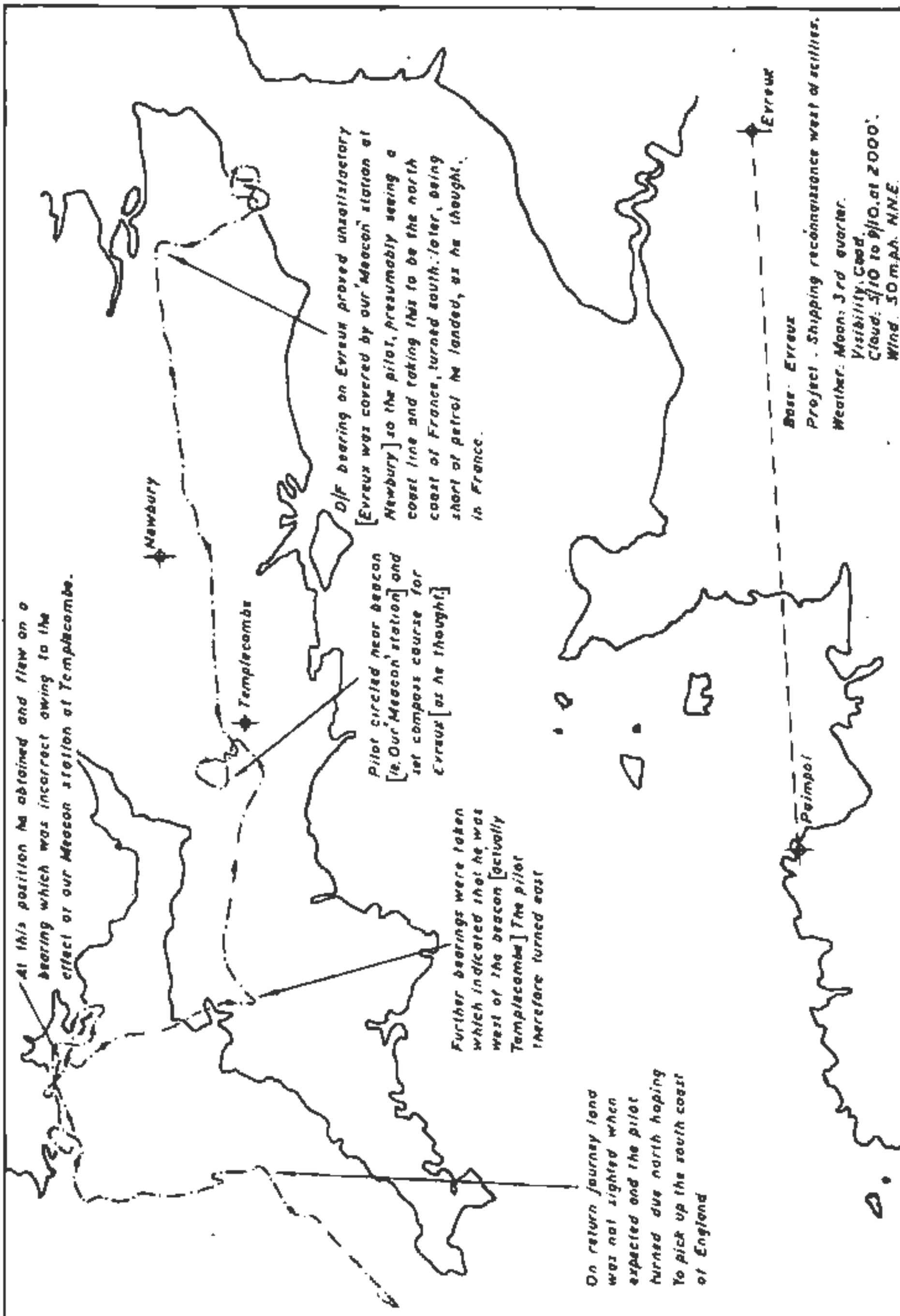
R.C.M. in the Mediterranean

The question of the use by the enemy of beacons and blind bombing aids in the Mediterranean theatre was dealt with in an appreciation written by the R.C.M. Section, Air Ministry, in June 1941, in which a general conclusion was reached that whereas effective counter-measures could not at that time be taken against beacons owing to the impossibility of providing effective cover over so large an area, a counter-measure organisation could be set up in Malta if the enemy employed a beam system in Sicily.[2] These recommendations were, however, almost immediately followed by information received from the Middle East Command to the effect that signals with Lorenz beam characteristics had been picked up in the Alexandria region. Since enquiries appeared to rule out the possibilities of these signals being reflections from enemy beam stations or enemy blind approach installations located in Europe, it was decided in June to send out an investigation aircraft together with a technical officer as adviser on R.C.M. matters. Two General Electric Company (G.E.C.) jammers were sectionalised and sent out by air for use in the Delta or at Malta in anticipation of the threat materialising.

It was concluded from test flights that no threat existed and, in August, arrangements were made for the return of the aircraft and technical staff to the United Kingdom after personnel had been trained in the Middle East. The investigation equipment and jammers were, however, retained. Further test flights were made in the region of Crete before the aircraft returned to the United Kingdom, and at Malta during the return flight. No evidence of beam signals was obtained during these flights.

In October the Middle East Command requested the formation of a small R.C.M. organisation mainly for watching purposes, and it was decided at an R.C.M. Board meeting held in November that the matter should be investigated and that any organisation set up would be a responsibility of Headquarters, No. 80 Wing.[3] As a result, further G.E.C. jammers were later despatched to

[1] Appendix No. 9.
[2] Minutes of R.C.M. Board Meeting, 18 June 1941, and Air Ministry R.C.M. Appreciation, 13 June 1941.
[3] Minutes of R.C.M. Board Meeting, 4 November 1941.



EFFECTS OF MEACONING ON NIGHT OF 21 OCT. 1941.

the Middle East to form a reserve pool for use if investigations proved at any time that counter-measures were necessary. Another officer was accordingly posted from No. 80 Wing to Middle East Command. No. 80 Wing was also instructed in January 1942 to prepare plans for the production of a number of mobile Meacon stations for possible use overseas.

M.F. Beacon System

Throughout this period, tracks indicated that the enemy continued to make considerable use of his medium frequency beacon system to mark turning points and for aircraft homing in those areas over the United Kingdom beyond the effective range of meaconing. It was clear that the lack of unspoiled beacon facilities over this country troubled him seriously since he made a number of changes in his organisation in an attempt to evade interference. Between April 1941 and March 1942, enemy beacon schedules became progressively more complex until, by the end of this period, system changes during operations took place at frequent intervals, even as short as 25 minutes. The power of his beacon transmitters were also further reduced in order to render more difficult the task of meaconing.

Concurrently with these difficulties, the Germans were faced with yet another problem—that of preventing the Royal Air Force rapidly-expanding bomber force from making use of their beacon organisation and high-powered, unsynchronised, broadcast transmitters which were easily identified by characteristic call-letters. Thus it was that as early as September 1941 there were indications of German broadcast stations being operated in synchronised groups except when the enemy required to use them during operations. Moreover, whereas in the early days of the air attacks against this country German beacons maintained a more or less constant schedule of transmissions over the whole twenty-four hours, whether or not required for operations, they were forced, even at the risk of bad security, to confine the periods of transmission to times which embraced operations—a fact of which the Royal Air Force Intelligence was able to take advantage.

As an additional safeguard, in September 1942, the enemy narrowed the frequency band of his beacons from 150–900 kilocycles per second to 500–600 kilocycles per second, a band not covered by the Allied General Purpose W/T set then in use. This frequency band was used for some months before additional frequencies were again introduced.

Despite the many measures adopted by the enemy to avoid the effects of meaconing it was apparent that this counter-measure frequently caused confusion to enemy aircrews, resulting in their becoming completely lost and, in some instances, landing in this country. A typical case was the forced-landing at Lydd in Kent of the first *Do. 217* aircraft to be captured, together with a complete model of the new *Knickebein* E.Bl.3 receiver on 21 October 1941. This aircraft became lost whilst returning from a shipping reconnaissance and made landfall near Pembroke, the crew thinking they were over Cornwall. An accurate track chart showed that the aircraft then set a course which brought it to Templecombe.[1] The track then turned in an easterly direction until it reached the north coast of Kent, thereafter turning south to where the landing was finally made at Lydd. On interrogation, the pilot stated that on the

[1] Diagram 5.

outward journey bearings were taken on Barfleur (Tocqueville) and Paimpol.[1] Records show that during the flight the Barfleur beacon was too weak to use. It is therefore evident that the aircraft could only have been making use of Paimpol, which was fully active but covered by the British Templecombe Meacon. On the return journey it is shown by the tracks recorded that the aircraft circled over Templecombe at about 0400 hours. In spite of the pilot's statement that he was over Barfleur (Tocqueville), it is evident that he must, in fact, have thought he was over Paimpol since—

(*a*) Templecombe was re-radiating Paimpol, and Barfleur was inactive.

(*b*) By his own admission, a course was set for Evreux. The bearing from Paimpol to Evreux is 083°; the actual track made good by the aircraft from Templecombe was 082°. As the track from Barfleur to Evreux is 110°, it is unlikely that an error of 27° could have been made in navigation.

The failure of the attempts to get a bearing on Evreux can be accounted for by the fact that this beacon was being meaconed by Newbury. While in the Templecombe area the bearings of those two stations would have been 90° apart and would therefore have been " filling in " each other's minima. It is thus safe to say that the aircraft homed on Templecombe in mistake for Paimpol. A course was set from there in the supposed direction of Evreux. The final success was due to the fact that Newbury spoilt all attempts to obtain a check on the Evreux beacon. The aircraft then carried on until the pilot thought they were in the neighbourhood of Evreux, and then turned south, landing at Lydd, out of petrol.

With the installation of a new Meacon station at Marske in May 1942, the Meacon scheme consisting of 16 sites covering a total of 60 channels was completed. No further sites were established during the European war period, although progress was maintained in improvements and additions to existing equipment as more powerful transmitters became available. During the period under review, those improvements included the provision of 150-foot masts, and a further expansion in the number of channels available for aircraft meaconing.

" B.B." Scheme

In June 1941 the " B.B." scheme involving the masking of Admiralty beacons situated on the Butt of Lewis and at Barra Head was introduced.[2] These beacons had been installed as navigational aids to shipping in the North Western Approaches, and a Meacon scheme was devised to restrict their use by enemy aircraft operating over Scotland and the north of England without interfering materially with the beacons' primary function. Meaconing was effected with small transmitters at Cupar and Mintlaw, the latter being operated by No. 80 Wing personnel. The installations were provided with aerial systems so arranged as to provide maximum cover in the required direction and yet enable bearings accurate to within five degrees to be obtained by shipping.[3] The scheme was in operation until June 1942, when it was discontinued, the equipment being retained.

---

[1] A.D.I. (K) Report No. 491/41.

[2] G.P.O Pamphlet, " The B.B. Scheme," W4/S B.B. 1–5 of 27 May 1941.

[3] Air Ministry Letter, File S 50085/Sigs. Plans, dated 31 May 1941.

"A.B." Scheme

This scheme using a similar principle was introduced in December 1941 to mask over Great Britain a beacon erected at Lough Erne for use on its unmasked westward side by Transatlantic Air traffic, special Meacon channels being installed at six No. 80 Wing Meacon sites for the purpose.[1]

See-saw

An enemy signal to which the name See-saw was given was observed systematically on frequencies between 3 and 12 megacycles per second from the beginning of 1942 although it had then almost certainly been in operation for a considerable period.[2] The signal was heard frequently until April 1942, after which there was no activity for some months. From 14 September a period of considerable activity commenced during which a great deal of data regarding the nature of the signal was obtained, from which the conclusion was reached that it emanated from a rotating beacon of some sort. It was not possible to say definitely whether the device was intended for the use of aircraft or surface vessels. Moreover, owing to the frequency being in the H.F. band with the consequent limits to accuracy due to variations in propagation conditions, it was considered improbable that the system would assume an importance comparable with that of the known V.H.F. aids. As a result of these considerations and as all evidence indicated that the device was still in the experimental stages, it was not thought necessary to expend effort, during the phase under consideration, in the active preparation of counter-measures, other than to obtain proposals from the Experimental Establishments. D.F. observations all agreed in placing the source of the transmissions in the Berlin/Stettin area.

Windjammer

In June 1942, C.I.U. reported the existence of an unusual aerial array at Desvres, near Boulogne, approximately six miles east of the *Knickebein* No. 6.[3] The installation consisted of two arrays, one mounted above the other, the lower being of the approximate dimensions of a *Knickebein*, and fitted with dipoles and reflectors of a similar size, and the upper consisting of a simple array, of the same frequency band, comprising three dipoles with a wire mesh screen. The overall dimensions were: diameter 40 metres, height 40 metres. The name of Windjammer was given to this installation, the purpose of which was, however, not discovered until considerably later, by which time similar installations had been identified at Bergen-Belveder (Holland), St. Vaast—La Penelle (Cherbourg), Sizub—St. Michel (Commana), Arcachon (Bordeaux), Pouzages (Nantes), Favières (Chartres) and Malemont (Reims). It was eventually found that these stations were radio aids used for the control of night fighters, known to the enemy as *Bernard*, the associated aircraft installation being known as *Bernhardine*.[4]

Operations Room Development at Headquarters, No. 80 Wing

The increase in operational commitments during 1941, combined with the rapid expansion of administrative and technical staffs, resulted in severe overcrowding at No. 80 Wing Headquarters at Aldenham Lodge, Radlett. As it

---

[1] No. 80 Wing Monthly Report No. 24.
[2] Minutes of R.C.M. Board, 12th Meeting, 15 December 1942. Paper R.C.M./33/42.
[3] Central Interpretation Unit Report No. G.308, dated 28 June 1942.
[4] Part 2 of this volume—" Radio Counter-measures in Support of the Bomber Offensive."

was considered that under such congested conditions the security of highly secret matters was liable to be jeopardised, it was consequently decided to open an entirely separate Operations Block to be accommodated at a nearby house, "Newberries."

Coincident with this move, which took place on 19 October 1941, modifications in both display and procedure were made, designed to increase speed in assessing enemy signals and the application of appropriate counter-measures, particularly as a considerable increase in the scale of enemy activity during the coming winter was anticipated. Experience had shown the necessity for centralising display in order that the Controller could, at any minute, appreciate the work of the Operations Room as a whole without having to move from section to section.

As Meacon Control could be operated with a minimum of supervision, this section was made comparatively independent of the rest of the Operations Room. A display was evolved to enable the Controller to see at a glance details of enemy beacon activity and the state of counter-measures applied. The new display consisted of a board divided into two sections, one showing beacon activity and the other details of Meacon Transmitter Availability and Allocation. The number of outstations dealing with aircraft meaconing bad increased substantially and operators at these sites were given standard frequencies to guard and cover when possible.

The major portion of the Operations Room was allotted to counter-measure action against V.H.F. aids, and methods of display and procedure were both modified. Sub-sections were eliminated and the Control was now divided into two parts—incoming information (Reports) and outgoing instructions to sites (Orders).[1] Co-ordination between these two sections was maintained by the Scientific Analyst and the Operations Officer, who assessed the incoming information and passed it to the Controller, who, in addition to maintaining general control of all operations, directed personally all activity through the Orders Section.

The two main display sections were employed as follows :—

(*a*) Directive.—This board, maintained by the Controller, showed enemy signals active in the various V.H.F. bands (*Knickebein*, Ruffian, Benito, etc.) together with the allocation of counter-measures required. This enabled preparation to be made for speedy and effective counter-measure action while holding back actual jamming until all information had been obtained.

(*b*) Executive.—This board was manned by Clerks S.D. in the Orders Section and displayed all counter-measure action taken on orders from the Controller.

[1] A typical R.C.M. night operation is given at Appendix No. 5.

CHAPTER 4

RADIO COUNTER-MEASURES, NOVEMBER 1942 TO SEPTEMBER 1943

After the cessation of the Ruffian threat in November 1942 the principal feature of enemy V.H.F. radio aids from that time until September 1943 was the development of *Knickebein* and Benito. The promise of this activity was not fulfilled, however, for there was no corresponding increase in long-range bomber raids. German fighter-bomber aircraft continued to operate, supplemented by small scale bombing raids at night. The enemy shewed increasing respect for the British air defences and a programme of equipping German night bombers with radar tail-warning devices was begun. The difficulties encountered by raiders navigating over this country were demonstrated by several aircraft landing in Southern England in mistake for the Amiens area.[1]

During this period the enemy beacon system reached its maximum expansion, introducing the group system in a further endeavour to evade the effects of meaconing. *Sonne*, a development of the *Elektra* type of beacon, was first heard in February 1943.[2] The opening of this station in the Brest area was rapidly followed by further stations in Holland, Norway and North-West Spain. The possibilities of *Sonne* as a navigational aid for use by the Royal Air Force were quickly appreciated, and in May 1943, No. 80 Wing produced data and diagrams for Headquarters, Coastal Command under the operational word " Consol."

A number of mobile Meacon Units, the development of which had commenced in February 1942, were completed during the period under review and three of these were despatched to the Middle East and North-West African theatres, and deployed against enemy beacons in the Mediterranean area and against enemy aircraft engaged in shadowing convoys. In this period also the Royal Air Force introduced spoof transmissions both by actual narrow beams and by artificial signals, designed to worry the enemy and cover the introduction of the British Gee system.

Knickebein and Windjammer

It was not until January 1943 that any of the new *Knickebein* frequencies covered by the *E.Bl.3* receiver were heard in operational use, although they had been intercepted during non-operational periods since September 1941. During this month *Knickebein* beams were set up by the enemy on three occasions, although in only one instance did the main aircraft activity coincide with the setting—London on the night of the 17/18 September, and even then examination of the tracks yielded no evidence of the beams being used. In addition to the beams set definitely on the target, others appeared to be set up indiscriminately, presumably intended as spoof.[3] From January until August 1943, it was frequently observed that two frequencies appeared to be

[1] Rise and fall of the German Air Force [2] Diagram 3.
[3] No. 80 Wing Signals, Nos. RX. 696, 697 and 699.

active simultaneously from the *Knickebein* No. 6 area, and since only one transmitting array of the *Knickebein* type had been identified at *Kn. No. 6* it was concluded that one of these signals must emanate from the Windjammer at Desvres, six miles to the east of it. Owing to the proximity of these two stations this differentiation was never satisfactorily determined.

The general scale of *Knickebein* activity remained at approximately the same level during the following two months with little evidence that the small numbers of attacking aircraft were using the beams. This was not easy to determine since analysis of tracks was rendered difficult by the arrival of enemy bombers coinciding with the return of friendly aircraft. On the night 13/14 February this occurred during a small-scale attack on Plymouth when *Kn. No. 10* and *Kn. No. 11* were set to give a cut over this target. It is interesting to note that *Kn. No. 6* and *Kn. No. 8* were at the same time set to cut over London but no attack developed.[1]

From April onward, *Knickebein* activity became less, and in general was employed only by day, until in August a marked increase in the number of transmissions was apparent. As usual *Kn. No. 6* was the most active. Frequency changes with associated changes of beam setting were made on several occasions. Although these changes were not effected with any speed, as had been the case with the Ruffians, it was considered possible that training was now in progress with a view to enabling a false setting to be used as spoof up to the time of arrival of aircraft in the chosen area of operation, with a last minute frequency/setting switch to the true objective. It was realised that this arrangement would, if carefully timed and skilfully executed, render prediction impossible and make the application of the counter-measures most difficult. An example of the frequency/setting changes made by *Kn. No. 6* during a single operation on 30 August is given below:[2]

31·7 megacycles per second/359°; 32·1 megacycles per second/296°;
31·7 megacycles per second/359°.

On five occasions during September enemy air activity coincided with *Knickebein* transmissions, and the beam settings, where these could be determined, were in approximate agreement with the respective areas of operations. A difficulty in the identification of *Knickebein* signals had arisen at this time, however, due to the fact that signals were heard in the frequency band which did not appear to originate from *Knickebein* stations. It was thought that owing to congestion in this band the enemy was now using some of his airfield beam approach beacons on frequencies intermediate to the standard frequencies of 30, 31·5 and 33·3 megacycles per second.

A further modification to the *Knickebein* system arose in June 1943 when C.I.U. reported the existence of lattice masts in the immediate vicinity of four of the *Knickebein* arrays, namely, *Kn. No. 1*, *Kn. No. 3*, *Kn. No. 5* and *Kn. No. 11*.[3] The photographic evidence suggested that these masts were not of the normal V.H.F. communication link type but that they were definitely associated with their respective *Knickebein*. It was of interest that the lines joining the *Knickebein* array centres to the corresponding masts passed through the major targets Edinburgh, Hull, London and Bristol respectively. Careful watch for any changes of pattern or signal failed to reveal any peculiarities.

---

[1] No. 80 Wing Signal No. RX. 723 [2] No. 80 Wing Signal No. RX. 921
[3] C.I.U. Letters MDM/S.1246/2/G, dated 29 March 1943.

At this time prisoner-of-war statements and captured documents suggested that *Knickebeine* were not now being set over targets but were being used in conjunction with *Elektra* transmission to enable pathfinding aircraft to fix a turning-in point some 20 to 50 miles off the English coast.[1] In this connection it had been noted that *Sonne* transmitters had been observed operating as *Elektras* for certain periods during attacks against land targets at this time. The turning-point distances off the coast represented ranges at which *Aspirins* could not be expected to jam effectively. A similar course of action had been observed in the early part of 1942 when aircraft flying on medium frequency beacons had selected similar turning-in points at distances beyond the effective range of the Meacon transmitters.

The use of the *Knickebein* beams to provide spoof accentuated by the periods of frequency/setting changes was most successful in keeping alive the high potential threat engendered by the enemy system as a whole. The continuance of this danger, together with the growing threat of Benito as will be seen later, was responsible for the radical change in Royal Air Force jamming policy introduced later in the year.

During the years 1941 and 1942 the number of available jammers having a high power output had increased steadily and the delivery of these new transmitters, particularly of the T.U.4 type, continued during 1943. This transmitter, the prototype of which was first produced in 1941, was designed specially for R.C.M. purposes in the frequency band 27-100 megacycles per second, and was provided with many variable features in connection with the signal characteristics, in order that it should be of universal application for use against any of the known enemy radio aids in the band.[2] This principle had also been applied as far as practicable to the later deliveries of other types of transmitters. A very large percentage of the jamming transmitters available at this period in No. 80 Wing could therefore be switched from one jamming commitment to another as occasion demanded. Thus, by January 1943, when the new *Knickebein* frequencies first came into operational use, the additional jammers required were available. The change in function was rendered permissible at this stage by reason of the final defeat of the Ruffian menace late in 1942. The increasing *Knickebein* threat, followed later by a similar threatened Benito increase, resulted in all T.U.4 and such other transmitters having universal facilities, as they could be readily set up for operation in either the Aspirin or the Benjamin bands.[3] The use of the additional jammers together with an improved operational technique enabled effective counter-measures to be taken in all instances. The efficacy of the later Aspirins was verified by a series of test flights, and from the interrogation of prisoners-of-war, which once more indicated enemy aircrews' pronounced mistrust of the *Knickebein* system.

Spoof

The appreciation by the enemy of the value of spoof transmission as a diversionary and cover measure, and its effect on the scale of effort expended on counter-measures has already been mentioned. The efficacy of spoof had not escaped the attention of the British authorities, and various plans were proposed and examined. Spoof beam transmissions had already been

[1] A.D.I. (K) Reports Nos. 297/43 and 368/43.
[2] Appendix No. 13. [3] No. 80 Wing Monthly Report No. 36.

employed during 1942, mainly as a cover for the introduction of the British Gee system, using for the purpose the so-called " J " beam system on the east and south-east coasts.[1] Although actual operational beams were used, this was not regarded as an effective method of spoof since the beacons employed transmitted in the 50 megacycles per second frequency band for which only a very limited number of special purpose aircraft carried suitable receivers. Similarly it was doubtful whether enemy aircraft would be equipped to intercept these transmissions which might or might not have been picked up by the enemy ground interception stations. For these reasons it was ultimately decided that special measures would have to be introduced by means of which spoof signals would be transmitted in the 30 megacycles per second frequency band and particularly on 30, 31·5 and 33·3 megacycles per second, receivers for which were carried by the majority of enemy aircraft. A proposal to use a beacon originally erected at Tenbury for experimental purposes was not proceeded with because, although this beacon had been designed for navigational purposes and was capable of radiating the correct type of signal, extensive modification would have been required to change it from an H.F. to a V.H.F. transmitter.

Rotate

The form of transmission finally employed as a spoof was entirely of an artificial nature and consisted of signals reproduced on a Marconi-Stille tape machine, the tape having a recorded signal simulating a navigational aid in the form of a rotating Lorenz type beacon with a periodicity of 15 seconds. In consultation with the Assistant Director of Intelligence (A.D.I. Science) it was decided that the recording should contain all the characteristics necessary for such an aid except one, which would be the signal indicating the starting point or orientation of the system. It was considered that the omission of this characteristic would worry the enemy intelligence service. These spoof transmissions on 30·0, 31·5 and 33·3 megacycles per second commenced in March 1943 under the code name Rotate, using high power V.H.F. transmitters at Oakley and Alcester. In order to make the spoof as realistic as possible the times of transmission were co-ordinated with the actual Bomber Command operations, no transmissions being made when conditions of good visibility prevailed.

Benito

Despite the enemy loss of confidence in this system occasioned by the efficacy of the counter-measures employed, the *Luftwaffe* steadily continued to expand its ground station organisation until, by July 1943, the following stations were in existence :—

Site.	*Aerial Arrays.*
Stavanger	2
Cassel	2
Boulogne	6
St. Valerie	3
Cherbourg	9
Commana	2

Note.—Both beam and range signals were also heard from Montdidier but it was thought that this station was not intended for operational use but only to assist Benito aircraft in making an approach into the operational beam.

[1] Part 2 of this volume.

Coincident with the operational use of the threatening *Knickebein* system already described, this expansion of Benito stations had attained such proportions by March/April 1943, that a re-organisation both in disposition and in method of employment of existing Royal Air Force jammers had to be considered. An examination of the situation revealed the fact that at least fourteen further Domino installations would be required to provide adequate cover should this counter-measure be adopted. A Domino station consisted of much complicated equipment requiring specially trained and experienced crews. Neither the equipment nor the crews could be made available in time ; consequently at an Air Ministry meeting held in May,[1] it was decided to adopt a programme of crude jamming of the Benito communication channels only, and to utilise for this purpose existing transmitters.

This decision came at the time when there were numerous other potential calls on the jammer strength of No. 80 Wing, namely, *Knickebein*, Windjammer, Benjamin, Cigar,[2] Cigarette, and necessitated a complete change in jamming policy. In the past, jammers had been allocated to specific targets, but it now became necessary to re-allocate them to provide " area jamming." Under the original scheme a number of transmitters had been located in the vicinity of each of the main vulnerable targets and were brought into operation whenever an attack appeared to be about to develop on the target concerned. The new policy provided for one suitably-located transmitter of sufficient power to deal with each of the enemy transmitters, whether for communication or beam radiation. In the case of range communication jamming, a signal consisting of scrambled morse was employed, a Marconi-Stille tape reproducer being used for the purpose. For beam interference a slightly lower standard of jamming had to be accepted in that, whereas in the past it had been the aim completely to obliterate all signals, it was now possible only to render unusable the actual beam.

The redistribution of transmitters with, in many instances, the erection of 105 feet towers supporting cage aerials (designed to ensure distribution of the maximum possible power over the desired area) was put into effect. The movement of transmitters and a re-organisation of the Operations Room control was completed rapidly, but the last of the 24 towers was not finally erected until the spring of 1944.

A change in Benito procedure was learned from the crew of a single aircraft which was shot down in May 1943 when attempting an attack on London.[3] In order to avoid counter-measures this crew had been briefed to fly by dead reckoning on a time schedule to a nominated point on the English coast where the coastline was crossed by the beam. At this time the beam was scheduled to commence operation to be followed five minutes later by the ranging transmission. It was evident from this close timing, apart from verifications subsequently obtained from later prisoners of war, that Benito counter-measures were achieving results. It is of interest that a clock, similar to the " X " *Gerät* clock, was found in this aircraft.

During the first few months of the period under review, Benito activity consisted only of training and testing transmissions, and it was not until 7/8 February 1943 that any enemy signals could be linked with possible

[1] Minutes of Air Ministry Meeting (D. of Tels.), 4 May 1943.

[2] Part 2, Chapter 8. [3] A.D.I. (K) Report No. 263/43.

operational activity. The scale of enemy testing and training transmissions continued at a low level for the remainder of the period, with no further direct evidence that operational raids were being attempted, and at no time did the volume of transmissions intercepted begin to approach the maximum handling capacity of the ground stations. The contrast between the large effort involved in the building up of the Benito organisation and the small scale of operational use, or even for training, was the main feature of Benito activity during the period under review.

Enemy R/T Control of Fighter-Bomber Attacks

For several months prior to April 1943, the enemy had concentrated mainly on daylight attacks using *F.W. 190* aircraft which made tip-and-run bombing attacks against targets on, and near to, the southern and south-eastern coasts of England. During the months of April and May 1943, however, these fighter-bomber aircraft were employed during full-moon periods for night attacks against London and the south-east. On the nights 16/17, 18/19, 20/21 April 1943, *F.W. 190* fighter-bombers carried out what appeared to be experimental night-bombing sorties. In order to provide them with some measure of navigational assistance, the normal aircraft radio equipment *FuGe 16* (38–42 megacycles per second) was provided with a tone generator which could be used to modulate the aircraft transmitter for "fixing" by ground D.F. stations. This enabled the ground controls located at Cassel and Poix to direct these aircraft to the approximate target area by passing, in plain language R/T, the vector and flying time to target and, at the estimated appropriate moment, an order to release bombs. On the return journey, vectors and times to base were passed in order to home the aircraft.

A typical example of this activity occurred on the night of 16/17 April 1943.[1] Between 0010 and 0130 hours, twelve *F.W.190* aircraft which came in with the returning Royal Air Force bomber force, were plotted over the Eastern Home Counties and in the Greater London area. Twelve scattered incidents resulted, but these caused little damage and no casualties. Of the twelve enemy aircraft engaged, two landed at West Malling airfield and two others crashed. At least four of the aircraft were ground controlled from a station in the Cassel area, working on a frequency of 41·4 megacycles per second. Communication was by R/T and English names were employed as call-signs; plain language was used throughout the transmissions, which lasted from 2309 to 0120 hours.

Two of the aircraft radiated, in turn, a continuous note of 950–1000 cycles for approximately 15 seconds when called by the ground station. The signal was apparently used to obtain a D.F. "fix," since the ground station then passed back to the aircraft the course and the distance to the target, which was acknowledged. The procedure was repeated up to the target area when the aircraft was instructed to "release." The aircraft were guided back by homing courses to steer sent from the ground station and, after crossing the English coast, both homing courses and distances to base were sent. It was reported that the signal to bomb differed in the cases of the two aircraft heard. It seemed probable that "voice-fixing" was used for these aircraft which did not radiate a tone.

During the following month fighter-bomber aircraft R/T was heard on the frequency band 38·5 to 42·3 megacycles per second. The procedure employed

[1] No. 80 Wing Signal No. RX. 785.

was identical with that observed during April, except that the control was shared between two stations in the Cassel and Poix areas respectively. The former acted as control during the offensive stages of the operation while the latter homed the aircraft to bases in its vicinity. In these operations, the aircraft and the offensive control had separate frequencies, those observed being :—

Control : 41·4, 39·3, 40·5, 39·8, 40·95 megacycles per second.
Aircraft : 39·3, 40·5, 39·95, 40·9, 39·95 megacycles per second.

For homing, both aircraft and ground station transmitted on a common frequency which was usually 42·1 megacycles per second.

Counter-Measures—Cigarette

Cigar[1] was an R/T jammer on the frequency band 38–42 megacycles per second and had already been developed as a counter-measure against enemy control of night fighters. It was, therefore, comparatively easy to apply the knowledge thus gained to modify existing high-powered jammers in the south-eastern areas to jam fighter-bomber control instructions. This counter-measure was known as Cigarette. A large proportion of the transmitters (Aspirins, Bromides, Benjamins) held by No. 80 Wing were capable of covering the frequency used for control of fighter-bombers. In April 1943 arrangements were made to use a number of these transmitters, keying their modulation frequencies, as an interim counter-measure. In the meantime, steps were taken to provide noise generators for modulating certain of the transmitters to give optimum jamming of speech, and arrangements were put in hand for fitting the potential Cigarette transmitters with Marconi-Stille reproducers in order that tape recording of German speech or any other form of modulation could be reproduced and fed to the transmitters concerned.

During this month, in addition to a transmitter Type T.1298 installed at Ide Hill, the Alexandra Palace B.B.C. " vision " transmitter had been modified to include the fighter-bomber frequency band (38–42 megacycles per second), and a Marconi-Stille tape reproducer installed to provide modulation. The S.W.B.4 transmitter at Harpenden also had its range extended from 42–48 to 38–48 megacycles per second, and was available for operation on the 28 May 1943, a 105 feet mast having been erected and a Cigar type aerial fitted. By the end of July 1943 the modifications of all U.S.B.2, S.W.B.8 and S.W.B.4 transmitters to enable the fighter-bomber band to be covered without a major coil-change had been completed.

The use of R/T by the enemy quickly waned. It was evident that the psychological effect on the pilots of jamming greatly outweighed any advantage to be gained from the very occasional assistance which the system was able to provide. During June 1943, the last month in which fighter-bomber attacks were attempted, vectoring was confined to homing instructions given beyond the range of the jammers.

Medium Frequency Beacons

The system of beacon rotas described in Chapter 3 continued until the spring of 1943, when, on 1 March the German Air Force introduced a completely new

[1] Described more fully in Part 2, Chapter 8, of this volume.

beacon scheme.[1] The principal beacons were now divided into fourteen beacon groups each consisting of three sites which interchanged, at fifteen minute intervals, the frequency in use, frequency numerals still being employed as call-signs. In April the four enemy coastal groups increased the number of transmitters at each site to three and, by July, some groups consisted of four sites each with three transmitters. The allocation of Meacons was simplified by the new enemy system, since a given frequency was always sited in the same area. A reduction in the number of Splasher transmissions had resulted in an increased number of transmitters being available for meaconing but, during this period, Meacon receiving sites and the " Y " service reported a marked reduction in the beacon strengths, which rendered meaconing frequently difficult and occasionally impossible.

Sonne

In February 1943 the *Elektra* organisation, by this time expanded to a total of six stations, was revolutionised by the introduction of *Sonne*. *Sonne* consisted of a fan of *Elektra* beams sweeping in azimuth, which, by a simple counting process and reference to a suitable chart, enabled an aircraft to determine its bearing from a *Sonne* transmitter to an accuracy of between 1/3rd and 1/6th of a degree at intervals of two minutes, with the additional advantage that, whereas *Elektra* was only of value on the equisignal lines, *Sonne* provided a true navigational aid anywhere within its area of cover.[2]

The first station to transmit *Sonne* signals was the latest identified *Elektra* transmitter (E.6), situated in the Brest area to the south of Morlaix. This *Sonne* was first heard in February 1943 and was followed in April by a new station in Holland (S.5) which had been identified on photographs as early as June 1942, but which had never previously transmitted. In April 1943 *Elektra* 1 (Stavanger) was converted to *Sonne* (S.1) and another new station S.15 (303·2 kilocycles per second) was established in north-west Spain (near Lugo). This had obviously been installed to cover the Bay of Biscay area in conjunction with S.6 at Brest. Subsequently S.18 (297 kilocycles per second) near Marseilles came into operation in June 1943, S.3 (306 kilocycles per second) at Caen in August 1943 (after a silence lasting from November 1941) and S.15 (311 kilocycles per second) near Seville (south-west Spain) in September 1943.

As in the case of *Elektra*, meaconing was employed on all occasions against *Sonne* transmissions which could be used against and in the vicinity of this country. Confirmation of the effectiveness of *Sonne* meaconing was obtained from two prisoners of war during this period.[3] One stated that it had been " jammed by day " whereas the other went much further by saying that (including *Sonne*) there was now a great number of navigational aids, but that they were all being jammed by the Allies.

Consol

At this period Coastal Command recognised the value of *Sonne* as a long-range navigational aid, and in May 1943 commenced to use *Sonne* under the code-name Consol, employing charts prepared by No. 80 Wing.[4] The stations at

[1] Appendix No. 3. [2] Diagram 3.
[3] A.D.I. (K) Reports Nos. S.R.A. 4050, 6 June 1943; *ibid*. S.R. Draft 3612, 6 June 1943.
[4] Diagram 3.

Brest (S.6) and north-west Spain (S.15) were used for this purpose, and, accordingly, arrangements were made to regulate the meaconing of the former in order that protection for this country should be ensured, whilst still leaving the signal unspoiled in areas over which Coastal Command conducted their operations.

See-Saw

Preparations against See-Saw had previously been confined to obtaining proposals for countermeasures from the experimental establishments.[1] Further investigations by the Naval Intelligence Bureau (N.I.B.) during the early part of 1943 confirmed the conclusion that these signals constituted a form of rotating beacon but it was still considered that the signals were of an experimental nature only.[2] Strong evidence was obtained that transmissions were also being made from Italy and that the original transmissions from the Berlin area were for the benefit of research workers in Italy or Sicily.

Although there was still no evidence of operational use of these beacons, No. 80 Wing was instructed to prepare an appreciation of the counter-measures that might be necessary. The position was considered by the Operations and Technical Radio Committee, and at the twenty-third meeting of the R.C.M. Board, held in November 1943, it was decided that for the time being action should be limited to preparations enabling counter-measures to be instituted at short notice if required.[3] As a result of this decision certain transmitters were to be earmarked for possible use in the United Kingdom. In order to provide the equipment recommended for the proposed North African combined watcher and jammer site, a contract was arranged with Messrs. Marconi for the necessary parts to be constructed to enable four of the existing No. 80 Wing special S.W.B.11 transmitters to be converted, if required, to the normal commercial type covering 2–20 megacycles per second. The designs for special crystal oscillators for the alignment of the transmitters was also put in hand. It was considered that the station in North Africa would constitute the principal effective jamming centre for use against the known or suspected See-Saw sites. Beyond these preparations, no further action was required and, as it turned out, no operational developments in connection with this suspected aid ever materialised.

Development of No. 80 Wing Operations Room[4]

Although the large-scale bombing attacks anticipated did not materialise, the great increase in the number of *Knickebein* and Benito transmitters available to the enemy resulted in the substitution of "area jamming" for "target jamming". This change in policy has already been described under the heading Benito. Control of V.H.F. jamming in No. 80 Wing Operations Room was altered as a result. The jammer capable of providing effective area cover over a particular enemy transmitter was always brought up first and known as First Line Cover. Any other jamming transmitters available were subsequently ordered as "backers up" and were known as Second Line Cover. It was essential that transmitters providing first line cover had priority in monitoring, and watcher stations were instructed to inform the Reports Section when the

[1] In Chapter 3. [2] N.I.B. Special Reports Nos. 14/43 and 16/43.
[3] Minutes of R.C.M. Board 23rd Meeting, 16 November 1943. [4] Appendix No. 4.

main jammer was monitored on to the enemy signal. The information was passed immediately to the Controller who could then order to be switched on the second line transmitters which had in the interim been lined up and were standing by.

With the passing of the Ruffian system, all available jammers were evenly distributed over the *Knickebein* and Benito frequency bands. Speed was becoming an ever-increasing necessity because the enemy, to avoid counter-measures, now delayed radiation of navigational beams until the aircraft were approaching the British coast. To avoid the delay caused by effecting major changes in transmitter tuning, each transmitter was allotted a "basic" frequency to which, pending operational instructions, it was permanently tuned. A map showing all jamming sites with the frequencies allotted to the different transmitters was displayed and by reference to this the Controller was enabled to select, at the site most suitable for first line cover, the transmitter nearest in frequency to the enemy signal.

CHAPTER 5

RADIO COUNTER-MEASURES, SEPTEMBER 1943 TO JUNE 1944

German air activity and use of long-range bombing and navigational aids showed a steady decrease during the spring and summer of 1943, and attacks were confined almost entirely to fighter-bomber activity on a small scale. September, however, saw an increase in the number and weight of attacks, which continued throughout the autumn. It became apparent also that the enemy had learnt many lessons from the Allied bomber offensive. Moderate use was made of *Duppel* (Window),[1] and airborne rear-warning radar was introduced for the first time.

By the beginning of 1944, large-scale attacks by as many as 130 aircraft were being made against London and the South-East Counties, and a new and elaborate *Luftwaffe* pathfinder technique involving the use of a specialist squadron (*K.G.66*) of Benito, *Hyperbel* (British Gee), and the new *Egon* procedure was in operation. The bombing began to the accompaniment of extravagant claims by the enemy as to the strength and effectiveness of his bombing force. Targets in London were described by the names of heavily bombed German towns, and these "large-scale" reprisal attacks were to be sustained and extended. Exaggerated claims were also made for the accuracy of the new pathfinder technique, whereas the pathfinder aircraft were responsible for misleading the main bomber force on numerous occasions.[2] Results compared unfavourably with those obtained during the heavy raids in 1941, and although for some time the German Air Staff apparently refused to be convinced, *Luftwaffe* pilots captured during April indicated that the pathfinders were becoming suspect, and efforts were being made to check their performance.

Attacks on British ports, coastal areas and shipping absorbed practically all the enemy's main effort during April and May. Small-scale intruder activity occurred during June, but with the launching of the Allied invasion of North-West Europe and the introduction by the enemy of pilot-less bombing, German aircraft attacks ceased completely.

German Attempts to Evade Counter-Measures against *Knickebein*

A great increase in *Knickebein* activity was observed during this period, and, in addition to transmissions which coincided with enemy night operations, considerable day-time activity occurred. During the day-time transmissions an attempt was made to mask the aligning of the beams by simultaneous transmissions, on a common frequency, by two *Knickebeine*.

The efficacy of the Aspirin counter-measures against this enemy navigational aid, the use of which continued throughout the whole period under review, was

[1] German jamming counter-measures against Allied early-warning radar are narrated more fully in Volume IV. On the whole they did not compare in intensity with Allied jamming of German early-warning, although there were localised incidents of thorough jamming by the enemy.

[2] A.W.A. Report BC/35 of 18 April 1945.

confirmed by certain changes in tactics, clearly adopted to render the *Knickebein* beams less vulnerable to jamming. Ground observations, substantiated by prisoner-of-war statements and captured documents, revealed that the beams were no longer set over targets, but were used instead (sometimes in conjunction with *Elektra* transmissions) to enable pathfinder aircraft to " fix " a turning-off point off the English coast sufficiently distant to be outside the influence of R.C.M.[1] The use of this procedure had been noted during earlier phases, but was now intensified. Frequency changes during operations were also employed. These, however, were not the rapid changes formerly associated with the Ruffian system, the time taken being of the order of 15 to 20 minutes. Further attempts to evade or delay British counter-measures were also evident. The policy of bringing up the beams within a few minutes of the beginning of an operation (thus making a pre-determination of the beam settings impossible) was adopted on many occasions ; and transmissions from a large number of *Knickebein* during each operation were made to confuse the counter-measure organisation.

Throughout the whole period, tracks of enemy aircraft showed little evidence of any attempt at beam flying. The interrogation of many prisoners-of-war revealed that a widespread mistrust in the system still persisted. This again confirmed the effectiveness of Aspirins ; and a series of test flights undertaken by No. 192 Squadron (successor to No. 109 Squadron) during February and March 1944, indicated a general confusion of enemy signals for many miles beyond the coast.[2] It is difficult to explain why the German Air Force authorities retained a system which was so obviously neutralised. One possible reason was that they hoped by the continued use of *Knickebein* to mask the introduction of their new *Egon* procedure.

Egon

An unusually high incidence of flares during small-scale attacks in December 1943 foreshadowed the introduction of a new form of pathfinder technique, known later to be employed by aircraft of the specialist *Geschwäder K.G.66*, and designed to enable the main body of aircraft to find the target area by means of a complex flare system. Although there was no direct evidence, it was thought that the operation of these aircraft might be associated with some new radio aid to navigation. In February 1944 the " Y " Service observations indicated the existence of a new enemy system somewhat similar to Oboe. This was first known as *Rubezahl* and later (from prisoner-of-war interrogation) established as *Egon*.[3] The use of this procedure for the accurate dropping of target marker flares was limited to a specially-trained *Staffel* of *K.G.66*. The accuracy expected was within 0·3° in bearing and 220 yards in range at 170 miles.

Egon aircraft were equipped with a comparatively high power I.F.F. unit (*FuGe.25A*), which responded on approximately 156 megacycles per second to *Freya* type pulses transmitted in the 123–128 megacycles per second band. *Freya* or *Mammut* radar stations were used to " trigger " the responders, which had individual coding units to enable particular aircraft to be identified and to plot the aircraft positions by range-plus-bearing measurements. The system could be recognised by the fact that the pulses of the controlling *Freya* and the

[1] A.D.I. (K) Report No. 78/44, para. 16.
[2] No. 192 Squadron Reports Nos. 89, 108, 120, 128 and 131/44.
[3] A.D.I. (K) Reports Nos. 160/44 and 187/44.

response of the *FuGe.25A* were locked. Control instructions consisting of vectors to target, and bomb or flare release orders were at first passed by radio telephony in the *FuGe.16* band (38–42 megacycles per second).

Counter-Measures against *Egon* Communication Channels

Counter-measure Special Cigarette (a development of Cigarette, which had already been organised to jam similar transmissions used for fighter-bomber control)[1] was brought into operation using the modified " vision " transmitter sited at Alexandra Palace, London. Provision was made at a later date to increase jamming cover to include, if necessary, the West Country, and the use of Benito jammers at No. 80 Wing Stations, Stockbridge and Templecombe, was sanctioned for this purpose.[2]

Tests under operational conditions presented many difficulties, since they entailed an aircraft flying through the Inner Artillery Zone, but flights made by No. 192 Squadron during non-operational periods gave satisfactory indications that the jamming was adequate.[3] Prisoner-of-war statements confirmed the effectiveness of the jamming, and the subsequent adoption by the enemy of alternative channels of communication provided conclusive evidence. Prisoners captured in March 1944 stated[4] that control instructions were passed simultaneously in three communication channels, namely :—

(*a*) 38–42 megacycles per second (*FuGe.16*).
(*b*) 3–6 megacycles per second (*FuGe.10*).
(*c*) 583 kilocycles per second (*PeiGe.VI*).

In addition, an automatic presentation device was said to be in course of development ; this equipment, the *Egon-Gerät*, would enable control to be effected without the use of R/T or W/T, but information received at a later period disclosed that *Egon-Gerät* was never used operationally. Signals in the H.F. band were never intercepted but a M.F. channel heard at a later date, and subsequently proved to originate from the Calais I Broadcast Station (100 kilowatts) was jammed by a high-power B.B.C. station under the code name of Bareback ; this operation was under the control of the Royal Air Force Station at Kingsdown.

Counter-Measures — Ranging System

Interference with the ranging system presented a more difficult problem. By the end of February 1944 the " Y " Service had established that the enemy radar stations normally employed for this system were located in the Pas de Calais area, and at an Air Ministry meeting[5] it was decided, as an interim measure, that the South Coast Mandrel[6] should radiate during periods of enemy activity to operate in a defensive role and prevent the plotting *Freyas* from using the direct aircraft reflection. It was realised that effective counter-measure action must also involve the jamming of the *FuGe.25A* or the *Freya*, or both. The development of experimental jammers was undertaken by Headquarters, No. 60 Group, working in close co-operation with Headquarters,

[1] Part 1, Chapter 4, of this volume.
[2] Minutes of Air Ministry Meeting on 28 April 1944—No. 80 Wing File T.S. 3041/11/Sigs., Encl 9A.
[3] No. 192 Squadron Report No. 105/44. [4] A.D.I. (K) Report No. 160/44.
[5] Minutes of Air Ministry Meeting, 28 February 1944—No. 80 Wing File T S 3041/11/Sigs., Encl. 1A
[6] Part 2, Chapter 8, of this volume.

No. 80 Wing, who were to be in control of all ground jamming. This decision was later modified and primary control vested in Headquarters, A.D.G.B. (Air Defence of Great Britain—formerly Headquarters, Fighter Command), using No. 80 Wing Liaison Officer for control of jammers through Headquarters, No. 80 Wing.[1]

Briar " H "

Two types of jammer, called Briar " H " and Briar " R ", were developed. Briar " H "[2] was designed to be " triggered " by the enemy radar station and from a knowledge of the position of the controlled aircraft, and by employing a suitable delay in the response, to transmit bursts of " mush " which would jam the enemy range tube over the band of ranges in use. Briar " H " stations were established at Eastcliffe (Portland Bill), Whitehawk (Brighton) and Ramsgate.

Briar " R "

Briar " R " was originally intended as a Domino type jammer, that is, to receive the re-transmission from the enemy I.F.F. and to use this to trigger a transmitter tuned to the *FuGe.25A* receiver frequency. Thus the Royal Air Force transmissions would keep the enemy I.F.F. in continuous transmission and prevent the *Freya* station from interrogating. Such a circuit was found to contain too great a delay for the pulse frequency required, and as a result it was finally decided to use A.S.V., Mark II transmitters in groups of four, each pulsing at a rate sufficiently high to prevent any useful response being obtained by the interrogating *Freya* station. It was intended that four Briar " R " transmitters should be used at sites chosen to provide cover for London, Portsmouth, Plymouth and Bristol, but only one (experimental) station was established, and sited at Hampstead Heath. Neither method was used operationally, and both were superseded by a system known as Red Queen which was controlled by A.D.G.B. Red Queen involved the control by selected G.C.I. stations of British night-fighter aircraft fitted with special receivers to receive the *FuGe.25A* transmission, thus enabling them to " home " to the enemy aircraft.

Since the enemy had many long range radar units suitable for *Egon* plotting, it was thought that extensive use would be made of the *Egon* procedure for bombing Allied bridgeheads and headquarters. No such operations were, however, identified. Although during a later stage of the war the system was used for the control of enemy nightfighters, its employment in an offensive capacity was short-lived, and by May 1944 had ceased completely.

Benito

The use of Benito continued sporadically throughout the period under review, but, as has already been stated, on no occasion was the enemy effort comparable with the capacity of the known Benito organisation. Ground station and aircraft transmissions coincided with enemy activity on many occasions, and signals which might have been bomb or flare dropping instructions were intercepted. It proved impossible, however, to correlate any Benito activity with incidents or enemy aircraft tracks.

---

[1] Minutes of Air Ministry Meeting, 17 March 1944—No. 80 Wing File T.S. 3041/11/Sigs., Encl. 3A.

[2] Appendix No. 12.

During the summer of 1943, in view of the great increase in the number of Benito range transmissions and the difficulty in obtaining sufficient numbers of Domino stations, a decision was made to abandon this counter-measure and concentrate instead on the jamming of the Benito beam system (Benjamin) and the communication channel. In October 1943 the new multiple morse modulated jammers (" M " Tape) to jam ground station W/T communication were used for the first time with very promising results. At a later stage (Spring 1944), in view of the small incidence of range transmissions, the Domino system was re-introduced on a small scale and used in addition to beam and communication jamming.

A prisoner-of-war statement provided direct evidence of the efficacy of counter-measure action taken during this phase[1]. The prisoner stated that during an attack on Portsmouth at the end of May 1944, the " Y " *Gerät* in his aircraft was jammed to such an extent that its use became impossible. There is little doubt that this statement refers to the attack on Portsmouth on the night 22/23 May 1944. On this occasion an aircraft was heard to operate alternatively with two stations at Cherbourg, after which it was heard on two occasions to re-radiate the Morse modulation (" M " Tape) which was being employed to jam transmissions from St. Valery. It is possible that an attempt was being made to work St. Valery in order to avoid counter-measure action.

As a final illustration of the scale of effort displayed by the enemy in the building up of the Benito organisation in contrast to the relatively small bomber operational use made of it, it is of interest to note that the last bomber Benito signals intercepted were heard on 14 August 1944, when a new station, just complete, at Aumale commenced test transmission only three days before it was dismantled, and seven days before the area was evacuated by the enemy[2].

Neptun

The intensification of air assault against this country resulted in the adoption by the enemy of various methods to protect his bomber force. In addition to employing *Duppel* (Window), airborne rearward warning radar was employed. As an interim measure a modified form of *Lichtenstein* A.I. (490 megacycles per second band) was used, but this was later followed by a specially developed equipment known as *Neptun*. The latter worked on a lower frequency band and was more convenient to use since it was fitted with a small presentation unit sited between, and equally available to, the pilot and observer. The tail-warning apparatus was first noted in a crashed enemy aircraft in October 1943, and in November a receiver in good condition was recovered from the wreckage of a *Ju. 88*.[3] A transmitter was later salvaged on the Continent and a captured document provided further details. The equipment was found to have a pulse frequency of approximately 1500 and to transmit on a nominal frequency of 167 megacycles per second.

This new device proved to be of considerable embarrassment to Headquarters, Air Defence of Great Britain (A.D.G.B.) and efforts were made to provide as a matter of urgency, a suitable counter-measure[4]. The task was not easy since the enemy transmission was beamed and, whereas a jammer of given

[1] A.D.I. (K) Report No. 276/44. [2] No. 80 Wing Monthly Report No. 57.
[3] A.U.2 (g) Report No. 1703, 20 December 1944.
[4] No. 80 Wing File M.S. 3041/10/Sigs., Encl. 1A.

power might prove successful if astern of the bomber, a considerably greater power was required with the jammer sited to one side of the aircraft. The use of both ground and airborne jammers was considered, and in January a decision was reached to provide six ground jammers on G.C.I. sites in South-East England.[1] The jammers were to have highly directional aerials and to be directed towards enemy aircraft with the aid of the adjacent G.C.I. stations. In addition it was proposed to prototype an airborne jammer. These counter-measures were to be developed and prototyped by the Telecommunications Research Establishment.

Meerschaum

Pending the production of these jammers, eleven Light Warning radar sets were modified and installed on selected A.M.E.S. sites and at No. 80 Wing Stations, Flimwell, Braintree and Henfield. They were tuned to the mean frequency of the transmissions which had been recorded and were switched on whenever enemy activity towards or over the coastline of this country coincided with "Y" Service interception of *Neptun* signals. The whole counter-measure scheme was given the code name Meerschaum and was controlled by the Filter Officer at Headquarters, A.D.G.B. The Light Warning sets came into operation at the end of February and the main Meerschaum scheme which had been developed by T.R.E. was completed by the end of May 1944. By this time, however, the use of *Neptun* had declined to a very low level. Prisoners of war stated that indications from other bombers in the same stream so confused crews that they preferred to rely on visual warnings.[2] Meerschaum in its final form was, for this reason, never used operationally.

Medium Frequency Beacons

A major change in the enemy beacon system was noted during this period, its introduction coinciding with the re-commencement of the large-scale bomber activity against this country.[3] During 1943, German Air Force beacons had been operated on a very complicated group system involving frequent changes in call-sign, frequency and location. When long-range bombing re-commenced in earnest in January 1944, the allocation of frequencies between the enemy beacon groups and sites remained fixed for the duration of each operation, although the old system was adhered to during non-operational periods. A prisoner of war stated[4] that the enemy had been forced to employ the new system, despite the fact that it simplified the application of counter-measures, since the overwhelming complexity of the original scheme had rendered it unworkable under operational conditions. Meaconing of enemy beacons during periods of activity continued normally throughout the period and its efficacy was confirmed by statements from prisoners of war who continued to show a general mistrust in the use of beacons outside their own coastline.

Sonne/Elektra

Two new *Sonne* came into operation during this period, S.16 (Seville, Spain) in September 1943 and S.19 (Beauvais, France) in January 1944. It is probable that the latter was a replacement for S.3 (Caen) which ceased to transmit in March 1944. Mention has already been made of the fact that whereas the

[1] Minutes of R.C.M. Board, 25th Meeting, 11 January 1944.
[2] A.D.I. (K) Report No. 157/44. [3] Appendix No. 3.
[4] A.D.I. (K) Report No. 51A/44.

Sonne system was advantageous for general navigation, *Elektra* was more useful for homing, for marking a predetermined landfall, and for approach runs to a target or turning-in point. With the commencement of the final long-range bomber assault against targets in Britain, it was observed that selected stations, which normally operated as *Sonne*, changed to *Elektra* during, or immediately prior to, the period of enemy activity. The principal stations which operated in this manner were S.3 (Caen), S.5 (Petten, Holland) and S.19 (Beauvais). The last named station was evidently erected to coincide with attacks on the London area since the central beam of the system passed through the capital. By this change of system the enemy frequently gave prior warning of impending attacks, since on a number of occasions *Elektra* signals were intercepted from the " key " *Sonne* stations above mentioned, long before his aircraft were plotted by Allied ground radar stations.

Prisoner-of-war reports received during November 1943 gave further confirmation of the success of meaconing as a counter-measure to *Sonne*.[1] It was stated that the system gave a good " fix " when undisturbed but that the zones appeared to be deflected when the transmission was meaconed. This was borne out during April 1944 by a flight made by No. 192 Squadron to investigate the meaconing of S.5 by a G.12A transmitter at Mundesley.[2] The D.F. bearings taken during the " beacon " period of the *Sonne* cycle were very inaccurate and the counts of *Sonne* characteristics sufficiently erroneous to result in completely false bearings.

---

[1] A.D.I. (K) Report No. SRA. 4530 of 17 November 1943.
[2] No. 192 Squadron Report No. 135/44.

CHAPTER 6

RADIO COUNTER-MEASURES, JUNE 1944 TO MAY 1945 (End of Hostilities in Europe)

The final phase in the defensive activities of No. 80 Wing opened with the Allied landing in Normandy on 6 June 1944. This involved the implementation of plans which had been in preparation for some months to provide radio counter-measures in support of Operation "Neptune." Radio counter-measures were considered necessary in view of the many navigational aids available to the Germans for use in attacks against the ports of embarkation, convoy assembly areas, and finally the landing area. The steps taken are described in detail later.[1]

Within a week of the Allied landing in North-West Europe, the Germans introduced the first of their much advertised secret weapons with the beginning of attacks on the London area by flying bombs (V.1). It was almost immediately established that although no radio control was used a small percentage of the bombs carried low-power M.F. transmitters which enabled the track, fall and time of the bomb to be plotted by ground D.F. stations. A special organisation was rapidly developed for meaconing the transmissions. At this time also, information became available which pointed to the need for the development of a large counter-measure organisation in anticipation of attacks by a rocket projectile (V.2) believed to be radio-controlled. These attacks did not occur until September when it became apparent that radio control was not being employed, although certain precautions were still considered necessary. The pilot-less bombing continued until the spring of 1945 when a brief recrudescence of aircraft bombing occurred. It was confined entirely to attacks by intruder aircraft and did not involve the use of any of the established enemy navigational aids. Certain airborne radar aids were, however, used and a watcher organisation was set up and other counter-measure preparations made against these devices.

It will be seen, therefore, that during this phase, the defensive activities of No. 80 Wing (which was also much occupied with the development of offensive counter-measures in support of Bomber Command) fell into four main categories :—

(*a*) Preparation for Operation "Neptune," described in Part III of this volume.

(*b*) Counter-measures against flying bombs ("Diver").

(*c*) Counter-measures against rockets ("Big Ben").

(*d*) Counter-measnres against radar aids used during intruder activity.

Flying Bombs (V.1)

Flying bombs were used by the enemy—initially against south-eastern England, and later against Allied-held positions on the Continent—from 13 June 1944 until March 1945. The vast majority of the bombs despatched against England were ground-launched from ramps situated along the Continental coast from the Cherbourg peninsula to the Scheldt estuary. When the campaign was at its height in July and August 1944 the number of flying bombs (known as divers) was normally about 100 per day and rose on occasion to nearly 200.

[1] Part 3, Chapter 18, of this volume.

The ground-launching of flying bombs against England came to an end with the Allied advance into Holland (August/September 1944), but a limited attack on a much smaller scale was kept up by the launching of flying bombs from aircraft, usually about 50 miles or more off the East Anglian coast at night. These operations continued until March 1945, being carried out mainly by *K.G.53* using *He.111* aircraft from about eight bases in North-West Germany. Some pathfinding was done by *I.K.G.66* who were suspected of providing navigational aids (*Schwan Buoy*) for the *He.111s* over the North Sea.[1] Ground-launched flying bombs continued to be used in considerable numbers against continental targets through the winter of 1944–45.

During the first few days of Diver operations, remnants of wireless equipment were found in flying bomb wreckage[2] and searches were maintained to receive and identify wireless signals transmitted by flying bombs. The first identification of such a transmission occurred on 22 June 1944 when a signal was heard by a D.F. operator at the Sutton Vallence (Kent) station consisting of a long dash and a keyed morse letter which sounded similar to the noise made by a flying bomb and which coincided with one flying over that station at the time, and reported as crashing at Carshalton a few minutes later at a time which corresponded to the cessation of the signal. It was assumed that the enemy might use these signals in one or more of the following ways:—

(*a*) To ascertain the track followed by the bomb.
(*b*) To determine the point of impact of the bomb.
(*c*) To gain information of bombs failing to reach their target, either due to failure of their mechanism or to interception by aircraft, anti-aircraft artillery or balloon barrage.

The signals transmitted by the flying bomb when received at direction-finding stations and compared for bearing and duration with the estimated trajectory of the missile, would have enabled the enemy to form tolerably accurate estimates of the success achieved by his attacks. Evidence was later obtained from prisoner-of-war sources indicating that German operators had been specially trained for this D.F. work, enabling a plot to be obtained and passed to Control within ten seconds.[3]

Examination of a number of crashed flying bombs indicated that the transmitted signal was switched on automatically and that there was a keying mechanism which produced a C.W. radiation of some 20–25 seconds' duration, usually followed by a 6–8 seconds' space, containing a slowly and badly keyed morse letter. Many signals with these characteristics, which were definitely associated with flying bombs, were intercepted on frequencies between 300 and 500 kilocycles per second. It is probable, however, that the signal radiated did not always occur on the frequency intended since the trailing aerial was found in several instances to have been only partly unwound.

The most obvious and least difficult counter-measure to apply against ground-launched flying bombs was the meaconing of their transmissions, the aim being to produce false bearings and prevent the enemy from getting accurate "fixes." Much consideration was also given to other forms of counter-measure, the principal types being the barrage jamming of the 300-600 kilocycles per second frequency band and the transmission of bogus signals resembling flying bomb

[1] A.D.I. (Science) A.S.I. Report No. 151, 11 December 1944.
[2] A.I.2 (g) Report No. 2244, 17 June 1944. [3] A.D.I. (K) Report No. 311B/44.

signals. The object of the former was to prevent any effective reception of flying bomb transmissions by the enemy and the latter to confuse direction finding and to prevent computation of the duration of flight by observation of the end of the signal.[1] Meaconing was applied by the provision of a suitable system centred on a special monitor and control organisation at the No. 80 Wing station at Ditchling with transmitters principally at Henfield.[2] The other types of radio counter-measures were not applied for reasons given later in this chapter.

By the time the air-launched flying bomb campaign started, the use of flying bomb radio had ceased. Counter-measures applied in this phase were therefore against navigational aids used by the aircraft. The only radio navigational aids of which there was evidence from identified intercepted signals were M.F. beacons (particularly Big Screw, Central European beacons and *Sonne*) against which Mimic and Meacon action were taken. V.H.F. counter-measures were also held available for use against the navigational aids on the 30 and 40 megacycles per second frequency band (*Knickebein*, *Cyclop*, *Hermine*, *Bernhard* and V.H.F. beacons) but were not used against specific signals as none was intercepted.

Meaconing of Flying Bomb Transmissions

In view of the position of the Diver launching sites and the targets—London, Portsmouth-Southampton and perhaps Bristol-Avonmonth (had the Cherbourg peninsula been held by the enemy)—it was assumed that a D.F. system might be employed by the enemy with receiver sites along the coast on a sufficiently wide front to give satisfactory cuts along the latter part of the tracks of the flying bombs and over their targets. It was therefore necessary to find one or more sites for Meacon transmitters which would not be on the line between the majority of launching sites or D.F. stations and the targets. The Henfield-Ditchling Meacon station met this requirement (being west of the main Diver approaches to London and east of Portsmouth) and was also well situated for reception. Arrangements were also made for Diver meaconing by the No. 80 Wing Meacon stations at Flimwell, Rogate and Windlesham, both in order to have more transmitters available (the scale of flying bomb launching was thought likely to increase) and to have the ability to " pull " bearings in various directions, depending upon the particular Diver track and the prevailing meteorological conditions, as might be required.

Diver meaconing was generally controlled from the Operations Room at Ditchling in which a watch of about twelve receivers was also maintained, eight of which could be used to drive Meacon transmitters at Henfield. The expansion was achieved by adding huts and incorporating a mobile Meacon unit receiver trailer which was " married " to the buildings. Additional spaced vertical aerials were also installed at Ditchling. At Henfield the transmitter portion of the mobile Meacon unit was set up on a site adjacent to the existing station. The need for additional transmitters at Henfield ceased when the G.P.O. Radio Research Department completed the installation of a modified Meacon system enabling a single M.24 transmitter to cover up to six flying bomb transmissions simultaneously without retuning, thus minimising delay.[3] Later this transmitter was replaced by a special wide band amplifier designed by the

[1] No. 80 Wing File S.3062/Sigs., Encl. 6A.
[2] Air Ministry Letter, D.D. of Tels. 2/530, 22 June 1944.
[3] Post Office Instructions G.B. 16, 19 July 1944 and G.B. 18, 26 July 1944.

G.P.O. to enable greater power per channel to be obtained. Receiver watches with limited D.F. facilities were maintained by No. 80 Wing at Aldington, and portable D.F. equipment was also installed at various times at Ditchling, Flimwell, Rogate and Windlesham. The object of the D.F. sets was to assess the effectiveness of meaconing by comparing timed bearings or fixes with Diver tracks. The signals intelligence service also maintained extensive listening watches, particularly in the earlier part of the flying bomb campaign ; and their system of D.F. stations was also employed to give bearings or fixes. The " Y " service information was passed to Ditchling by tie-line. All plots and tracks identified as Diver were passed from the A.D.G.B. Operations Room via Radlett to Ditchling where they were plotted on an illuminated display, which served to give assistance to the receiver watches and also provided some data for analysis of Diver signals activity. A telephone system was provided linking the control room at Ditchling externally with Radlett, the other No. 80 Wing stations in the scheme and Sutton Vallence, and internally between the Controller's position and all receivers, thus permitting signals to be monitored at will.

The strength of personnel at Ditchling was augmented to provide sufficient officers (Flight Lieutenants or Flying Officers) for one to be on duty at all times in charge of Diver R.C.M. Control assisted by one or two N.C.O.s as deputies and about fifteen airmen per watch, including the manning of a heterodyne wavemeter, a recorder, the telephone exchange and (for a time) a D.F. set, in addition to the search receivers. At the transmitting site the existing strength plus that of the mobile unit sufficed.

Searches were maintained initially by dividing up the band between the available receivers and maintaining a general search. As experience increased, the bands were varied so that the regions in which signals were most often heard were covered more closely, each receiver having a smaller range to search, in order to minimise the delay in picking up a signal in any given range. Technical modifications, training and experience brought the average delay in detecting, identifying and covering a signal down to under one minute.

During the first week of operations (27 June–4 July) about sixty signals were reported to have been meaconed. It is doubtful whether all these " signals " in fact emanated from flying bombs. Due to congestion in the M.F. band a mixture of several signals giving a " rough rippling note " was often audible which closely resembled a Diver signal in practically every respect except that it lacked a keyed letter and, until the operators gained experience, it is most likely that some of these noises were meaconed, either because they were mis-identified or in order to be " on the safe side." The totals of flying bomb signals (and suspected signals) heard and meaconed were as follows :—

Period.	*Number.*
27 June—4 July	63
5 July—12 July	21
13 July—20 July	25
21 July—28 July	18
29 July— 5 August	14
6 August—13 August	4
14 August—21 August	2
22 August—29 August	1
30 August onwards	Nil
27 June—29 August	148

In addition, one signal in March 1945 was meaconed by Mundesley. This signal was probably associated with ground-launched flying bombs against Antwerp. A few other signals of this kind were reported at about this time by the " Y " Service. It will be seen that the number of intercepted transmissions declined steadily. Even if the figure of 63 were accepted for the first week after the signals had been identified, the percentage of flying bombs transmitting signals did not, at its highest, exceed 5 per cent. of the total launched and in fact the proportion soon dwindled to a negligible fraction.[1] It was not known, moreover, how many bombs were fitted with radio, or how many of those fitted were supposed to be switched on in flight. Nor was it known what use the enemy either intended to make or succeeded in making of this equipment, nor what ground organisation was employed. It was apparently not used extensively, and when a new target area (Portsmouth) was attacked no signals were heard which linked up with known bombs, suggesting that the enemy did not place much reliance upon it in assessing results.

Radio Counter-Measures against Enemy Ground Radar

It was evident that the enemy could gain some help in assessing the performance of flying bombs by following them with his coastal radar stations (particularly large installations such as " Hoardings " and " Chimneys ") for the first part of their track—say 30 to 50 miles, depending on the type and site of the radar and the height of the flying bomb—and coupling this information with the time of cut-off of the wireless transmission. There was also the possibility that the raising and lowering of some portions of the " Diver " balloon barrage might have been discernible to his radar. Extra radar jamming was therefore applied. The No. 80 Wing Ground Mandrel station at King Lear, situated on the high ground just west of Dover, was ordered to jam the enemy early warning radar on the opposite coast. This equipment could be operated on about twenty-four channels at will in the frequency band 65–230 megacycles per second. In order also to cover the *Seetakt* and *Wurzburg* equipments, arrangements were made for the use of the Carpet equipments (220–550 megacycles per second) which were under the operational control of the Royal Navy on the same site. In order to reinforce the radar jamming, the Fairlight Mandrel station (supplemented by the equipment from the Mandrel station at Ventnor) was rebuilt on a more favourable site nearby at Firehills.

Alternative forms of R.C.M.

The following forms of R.C.M. were also proposed but, on further consideration, not actually employed, although in some instances personnel and equipment were provided and installed for use if needed :—

(*a*) To prevent the enemy from receiving flying bomb signals it was proposed to jam the M.F. band from 300–600 kilocycles per second continuously with noise. An undercliff site at Hastings was selected for this purpose and a barrage of M.24 transmitters installed. The scheme was not put into effect due to the adverse effect which it would have had upon Allied communications, particularly Navy, R.A.F. and U.S.A.A.F.

[1] Minutes of R.C.M. Board 31st Meeting, 25 July 1944.

(*b*) An alternative to continuous barrage jamming was monitored spot jamming. This was rejected mainly because of the inevitable delay in finding the signal (on a frequency which could not be predetermined) and applying a jamming transmission in time. This delay would probably have exceeded that associated with meaconing, and in any event would have given the enemy an initial opportunity to receive the signal, to time it and probably take snap bearings for a fix. This therefore had no advantage over meaconing, and had the disadvantages of requiring extra effort and causing interference to Allied signals services in general and to the Ditchling search for flying bomb signals in particular.

(*c*) To confuse the enemy in taking bearings on flying bomb signals, by transmitting bogus similar signals on adjacent frequencies.

(*d*) To prevent the enemy from observing the end of a transmission and thereby determining time of flight, by transmitting a copy of the bomb signal to continue after the true signal ceased.

The last two proposals required the production of some form of record resembling the enemy signal against which it was proposed to apply the counter-measure, since the flying bomb signals were distinctive in sound and included a characteristic morse letter which (like its exact repetition rate and signal frequency) was obviously not determinable in advance. There was no technical difficulty in making such a recording but immediate play-back at any desired point was a different problem, and this had not been overcome by the time when it became apparent that only negligible use was being made of radio.

R.C.M. against Aircraft Launching Flying Bombs

Since there was no evidence that air-launched flying bombs carried a wireless transmitter there was no occasion for the use of counter-measures employed against ground launched ones. Flights were made by No. 192 Squadron to determine if any V.H.F. navigational aids were in use to assist these aircraft in reaching the launching area, but with negative results.[1] Reports indicated, however, that use was probably being made of certain low-power enemy beacons inland and on the coast, whose activity appeared to coincide with attacks by flying bombs. In this connection it is interesting to observe that *K.G. 53* appear to have been so regular in their use of M.F. beacons that flying bomb attacks were predictable with a very fair degree of accuracy, and with anything up to two or three hours notice, by careful observation of activity of certain beacons in North-West Germany, Holland and Denmark.

Meaconing was employed as a counter-measure against this possible aid, and on these occasions when the signal strength was insufficient to permit effective meaconing, use was made of Mimic. This was effected by causing the meacon transmitter to self-oscillate, by " squealing in " this transmission to the frequency of the enemy signal and hand-keying the enemy callsign. This arrangement enabled the full power of the meacon transmitter to be employed with a corresponding increase in range. As a safeguard against the Mimics being plotted for use as beacons, these were in turn meaconed by suitably located transmitters.

[1] Cheadle Reports CL/S. 101/32/M.3.

The German airborne efforts were all—with one exception—apparently aimed at the London area.[1] The exception was an attack (23/24 December 1944) on the north of England, supposedly Manchester, which was on a relatively large scale, about fifty bombs being launched. This attack must be regarded as a tactical failure as none of the bombs found its mark and in fact they were largely dissipated over the Yorkshire Moors and the Derbyshire Peak District. It did have some detrimental effect, however, in causing a redisposition of A.A. and night fighter defences. During this period certain B.B.C. transmitters were removed from the synchronised groups. These unsynchronised transmissions were meaconed regularly during the hours of darkness as a safeguard against their possible use by aircraft launching flying bombs.

Rockets (V.2)

The launching of long-range rocket projectiles against this country and Allied-held targets on the Continent took place during the period September 1944 to March 1945 and a total of over 3,000 incidents was reported. This total, which does not include abortive launchings, consisted of 1,115 rockets launched between 8 September 1944 and 27 March 1945 against England, and 2,050 between 14 September 1944 and 28 March 1945 against Continental targets.

In July 1944, Headquarters, No. 80 Wing were ordered to prepare counter-measures against anticipated rocket operations after the discovery of the remains of a rocket in Sweden. Examination of the parts revealed the presence of various types of radio equipment presumed to be associated with its control, and possibly also for observation of its characteristics during trials.[2] Various forms of offensive and defensive counter-measures were planned and carried into effect against the rocket campaign, air attacks against launching bases being the main offensive measure. The radio counter-measures were, of course, intended to interfere with whatever radio devices might be used in the control (aiming, ranging, and perhaps detonation) of rockets. The planning and execution of these counter-measures was rendered difficult by lack of information of the types and purposes of the radio systems which would be used for the new weapon.

The first evidence throwing any light on the matter was the damaged pieces of wireless equipment recovered after the Swedish incident.[3] These damaged specimens, when reconstructed (as far as their condition, available information, and surmise would permit) appeared to show that the rocket in question—which had, presumably, been fired experimentally—had contained four pieces of radio equipment :—

(*a*) A Receiver-Transmitter apparently arranged so as automatically to re-transmit in the 45–55 megacycles per second region a signal received in the 19–27 megacycles per second frequency band.

(*b*) A second Receiver apparently of a type already known to be used for control of German Glider Bombs (usually working in the 47–50 megacycles per second frequency band) ; but sets of the same type were suspected of being used down to a frequency of about 40 megacycles per second.

---

[1] H.Q. Anti-Aircraft Command Daily Summary No. 360/44.

[2] Minutes of Meeting at No. 80 Wing, 12 July 1944—No. 80 Wing File T.S. 3063/Sigs., Encl. 1A.

[3] D. of Tels. B.B. Meeting, 26 July 1944.

(c) A third Receiver apparently capable of working in the 46–53·5 megacycles per second frequency band.

(d) A Unit containing a complex system of tone generators and filters.

(e) There were also some parts, possibly constituting a small V.H.F. transmitter and miscellaneous components.

More or less informed speculation suggested that these equipments might be used for indications of range (later velocity), azimuth and elevation stability as in the Glider Bomb, and possibly for fuel control. Such little other information as was available indicated a fairly high initial trajectory, a maximum range of about 200 miles, and radio control during the first ten miles of range, some 45–70 seconds after launching.

Proposed Radio Counter-Measures

Acting on the foregoing assumptions, it was decided that means should be provided to apply counter-measures :—

(a) Primarily on the 19–25 and 40–55 megacycles per second frequency.

(b) Using plain carrier or modulation (A.M. or F.M.) with tone or noise.

(c) Employing maximum possible power.

(d) When rocket signals were heard but if not intercepted when rocket launchings (flash) were reported.

(e) From bases as far forward as practicable.

(f) Aimed towards any areas still available to a retreating enemy within 200 miles from London.

(g) On the assumption that up to 20 signals (whether genuine or bogus might not be immediately perceptible) would be active simultaneously.

To this end, and due to the absence of suitable equipment, a plan was produced for the provision of the R.C.M. system in three interdependent stages, much of the equipment for the second and third stages being specially ordered to meet the anticipated requirements.[1] In each stage the general requirements were those for any other R.C.M. system, that is to say, an organisation providing three components :—

(a) Radio intelligence (finding, identifying, locating sources, and discovering purposes of new types of signals).

(b) R.C.M. control (selecting, ordering on, and monitoring transmitters on to signals with which it is desired to interfere).

(c) R.C.M. transmitters.

The noteworthy difference between the plan for these operations and normal No. 80 Wing activities was that the control of the radio intelligence and R.C.M. activities was to be jointly exercised by the " Y " Service and No. 80 Wing personnel in a physically-combined Operations Room. Of the three planned stages,[2] the first used adaptations of existing equipment, while the second and third stages employed specially provided gear, much of it supplied from American sources. The third stage was never reached as orders were given by Air Ministry early in September 1944 to stop work on the scheme, in view of the rapid advance of the Allied ground forces in North-West Europe.[3]

[1] No. 80 Wing B.B. Signals Instructions Nos. 1, 2 and 3—No. 80 Wing File T.S. 3063/7/Sigs., Encls. 1A, 2A and 5A.

[2] Air Ministry letter Tels. 2/S.196/6, dated 8 September 1944.

[3] The method of implementing these stages is described in detail in Appendix No. 13.

In addition to the ground R.C.M. system, provision was made for airborne counter-measures, and a total of four squadrons under the control of Headquarters No. 100 Group were specially equipped with search receivers and jamming transmitters to operate in the suspected " control " frequency bands. Aircraft of No. 192 Squadron working with the " Y " Service carried out routine investigational flights for the provision of additional intelligence.

The control facilities for the final stage were planned as follows ;—

(*a*) A receiver for searching and monitoring was to be provided for operation in conjunction with each transmitter. Landline circuits were to be arranged to link any receiver with any transmitter.

(*b*) The control station at Canterbury was to be connected by landlines to the receiver-monitor sub-control stations " A " and " B " at St. Margaret's Bay which were in turn associated with the transmitting stations at Hope Point, at Whitfield Tower and Crowborough, respectively.

(*c*) Receiving equipment was provided at the Canterbury control station for analytical purposes and to enable general observation of " Big Ben " signals and R.C.M. activity. Sufficient receivers were to be arranged at St. Margaret's Bay " A " and " B " to provide for one to be associated with each transmitter at Hope Point, Whitfield Tower or Crowborough as the case might be. Each receiver was to be provided with a panoramic adaptor giving the visual display on a cathode ray tube of signals active within 100 or 500 kilocycles per second on either side of whatever the frequency might be to which the receiver was tuned. Audio oscillators, wavemeters and other ancillary equipment were also available. To obtain full flexibility an elaborate network of lines, many of high fidelity, with terminal equipment was provided and installed by the G.P.O.[1]

Each receiver operator would search a band within the range allocated to his associated transmitter (approximately 250 kilocycles per second). On reception of a suspected " Big Ben " signal, acting on instructions from the Controller, the operator either (*a*) tuned the transmitter to the signal by remote control, or (*b*) passed the rocket signal and the nominal frequency to the transmitter mechanic to enable the latter to tune his transmitter to the signal. If modulation was required, this was passed over a tone line to the transmitter using at the receiving end either a local oscillator or the modulations of the suspected signal.

The first opportunity to discover what radio equipment was in fact being used operationally in rockets did not present itself until after 8 September 1944 when the first incident in England was reported. From an examination of the remains[2] it appeared that some rockets contained two sets :—

(*a*) A receiver-transmitter operating on about 30 and 60 megacycles per second, the re-transmission being on exactly double the received frequency, suggesting use for velocity or ranging data by Doppler method with plain C.W. signals.

---

[1] Appendix No. 12—final section.

[2] R.A.E. Technical Note No. RAD. 251, November 1944, issued as A.I.2 (g) Report No. 1732.

(*b*) A receiver working on about 52 megacycles per second associated with a complex filter system and a procession of switches and relays by which signals modulated in a complicated way might operate various controls in the rocket (such as fuel supplies and/or directional control surfaces).

It will be seen that the arrangements for transmission in the 19–25 megacycles per second frequency band required modification to be of use against the receiver-transmitter found in the operational rockets. It was moreover doubtful, at first sight, what type of jamming would be required to be effective against the 52 megacycles per second receiver.

Some R.C.M. transmissions were made during the period 8–15 September when Rocket warnings were received, of which some were followed by incidents and some were not.[1] These transmissions were all in the 52 megacycles per second region and were very brief, usually about five seconds, their speculative aim being to interfere if possible with the fuel supply control of the rocket. On 15 September, all ground-controlled R.C.M. transmissions were stopped in order to avoid the risk of interfering with the search for Rocket signals although, so far as is known, none was identified. It was later reported that after about the middle of October the use of radio control was discontinued in favour of the "integrating accelerometer." As a result authority was given by the Air Ministry for the cancellation of the "Big Ben" jamming organisation in the U.K.[2]

When it appeared that the rocket campaign might continue during the winter, arrangements were made to send a R.C.M. formation to operate on the Continent in conjunction with No. 105 Mobile Air Reporting Unit (M.A.R.U.), which subsequently became No. 33 Wing, under S.H.A.E.F. For this purpose a Headquarters, three Special Receiver Units and two Transmitter Units were sent to operate in Belgium and Northern Holland. This formation was based at Wenduine on the coast north-east of Ostend. The R.C.M. unit worked in conjunction with No. 365 Wireless Unit which was supplied by the "Y" Service. Since no signals were positively identified, transmission was not made, but the equipment was later used for bomber support counter-measures. In general, despite the enormous effort expended in the installation of the R.C.M. stations, the effectiveness of "Big Ben" counter-measures was never determined. This was entirely due to the fact that although certain signals were intercepted at the time of rocket incidents none was positively identified.

Intruder Activity

A brief recrudescence of intruder activity occurred during March 1945, the main targets being Allied airfields, built-up areas, and road and rail transport in Yorkshire and Lincolnshire. The majority of these attacks were by machine-gun and cannon fire and a total of 110 enemy aircraft made landfall, in the majority of cases under cover of returning friendly bombers. There was no evidence of the use of the accepted long-range bombing and navigational aid systems during any of these attacks, but since the intruder aircraft approached under cover of returning Allied bombers it was suspected that extensive use would be made of the enemy A.I. (*S.N.2—FuGe220*)[3] in order to locate and follow the bomber stream. It was also expected that *Neptun* (*FuGe216*) would be used for rearward warning.

---

[1] No. 80 Wing File T.S. 3063/7/Sigs., Encl. 6A.
[2] A.M. letter Tels. 2/S.195/2 of 15 December 1944.
[3] Part 2, Chapters 12 and 15, of this volume.

Airborne counter-measure (Piperack) was already in operation against *S.N.2* and, in view of the threat of intruder activity, certain airborne equipment was set up by No. 100 Group on some of their airfields to act as a jamming barrage. Search (including D.F.) and monitoring was carried out at Headquarters No. 80 Wing watcher sites on the east coast, the information being passed to Headquarters, No. 100 Group. In addition, some 0·5 kilowatt G.E.C. transmitters were modified to cover the *S.N.2* frequency band (75–100 megacycles per second) and provided with noise modulation to act as jammers. These also were installed at east coast sites.

This concludes the account of radio counter-measures employed during the War in a defensive role. Any attempt to assess their value must point out the essentially passive and conditional nature of radio counter-measures in air defence. During the early part of the War they undoubtedly had considerable effect in mitigating the destruction of cities and industrial targets by the German night-bombers.

The effect of radio counter-measures during the period before May 1941 was enhanced by the weakness of the British air defence. Until the ground and airborne radar equipments were sufficiently effective in operation to enable night-fighters to find and destroy the bombers, it was all the more important to deny the advantages of radio navigation and bombing aids to the Germans. When more positive means of defence became available in the shape of high performance A.I.-equipped night-fighters, the effective value of defensive counter-measures was less apparent.

The value of defensive counter-measures was proportional, also, to the extent of the reliance which the enemy placed on radio aids. The German bomber crews made great use of radio navigational aids and were consequently heavily handicapped when deprived of them. The flying bombs, on the other hand, were not appreciably dependent on radio; counter-measures against them had therefore little or no effect.

PART II

RADIO COUNTER-MEASURES IN SUPPORT OF THE BOMBER OFFENSIVE

PART II

INTRODUCTION

Radio counter-measures used in support of the bomber offensive were sometimes called offensive counter-measures, not because of any inherent difference in radio technique, but simply as a result of their use in conjunction with bomber attacks. The defensive counter-measures described in Part I were intended to prevent the Germans deriving benefit from radio aids in their attacks on the United Kingdom. Later, during the development of Bomber Command's offensive against Germany, it was found that the German air defence was substantially dependent on wireless and radar. Attempts were consequently made to hinder and prevent the working of German air defence radio, and thus to increase the effectiveness of the attack and to reduce the bomber losses incurred.

The growth of the organisation which was evolved to derange the German radio system was neither smooth nor rapid. Lack of knowledge of the working of the enemy organisation, and fear lest the counter-measures put into force might in turn be exploited against the defence of the United Kingdom, were only two of the many obstacles to be overcome.

CHAPTER 7

THE INCEPTION OF OFFENSIVE COUNTER-MEASURES

Investigation of the German Air Defence System

From October–November 1939 the "Y" Service had been investigating the existence of enemy R.D.F., but the results obtained from interception of radio signals were meagre.[1] Although the evidence from this source was very scarce, information had been obtained from prisoners of war that there was without doubt a radio detection method in existence in Germany. In June 1940 one prisoner enquired whether the Royal Air Force had any system for the detection of aircraft comparable with their own at two stations in the Bay of Heligoland. Information was also received that an aircraft reporting system known as *Freya* was in operation, though its principle of operation was not known. The existence of two *Freya* stations, one near Lannion and a second on Cap de la Hague, was suspected, and by August 1940 the Assistant Directorate of Intelligence (Science) stated that two stations had been definitely located in these areas.[2] There was also some evidence that an aircraft reporting centre in Rumania had been allotted new apparatus known as *Wurzburg*, but no particulars of this were available to give any indication of its nature or purpose.[3]

After the fall of France, listening stations were set up on the south coast by the "Y" Service and by the Telecommunications Research Establishment (T.R.E.). By the end of 1940 watches were being kept on 8–7 metres, 401 metres and 150–30 centimetres wavebands. Receivers were also installed in aircraft, and investigation flights were made over the English channel. At the end of 1940 radar-type signals had been intercepted on 79–80 centimetres and on 53 centimetres. The former were considered to be associated with a gun-laying system used in the shelling of convoys, but the use of the latter was unknown. Radar-type signals were later heard on frequencies between 115 and 130 megacycles per second (about 2·5 metres wavelength).[4]

At about the same time, the Photographic Reconnaissance Unit had taken an excellent photograph of an enemy radio installation on the Cap de la Hague. Measurement of the photographs showed that the aerial array was consistent with a frequency of about 120 megacycles per second, and the position was within half a mile of the source of signal on a similar frequency as fixed by D.F.[5] It was concluded that this installation was the *Freya* station known to be located in that area.

Ground and aircraft listening watches were continued, and in May 1941 sufficient information had been accumulated for a report to be issued by Air Ministry, A.I.1(e), on the type of radar believed to be used by the Germans for early warning, anti-aircraft fire control, and naval and coastal gun-laying stations.[6] It was concluded that the early warning system extended at least

[1] Air Ministry File R.C.M. 81, 1B and A.I.1. (e) Report, 4 January 1941.
[2] A.S.I. Report No. 8. [3] Air Ministry File R.C.M. 81.
[4] A.I.1 (e) Report No. 1, 4 January 1941, and Report, dated 10 January 1941.
[5] A.S.I. Report No. 13.
[6] A.M. File R.C.M. 81, Encl. 13A and A.I.1 (e) Report No. 4, dated 20 May 1941.

from the West Frisian Islands to Brest and might even be continuous from Denmark to the Spanish frontier. The equipment operated on a frequency of between 119 and 128 megacycles per second with a pulse recurrence frequence (p.r.f.) of 1,000 or 500 cycles per second. The estimated range on an aircraft above 5,000 feet was 90–100 miles. It did not appear to measure height. The set which seemed to be used for anti-aircraft and possible searchlight control operated on a frequency of 566 megacycles per second while the coastal and naval gun-laying sets used frequencies of 375 megacycles and and 526 megacycles per second respectively. As a result of further investigation it became apparent that the 566 megacycles per second stations extended for a considerable length of the enemy coastline, with several inland.[1] They were believed to be aircraft detecting stations known as *Wurzburg*, the existence of which had become known in January.

In the case of the 120 megacycles per second stations, measurements were made of the pulse width, pulse recurrence frequency, and beam width and an estimate was made of the power of the transmitter.[2] By October 1941, sufficient information was available for calculating the effect that radio countermeasures might have. Characteristics of the 566 megacycles per second stations were not fully available until a *Wurzburg* apparatus was captured in the Commando raid on the enemy radar station at Bruneval in February 1942.

While the investigation into the enemy's radar was being pursued, information was also being obtained on the German methods of fighter control.[3] During 1940, " Y " watches on the 3–6 megacycles per second frequency band intercepted signals which seemed to be part of a system for controlling night fighters from the ground.[4] The details of the system could not, at first, be deduced owing to the use of code words for the various equipments used in the operation. The mystifying code word was *Kleine Schraube* or Little Screw, which was at first thought to be a radio beam for directing aircraft on to bombers. As the British night bomber activity increased, so was a corresponding increase of enemy R/T traffic intercepted, and by September 1941 it was possible for the Wireless Intelligence Service (W.I.S.) to issue a report which gave a fairly complete description of the German night fighter system.[5] This report indicated that the night fighters operated in separate and limited areas and were directed by the ground stations to the raiding aircraft which was then illuminated by searchlights. The meaning of Little Screw was still not known, although it was thought to be a form of radio beacon. This was later confirmed.

The type of ground equipment used in the German Ground Controlled Interception (G.C.I.) stations was established after a study by A.D.I. (Science) of reports from secret sources and photographs taken by the Photographic Reconnaissance Unit. It was apparent in the autumn of 1940 that the Germans defined certain night fighter areas as circles of 40 kilometres radius, and in the spring of 1941 further circles of 60 kilometres radius appeared. It was presumed that these radii represented the ranges of the detection equipment used. The tentative identification in the summer of 1941 of the 3,750 p.r.f. transmissions on 53 centimetres wavelength with the *Wurzburg* suggested that this apparatus might be used in the case of the 40 kilometres circles, since the pulse recurrence

---

[1] T.R.E. Investigation Group Report No. 5/24, dated 6 July 1941. A.S.I. Report No. 13.

[2] Report by D. J. Garrard, dated 20 October 1941, and Enemy Investigation Group T.R.E. Report No. 5/37, dated 30 October 1941.

[3] A.M. File R.C.M. 103, Encl. 1A.

[4] A.I.1 (e) Report, dated 3 January 1941.

[5] A.M. File R.C.M. 103, Encl. 38A. A.D.I (e) Report No. 2, dated 10 September 1941.

frequency corresponded approximately to that range, and that the apparatus used in connection with the 60 kilometres circles would probably have a repetition rate of about 2,000 p.p.s.

By the end of 1941 reports of the positions of inland radar stations were being received from various sources,[1] and these led, in the spring of 1942, to the photographing by the Photographic Reconnaissance Unit of a *Freya* and another apparatus consisting of a large paraboloid on a site near St. Trond. From its proximity to the *Luftwaffe* night fighter base there, it appeared probable that this was a German G.C.I. station. Confirmation was soon forthcoming, for another source stated that a night fighter control station existed at Domburg on the island of Walcheren, and vertical photographs showed the presence of a *Freya* and two wire mesh paraboloids. Later photographs of St. Trond showed that a second paraboloid also existed there.

Examination of the *Wurzburg* equipment captured at Bruneval had shown it to be in large-scale production, and it was therefore considered likely that the same transmitter would be used in its giant brother, particularly since the larger paraboloid would amply account for the greater range. A search was therefore made by T.R.E. for 53 centimetres wavelength pulse transmissions with a pulse rate of about 2,000 p.p.s from the direction of Domburg. Such transmissions were heard in May 1942.

The photographs of the Giant *Wurzburg* near St. Trond showed it to be surrounded by three searchlights,[2] and from their intimate association it was reasonable to assume that these lights were directly controlled from the *Wurzburg*. An attempt was made to support this assumption by photographing other searchlight emplacements, but unfortunately by this time (May 1942) the searchlights were being removed from the night fighter belt and the photographs could not be obtained. The drive to make Secret Intelligence "searchlight-conscious," however, produced an intelligence item of tremendous value. A map was obtained from a German Headquarters showing deployment of a whole searchlight regiment covering 90 kilometres of a searchlight belt. The area covered fortunately included the one known inland G.C.I. station near St. Trond, and it was immediately obvious that this was shown on the map by a special symbol of which there were two others. These presumably represented further G.C.I. stations which were spaced at intervals of roughly 30 kilometres in front of the searchlight belt. Photography and information from other sources soon confirmed this, and photographs were taken of five G.C.I. stations roughly in a straight line at 30-kilometre intervals.

These stations showed a great similarity of equipment. The essential components appeared to be two Giant *Wurzburgs*, one of which was accompanied by three searchlights (until May 1942), while the other was always isolated. This suggested that the second giant was essential and not merely a standby, since the searchlight would also have been duplicated. It further suggested that since two aircraft (bomber and fighter) were involved, one *Wurzburg* was devoted to each, the main difference between their functions being that the bomber *Wurzburg* might need to direct searchlights while illumination of the intercepting fighter was not required. Nearly every station had a *Freya*, but the absence of this equipment in one case suggested that the G.C.I. system could

[1] A.M. File R.C.M. 103, A.D.I. (Science) Report, dated 6 April 1942.
[2] *Ibid.*, Encl. 86A. A.D.I. (Science) Paper, dated 18 April 1942.

operate without it. It was believed that the *Freya* might be used as a standby interception system, although some theorists held that it was used to direct the narrow beam *Wurzburgs* in the direction of their target. In September 1942 an Intelligence source of information described a hut in which the plotting of aircraft and control of fighters was carried out, and shortly afterwards similar huts were identified at those points included on the map as *Abteilung* Headquarters.

Information from various sources grew, and by the end of 1942 A.D.I. (Science) was able to publish a detailed report of the German Night Fighter Control System.[1] This report described a German G.C.I. station and showed how the stations were deployed along a line of " boxes " 70–100 kilometres wide stretching from Schleswig Holstein almost to the Franco-Swiss frontier. This report proved surprisingly accurate; statements obtained after the end of hostilities in North-West Europe from prisoners-of-war who were intimately connected with the German air defence system gave ample corroboration.[2]

Early Offensive Counter-Measure Policy

No definite jamming policy had been formulated during the years before the war. The matter had been raised, but the general view held was that jamming would probably be a two-edged weapon. Such consideration as had been given to this problem had been confined mainly to the possible jamming of communication channels. So limited an outlook was not entirely unexpected, for few could have envisaged all the radio devices of modern war which were eventually to be employed and the vast field unfolded for the application of counter-measures.

As knowledge of enemy radio aids both offensive and defensive grew, the question of counter-measures recurred, necessitating an urgent and immediate investigation as to how best the effectiveness of the various enemy systems could be reduced. Each counter-measure to be proposed caused various authorities to express the fear that repercussions would follow, probably greatly to our disadvantage. However, the operational advantages were fully realised, not only by the Air Ministry air and signals staffs but by the respective Royal Air Force commands, with the result that the risk of repercussions was eventually accepted.

At a meeting of the R.D.F. Policy Sub-committee on 16 September 1941 it was suggested by the Director of Signals that some measure of co-ordination of radio counter-measures was necessary.[3] The R.C.M. Committee, over which he presided, dealt with, *inter alia*, counter-measures against enemy navigational aids. These counter-measures were in the main the concern of the Royal Air Force, although both naval and army representatives were in the habit of attending meetings of the R.C.M. Committee.

The " X " Committee of the W/T Board dealt with the jamming of enemy communications. This was mainly the concern of the army, although representatives of the Admiralty and Air Ministry usually attended its meetings. The Admiralty had arranged for the jamming of certain enemy fire control

[1] A.S.I. Report No. 1 of 29 December 1942.

[2] A summary of statements obtained from prisoners-of-war after the end of the European conflict is given in Appendix No. 14.

[3] R.D.F. Policy Sub-Committee Meeting, 16 September 1941.

R.D.F. operating over the Straits of Dover independently of the above-mentioned committees. It was therefore evident that some degree of co-ordination between jamming and counter-measures against enemy communications, and jamming and counter-measures against enemy R.D.F., might be desirable. It was then decided by the R.D.F. Policy Sub-committee that the R.C.M. Committee and the " X " Committee of the W/T Board should keep the R.D.F. Policy Sub-committee informed before introducing jamming or counter-measures against enemy navigational aids, communications, or R.D.F. It was also decided to review the situation later, with a view to making recommendations to the Chiefs of Staff in respect of any co-ordination which might be necessary or desirable.

Early in 1941, the Director of Signals asked the Scientific Adviser on Telecommunications (S.A.T.) whether any simple counter-measures could be applied to enemy radar,[1] but it was not until October 1941 that sufficient information on the enemy's radar had been obtained for a paper to be prepared by T.R.E.,[2] outlining what could be done by airborne and ground jammers against the enemy early warning radar and stating that it would also be possible to interfere with the early warning system by producing artificial echoes representing a concentration of aircraft.

In view of the suspicions that the enemy searchlights were controlled by radar operating on a frequency of 566 megacycles per second the Director of Signals, in a paper submitted to the R.D.F Policy Sub-committee, indicated that before any concrete proposals could be put forward for countering controlled searchlights it was necessary to confirm that searchlights were in fact R.D.F. controlled and that the frequency was 566 megacycles per second.[3] These points could be dealt with by operating a small jamming transmitter in an aircraft flown over the enemy searchlights.

Already some progress had been made by T.R.E. in the production of a 53 centimetres experimental jamming transmitter and although it was intended to use this jammer very sparingly and intermittently, many reasons were raised why it should not be used and why jamming in general should not be started.[4] The main reason was the desire not to initiate a jamming war whereby repercussions might be greatly to our disadvantage ; it might, it was argued, give the enemy the idea of how to jam Royal Air Force R.D.F. and lead him to retaliate. Moreover it was most desirable that such a radio war should not be initiated until we were in a sound position to take effective jamming action. It was the view of S.A.T. that in determining the enemy system of searchlight control every other method of solving the problem should be exhausted before jamming was resorted to.[5] The view was also expressed that jamming would interfere with reception of enemy signals by the " Y " Service and thus decrease the amount of information likely to be obtained by such means.

In October 1941 the Air Officer Commanding-in-Chief, Bomber Command, drew attention to a small but steady increase in losses sustained during the night operations.[6] These losses, he suggested, were due to the Germans improving

[1] A.M. File R.C.M. 155, Encl. 2A.
[2] A.M. File R.C.M. 119, T.R.E. Report No. 5/37A.
[3] Annex to R.A.F. Policy, Sub-Committee Paper (41) 23, 12 September 1941.
[4] A.M. File R.C.M. 103, Encl. 14A. R.C.M. Committee Meeting, 30 July 1941
[5] *Ibid.*, Encl. 26A, 23 September 1941.
[6] Bomber Command File BC/S.25782/C.-in-C., 22 October 1941. A.M. File CS. 11472, Encl. 9A.

their night defence system, particularly in R.D.F. control. He recommended that as soon as the main details of the German radio defence methods had been established, all countermeasures which might suggest themselves should be tried and developed on the highest priority.

The many views which had been expressed both for and against jamming having been summarised, and after considerable discussion had taken place, the Director of Signals called a meeting to arrange a programme of experiments.[1] At this meeting, however, the idea was again opposed by the Scientific Adviser on Telecommunications on the grounds that it would disclose prematurely to the enemy our intention to jam and might also incite him to take corresponding action. It should be noted that at that time the only jammer for use against 53 centimetre R.D.F. was the experimental one to be used in the trial and no model was in production or available for use by Bomber Command aircraft.[2] It was eventually decided that not only could the problem probably be settled by intensifying investigation by special observers but that investigation might well supply information which would simplify the development of a suitable jammer.[3] The jamming experiments were therefore postponed in favour of intensified investigation. These decisions were communicated by the Director of Signals to the Air Officer Commanding-in-Chief, Bomber Command, informing him that counter-measures were to be provided at the earliest possible moment without unnecessarily compromising such counter-measures by premature disclosure.[4]

The jamming and the spoofing schemes suggested in the T.R.E. paper mentioned above were referred to at a meeting held on 12 December 1941 under the chairmanship of the Deputy Chief of the Air Staff (D.C.A.S.) to discuss the effect of the German early warning system on Royal Air Force operations. The need for counter-measures was generally accepted and in the discussion which followed regarding the priority which should be allotted to the development of counter-measure equipment, it was decided that the priority for counter-measures against the early warning system should be subordinated to that given to a jammer for the enemy 53 centimetre R.D.F. equipment.[5] The possibility of jamming or interfering with the W/T broadcast of R.D.F. plots was also discussed, but no definite decision was taken.

A similar consideration of countermeasures against the R.D.F. used in the night-fighter control system could not be made, as exact information on the type used was not available. It was known, however, that the system depended to some extent on a radio telephone link, and at a meeting of the Air Fighting Committee it was suggested that if the night fighter became a serious menace, jamming the radio telephone channel might be the most effective counter-measure.[6] This suggestion, and another that some special jamming transmitters which already existed should be used for the purpose, was considered at a small meeting held by the Air Ministry R.C.M. Section. The meeting recommended that the enemy night-fighter frequencies should be left unjammed so that the " Y " Service could continue to obtain urgently required information on the German night fighter system and that the special transmitters, which were intended for jamming German communications in an invasion attempt, should not be used as this would " show our hand " and give the enemy the chance to re-plan his communications arrangements.

[1] A.M. File CS/11472, Encl. 14B
[2] Narrator's Note.
[3] A.M. File CS/11472, Encls. 18 and 19A.
[4] A.M. File CS/11472/D. of S., Encl. 18A.
[5] A.M. File R.C.M. 81, Encl. 66A.
[6] A.M. File R.C.M. 102, Encl. 12A.

Proposal for Jamming the German Night-Fighter R/T

Jamming the R/T channel was reconsidered when in September 1941 Headquarters, Bomber Command reported that a wireless operator had carried out what appeared to be successful jamming of an enemy night fighter control by using his aircraft transmitter.[1] Permission was sought to make extended use of this idea which, it was felt, might contribute to a reduction in casualties. The Chairman of the R.D.F. Policy Sub-committee (Sir Henry Tizard) expressed some misgivings as to the effect of a general adoption of this practice on the part of aircraft of Bomber Command.[2] It was his opinion, speaking generally, that German radio and communications technique was inferior to that of the Allies. Great care was therefore necessary to ensure that jamming and countermeasures introduced by the Allies should not result in presenting the enemy with ideas which he himself had not evolved and which could be turned to account against the Allies. Exceptions to this would be cases in which urgency or importance justified the risk. It was generally thought that no particular harm was likely to result from the suggested special jamming, provided it was kept within reasonable limits. It was therefore recommended by the Sub-committee that aircraft of Bomber Command should be allowed to initiate jamming of the nature reported, provided such jamming was not conducted upon an unnecessarily wide scale; the Air Ministry was invited to keep the exploitation of this jamming under close observation to ensure that it did not extend unnecessarily. Air Ministry gave permission, but owing to a desire not to initiate a jamming war stated that the jamming should be limited to individual use when circumstances warranted.[3] Instructions were issued to Groups who were asked to make reports on any attempts at jamming.[4] No reports were made and no evidence can be found to suggest that any jamming was, in fact, ever carried out.

Early Jamming of Enemy Radar—the "J" Switch

Although the 53 centimetre jamming experiments were postponed it was possible that interference to the enemy's radar had already been caused in a purely accidental way.[5] In October 1940 a Bomber Command pilot reported that when his I.F.F. set was switched on, enemy searchlights which had been playing on him were extinguished. As a result, Bomber Command instructed all Groups to experiment in the use of I.F.F. (Identification, Friend or Foe) in this way and to report results. At the end of a week analysis disclosed that in the majority of cases enemy searchlights were extinguished when I.F.F. was used. A suggestion was thereupon made that the searchlights were controlled by some form of radar and that the I.F.F. interfered with the enemy equipment.[6] The fact that in some instances I.F.F. was ineffective was explained by suggesting that in some areas enemy searchlights were not radar controlled. A map was drawn showing the position over which I.F.F. had been tried, which indicated that in some places—in particular Hamburg—I.F.F. had been consistently effective, whereas in others it had not.

A very close observation was made of further results and during November 1940 it was noted that searchlights had only been affected on 99 out of 171

---

[1] Bomber Command File BC/S.25707, Encl. 7A.
[2] D.F.C. Policy Sub-Committee Meeting, 17 October 1941.
[3] A.M. File R.C.M. 112, Encl. 3A. [4] Bomber Command File BC/S.25707, Encl. 13A.
[5] A.M. File S.7084, Encl. 52B.
[6] Bomber Command File BC/S.22153/1/Ops. 1 (a), 24 October 1940 and A.M. File S.7084, Encl. 1A.

occasions when I.F.F. had been switched on.[1] Efforts were made to explain this phenomenon without success, and when it became known that the enemy was using radar on 2·5 metres and 53 centimetres wavelength, equipments were set up on these wavelengths and experiments carried out to determine whether any spurious radiation from the I.F.F. set caused interference.[2] No unusual responses were, however, observed.

It should be noted that the problem was not only to find why the I.F.F. transmissions apparently interfered with the searchlight control, but also *what caused the I.F.F. set to radiate. Normally* an *I.F.F. set only radiates* when it receives the transmitted pulse of a radar station or interrogator. It may radiate however, without being "triggered" in this way if it is adjusted so that the set is in a continuous state of oscillation. The set is then known to be "squittering." This state is also obtained, even with normal adjustments, when the set is first switched on and while the valves are warming up. The I.F.F. set can, of course, only be "triggered" by radar stations whose frequency lies in the frequency range of the I.F.F. set.[3] It seemed, therefore, that if the searchlight control was indeed upset by radiations from the I.F.F. set then the radiations were either caused by an unknown type of enemy radar station, by our own radar stations (which might occur at ranges of about 100 miles), or by the set "squittering."

In March 1941 all Bomber Command units were informed that switching the set nn and off at five-second intervals had been found more effective than leaving the set switched on continuously, and it became a regular practice to do this.[4] The reasoning behind this was, of course, that the set would "squitter" for a short time whenever it was switched on. Evidence obtained from the Operational Reports, however, was never sufficiently convincing that I.F.F. was acting as a safeguard to aircraft illuminated by searchlights and, in fact, A.D.I. (Science) produced some evidence which suggested that the enemy might even be using I.F.F. transmissions to assist him in locating and intercepting our aircraft. He argued that the enemy might be illuminating and then dowsing with the deliberate intention of inducing our aircraft to switch on I.F.F. As a result, no steps were taken to intensify the radiation from the I.F.F. set, although the use of I.F.F. over enemy territory was not banned.

When an enemy 53-centimetre R.D.F. set was captured from Bruneval in February 1942, experiments were carried out to determine whether I.F.F. could affect it.[5] The experiments were delayed because certain missing items of the radar set had to be manufactured and were not completed until 27 June 1942. They showed, however, that a "squittering" I.F.F. set did cause interference, due to its radiation being picked up by the badly screened intermediate frequency (I.F.) stage of the German receiver which was tuned to a frequency of 25 megacycles per second.

Bomber Command immediately proposed that the I.F.F. set should be modified so that it could be made to "squitter" when required by closing a switch. The modification ensured that when the switch was closed the set would remain in a state of continuous oscillation but would only radiate on

---

[1] Bomber Command File BC/S.23734/3/Ops. 1 (a), 22 December 1940 and A.M. File S.7084, Encl. 26A.

[2] T.R.E. Report 5/28, 22 July 1941 and A.M. File S.7084, Encl. 62B.

[3] Narrator's Note.

[4] A.M. File S.7084, Encl. 68A.

[5] T.R.E. Report 6/R/27 R.G.S. and A.M. File S.7084/II, Encl. 6A.

25 megacycles per second when the tuning sweep passed through that frequency —that is to say, it would radiate for about half a second every twelve seconds. T.R.E. proposed a similar scheme but with an additional modification, that the tuning sweep should be reduced so that radiation would be continuous on 25 megacycles per second.[1] The R.D.F. Board, however, opposed the idea of making any modification to the I.F.F. set which would make it clear to the enemy, if he captured a set, that it had been done for the purpose of jamming,[2] and it was decided at a meeting of the R.C.M. Board on 30 June that the simple though less effective Bomber Command modification should be adopted. The modification became known as the " J " Switch. An attempt to analyse the effect of the " J " Switch was made by Operational Research Section (O.R.S.) Bomber Command, but no definite conclusions could be drawn.[3] The opinion of many bomber crews, however, was that it was effective, and the report recommended that its use should be continued.

Although during 1941 no positive action, apart from the use of I.F.F., was taken to interfere with the enemy's defensive radio system, the development of jammers and spoofing devices was begun. The 53-centimetre jammer had been given a priority above the development of devices for use against the 120 megacycles per second R.D.F., but as the technique required for this waveband was comparatively new, difficulties were experienced in obtaining certain items such as valves. Furthermore, complete details of the enemy's R.D.F. on this wavelength were lacking, and it was not known whether the frequency band covered for various purposes would be such that " barrage " jamming would be possible, or whether the frequency band would be so wide as to make it necessary to use a spot frequency tunable jammer. It seemed possible, however, that serious interference could be caused to the enemy 53-centimetre R.D.F. by dropping metallic strips cut to such a length that they would act as reflectors and thereby cause spurious responses in the enemy's equipment. Arrangements were made for experiments to be carried out.[4] Since this device, eventually known as Window, was not used operationally until July 1943, it has been considered preferable for chronological reasons first to describe those other R.C.M. devices which were to be used in support of the Allied air offensive during 1942 although the development of Window proceeded concurrently.[5]

Fighter Command Proposal for Jamming

In March 1942, in a letter to the Director of Signals, the Air Officer Commanding-in-Chief, Fighter Command, urged that increased effort should be applied to the development and production of counter-measure apparatus.[6] He referred to the jammers for the 120 megacycles per second and 53 centimetre R.D.F., the idea of producing the effect of large raids on the enemy's R.D.F. by means of artificial responses, and also the possibility of reducing the efficiency of the enemy's fighter defence system by jamming communication channels and by interfering with the broadcast of radar plots. The Air Officer Commanding-in-Chief made it clear that he was aware of the danger of starting a " jamming war " but pointed out that, up to the present, it was the British

[1] A.M. File S.7084, Encls. 96A and 105A.
[2] R.C.M. Board Meeting, 30 June 1942 and A.M. File S.7084/II, Encl. 7A.
[3] O.R.S. (Bomber Command) Report No. 50 and A.M. File S.7084, Encl. 40B.
[4] R.C.M. Meeting, 3 December 1941 and A.M. File R.C.M. 48/II, Encl. 132A.
[5] Part 2, Chapter 9, of this volume.
[6] A.M. File R.C.M. 155, Encl. 16A and Fighter Command File FC/S.28012, dated 20 March 1942.

R.D.F. which had been jammed (the *Scharnhorst* and *Gneisenau* incident) and that retaliation was impossible owing to lack of equipment.

In his reply, the Director of Signals referred to the limited resources for development work and asked the Air Officer Commanding-in-Chief for his views as to the priority which should be allotted to the various R.C.M. projects.[1] With regard to interfering with communications, the Director of Signals pointed out that the broadcast of R.D.F. plots provided us with very valuable information and the desirability of jamming was very questionable. He referred to a paper on the jamming of enemy High Frequency (H.F.) radio telephony (R/T) which argued that the wide frequency band and the large number of R/T channels used by the enemy would make such jamming extremely difficult, whereas Royal Air Force Very High Frequency (V.H.F.) R/T, with its comparatively narrow band, could easily be jammed by barrage jammers and that it was therefore in our interests to avoid starting a jamming war on communications.

The Air Officer Commanding-in-Chief, Fighter Command then submitted his requirement for the spoofing and jamming of the enemy early warning system, and agreed that communications jamming was undesirable.[2] As a result, the priority given to the development of spoofing equipment which was given the code name Moonshine, and of jamming equipment which was given the code name Mandrel, was raised. The Air Officer Commanding-in-Chief asked that both counter-measures should be ready for operation by the middle of June 1942.

"Moonshine"

The idea of this device originated in July 1941, when a Raid Analysis made by No. 11 Group showed that a Blenheim aircraft when flying over the North Sea engaged in calibrating our radar stations had created a large fighter reaction in the Lille/Courtrai area.[3] It was thought that this was brought about by the equipment carried for calibration purposes—a form of I.F.F. which received the enemy R.D.F. pulse and re-radiated it at greater power than would have occurred if the pulse had been reflected by the aircraft. The operational value of being able to produce spurious responses in the enemy's equipment was realised by Headquarters, No. 11 Group, and although further attempts to produce a similar enemy reaction by using the calibration Blenheim were unsuccessful, the development of special apparatus for the purpose was proposed.

The proposal was considered at a meeting of the Air Interception Committee in August 1941 and the Director of Communications Development was requested to examine the problem.[4] In October 1941 T.R.E., in a report on counter-measures against the enemy's early warning system, stated that it would be possible to develop a suitable I.F.F. set whose re-radiation could be varied to produce the desired effect on the enemy's R.D.F. equipment. A laboratory model was made early in 1942 and in April T.R.E. was able to report to the R.C.M. Board that experiments against our own 200 megacycles per second R.D.F. had been successful, and proposed that the equipment should be tested on the enemy frequency of 125 megacycles per second.[5] A C.H.L.

---

[1] A.M. File R.C.M. 155, Encl. 19A and Fighter Command File FC/S.28012, dated 20 March, 1942.

[2] *Ibid*, Encl. 33A.

[3] A.M. File R.C.M. 121/II, Encl. 53A.

[4] A.M. File R.C.M. 119, Encl. 4A.

[5] A.M. File R.C.M. 121, Encls. 3A and 10A.

apparatus was modified to operate on this frequency and plans were made for Moonshine to be fitted in two Defiant aircraft and for flight trials to be carried out at Drem.[1]

By this time the production of Moonshine was on high priority, and arrangements were made for the production of sufficient sets for installation in a further seven Defiant aircraft to make a total of six operational and three reserve Moonshine aircraft for one flight of No. 515 Squadron. The installation work was to be carried out by fitting parties of No. 26 Group under the direction of No. 80 Wing. In its developed form Moonshine consisted of a small pulse transmitter, tuned to the frequency of the enemy *Freya* R.D.F. station, and being triggered when a signal was received. The amplitude of the transmission was automatically controlled by the received pulse to produce a signal of similar size to the aircraft echo, and the transmitter was modulated to give it the beating and interweaving characteristic of the echo originated from a number of close flying aircraft. The duration of the spurious signal could be adjusted manually to correspond with an aircraft concentration of several miles in depth. The set had to be tuned to the frequency of the *Freya* before the operation, and as the equipment would only work on that frequency it was necessary to use as many sets as there were *Freyas* likely to look at the Moonshine aircraft. This called for an average of six sets and therefore six aircraft. Successful flight trials with the prototype Moonshine on 125 megacycles per second were flown in June, and the production of equipment for installation in operational aircraft went ahead. The story of the use of Moonshine for purposes of feint attacks against the enemy is recounted later.[2] It is sufficient to mention here that this equipment played a useful part in the air offensive.

Bomber Command's Need of R.C.M. Support

In August, 1942, an analysis of Royal Air Force bomber losses was made by the Operational Research Section of Bomber Command,[3] and the conclusion reached was that if complete counter-measures could be taken against the German radio defences the total wastage of bomber aircraft could be reduced by about 60 per cent. or 30 per cent., depending on whether searchlights were radio-controlled or not. Moreover, if the effectiveness of anti-aircraft guns over the target could be reduced, an increase in the accuracy of the attack would be achieved. It was recommended that the highest priority should be given to the development of all possible counter-measures against German R.D.F., counter-measures over the target area being considered of the first importance and those against G.C.I. en route to the target, second.

The Air Officer Commanding-in-Chief, Bomber Command, agreed that the time had come when technical as well as tactical means should be exploited in order to minimise the effectiveness of the enemy defences, and asked Air Ministry to provide suitable counter-measures on the highest priority.[4] At that time Mandrel[5] and Moonshine had been developed for jamming and confusing the enemy early warning system, and although properly designed counter-measures

[1] A.M. File R.C.M. 121, Encl. 14A and No. 80 Wing Operational Order No. 2.
[2] Part 2, Chapter 15, of this volume.
[3] O.R.S. (B.C.) Report No 379 and A.M. File R.C.M. 155, Encl. 100A.
[4] Bomber Command File BC/S.25782/C.-in-C., 26 August 1942, and A.M. File C.S. 11472, Encl. 24A.
[5] *See* Part 2, Chapter 8, of this volume.

were not yet available for use against the enemy's anti-aircraft gun control and G.C.I., it was believed that the I.F.F. set suitably modified would cause some interference.

A meeting, presided over by the Senior Air Staff Officer, Bomber Command, and attended by Sir Henry Tizard, the Director of Bomber Operations, the Director of Signals, the Chief Signals Officer and a representative of the Operational Research Section of Bomber Command, was held at Headquarters, Bomber Command, on 6 October 1942.[1] The following recommendations were made :—

(*a*) Increased advantage should be taken of the interference caused to German R.D.F. by I.F.F. by the immediate use of sets which had been specially modified to "squitter" continuously on the intermediate frequency of the enemy 53-centimetre R.D.F.

(*b*) Mandrel should be installed in bomber aircraft for jamming the *Freyas* which at that time were believed to be used in the G.C.I. operation for directing the narrow beam *Wurzburgs* on to the aircraft in the early stages of an interception.

(*c*) The ground Mandrel stations of No. 80 Wing, and the airborne Mandrel of Fighter Command, should be used to reduce the enemy early warning cover.

These recommendations were approved by Air Ministry on 19 October 1942.[2]

The use of Moonshine was also considered as a means of drawing enemy fighters away from the bomber route.[3] It was decided not to do this, however, as Moonshine gave the impression of a large formation of aircraft rather than a stream of bombers and was therefore unlikely to mislead the enemy. Moreover, the operations of Moonshine aircraft in formation at night would have been difficult and hazardous.

"Shiver"

The modification to I.F.F., Mark II, to make it squitter continuously has already been described.[4] It was decided not to make immediate use of it, but arrangements were made for the manufacture of 1,000 modification kits, so that the modification could be put into use without delay if the need arose. In September 1942 it was decided that 200 of the kits should be used for modifying I.F.F. sets for installation and operational trial in aircraft of No. 1 Group. The sets were completed by the end of September[5] and arrangements were made for them to be used on 7 October, after the meeting on R.C.M. held at Bomber Command on 6 October referred to previously. The modification was first known in Bomber Command as Monkey, but this code word was subsequently changed to Shiver.[6]

When the introduction of Mark III I.F.F. was proposed, a decision had to be made whether Shiver should be abandoned or whether arrangements should be made for it to be carried in addition to the new type of I.F.F. In February 1943, therefore, Bomber Command carried out an investigation to determine the value of Shiver. A precise assessment of results was complicated by the fact

[1] A.M. File C.S. 11472, Encl. 27A.
[2] A.M. File C.S. 11472/ACAS (Ops.), dated 19 October 1942, Encl. 41A.
[3] Fighter Command File FC/S.30732, Encl. 48A, 2 November 1942 and A.M. File C.S. 11472/ACAS (Ops.), Encl. 49A, 4 November 1942.
[4] A.M. File S.7084, Encl. 18A.
[5] *Ibid.*, Encls. 21A, 34A and 42A.
[6] *Ibid.*, Encls. 74A and 35A.

that other counter-measures (Mandrel and Tinsel) had also been in use over the same period. Furthermore, it was evident that the efficiency and effort applied to the German night defences as a whole was increasing and comparative figures against earlier periods were therefore liable to be misleading. Instances of probable effects of Shiver were as follows :—

(*a*) R/T intercepts recorded three or four references by German pilots to interference on A.I.

(*b*) Intercepts from control stations referred on several occasions to interference or to loss of R.D.F. contact.

(*c*) During the first month of use, the only aircraft fitted sustained considerably less *flak* than those not fitted. During later months, however, figures for the force as a whole showed no noticeable difference by comparison with the months previous to the introduction of Shiver.

As evidence of ineffectiveness, pilots reported intense and accurate *flak* in spite of heavy and complete cloud cover, indicating accurate R.D.F. gun laying It was also noted by those aircraft fitted with Boozer (53-centimetre R.D.F. detector) that steady G.L. indications were received at a time when Shiver was switched on. It appeared therefore that although when it was first introduced it possibly had some effect, it was not long before the enemy was able to take steps, probably by improving the screening of his receiver, to eliminate the interference caused. In view of this, and as Shiver caused considerable interference to our own R.D.F. stations, it was decided to discontinue its use as soon as Mark III I.F.F. was installed.[1]

Jamming of German Tank R.T.

An interesting and apparently unique jamming operation against German tank radio telephone communications in the 27–33 megacycle band was carried out in November, 1941. Six Wellington aircraft were fitted with a V.H.F. transmitter Jostle II and flown to the Middle East in time for the Crusader offensive. Their task was to fly over the German tank units engaged in the land battle, and to make a continuous jamming transmission which would interfere with inter-tank communication and prevent effective tactical control. Information subsequently obtained from prisoners indicated that technical success had been obtained, and it was reasonable to assume that much inconvenience had been caused. There was no evidence, however, that the handling of enemy tanks was being adversely affected. Without fighter escort and cloud cover the Wellingtons were practically defenceless, and after two had been destroyed and all of them damaged by enemy action in the course of some twenty sorties, the crews were relieved of their " very thankless and hazardous task ".[2]

[1] Bomber Command File BC/S.28388, Encl. 70A.

[2] R.A.F. Narrative—Middle East Campaigns, Volume II

CHAPTER 8

THE DEVELOPMENT AND APPLICATION OF R.C.M. FOR BOMBER SUPPORT FROM OCTOBER 1942 TO AUGUST 1943

Tinsel

Consideration by the Director of Signals[1] of possible methods of jamming enemy night-fighter R/T brought forth, in October 1942, a paper by the Royal Aircraft Establishment (R.A.E.) in which it was proposed that the transmitter T.1154, normally carried in bomber aircraft for communication purposes, should be used as a jammer and should be modulated by "noise" from a carbon microphone hung in the engine cell or airframe.[2] To overcome the difficulties of searching for and jamming the frequencies used by the enemy, it was suggested that each bomber aircraft should be allotted a band of 150 kilocycles out of the total band used by the enemy, the wireless operator being responsible for searching this band and jamming any German R/T that he might hear. The scheme appeared to be practicable and to meet the requirements of Bomber Command. Air Ministry therefore suggested to Bomber Command that this form of jamming should be introduced and that it should be carried out on a larger scale than had previously been authorised.[3] After satisfactory trials had been carried out by aircraft of No. 1473 Flight—the special R.C.M. Flight of No. 80 Wing—Bomber Command initiated jamming operations in December 1942, at the same time as Mandrel.[4] The code name Tinsel was allocated to this counter-measure, which was first used on 2/3 December 1942.

The efficacy of Tinsel depended primarily on two factors :—

(*a*) The scale and rapidity of action on the part of the operator in detecting a German R/T transmission within the band allotted to him and in applying his jamming.

(*b*) The number of bombers engaged and the size of the area over which they were operating, *i.e.*, the greater the number and the greater the concentration in time and space the better the effects of the jamming.

In the beginning, the effects noticed were not particularly encouraging. This was probably due to the fact that the operators had not acquired the necessary skill and that the raids when Tinsel was first used were usually neither in great force nor very concentrated. Early in 1943, however, when the operators had gained experience and were, consequently, much more skilful, and when, also, the raids were larger and more concentrated, the results achieved undoubtedly contributed to a reduction of losses. Concurrent with the growth of this success the moral effect of the counter-measure increased by leaps and bounds, not only because of the fact that the operators were able themselves to judge the effect they were producing but also because they felt they were being employed offensively during the most dangerous period of the raid.

---

[1] Then Air Commodore E. B. Addison.

[2] A.M. File Radio/S.4233/GEB/16, 2 October 1942, and Bomber Command File B.C./S.25707, Encl. 14B.

[3] A.M. File 186/D. of S., 4 November 1942.

[4] Bomber Command File B.C./S.25707, Encls. 28A, 34A, and A.M. File C.S. 11472/ACAS (Ops.), 18 November 1942.

Evidence as to the results came from two sources: first, from the crews themselves, and, secondly, from " Y " Services.[1] The crews reported fully on their Tinsel activities and their reports were received daily at Headquarters, Bomber Command, where the results were recorded, analysed and assessed. The following are some extracts from typical crews' reports :—

(a) No. 75 Squadron :

" German R/T became very exasperated, and finally ceased."

(b) No. 300 (Polish) Squadron :

" Enemy pilots became nervous and swore. Enemy tried to pass the same message for ten minutes beginning with the same phrase. Heard enemy pilot getting nervous. Several Tinsels on one channel." (Many of the Polish crews, of course, understood German.)

(c) No. 35 Squadron :

" Jamming transmissions appeared to be effective. In every case upon lifting key, an appreciable pause was noticed before R/T recommenced."

(d) No. 214 Squadron :

" Enemy aircraft heard to repeat messages through interference."

Intelligence reports issued by Air Ministry (A.I.4) frequently contained references to chases being abandoned, or contact lost, through R/T interference. Typical instances are as follows :—

(a) Mannheim—6/7 December.

Night-fighter R/T heavily jammed. As a result little R/T traffic heard at Intercept Station. At 2043 hours Control attempted an interception, but interference was so heavy that it had to be broken off. Amount of interference reported on this night is outstanding.

(b) Turin—8/9 December.

Messages heard included :—

" R/T is still no better."
" R/T contact is poor."
" Can no longer understand you."
" Outside interference."

(c) Cologne—26/27 February.

Increase on this night in the amount of interference probably owing to the large number of bombers operating. In consequence of this it was not possible to allocate R/T to specific Controls.

(d) Berlin—1/2 March.

On sixteen occasions aircraft were ordered to change R/T frequencies because of interference, and many messages were missed because of this marked interference.

Mandrel and Carpet

With the building up of the Fighter Command sweeps and Bomber Command offensive towards the end of 1941, technical and intelligence investigations and plans were begun by the R.C.M. group at T.R.E. and at Air Ministry

[1] A.M. File R.C.M. 112, Encl. 30A. Report to C.A.S. by D.G. of S., 20 March 1943.

respectively, with a view to instituting a jamming offensive against the early warning R.D.F. chain deployed along the enemy-occupied coast opposite the United Kingdom.[1] The aim of this jamming was to push back the long range R.D.F. cover beyond a line at which the short range R.D.F. took over on a different frequency. Concurrently with the early warning jamming, work was also commenced with a view to similar action against the short range and night-fighter interception system, the code words Mandrel being given to the former and Carpet to the latter.

The means of jamming the enemy early warning system had been first set out in detail in a report prepared by T.R.E. in October 1941. This paper calculated the power required to reduce the range of the Freya to 20 miles for both air and ground transmitters and outlined the effect that would probably be produced by ground transmitters operating in the Dover and Isle of Wight areas, and by airborne transmitters carried in six aircraft disposed so as to present a continuous line of jamming to the R.D.F. stations. The use of barrage instead of spot frequency jamming was recommended; that is to say, the use of transmitters whose radiation energy was spread over a band of frequencies instead of being concentrated on one frequency of a single R.D.F. station.[2] The advantage of this type of jamming was that it overcame the difficulties of monitoring and ensured that all enemy R.D.F. stations looking at the jammer were jammed. The modulation of the transmitter was not specified and it was stated that this subject was under investigation.

The type of modulation used for jamming any type of radio receiver is a matter of great importance, as it is possible to reduce the effectiveness of the jamming by using filters or other devices to reject certain components of the modulation. To avoid this possibility it is necessary to produce in the enemy receiver modulations which are quite random in form and do not have, for example, any components of a definite frequency.[3] One method of achieving this was the use of "noise" as a source of modulation. T.R.E. attempted to generate noise electrically by using a resistance, but the power obtained was too small to be of use. A noise source of usable power was, however, developed by the General Electric Company Limited research laboratories making use of the thermionic noise produced by certain types of radio valve.

The development of ground and airborne Mandrel sets was at first given a priority below that given to the development of a 53 centimetre jammer and progress was accordingly slow. But in May 1942, the development of the three offensive radio counter-measures Mandrel, Moonshine and Carpet was considered to be sufficiently far advanced to warrant the prototyping of aircraft for the airborne equipment and the selection of sites for the ground Mandrel stations.[4] The scheme as now proposed, which had as its immediate object the assistance of Fighter Command in their task of destroying enemy fighters in order to hold as large an enemy fighter force as possible in the west, was to consist of both airborne and ground Mandrel to reduce the range of the enemy long range early warning system to some twenty miles from the enemy coast, together with airborne Moonshine to bring enemy fighters into the air and, finally, the use of ground Carpet to jam the short range enemy R.D.F. warning system over a short length of the coastline opposite Dover.[5] Any larger

---

[1] Minutes of R.C.M. Meetings held at Air Ministry between August 1941 and May 1942.
[2] T.R.E. Report No. 5/37A. A.M. File R.C.M. 119, Encl. 4A.
[3] Narrator's Comment. [4] Minutes of Third R.C.M. Board Meeting, 5 May 1942.
[5] Paper R.C.M./7/42, 29 May 1942.

ground effort against the supplementary short range warning system, which operated on a wavelength of 53 centimetres, was considered impracticable. Mandrel, Carpet and Moonshine together formed a protective and spoof screen, the tactical use of which could be applied in a variety of ways, the airborne Mandrel aircraft flying at suitably spaced intervals over the Channel supplemented with ground Mandrel stations at Dover, Hastings, Ventnor (Isle of Wight) and Kimmeridge (near Swanage). The single ground Carpet station was installed adjacent to the Dover Mandrel station and the Moonshine aircraft were flown over the Channel in accordance with the plan in operation at any time.

Ground Mandrel

It was proposed that No. 80 Wing should install on each of the grouud Mandrel sites six Type 1431 transmitters, designed and manufactured by T.R.E. Noise modulation was produced by means of a neon striker time-base circuit generating three independent and random frequency saw-tooth wave forms. The transmission spread over approximately two megacycles.

The first ground Mandrel site on Shakespeare Cliffs, Dover, was completed in July 1942, its six Type 1431 transmitters between them barraging over the frequency band 118–128 megacycles per second, the bulk of the radiation being concentrated on the sector between Boulogne and Calais.[1] This was followed almost immediately by a site at Fairlight, near Hastings, with the radiation concentrated towards the south. Two further sites, with their radiation directed towards the Cherbourg Peninsula, at Ventnor and Kimmeridge, were completed in November, but owing to siting difficulties and to their greater distance from the nearest *Freya* stations their efficiency was doubtful; consequently they were made on a transportable basis, the transmitters being fitted into vehicles and a transportable type of aerial array designed. The transmitter equipment of each station was similar to that at Dover and consisted of six Type 1431 transmitters. The sites at Dover and Ventnor were considered the principal sites in each pair with Fairlight and Kimmeridge as subsidiaries to afford insurance against breakdown on the main sites and to give a slight additional coverage in each case.

As it was the intention to barrage over the whole of the *Freya* band then in use by the enemy, only primitive monitoring was required to ensure that the spread of each transmitter was in operation and that the individual transmitters were so spaced in frequency as to cover the whole band without leaving gaps. This was achieved by the erection of small receiver stations adjacent to the transmitter sites to which they were connected by telephone.

Ground Carpet

The single Carpet station at Dover was completed with a special monitor site in August 1942 and was tested in the 80 centimetres wave-band in conjunction with the Admiralty coastal jamming chain working in this band and deployed in the neighbourhood of Dover for use against the opposing gunlaying and coastal watching R.D.F. This use of Carpet, pending a possible use for Royal Air Force purposes in the 53 centimetres wave-band, for which

[1] For details of the first ground Mandrel site, *see* Appendix No. 11.

it had been designed, enabled the mechanics and operators to be trained in the recognition of signals and manipulation of the transmitters on to the signals to be jammed. In October this station was formally placed at the disposal of Vice-Admiral, Dover, and ultimately, no operational use for the designed purpose having arisen, the station and monitor site were handed over completely to the Admiralty and the Royal Air Force personnel withdrawn. This station, like the Mandrel stations, consisted of the battery of six transmitters, the sets employed, Admiralty Type 91, being modified to cover the special band required.[1] The transmitters were provided with wave-guide arrays mounted on scaffolding which permitted each wave-guide to be rotated independently through an arc of 30°. Admiralty Type J.19 receivers were supplied for monitoring purposes and were also provided with rotating arrays.

Airborne Mandrel

A laboratory model of the airborne transmitter had been completed by T.R.E. in March 1942 and in April, when the priority on this equipment was raised, the General Electric Company were asked to produce eighteen sets.[2] Arrangements were also made for the installation of the equipment in nine aircraft (Defiants) of No. 515 Squadron to form a second flight of R.C.M. aircraft in addition to the flight of Moonshine aircraft. No. 80 Wing was charged with the responsibility of co-ordinating the programme of prototyping and installation, the installation work being carried out by fitting parties of No. 26 Group.

On 8 July 1942, the General Electric Company issued a report on the performance trials of Mandrel as fitted in the Defiants.[3] The results were satisfactory and indicated that airborne Mandrel was easily capable of reducing the range of the *Freya* to 20 miles when at a distance of 60 miles and covering a frequency band of 121–128 megacycles per second. This met the requirement for the proposed Mandrel jamming screen. The modulation used was from a noisy diode valve. Eighteen sets were delivered in August 1942 and a further contract was made for 192. Arrangements were made for a prototype installation in a Lancaster aircraft, and when the Bomber Command operational requirement became known, installations were also made in Stirling, Wellington and Halifax aircraft.[4]

It will be recalled that on 6 October 1942 at a Bomber Command meeting attended by Sir Henry Tizard, it had been recommended that Mandrel should be installed in bombers.[5] As a result, it was decided that thirty-six bomber squadrons should be fitted with airborne Mandrel and No. 80 Wing was made responsible for co-ordinating the programme of experimental work, the prototyping of aircraft, and the fitting of the equipment. At this stage the scale per squadron was to be two aircraft fitted complete with Mandrel and two more aircraft fitted ready to take the equipment if required. Fitting of the squadrons commenced early in November, being carried out, as for No. 515 Squadron, by fitting parties of No. 26 Group and by squadron personnel. A big effort was put into the production and installation in Bomber Command aircraft of Mandrel and by 1 December 1942, in addition to the Mandrel Flight

[1] Appendix No. 11.
[2] A.M. File R.C.M.155, Encls. 20A and 25A.
[3] A.M. File R.C.M. 119, Encl. 65A. G.E.C. Report, dated 8 July 1942.
[4] A.M. File R.C.M. 119, Encl. 83A *et seq.*
[5] Minutes of Ninth R.C.M. Board Meeting, 22 September 1942.

of No. 515 Squadron and the ground Mandrel stations, four aircraft in each of thirty-six squadrons of Bomber Command had been fitted. Mandrel was now ready for operational use. It was planned to use Mandrel for two purposes:—[1]

(*a*) To reduce the range of the enemy's R.D.F. early warning system by using the airborne Mandrel of No. 515 Squadron and the ground Mandrels of No. 80 Wing as a jamming screen.

(*b*) To reduce the effectiveness of the enemy's G.C.I. system by jamming the *Freya* associated with most G.C.I. positions with the airborne Mandrel of Bomber Command.

The value of jamming the G.C.I. *Freya* was doubted by A.D.I. (Science) since it was his opinion that the *Freya* was a reserve system of interception and was not used for directing *Wurzburg* on to their targets. This point was considered at a meeting of the R.C.M. Board, and it was decided that even if this were so, the jamming should be continued, as it was doing no harm and the production and fitting of Mandrel was not delaying the development of counter-measures against the *Wurzburg*.[2]

As Mandrel was introduced at the same time as Tinsel (the counter-measure against radio telephony transmissions used to direct German night-fighters) it can claim only a share in the fall in bomber losses observed during that period. There were, however, other indications of the effect of Mandrel, namely a delay in first interceptions and attacks by German fighters caused by lack of early warning, attempts on the part of R.D.F. stations to avoid jamming by changing frequency, and " Y " Service reports of interference from the intercepted R/T traffic. During a raid on Mannheim on 6/7 December 1942 the first Little Screw traffic, which normally began early, was not heard until 32 minutes after the first two Royal Air Force bomber aircraft had crossed the French coast, and the first reported interception not until 21 minutes after the coast had been crossed, indicating a lack of early warning.[3] On 20/21 December, when Duisburg was raided, aircraft were to be over the target at 1945 hours ; the " Y " Service, however, reported that no mention was made in the R/T traffic of any British aircraft until 1930 hours, and the first reported attack that night was at 1942 hours. Alterations in the frequency of the coastal *Freya* stations were observed, suggesting that the jamming was technically effective, and a review of all intelligence by A.D.I. (Science) in March 1943 confirmed this.[4]

Risk of Homing on Airborne Mandrel[5]

It is possible, given a receiver and suitably designed aerials, to D.F. and home to transmissions from radio apparatus. Soon after Mandrel had been produced it was found comparatively easy to D.F. Mandrel radiations from individual aircraft, mainly because the carrier frequency in the middle of the radiated band was of relatively large amplitude, and also because it was not possible to set up or tune all Mandrel sets to the same spot frequency.[6] In order to reduce the increased danger of interception which Mandrel-carrying bomber aircraft ran,

[1] Bomber Command File B.C. S.I. No. 16 and B.C.S. 28389/I, Encl. 26A.
[2] A.S.I. Report No. 1, 29 December 1942 and R.C.M. Board Meeting, 12 January 1943.
[3] Bomber Command File B.C. S.28389/I, Encls. 78A and 79A.
[4] A.D.I. (Science) Report No. 111, 29 March 1943. Bomber Command File B.C. S.28389, Volume II, Encl. 8A.
[5] For an account of the efforts actually made by the G.A.F. to home fighter aircraft on to Allied airborne Mandrel, *see* Chapter 14 below (German Air-to-Air Homing).
[6] A.M. File R.C.M. 119/III, Encls. 120A and 121A.

the sets were modified by the incorporation of a vibrating condenser in the tuning circuits, causing the carrier wave frequency to vary rapidly over a bandwidth of two megacycles per second. This had the effect of making it more difficult for the carrier of any particular set to be selected.

The danger of the enemy homing on Mandrel was considered again in January 1943 when No. 1 Group of Bomber Command reported that the loss rate of their Mandrel-fitted aircraft was higher than for those not fitted.[1] But an analysis of losses throughout the Command, showed that, if anything, the reverse was occurring, the loss rate of aircraft fitted with Mandrel being lower than that of those not fitted. By this time the vibrating condenser modification had been produced and was being fitted.[2] In May 1943 it became known that the enemy was evidently alive to the possibility of homing to Mandrel transmissions and was developing a homer for the purpose known as the *Freya Halbe*.[3] Precautions in addition to the vibrating condenser were considered desirable, and a suggestion was made by T.R.E. that Mandrels should be switched on and off for periods which would interrupt transmission sufficiently to make it difficult for the enemy aircraft to home to an individual transmitter.[4] It was also suggested that Monica, a Royal Air Force tail warning device, should be fitted to the Mandrel aircraft to indicate when Mandrel should be switched off. In addition, avoiding action was to be taken immediately an enemy aircraft was disclosed by Monica to be within a certain distance. The duration of the periods for which Mandrel should be switched on and off was decided after considerable discussion, a period of two minutes on and two minutes off being accepted.[5] This period was supported by trials which had been carried out by Fighter Command.[6] To simplify the execution of this switching technique Bomber Command arranged for their Mandrels to be modified so that the "pip squeak" contactor system could be used to make the switching automatic. The system was put into effect at the beginning of July.

A close watch was kept on the losses of Mandrel fitted aircraft, but apart from a brief period of excessive losses by No. 4 Group Mandrel aircraft in June 1943, no cause for anxiety appeared until the end of the year when No. 4 Group losses of fitted aircraft again began to rise.[7] An investigation was made as to the possibility of No. 4 Group aircraft fitted with Mandrel being in some other way a special class—whether, for instance, they were flown by inexperienced crews. Despite the investigation, however, no adequate explanation could be offered.

Spreading of *Freya* Frequencies

The first indication that the enemy was using frequencies outside the band covered by Mandrel came in January 1943 when signals were heard from the Cap Gris Nez area on 107·5 megacycles per second.[8] The signals had a pulse recurrence frequency of 500 cycles per second, and it appeared likely that they

[1] Bomber Command File B.C. S.28389, Encls. 86A and B and 87A.
[2] A.M. File R.C.M. 119/II, Encl. 163A.
[3] A.M. File R.C.M. 119/II, Encl. 30A and Bomber Command File B.C. S.28389, Minute 8.
[4] A.M. File R.C.M. 119/II, Encl. 62A. [5] *Ibid.*, Encls. 109A and 110A.
[6] Bomber Command File B.C. S.28389/II, Minute 12.
[7] Bomber Command File B.C. S.28806/3/I, Encl. 72A. On 11 June 1943, whereas total bomber losses were just under 5 per cent., those of the Mandrel, Halifax aircraft were 21 per cent., Wellington aircraft 19 per cent., Lancaster aircraft 7 per cent. and Stirling aircraft nil.
[8] A.M. File R.C.M. 119/II, Encl. 174E.

came either from a *Freya* or from a new type of equipment believed to be a long-range *Freya* which according to Intelligence sources was known as *Mammut* or Hoarding.[1]

In June *Freya* signals were intercepted on frequencies between 129 and 131 megacycles per second, and soon afterwards on 140 megacycles per second. It was now evident that the enemy was taking definite steps to overcome the Mandrel jamming by extending the frequency range of his equipment.[2] This meant that not only had Mandrel to be modified to transmit on the new frequencies, but as each set covered a frequency band of only 10 megacycles per second, more transmitters would have to be used if a continuous barrage over the enemy's frequency band was to be maintained. Action was taken by the Director of Telecommunications[3] to increase from 100 to 600 a contract which had been placed for an American version of Mandrel which was designed to be tunable over the frequency band 85 to 140 megacycles per second.[4] He also asked T.R.E. to modify the British Mandrel so that it, too, could be used over the extended enemy frequency band. At the same time the contract for British Mandrels was increased by a further 600 sets.

The continued operation of the airborne Mandrel screen, covering what was now only a small part of the *Freya* frequency band, was clearly a waste of effort, and in July these operations were abandoned until such time as No. 515 Squadron could be re-equipped with a new type of aircraft capable of carrying more than one Mandrel jammer.[5] By the beginning of August it had been established that the spreading of frequency was not confined to the *Freyas* of the coastal early warning chain, but that the inland *Freyas* were also operating on new frequencies.[6] It was discovered, too, that the upper limit was now 150 megacycles per second. This fact confirmed that the inland *Freyas* were being inconvenienced by our jamming.

By this time it had been found possible to modify the airborne Mandrel so that it could be made to cover a 10 megacycles per second frequency band within the limits 88 to 148 megacycles per second. In view of this, early in August the General Electric Company were asked to produce 200 modification kits, 100 for the frequency band 128 to 138 megacycles per second and 100 for the band to 148 megacycles per second. These kits were to be used for the modification of sets already held by Bomber Command.[7] In addition, it was arranged that the production of future sets should be divided equally over the three ranges—118 to 128, 128 to 138, and 138 to 148 megacycles per second. No immediate requirement was foreseen for frequencies below this. The modification kits were completed by the end of August and forty Mandrels of each of the new frequency bands were modified and distributed in Bomber Command.[8]

The use of Mandrel and the enemy's efforts to overcome its effect had now started a battle of radio engineering skill which was to continue for the rest of

---

[1] A.D.I. (Science) Report, 21 November 1942, and A.M. File R.C.M. 174, Encl. 3A.
[2] A.M. File R.C.M. 119/III, Encls. 86A and 93A
[3] In March 1943, responsibility for R.C.M in Air Ministry was transferred from the Directorate of Signals to the Directorate of Communications on transfer of Air Commodore E. G. Addison from the one to the other.
[4] A.M. File R.C.M. 119/III, Encls. 63A, 92A and 103A.
[5] A.M. File C.S. 11471/ACAS (Ops.), 27 July 1943, and A.M. File R.C.M. 119/III, Encl. 156A.
[6] A.M. File A.I. 4/215/1, 4 August 1943, and A.M. File R.C.M 119/III, Encl. 115A.
[7] A.M File R.C.M. 119/III, Encl. 182A.
[8] *Ibid.*, Encl. 205A, and Bomber Bommand B.C. S.28389/II, Encl. 46A.

the war, with the Germans changing the frequency of existing equipment or producing new equipment to overcome the effect of jamming, and the Royal Air Force seeking for intelligence of these changes and then endeavouring to produce new or modified jammers in time to prevent the enemy gaining any great advantage.

Enemy M.F. Counter-Measures

Although the Germans were never to develop counter-measures to the same extent as did the British, they did make efforts to interfere with the Royal Air Force radio aids to navigation, particularly those used by Bomber Command and the United States Army Air Force. The first identified radio counter-measure to be employed by the enemy was the jamming of M.F. beacons used by Bomber Command. Intentional enemy interference with several beacon groups commenced on 25 March 1942 and originally consisted of hand-keyed imitations of the beacon transmission radiated from relatively high-powered transmitters situated in the Amiens area. This crude jamming was later replaced by the meaconing method and the enemy counter-measure scheme developed rapidly causing considerable inconvenience to Bomber Command who, before the completion of the Gee programme, relied to a very large extent on the use of M.F. beacons for navigation and homing. As a result of meetings between representatives of Air Ministry, Headquarters, Bomber Command, Headquarters, No. 80 Wing, and the British Broadcasting Corporation, a decision was reached to counter the enemy system by two methods,[1] viz. :—

(*a*) By leaving the high-powered B.B.C. transmitter at Droitwich " unspoiled " when required for use by Bomber Command.

(*b*) By using No. 80 Wing Meacon transmitters as beacons.

The code names Washtub and Splasher respectively were assigned to these operations, which are considered in detail below.

Washtub

In order to render them useless to enemy aircraft for navigational purposes, the high-power B.B.C. transmitters operated generally during the period of hostilities as members of synchronised groups and their use by friendly aircraft for homing purposes was therefore not possible. With the introduction of operation Washtub the higher-powered transmitter at Droitwich 5 (200 kilocycles per second, 200 kilowatts) which was used for foreign propaganda was left " unspoiled " from two hours after sunset on any night when it was required by Bomber Command for navigational purposes. During these periods of unsynchronised transmission the transmitter remained subject to control by Headquarters, No. 80 Wing, via the Liaison Officer at Headquarters, Fighter Command who could issue orders to " spoil " or close down the transmission should enemy activity necessitate such action.

Washtub, which came into operation 4 April 1942 proved effective in practice, and the transmitter was reported by crews as providing excellent homing facilities for aircraft within ranges of 150 miles, the signal being particularly easy to distinguish and giving very sharp minima. The scheme had, however, been regarded purely as an emergency measure and in view of the fact that the Splasher system introduced on the same date proved immediately successful,

[1] Minutes of A.M. Meeting, 28 March 1942, and Minutes of Headquarters No. 80 Wing Meeting, 29 March 1942, No. 80 Wing File S.3043/3/Sigs., Encls. 2A and 3A.

Washtub was discontinued on 12 April 1942. In December of that year, as a result of continued enemy interference with Splasher transmissions, the system was again brought into force and augmented by the addition of the B.B.C. transmitter at Start Point, known as Washtub II. Washtub I and II operated until the introduction of the expanded Splasher schedule in January 1943 when their use again became redundant. Washtub remained available if required until June 1943 when it was finally discontinued.

Splasher

The Splasher system involved the use as M.F. beacons of certain No. 80 Wing Meacon transmitters sited in groups of four at points along lines roughly parallel to the Eastern and Southern coasts of England, the original groups being situated at No. 80 Wing stations Marske, Louth, Scole, Flimwell, Ashmansworth, Fairjile and Mintlaw. This organisation provided a large number of additional beacon transmissions on different frequencies; transmitters at any given site employed a common callsign and thus, if one frequency was suspected as being subject to enemy interference, it was possible to obtain a check bearing by moving to another frequency with the same callsign. Callsigns and frequencies operated to a scrambled schedule prepared by Headquarters, Bomber Command. Control of the Splasher organisation was vested in Headquarters, No. 80 Wing, who retained the right to close down any transmitters in the system in the event of their being required for meaconing.

Splasher was introduced on 4 April 1942 and proved an immediate success since the enemy R.C.M. organisation was swamped by weight of numbers. Reports received from Headquarters, Bomber Command, indicated good results from the system, many crews preferring it to the standard M.F. beacon organisation owing to the simplified schedule.[1] Towards the end of 1942 the enemy commenced to expand his jamming organisation and as a result, a substantial increase in the number of Splasher channels was effected and in January 1943 a total of fifteen sites (54 channels) was available.

During the spring of 1943 the American VIIIth Air Force began to employ Splasher for use during daylight attacks and particularly as rendezvous points. It is of interest to record that in a letter addressed to the Director of Telecommunications, Air Ministry, the Commanding General, American VIIIth Bomber Command, stated that "no other single radio aid has been more urgently needed or more extensively used than the Splasher beacons."[2]

Enemy interference with Splasher channels was, for several months after the initial introduction, on a small scale. It later increased, however, and a special cathode ray D.F. station was therefore established at Aldington (Lympne), and a continuous watch maintained on all Splasher transmissions.[3] On information supplied from this station to the Operations Room at Headquarters, No. 80 Wing, warning of unreliability was provided by the random mutilation of the callsign of the affected transmission. The monitor station at Aldington was at first controlled by Headquarters, Bomber Command, but at a later date (14 May 1943) it was handed over to Headquarters, No. 80 Wing.

In April 1943 the Bomber Command Gee programme was sufficiently advanced to render the use of Splasher unnecessary, and from May 1943 a modified system

---

[1] No. 80 Wing File S.3043/3/Sigs., Encl. 9A. [2] *Ibid.*, Encl. 50A, 28 October 1943.
[3] Bomber Command Letter B.C. S.25294, 15 June 1943, and No. 80 Wing File S.3007/71/Sigs., Encl. 4A.

was introduced, the number of frequencies employed being reduced to twenty-four channels. These were used by the U.S. VIIIth Bomber Command during the day, spoof transmissions being made nightly to disguise any changes in radio navigation systems introduced by Bomber Command.

Introduction of V.H.F. for Enemy Fighter R/T

Although V.H.F. R/T was used by the German bombers earlier, there was, until October 1942, no suggestion that the enemy night-fighters were using it. In October 1942, V.H.F. R/T, associated with Little Screw training, was intercepted by day.[1] The use of V.H.F. for operations, however, was not heard until January 1943, when interceptions were made in the Mediterranean of R/T transmissions made by a German Unit *N.J.G.2*. At the end of March 1943 R/T on frequencies of 39·5 and 39·6 megacycles per second were heard on the Western Front, and during April further frequencies were heard which suggested that the enemy was using V.H.F. for night operations on an increasing scale within frequency limits of 38 to 42·6 megacycles per second. There was some claim that this sudden change had been made necessary by the success of Tinsel against enemy R/T in the H.F. band.[2] It was also assumed that the Bomber Force would before long be denied the protection afforded by Tinsel. This prompted Headquarters, Bomber Command, to ask Air Ministry to provide a suitable V.H.F. jammer for installation in bomber aircraft.

T.R.E. had examined the possibility of jamming the enemy R/T, and concluded that the most effective way would be to use Jostle II, a jammer which had been produced as an airborne monitored spot frequency jammer for jamming enemy tank R/T.[3] T.R.E. also estimated that jamming from ground transmitters was possible at ranges of about 160 miles. Since it was not possible to produce immediately the requisite number of airborne jammers, which were eventually known as Airborne Cigar (A.B.C.),[4] attention was directed to the possibility of jamming from ground transmitters. This operation was to be termed Ground Cigar.

Ground Cigar

In April 1943 it was decided to carry out tests at Bricket Wood, near St. Albans, to investigate the possibility of using a modified Jostle transmitter from a ground site with an aerial capable of producing a " lane " of jamming, similar to the jamming of the A.I.[5] A comparison between this transmitter and one of No. 80 Wing's G.M.C. transmitters was made during these tests, and as a result it was concluded that the latter was the more satisfactory. It was therefore decided to install four G.M.C. transmitters at a site that had been selected on the East Anglian coast at Sizewell (near Saxmundham), and to use these for barrage jamming over a 1-megacycle band. It was proposed to use 105-foot towers to support elevated wide-band cage aerials. Before this plan was completed, however, a further comparative test was carried out between the first G.M.C. transmitter installed at Sizewell and a G.M.C. transmitter installed on the No. 60 Group Station at Bawdsey, utilizing an aerial erected on one of the 560-foot towers.[6] Reflectors were employed with each aerial system set up to

[1] A.M. File A.I. 4/429/J and Bomber Command File B.C. S.29922.
[2] Bomber Command File B.C. S.29922, Encl. 2A, 7 April 1943.
[3] T.R.E. D.1563/H.H./408, 4 January 1943, and A.M. File R.C.M. 182, Encl. 3A.
[4] *See* Part 2, Chapter 10, of this volume for details of Airborne Cigar.
[5] Minutes of Sixteenth R.C.M. Board Meeting, 6 April 1943. *See* Chapter 12.
[6] Minutes of Seventeenth R.C.M. Board Meeting, 4 June 1943.

give a mean line of "shoot" of 125° T. for the broad forward beam. As a result of test flights by No. 192 Squadron, who accompanied the main bomber force over enemy territory, it appeared that the lower aerial at Sizewell gave the best results at 18,000 feet, where a jamming range of approximately 210 miles was obtained. Consequently, in June 1943, it was decided to expand the original programme of four transmitters at Sizewell to fifteen, thereby providing a complete barrage for the whole frequency band (38–42 megacycles per second).

It was realised that barrage jamming in this band was likely to cause a great deal of interference to wireless services in friendly operations, in particular to Admiralty stations listening for enemy E-boat traffic, and to certain blind approach beacons in East Anglia. The loss of wireless interception of enemy traffic whereby the effect of both Cigar and Grocer jamming could be judged was also realised.[1] It was, however, decided that the benefits to be obtained from the use of Cigar were of paramount importance.[2] Interference to the blind approach beacons could be tolerated provided arrangements were made to switch off Cigar on request by the airfields concerned. The Admiralty also were prepared to accept the loss in listening efficiency, provided Cigar jamming was confined to those periods when friendly aircraft were actually engaged on operations.

A more serious interference was that caused to the A.M.E. Station at Dunwich by the fifth harmonic of Cigar. This was investigated by the Anti-Jamming Unit, but despite the use of special matching units, no practicable cure was found, and ultimately it was decided to alter the frequency on which the radar station operated. The interference was, of course, even more pronounced in the case of the radar at Bawdsey, where a Cigar was operated, and in consequence it was decided that all Cigar transmitters should be concentrated at Sizewell, and that the use of the high towers at Bawdsey and other radar stations should be abandoned.

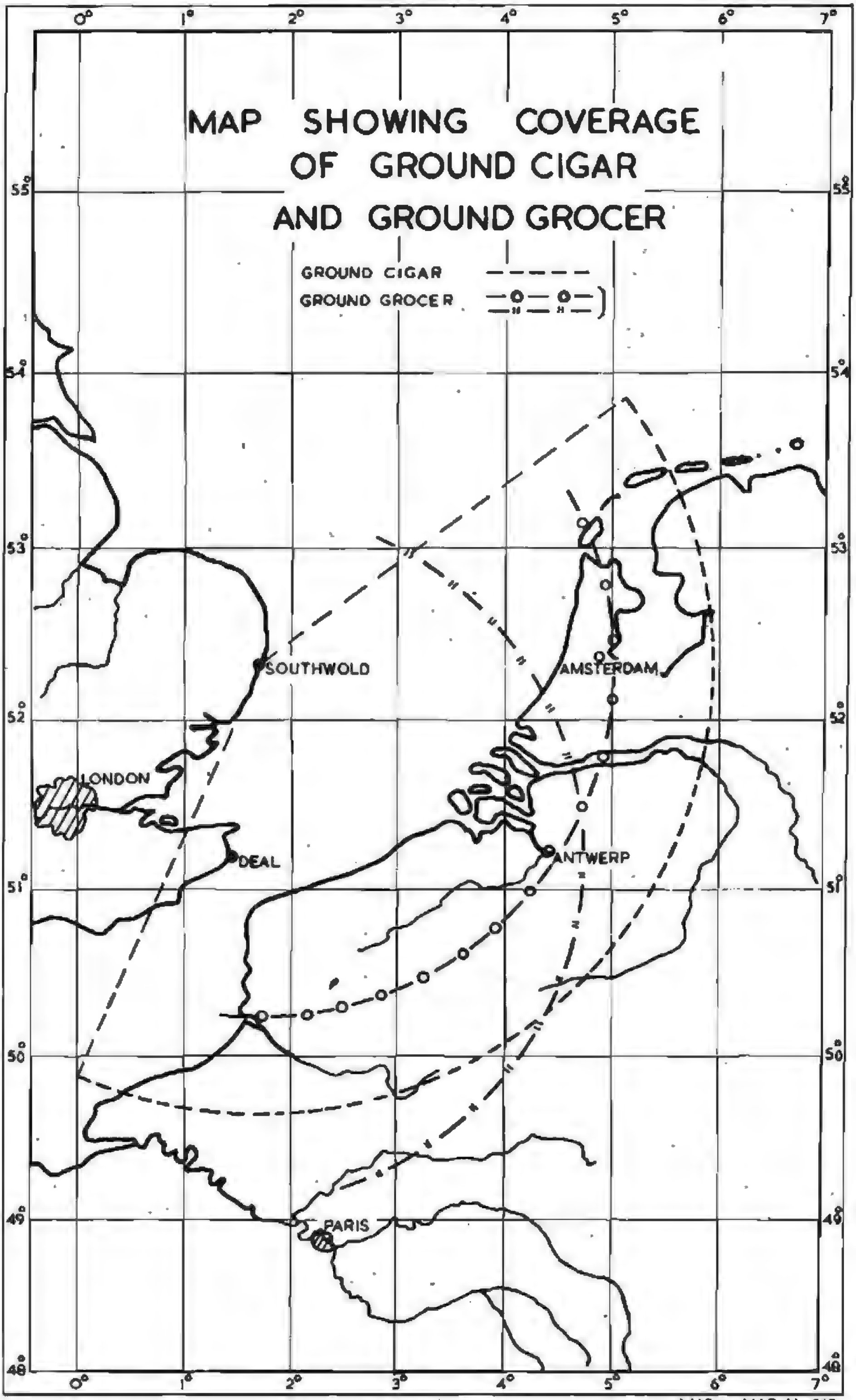
The first G.M.C. transmitter was installed on the Sizewell site in May 1943. In the following month three G.M.C. transmitters were in operation in Sizewell, and by the end of July the full complement of fifteen transmitters had been completed. To obtain full barrage jamming from 38·5 to 42·3 megacycles per second, each transmitter was set up in frequency 0·25 megacycle per second from its neighbour, and by means of a motor-driven rotating fan capacitance across the oscillator circuit, was "wobbulated" over 125 kilocycles on either side of its spot frequency setting. Slow speed "wobbulators" were used in the first instance giving a pulse of power four hundred times a minute over the band covered with, in addition, grid modulation of the power amplifier stage with a sliding three-tone note produced by a phase-shift oscillator. The slow speed "wobbulation" was later replaced by high speed fans producing frequency modulation over the same sweep but at 400 to 500 cycles per second. A wide-band aerial comprising four half-wave cages in a vertical stack fed in phase was employed with each transmitter. A wire mesh screen mounted approximately one-quarter wavelength behind the aerials gave a forward gain estimated at 3 decibels and a horizontal lobe of about 130°.

An experimental panoramic receiver produced by the Anti-Jamming Unit at Bawdsey was tested for monitoring purposes, but for the later stages when spot

---

[1] A.M. File C.M.S. 34/Tels., Encls. 1A, 22 June 1943, No. 80 Wing File S.3093/3/Sigs., Encl. 46A, A.M. File R.C.M. 182, 31 July 1943, and No. 80 Wing File S.3095/3/Sigs., Encl. 55A.

[2] A.M. File R.C.M. 182, 20 June 1943, and No. 80 Wing File S.3055/3/Sigs., Encl. 44A.



A.H.B.1 MAP No. 315

jamming was frequently employed, carefully calibrated Type S.27 receivers with accurate calibration of the transmitters were found to be the most satisfactory method. Even so, experienced operators were indispensable if the monitoring time was to be reduced to a minimum. It will be appreciated that to put several transmitters on to one given frequency in the shortest possible time, when all transmitters are radiating and sweeping into each other's frequency band, entails skilled operation. The maximum number of changes experienced in the shortest time was 27 in one hour.

The test operations carried out in May by No. 192 Squadron using one transmitter at Sizewell and one at Bawdsey were made on three frequencies identified by Kingsdown as being used operationally by enemy G.C.I. stations, and signals intercepted on the nights in question made various references to unserviceable apparatus and to interference. It was not, however, possible to identify such references with Cigar operations until the following month, when the three transmitters by then available were operated during twelve Bomber Command attacks. During the operations the " Y " Station at Kingsdown kept No. 80 Wing " Operations " informed of the frequencies which were operationally active together with their areas of operation. Since only three bands of the order of 0·25 megacycles per second were covered at this time, it was not always possible to attempt to jam all the frequencies active, but frequent re-allocation of transmitter frequencies enabled a reasonable proportion of the more active and accessible controls to be included in the jamming cover.

Traffic interception in this band (38–42 megacycles per second) often proved difficult due to interference from Cigar, but a number of references to enemy communication difficulties was received together with definite reports of interference and jamming. Some intercept examples of interest are given in the following table :—[1]

Date.	*Frequency.*	*Area of Operation.*	*Intercept.*
1943 June			
12	41·55	Alkmaar	" Can we return to base because of R/T interference."
12	41·55	Alkmaar	" Return to base—interference very bad."
16	42·15	Eindhoven	" I have strong enemy interference."
22	40·15	Deelen	" Interference from here onwards " (? investigation flight).

The number of available transmitters increased steadily during July and on the night of the 30th the full complement of fifteen transmitters came into operation to provide a barrage over the complete frequency band. Further evidence of successful jamming was intercepted during the month.[2]

Use of Boozer Tail Warning

The airborne equipment to which the code name of Boozer was allotted was not strictly speaking a radio counter-measure, but rather a warning device to inform the pilot of an aircraft whenever hostile radar was being directed at it. The equipment, produced in October 1942, was in its original form simply a receiver which lit a warning lamp when the aircraft was " illuminated " by an

[1] No. 80 Wing Monthly Report No. 45.

[2] *See* Diagram 6.

enemy radar transmitter: the pilot would then take evasive action until the lamp went out. This was a sound and popular idea, as Boozer did not radiate, and hence did not act as a radio beacon to which German fighters might home. The operational requirements submitted for this tail-warner were:—[1]

(*a*) Warnings were to be certain, and their absence should signify that there was no danger.

(*b*) The receiver was to be able to distinguish between "sweeping" and "holding" by the enemy beam as only the latter was a real threat. The receiver was therefore not to indicate until it had been held for an appropriate time.

(*c*) The receiver was not to respond when the enemy beam was holding a neighbouring target.

(*d*) An indication of signal strength was desirable.

(*e*) A high degree of reliability and a means of indicating when the equipment was unserviceable were needed.

After a trial of six sets of Boozer had been made in No. 7 Squadron of the Pathfinder Force on 15/16 and 20/21 November 1942, it was decided to do more extensive tests.[2] The whole of No. 9 Squadron in No. 5 Group was fitted with what was known as an improved double-channel Boozer. This gave discrimination between an aircraft held by a G.C.I. *Wurzburg* (for interception purposes) and a G.L. *Wurzburg* (for *Flak* control), and results were encouraging. In the meantime, a triple-channel Boozer had been developed which warned the pilot not only of G.L. and G.C.I., but also of the presence of an enemy A.I. fighter. While this appeared to be the immediate solution of many of the difficulties in dealing with the enemy radar, the situation was complicated by the fact that Boozer and Monica—a tail-warning radar device then coming into service—interfered electrically with one another. However, in view of other difficulties with Monica and the urgency of dealing with enemy radar, in particular with his A.I., it was decided to ask for Boozer as a standard fitting in all bomber aircraft. The requirement was specified in detail to the Air Ministry on 3 April, 1943.

From this point till the discontinuance of Boozer on 11 September 1944, the story is not a happy one. Apart from the fact that owing to lack of the necessary technical data the A.I. side of the Boozer set was subsequently found to be insensitive to the enemy's A.I. at ranges over 1,500 yards, the visual range fighter bomber being about 1,000 yards under average conditions, the sets themselves never came forward in anything like the required quantities. Due to the comparatively small number of Boozer sorties flown over any given period compared with total sorties during that period it was almost impossible to gauge the effectiveness of the device, and the most careful analysis by O.R.S. failed to produce any evidence that Boozer was making a useful contribution.

There were other difficulties. As late as October 1943, the original design of the triple-channel model was still undergoing modification, and it was not till the end of that month that a few units of the finalised design became available. Monica fitting had begun in the Bomber force and, as already mentioned, the two equipments interfered with one another, though this difficulty was subsequently overcome. It was also becoming clear that the enemy was giving

[1] H.Q.B.C. Memorandum: "Particulars of R.C.M. and R.D.F. Equipments" and A.M. File R.C.M./170/Tels. 2.

[2] A.M. File R.C.M./120/Tels. 2.

up the use of A.I. on a frequency of 490 megacycles per second for which the Boozer A.I. unit was designed, while the G.L./G.C.I. feature was of limited use because the tactics of the Bomber Force (concentration in time and space along a prescribed route) rendered this of value to stragglers only. However, in view of the potential value of Boozer to stragglers, and since every aircraft was a possible straggler, Bomber Command still considered Boozer to be of operational significance. In January 1944 the Air Ministry was again pressed on the matter, but it was not until March that it was possible to inform Groups what production sets were becoming available, 850 sets being promised by the end of May. Fitting went on through the summer in a desultory fashion, but by September 1944 it became evident that Boozer could not be further justified because of changes in the enemy's A.I. equipment, and of the introduction into Bomber Command of other types of R.C.M. which made Boozer redundant.

There is no doubt that originally Boozer held great promise and should have been more fruitful. It was, however, a failure from the design stage for two reasons. There was insufficient technical data on the enemy equipment against which it was to work, and it was not until a German night fighter aircraft fitted with *Lichtenstein* was captured, enabling practical trials to be carried out, that the design error was discovered. After that, production was complicated by the necessity for further modification, with the result that production sets were never up to the original specification which called for a maximum warning range of 10,000 feet. In addition, it was found that the pulse recurrence frequency in the G.L./G.C.I. section of the receiver had been incorrectly set up. It is doubtful whether these warnings ever had any real value.

CHAPTER 9

"WINDOW"

Window was the code name given to the operation of dropping metallised strips from the air to confuse the enemy R.D.F. early warning system and R.D.F.-controlled searchlights and anti-aircraft guns. It was to prove one of the most effective radio counter-measures used against the German air defence system. The use of leaflets for this purpose was first mooted in 1941, but it was not until the night of 24/25 July 1943 that Window was first used, and then only after the Prime Minister's authority had been obtained.

The efforts to interfere with German R.D.F. control of searchlights and anti-aircraft guns by the use of modified I.F.F. sets by Bomber Command, and the development of a jammer on 53 centimetres wavelength also for this purpose have already been described. As part of the investigation into likely methods of interfering with enemy R.D.F. for gun-laying and searchlight control, two principal schemes had been considered by T.R.E. and the R.C.M.Committee—the transmission of jamming signals and the dropping from aircraft of metallic reflectors. It will be recalled that priority had been given to the development of the 53 cm. R.D.F. jammer, but it was apparent after experiments had been proceeding for some time that a great deal of work remained to be done in order to produce suitable sets for the transmission of jamming signals, and that a large effort to equip the bomber force adequately would be involved.

On the other hand, experiments in the dropping from aircraft of suitable materials to produce spurious R.D.F. echoes to mask or confuse those from aircraft seemed promising. Many suggestions to achieve this had been considered by the R.C.M. Board during 1941 and among the methods which had been studied were balloons carrying linear oscillators, crossed oscillators or wire netting, towed trains of such responders, bottles filled with iron filings or turnings, "arrows" of appropriate lengths of wire with vanes to give good gliding characteristics, and parachuted arrows.[1]

In June 1942, Air Ministry learnt that in September of 1941 packets of 20-gauge aluminium sheet in strips 18 inches long and one inch broad had been dropped by aircraft of No. 148 Squadron in an attempt to defeat a very successful master searchlight situated at Benghazi.[2] Only one attempt was made and the device was found to be unsuccessful, possibly because the searchlight was sound-controlled. It is not certain how this experiment came to be tried, but it is possible that it was attempted as the outcome of some investigations carried out by British scientists in North Africa during 1941, when little was known about enemy R.D.F.[3] A Naval search receiver had been installed in an aircraft fitted with dipoles and was flown over certain enemy defended areas during an attack by our bombers. The investigators found to their surprise that their aircraft seemed to be constantly singled out as the main target for *flak*. It occurred to them afterwards that their aircraft, because of its fitted dipoles, was giving a much stronger echo in the enemy's

---

[1] A.M. File R.C.M. 155, Encl. 12A, 31 August 1941.
[2] A.M. File R.C.M. 120, Encl. 111A, 20 June 1941.
[3] *Ibid.*, Encl. 116A, 25 June 1942.

gun-laying R.D.F. equipment than that from the remaining aircraft. This gave them an idea to protect the bombers, and the metal strips were dropped. In view of the secrecy associated with the Window project, Headquarters, Middle East were instructed by Air Ministry that no further experiments were to be conducted.

Some success had been obtained by T.R.E. with the dropping of metallised sheets of paper.[1] It was possible to distinguish the indication given by nearly stationary sheets from that produced by fast moving aircraft, but for this, further careful study of the indications was necessary. It was reasonable to assume that if a sufficient number of spurious indications could be produced, the operation of enemy R.D.F. gun-laying equipments would at least suffer considerable interference. This information was passed to the R.D.F. Policy Sub-Committee by the Director of Signals, who stated that although it was possible that the best form of material had not yet been found, in view of the success obtained with such simple means it was desired to implement the scheme forthwith.[2] The plan proposed was to drop the paper sheets in batches of 20 to 40 every minute or so when over an area of intense *flak* or search-light activity. The need for such a scheme was felt most when attacking small heavily-defended areas such as Brest.

It was realised that if the enemy discovered the purpose of this device, its use by him in a similar manner might be as effective against British R.D.F. equipments. The possibility that repercussions might outweigh the advantages was to be continually emphasised by the scientists who advised further experiment and trials. On the other hand, the Bomber Command offensive against Germany was being very seriously affected by enemy guns and search-lights and it was thought therefore that the risk of retaliation should be accepted. The Air Staff attitude towards this and similar proposals was based upon the strong view held by the Chief of the Air Staff that we should not deny to our bombers the assistance of any device merely because the capture of such a device by the enemy might assist him in combating our defences.[3] In view of this, the R.D.F. Policy Sub-Committee recommended that as insufficient details were available to enable them to make a decision, further experiments should be undertaken, and that the Air Ministry should submit the considered view of the Air Staff based upon comprehensive trials and the advice of the Technical Departments. Consequently, throughout the early months of 1942, tests were carried out against Royal Air Force R.D.F. stations.

At the same time every effort was made to produce the most suitable material for use as leaflets. It was also desirable that their purpose should be disguised from the enemy for as long as possible.[4] A possible solution submitted by the R.C.M. Board was the printing of propaganda on the leaflets, and on 3 January 1942 approval was given by the Deputy Chief of Air Staff for their preparation, but he emphasised that their ultimate use must depend on sanction from the R.D.F. Policy Sub-Committee.[5] Assistance was sought from the War Office Political Intelligence Department[6] who had had considerable experience in the dropping of leaflets and who were thus able to advise on the

---

[1] The majority of Window trials at this stage, however, were made by Fighter Command.
[2] Annex to R.D.F. Policy Sub-Committee Paper, R.D.F. (42) 1, 5 January 1942.
[3] R.D.F. Policy Sub-Committee Meeting, 9 January 1942.
[4] A.M. File R.C.M. 120, Encl. 11A, 3 January 1942.
[5] *Ibid.*, Encl. 13A, 3 January 1942.
[6] *Ibid.*, Encl. 15A, 8 January 1942.

types of paper used and on the methods of dropping.[1] Leaflets of various types and sizes were supplied by this Department during January 1942, with information as to the methods of folding and dropping, and how each bundle should be tied to ensure unfolding after launching from the flare chute.[2] Samples of metal foil covered with paper on both sides had been prepared. The propaganda printing of this sandwich material was not a difficult process although supplies at first were small. No difficulty, however, was foreseen in the supply of important quantities of propaganda leaflets of which the metallic nature was by no means apparent. The proposal presented a promising field, especially if the camouflaged metallised leaflets were accompanied by an adequate cover of normal leaflets. Already many millions of leaflets had been dropped over Germany and many thousands had been dropped in comparatively close concentrations. It was likely therefore that a dilution by metallised leaflets of which only a small proportion might actually be picked up had a good chance of passing undetected.

Experiments with dropped reflectors continued, and although by the end of January 1942 the tests were not finished, the indications were that the size of the individual elements dropped bore some definite relation to the wave-length. It had been found that some 40 sheets of metallised paper of about 8½ inches by 5½ inches produced on 53 centimetres R.D.F. an effect equivalent to that of an aircraft.[3] On 200 megacycles per second, however, some 60 sheets five or six times as large had not been large enough. It therefore appeared probable that the Germans would have considerably greater difficulty in interfering with British gun-laying and searchlight installations than the Royal Air Force would have in interfering with German ones. British 10 centimetre equipments were likely, however, to be more easily affected than the enemy's 53 centimetre sets.

By 22 March 1942, the technical investigation of Window by T.R.E. was completed and formed the subject of a detailed report.[4] The primary object had been achieved and it had been shown that for frequencies of the order of 200 megacycles per second and above, echoes could be produced by jettisoning material from an aircraft and that the quantities of the material necessary to give rise to an echo equal in magnitude to that of the aircraft were not in any way excessive. The report demonstrated that when considering the operational use of Window there were three main points which immediately came under consideration :—

(*a*) The duration of the echoes.

(*b*) The weight of the material necessary to produce one spurious echo.

(*c*) The time taken in "laying" a sufficient number of echoes to cause confusion to the R.D.F. installations.

The report suggested that these factors would determine the possible uses of Window as a "smoke screen" to conceal large movements, or as a means of protection for individual aircraft. Most of the tests carried out at 5,000 feet had indicated a duration of 15 minutes for the echoes produced by the leaflets. The quantities of leaflets required to produce spurious echoes varied with the type of leaflet used and the wave-length of the installations jammed. Under

[1] A.M. File R.C.M. 120, Encl. 16A, 16 January 1942.
[2] *Ibid.*, Encl. 18A, 17 January 1942.
[3] *Ibid.*, Encl. 21A, 27 January 1942.
[4] *Ibid.*, Encl. 35A, T.R.E. Report, dated 22 March 1942.

factor (c) above, consideration of the density of spurious echoes needed to jam the installations was necessary. It was possible that ten echoes per square mile over the target area would provide sufficient clutter to conceal any aircraft echo. The total weight involved might thus be of the order of 10 lbs. per square mile (on 650 megacycles per second) and would not be excessive, the limiting factor being almost entirely the time necessary for the aircraft to jettison the material. The most likely immediate application appeared to be as an addition to the normal jinking technique. The aircraft would continue its usual jinking and instructions would be given to jettison the material at the same time.

The gist of this report was passed by the Director of Signals to the Air Staff to enable them to submit their considered views on the use of Window as requested by the R.D.F. Policy Sub-Committee in January 1942.[1] Meanwhile, the Chief of the Air Staff had ruled that the Air Officer Commanding-in-Chief, Bomber Command, was at liberty to use these aids as he thought fit.[2] Some misgiving was, however, expressed by Sir Henry Tizard, who suggested in a note for consideration by the Radio (late R.D.F.) Policy Sub-Committee that it was possible that the Chief of Air Staff had not been fully informed of the repercussions of this policy on the offensive or defensive power of the other Services, particularly of the Navy.[3] He could not say how far the use of the proposed counter-measures would interfere with German R.D.F. controls, but on the assumption that it would interfere considerably it followed that this was a counter-measure which could be used with even greater efficacy against our own centimetre R.D.F. He pointed out that we were relying more and more in the future on centimetre R.D.F. for offensive and defensive measures of extreme importance, and it was only by the use of centimetre R.D.F. that we could hope to get, for example, really accurate unseen fire from ship to ship. Naval Type 271 sets were used for coastal watching, for the detection of E-boat attacks, and for detection of submarines. It was the only set which was not effectively jammed during the *Scharnhorst-Gneisenau* episode and, as a result of this, destroyers of the Royal Navy were able to intercept efficiently. If the Germans had used this comparatively simple counter-measure that interception would not have been possible.

This and other representations that the possible repercussions of metallised leaflets had not been sufficiently explored resulted in the Chief of the Air Staff suspending action pending an early report on the matter by the Radio Policy Sub-Committee who at their meeting held on 11 April 1942, invited the departments concerned to prepare papers on which recommendations to the Chiefs of Staff could be based.[4]

The Air Staff Case for the Use of Window—April 1942

Four days later, on 15 April, a memorandum by the Air Staff on the subject of the use of Window was submitted to the Radio Policy Sub-Committee.[5] It included an analysis of bomber casualties over the period 1 September 1941 to 28 February 1942, based on statistical records, Intelligence sources, W/T

[1] A.M. File R.C.M. 120, Encls. 33A and 33B, 12 March 1942.
[2] *Ibid.*, Encl. 40A, 4 April 1942.
[3] R.P.C. Paper (42) 34, 10 April 1942.
[4] A.M. File R.C.M. 120, Encl. 51A, 11 April 1942.
[5] A.M. Folder D.C.A.S./023/127, 15 April 1942.

information from our own aircraft, rescued crews, and other sources showing that losses, the causes of which were traceable, could be divided up as follows :—

Casualties due to *flak*	46 per cent
Casualties due to fighter aircraft	33 per cent
Casualties not due to enemy action	21 per cent
	100 per cent

These figures were calculated from records of 169 casualties out of a total of 323, the balance of casualties being due to unknown causes. Thus of the total data available, 48 per cent. was incomplete. These figures suggested that enemy *flak* was the chief cause of casualties due to enemy action, while *flak* and fighters together might well have been responsible for as much as 80 per cent. of our bomber casualties missing on operations. The analysis ignored bomber wastage by day and losses occurring on sea-mining ; thus the figures covered solely the losses sustained by the bomber force in night operations against land targets on the Continent.

It was known that R.D.F. aids to British anti-aircraft guns and searchlights had greatly improved both. This was most marked in respect of searchlights where the introduction of R.D.F. had made the whole difference between ability to illuminate aircraft targets and failure to do so. There was scientific evidence that the enemy also used R.D.F. control for anti-aircraft guns. Until recently no such evidence had been available respecting R.D.F. direction of searchlights. However, operational pilots were unanimous in their reports of German searchlight accuracy and since our own accuracy had been achieved through R.D.F., and as the direction of searchlights presented the simplest of all R.D.F. problems, it was reasonable to suppose that the enemy had not overlooked such an obvious application. Recent radio investigation flights undertaken by No. 109 Squadron had confirmed this conclusion.

It had been suggested that the enemy might have achieved efficient searchlight control through refinements in sound location technique. This particular development had received constant study by our own experts without pronounced success. It was reasonable to suppose that our own technicians were not less skilful and resourceful than those of the enemy. There was, therefore, no reason to seek an abnormal explanation of the enemy's searchlight success when a normal one (the effective application of R.D.F. to searchlights) was not only possible but probable. It was concluded that the enemy's anti-aircraft gun and searchlight efficiency was traceable in part to the application of R.D.F. methods of control and consequently any action calculated to confuse that R.D.F. would result in reducing our bomber casualties due to *flak* and fighter action.

British night fighting success had been due in considerable degree to the employment of A.I. fighters operating under G.C.I. control. It was known that the enemy were developing a technique of interception based on ground control employing apparatus akin to the Royal Air Force G.C.I. equipment. There was no evidence that he was using airborne R.D.F., but this might be a future development. It was concluded that any action calculated to reduce the efficiency of his ground R.D.F. system would further the bomber offensive.

From a summary of experiments conducted with leaflets and dipoles it was concluded that it was, technically, comparatively easy to interfere with ground

R.D.F. equipments operating on 50-cm. wavelengths or less, by dropping metallised leaflets of appropriate size. This would include the enemy's equipments equivalent to the British G.C.I., S.L.C. and G.L. The weight of material required by one aircraft to produce 20 minutes interference varied between 15 pounds and 60 pounds, depending upon the frequency of the R.D.F. equipment. (The smaller weight was needed for the shorter wavelengths.) Leaflets could not deal adequately with wavelengths much over 50 cm. Metallised cardboard dipoles, however, produced promising results. A weight of 140–200 pounds of dipoles per aircraft might be necessary to deal for some 20 minutes with R.D.F. equipments working in the 150-cm. waveband.

A single bomber which laid a trail of strips or dipoles would help rather than hinder apparatus of the G.C.I., S.L.C. or G.L. type lying on the approaches to a target. A number of aircraft maintaining a mass of strips over a limited part of a heavily defended area, or over a target area, however, would confuse G.C.I., G.L. and S.L.C. apparatus in the vicinity, and so would decrease gunnery accuracy and searchlight illumination.

A few experiments had also been made to test the effect of the strips on A.I. These suggested that it would be negligible, even if they produced pronounced reaction in the A.I. equipment. It seemed probable that a trail of strips would tend to assist rather than cause jamming, since the path of the aircraft would be marked by a series of reflectors which might well give a good response even when the target was beyond effective A.I. illumination. Simple direction from the ground control station would inform the fighter pilot of the direction which he should follow. That the echoes were spurious would be apparent from the rate of travel of the response in the viewer. It was concluded that strips and dipoles would only be of use over limited parts of heavily defended areas and over target areas and consequently against G.L., G.C.I. and S.L.C. equipments covering such areas.

The employment of G.L. and S.L.C. type apparatus working on 150 cm. or longer wavelengths, enabled the target to be seen " through " the strip screen. Suitable methods of correlating this apparatus with that working on higher frequencies was possible, the more accurate apparatus being used to make measurements on the real target selected from the spurious by the lower frequency apparatus. It was probable that many other ways of countering strips could be devised, but the previous example illustrated a typical method which could be employed.

In deciding whether the use of these strips should or should not be initiated against the enemy, the major tactical factor to be borne in mind was that they were only likely to be of value over limited areas. At that time the enemy's *flak* concentrations at the vital areas were heavier than our own and were directed by G.L. apparatus of shorter wavelength. German *flak* was, therefore, more dense, accurate and dangerous than ours but because of the short wavelength of its controlling G.L. apparatus it was more susceptible to strip interference. In the circumstances, the strips were of greater value to us than to the enemy. The British army G.L. III apparatus with its short wavelength (when introduced) would give at least as high a degree of accuracy as the German apparatus, and would be at least equally susceptible to strip interference. By retaining earlier forms of G.L. equipment in action, however, we could counter enemy strips by tactics on the lines suggested above. The enemy, on the other hand, were unlikely to construct large quantities of G.L. equipment of longer wavelength to counter our strips.

The previous considerations related only to the tactical field. The crucial arguments, however, lay in the strategic sphere. Germany's air force had been greatly weakened in the preceding twelve months and her production did no more than keep pace with wastage. Her army was fully stretched on the Russian Front, where a major land/air campaign had to be fought out after a hard winter of desperate defensive fighting. In the west Germany was on the defensive. The striking power of the metropolitan bomber force (possibly augmented by that of our American allies) presented the main weapon with which to assist the Russians in the immediate future during what might prove to be the crucial campaign in the Eastern European theatre. Consequently the Western allies had to maintain and, if possible, increase offensive action against Germany in the coming months. The effort that could be exerted with given resources depended inversely upon the casualty rate. A device which lowered casualties made possible a greater effort. The strips offered such a device and, consequently, would be of substantial assistance to the general effort in the critical months ahead. Furthermore, the comparative freedom from interference which the strips afforded would enable the Allied air attacks to be pressed home and delivered with greater accuracy.

Conclusions of the Radio Policy Sub-Committee

In view of the foregoing representations by the Air Staff the Radio Policy Sub-committee were able to submit their conclusions to the Chiefs of Staff on 22 April 1942.[1] These conclusions were summarised as follows :—

(*a*) Metallised strips provided a device which favoured the air offensive at the expense of the defensive.

(*b*) During the next six months metallised strips would be more effective against the enemy's defences than against our own.

(*c*) When G.L. Mark III equipments came into general use for the control of British anti-aircraft guns, metallised strips would be at least as effective against these devices as would be Royal Air Force strips against the enemy R.D.F. equipment.

(*d*) The retention of G.L. Mark II equipments in our own defences would provide a means of counteracting the effect of enemy strips. It was unlikely that the Germans would be able to use a similar technical counter-measure.

(*e*) Metallised strips were unlikely to have any serious effect on naval operations.

(*f*) Should it be the strategic policy of the Chiefs of Staff to develop and sustain the bomber offensive against Germany in the coming months, the employment of metallised strips by the bomber force was recommended.

(*g*) To be effective, metallised leaflets should be used in quantity and concentrated in vital points and areas, and the tactics developed by the Air Staff should be designed to achieve this aim.

[1] A.M. File R.C.M. 120, Encl. 53B, 15 April 1942. R.P. Sub-Committee Meeting, 22 April 1942.

Issue of Instructions by Air Ministry to Bomber Command

As a result of these submissions the Air Officer Commanding-in-Chief, Bomber Command was informed by Air Ministry on 28 April 1942, that metallised strips would shortly be issued to his Command for use at his discretion, and that the code word for this operation was Window.[1] The Air Officer Commanding-in-Chief was requested to render a report upon the operation four weeks after the issue of the strips, containing his views on their success and value, and to forward recommendations on their future use and scale of provisioning.

The instructions forwarded to the Air Officer Commanding-in-Chief included particulars of the leaflets, and the various methods of use likely to prove most effective. These were as follows[2] :—

(*a*) When dropped in bundles of about 300 an echo would be produced comparable to that from an average aircraft on the screen of an R.D.F. installation working on 53 cms., the wavelength used by the enemy for his gun and searchlight control and for some form of G.C.I. If it were desired to simulate a large aircraft each bundle should contain more than 300 strips ; when used with Wellington and Stirling aircraft for example, a suitable number would be about 500 strips per bundle.

(*b*) The rate of fall of the strips was about 300 to 400 feet per minute and the duration of the " echoes " was 10 to 20 minutes from 10,000 feet. The duration was, however, dependent upon the dispersion of the strips and might be greater from a higher altitude where wind strengths might be less strong.

(*c*) For use as a counter-measure it was necessary to produce a considerable number of these spurious " echoes " spaced well apart so that the enemy observers might have difficulty in deciding which were spurious and which were true. It was therefore important that the bundles should be dropped one by one at suitable intervals over an area in which protection was desired, due allowance being made for wind.

(*d*) Each bundle was backed with a sheet of cardboard or made up between two sheets of cardboard with a rubber band arranged around the bundle at about one inch from the end. When a bundle was jettisoned through the flare chute the rubber band was thrown off because of its asymmetrical arrangement, the strips separating under the action of the wind.

(*e*) It was estimated that considerable protection would be afforded if a density of about 10 bundles of strips (*i.e.*, 10 " echoes ") per square mile could be built up and maintained, the intention being that the strips should be used for the early operations over heavily defended areas only.

(*f*) The weight of a bundle of 500 strips of the kind mentioned above was about 2½ lb. The " sandwich " form of bundle weighed about 4½ lb. If a suitable quantity for an aircraft to carry were 15 bundles of 500 strips each, the weights of such quantities of these two types would be about 40 and 70 lb. respectively.

---

[1] A.M. File R.C.M. 120, Encl. 68A, and A.M. letter C.S. 14198/D.C.A.S., 28 April 1942.
[2] A.M. File C.S. 14198, 28 April 1942.

Bomber Command was also informed that it was expected that the leading aircraft dropping strips during an attack would itself derive no benefit of protection, and might be at a disadvantage on account of the trail of "echoes" which would be observed astern of it. The enemy would only have to pick out the leading " echo " in order to distinguish the aircraft. Experiments were therefore being undertaken in an attempt to provide means for shooting the strips forwards, so that false echoes could be produced ahead as well as astern of the aircraft. Pending the outcome of this proposal the hazard for the leading aircraft was unavoidable but for the remaining aircraft the greatest protection was likely to be had by flying through areas already filled with strips at a height not differing greatly from that of the aircraft. It was suggested to the Command that some account of this might be taken by arranging for later aircraft to fly at suitable distances to leeward and lower than earlier aircraft. The experiments mentioned above did not, however, proceed beyond discussions between the air and technical staffs.[1] The most hopeful way of projecting reflecting material ahead of an aircraft was by means of rockets but this involved the fitting of external gear to the aircraft which would affect performance, and as no alternative methods could be suggested, the proposal was abandoned.

Meanwhile, acting on the Chief of Air Staff's decision at the beginning of April that the Air Officer Commanding-in-Chief, Bomber Command, was at liberty to use Window, the Director of Signals had ordered a supply of leaflets through the Ministry of Information.[2] It will be recalled that this department was responsible for printing on the leaflets appropriate propaganda[3] whereby it was hoped to provide a measure of security against the early discovery by the enemy of their primary purpose. Although the printing of propaganda on metal had been carried out it was doubtful whether this was now possible with the present technique and the quantities of leaflets required. The operational directors in the Air Ministry did not lay great weight on concealing the purpose of the leaflets but it was agreed at this stage to try and print at least a slogan on the metal.[4] This could not be guaranteed, and when eventually strips of very narrow width were manufactured, printing of propaganda was abandoned.

Supplies were maintained, but not without some difficulty. In April it was clear that the quantity of tin required would not be easy to obtain, and already there was only one week's supply of tin in hand. Aluminium was likely to be a satisfactory substitute, but experiments were necessary to confirm this. In any case, it was considered advisable that as aluminium was controlled, arrangements should be made for supplies to be released to the manufacturer's firm of Vanesta, Ltd. By mid-May tests with aluminium strips had been completed and were successful. By the first week in May the first large consignment of operational Window material had been delivered to Bomber Groups. This effort was praiseworthy in view of the difficult circumstances in which the strips had been produced. It was therefore most disappointing when on 5 May 1942 Air Ministry ruled that the use of the metallised strips must be withheld until further notice.[5]

---

[1] A.M. File R.C.M. 120, Encl. 96B, 23 May 1942.
[2] *Ibid.*, Encl. 39A, 8 April 1942.
[3] *Ibid.*, Encl. 68A, 28 April 1942.
[4] *Ibid.*, Encl. 57B, 23 April 1942.
[5] *Ibid.*, Encl. 64A, 27 April 1942, and A.M. File C.S. 14198, Encl. 4B, 5 May 1942.

Postponement of the Use of Window

It will be remembered that throughout the many discussions arising from proposals to apply various counter-measures the scientists had laid great stress on the repercussions which might arise as a result of their use. This point had been emphasised particularly with respect to Window, but any fears which existed had been allayed by the recommendation of the Radio Policy Sub-Committee, resulting from their conclusions summarised above. These fears were, however, revived when Lord Cherwell advised the Chief of the Air Staff that in his view the experiments so far carried out to determine the effect of Window on British R.D.F. devices, particularly A.I., were insufficiently comprehensive. He was concerned that the serious results which might ensue if the enemy were to retaliate by using suitable Window against British R.D.F. had not been sufficiently appreciated. Consequently, after a discussion with the Secretary of State for Air, Lord Cherwell, the Director of R.D.F. and the Air Officer Commanding-in-Chief, Bomber Command, the Chief of the Air Staff ruled that the use of Window must be postponed until further experiments were completed.[1] These trials were to be conducted with the greatest despatch.

Trials to Determine the Effect of Window on British A.I.

A programme of experiments was prepared by Air Ministry, and the Air Officer Commanding-in-Chief, Fighter Command was made responsible for their conduct.[2] The tests required a pursuit by fighter aircraft fitted with A.I., Mark IV, and with 10-cm. A.I. through a Window-infected area to determine in what manner the A.I. was affected ; also an A.I. pursuit of a bomber laying a protective Window trail while flying a steady course and while taking evasive action, the object being to determine whether the A.I. operator could follow the bomber during such manœuvres and to note the effect of the Window on his interception technique. An important point made in order to preserve security was that the trials should take place over the sea.

The results of these trials showed that the interference caused to A.I., Mark VII, was very serious and that A.I., Mark IV, was also affected although not so seriously.[3] The Air Officer Commanding-in-Chief, Fighter Command, while appreciating that the Window would effectively reduce the efficiency of the enemy's R.D.F. controlled guns and searchlights, and also his A.I. if in use operationally, was certain that the enemy would retaliate in kind as soon as he was in a position to do so.[4] This would mean that Royal Air Force night air defence R.D.F. devices would be affected adversely. He therefore recommended that the dropping of Window by Bomber Command should be prohibited.

Air Staff Views on Window Trials

These submissions were then considered in detail by the Air Ministry Operations Directors and their views were summarised by A.C.A.S. (Ops.).[5] Briefly, these were as follows :—

(*a*) The effects on A.I., Mark IV, and G.L., Mark II, were not such as to cause any material reduction in the efficiency of these equipments on which we relied at that time and would continue to do so for the next six months.

[1] A.M. File C.S. 14198, Encl. 4A, 5 May 1942. [2] *Ibid.*, Encl. 5A, 7 May 1942.
[3] *Ibid.*, Encl. 10A. [4] Fighter Command File F.C. S.28647, 16 May 1942.
[5] A.M. File C.S. 14198, A.C.A.S. (Ops.), Minute 11 to V.C.A.S., 19 May 1942.

(*b*) The effects of the strips on our very high frequency equipments such as A.I., Mark VII, and C.H.L.s equipped with P.P.I. were pronounced. So far as A.I. was concerned, however, it was probable that there would be greater areas of air over this country free from strip than areas likely to be infected. Thus the Mark VII A.I. night fighters could hunt in the free areas, but for infected areas produced on approaches to the target, Mark IV A.I. could be used.

(*c*) The quantity of strips that could be carried in bomber aircraft was limited by weight, approximately 3 lb. per false echo; consequently in practice an aircraft could not drop strips continuously but must have means for discovering that it was being followed.

(*d*) These test results gave the first reaction of A.I. operators to strip counter-measures which naturally proved very disconcerting at first. With practice it might be possible to avoid the distraction of false echoes approaching very rapidly and concentrate on the aircraft echo which was nearly stationary.

It was felt that the view of the Air Officer Commanding-in-Chief, Fighter Command must be accepted with regard to the extent to which the use of strips by the enemy would interfere with the efficiency of the air defence of this country, and the general conclusion was that the strips would undoubtedly reduce it. There were, however, methods of countering the strips which were not at that time at the disposal of the Germans. During the following six months strips would affect the Germans more than they would affect the Allies. After that period both sides would have their defences reduced in efficiency, but the enemy was likely to suffer more. It now remained to decide to what extent the standard of night defences should be sacrificed for the very considerable gains to the offensive. The degree of these gains could be estimated from the effect which the Air Officer Commanding-in-Chief, Fighter Command believed would be felt by our own defences.

Other factors to be taken into consideration in arriving at a decision were as follows :—

(*a*) Unless the Germans achieved some considerable success in the near future on the Russian Front there was not likely to be any heavy scale of attack on this country, at any rate until the next winter (1942/43).

(*b*) Gee had been used for the past two months, and 109 equipped aircraft had been lost. We could expect enemy counter-measures to become effective in three to four months' time. During the next three months therefore we should exploit every means to sustain and press our offensive to the utmost.

(*c*) By the end of the summer of 1942 the German Air Force was likely to be very much reduced in strength as a result of major operations in Russia. By this time preparations for a large scale Anglo-American offensive should be well advanced. We should therefore be in a much stronger position than the enemy and should profit more than he by the continued use of strips.

The general conclusion of A.C.A.S. (Ops.) was that Bomber Command should be permitted to use the strips to further the needs of the offensive as early as possible.

These conclusions were not agreed by Lord Cherwell, who upheld the views of the Air Officer Commanding-in-Chief, Fighter Command.[1] He again asserted that once the enemy started thinking on similar lines, he would not stop short of strips, but would certainly proceed to improved methods which no amount of practice by Royal Air Force A.I. operators would be able to overcome. Sir Robert Watson-Watt (S.A.T.) also advised against the use of Window.[2] Its use had been recommended on the score that it would make a very early and substantial reduction in the Bomber Command casualty rate, and that its early use was not likely to prejudice the future to a disproportionate degree by stimulating the enemy to defeat Window and to use Window effectively in retaliation. He suggested that the first implication assumed that such R.D.F. aids as might be seriously deranged by Window were contributing substantially to the casualty rate. He submitted figures of Bomber Command losses due to various hazards which were admittedly approximate, but if they were accepted, he suggested that the very speculative reduction of write-offs from operational sorties (0·1 per cent. of sorties or 2½ per cent. of write-offs) was a poor justification for premature release to the enemy of a device which was more effective against all the newest British R.D.F. than against his, and to which there was no effective reply in sight.

Sir Robert Watson-Watt concluded by recommending that all preparations for Window operations should be completed, that operational practice at home to develop tactical schemes of use were of the essence of this preparation, and that use against the enemy should be withheld until the casualty rate showed a significant rise, or until we had an exceptionally difficult major operation specifically suited to Window, or until a counter-measure was available for Window used against 10-cm. A.I. (whichever was the earliest of these three).

In view of these submissions, both from the Air Staff and the scientists, the Chief of the Air Staff decided to withhold any action on this matter until it was clear what course the operations on the Russian Front would take—the problem to be reviewed some time during June.[3] This was done, and a further case for Window established by appreciating Bomber Command losses from a summary of the attacks made on Essen for the past three months.[4]

The Air Staff Case for Window—June 1942

Although at first bomber force casualties were slight, later they greatly increased until the night of 30-31 May, when the " thousand aircraft " plan supplied the opportunity of attempting to saturate the German defences. The percentage losses immediately fell to the earlier low figures. After that, despite the fact that the attacks had been made in the dark period, the casualties once again increased until on 18/19 June they were as high as nearly 16 per cent. of the effort, and all crews reported an immense strengthening of the enemy gun and searchlight defences. The casualty figures were regarded as significant. They showed the need and value of concentration to saturate the defences and they indicated that we could no longer hope for a lower rate of casualties in the dark periods. The latter suggested not only a quantitative but a qualitative improvement in the gun and light defences which could only be due to an increasing use of R.D.F. control methods.

---

[1] A.M. File C.S. 14198, Encl. 15B, 21 May 1942.
[2] *Ibid.*, Encl. 15C, Minute to V.C.A.S., 23 May 1942.
[3] *Ibid.*, Minute 17, 30 May 1942.
[4] *Ibid.*, Minute 20, 11 June 1942.

By the recent attacks on Lubeck, Rostock and Cologne, Bomber Command had shown what a decisive contribution it could make to offensive strategy given either the numbers to saturate the defences or the ability to concentrate against less well-defended areas. It was felt that there was an outstanding need in strategy to continue to press the air offensive while Germany was so heavily committed to her campaigns on the Eastern Front and in the Mediterranean. On the other hand, the figures showed how much the enemy had been able to strengthen the defences of his vital areas. Unless it was accepted that these defences were now too strong, and that Bomber Command attacks should be restricted to the less well defended and therefore the less vital areas, there were only three courses of action :—

(*a*) To confine the attacks to those infrequent intervals when it was possible to gather enough strength for a decisive concentration on the principle of the " thousand " plan.

(*b*) To accept the heavy losses in sustaining attacks witb the smallest forces normally available.

(*c*) To introduce Window, saturate the enemy defences by this means and so enable the smaller numbers to press home their attacks without disproportionate loss.

It was the view of the Air Ministry Operations Staff that there was now a strong case for choosing the last of these three courses and not to delay longer in reaching a decision to introduce Window.

Meanwhile discussions had been proceeding between Lord Cherwell and the Director of Signals. Lord Cherwell signified that he would agree wholeheartedly to the use of Window if a self-destroying strip could be produced.[1] He suggested the collaboration of other scientists, but it was generally accepted that the practical difficulties of producing such a strip would be considerable. Obviously, as soon as a crashed bomber containing undisturbed bundles of Window had fallen into enemy hands, the proposed self-destruction secret would be out. He was entirely in favour of carrying out trials and practice to ascertain whether with experience and skill night fighter aircraft fitted with 10-cm. A.I. could defeat Window. He felt that whether or not the Royal Air Force used it, the enemy might, and that it was important for Fighter Command to be prepared. If it could be shown that A.I. aircraft would not seriously be affected after some practice in the presence of Window, then his objections would be withdrawn. These representations were considered by the Chief of the Air Staff, who decided that Window should be used as soon as either our own A.I. could defeat it or when a large-scale bombing offensive against this country was no longer practicable for the Germans in the light of their war with Russia.[2]

As a result of this decision the Air Officer Commanding-in-Chief, Fighter Command, was instructed to carry out furtber trials as rapidly as possible in order to decide[3] :—

(*a*) The extent to which the employment of strips by the enemy would interfere with the British A.I. night fighting technique using both 1½ metre and centimetre equipments.

(*b*) Any adjustments to existing technique which might be necessary in order to counter the use of strips by the enemy.

[1] A.M. File R.C.M. 120, Encl. 110A, 18 June 1942.
[2] A.M. File C.S. 14198, Encl. 23A, 20 June 1942.
[3] *Ibid*, Encl. 24A, 23 June 1942.

He was also requested that in the course of these trials G.C.I. control of the A.I. aircraft should be included as part of the test. Arrangements were thereupon made by Fighter Command for trials to be conducted with A.I. aircraft equipped with A.I., Marks IV, V and VII under both G.C.I. and C.H.L. control.[1] In addition to the normal strips used in previous trials, the Command was supplied with leaflets having the longest dimension, three times that of the former type, in order to determine whether they would have a greater effect on 1½ metre A.I.[2]

Cause of Damage to British Night Bombers

Early in July 1942 the Chief of the Air Staff enquired what proportion of disabled night bombers returning to this country were damaged by *flak*, by fighter aircraft, and by both *flak* and fighters, respectively.[3] For the period January to the end of April the figures were 83·28 per cent., 15·8 per cent. and 1 per cent. respectively. The percentage of aircraft damaged by both *flak* and fighter aircraft was very low, and for purposes of comparing the relative efficacy of the two enemy methods of defence, they could, in the opinion of the Operational Research Section (O.R.S.), Bomber Command, be ignored. The monthly percentage figures for aircraft damaged by *flak* or fighters from February to May showed a heavy preponderance by *flak* (85 per cent. approximately) against the 11 per cent. by fighters. The comparative figures for the large-scale raids on Cologne and Essen were :—

	Fighter Aircraft	*Flak*
Cologne—29/30 May ..	12·7 per cent.	87·3 per cent.
Essen—1/2 June	14·2 per cent.	85·8 per cent.

O.R.S., Bomber Command, suggested that on these large-scale raids there appeared to be a tendency for *flak* damage to be lower. A consideration of these figures resulted in the Chief of the Air Staff stating that they supplied a strong case for the use of Window.

Results of Trials of Window on British A.I. Night Fighting Technique

On 15 July the Air Officer Commanding-in-Chief, Fighter Command, reported on the latest trials with Window.[4] He confirmed that in this second series of tests the smaller strips caused serious interference to A.I. Mark VII making interception impossible in all but the simplest cases, and that A.I. Mark IV, G.C.I. and C.H.L. were still affected to a limited degree. With the larger strips which had been supplied for the tests, the effect was that A.I. Mark VII, A.I. Mark IV, G.C.I. and C.H.L. were all rendered unusable and that it was reasonable to assume that S.L.C. would be similarly affected. As regards evolving a technique to overcome the effect of the strips, the most experienced Observers (Radio) had been employed for the tests, and they had expressed the opinion that no amount of practice was likely to lead to any successful results in that direction, as the responses from the strips were far too strong and obliterated the responses from aircraft.

---

[1] Fighter Command letter F.C. S.28647/Sigs., 29 June 1942.
[2] Fighter Command letter F.C. S.28647/R.D.F.2, 1 July 1942 and A.M. File C.S. 14198, Encl. 33A, 8 July 1942.
[3] *Ibid.*, A.M. File C.S. 14198, Encl. 34B, 2 July 1942.
[4] Fighter Command letter F.C. S.28647, 15 July 1942.

The Air Officer Commanding-in-Chief, Fighter Command, considered that the results of these trials had proved that the possible use by the enemy of metallised strips was a most serious menace to our night defence system and that there were as yet no means of reducing or overcoming their effect. The corollary to this was that the vast amount of work which had been put into the production of the various scientific devices which had enabled night interception to be brought to a reasonable degree of efficiency during the past two or three years would be completely wasted ; and, as no alternative devices existed, the position would become extremely serious were the enemy to discover the effect of the strips. He therefore requested that any proposal to use metallised strips against the enemy R.D.F. system should be abandoned.

In a letter to the Air Officer Commanding-in-Chief, Fighter Command, the Chief of the Air Staff explained that the results of these trials created a very serious dilemma.[1] On the one hand, it might be assumed that the idea of Window had not occurred to the enemy. On the other hand it was possible that he had already the idea but was afraid to use it because at that time we had a stronger bomber force on the Western Front than he had. Under the first hypothesis we should be taking serious risks by attempting to train the Fighter Command in tactical methods designed to overcome Window because the news of this training might leak to Germany and give them the idea. Under the second hypothesis, training on the largest scale could do no harm and might lead to a way of at least partially defeating the use of Window by enemy bombers when the enemy's chosen moment to use it came.

The case for giving more weight to the second hypothesis was strengthened by the possibility that the enemy might suddenly get the idea without any help from us, and if he were to do so, we should have handicapped ourselves to no purpose and might be suddenly confronted with a form of defence, to defeat which we had made no preparations at all. The question was so difficult and the problem so serious that the Chief of the Air Staff suggested he would probably have to submit the case to the Chiefs of Staff and the Prime Minister. He assured the Air Officer Commanding-in-Chief that Window would not be used for the present, not only because of the views expressed so far, but also because it was thought that other methods were likely to give quite a lot of protection against the German defence, which as far as was known, did not include A.I.

Window Conference, July 1942

In view of the complexity of the Window problem and in order to determine what course of action should be followed, the Chief of the Air Staff called a meeting on the 21 July[2] at which were present the Chief of the Air Staff, Air Officer Commanding-in-Chief, Fighter Command, members of the Air Staff, the Director of R.D.F., Lord Cherwell and other scientific advisers. At this meeting the question was raised as to how far the enemy might or might not be familiar with this weapon. A.D.I. (Science) explained that the idea of Window was a simple one and that it was unlikely that German scientists were not well aware of it. It might however be that it had not yet been adopted by the German High Command and pushed forward to a stage of readiness for operational use. On the whole, on the scanty evidence available he was inclined to think that this was the most probable answer. It was, however, possible that the development

[1] A.M. File C.S. 14198, Encl. 38A, 16 July 1942. [2] *Ibid.*, Encl. 44A, 21 July 1942.

had been completed and that the device was being held back for operational reasons so long as the German Air Force were not engaged on large-scale night raiding operations against this country. The Scientific Adviser on Telecommunications (S.A.T.) was also inclined to the view that the device was known to the enemy and was being held back for these same reasons.

It was imperative that any knowledge of Window development should be prevented from reaching the enemy. Already throughout the many discussions and trials, emphasis had been laid on the need to preserve the greatest security and avoid any leakage of information. It was the opinion of A.D.I. (Science) that reports of the equipment were most likely to reach the enemy through prisoners of war and possibly through general Royal Air Force gossip. This was particularly likely in view of the fact that the equipment had been practically ready for use in Bomber Command. Lord Cherwell suggested it was not likely to be possible to suppress such rumours completely and that the most effective method might be to put it about, with some emphasis on secrecy, that equipment of this kind had been tried but had been found totally ineffective. This view was generally agreed and A.C.A.S.(I) was instructed to initiate the necessary action.

The effects of Window on air defence R.D.F. systems were discussed at this meeting. Its effect on S.L.C. was not yet known since trials which had been commenced early in 1942 to determine its effects against S.L.C., G.L. Marks II and III had not yet been completed. There was a possibility that the effect on S.L.C. might not be severe due to the different method of presentation and the fact that S.L.C. would be operating from the ground and not directly in the path of the enemy aircraft.

With regard to developing A.I. equipment to overcome the effects of Window it was explained by S.A.T. that he saw no means of bringing about any substantial improvement in Mark VIII or earlier marks of A.I. Mark IX, which was not likely to come into service before mid-1943, had possibilities, as the automatic following device would make it simpler to distinguish the objectives from the spurious echoes. This, however, would not be a complete answer and it was the view of the Air Officer Commanding-in-Chief, Fighter Command that at the worst this might force us to return to the use of sound locators. He had arranged that one sound locator should be retained at each gun site although he was not confident of the results which could be expected in view of past experience. Lord Cherwell, however, suggested that there was still considerable scope for scientific development of sound location apparatus which had been set aside when all the emphasis had been laid on the development of R.D.F. Since, however, there seemed to be some hope of a sulution which would allow the continued use of ground R.D.F., the Chief of the Air Staff instructed the Director of R.D.F. to assume general responsibility for following up and reporting on various technical possibilities which included the possible modification of A.I., G.C.I. and C.H.L. equipment. If necessary, he was to bring the matter before the R.D.F. Board, in order to enlist the co-operation of the other services in developing other types of equipment. Enquiries were also to be made whether the use of sound locators could not be exploited more than had been done in the past.

It was most desirable that further development of Window should not be neglected because of the decision that it should not be used for the present. Lord Cherwell pointed out that existing Window equipment was in a relatively primitive form. With further development it might be a weapon which could be used with great effect at a later stage. He added that there was a serious danger that new developments of this kind might be put into action by subordinate formations of one of the services without due regard to the possible resulting implications. The use of Window had for instance been prevented with difficulty in connection with a recent minor combined operation. The meeting agreed that the only remedy was a precise instruction to lower formations, to be issued widely throughout the services, requiring that no such action should be taken without specific authorisation from some definite body responsible to the Chiefs of Staff. This body must be the Radio Policy Committee who were to be sent a paper by the Director of R.D.F. for consideration and forwarding to the Chiefs of Staff.

Submission of Window Problem to the Chiefs of Staff

The results of this meeting were summarised in a paper submitted to the Chiefs of Staff.[1] This paper described the results of the trials which had proved conclusively that leaflets of the appropriate size ruined the effectiveness of the airborne R.D.F. used by Royal Air Force night fighter aircraft. They also had a considerable effect on the ground control apparatus employed in our night fighting technique. The Chiefs of Staff were informed that a comprehensive series of tests against all types of British R.D.F. equipment had not yet been completed, but sufficient evidence was available to show that it would be inadvisable to employ these strips until a means had been devised of countering them, or until the enemy employed them. The Chief of the Air Staff had therefore issued instructions that these strips were not to be dropped over Germany. There remained, however, the important matters of :—

(*a*) Completing experiments to determine the effect of strips on our own radio aids to air defence ;

(*b*) Devising technical counters to the strips.

Since the technical data was at that time incomplete regarding the effect of strips on G.L. Mark II, G.L. Mark III and S.L.C., the conduct of further experiments in this field was to be a matter for the War Office.

The paper then described the arrangements which had been made :—

(*a*) Instructions had been issued to the Air Officer Commanding-in-Chief, Fighter Command, to press on the development of tactics designed to overcome the effects of interference by these strips without radio aids to night interception.

(*b*) The possibility was being examined of modifying A.I., G.C.I. and C.H.L. equipment to counter the strips, and if necessary, this matter was to be brought before the R.D.F. Board in order to enlist the cooperation of the other services in developing further types of equipment.

(*c*) Instructions had been issued to the Director of R.D.F. at the Air Ministry to approach the appropriate authorities with a view to further development of the sound locator systems in order to provide a backing in the event of R.D.F. ground detection devices being defeated by the strips.

---

[1] A.M. File C.S. 14198, Encl. 47A, 30 July 1942

Finally, the Chief of the Air Staff invited his colleagues to note the action initiated, to develop counter-measures to strips in case the enemy should employ them, and to endorse the proposal that experiments with strips to develop counter-measures should continue on an Inter-Service basis, and that the highest degree of security should be observed in all such experiments and developments. The proposals were approved by the Chiefs of Staff on 31 July.[1] Action was thereupon initiated.

Further Trials of Window against British R.D.F.

Fighter Command, meanwhile, had prepared a programme for the trials they were to conduct.[2] This programme was accepted by Air Ministry who suggested that in order that the effects of Window should be fully determined, the actual number of aircraft engaged in the dropping of Window during an attack should be considered. The officer in charge of the trials had visualised that one aircraft (or perhaps more) would be detailed specifically for laying Window. It was expedient, however, to consider the possibility that all aircraft in a bombing raid might carry a given load of Window.[3] It had to be determined which of these two methods (or possibly a combination of both) would be the most difficult to overcome.

The enemy might attempt to cover both the target area and the approach with Window. If this were attempted there would very likely be a time when Window would be detected before developing to such an extent as to upset our interception technique. In such circumstances an obvious tactic would be to destroy the Window aircraft as quickly as possible thus preventing the development of a Window curtain. This postulated an ability to detect at once hat Window was being laid. Air Ministry therefore recommended that the experiments with ground equipments should include the problem of the early detection and reporting of the presence of Window.

Preparation of Plan for Tactical Use of Window by Bomber Command

While these trials were in progress Headquarters, Bomber Command suggested that the results so far obtained indicated that it should be possible to make use of Window as an aid to the bomber offensive, but until tactical trials against 53 cm. wavelength R.D.F. equipment had been made it was difficult to decide the most effective use of the device.[4] While permission had not yet been given for the use of Window in the offensive, it was considered most desirable to have complete plans ready for its use so that operations could be carried out effectively should the ban be lifted. Bomber Command therefore requested that a 53 cm. R.D.F equipment with the German presentation so far as it was known in this country, together with suitable operating personnel, should be made available for the further tactical trials. In their reply Air Ministry advised Bomber Command that they should be represented at the trials and to include such experiments as would enable the Command to arrive at the best method for the tactical use of Window.[5] Bomber Command was also informed that arrangements were being made for the supply by the Ministry of Aircraft Production of a suitable 53 cm. equipment.[6] In this connection it had

---

[1] A.M. File C.S. 14198, Minute 50, 3 August 1942.
[2] *Ibid.*, Encl. 48B, 26 July 1942.
[3] *Ibid.*, Encl. 49A, 1 August 1942.
[4] Bomber Command File B.C. S.26861/Air, 7 August 1942.
[5] A.M. File C.S. 14198, Encl. 53A, 8 August 1942.
[6] *Ibid.*, Encl. 57A, 12 August 1942.

been hoped to provide the actual German equipment captured in the Bruneval raid, but unfortunately it was incomplete and it would take several months to produce the necessary display attachments. In its place a Type II set was being suitably modified to operate on the required frequency and would be shortly available for the trials.

At his conference on 21 July 1942 the Chief of Air Staff had directed that a progress meeting on the trials should be called on 20 August, but although a considerable drive had been in train the trials were insufficiently advanced to justify such a meeting.[1] This meeting was not to take place until 4 November 1942, when the results of the trials would be discussed.

Results of Trials

Regarding the tactical trials, the Air Officer Commanding-in-Chief, Fighter Command, considered that should the enemy use Window intelligently, no tactical methods of using our present air and ground R.D.F. equipments could be devised to do more than slightly offset the interference caused.[2] If the enemy aircraft crossed its own or another trail of Window, the G.C.I. stations could not direct the fighter to an interception. If, however, the enemy aircraft did not cross a trail, a G.C.I. or C.H.L. station could successfully direct the fighter in the early stages of Window dropping, but after Window had been laid for a comparatively short period, interception became impossible. It was reasonable to assume that S.L.C. would be affected in a similar manner if the correct size of Window was used.

With regard to Window used against A.I., an interception with Marks IV, V, or VII would be possible provided the enemy tactics did not involve crossing its own or another trail of Window, though a higher degree of training would be necessary. If a trail were crossed, interception with A.I. Marks IV and VII would be rendered extremely difficult, and with Mark V impossible.

At an Air Ministry meeting held on 4 November 1942, when these results were discussed it was apparent there was little hope of modifying existing type of A.I., G.C.I., C.H.L., G.L. or S.L.C. equipments to render them less susceptible to Window interference. The vulnerability of R.D.F. equipment to Window depended to a great extent upon the resolving power or discrimination of the apparatus, and as there was reason to suppose that the form of presentation used in the latest type of A.I. equipment being developed in the United States might effect a slight decrease in this vulnerability, action had been taken to obtain one of these sets from America for examination.[3] Apart from this, the tactical trials and technical examination of the problem had not produced any promising suggestions as to possible modifications whereby Window interference could be avoided. There was some hope that ground equipment could be designed to offer a better compromise between high discrimination on the one hand and rapidity of plotting and continuity of tracking on the other. The Type 11 equipment might offer some solution and fifty of these sets to embody height-finding facilities had been asked for on high priority.

Regarding the possible greater exploitation of Sound Locators, it was apparent that the handling of the latest type of equipment required such a high

[1] A.M. File C.S. 14198, Minute 58, 20 August 1942.
[2] Fighter Command File, Fighter Command letter F.C. S.28647, 5 September 1942.
[3] A.M. File C.S. 14198, Encl. 80A, 4 November 1942.

degree of skill that the provision of crews was impracticable. Even if such crews could be provided its utility for interception purposes would be small. Sound Locators therefore did not offer a solution to the problem.

The result of this meeting was yet another decision to withhold the operational use of Window, but it was agreed that all preparations for its employment at short notice should be made.[1] Apart from the tactical plans being prepared by Headquarters, Bomber Command, this entailed the manufacture of an adequate supply of material for the initial operations, and the design of a suitable launching device. Bomber Command was therefore informed that a decision had been taken to manufacture a sufficient quantity of the material for one month's intensive operations.[2] Since this quantity was estimated to weigh some 450 tons, and in order that it should be available for operations at short notice, Bomber Command was instructed to make the necessary arrangements for its storage. This was provided amongst airfields of various Bomber Groups, the distribution being accompanied by most comprehensive precautionary measures designed to preserve secrecy and security.

Window Launcher

The need for a suitable method of launching Window from the operational aircraft of Bomber Command was now urgent.[3] It had been intended to use the flare chute but it was the Command's view that this could no longer be depended upon. At an early date consideration had been given to the question of designing and installing a special launching device, but in view of the modification difficulties and the fact that the Small Bomb Container (S.B.C.) could be adapted for this purpose the requirement was dropped. But now that Window would have to be dropped almost continuously, the bomb doors would have to be open for longer periods, which operationally was unacceptable. Thus an alternative to the S.B.C. became necessary, and as Window might be implemented at short notice, the design and production of a suitable launching device for fitting in all bomber aircraft became an urgent operational requirement.

The design of the launching device was governed by several factors, among which were the size of the bundles of Window, the weight of Window to be carried in each aircraft, and the types of aircraft.[4] For technical reasons it was considered preferable that the material should be dropped in smaller bundles than those originally proposed. Instead of a 9-lb. bundle a smaller one of 2 lb. was decided upon as the most suitable. The specifications for the launching apparatus were prepared by Bomber Command and by January 1943 the possibilities of meeting this requirement were being considered by an installations section of the Ministry of Aircraft Production (R.D.Q.).[5] It soon transpired, however, that no automatic device was likely to be available in under eighteen months and that reliance must be placed on hand launching methods. It was found that standard chutes could be used for all the heavy bomber aircraft, and a special chute had been made and found satisfactory for the Wellington aircraft.[6] Thus the heavy and medium

[1] A.M. File C.S. 14198, Minute 87, 4 November 1942.
[2] A.M. File C.S. 14198/DB. (Ops.), Encl. 86A, 4 November 1942.
[3] A.M. File C.S. 14198, Minute 87, 4 November 1942.
[4] *Ibid.*, Minute 88, November 1942.
[5] Bomber Command File B.C. S.26861/Air, 20 December 1942, A.M. File C.S. 17864.
[6] A.M. File C.S. 14198, Minute 116, 7 March 1943.

bombers in Bomber Command could be rendered operationally suitable for dropping Window at short notice.

Possible Effect of Window on H.2.S.

While these preparations were in train, Air Officer Commanding-in-Chief, Bomber Command raised the question of the possible effects on the performance of H.2.S. which might result from the use of Window and requested that action should be taken to determine the nature and extent of such effects.[1] Preliminary enquiries had led to the belief that the effect might be serious, not only while the strips were in the air but even after they had reached the ground, where it might possibly continue to give misleading echoes. Obviously if this proved correct, the successful use of H.2.S. would be seriously prejudiced. This prediction was supported by Air Ministry who authorised the early conduct of trials to determine the effects of Window on H.2.S.[2] The result of these trials conducted by Headquarters Fighter Command was that there was no danger that Window used in the quantities required would interfere with the operation of H.2.S.[3]

Bomber Command Plan for the Operation of Window

By 18 February 1943, Headquarters Bomber Command had worked out a plan for a specific operation in order to appreciate what the use of Window involved.[4] After a prolonged series of discussions with Headquarters Fighter Command, who had carried out trials with Window, and with A.D.I. (Science), the Operational Research Section of Bomber Command had prepared a paper giving the quantities of strips which would be required for an operation involving the use of 300 bomber aircraft against a target such as Cologne.[5] The quantities needed for operations against other targets with different numbers of aircraft and concentration could, by using the same data, be calculated without difficulty. Apart from the uncertainty about the enemy equipment, upon which the actual quantity of material must depend, the Command suggested it was desirable to determine the effect of Window on Monica and whether the 2-lb. Window bundles were representative of a heavy aircraft, or if the size of the bundles could be reduced. The Command recommended that trials be undertaken to ascertain these facts.

The trials suggested by Bomber Command were at once ordered by Air Ministry, and Fighter Command, who had conducted all the previous trials associated with the effects of Window on our R.D.F. devices, was made responsible.[6] These trials were also to determine the effectiveness of the present size of material (25 by 2 cm.) against enemy A.I. on 62 cm.,[7] and to test the performance of strips of lengths 21 and 25 cm. with varying widths of 1, 1½ and 2 cm. These trials were completed and a report rendered by 15 March 1943, indicating that Monica at close ranges gave a strong response to Window, but providing the density of Window was not too high and range was restricted to 3,000 feet, Monica could be used satisfactorily in Window-infected areas.

[1] Bomber Command letter B.C. S.26861/Air, 31 December 1942.
[2] A.M. File C.S. 14198, Encl. 98A, 6 January 1943.
[3] Fighter Command letter F.C. S.31389/Sigs. I, 20 January 1943.
[4] Bomber Command letter B.C. S.26861/O.R.S., 18 February 1943.
[5] A.M. File C.S. 14198, Encl. 103A–B.
[6] *Ibid.*, Encl. 112A, 26 February 1943.
[7] *Ibid.*, Encl. 113A, 27 February 1943.

On seeing the plan submitted by Bomber Command for the tactical operation of Window, the Chief of the Air Staff ruled that as soon as the Command approached readiness to use Window, another conference should be called in order to decide whether its use should be recommended to the Chiefs of Staff.[1] As a result a comprehensive memorandum on the use of Window for bombing operations was produced by the Air Ministry Air and Technical Signals Staffs for consideration at a conference held by the Chief of the Air Staff on 2 April 1943.[2] This paper was to form the basis of a note by the Chief of the Air Staff to the Chiefs of Staff on which the decision to use Window was taken by the Cabinet. It is also of great interest because it summarises the operational considerations both tactical and technical, which were the outcome of the many discussions between the Air Staff and the scientists which had taken place since the use of metallised leaflets had been first proposed in 1941.

Final Case for Window Submitted to the Chiefs of Staff

It will be recalled that on 27 April 1942, the Chiefs of Staff Committee had approved the proposal to employ Window as a counter-measure against enemy R.D.F.[3] but since subsequent experiments showed that the effect of Window on our own A.I. was likely to prove serious the Chief of the Air Staff had decided that the use of Window should be withheld until—

(*a*) British R.D.F. air defence equipment could defeat it ; or

(*b*) There was confidence that a large-scale bombing offensive against this country would no longer be practicable for the Germans in the light of their commitments with Russia.

In the meantime all preparations had been made for the employment of Window at short notice and appropriate plans made by the Air Officer Commanding-in-Chief, Bomber Command.

After a detailed review of all the factors involved, the Air Staff had concluded that it would be advantageous to introduce this counter-measure to operations at an early date. In view of the far-reaching implications of such a step the Chief of the Air Staff asked the Chiefs of Staff to confirm the decision which they gave in April 1942 and to approve the use of Window on operations as from 15 May 1943.[4] In view of the Chief of the Air Staff's representations, the Chiefs of Staff agreed[5] that there were very strong arguments for introducing Window in the near future. The difficulty in doing so immediately was that it might adversely affect operation " Husky " (the invasion of Sicily from North Africa). If the enemy were to use Window there would be a considerable reduction in the effectiveness of the night defence of Allied ports and bases and also of the shipping and beach organisation during the operation itself. The Chiefs of Staff view therefore was that nothing should be allowed to prejudice the success of Operation Husky, but that as soon as this objection was removed Window should be used. They accordingly decided that all preparations should be made for it to be introduced on 1 July.

Meanwhile, the Chief of the Air Staff had asked the Joint Intelligence Sub-Committee to provide an estimate of the time that would be likely to elapse between the introduction of Window by the Royal Air Force and its use by the

[1] A.M. File C.S. 14198, Encl. 105A, Minute by C.A.S., 26 February 1943.
[2] *Ibid.*, Encl. 128A, 27 March 1943.
[3] C.O.S. (43), 132nd Meeting, Minute 6.
[4] The appreciation on which this request was based is at Appendix No. 15.
[5] A.M. File C.S. 14198, Encl. 151A, 9 June 1943.

Germans in the Mediterranean.[1] Such an estimate would help to determine the actual date on which we should introduce Window. The Joint Intelligence Sub-Committee found it extremely difficult to give any accurate forecast of the time it would take the enemy to copy our methods, but estimated that it would take eight weeks at the very least for him to be in a position to use Window on a sufficiently wide scale for it to be effective.[2]

Use of Window Authorised

A provisional date for the introduction of Window was given to Bomber Command in Air Ministry signal AX 874 dated 22 June 1943, but confirmatory orders were withheld until instructions from the Prime Minister had been obtained nearer the date.[3] This matter was eventually to be raised with the Prime Minister on 1 July, but it was not until 15 July that the Chief of the Air Staff, in a pencilled note from No. 10 Downing Street was able to indicate that authority had been given for the use of Window with effect from 23 July 1943.[4] Headquarters, Bomber Command, was informed accordingly on 16 July, and Window was used for the first time on the night of 24/25 July in an attack on Hamburg.[5]

Window in the Attack on Hamburg, 24/25 July 1943

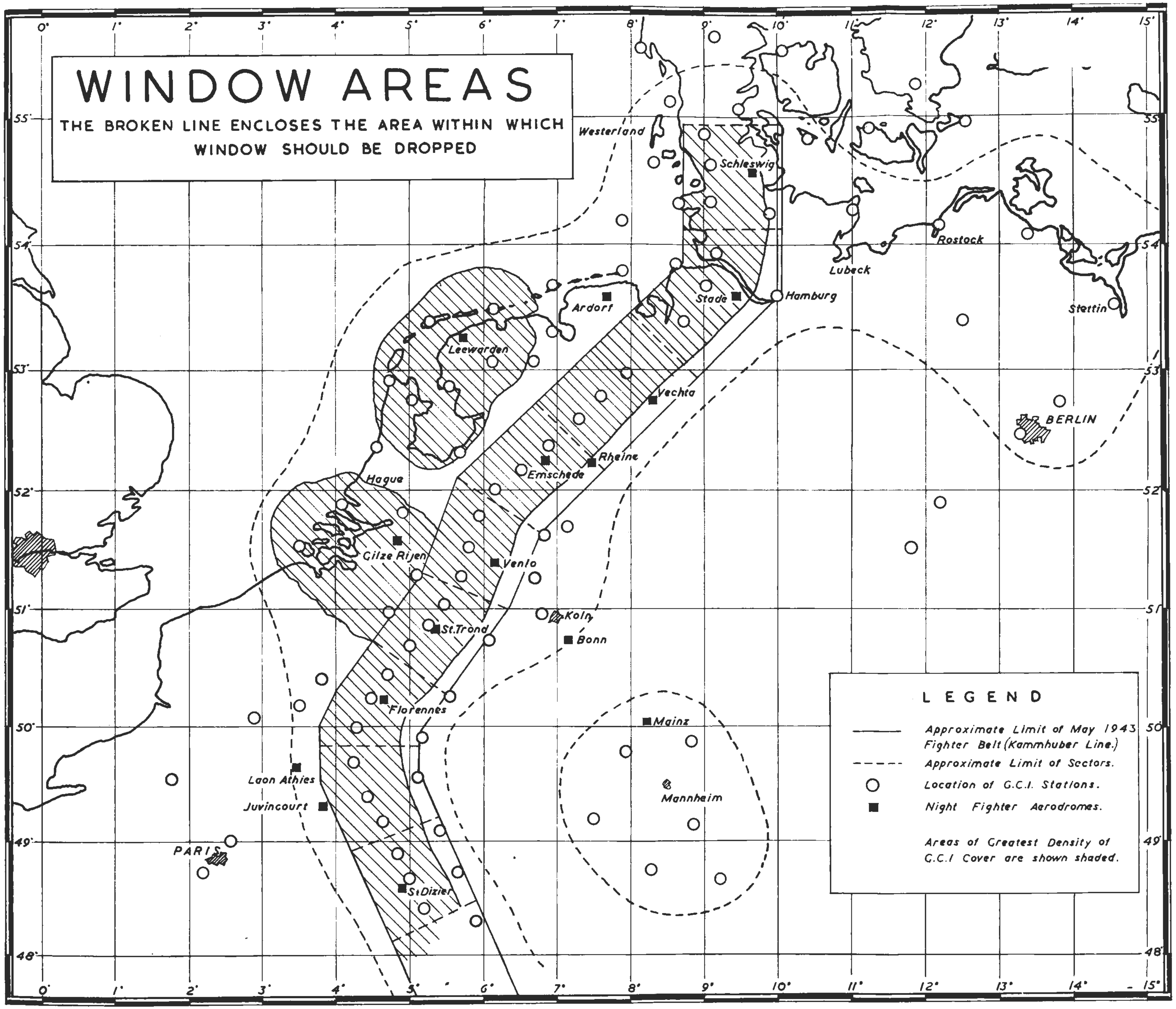
The first operational use[6] of Window was attended with marked success. A report by the Air Operational Research Section of Bomber Command was prepared by 30 July 1943, based on information which had by then become available ; and although there was much analysis still to be done before definite information could be gained regarding the effect of Window on enemy defences and before any improvements in the tactical use of Window could be confidently formulated, there was certainly evidence from the intercepted enemy R/T traffic on the night of 24/25 July that the effect of Window on the ground control of fighters was most serious. There were strong indications that free-lancing and co-operation with searchlights had to be resorted to because of the confusion caused. Among the many examples of intercepted R/T traffic indicating enemy reaction to Window during the first Hamburg raid were the following :—

> " The enemy are reproducing themselves."
> " It is impossible, too many hostiles."
> " Wait awhile ; there are many more hostiles."
> " I cannot control you."
> " Try without your ground control."
> " I am searching without your control."

The losses on this night were very much less than would have been expected for a raid on this target. Not only was the enemy night-fighter efficiency impaired, as indicated by intercepted R/T traffic and percentage of bombers attacked, and also by the low attack/interception ratio, but from *flak* damage sustained it was clear that the guns, too, were not very effective. Searchlights were also hampered in operation.

---

[1] A.M. File C.S. 14198, Minute 151, 9 June 1943.
[2] *Ibid.*, Encl. 153A, 11 September 1943.
[3] *Ibid.*, Minutes 161, 162, 24 June 1943.
[4] *Ibid.*, Minute 165, 15 July 1943.
[5] *Ibid.*, Encl. 167A, A.M. Signal AX 829, 16 July 1943.
A map showing the general plan for dropping Window is given at Diagram 7.
[6] Bomber Command O.R.S. Report S.95, 30 July 1943.


WINDOW AREAS
THE BROKEN LINE ENCLOSES THE AREA WITHIN WHICH WINDOW SHOULD BE DROPPED
LEGEND
Approximate Limit of May 1943 Fighter Belt (Kammhuber Line.)
Approximate Limit of Sectors.
Location of G.C.I. Stations.
Night Fighter Aerodromes.
Areas of Greatest Density of G.C.I Cover are shown shaded.
Westerland
Schleswig
Stade
Hamburg
Lubeck
Rostock
Stettin
Ardorf
Leewarden
Vechta
BERLIN
Rheine
Emschede
Hague
Gilze Rijen
Venlo
Koln
St.Trond
Bonn
Florennes
Mainz
Mannheim
Laon Athies
Juvincourt
PARIS
St Dizier

No serious difficulties were experienced in the actual throwing-out of the Window. In the majority of cases the physical effort involved was not found to be excessive. One of the main troubles was the discomfort caused to the man at the chute when the aircraft was taking evasion action. There were reports of some Window packets not opening properly, but to what extent it was not possible to determine. Methods for improving the opening of the packets were immediately considered. As had been expected, Window apparently had not caused any difference to the operation of H.2.S or Gee. There were a few reports of indications on Monica caused by Window, but these were easily distinguishable from echoes due to other aircraft.

Window in Bomber Command Attacks, 24 July-11 August 1943

A further report was prepared by the Operational Research Section of Headquarters, Bomber Command, on 19 August 1943, when they were able to cover the period 24/25 July to 10/11 August after Window had been in use for a sufficient length of time to enable some preliminary assessment of its value to be made and to submit some suggestions which might improve the efficiency of the operation.[1] It was seen that a marked reduction in the effectiveness of the enemy defences had been achieved by the use of Window. The recent Hamburg raids showed reductions compared with the non-Window Hamburg raids in respect of missing (2·8 per cent. from 6·1 per cent.), fighter attacks (1·3 per cent. from 2·6 per cent) and *flak* and fighter damage (3·9 per cent. from 8·4 per cent. and 0·5 per cent. from 1·3 per cent.). In general, these improvements were also apparent for each separate raid carried out during the period reviewed. The casualties on Essen were considerably lower than the average of those sustained on raids on all German targets, and also on Ruhr raids of over 600 sorties. The extent of the reduction in relation to raids on all German targets during the period May/June 1943 was about 40 per cent., and this had occurred at the time of year when bomber losses normally rose.

More evidence of the trouble caused to the German fighter control system during the first Essen raid on the night of 25/26 July is shown by the following R/T intercepts :—[2]

> " Break off contact, hostiles are multiplying."
> " Search well in your area—there must be many hostiles near you."
> " On higher authority, break off."
> " Everything has gone wrong."
> " Are hostiles coming from the north or south ? "
> " It is a sorry mess . . . I will explain everything when you come down."
> " I cannot follow any of the hostiles, for they are very cunning."

In the raids which followed, less information was given on R/T, but intercepts[3] of interest were as follows :—

> " We cannot work without searchlights."
> " There are too many hostiles—wait until there are single ones."
> " I cannot see hostiles."
> " My *Emil* is being interfered with."

[1] Bomber Command O.R.S. Report S.98, 19 August 1943.
[2] A.M. File R.C.M. 120/III, Encl. 146A and 452/N/A.1.4, 26 July 1943.
[3] A.M. File R.C.M. 120/IV, Encl. 52B, 15 August 1943.

In addition to the indications obtained from these R/T intercepts further effects of Window noted since its introduction were summarised[1] as follows :—

(*a*) The missing rate on German targets had been reduced by more than one-third.

(*b*) The proportion of sorties returning to this country and reporting attacks by enemy aircraft had been reduced to about one-half.

(*c*) Both of these effects had occurred at a time when past experience indicated that the rates would rise.

(*d*) The number of sorties damaged by *flak* had been reduced to about one-half of its previous value, and the extent of the *flak* damage received by those aircraft which were hit had also been reduced.

(*e*) There was evidence of considerable disorganisation in the enemy night-fighter defence, and that the enemy had been using to a large extent a much looser control of his fighters.

German Reaction to Window

The first effect of Window on the German night-fighter system was obtained from the interception of R/T between enemy ground stations and aircraft, and has already been described. Meanwhile, less obvious reactions of the German defensive system had been made available from other sources. An interference report for the first Hamburg raid had come to hand from the R.D.F. station on Heligoland, which complained that it was disturbed by many apparent point targets looking like aircraft but either stationary or slow moving[2]. The picking up of genuine aircraft was made extremely difficult , once they had been picked up, it was possible but not easy to follow them. While this applied definitely to the Giant *Wurzburgs*, it was possible that the *Freya* was also affected. The station on the southern tip of Sylt, and others unspecified, had similar trouble except that no *Freya* reaction was reported.

After the Essen raid, the German Air Staff Operational Summary, compiled early the same morning, claimed 21 aircraft shot down and remarked specially that Giant *Wurzburgs* and *Lichtenstein* A.I. (*Freyas* not mentioned) were upset by the dropping of metal leaves. On 29 July, the German Staff sent a general warning to *Flak* Brigades telling them of the first two Window raids and stating that the entire radiolocation system became impossible. Visual and sound location therefore would again become of decisive significance and barrage fire was to be adopted as soon as Window was detected. A new barrage fire technique was being worked out, and in the meantime the old sound-controlled barrage technique was to be practised exhaustively. It is apparent therefore that Window had achieved its purpose. The *Himmelbett* control and *Flak* control, both dependent on the *Wurzburg*, had been completely disrupted.

German Anticipation of Window

Even before Window was used for the first time there were grounds for suspicion that the Germans were aware of its potentialities, but it was not until evidence had been obtained from a post-war interrogation of General Martini, the German Director General of Signals, that the position was made clear[3]. The Germans were not unaware of the possibilities of Window as a

[1] Bomber Command O.R.S. Report S.98, 19 August 1943.
[2] A.S.I. Report No. IV, 3 August 1943.
[3] A.D.I. (K) Report 334/1945.

weapon. For a year prior to its use by the British the question had been studied by engineers at the *Technischig Amt*, and six months before the Hamburg raid their experiments had proved conclusively what a menace the metal strips represented. When the results of *Duppel* (the German equivalent of Window) research were placed before Goering, he had been so impressed by its potential effect as a jamming measure that he had ordered the immediate suppression of further research. This course was dictated by the fear that only the most stringent measures of secrecy could prevent a leakage to the Allies, who could employ it to far greater advantage than the Germans themselves. "It was thus extremely difficult," said General Martini, "to work out counter-measures because we dared not experiment with the little beasts for fear of their being discovered. Had the wind blown where we dropped the metal strips, people would have picked them up, talked about them, and our secret would have been betrayed." It was not until Bomber Command had actually used Window that the German research workers were allowed to tackle the problem of how to counter the effects.

British Delay in the Use of Window

Some eighteen months had passed from the time when Window was first proposed in 1941 until its first use in July 1943. So long a delay was disappointing to some, particularly in view of its eventual successful operation. Nevertheless, the period of deliberation and experiment enabled the Air Staff to determine the probable effects of German Window against the many British R.D.F. equipments and to make plans for minimising its danger. Had it been employed earlier, German retaliation might well have caught us unprepared.

The postponed use of Window undoubtedly facilitated the production of the large stocks of strips needed to meet Bomber Command's requirements. It was evident at a very early date that the quantities that would be required were large, although it was not until much later when it was realised that complete infection of an area should be aimed at, that the full size of the production undertaking was apparent. When finally the decision to use Window was taken, the building up of adequate stocks of material proved more difficult than had been anticipated. The accumulation of the initial stock of 850 tons had not been easy, but this was mainly due to the strict security regulations which permitted only one or two approved manufacturers to produce Window. It was held that once the counter-measures had been used over enemy territory, the need for such strict secrecy would no longer apply and that it would then be possible to go into the open for supplies. But the anticipated consumption of Window was at least 450 tons per month, which was sufficient for less than ten major raids, and this weight then represented nearly 150 tons of aluminium. Furthermore, consumptions of as much as 1,000 tons a month by the end of 1943 were being discussed.

Only in April 1943 was attention drawn to the fact that aluminium and not factory space was the limitation. It was estimated that the quantity of aluminium involved would reduce the output of heavy bombers such as Lancaster aircraft by 250 a year or Spitfire aircraft by as many as 1,800. The effect on production was tersely summed up by Air Chief Marshal Sir Wilfred Freeman, the Chief Executive of the Ministry of Aircraft Production, in a letter dated 11 April 1943: "By using the foil you save aircraft and crews—

you lose more aircraft off production than you save." The Air Staff decision, however, was to proceed with Window and to forgo its equivalent in Lancaster bombers in view of their estimate that this would be more than compensated by the economy of aircraft.

Having regard to the magnitude of the task of producing the amount of Window required, complicated as it was by the need for security and other factors, the delay in the decision to use it carried certain advantages. Ample time was gained in which to build up the required stocks, and even then it was often "touch and go" whether the requirements would be met punctually. On the other hand, of course, earlier approval for the use of Window would have caused an earlier acceleration of the production programme.

The decision that we should "now open the Window," as the Prime Minister expressed it in his executive minute, was evidently a very difficult one. In the light of subsequent events and from the purely military point of view, it seems that Window might have been introduced some short time, say six months, before it actually was, with benefit to Bomber Command and without detriment to defence. Judged from the wider angle of national defence, however, it is probable that it was brought into use at just about the right time.

New and improved types of Window were to be produced and used throughout the War as and when new enemy R.D.F. devices became known. Help was also forthcoming from America in Window production in the shape of supplies of material, thinner and lighter strips, alternative conducting coatings for the papers, together with suitable cutting machines which were to prove invaluable in augmenting the British effort to produce the stocks required.

CHAPTER 10

RADIO COUNTER-MEASURES AGAINST THE GERMAN NIGHT-FIGHTER CONTROL, AUGUST 1943 TO MAY 1945

In the German air defence system, there were two stages in the process of directing a German night fighter from his waiting position in the *Himmelbett* (sky-box) to within visual range of a bomber. In the first stage, the ground controller, on the basis of *Wurzburg* information, picked out a single bomber and directed his fighter aircraft towards it by radio telephone, keeping a check on the fighter's progress by means of a second *Wurzburg*. In the second stage, when the fighter aircraft was judged to be near enough to the bomber, the navigator was instructed to use his A.I., and by that means he directed his pilot until the target bomber was within night-vision range.

The progressive introduction of R.C.M. had made the task of both the German ground controller and the night fighter pilot increasingly more difficult. By the beginning of August 1943, the British bombers were being supported by Window which was rendering the G.C.I. *Wurzburgs* ineffective, while Mandrel jammers were dealing with the early-warning *Freya* stations. Tinsel and Ground Cigar were jamming the German R/T night fighter control in the 3 to 6 and 38 to 42 megacycles per second bands[1] respectively, and Ground Grocer was spoiling his A.I.—a formidable marshalling of R.C.M. against the enemy's night fighter defence system. A change in his plans was consequently expected.

Wilde Sau

It has already been mentioned that shortly before Window was introduced, the Germans had been considering the employment of single-engined fighter aircraft at night against the bomber stream.[2] It was learnt later through Intelligence sources[3] that the success of Window accelerated the introduction of the new technique, called *Wilde Sau* (Wild Boar). *Wilde Sau* and daylight defensive fighting were basically similar, the main difference being that each *Wilde Sau* aircraft operated alone, freelance, and was more dependent upon special aids to navigation.

The problem of navigation at night had been satisfactorily solved by an elaborate system of ground W/T and visual aids,[4] together with control from the ground whereby the fighter aircraft were directed to the scene of operations, information being given by a radio running commentary from the Central Operational Headquarters. During operations the aircraft relied entirely upon this form of control. *Wilde Sau* enjoyed a high measure of success while the fine summer weather of 1943 lasted, but when bad weather conditions came in the autumn it was less effective.

[1] Part 2, Chapter 8, of this volume. [2] Part 2, Chapter 9, of this volume.
[3] Air Ministry A.D.I. (K) Report No. 283/44. [4] W.I.S. Paper, 9 August 1943.

Zahme Sau (Tame Boar)

Meanwhile the Germans had been considering the more advantageous employment of the twin-engined night-fighter aircraft normally employed with *Himmelbett* by using it for the purpose of long-range night pursuit. It was some time before the new method, known as *Zahme Sau*, was operated with any degree of success, due mainly to the fact that the crews of these aircraft had been employed on short-range work within the close confines of the *Himmelbett* box and were used to landing on the same airfield after each operation. *Zahme Sau* entailed long-range flying and landings on unfamiliar airfields, necessitating additional training and a period for assimilation of the new technique. *Wilde Sau* and *Zahme Sau* used similar ground/air controls and it was against their communication channels, interception and navigational aids, and the early warning system, that radio counter-measures were subsequently directed.

Special Tinsel against the Radio Running Commentary

It was important to jam the broadcast running commentary which the Germans were using for the loose control of their fighter aircraft and which gave information as to the position, height, course, and speed of the leading bomber formation and also general directions to feed the fighter aircraft into the British bomber stream.[1] It was therefore hoped that a development of Tinsel which had been used since 2/3 December 1942, for jamming R/T in the 3 to 6 megacycles per second frequency band, would be effective. The jamming of the German R/T commentary called for a revision of the Tinsel operation since the enemy was no longer using a number of independent transmissions for the control of individual aircraft but now employed one or two high-powered stations for the mass control of all his fighter aircraft. The frequency chosen was as hitherto unpredictable, but could be measured by the " Y " Service very quickly. Consequently if aircraft W/T operators could be warned while airborne of the frequency being used, it would be possible to concentrate on the broadcast frequency a large number of jamming transmitters. Thus arose a variant of Tinsel known as Special Tinsel.

During the operation the required enemy frequency was found by the " Y " Service, who informed the Duty Signals Officer at Bomber Command: he in turn instructed the Bomber Groups whose aircraft were operating to pass the frequency to be jammed to the aircraft W/T operators who would then apply the jamming.[2] Since it was known that the enemy had not altogether abandoned his G.C.I. system it was thought advisable to detail only two-thirds of the available jamming for Special Tinsel, and each Group, while briefing all Tinsel operators in the ordinary way, directed two-thirds of these operators to act on the Special Tinsel instructions from the ground, the remainder observing the normal Tinsel practice of continued searching for transmissions from G.C.I. stations.[3]

The results obtained with Special Tinsel were well up to expectations, judging by the enemy's reaction reported by the " Y " Service.[4] On the night 30/31 August 1943 (target Munchen-Gladbach), the German control was fully and effectively jammed within thirteen minutes of the frequency having been found by the " Y " Service. After seven minutes jamming the enemy controller

[1] Bomber Command File B.C. S.30525, Encl. 2A, 24 August 1943.
[2] Bomber Command File B.C. S.30525/Sigs., Encl. 6A, 25 August 1943.
[3] *Ibid.*, Encl. 12A, 29 August 1943.
[4] *Ibid.*, Encl. 16A, 1 September 1943.

ordered a change of frequency and all transmissions ceased for about fifteen minutes, recommencing on a new frequency which was similarly jammed. Again on the night 31 August/1 September 1943 (target Berlin), the enemy attempted to evade the jamming by transmitting his running commentary on three frequencies simultaneously. This move, an obvious one, had been anticipated and it was only a matter of splitting the Command effort by Groups over the three channels. The jamming effect was correspondingly reduced, but it was still enough to prevent control of the enemy aircraft operating in the vicinity of the bomber stream.

It was realised that the enemy could reduce the jamming potential still further by increasing the number of frequencies for control purposes.[1] By this means, combined with the use of high power, the enemy could in some degree overcome the effect of the jamming. Nevertheless it would complicate his own problem in that his aircrews would either have to be prepared to use any of the frequencies intended for use during a particular operation, or to remain on one channel in the hope that it would not be jammed. It was to be expected that the use of multiple simultaneous transmissions would be considerably extended, and this did happen, although later developments on high-frequency were largely dictated by changes in the German night fighting technique. In any event, Tinsel and Special Tinsel remained a necessary counter-measure until the end of the war.

Jostle IV. Projected Airborne Jammer against High Power H.F. Transmitters

Now that the enemy had been forced by Tinsel and Special Tinsel to employ higher power H.F. ground transmitters for raid reporting or running commentary which was transmitted simultaneously on several channels, thereby dissipating the Special Tinsel effort, discussions followed between Bomber Command, T.R.E. and Air Ministry how best the problem could be solved.[2] The use of higher power airborne jammers seemed to be the solution, but unfortunately it appeared impossible to produce anything of sufficient power within three or four months.[3] However, steps were at once taken to put in hand the necessary development of a suitable transmitter. There was already in existence the Jostle II V.H.F. transmitter, which had been provided as an airborne barrage jammer against enemy tank communications, and which was to meet the airborne Cigar requirements.[4] The low power of this equipment involved flying the aircraft very close to the battle area when jamming tank communications, while the introduction of high power night fighter control stations was expected to reduce its effectiveness in airborne Cigar operations. To meet these difficulties Jostle IV was developed to provide an output power of two kilowatts, this being a satisfactory advance on Jostle II and being obtainable with equipment within the limits of size and weight imposed by aircraft fitting. At the same time it was decided to extend the frequency coverage of the new equipment to include the H.F. band in order to deal with the high power H.F. broadcasting stations.

Corona

Meanwhile, in order to apply an immediate counter-measure while the necessary development proceeded, and to counteract the dissipation of the

[1] Bomber Command File B.C. S.30525/Sigs., Encl. 19A, 3 October 1943.
[2] Bomber Command File B.C. S.30525, Encl. 23A, 6 December 1943.
[3] Bomber Command File B.C. S.30726, Minute 3, 1 November 1943.
[4] T.R.E. Report No. T.1919.

Special Tinsel effort, the Air Ministry (D. of Tels.) decided to employ high power transmitters in the United Kingdom, to be steered by the " Y " Service on to the frequency to be jammed, a counter-measure which became known as Corona. Some objections had been raised to the use of ground jamming installations on the score of range and jamming area limitations, inevitable when the source of the jamming was far removed from the theatre of operations. But in the case of Corona the high frequency band was used. Propagation conditions in the H.F. band (3–6 megacycles per second) enable the sky or reflected wave to be made use of to give communication by night over distances between 300 and 600 miles approximately. Consequently, if sufficient power were available and the Corona transmitters were suitably modulated, a jamming signal could be imposed on the receivers of the German fighter aircraft and ground control sets which would be at least as strong, if not more powerful than that which they received from their own ground transmitters.[1]

There were no spare Royal Air Force radio telephony transmitters of sufficient power and covering the required frequency range, so negotiations were conducted with the B.B.C., the G.P.O., and Messrs. Cable & Wireless.[2] These resulted in the unrestricted use by Bomber Command at night of three transmitters at the G.P.O. main station at Rugby, and of one at Leafield. The provision of these equipments by the G.P.O. involved the complete reorganisation of some of their most important overseas radio telephony services, as well as modifications to the sets themselves, and the building of special wide-band aerial systems, directional on the line-of-shoot of 100° to give maximum power over Germany. The transmitters were linked with the main G.P.O. Control Board (Radio Telephone Terminal) and from there a line was taken to the " Y " Control Station at West Kingsdown.[3] The method of application of the counter-measure was as follows—the " Y " Service found the frequency and informed the R.T.T. Board who selected the transmitter to be used, and tuned it to the frequency to be jammed. With the " Y " Control Station monitoring the frequency for accuracy, the whole process could usually be completed in less than two minutes, the engineers at the transmitters having devoted much attention to the detail of quick frequency changing.

While this preparatory work was going forward a suggestion was made which was to have far-reaching consequences.[4] Corona was originally conceived purely for noise jamming purposes. It became clear, however, that combined with the knowledge possessed by the " Y " Service, it could be used as a means of confusing the enemy to the extent of giving the German fighters instructions contrary to those which they received from their own ground controllers. In other words, instead of modulating the transmitters with noise, it could be used as a " Ghost Controller." Before the technique was finally adopted there was considerable discussion as to how much the " Ghost Controller " (who had, of course, to be a fluent German speaker), was to be allowed to say. Should the " Y " Service by reason of their " up to the minute " knowledge of the enemy fighter dispositions during a Bomber Command attack, be allowed full discretion to attempt to divert the fighters from the real target or should they be permitted only to confuse the situation within certain limits ? In order to appreciate the background of this discussion, it is necessary to examine the tactics of

[1] Bomber Command File B.C. S.30726, Minute 3, 1 November 1943.
[2] *Ibid.*, Minute 1, 18 October 1943.
[3] *Ibid.*, Encl. 1A, 16 October 1943.
[4] *Ibid.*, Encl. 5A, 20 October 1943.

the bomber force at the time, September 1943, and the methods in use by the enemy to counter these tactics. Bomber Command attacks were planned on the basis of concentration in time and space with all aircraft timed along a prescribed route. For the enemy the main problem was that of intercepting the bombers and for this purpose he was in the habit of concentrating all available fighter aircraft at what he thought would be the target, timing them to arrive shortly before the bomber force. It had been found that the enemy could often be deceived as to the target by the use of circuitous and " dog-leg " approach routes.

The orders to the enemy night fighter aircraft were issued through the medium of the broadcast running commentary already described, so that there were good grounds for believing that it should be possible to contradict and confuse the orders put out by the German controllers. Apart from the instructions concerning the rendezvous and the target to be protected, the night fighter aircraft were also given information regarding weather at their own airfields, whether they were safe for landing and general flying control instructions. A necessary part of the procedure was the constant repetition of tuning signals by the enemy ground station to enable their aircraft to keep on frequency. As a result of consideration of this tactical background it was eventually decided, in a directive issued to the " Y " Service on 26 October 1943, that the broadcast messages should contain no mention of :—[1]

(*a*) Any real or imaginary position or routeing of our own aircraft.

(*b*) Any reference to a target, whether genuine or otherwise, or of a place name.

The reasons for this decision are interesting. While it was possible that the night fighter crews might be deceived by " ghost " orders it was unlikely that the German controllers, working in comfort with reasonably good information as to the actual targets of the attacking force, could be so deceived. To them the contradictions of the " Ghost Voice " might serve to give indication of the real intentions of the attacking force. If, for example, the target was Leipzig and the German commander was perhaps still in some doubt as to whether this was the actual target, and had ordered his fighter aircraft there, his doubts might disappear if the " Ghost Voice " then tried to divert the aircraft to Brunswick or some other imaginary target. Clearly the danger was that information might be given to the controller by implication. Though many of the German fighters might well have acted on the false order, there could never be any guarantee that every one would, and with all doubt removed the enemy controller could reinforce the then known target area, not only from the air but also from the ground. It can be argued that the possibility of " double spoofing " still existed under these conditions, but in view of the risks which would have to be taken, it was agreed that this aspect could not justifiably be entertained. The directive still left plenty of scope for ingenuity and the " Y " Service exploited the possibilities to the full.

Corona came into use on the night of 22/23 October 1943, and was immediately successful. The target was Kassel and before the end of the night there was chaos in the enemy night defence organisation. A furious German ground controller was heard to warn his aircraft, " Beware of another voice " and, " Don't be led astray by the enemy," and finally, " In the name of General Schmidt I order all aircraft to Kassel." The General Schmidt on

[1] A.M. Letter A.I.4/452/P, 29 October 1943.

whose authority he spoke was the Commander of the German Air Force on the Western Front who had relieved General Kammhuber shortly after the introduction of Window. The "Ghost Voice" not only spoke idiomatic German but had also been trained to mimic perfectly the voices of his opposite numbers.[1] It was the "Ghost" who on one occasion, after a particularly violent outburst by the German Controller, remarked into his microphone "The Englishman is now swearing." The German's immediate and somewhat fatuous rejoinder was "It is not the Englishman who is swearing, it is me." On another night the enemy attempted to beat the "Ghost" by putting quite suddenly and in the middle of the proceedings, a woman controller at the microphone. But this had been foreseen and a German-speaking W.A.A.F. operator was sitting ready against just such a contingency. The Germans never attempted to repeat this stratagem.

Various other expedients were tried by the enemy; for instance, they commenced prefixing every R/T message with a different three figure code group as, "763 all Fighters to beacon P." The immediate answer to this was of course, "763 all Fighters to beacon O." The night fighters were left to wonder whether their code was wrong and which was the correct order, while the controllers were in doubt as to which instruction the fighters would follow. Another enemy idea was to have his orders repeated by a second voice. This also was quite easy to counterfeit and the confusion which resulted on some occasions can best be imagined.

The operational intention of Corona being to disrupt and confuse the enemy's organisation by the transmission of false or contradictory instructions, one of the most fruitful objects for attention was that part of his organisation concerned with the disposal of fighter aircraft after the Bomber Command raid was over. Since fighter aircraft were normally drawn from all over Germany for these operations, the enemy's problems for the night did not end with the return of the Bomber Command force to its base. The night fighter aircraft, of which there may have been up to three hundred or more airborne, had to be sorted out and instructed concerning the airfields they were to land at. It was in connection with this phase of the operations that Corona sowed great confusion. If fighter aircraft were instructed by their own Controller to go to Gilze-Rijen the "Ghost Voice" soon warned them that the weather was doubtful at Gilze-Rijen and that they should therefore land at Stade, some 250 miles away. If the Germans said that the weather was bad in the southern airfield area and aircraft would have to return to northern bases, the "Ghost Voice" told the fighters to hasten to the south before the weather closed in. On occasions in the middle of operations the "Ghost Voice" would order all night fighter aircraft to land at the nearest airfield. All this was invariably accompanied by a running fire of contradiction and cross talk with the enemy Controller, helped out with extracts from Hitler's speeches and urgent requests to aircraft operators to "re-adjust their receivers."[2]

The effect of it on the enemy aircrews is easy to imagine. Occupied with the normal difficulties and hazards of night fighting they could never be sure whether they would be correctly controlled or deliberately misled during their sorties by the "Ghost Voice" whose patter, terminology and procedure was always exactly the same as that of their own Controllers. To be sent off to meet

[1] Bomber Command File B.C. S.30726, Encl. 12A, 29 November 1943.
[2] *Ibid.*, Encl. 10A, 3 November 1943.

a Bomber Command attack with which they might never be able to make contact and then not be sure of landing at a safe airfield undoubtedly undermined the morale of the hardiest of night fighter pilots. There is evidence that many of the less resolute succumbed, and for them the false landing orders in particular were always a good excuse for evading further trouble.

The end of Corona was, however, in sight. With the increasing use by the enemy of V.H.F., the introduction of W/T control, and another change in night fighter organisation whereby individual units controlled their own aircraft, its effect began to dwindle. By the spring of 1944 the enemy had become inured and the last days of Corona came when the Germans were able to ridicule the efforts of the " Ghost Voice " before the night's proceedings had started. Nevertheless, the Corona organisation was kept in being and instead of modulating the transmitters with speech they were modulated with noise and used to augment the Special Tinsel effort.[1] In this form Corona remained in operation till the end of the war.

Airborne Cigar (A.B.C.)

It will be recalled that with the introduction of V.H.F. for R/T control channels of communication, the enemy had hoped to avoid the Tinsel jamming of H.F. channels, and that an immediate counter-measure had been provided by a barrage of jamming transmitters sited at Sizewell on the East Anglian coast. Although it was known from " Y " Service intercepts that considerable interference was being experienced by enemy fighter aircraft, it will be appreciated that the effect of Ground Cigar was limited to that area of enemy country over which the jamming was directed. If the Bomber Force was to be fully protected, it was essential that V.H.F. jamming should be applied to any area over which it operated, particularly those out of range of Ground Cigar. The solution was to employ an airborne jammer carrying the jamming right into enemy territory, thus protecting Bomber Command aircraft over the whole route to and from the target. As a result of a suggestion by the Air Ministry, Bomber Command agreed to earmark one squadron of the Bomber Force for the specialist role of V.H.F. jamming in addition to its normal function of dropping bombs.[2]

Thus was introduced the counter-measure Airborne Cigar (A.B.C.), first used operationally on the night of 7/8 October 1943.[3] No. 101 Squadron, a normal Lancaster bomber squadron in No. 1 Group, was fitted with modified Jostle II transmitters for jamming enemy R/T in the 38–42 megacycles per second frequency band. Each aircraft carried a specially trained German-speaking operator as an additional crew-member, whose duty it was to find and jam the enemy frequencies. It was also the intention that the aircraft, which were to accompany the bomber force in order to apply the jamming, should carry a normal bomb-load less the weight of the special operator and his equipment, which amounted in all to about 1,000 lb.

In the five months which elapsed during that summer before aircraft were equipped for this squadron, the enemy had full and free use of his V.H.F. channels operated outside the area covered by Ground Cigar. At times, it

---

[1] A.M. Letter R.C.M./208/Tels. 2, 22 January 1944, Encl. 14A, and Bomber Command File S.30726.

[2] A.M. Letter C.28902, Encl. 3A, 23 April 1943.

[3] Bomber Command File B.C. S.29922/Sigs., 12 June 1943.

seemed that the difficulties of design, manufacture, and installation would prevent Airborne Cigar ever coming to fruition. Unfortunately, the main reason for the delay in keeping to the A.B.C. schedule was a strike at the firm responsible for delivering the aircraft for fitting.[1] The need for A.B.C. was undoubtedly urgent, particularly as it was becoming probable that the enemy was developing the full use of V.H.F. throughout his night defence organisation.[2] In order to establish this point, two preliminary survey flights were carried out by aircraft of No. 101 Squadron, fitted with receivers only, and accompanying the main Bomber Force on deep penetration raids. These surveys disclosed that the incidence of night fighter V.H.F. in the interior of Germany was, if anything, greater than in the coastal belt within range of the " Y " Service.[3] By that time, the cumbersome code-name of Airborne Cigar had been shortened to A.B.C., by which it was always known afterwards.

The equipment of each aircraft consisted of three Jostle II transmitters, all capable of being tuned rapidly to any frequency in the 38–42 megacycles per second band, together with one panoramic search receiver and the necessary power supply.[4] The aerials consisted of three 7-foot spars, two along the upper fuselage and one below the nose, giving the aircraft the appearance of a prehistoric monster. It was feared that the spars would reduce performance, but in fact no appreciable effect was noticed. It was later found, furthermore, that the bomb-load was not greatly affected in spite of the extra equipment. The type of jamming can best be described as a " wig-wog " noise, which produced a constantly varying audio note, running up and down the scale, on the speech-channel which was being jammed. The receiver had been specially designed for its purpose. While constantly searching the band electrically, it presented the whole radio frequency range to the operator in panorama on a cathode ray tube. A signal appeared as a blip on the trace and the operator could then stop the receiver on this blip, check its origin, and if it was to be jammed, tune one of his transmitters to the blip, also by visual manipulation. The whole process could be carried out in a matter of seconds, and the object of each operator was to tune his transmitters to active enemy control frequencies as rapidly as possible.

Operational Control

In its original form, the A.B.C. operation involved the close co-operation of the " Y " Service, which was to ensure that, while the A.B.C. aircraft were within range of the " Y " station, the special operators would be instructed by radio as to which frequencies to jam. This was facilitated by providing the A.B.C. operators with a gridded map of the area of enemy V.H.F. activity which was in " Y " range; the grid references were purely arbitrary and were changed for each operation. The " Y " control station had a similar map and when an enemy V.H.F. transmission was identified, its frequency was measured and its source determined by D.F. This information, in the form of a short message giving the grid reference of the source and frequency of the signal, was then broadcast direct to the A.B.C. aircraft by the " Y " control station, using a high-power ground transmitter. Operators could give a particular

---

[1] Bomber Command File B.C. S.29922/Sigs., Encl. 26A, 8 August 1943, and Minute 28, 13 August 1943.

[2] *Ibid.*, Encl. 31A, 24 August 1943.

[3] *Ibid.*, Encl. 100A, 6 September 1943.

[4] *Ibid.*, dated 2 October 1943.

transmission special attention if the source, by reference to the gridded map, lay close to the track of the bomber stream.

The method of control was employed on the introduction of A.B.C. mainly to assist the special operators in selecting the most important frequencies to jam. It was thought that there might be a large number of signals visible on the receiver, the sources of some of which might be so distant that they could not possibly be associated with the attack. In practice, it was found that the A.B.C. operators, who in any case had necessarily to be left to their own initiative when they passed out of V.H.F. range of the " Y " control station, could differentiate without difficulty between the transmissions which mattered and those that did not. The " Y " control scheme was accordingly dropped not long after the start of A.B.C. operations, though for a time active V.H.F. frequencies continued to be passed to the aircraft for their information value.

Selection and Training of Operators

Special attention was paid to the selection and training of A.B.C. operators. No. 101 Squadron contained three flights, and all the aircraft were fitted to carry A.B.C. The initial requirement was therefore for at least thirty special operators, and in the first instance they were recruited from within Bomber Command itself. The various Groups were asked to nominate aircrew personnel of quick intelligence of any flying category, the only other qualification required being a good working knowledge of the German language. Among the first special duty operators posted to No. 101 Squadron for A.B.C. were navigators, flight engineers, wireless operators and air gunners. They received two courses of training, the first lasting a week at the " Y " control station at West Kingsdown, followed by a second week spent on manipulation of the equipment, with a ground trainer designed for the purpose by T.R.E. Subsequently, the week at West Kingsdown was dispensed with, and all the training, both in the " Y " aspects and in the handling of the equipment, was given at a training centre established for the purpose at Ludford Magna, where No. 101 Squadron was based throughout the A.B.C. period.

From the outset, the A.B.C. operators showed the utmost keenness for and proficiency in their task. The subsequent and continuing success of A.B.C. was largely due to their efforts, while the comprehensive reports made regularly after each raid were of the greatest value for R.C.M. planning generally.[1] Although an A.B.C. leader, in conformity with the policy of having a leader for all the non-pilot aircrew categories, was established in the usual way, the initial training and ground organisation for A.B.C. was carried out by a Signals officer at Headquarters, Bomber Command, who also undertook the first survey flight and acted as the Command Liaison Officer at Ludford Magna until the station took over direct control of the operation.

As to the results of A.B.C., it can be said that the enemy was deprived of effective R/T working on V.H.F. whenever he attempted to operate in the neighbourhood of the Allied bomber force.[2] After the night of 7/8 October 1943 A.B.C. aircraft of No. 101 Squadron accompanied all main force attacks on German targets by night, the number of A.B.C. aircraft operating on each of these attacks varying from six to twenty-seven. The usual practice was to distribute the jamming aircraft throughout the length of the bomber stream,

[1] Bomber Command File B.C. S.29922, 5 October 1943, Minute 1.
[2] *Ibid.*, Encl. 18B, 24 October 1943.

flying at the same height and conforming in all respects to the main force attack plan. Thus, apart from carrying a bomb-load which was nominally 1,000 lb. per aircraft less than any of the other Lancaster squadron in the main force, No. 101 Squadron carried out its A.B.C. function whilst operating in all other respects as a normal component of the main bomber force. As time went on, the A.B.C. operation underwent various changes to keep pace with enemy V.H.F. developments. As already mentioned, control from the ground was dispensed with when it became apparent that operators were, in the main, able to find and jam frequencies without this assistance. When operating within range of the " Y " control station, the A.B.C. modulation could always be heard very strongly and this served as a valuable cross-check on the efficiency of the jamming. On some occasions, under good radio conditions, the A.B.C. jammers were audible on the ground in this country throughout the raid.

Benito

It will be recalled that most of the enemy *Himmelbett* patrols had been abandoned after the appearance of Window. A few, however, were retained to deal with British bombers which, especially on the return route, straggled away from the main force, and thus lost the protection afforded by the Window concentration. This meant that to a minor degree the *Himmelbett* system of night-fighting could still be employed. A second method of individually controlled fighter interception had already made its appearance over Holland during the late spring and early summer of 1943.[1] Called the Benito method, it enabled a controller to follow the position of his fighter aircraft by means of range and bearing determination at a ground station. The equipment was similar to that of the Benito Bomber Control in that the principle of range measurement was the same, but it did not involve the use of a beam. The ground station transmitted a V.H.F. carrier wave modulated by an audio tone of 3,000 cycles which was received and re-transmitted by the aircraft. By measuring the phase difference at the ground station between the transmitted and received tones, the range of the aircraft was calculated. Bearing was found by direction-finding, and the position of the aircraft was thus determined. The advantages of this system were firstly, that it was not subject to the interference of Window, and secondly, that a fighter aircraft could be plotted over a much greater distance than by the *Wurzburg*. By using a multiple array apparatus, it was possible for the ground controller to keep a check on the activities of up to twelve fighter aircraft. Within a few weeks of the introduction of Window the Benito method of control was in limited operational use over Holland, where the *Wilde Sau* free-lance fighter aircraft were not operating.

As a counter-measure to Benito, the Air Ministry suggested that a homing device[2] capable of locating and following the Benito aircraft transmission should be installed in the Mosquito aircraft of two Fighter Command squadrons, as an alternative equipment to Serrate. Development of the new homer proved slow, however, firstly due to higher priority projects at T.R.E., and later owing to technical difficulties associated with D.F. ambiguity and with fitting the large aerials required to the aircraft. Eventually the aerials were designed and fitted to Mosquito VI aircraft, but the work was not completed until 1945, when the War was nearly over and the immediate need had disappeared.

---

[1] Bomber Command Instructions No. 20, 2 October 1943.
[2] A.M. File C.28902, Encl. 30A, 19 August 1943.

Although the A.B.C. type of R/T jamming was used against Benito from the outset, there was some doubt as to its effectiveness. Two possible solutions were considered.[1] One was the production of an Air Domino, an airborne version of the Benito jamming technique as used in No. 80 Wing, and the other was the easier alternative of modifying one of the A.B.C. transmitters in each A.B.C. aircraft to radiate a tuneable Benito note. Thus, the Benito audio tone could be simulated and the jamming signal would be confused at the ground station with the genuine one, and so prevent the fighter aircraft from being ranged. The latter solution was accepted. Sufficient new type modulators were produced by T.R.E. to equip six aircraft of No. 101 Squadron, and Benito jamming, which was rather of a stop-gap nature, was carried out on the nights of 27/28/29 January 1944.[2] No difficulty was experienced by the special operators in applying the jamming but the need for further modification of the modulators was apparent. Even so, it seemed that the jamming, possibly combined with the normal A.B.C. operation, was having some effect. An examination by the " Y " Service of Benito type signals had disclosed that an unusual form of signal had been heard on a frequency of 39·9 megacycles per second. It was almost certain that it consisted of re-radiation without the usual 3,000-cycle note which was only superimposed at very low modulation level for a few seconds at a time.[3] The following month, signals were heard instructing a night fighter aircraft to go over to Benito, and to receive on 40 megacycles per second and transmit on 38·6 megacycles per second.[4] This, coupled with the fact that the frequencies did not conform to the normal 1·9 megacycles separation and were both outside the normal jamming barrage frequency range of 40·2–42·3 megacycles per second, indicated an attempt by the enemy to avoid the barrage jamming. In view of this, " A.B.C." operators were instructed to search for Benito transmissions towards 39 megacycles per second, and the special modulators were again modified to extend the audio range to cover the lower frequency used by the enemy.[5]

By July 1944, enemy use of Benito had increased considerably and attention was turned to improving the Benito jamming technique as applied by the A.B.C. aircraft of No. 101 Squadron.[6] T.R.E. examined the possibility of adopting the Air Domino scheme, but after prolonged experiments found that it was not possible to receive and re-radiate on channels as close together as those used by the enemy for Benito control.[7] T.R.E. advised that the modified Airborne Cigar operation was still the best method of jamming. This resulted in steps being taken to improve the modulator of the jamming transmitter to a higher degree of accuracy, a successful prototype being sent to the Bomber Support Development Unit of No. 100 Group where sufficient modulators to equip No. 462 Squadron were constructed.

It has not been possible to assess the degree of success with Benito jamming. Theoretically, the modified A.B.C. jammers should have caused much confusion. At least, with all the various counter-measures which were applied

[1] Bomber Command File B.C. S.29922/151, Encl. 4A, 23 January 1944.
[2] *Ibid.*, Encl. 7A, 30 January 1944.
[3] *Ibid.*, Encl. 8A and A.I.4/452/M, 31 January, 1944.
[4] *Ibid.*, Encl. 9A, and A.I.4/352/M, 8 March 1944.
[5] *Ibid.*, Encl. 12A, 25 March 1944.
[6] *Ibid.*, Encl. 15A, 3 July 1944, and A.S.I. Report No. 25, 14 January 1944.
[7] A.M. Letter Tels. 2/S.50, 10 November 1944.

against the German Air Defence System, it probably made some contribution to the difficulties which were created.

A.B.C. against V.H.F. W/T

Benito was not the only V.H.F. development with which Bomber Command had to contend. The regular reports from A.B.C. operators after each flight disclosed that the enemy was attempting to work through the A.B.C. jamming by the use of W/T.[1] This had become evident within a month of the introduction of A.B.C. From the enemy's point of view it was far from being the ideal solution. He must now either include a wireless operator in the aircraft or give the pilot extra training in W/T. There was also the need to use codes to shorten the messages, and the increased possibility of mistakes being made, accompanied by the inevitable slowing down of the control procedure. However, despite these disadvantages, W/T had been adopted and tests were therefore conducted by T.R.E. using the A.B.C. jammers with various types of modulation, the conclusion being that no improvement on the normal Jostle tone could be obtained, and that the A.B.C. jamming, so successful against R/T, would give similar results against W/T.[2] This was confirmed from intercepts of the " Y " Service.[3] Little or no advantage could have been secured by the enemy in his use of W/T in the V.H.F. band.

Ottokar

Another enemy V.H.F. development for control of night-fighter aircraft was indicated in December 1943 by reports[4] received from the " Y " Service Stations on the east coast, that during Bomber Command operations enemy R/T intercepts on a frequency of 31·2 megacycles per second referred frequently to a navigational aid known as *Ottokar*. An example is given of the traffic intercepted on this frequency on the night 2 January 1944.

" 1345 hours *Ottokar* is laid on Leipzig.
0243 hours British bombers on course in left and right of *Ottokar* 3.
0408 hours British bombers in *Ottokar* 5.
0423 hours *Ottokar* switched off."

Alternating with these R/T instructions, beam type signals with an audio modulation of 1150 cycles per second were received on the same frequency, and from a series of investigation flights undertaken by No. 192 Squadron it was apparent that the beam transmitter was situated in the *Knickebein 3* (Den Helder) area. It was therefore assumed that use was being made by the enemy of the *Knickebein* system in a defensive capacity as an aid to his night fighters.

In considering appropriate measures against this aid it was realised that as the targets of the British night bombers varied, it would not be easy for the enemy to use radio beams to assist his night fighter aircraft to find the bomber stream, due to the time taken to set up his aerial arrays in the changing directions required. It was, therefore, decided that the most effective countermeasure would be obtained by attacking the R/T control channel.[5] Since the Germans were using the beam approach receiver in the *Knickebein* band of 30 megacycles per second, which was outside the frequency band of A.B.C.,

---

[1] Bomber Command File B.C. S.29922/Sigs., Encl. 18B, 24 October 1943.
[2] *Ibid.*, Encl. 36B, 8 November 1943.
[3] *Ibid.*, Encl. 44A, 5 December 1943.
[4] *Ibid.*, Encl. 53A, " Y " Minute, 20 December 1943.
[5] *Ibid.*, Encl. 56A, 28 December 1943.

three A.B.C. transmitters, one in each of three aircraft of No. 101 Squadron, were quickly modified to radiate on a frequency of 31·2 megacycles per second, radiation to take place whenever the other two transmitters in the aircraft were jamming. Since the panoramic A.B.C. receiver could not cover the new frequency, this amounted to unmonitored jamming on 31·2 megacycles per second. This shortcoming was accepted, however, because the immediate creation of interference in the 30–33 megacycles per second frequency band was thought likely to lead the enemy to believe that preparations for jamming had already been made, and that the continued use of these frequencies would not be profitable.[1] While there is no positive evidence of the results of this move, there was no further report of attempts by the Germans to control fighter aircraft in this band, and the episode may well be instanced of the deterrent effect of rapid action.

Rayon

A further counter-measure was undertaken by Headquarters, No. 80 Wing early in January 1944, under the code name Rayon, against the *Ottokar* R/T channel. For this purpose a high-power transmitter sited at the No. 80 Wing Station Mundesley, using Jostle type modulation, was employed. Although the efficiency of this counter-measure was considered doubtful owing to the long range, there is evidence from prisoner-of-war sources that a measure of success was obtained.[2] A prisoner stated that *Knickebein* had been used for night-fighter patrols, but that the fighter commentary was unsuccessful, due to jamming by R/T.

The use of this method of control was continued sporadically for approximately three months.[3] The full number of *Knickebein* stations employed for the purpose was not determined, though transmissions from the *Knickebein 5* area were intercepted, and an alternative frequency of 32·1 megacycles per second was occasionally used. In May 1944, as the enemy had ceased to use *Knickebein* for night-fighter R/T and navigational control channels, Headquarters, Bomber Command ordered the cancellation of R/T jamming on 31·2 megacycles per second.

Enemy Measures to Overcome Jamming

With the enemy change-over from close control to the mass-control system of fighter aircraft—already discussed in connection with Special Tinsel—the running commentary broadcast on H.F. was radiated simultaneously on V.H.F. for the benefit of the V.H.F.-equipped fighters. A.B.C. operators found that most of the jamming required was against a comparatively few high-power R/T channels in the 38–42 megacycles per second frequency band. The running commentary was itself varied considerably in the endeavour to overcome the effects of jamming. On some occasions women R/T operators were employed, whose higher-pitched voices gave the German pilots a better chance of hearing their orders.[4] Another ruse was to use a captured A.B.C. transmitter on the required frequency and to fade out the jamming when orders were required to be radiated; this was apparently done in the hope that A.B.C. Operators would not tune on to another jammer, whereas in fact they had instructions that when there were no R/T signals on their own screens they should reinforce

[1] Bomber Command File B.C. S.29922/Sigs., Encl. 61A, 8 January 1944.
[2] A.D.I. (K) Report S.R.A. No. 5582, 31 August 1944.
[3] Bomber Command File B.C. S.29922/Sigs., 9 May 1944.
[4] Bomber Command R.C.M. Operational Summary No. 1, 14 December 1943.

any other jammer which they could hear. One of the more effective enemy moves against jamming was the introduction of a greatly speeded-up R/T procedure. For this, the ground transmitter had only to be on the air for a few seconds, making it often very difficult to put an A.B.C. jammer on before the enemy transmitter was switched off. This method of working would have had more success if the procedure had not been too fast for many of the German night-fighter pilots, who frequently asked for a repetition. Another subterfuge was to transmit a musical programme, breaking off suddenly to snap out an order, the music then being resumed.

Under these varying conditions A.B.C. had been operated by No. 101 Squadron from 7 October 1943. In October 1944, Headquarters, Bomber Command, proposed the transfer of the A.B.C. commitment from No. 101 Squadron of No. 1 Group to No. 100 Group, a Halifax III squadron being transferred from the main bomber force for the purpose.[1] But it was not until March 1945 that the task was taken over by a specially established Halifax squadron, No. 462, fitted with the latest A.B.C. equipment, and capable of either R/T, W/T or Benito jamming. By that time the war was nearly over and R.C.M. activity had almost ceased, so that No. 462 Squadron had little opportunity in an A.B.C. role. Throughout the long period that No. 101 Squadron had been engaged in the A.B.C. role, it had played a great part in the radio war against the German night fighter. In all, the squadron had flown 2,477 A.B.C. sorties with the loss of a total of 77 aircraft.

Enemy Use of Medium Frequency Band for Fighter Control

By November 1943 counter-measures against night-fighter R/T control on the H.F. and V.H.F. bands had presented the enemy with serious difficulties. Since the German night-fighter communication equipment could also work on the medium frequency band, it seemed that this was a likely alternative. On the other hand the use of the medium frequency band by all nations for public broadcasts and propaganda talks introduced certain drawbacks. On the night of 3/4 November 1943 it appeared that the Germans had decided to accept the disadvantages, for the high power broadcasting station at Stuttgart was brought into use for night-fighter control, the instructions being superimposed on the normal programme. The procedure used was similar to that used in the H.F. and V.H.F. running commentaries, the transmissions being in fact simultaneous on all three frequency bands. The use of Stuttgart continued spasmodically for some weeks but by the beginning of December it had become clear that the permanent use of the station was intended.

Dartboard

The immediate problem was the neutralisation of the 100 kilowatts broadcasting transmitter at Stuttgart—no mean undertaking in view of the power of the station and its distance from any similar station in this country which could be brought to bear.[2] Fortunately a sufficiently powerful jammer was available in the shape of an 800 kilowatts set, probably the most powerful M.F. transmitter in Europe, which was under Foreign Office control for propaganda purposes. This was installed in H.M. Government Communications Centre at Crowborough and was to be known as Aspidistra. Negotiations for the use of the transmitter for radio counter-measures were successful, and on the night of

[1] Bomber Command Letter B.C. S.29922/Sigs., 7 August 1944.

[2] A.M. Sigs. Plan (C) Instructions C.M.S. 79, 27 January 1944, and No. 80 Wing File S.3019/11/Sigs., Encl. 3a.

6/7 December 1943 the counter-measure which was at first known as Light-up, and was later named Dartboard, went on the air. In accordance with the requirements of impending night operations, prior requests for Dartboard were given daily by Headquarters, Bomber Command to the "Y" Service, which were responsible for its operational control.[1] An over-riding control was exercised by the No. 80 Wing Controller (on advice from the No. 80 Wing Liaison Officer at Headquarters, A.D.G.B.) for closing down should enemy attacks develop over the United Kingdom. Prior to the cessation of hostilities, arrangements were completed for No. 80 Wing to assume control of Dartboard and, although only one such operation was so controlled, the necessary modulation and landline facilities had been made available.

The means of application comprised a listening watch for the Stuttgart radio station broadcast programme and, as soon as the latter was faded out for enemy control instructions to be given, the "Y" operator pressed the key which gave direct control of the transmitter. With an eight to one advantage in power, the Dartboard signal was sufficient to nullify the Stuttgart transmission over the northern area of Germany, and to interfere seriously even in the south. The hours of operation were kept to the minimum owing to the high priority propaganda work on which Aspidistra was normally engaged. Another transmitter, "Moorside Edge 3" (near Huddersfield) was also available for the same purpose and later one of the B.B.C. Droitwich transmitters was employed. The procedure was modified in March 1944, and unless the listening watch considered the jamming was not effective, Aspidistra radiated its normal "Calais" or "Atlantic" propaganda programme, "Moorside Edge" only being keyed. It was anticipated that this change would put the enemy in a quandary. He had the choice of accepting unjammed propaganda covering the whole of Europe from the powerful Aspidistra, probably causing nearly as much interference as he was already experiencing, or of attempting to jam Aspidistra, which course would entail spoiling his own fighter control transmissions.

The *Anna Marie* Programme

Some idea of the straits in which the Germans found themselves can be gauged by the extraordinary method adopted after the use of Dartboard.[2] It was reported that the broadcast programmes radiated by the German Forces Station *Anna Marie* at Muhlacker, Stuttgart, were completely out of balance. Investigations revealed that the programme was coded, the nature of the music indicating in which of the eight main defence areas Royal Air Force bomber aircraft were flying. The key to the code was as follows[3] :—

Defence Zone	Nature of Music
Quelle	Wurlitzer Organ.
Kurfurt	Marches.
Phillip	Xylophone.
Otto	Violin.
9	Piano.
10	Soldiers' Songs.
Berta	Waltzes.
Ponto	Accordion.

[1] A.M. Sigs. Plan (C) Instructions C.M.S. 79, 16 March 1944, and No. 80 Wing File S.3019/11/Sigs., Encl. 4B.
[2] Bomber Command Operational Summary of R.C.M. No. 3, 8 April 1944.
[3] A.D.I. (I) Report No. 491 D/1944, 28 August 1944.

If, for example, bomber aircraft were flying into the Quelle area, the broadcasting station *Anna Marie* would play cinema organ music as long as the bombers remained in that area. Instructions were given that the musical items would be interspersed with orders to the fighters. The code was put into effect on 26 December 1943, and according to captured information was intended to be used only when the Corps and Divisional commentaries were jammed. When this occurred and no verbal orders were given by *Anna Marie* the fighter aircraft were to fly to the W/T beacon in the area indicated by the type of music broadcast. The areas Quelle, Kurfurt, Phillip and Otto were sub-divided into northern and southern halves. When bombers were in the northern half of these areas each piece of music was announced individually, but when in the southern half two pieces of music were announced at a time. Finally, the conclusion of operations was always indicated by the station playing the German march "Old Comrades." In the event of Allied aircraft not entering any of the eight defence areas the radio station *Anna Marie* was to broadcast its usual dance music.

The Germans may have hoped that the introduction of this novel but clumsy method of fighter control would escape notice by the Allied radio counter-measure organisation. It was an open admission to their own fighter pilots of serious embarrassment. Dartboard jamming was applied to the transmissions and they were discontinued after a few more operations.

Other important developments on medium frequency were, firstly, the use of navigational radio beacons by the Germans for passing plots and control instructions by W/T, and secondly, the establishment of comparatively high-power M.F. control stations in each German night fighter Divisional area, of which four mainly concerned Bomber Command.[1] The radio beacons provided a serious problem ; there was a number of them and their function in the enemy night fighter organisation was an important one. Each beacon site comprised an M.F. radio transmitter associated with a visual beacon flashing a characteristic recognition code group. They were used as rallying points for the night fighter aircraft which were directed by the ground control from beacon to beacon ; the fighters homed by radio to the particular beacon to which they were ordered and checked their position by observing its visual characteristic.[2] When the enemy began to use these beacons for passing plots and control instructions, the situation was first met by the introduction of counter-measure Fidget, which is discussed later in this narrative.

In summarising M.F. development, it is probably true to say that by increasing the number of frequencies in use, the enemy was able to evade to some extent the full effects of M.F. jamming. Such an evasive measure may also be applied for all wavebands. Nevertheless, the general disorganisation and complication caused by the jamming was such as to make it in the highest degree improbable that more than a proportion of aircraft operators were able to find a clear channel. In effect, a situation had been reached in which the wireless operator of the German night fighter aircraft was required to search his allotted frequencies over the whole range from V.H.F. to M.F., involving the use of two separate aircraft receiving installations, in order to find an unjammed channel and knowing that it might at any moment be engaged by a jammer. This was the situation by the end of 1943, brought about by the combined effect of Tinsel, Special Tinsel, Corona, A.B.C. and Dartboard.

---

[1] A.S.I. Report No. 79, 16 November 1944.
[2] A.H.B./II.E/76. "War in the Ether." An account of R.C.M. in Bomber Command.

By the adoption of a very wide selection of frequencies within the M.F., H.F. and V.H.F. bands, the German night-fighter control was probably able to retain fighter communication to some degree. Nevertheless, the *Luftwaffe* night control organisation was very seriously handicapped by R.C.M. This was shown not only by the enemy's resort to so desperate a measure as the Anna Marie programme, but was directly confirmed by prisoners after the War.[1] Interrogation of a number of experienced and reliable night-fighter pilots of the German Air Force confirmed that by 28 October 1944, only high-power W/T beacons were of any real use to them. The very experienced pilots could operate only in the most favourable conditions, and night-fighter aircraft could no longer operate as units. All German night-fighter crews confirmed this experience of frustration. On the other hand, the enemy showed great resource and flexibility, requiring a considerable effort by Bomber Command in attempting to neutralise it. The jammers, moreover, deprived the Allied " Y " Service of a good deal of information.

The early policy of mixing all the A.B.C. jammers with main force bombers had its dangerous side, as it not only gave the German Raid Tracking Service a further source of information, but also provided the enemy night-fighter aircraft with potential radio beacons by which to home into the bomber stream. Fortunately, the enemy exploited neither, but it would have been more effective, and more economical if this task had been allotted much sooner to a specialist R.C.M. Group. The vulnerability of high frequency communications to ground jammers situated at skip distance from them, and the corresponding advantage of V.H.F. to the Germans, were brought out. There are claims that the success of jamming on high frequencies forced the enemy to use V.H.F. Having regard to the distinct technical and tactical advantages otherwise to be derived by him from such a change, these claims are probably exaggerated.

Before proceeding further with the history of offensive radio counter-measure operations, it would be appropriate to trace the origin of the Royal Air Force specialist radio counter-measure formation, No. 100 Group, which came into being at the end of 1943 as a result of the realisation of the significance of offensive radio counter-measures in support of the Allied night bomber offensive.

---

[1] Air Ministry A.D.I. (K) Report No. 599/44, and No. 700/44

CHAPTER 11

THE FORMATION OF No. 100 GROUP

Throughout 1943, a belief grew that R.C.M. requirements for Bomber Command could best be met by the provision of specialist squadrons to provide the airborne counter-measures for the bomber force. The use of specialist units was not new, for in 1942 No. 515 Squadron of Fighter Command had been employed for "Moonshine" and airborne "Mandrel" operations. In Bomber Command too, a similar arrangement had been the employment of No. 101 Squadron on Airborne Cigar duties, which had been amply justified. Despite the additional weight of a special operator and the Jostle II apparatus, this squadron had been able to carry out the dual function of jamming and bombing. The need was now arising, however, for apparatus of greater complexity, increased size and weight, and involving problems of increased power supply. Moreover, a factor of greater importance was the growing realisation that the extent and complexity of R.C.M. required to keep Bomber Command's losses within acceptable bounds undoubtedly called for specialist R.C.M. units to accompany the main bomber force.[1]

In June 1943, Headquarters, Bomber Command had made enquiries as to the feasibility of countering all forms of enemy radio-controlled night defences by the employment of a few specialist aircraft carrying high-power jammers.[2] The need for specialist R.C.M. squadrons had been strengthened by a desire to avoid the inevitable complication of aircraft installations and their maintenance, and the need for training every bomber wireless operator in their operation.[3] The tendency was to favour a separate formation which could be made solely responsible for radio counter-measures. It had become clear that radio warfare in Bomber Command, if it were to be successfully applied, would call for day-to-day control and the undivided attention of the signals staff concerned with the technical and operational aspects of R.C.M.[4] But it was not only in Bomber Command that R.C.M. requirements had to be met. There were also those of all other Royal Air Force Commands, the Director of Telecommunications under the Director General of Signals being the co-ordinating authority responsible to the Air Staff. This responsibility had been exercised by the Air Ministry since 1940 when the need for counter-measures had first arisen in connection with the German radio beams.

Before any counter-measure can be taken, information must first be obtained on the methods and devices employed by the enemy. Until these are discovered the enemy will possess undisputed use of the aids he employs, the period of such use being governed by the time taken in determining their nature and the best course to adopt in order to nullify them, and in the design and production of the necessary equipment. It was clear that this period should be reduced to a minimum. The closest possible liaison was therefore maintained with the Intelligence branches concerned, with Scientific Advisors in the Air Ministry,

---

[1] Narrator's Interview with A.V.M., E. B. Addison, A.O.C., No. 100 Group.

[2] Director of Telecommunications Folder. Minute from the Director-General of Signals to the Deputy Chief of Air Staff. [3] A.M. File C.28902, Encl. 3A.

[4] A.H.B./II.E/76 (a)—"War in the Ether, 1939–1945. Signals in Bomber Command"

with physicists and radio engineers of the Research Establishments and with the Radio Industry. Moreover, an intimate liaison was required with the Commands who were to apply the counter-measures. This in turn meant the formation of R.C.M. Sections within the Signals Staffs of the Commands.

Thus there were many reasons for the trend towards the formation of an operational R.C.M. organisation. The necessary impetus was given by a letter to the Air Ministry on 31 August 1943 in which the Air Officer Commanding-in-Chief, Bomber Command referred to the night fighter and intruder operations carried out by Fighter Command in support of the Allied bomber offensive.[1] He stated that these operations were excellent as far as they went, but did not exercise more than a minor effect upon the enemy's defensive organisation, which was expected to become even more powerful in an attempt to reduce the efficiency of Bomber Command operations. He contended that if the bomber offensive were to be given the best chance of fatally weakening Germany, it was essential that complementary offensive action of all kinds calculated to disorganise the German night fighter and *flak* defences, should be given the highest priority and organised in the most effective manner. This action consisted of :—

(*a*) R.A.F. night fighter operations.

(*b*) R.A.F. bombing intruder operations.

(*c*) R.C.M. against the German R/T system.

It was the view of the Air Officer Commanding-in-Chief, Bomber Command, that as long as such action remained a side issue for Fighter Command, air offensive action on the scale required was unattainable. He advised that night fighter and intruder squadrons should be formed into a Bomber Command Group whose specific duty it would be to conduct offensive measures in support of bomber operations. He also suggested the inclusion of a radio counter-measures squadron responsible for operations against the German R/T system on which the enemy's night fighter aircraft were largely dependent.

In a further letter the Air Officer Commanding-in-Chief suggested that the offensive against German controlled night fighter aircraft in 1944 should take the form of barrage jamming of the whole radio defence system, including R.D.F. tracking and fighter R/T.[2] The introduction of Window was seriously interfering with the ground control of German night fighter aircraft, but the relief thus gained was only partial, in that Window only affected part of the ground tracking system and the A.I. tactics employed by enemy night fighter aircraft. It could not prevent the height of the top layer of the bomber stream from being determined or confuse that part of the enemy G.C.I. system which made use of *Freyas*. There might also be a limit to its usefulness in the case of deep penetrations into German territory set by the quantity of Window which would need to be carried and the physical effort required to maintain the necessary rate of discharge, especially at great altitudes. Moreover, it was now time to aim at reducing to the minimum the number of counter-measure devices carried by individual aircraft and to replace them by specialised jamming equipment capable of dealing with the entire enemy system and thus giving

---

[1] Bomber Command Letter BC/S.30522/Air/C.-in-C., dated 31 August 1943, Encl. 1A, and A.M. File C.M. S.265.

[2] Bomber Command Letter BC/MS.27933/Sigs./C.-in-C., Encl. 7A, 7 September 1943, and A.M. File C.28904, Part I.

protection to the force as a whole. Of the devices employed, all aircraft used Tinsel, about 12 per cent. carried Mandrel, a proportion were fitted with Boozer, and No. 101 Squadron was being equipped with A.B.C. He recommended that the specialised equipment to supersede these devices should be carried in a small number of special high flying aircraft and be capable of obliterating the radio defence system over the whole bomber lane. It was apparent that these aircraft with their barrage jamming equipment would be vulnerable to homing, so that height and speed should be their chief defence. These requirements demanded an aircraft with an effective operating height of 28–30,000 feet, a speed and endurance at least equal to that of the main bomber force, and having the space, lift and power supply needed for the equipment. The aircraft which suggested itself for this purpose was the American Fortress, which met the technical specification, and which as an additional recommendation possessed a powerful defensive armament. The Air Officer Commanding-in-Chief, Bomber Command, therefore recommended that sufficient Fortress aircraft should be obtained to equip and maintain one squadron, and that development on the highest priority of barrage jamming equipment against enemy V.H.F., R/T, A.I., *Freyas*, and G.L./G.C.I. should be instituted immediately.

The matter was fully examined and brought up for discussion by the Air Staff on 29 September 1943.[1] A memorandum was prepared pointing out that whereas up to date the enemy's air defence system had been attacked by means of various radio equipments installed in Bomber Command aircraft, by aircraft of Fighter Command, by ground radio stations in this country, and by Intruder and Serrate[2] Squadrons, so far there had been no central operational organisation solely responsible for the co-ordination of the application of all possible means for breaking down the enemy's air defence system. The inclusion of the Serrate squadrons in such an organisation was needed on the grounds that more rapid development could be expected both technically and operationally. Similarly, as the night Intruder operations would have to be dovetailed into those of Serrate and other squadrons proposed for radio counter-measures, there was a case for these also to be operated and controlled in the same organisation. While the American bomber force was increasing rapidly in effectiveness, the main offensive force was Bomber Command. This Command would accordingly have the most urgent demands on the proposed R.C.M. Group and should, therefore, have operational control of it. For matters relating to the new Group's technical administration it could best be directly under Air Ministry.

A conference was held at Air Ministry on 29 September 1943 to discuss this memorandum. Among those present were the Deputy Chief of Air Staff, Deputy Commander-in-Chief, Bomber Command, Major General Eaker Commanding the American 8th Air Force, the Air Officer Commander-in-Chief Fighter Command, and the Air Officer Commanding 2nd Tactical Air Force. The following decisions were made :—

(*a*) that the air offensive would be more effectively supported than at present by the formation of a central organisation for the operational employment of radio and other counter-measures to the enemy's defence system, and that such an organisation should cover the technical and intelligence sides;

[1] A.M. File C.M.S. 265, Encl. 12B.

[2] Night-fighter aircraft employing homers for homing to enemy night-fighter A.I.

(*b*) that the decision as to whether the Intruder squadrons of Fighter Command should be transferred to the Operational control of the new organisation, should be deferred;

(*c*) that the following units should come within the operational control of the new Group.

No. 141, 169, 239 Squadron (the Serrate squadrons).
No. 515 Squadron.
The Radio Development Unit at the Royal Air Force Station, Drem.
No. 1473 Flight.
No. 192 Squadron;

(*d*) that a development unit should be included within the Group, in order to carry out research work on radio attack on the various types of enemy ground stations;

(*e*) that the new central organisation should undertake both ground as well as air jamming;

(*f*) that the operational control of the Group should be under Bomber Command and the technical control under Air Ministry;

(*g*) that General Eaker should ask General Arnold for an allocation of the required number of Fortress aircraft with which to form the Group, and that in the meantime, two Fortress aircraft should be made available immediately out of existing resources for the initial development work and the commencement of operations. It was estimated that an initial Fortress force of six to ten aircraft would be required to accompany each major raid, which meant that a squadron of 16 I.E. aircraft would be the ultimate object.

The authority for the necessary action to be taken to form the Group came on 28 October 1943, when the Secretary of State for Air, in a minute to the Chief of Air Staff, described the proposed Group as "a most important and hopeful project which should be vigorously pressed forward." Acting on this, the Director General of Organisation and the Director of Policy submitted a paper to the Expansion and Re-equipment Policy Committee at its 49th Meeting asking that a decision should be taken as to which Royal Air Force Command should provide the personnel.

At its 49th Meeting on 29 October 1943, the Committee agreed that the formation of the new Group should not be met by adding to the already considerable deficiencies of manpower in the Home Commands, and that it could only be formed by a corresponding reduction of units.[1] It was considered that this was a matter for Air Staff decision. In a letter from the Director of Policy to the Director General of Organisation on 5 December 1943, the former stated that, as regards the manpower position, the best way would be to instruct Bomber Command to re-equip one of their Stirling squadrons with Fortresses.[2] This would not diminish Bomber Command's impact upon Germany since the Command had already stated that they intended to withdraw the Stirling aircraft from the line.

On 8 November 1943 instructions for the formation of the Radio Counter-Measures Group had been issued, to the effect that No. 100 Group was to form forthwith to establishment WAR/B.C./386 at the Royal Air Force Station,

[1] A.M. File C.M.S. 265, Encl. 30A. [2] *Ibid.*, Encl. 41A.

West Raynham, at which station accommodation was to be improvised pending a move to Bylaugh Hall, East Dereham, Norfolk, as soon as the latter was vacated by Headquarters, No. 2 Group, 2nd Tactical Air Force. The locations for all the units were to be decided by Bomber Command. Consequently the full layout of the Group was given at a meeting by the Deputy Commander-in-Chief of Bomber Command on 8 November. The new No. 100 Group became established officially from that date, and ten days later No. 80 Wing was incorporated in it. Air Commodore E. B. Addison was appointed to command it. Full terms of reference for the Group had, however, yet to be decided.

It was intended to have two Fortress squadrons in No. 100 Group, viz. :—

(*a*) The 8th Air Force would provide one squadron consisting of 12 + 2 Fortresses. This United States squadron was already in being and two Fortress installations were undergoing trial at Defford. This squadron was entirely a United States unit, fully administered by the 8th Air Force although under the operational control of Bomber Command.

(*b*) The second squadron, No. 214 (R.A.F.) was to be armed with 12 + 2 Fortresses, and application for these, plus wastage, would be made to Washington by General Eaker. Britain possessed no other squadrons of Fortresses except two in Coastal Command which could not be diverted.

At a conference held at Air Ministry on 29 September, General Eaker had agreed to ask General Arnold for an allotment of the required number of Fortress aircraft. Meanwhile two Fortresses were made available and were undergoing trial installations at Defford. As no reply was forthcoming from General Eaker, the Deputy Chief of Air Staff brought the matter to his notice in a letter on 12 November 1943.[1] In a further letter to General Eaker on the 27 November 1943, the Deputy Chief of Air Staff stated that, on the assumption that General Arnold would approve of General Eaker's provisional offer to contribute to the squadron to the extent of 50 per cent. of aircraft, the British representative in Washington had been asked to obtain allotment of the necessary number of aircraft to equip 50 per cent. of the squadron initially and to meet 50 per cent. of wastage. The Deputy Chief of Air Staff now requested General Eaker to ask permission for an immediate allotment. It was intended to repay the U.S.A.A.F. when the 1944 consignment of Fortresses from the United States became available. It was not expected, however, that this would arrive before March or April, and as the urgency to equip the Fortress Squadron was such that it was impossible to wait until then, the only way in which these aircraft could be got in time was by means of a loan from the 8th Air Force.

The War Department in Washington approved by cable on 4 December 1943 General Eaker's recommendation that 12 Fortresses with crews be made available for the formation of an American section in the Radio Countermeasures Group.[2] General Eaker, after discussion with the Deputy Commander in-Chief, Bomber Command, concerning the organisation for the Fortress Squadron in No. 100 Group, felt that there was need for a conference to discuss its formation, and the responsibilities of the U.S.A. authorities towards it.[3] A meeting was subsequently arranged at the Air Ministry for 15 December. By

[1] A.M. File C.M.S. 265, Encl. 38A. [2] *Ibid.*, Encl. 43B. [3] *Ibid.*, Encl. 44A.

20 December 1943, the Air Ministry had still made no headway with the American 8th Air Force in the matter of arranging a loan of the Fortress aircraft to form No. 214 Squadron. A meeting was, however, held on 21 December 1943,[1] in response to a request by the Air Officer Commanding-in-Chief, Bomber Command, for a speed-up of the formation of the Group, but no decision as to the allotment of the Fortresses was made. The meeting met to discuss whether sufficient priority was being given to the formation of No. 100 Group, and if not, what further action should be taken. The meeting decided that, in order to speed up the formation of No. 100 Group, representatives of Air Member for Supply and Organisation, Director-General of Signals and No. 2 Group should visit Mongewell Park, Wallingford, Berks, immediately after Christmas in order to fix the target date for the transfer of the nucleus operational staff of No. 2 Group to Mongewell Park and so allow the Headquarters of No. 100 Group to move in to Bylaugh Hall.

The Deputy Chief of Air Staff on 27 December reviewed the delays in the formation of No. 100 Group in a minute to the Chief of Air Staff.[2] He pointed out that, while the Group had already been formed, it was handicapped by the lack of aircraft for the two Fortress squadrons and the three Serrate squadrons, and lack of accommodation for the Group Headquarters. Furthermore, Washington had not as yet replied to the request by the Air Member for Supply and Organisation for the loan of 14 Fortresses. Whereas full radio jamming equipment for these Fortresses would not be available until March or April, 1944, a start could be made by fitting the equipment which had already been obtained as soon as the aircraft themselves were available.

The position of the Serrate squadrons was no better. Only one was operational, the remaining two being short of aircraft on account of a hold-up of Mosquito aircraft equipped with A.I. S.C.R. 720 which had prevented the Mosquito IIs from being handed over to the Serrate squadrons from Air Defence Great Britain (A.D.G.B.). In reply, the Chief of Air Staff, on 28 December, in a minute to Assistant Chief of Air Staff (Ops.) requested a fortnightly report on the progress of No. 100 Group.[3]

The move of H.Q. No. 100 Group to Bylaugh Hall was completed on 8 January 1944,[4] and by 9 January the first British Fortress squadron, No. 214, was forming at Sculthorpe. On 24 January 1944, eight Fortress aircraft had been received from the American 8th Air Force, three being used in No. 214 Squadron to convert the Stirling crews, two being installed with high-power jamming equipment, and one undergoing trial installation of Monica. As an interim measure against the use of *Knickebein* frequencies by the enemy for night-fighter control, six of No. 100 Group's Fortresses were to be equipped with a special form of Airborne Cigar. As for the Serrate squadrons, 18 Mosquitos were carrying out operations by 24 January.[5] No. 515 Squadron was, however, encountering delay in re-equipment with Beaufighter II aircraft fitted with Bi-Mandrel, Bi-Moonshine and Carpet as a result of failures of the trial installations.

By 5 February 1944, 13 out of 14 Fortresses on loan from the 8th Air Force had been delivered to the British squadron at Sculthorpe,[6] and arrangements had been completed with Washington for the delivery of enough aircraft to cover estimated wastage in the next six months. The aircraft, which

[1] A.M. File C.M.S. 265, Encl. 53A. [2] *Ibid.*, Minute 5. [3] *Ibid.*, Minute 52. [4] *Ibid.*, Encl. 54A. [5] *Ibid.*, Encl. 55A. [6] *Ibid.*, Encl. 56A.

unfortunately, were B.17Gs, had to be exchanged for B.17Fs, as the former, being fitted with chin turrets were unsuited to R.C.M. purposes. Nine of these aircraft were being used for conversion training, and the remainder were fitted with the interim Airborne Cigar equipment. Twenty-five fully-fitted aircraft, now operational in the three Serrate squadrons, encountered fresh trouble over the unreliability of the Merlin XXI engine and the age of their Mosquito II aircraft. It was decided consequently to have a number of Mosquito IIs overhauled and to install Merlin XXII engines. Meanwhile one Serrate squadron was to be re-equipped immediately with Mosquito VI aircraft which had become available on account of reduced Operational Training Unit requirements, while the other two were to continue with the reconditioned Mosquito IIs until the latter half of 1944.

The fitting of equipment in No. 515 Squadron was now stopped as the increased number of frequencies on which the German radar stations were working made the use of Moonshine difficult, if not impossible. The rôle of No. 515 Squadron, pending investigation, was accordingly modified to that of Night Intruder with an alternative rôle of R/T jammer. As No. 515 Squadron, like the Serrate squadrons, suffered from old aircraft, the Vice-Chief of Air Staff agreed that they also should be re-equipped with Mosquito VI aircraft, second in priority to the Serrate squadrons. Re-equipment was expected to start about April. By 6 March 1944, as the B.17F Fortress was no longer being made, it was decided reluctantly to use the B.17Gs which Washington were delivering.[1]

By 20 March 1944, all crews in the R.C.M. Fortress squadron were flying Fortress aircraft by day and night for training purposes.[2] The order of battle in No. 100 Group was then as follows :—

Squadron No.	*Location.*		*Type.*	*Type to which re-equipping.*	*Remarks.*
141	West Raynham	16+2	Mosquito II	Mosquito VI	Operational.
169	Little Snoring	16+2	Mosquito II	No change	Operational.
239	West Raynham	16+2	Mosquito II	No change	Operational.
515	Little Snoring	16+2	Beaufighter II	Mosquito VI	Non-Operational.
192	Foulsham	6+1	Wellington X	No change	Operational.
		3+0	Mosquito IV		
		8+2	Halifax IV/V		
214	Sculthorpe	12+2	Fortress B.17F.	Fortress B.17G.	Non-Operational.

Seventeen crews of the Fortress Squadron were operational by 12 April 1944.[3] Six aircraft with the interim Airborne Cigar equipment were delivered to the squadron at Sculthorpe, but fresh delays over the delivery from Scottish Aviation Ltd. of the universal jammers for the main R.C.M. programme occurred. Difficulties with the Serrate prototype installation in the Mosquito VI aircraft continued. Trouble was also encountered over the transmitter aerial system of the Monica IIIA installation as, on account of its projection into the slipstream, the port half of the reflector had broken. No. 515 Squadron, however, had completed its re-equipment with Mosquito VI Aircraft. Certain crews were detached to No. 615 Squadron for coaching in Intruder technique, and the first sorties were carried out by this detachment.

[1] A.M. File C.M.S. 265, Encl. 61A. [2] *Ibid.*, Encl. 64A. [3] *Ibid.*, Encl. 73A

By 18 April the trouble over the aerial system of Monica IIIA had been overcome and six Fortresses of No. 214 Squadron, fitted with the interim Airborne Cigar, operated for the first time on the night of 20/21 April 1944.[1] The formation of the American squadron was also making headway—five American Fortress aircraft, fitted with a variety of Mandrel and Carpet, and one American Fortress fitted with a search receiver, all six aircraft having American crews, had now arrived at Sculthorpe. As the U.S.A.A.F. did not require these aircraft for their day raids at that time, the crews began training in night-flying in support of Bomber Command. By 1 May the American Fortresses were incorporated in No. 803 Squadron, U.S.A.A.F. and four aircraft first operated with jammers on the night 5/6 June against the German long-range radar warning stations to cover the landing of the American forces in North-West Europe. Moreover, several additions were to be made to No. 100 Group. No. 199 Stirling Squadron was to be transferred to the new Group on 1 May 1944.[2] The squadron was to be located at North Creake, and was to be fitted with a battery of Mandrel in each aircraft. It was also proposed to employ it for spoof purposes using the new Freya type Window. This squadron first operated on the night of June 5/6 in support of the D-day landing of airborne forces. Two other squadrons, Nos. 157 and 85, both night-fighter Mosquito squadrons, were to be transferred to No. 100 Group on 1 and 5 May, respectively. No. 157 Squadron was to be re-equipped with Mosquito XIX aircraft and No. 85 was to have its Mosquito XVII fitted with A.I., Mark X.

Rôle of No. 100 Group

Thus the beginning of May 1944 saw the elimination of most of the difficulties besetting the formation of No. 100 Group. It was to be primarily responsible for supporting the forces operating under Bomber Command, but had in addition to meet a proportion of the requirements of other formations, including the Allied Expeditionary Air Force and Air Defence Great Britain. Its function, therefore, was to co-ordinate the activities of its airborne and ground units, and its rôle was summarised in a directive issued by Bomber Command on 21 March 1944 as follows :—[3]

(*a*) To give direct support to night bombing or other operations by attack of enemy night-fighter aircraft in the air, or by attack of ground installations.

(*b*) To employ airborne and ground R.C.M. apparatus to deceive or jam enemy radio navigational aids, enemy radar systems and certain wireless signals.

(*c*) To examine all Intelligence on the offensive and defensive radar, radio navigation, and signalling systems of the enemy, with a view to future action within the scope of (*a*) and (*b*).

(*d*) From the examination of this Intelligence, to plan for use in future operations means of disorganising the enemy offensive and defensive radio systems.

(*e*) To provide immediate information, additional to normal Intelligence information, as to movements and employment of enemy fighter aircraft to enable the tactics of the bomber force to be immediately modified to meet any changes.

---

[1] A.M. File C.M.S. 265, Encl. 74A. [2] *Ibid.*, Encl. 75A.
[3] A.M. File C.M.S. 265.

The task of forming a new Group with unique and peculiar functions during the six months period which preceeded the landing in Normandy was a strenuous one. The formidable undertaking of fitting squadrons of aircraft of the heavy bomber type with special electronic gear, of re-equipping night-fighter squadrons with more serviceable types of engines and aircraft also carrying special radio equipment, and the training of aircrews in their new role, required great efforts. During the same period the Group was operationally active, achieving not only valuable jamming and radio investigation but also more tangible results in the shape of German aircraft destroyed by the fighter units. Accounts of the varied operational activities are contained in appropriate succeeding chapters.

A noteworthy feature in the formation of No. 100 Group was the successful blending of bomber and fighter activities under the same command, and also the absorption of American units within the organisation. The smooth amalgamation of elements which were bound to be diverse in their approach to the common end shewed a measure of the *esprit de corps* of the new Group. The constant personal attention given to its formation by the Chief of Air Staff testified to its operational importance.

CHAPTER 12

RADIO COUNTER-MEASURES AGAINST ENEMY AIRBORNE INTERCEPTION DEVICES

Investigation of German A.I.

From information disclosed by R/T intercepts, Air Ministry (D.D.I.4) issued a report in July 1942 that an interception device, known to German aircrews as *Emil-Emil*, which at the beginning of 1942 appeared to be used by night fighters in the Flushing area only, was being used on an increased scale and that this increase seemed to coincide with the decrease in searchlight co-operation.[1] Though it was evident that *Emil-Emil* was an airborne interception device, it was not clear whether it was A.I. or infra-red, and little information was available to indicate its performance. By October, it was apparent that the operational use of this device had spread considerably, and that enemy night fighters were being equipped with it as soon as it became available. The security of the German R/T, however, was very high and there was still no indication of its nature.

A search for German A.I. transmissions was made by T.R.E. from the East Coast, where it was expected that transmissions would be intercepted from enemy fighter aircraft operating in the Flushing area. As a result, radiations received on a wavelength of 61 centimetres and having a pulse recurrence frequency of 3,000 cycles per second were strongly suspected as being connected with the enemy's A.I. The importance of confirming this suspicion became paramount and steps were at once taken to use wireless investigation aircraft on special flights over hostile territory in areas where night fighters would be encountered. In order to obtain this vital information the investigating aircraft had to invite attack by night fighters.

Several sorties had been carried out by an aircraft of No. 1474 Flight, but with no success.[2] However, on the night of 2/3 December 1942 the aircraft was attacked several times by an enemy night fighter, signals on 61 centimetres wavelength being received at maximum intensity throughout the attacks.[3] In spite of the crew (including the special operator) being wounded, the radio and pulse recurrence frequencies were checked three times, and the information successfully conveyed to the appropriate intelligence branch. The report[4] of this investigation flight describing how the frequency of the *Lichenstein* B.C. was established follows.

The operation took place across the north coast of France to an area near Frankfurt. The aircraft was engaged on its eighteenth sortie on this particular investigation, which necessitated the aircraft being intercepted by an enemy night fighter, and up to this sortie all efforts to get such an interception had failed. At 0431 hours the special operator reported that he had been receiving signals on his special wireless equipment which he thought were the ones to be investigated. He warned the crew to expect a fighter attack. The

[1] R.A.F. Wireless Intelligence Service " Little Screw " Report No. 5, A.M. File R.C.M. 103, Encl. 103A.

[2] A.S.I. Report No. 1. [3] A.M. File R.C.M. 151, Encl. 29A.

[4] Operations Record Book (O.R.B.) No. 1474 Flight.

signals grew stronger and Pilot Officer Jordan repeated his warning. A code had previously been arranged to ensure that, if the signals were picked up, the frequency would immediately be sent back to base by W/T, it being absolutely vital that this information should reach base at all costs. The special operator passed the coded message to the wireless operator for transmission to base, giving in the message the required frequency and that this frequency was very probably the correct one.

Jordan then warned the crew that his receiver was being saturated and to expect an attack at any moment. Almost simultaneously the aircraft was hit by a burst of cannon fire. The rear gunner gave a fighter control commentary during the attack and identified the enemy aircraft as a *Ju.88*. Violent cork-screw turns were used as evasive action. Jordan was hit in the arm on this first attack, and, realising that now there was no doubt at all about the signal being the correct one, he changed the coded message, a change that would tell base that the frequency given was undoubtedly correct and that it applied to the signal being sought. Although hit in the arm he still continued to work his sets and to note further characteristics of the signal. The rear gunner fired about 1,000 rounds at the attacker, but his turret was hit and made completely unserviceable and he was wounded in the shoulder. On the second attack Jordan was hit in the jaw, but he still continued to work his sets and log the results and told the captain and crew from which side to expect the next attack. On the third attack the front turret was hit and the front gunner wounded in the leg. The wireless operator went forward to let him out of the turret but he was hit in both legs by an exploding shell and had to return to his seat. Pilot Officer Barry, navigator, then went forward and let Grant out of the turret. Jordan was hit once more, and this time in the eye, and although he continued operating his equipment and noting further details of the signal, he realised that he could not continue with the investigation much longer, owing to his condition. Realising that his inter-com. had also been shot away, he went forward and brought back the navigator and tried to explain to him how to continue operating the equipment and so bring back some more information. By this time he was almost blind, but although he tried hard to show Barry what to do, he realised that it was an impossible task and in the end gave up the attempt.

Flight Sergeant Vachon had by this time come out of the rear turret and had taken up position in the astro hatch, from where he continued to give evasive control, but he was hit again in the hand and Barry went back and took over from him in the astro dome. During this period the aircraft had lost height from 14,000 feet down to 500 feet above the ground, violent evasive action still being taken by the captain. After ten or twelve attacks the enemy aircraft broke off his engagement and disappeared. The Wellington had been damaged, both engine throttles being jammed and both gun turrets unserviceable, in addition to other controls and instruments out of action.

The wireless operator, Sergeant Bigoray, in spite of his injuries, transmitted the coded message back to base, but receiving no acknowledgment for it, continued to send it in the hope that it would be picked up. It was received at 0505 hours. The captain kept the aircraft on the course for home and managed to climb up to 5,000 feet, at which height he came back. At 0645 hours the aircraft crossed the enemy coast at about ten miles north-east of Dunkirk, where searchlights tried to pick it out but these were dodged by evasive action and by coming down low over the sea. When they were switched off, the pilot again managed to gain height.

At approximately 0720 hours the English coast was reached. The pilot tested the landing light to see if he could " ditch " using it, but decided it was impossible. He decided to wait for daylight before " ditching " and asked the crew if anyone preferred to bail out rather than " ditch." The wireless operator stated that he preferred to jump, as one of his legs had stiffened up to such an extent that he thought he would not be able to climb out of the aircraft in the water. He made his way to the escape hatch in the rear of the fuselage, from where he intended to jump, but having reached that position he remembered that he had not clamped down the W/T transmitting key, and in spite of his injury he returned to his set, clamped the key down, and warned the crew not to touch it. He jumped out over Ramsgate and made a safe landing. The pilot " ditched " the aircraft at approximately 0824 hours in the sea about 200 yards off the coast at Deal. The dinghy inflated but had been holed by cannon fire. The special operator tried to make it airtight by holding some of the holes, but it was impossible and the crew got out of the dinghy and climbed on to the aircraft. About five minutes later a small rowing boat appeared, took them off and rowed ashore.[1]

A Counter-Measure to *Lichtenstein* B.C. (" Ground Grocer ")

The existence and transmission characteristics of the German A.I. *Lichtenstein* B.C. having now been confirmed[2] it was urgent that radio counter-measures should be taken against it. T.R.E. had examined the problem of jamming the German A.I. in November 1942 and as soon as the frequency of the A.I. became known, designed and produced a suitable jammer in ground station form known as Ground Grocer, which came into operation at Dunwich, near Southwold,[3] on 26 April 1943. Originally it had been intended to employ the form of jamming known as Railings, but so much research was involved in the perfection of this, that it was eventually abandoned in favour of noise jamming. Operating on a frequency between 486 and 501 megacycles per second a paraboloid aerial was used to pick up the *Lichtenstein* pulses, which were panoramically displayed to the operator.[4] The latter, by means of remote control, tuned the jammer transmitter to the same frequency. The transmitter fed into a similar aerial, orientated in the same direction, thus modulating a beam 16° wide. It was estimated that Grocer would reduce the range of *Lichtenstein* B.C. to 500 yards if the aircraft were as far distant as 140 miles, at a height of 12,000 feet and within the beam of the paraboloid and flying towards the station. With the aircraft flying away from the station, however, the effectiveness of Grocer was greatly reduced,[5] the power required to jam as effectively as head-on, for a given range, being some 250 times as great as for the head-on case. Thus Ground Grocer was mainly a cover for Allied bombers on their return journey. In order not to give the enemy early warning of the approach of Allied bombers Ground Grocer was not switched on until the leading aircraft were within 30 miles of the enemy coast. The beam was swung to cover both the outward and return journeys.

---

[1] The following immediate awards were made to personnel concerned in this flight:—P/O Jordan—D.S.O., P/O Paulton—D.F.C., F/Sgt. Bigoray—D.F.M.

[2] K.B.L./J.H./V.R., 28 November 1944, A.M. File F.C.M. 155, and 80W/S.3032/2/Sigs.

[3] A.M. File R.C.M./175/Tels. 2.

[4] H.Q.B.C. " Particulars of R.C.M. and R.D.F. Equipments," November 1943.

[5] A.M. File R.C.M./175/Tels. 2, Part II.

That this counter-measure achieved some success is supported by the fact that of the seven cases of interference reported by German night fighters to their ground control and intercepted by our " Y " Service during the period ended 30 June 1943, six took place after Ground Grocer went into operation. It was estimated that effective cover against the German A.I. had been given at least up to, and over, the enemy coast.

Use of Window against *Lichtenstein* B.C.

Meanwhile, intensive preparations for the first use of Window were being made, and it came into use on the night of 24/25 July 1943. The main use of Window was against the German 53-centimetre (560 megacycles per second) ground search radar, but there was good reason to believe that it would also give some protection to a bomber aircraft from the 60-centimetre (490 megacycles per second) *Lichtenstein* B.C.[1] The use of Window against an airborne radar equipment could never be so effective as against ground radar because the strips did not remain for more than a brief time in the narrow beam. A great deal of Window was therefore required and it was necessary to keep up a high rate of discharge. Furthermore, unless the rate of discharge was sufficient to keep the whole of the Lichtenstein tube fully covered, it was possible for the operator to distinguish the echo of the bomber aircraft from those made by Window, because the aircraft appeared as an almost stationary object relative to the pursuing *Lichtenstein*, while the Window strips appeared to be approaching at high speed. While it was generally accepted, therefore, that Window could be an embarrassment to fighters operating *Lichtenstein* B.C., it was considered probable that a competent operator would be able to work through it.[2]

Airborne Grocer and Tuba

An airborne version of Grocer, a barrage jammer developed from the ground-station version, was also planned to work against *Lichtenstein* B.C.[2] This jammer was calculated to reduce the effective range of the set to about 900 yards when the enemy aircraft was less than 22 miles behind our jamming aircraft. It was estimated that 11 aircraft carrying Airborne Grocer were needed to protect a bomber lane 180 miles long by 20 miles wide, the jamming aircraft flying some 5,000 feet above the main bomber stream. Much ingenuity was put into the design of this counter-measure and especially the aerial system. The transmission was beamed in the form of a 60° cone, tilted slightly downwards, with its apex at the tail of the aircraft radiating it.

Airborne Grocer was long delayed from coming into operation. Although available in June 1944, it was decided to postpone it, as its use as a homing beacon or a plotting beacon to the enemy was considered to outweigh its anticipated value as a jammer during the summer nights. In mid-summer, conditions of absolute darkness never occurred on fine nights at the altitude of operation of the bomber aircraft, and once the enemy night fighter had been directed into the bomber stream he had little need of radar to complete his interception, which could be done visually. On the other hand, the enemy could have used the Airborne Grocer transmissions both for tracking the stream

---

[1] A.S.I. Report No. 79, Part III.

[2] No. 100 Group " Reports of Activities, December 1943–April 1945." Reference: A.H.B./II H1/45, and A.H.B./II E/76.

and for homing fighters into it. By the time the dark nights came round again it was clear that *Lichtenstein*, for which Airborne Grocer was designed, was obsolete. In a similar manner, a high-power version of Ground Grocer, called Tuba, of American design, became available just too late to be of use.

S.N.2

By the end of April 1944 *Lichtenstein* B.C. was almost out of operation in the European theatre; yet it was evident from the scale of German successes with bomber interception on the darkest nights that they had developed a new radar equipment or radio homer for use in night fighter aircraft. Information received suggested that the use of a much lower frequency was to be expected.[1] With the simpler aerial system and wider beam to be associated with a change of this sort, the enemy fighters' task would be somewhat simplified, and also a much lower frequency would probably be free from any form of Allied jamming then in use.

The new development was eventually coupled with the code name *S.N.2.* Until the frequency was known, effective counter-measures could not be taken. An air search for signals with the appropriate characteristics was accordingly made by No. 192 Squadron in all likely frequency bands, but it was not until a blurred photograph of a German night fighter standing at a dispersal point on an enemy airfield was obtained by the camera gun of a ground-strafing American aircraft, that the first reliable clue was obtained. The photograph showed that in the nose of the fighter was an exceptionally large aerial system of a kind likely to be used for A.I. working on what appeared from its dimensions to be a frequency of about 100 megacycles per second. The use of such a frequency seemed most unlikely, but when signals which were airborne in origin and with A.I. characteristics were heard on a frequency of about 160 megacycles per second, it was concluded that they might emanate from the new A.I. set. This conclusion was strengthened by knowledge of the existence of a German bomber rear-warning device, on about this frequency, which it was then thought could easily be modified to be forward-looking and used for interception purposes.

Decision to use Window against *S.N.2*

Bomber Command accepted the evidence as sufficiently conclusive for counter-measures to be taken, and put into force two methods of jamming an A.I. set on such a frequency.[2] One method was the use of a Mandrel type of signal, giving direct electrical interference, and the other was the use of Window to confuse the operator. As the first step, all Mandrel sets were removed from main force aircraft and modified to work on 160 megacycles per second. Preparations were also made for the alternative method, for it had become clear that if manufacturing and launching difficulties could be overcome, Window could be used successfully against all types of search radar. The particular problem was that associated with the design, production, and launching of long lengths of Window. On 6 May 1944, Bomber Command asked the Air Ministry to produce, as a matter of the utmost operational urgency, a large quantity of Window for use on the presumed new A.I. frequency band 156–176 megacycles per second.

[1] A.M. A.D.I. (Science) Reports, April 1944.
[2] A.H.B./II E/76. "War in the Ether." An account of R.C.M. in Bomber Command.

These measures were never, however, put into effect because information about the true frequency of the new German A.I. set came into British hands shortly afterwards. On the night of 13 July 1944 a *Junkers 88* night-fighter aircraft which had been engaged on a routine patrol over the North Sea made an elementary navigational error when setting course to return to base and made landfall over the coast of Suffolk, believing it in the dark to be Holland. After circling Woodbridge airfield the aircraft was given the green signal from the Watch Office, and the pilot, thinking himself in the neighbourhood of Venlo, made a normal approach and landing, taxied to the end of the runway and switched off his engines. It was not until the Royal Air Force Flight Sergeant who went out to meet the aircraft found himself face to face with the German crew, with mutual astonishment, that anyone realised that a mistake had been made.

The enormous value to the Royal Air Force of this occurrence became apparent when the *Junkers 88* was found to be fitted with not only the *S.N.2* set but also the *Flensburg*, a device for homing to Monica. The crew disclosed that *Naxos*, of which they did not know very much, was the code name for the German homer to H2S. On the initiative of the Chief Signals Officer, Bomber Command, agreement was obtained from the Controller of Research and Development, Ministry of Aircraft Production that the *Junkers 88* should be held by the Royal Aircraft Establishment, Farnborough at the disposal of the Command for such tests and experiments as might be considered necessary. Stringent security precautions were taken to prevent the enemy knowing that the aircraft had arrived safely in this country, even to the extent of keeping the crew segregated for some months. The value of the information represented by the aircraft was very much the greater because of the paucity of intelligence of German radio equipment at the time. The names *S.N.2*, *Flensburg* and *Naxos* had been mentioned in connection with night-fighting but no useful details were available. It was difficult to gain much information now that the air war was being carried on over German territory, and the Germans were normally careful to avoid any risk of their night-fighter equipment falling into British hands. The fortunate acquisition of the *Junkers 88* was therefore a remarkable stroke of luck.

The immediate result of the capture was to enable Bomber Command to adjust their counter-measures against *S.N.2* to the proper frequency of 90 megacycles per second, and the use of Window was thought likely to give the speedier success. A good supply of Window, Type MB, was happily available, having been surplus to requirements for the landing in Normandy. This material had been designed for use against enemy radar in the frequency range of 60–200 megacycles per second, and there was every hope that it would give a good enough response on 90 megacycles per second to make *S.N.2* difficult to operate, if not unworkable.

First Use of Window against *S.N.2*

Window, Type MB, was first used on the night 23/24 July 1944 in the raid on Kiel, and again on the two following nights when Stuttgart was attacked. There is no doubt that on all these raids the enemy would have inflicted heavier losses had he had the unrestricted use of his A.I.[1] It would, however, be wrong to attribute the extraordinarily light losses experienced entirely to Window.

[1] Air Ministry A.D.I. (K) Report No. 416/1945.

A new version of Jostle IV (an R/T night fighter control jammer) was introduced by No. 214 Squadron at the same time, and by chance its second harmonic seriously affected *S.N.2.*[1] Whilst it is impossible therefore to assess precisely the effect of Window, it seems that Window and Jostle IV together had good results against *S.N.2*. Some credit for the lightness of the losses must also be given to diversions which took place on the first two of the three nights.

Experiments made later showed that the maximum range of *Lichtenstein* B.C. was reduced by Window to about half a mile, and that *S.N.2* was completely ineffective within the bomber lane.[2] Nevertheless, it was found that *S.N.2* could be effective against bombers above, at the head of, or on the windward edge of the stream, and against stragglers. Althought it is possible that the more experienced A.I. crews eventually learnt to read through Window of this type, it seems more probable that the majority of claims to this effect arose from unusually good optical visibility coupled with the high density of bombers in the vicinity of the contacts.[3]

Use of Piperack

It was becoming evident, however, especially to the R.C.M. Group, that the failure of Window to protect the fringes of the bomber stream and the stragglers was a serious weakness. Electronic jamming such as had been accidentally caused by Jostle, on the other hand, had no such limitations. Furthermore, it could be delegated to a small specialist R.C.M. force, thus relieving the main force bombers of a considerahle Window task.

In November 1944, prototypes of a new airborne jammer of the type required, called Piperack, were put on trial in Nos. 214 and 233 Squadrons.[4] The installation, designed to jam *S.N.2*, comprised an American jammer called Dina (originally used to reinforce Mandrel), coupled with an amplifier. It thenceforth became customary for Nos. 214 and 233 Squadrons to operate Piperack to cover the main bomber force and the No. 100 Group spoof force.[5] A number of sorties were flown in the early stages by No. 192 Squadron for the purpose of analysing the effect.[6] The squadron's analysis and the low bomber loss at the hands of German A.I. fighters showed that Piperack was proving very effective. That held good until the end of January 1945, by which date it was becoming clear from the nature of enemy A.I. successes that he was again enjoying a measure of immunity from radio counter-measures. Both Intelligence Service and No. 192 Squadron reports indicated that *S.N.2* was being operated on frequencies outside the range of Allied jammers and covering a band from approximately 70 to 120 megacycles per second.[7] Arrangements were accordingly made to double the number of jammers in each aircraft and to extend the fitting of jammers to the Mosquito aircraft of No. 192 Squadron. In addition, Piperack was being modified to a T.R.E. design for operation below 85 megacycles per second, and this change finally enabled it to cover the entire *S.N.2* frequency band. By February the modified jammers were operational. Fortress aircraft of No. 214 Squadron were operated in pairs with their jammers set up on alternate

[1] No. 100 Group. "Report on Activities," July 1944 (A.H.B./II H1/45).
[2] H.Q., No. 100 Group File 100G/TS.1223/2.
[3] A.S.I. Report No. 79, Parts III, IV and V.
[4] A.H.B./II H1/45, November 1944. "No. 100 Group Monthly Report of Activities."
[5] *See* Part 2, Chapter 12, of this volume.
[6] A.H.B./II H1/45, December 1944.
[7] *Ibid.*, January 1945.

frequencies, thus covering the required frequency band without having to change aerials. The normal procedure was as follows. Specialist Piperack aircraft flew to the target area over routes well clear of the bomber stream, gaining information and recordings of enemy R/T communications *en route*. When they arrived at the target they remained there to jam German A.I. with Piperack until the bombing mission had been completed and the bombers had left on their return to base. Thus the bomber stragglers were covered.

There are two especially interesting points in the enemy's use of *S.N.2*. The first is the adoption of a lower frequency band which would appear to have been a retrograde step in development. The simple type of aerial employed gave a " floodlight " coverage and was easier to jam, either by Window or electronic means, than was a narrow-beam system. A possible reason for its adoption is that having been deprived of his close fighter control by Window, the enemy required a wide-beam type of equipment to enable fighters to search in the bomber stream without close control.

The second point is the great advantage which a radio weapon can confer, as long as the secret of its employment can be maintained. The crew of the *Junkers 88* captured on 13 July stated that the *S.N.2* was fitted in 80 per cent. of the aircraft of the German night fighter force and had been in operation since December 1943.[1] The enemy had been using the *S.N.2* for six months before it was successfully jammed, and during that period it gave excellent results. By the spring of 1944, also, the German ground search radar stations had been modified to enable them partially to overcome the effects of jamming, and the enemy's air defences had thus almost recovered from the initial set-back caused by Window. During the raid on Nuremburg on the night of 30/31 March 1944, for instance, the enemy scored one of his biggest defensive successes of the War. Supremacy in the radio war, together with a lower rate of losses for Bomber Command, was only gained after a wider outlook had been adopted on radio counter-measures, and tactical use was made of the technical advantages which were at hand.[2]

Development of German Metric A.I.

After the neutralisation of the *S.N.2*, a radical change in the technical form of enemy A.I. was to be expected. It was known that the Germans were aware of the potentialities of centimetric technique and that they had captured a Royal Air Force centimetric H2S, and hence it might be expected that they would produce an A.I. set operating on centimetric wavelengths. Before doing so, however, the enemy made attempts to modify metric *S.N.2* to defeat Window and Piperack jamming.[3] At the same time he managed to reduce the minimum range from 400 metres to 200 metres—an essential requirement from the time when Bomber Command commenced its bad visibility massed raids.

In pursuance of the general anti-jamming policy of the Germans, the *S.N.2* sets were manufactured to make a series of different wavelengths available. Change of frequency in the air was not possible as it involved the use of a different receiver and transmitter, in addition to which alterations to the aerials were necessary. As Window and later electronic jamming increased in intensity, new frequencies were prepared in an attempt to escape interference and in all

[1] A.M. A.D.I. (K) Report No. 416/1945, para. 44. [2] *See* Chapters 14 and 15.
[3] A.M. A.D.I. (K) Report No. 370/1945, paras. 35–37 and 56–60.

some ten *Streuwellen*[1] were prepared, though only about four had been used up to the time of the capitulation. During the final stages of the war, the Germans' apprehension of jamming was so pronounced that an *S.N.2* equipped with wire aerials (*Drahtantennen*) and operating on a frequency of 34 megacycles per second was undergoing trial. The only attempt to install an anti-jamming component in the *S.N.2* was made towards the end of the war when *Taunus*[2] was employed to obtain better resolution against Window, but no conclusions as to its effectiveness had been drawn.

In early 1944 a new tactical requirement was put forward for a metric A.I. set, the frequency of which was to be capable of being changed in the air. The resulting set was the *S.N.3*, which offered ten alternative frequencies. Only one specimen was completed during 1944 which gave every promise of success when under test. The first sets were to be available early in 1945, but production was not started as towards the end of 1944 German A.I. policy was changed and concentrated on centimetric equipment.

The modifications of *S.N.2* enabled the more experienced crews to operate through Window jamming and in considerably worse conditions of visibility. Similarly, they could operate, but with difficulty, through Piperack electronic jamming, which normally reduced maximum range to half. At the same time, the aerial arrays needed for metric A.I. reduced the performance of the fighter aircraft and the various presentations of response from the target aircraft tried were never easy to interpret.

Only a few *S.N.3s* were ever completed. At the last moment the *S.N.3* was abandoned, firstly because the band on which it worked was heavily jammed as it included *Freya* frequencies, and, secondly, because a new equipment, the *Fu.Ge. 218* (*Neptun V.R.*), operating on the 1·60–1·85 metre band and offering six alternative spot frequencies, was not jammed. It was therefore decided, as long as centimetric equipment was not available, to use the *Neptun V.R.* in place of the *S.N.2* in night fighter aircraft.

The *Fu.Ge. 218* was originally developed as a pilot-operated A.I. set for single-seater night fighters. As it operated on a frequency band which hitherto had been unjammed and had six alternative frequencies which could be selected in the air, it was proposed to install the *Fu.Ge. 218* in both single and multi-seat night fighters with a forward-looking and backward-looking antler-type aerial array, instead of the Yagi type usually used with the *Neptun* series. The last big effort to make metric A.I. effective appears to have been the introduction of a far more powerful transmitter for the *Neptun*.

Piperack against *Neptun V.R.*

The new German A.I. began to be effective in February 1945, during which month enemy night fighters had more successes against bombers than for some considerable time.[3] At the same time, Mosquito successes against the fighters, together with numbers of Serrate contacts, declined appreciably. By the end of March it had grown clear that, but for the very small number of Luftwaffe fighters engaging British bombers—due mainly to No. 100 Group spoof[4]—the new A.I. was a serious menace.

[1] *S.N.2* equipments covering different frequency ranges.
[2] An anti-jamming modification to *S.N.2*.
[3] A.M. A.D.I (Science) Reports, February 1945, and A.H.B./II H1/45, February/March 1945.
[4] *See* Part 2, Chapter 15, of this volume.

As soon as the frequency of *Neptun* had been measured, work was begun in March in No. 462 Squadron on a new version of Piperack to operate against the new enemy A.I. In this installation, a non-directional aerial was mounted on the fuselage at an angle of 45° to the horizontal in order to enable it to deal with horizontal as well as with vertical polarisation. The new Piperack became operational in the following month, but with what success it was not possible to judge. So many factors entered into this as the enemy became rapidly overrun by the advancing Allied forces in North-West Europe that a reliable analysis was found to be impracticable.

German Centimetric A.I.

During the final stages of modifications to metric A.I., on which comment has just been made, the enemy was working hard to produce a centimetric A.I. equipment. The Germans discovered the existence of the Royal Air Force 9 cm. H2S set in January 1943, and in July of that year, parts of the latest British centimetric set, A.I., Mark VIII, were captured by them from a crashed Mosquito aircraft. A German 9 cm. A.I. set was quickly developed from his reconstruction of the H2S set and was called *Berlin N.1.A*. It had the disadvantage of being a manual scanning type and of being under-powered, but plans were in hand when the war ended to introduce automatic scanning and 3 cm. operation. There is no doubt that but for the capitulation of Germany in May 1945, the Allies would have had to wage a serious radio counter-measure campaign in this new field of A.I. operation.

CHAPTER 13

RADIO COUNTER-MEASURES AGAINST THE GERMAN RAID-TRACKING SERVICE

Radio counter-measures against the German air defence radar had left the *Luftwaffe* without an adequate supply of information about the approach and movements of the Allied bomber forces. Having thus lost the use of their eyes, in the electronic sense, the Germans applied themselves more energetically to the use of their ears, also in the electronic sense, taking the greatest possible advantage of the information to be obtained from listening for all wireless and radar transmissions made by Bomber Command aircraft.

A large raid-tracking organisation called the *Horchdienst* (Listening Service) was formed for the purpose of providing information of the approach, direction and route of the bomber stream. The building up of this service was the result of much improvision by General Martini, Head of the German Signals Service, for the organisation of the *Luftwaffe* Signals Intelligence at the beginning of the War had been merely sufficient for the needs of Blitzkreig tactics. The great value of the service was impressed on the Germans by the success of the British radio counter-measures. The *Horchdienst* gained a new importance with the adoption of free-lance night-fighter tactics by the German air defence.

The Horchdienst was a distinct part of the enemy's general Intelligence Service and, more particularly of that part of it responsible for purely signals matters called the *Chiffrier-Stelle, Oberbefehlshaber der Luftwaffe.*[1] It was maintained as an organisation wholly separate from the German Air Defence Command, information from the former being fed to the *Jagddivision* Operations Room in which a special Signals Intelligence section examined information from central Intelligence sources and from individual *Horchdienst* stations in the Division area. The officer in charge of this section was responsible for seeing that information so obtained was properly displayed on the main operations map and that it was fully available to the Chief Operations Officer and to the Air Situation Control Officer. This close link was, however, only achieved by General Schmidt after a long struggle with General Martini, the Head of the *Luftwaffe* Signals Services, to whom the *Horchdienst* (Listening Service) " belonged ".[2]

The Germans eventually attached great importance to the information derived from their signals and radar listening stations. This service had three distinct functions, namely, the reception and analysis of :—

(*a*) Allied R/T and W/T aircraft transmissions.

(*b*) Allied radar transmissions.

(*c*) Allied jamming transmissions.

A network of intercept stations was spread over all probable areas of approach for Allied bombers.[3] Each station had a group of 45 ft. wooden towers associated with small huts in which intercept-receivers with D.F. aerials were installed. In addition, each site had a *Flammefreya* installation for triggering

[1] A.H.B./II E/88A. Report on an investigation of a portion of the German Raid Reporting and Control Organisation.

[2] A.D.I. (K) Report No. 416/45, Part VII. [3] A.H.B./II E/88A, Appendix C.

Allied I.F.F. sets and for measuring their range and bearing, together with *Korfu* apparatus to obtain bearings on H2S and 10 centimetre transmissions from Allied bombers.[1] The minimum range of each station of this kind was of the order of 100 kilometres. They were accordingly spread at intervals of 200 kilometres.

Every form of transmission to and from and on behalf of Allied bombers was capable of interception with D.F. and, in some instances, of being measured for range by the *Horchdienst*. The transmissions intercepted included A.I., A.S.V., H2S, H2X, I.F.F., Monica, Oboe, and radio telephony and telegraphy on all used frequency bands. The signals from A.I. and Oboe were obtained from interrogation by German as well as British equipments.

It was realised by the Royal Air Force that every wireless and radar equipment employed in connection with bombing operations would sooner or later be made use of by the Germans to ascertain the intentions and movements of raiders. The only way to ensure that the enemy did not make any such use of transmissions by radio equipment was to place rigid restrictions on its employment. This course was invariably incompatible with the effective use of the equipment. The decision as to the most advantageous compromise between rigid restriction and the unlimited use of a set was a very difficult one. Similar problems, of course, occurred in other directions, as for example the choice which the Germans had to take between non-interference with Allied transmissions for the benefit of Horchdienst, and the more direct action of jamming which was sometimes favoured by other sections of the enemy air defence organisation.

The obvious line of action for a bombing force against a raid-tracking listening service of this type was to refrain from transmitting during certain phases according to the strategic and tactical plan. The importance of planned "radio silence," as this practice was termed, was brought home to the Royal Air Force from the very start of bomber operations. As early as December 1939 a force of *Wellington* bombers attempted a daylight raid on Wilhelmshaven. In the approach flight its radio traffic was picked up by German intercept units which immediately passed the results (location, height and course) direct to the German Air Force Fighter authority concerned.[2] As a result, German fighters were directed to a favourable point for interception and were enabled to inflict heavy casualties on our aircraft.

It was the normal practice in those days for the Royal Air Force bomber to make a brief transmission to test his transmitter (W/T Go procedure) immediately after take-off. As a result of the incident just described, an effort was made to intersperse dummy transmissions between those of genuine sorties. Even so, the enemy was able to discriminate between them to a great extent in spite of careful simulation of airborne transmitter characteristics in dummy ground transmissions. Even daily inspection tests on aircraft at dispersal points, in which check and calibration tests on open aerials were made, afforded the enemy valuable evidence of the intentions of Bomber Command. Furthermore, wireless discipline in bomber aircraft was initially bad and the enemy obtained tracking information from D.F. bearings on illicit traffic. Bomber Command was quick to improve signals discipline, to stop all

---

[1] *See* A.H.B./II E/88A. Appendix D, paras. 51 to 53, and Appendix E for Technical details.

[2] A.D.I. (K) Report No. 406/1945.

transmissions on the outward journey, and to have all ground checks made on artificial aerials. But even the apparently innocent process of back-tuning the R.1155 receiver from the master-oscillator of the T.1154 transmitter while over enemy territory was detected by D.F. and used by the enemy to good purpose.

It has been found from post-war examination of *Luftwaffe* records and personnel that, after 1941, signals discipline in Royal Air Force bomber aircraft in general was considered by the enemy to be of a high standard.[1] Activities of other services, however, often gave useful information away through unguarded transmissions or by virtue of the amount and nature of their transmission activities. W/T and R/T activities at bases, meteorological messages, D.F. section tuning, Air/Sea Rescue traffic and later specific messages from the Allied Expeditionary Air Force Aircraft Reporting Centre broadcast for the warning of anti-aircraft and night-fighter units on the Continent of the imminence of arrival of Allied bombers all contributed something useful to the German raid tracking service. The Germans claim that no major raid by United States Army Air Force aircraft ever came as a surprise. Their aircraft signals traffic, especially during assembly, gave them away, and air-to-air R/T traffic between bombers and escorting fighters provided a reliable track to the enemy. Day-to-day aircraft codes were readily broken down by the Germans if used much during the day: hence only complete W/T and R/T silence on the way to the target could hope to afford immunity from the watchfulness of the *Horchdienst*.

When the Allied landing in North-West Europe became imminent, and again later when it had become quite clear to the German High Command that they were overwhelmed in the air, the insistence by German Signals Intelligence that Allied aircraft W/T and R/T should not be jammed, was resisted.[2] The ground jammers intended for use against Allied invasion forces on D-day were, however, destroyed by Allied fighter-bombers, and the large jammer offensive planned during 1945 was mainly forestalled by the capitulation.

I.F.F. Transmissions

A ground radar station capable of triggering the I.F.F. set of an aircraft could obtain response from very much greater range than was obtainable with a radar reflection from the aircraft in the normal way. At the same time, both range and bearing of the aircraft so triggered could be ascertained. Furthermore, the radiation from I.F.F. sets in Royal Air Force aircraft, when triggered by British ground radar stations, was capable of being received by ordinary V.H.F. D.F. stations to give a bearing (employing one station) or to give a fix when two or more D.F. stations were employed. The enemy early became aware of the existence and main characteristics of British I.F.F. sets and it was immediately clear to him that he could exploit in this way any use by the Allies of I.F.F. during the outward flight to Europe.

The anxiety of the Air Staff to ensure absolute discrimination between friendly and enemy aircraft in order to avoid casualties to friendly aircraft from Royal Air Force fighters, can easily be appreciated. Orders were issued that I.F.F. should be used in all operational Commands as soon as aircraft

[1] A.D.I. (K) Report No. 406/45, paras. 7–19. [2] A.D.I. (K) Report No. 380/45.

crossed the British coast. Thus I.F.F. was used liberally from the outset of the Bomber Command offensive. Whether, and if so to what extent, the enemy could glean any information from the I.F.F. was at that time considered hypothetical, whereas the importance of discrimination between friend and foe was real. Furthermore, at that time Bomber Command raiding was normally in waves and massed concentrated raids were not yet being used, so that the main bomber intention was not so easily to be divulged to the enemy tracking service as it became from mid-1943 onwards. Thus on 27 October 1940, Air Ministry ordered that bomber aircraft were to keep their I.F.F. sets switched on until they reached their home bases.[1] This regularised I.F.F. procedure. In February 1941, by which time all concerned had become more conscious of the tracking and homing danger of I.F.F., Bomber Command limited its use to within fifty miles of the English coast on the way out and one hundred miles from the coast on return. There were exceptions; aircrew discipline in this matter was not always good, and there were technical faults. It is known now that the enemy were able to get an excellent picture of the British bomber rendezvous and early tracks from tracking of outward-bound transmissions from I.F.F.[2]

It has already been recounted how, in October 1940, Bomber Command came to the conclusion that I.F.F. interfered with enemy radar searchlight directors, thus affording protection to the bombers, and how I.F.F. was used over enemy territory for that purpose.[3] Ultimately statistics appeared to show that no real benefit was being derived in the way intended. Having regard on the one hand to the apparent failure of the " J Switch " procedure and on the other, to the increased vulnerability of Royal Air Force bombers to German night-fighters when massed raid tactics had been adopted, Bomber Command asked the Air Ministry on 7 July 1943, for permission to discontinue use of I.F.F. throughout the outward journey.[4] Air Ministry and Fighter Command at once agreed, provided that the bombers kept above 5,000 feet.

Monica Transmissions

The danger that the transmissions of Monica might be used as a beacon to which enemy fighters could home has already been mentioned. The same transmissions also offered an opportunity to the enemy of plotting the movements of bombers which carried the equipment. It was therefore necessary to decide whether the value of Monica as a warning device was outweighed by the advantage it gave to the Germans. Trials in which a captured *JU.88* aircraft fitted with *Flensburg* homed to Monica transmissions from a bomber in the face of a Window screen, so emphasised the danger of Monica on balance of all considerations that, on 12 September 1944, Monica was withdrawn from service. It was the homing threat, however, which brought about this last measure, but in the meantime the early-warning and tracking threat led to a limitation of the use of Monica to periods while flying over enemy territory. There is no evidence to show that tracking on Monica played a very important part in enemy plotting as a whole, but there is evidence that it made a contribution to the final picture. This was probably because tracking on H2S and I.F.F. was already adequate from the time when the *Horchdienst* raid-tracking became an integral part of German air defence.

---

[1] A.M. File S.6430, Encl. 10A.
[2] A.D.I. (K) Report No. 416/45.
[3] In Part 2, Chapter 7, of this volume.
[4] A.M. File C.S. 3062/II, Encl. 72B.

H2S Transmissions

H2S was of the highest importance to Bomber Command. It enabled British bombers to reach and identify their targets in almost the worst type of weather on any line of approach and without the need for communication between the ground and air. Finally, it enabled the bombers to bomb many targets fairly accurately in blind conditions, irrespective of range from base. It is therefore easy to appreciate why the Air Staff should have resisted any proposal not to use H2S on the grounds that it would probably afford the enemy both tracking and fighter homing facilities. Effective use of H2S called for a good deal of practice on the part of aircrews in the air and their confidence in the new equipment had to be established. The tempo of operations from mid-1943 onwards left inadequate time for training, and advantage was taken of operational flying for this purpose. The additional operational use of H2S in this way did not appear to increase the casualties of bombers fitted with this device (which were low, over-all) although analysis by the Operational Research Section was confused by the multitude of factors to be taken into account. All of the arguments combined to make a good case against restriction of the use of H2S.

But the counter-arguments were equally cogent. In the first place the enemy, by using H2S for long-range plotting of the movements of the bomber force in areas where Gee cover existed, was deriving more immediate benefit from H2S in those areas than was Bomber Command. The bomber force, on the other hand, only derived training value over those areas and that could be gained on the return flight. Secondly, whereas it was true that the over-all casualty loss rate was low, that was not so if operations against Germany alone were considered. For the month of July 1944 the Bomber Command loss from all operations was only 1·6 per cent., but taking German targets only, the loss rate was 4 per cent. Furthermore, the homing risk had to be weighed in this balance: whereas there was probably little risk to individual bombers from *Naxos* homing, the bomber force as a whole could be endangered by H2S transmissions over Germany enabling *Naxos*-equipped enemy fighters to home into the bomber stream generally, and so to complete their interceptions of individual bombers by means of German A.I. Thirdly, the proposal to switch off H2S while within Gee cover could not affect bombing accuracy, which was the primary consideration. As there was ample opportunity for practice during the return flight, considerations of security and secrecy on the outward flight outweighed those of additional training to be derived from H2S practice on the way to the target.

The Air Officer Commanding-in-Chief, Bomber Command was well aware that the Command might lose some of the effectiveness of H2S if crews came to regard it as a source of danger. On the other hand, it was imperative to deny to the enemy the ability to plot the bomber force at long range. With the Air Officer Commanding No. 100 Group pressing continually for the maximum of H2S silence, discussion and argument swayed around all these points until 22 July 1944, when the Air Staff decided that H2S should remain switched off until within 40 miles of enemy territory. This restriction was put into force on the night of 28/29 July 1944 (target Hamburg), when radar silence was to be observed up to 06° 00 E, together with a height restriction of 4,000 feet for the sea crossing. Unfortunately these orders were not obeyed by all aircrews and this first experiment was accordingly a failure. The principle was nevertheless recognised to be sound and, when the full co-operation of aircrews was eventually obtained, the procedure proved most effective.

In some quarters, however, the opposition to restrictions on the use of H2S continued and the Command was indeed accused of mismanaging its affairs in this respect. There was considerable uneasiness among aircrews over the situation and the Command Air Staff was warned by Groups that confidence in H2S was rapidly being lost. As a result, on 13 October 1944, Command Headquarters gave Groups a full appreciation of the subject and instructed them to inform aircrews fully in the matter.[1] Professor P. I. Dee, who was in charge of H2S development at T.R.E., was appointed to investigate this vexed question. His findings were a complete vindication of Bomber Command's policy.

Lack of co-operation between the *Luftwaffe* listening service (*Horchdienst*) and the *Fliegerkorps XII* at one time jeopardised the benefit to be derived by the German night-fighter force from raid-tracking signals intelligence information and from interception of H2S in particular. General Schmidt (commanding *Fliegerkorps XII*) tried to break the barrier which had risen between the two organisations by unconventional means, and has recounted how a "tragicomical" situation—as he termed it—then arose. When the possibility of tracking raids by their H2S transmissions first became known Schmidt "took up" an officer belonging to a neighbouring *Horchdienst* unit, a certain *Oberleutnant* Rückheim. Their meetings, ostensibly for the dispensing of schnapps, were kept secret as General Martini's orders forbade official contact. Bringing about unofficially what Martini refused to sanction officially, Schmidt introduced Rückheim to the *Jagdkorps I* operations room during the course of several night operations. These visits bore fruit and, up to November 1943 Rückheim was able to reciprocate Schmidt's hospitality by supplying him with up-to-the-minute reports on H2S concentrations. Schmidt, however, was not allowed to continue this arrangement as *Horchdienst* Battalion West—the intercept unit which covered the area from the Heligoland Bight to the Channel coast—was subordinated through a superior formation in Paris to *Luftflotte 3* and its reports had therefore to be passed back to Paris before distribution to outside commands. When General Martini heard of the evasion he ordered removal of the radar personnel and equipment to Paris. General Schmidt countered this by himself providing the necessary sets and personnel, and, after a period of intense training, the work went on as before. The struggle reached its climax when General Schmidt, by direct approach to Goering, obtained Rückheim's promotion to Hauptmann and commanding officer of a *Horchdienst Abteilung*. But he never succeeded in obtaining the subordination of *Horchdienst* Battalion West to his own command.

H2S plots covering the area up to the line Bremen–Stuttgart were collated at Zeist and a further station was set up in Berlin to cover from Bremen to Stettin and was later extended to take in Southern Germany. This latter was subordinated to *Befehlshaber Mitte* (later Luftflotte *Reich*) so that once again Schmidt was obliged to receive H2S reports at secondhand. All these difficulties occurred at a time of intense British night bombing activity, when delayed or wrongly interpreted H2S reports might have had a serious effect on decisions of the German night-fighter command.

---

[1] As this appreciation sets out fully the arguments surrounding this decision, it is reproduced at Appendix No. 16

With the liberation of France in the late summer of 1944 a considerable number of sets employed for plotting Allied H2S transmissions were allowed, by negligence of the German Air Force signals personnel, to fall into Allied hands. A large number of expert *Luftwaffe* listening service personnel were taken prisoner and a gap was torn in the *Horchdienst* organisation between the Eifel and the Swiss frontier. The effectiveness of the new radar silence drive found much testimony. For example, on 9/10 July 1944 when the Germans were still in France, No. 5 *Jagddivision* reported that, as no H2S signals were intercepted until the Royal Air Force bombers were over the Channel, the German defensive fighters could not take off in time.[1] In a raid on Cologne on 13/14 October 1944 the bombers were not picked up at all until they had dropped their bombs. An outstanding example was the breakdown of the German defences during the twin attack on Dortmund and Bremen on 6 October 1944.[2] The Bremen raid made a low approach under radar silence and covered by a Mandrel screen. As a result enemy fighters were only able to come into action at the target ten minutes after bombing had begun. The Dortmund force flew low over France, turned north and climbed towards the Ruhr, while a Window force and some Mosquito aircraft went on to threaten Mannheim. Only 13 bombers were lost out of a force of 949 aircraft. General Schmidt's castigatory diatribe against his defence organisation is almost unprintable, but in it he makes it quite clear that information from the radar and raid-tracking services was "wholly inadequate" and, in particular, that the H2S picture was obscure. He stated, "I am astonished that, in spite of pains, admonitions and orders throughout a whole year, I have not succeeded in bringing the *Jagddivision* at least to the point of being able to distinguish in what strength and from what direction the enemy are approaching. In my view there is no excuse for this failure." It is significant that the General's displeasure was expressed mainly to the raid-tracking organisation, and that the Germans started to complain of lack of early warning as soon as radar silence measures were properly established.[3] Of all radio silence measures, those concerned with H2S made the biggest contribution.[4]

Oboe Transmissions

Commencing in January 1941 there was developed a British ground-controlled radar blind bombing device known as Oboe. It ultimately conferred upon the Royal Air Force Pathfinder Force the ability to lead a bomber raid through all but severe icing or the worst cumulo-nimbus conditions with deadly accuracy against pin-point targets within Oboe range. The principle of Oboe was that the aircraft was kept on a constant-range track relative to a Cat radar station, the bomb release point and ground speed being determined by range measurement from a second radar station, the Mouse, abaft the aircraft in relation to its run in to the target. W/T signals were given to the pilot in the form of a dot-dash modulation to enable him to keep on track, and to the navigator to indicate his position along the track and the point of bomb release. Aircraft had to be ground-controlled for at least ten minutes. For short-range operation the normal radar "echo" from the aircraft could be used for both range measurements but at longer range a higher power I.F.F.-type repeater

---

[1] A.S.I. Report No. 79/1944, Part III (3).
[2] *Ibid.*, Part IV (4).
[3] A.D.I. (K) Report No.416/1945, para. 106.
[4] The Germans often heard H2S signals after the silence had been imposed, but these were signals deliberately made by the No. 100 Group spoof force to mislead the enemy. This aspect of radio counter-measures is dealt with in Chapter 15.

was required in the aircraft. Oboe, Mark I operated on the 200 megacycle per second frequency band, and later marks used much higher frequencies.

It will be evident, therefore, that Oboe gave the enemy a further raid-tracking means. By reception by D.F. of the transmissions from the bomber's repeater, he could track the Pathfinders and ascertain their target and hence that of the main bomber force following. This he proceeded to do effectively, helped by the inadequacy of spoof in the use of Oboe for our attacks. The first Oboe, Mark I raid was made against Lutterade on the night 20/21 December 1942. In the autumn of 1942 a German monitoring station at Calais had intercepted a new type of signal in the 200 megacycles per second band.[1] Statistics were kept and it was observed that these transmissions occurred mainly at night and seemed to be associated with British M.T.B. activity in the Channel. In June 1943 the same type of radar signals were heard in Essen during a very heavy bomber raid on Cologne and Dr. Scholz was able to correlate them with the dropping of target indicators. It was realised at once that these signals were the same as those heard at Calais and an immediate investigation was made. For this purpose a " noise investigation " commission was formed and a special experimental *Freya* with a number of D.F. receivers was set up. The *Freya* was used to plot the course of the target indicator carrying aircraft while the receivers took bearings on the signals. Some six to eight weeks after this discovery had been linked with Royal Air Force Pathfinder aircraft, a satisfactory theory had been worked out by the Germans as to how Oboe—called by them *Bumerang*—worked. From this time onwards Oboe raids were systematically monitored by the normal monitoring service.

In September 1943 the centimetric Oboe, Mark II commenced operations. In the following month the German coastal interception stations picked up 9 cm. transmissions but were unable to identify them as emanating from the new Oboe system.[2] It was some five months later before the new phenomenon was understood and raid-tracking was again made possible.[3] The enemy was never able to discover technical details of the centimetric Oboe system. He could find no explanation, for instance, as to why certain aircraft transmitted pulses which did not appear to have normal Oboe coding, although those aircraft flew along tracks and at heights which identified them with Oboe procedure. It is significant that the enemy raid tracking service obtained no advance information of the target from these aircraft but did so instead from the transmissions from associated W/T ground stations.

The vulnerability of Oboe, Mark I to jamming was fully appreciated by T.R.E. and the Royal Air Force, and the relative immunity of Oboe, Mark I, and Mark II (centimetric) from jamming throughout their operations is a matter for wonder.[4] There was a scare, however, when No. 109 Squadron, operating Oboe, Mark I, on 17 August 1943 experienced interference sufficiently severe to make the equipment wholly inoperative. Patient research revealed, however, that this interference came from other British radar equipments, amongst which were Monica, Rebecca and from harmonics from ground stations, which amply demonstrated the vulnerability of Oboe, Mark I, to jamming, both intentional and unintentional. Attempts made to remove or reduce unintentional interference met with little success but served to hasten the

[1] A.D.I. (K) Report No. 380/1945, paras. 78–105.
[2] A.M. File C.28852, Part I.
[3] A.D.I. (K) Report No. 380/1945, para. 92.
[4] A.M. File C.S. 16261/Radar 3A, " Oboe Interference."

introduction of centimetric equipment, which was calculated to be considerably less vulnerable to unintentional jamming.[1] The remarkable freedom from jamming by the enemy seems to bear out that, in the circumstances prevailing, German intelligence had more to gain by permitting the Allies to continue unrestricted use of Oboe than the German night defences had to lose thereby.

General Schmidt, Commander of the German Air Force night fighter force in Western Europe, has stated that from November 1943 until May 1944 the German Signals Intelligence Service was able to follow the tracks of the Allied main bomber stream from the take-off to the target and back again to base.[2] As an illustration of the invaluable advanced warning this provided, he stated that on the occasion of a raid on Berlin in March 1943, when the first bombs dropped at 19.30 hours, he was informed at 17.18 hours that Royal Air Force bombers were assembling over the British mainland. Following this, he received a report every three minutes on the progress of the bomber stream enabling him to plot the track with ease, making allowance for a time lag of only five minutes. The enemy's raid tracking service was, however, to become a two-edged weapon ; his very dependence upon it made him more vulnerable to spoof radio counter-measures by the Allies.[3]

[1] A.M. File C.S. 28852, Parts I and II.
[2] A.D.I. (K) Report No. 416/1945.
[3] *See* Part 2, Chapter 15, of this volume.

CHAPTER 14

HOMING BY ALLIED FIGHTER AIRCRAFT TO GERMAN AIRBORNE RADAR

Up to the end of 1942, the users of radar had enjoyed the advantages of their equipment without incurring corresponding repercussions, but by that time both the Germans and the Allies were searching for some means whereby radar transmissions could be turned to the disadvantage of the side making them.[1] Jamming merely neutralised the transmissions, depriving everyone of any benefits to be gained. Tactical advantages could be gained by recording and plotting the transmissions of enemy bomber aircraft to obtain information of the course of their raids. A more direct exploitation of an enemy's use of radar was to utilise the transmissions of his radar sets as beacons to which offensively-armed aircraft might home. Applications of this technique being envisaged by the Allies were the homing of fighter-bomber aircraft to enemy ground radar stations (Abdullah), and of Fleet Air Arm aircraft to radiations emanating from enemy surface vessels.[2] Another form of offensive homing was Serrate, employed in night-fighter aircraft to seek out German night-fighters using airborne radar for the interception of Royal Air Force heavy bombers.

Both the Germans and the Allies were slow to introduce air-to-air homing devices. As far as the Royal Air Force was concerned, the demands of air defence in the first years of the War had been too heavy to allow either aircraft or scientific research effort to be diverted to operations which would be dependent on the enemy's initiative in the use or radar. Later, the slackening of the German bombing raids enabled defensive fighter aircraft in the United Kingdom to be released for offensive homing operations. It appeared from first consideration of the tactical problems that it would be difficult for fighters to operate at night outside the range of G.C.I. cover, but no obstacle was found in practice. The effective range of the homer in detecting enemy radar transmissions was considerably greater than that of an A.I. set dependent on reflected energy from the target, and it was shown that free-lance interception could be achieved when operating over enemy territory as well as over the United Kingdom. Identification of the target could be obtained by means of identification of the radiations.

Further examination of the homing technique showed far-reaching possibilities for the future. German bombers used at various times a rear warning radar, a radio altimeter, a form of I.F.F., and Benito, all of which gave an opportunity for homing to be practised against them. Experience in the free-lance interception technique might have proved an advantage to the Royal Air Force in certain conditions, such as those forced on the Germans during the massed raid tactics at the end of 1943 when *Himmelbett* or G.C.I. control became impracticable because of saturation, except against stragglers.[3]

---

[1] T.R.E. Monograph "The Radio War."
[2] T.R.E. Report No. 3/M/6/D.R.
[3] T.R.E. Report No. 14/M/6/EHCY.

An important argument in favour of the adoption of offensive homing operations at the end of 1942 was that Bomber Command could not expect to keep their losses low for an indefinite period by relying wholly on tactics of evasion. A wide introduction of centimetre equipment by the Germans on the ground and in the air was inevitable in the long run, and when that occurred the advantage was likely to pass to them if an offensive policy against their night-fighters were not adopted.

The Technical Problem of Metric Wavelength Homers

The aerial systems adopted for offensive homing in the metric wavelengths were, by nature of the principle they employed, very inflexible in the matter of frequency and dependent in characteristics on their fitting in relation to the airframe. Each requirement for change of operational frequency or type of aircraft involved a very big design and development effort.[1] It soon became clear that special measures would be required for the development of homing equipments if the enemy's initiative in changing frequencies were to be followed promptly enough for operations to be effective. The delay caused by the need to obtain adequate information about the enemy transmissions, together with the three to six months necessary to design and fit the homing sets, would largely nullify the effectiveness of the counter-measure. In order to reduce this delay, the group responsible for homing development at T.R.E. was transferred to the T.R.E. R.C.M. Division in November 1942, and a thorough revision of policy and technique took place. The first aim was to produce a D.F. system covering a wider frequency band, and independent of the type of airframe. There had been a tendency to utilise the A.I. type of aerials for homing: but by sacrificing some of the sensitivity essential for A.I. purposes, aerial systems of wide-band characteristics were developed for homers. These took the form of loaded heavily damped di-poles located symmetrically relative to the airframe and remotely on the wing tips. Facilities for easy change of aerial heads without disturbance of the installation were also provided. This aerial development work was started in January 1943 and by June, homing aerials above a frequency of 150 megacycles per second became available with predictable performance, able to cover half an octave of frequency and to give D.F. in azimuth and elevation.[2]

The Technical Problem of Centimetric Wavelength Homers

Centimetric A.I. was considered to be virtually unjammable. Had, therefore, the Germans been able to use it from the beginning of Bomber Command's massed raid tactics, our bomber losses would probably have been enormous. T.R.E. actually estimated on 30 March 1943,[3] a potential casualty figure of 25–50 per cent and the experiences of escorting night fighters flying in or near our bomber stream amply testified to this probability. The only feasible counter-measure was a direct offensive by Royal Air Force fighters homing to centimetric A.I. transmissions of enemy fighters. In consequence, high priority was accorded to research and development for centimetric homers. The problem was technically and operationally more difficult than for V.H.F. homing because of the highly-beamed and intermittent nature of the scanning signals to be received, the wide frequency band to be covered, and the confusion

[1] A.D.I. (Science) Reports. [2] Reference T.R.E. File D.1606, Encl. 128A.
[3] T.R.E. Report Reference 5/M/78/RC of 30 March 1943.

caused by friendly transmissions. Fortunately the war ceased before the enemy introduced centimetric A.I., but there is little doubt of the importance of research in this direction for the future.

Serrate Operations, June to November 1943

The offensive homing operations by our long-range fighters against enemy fighters were known as Serrate operations,[1] a code word also applied to the homing equipment employed. After the discovery, towards the end of 1942, that the enemy night-fighters were using A.I. in the 490 megacycles per second frequency band, the new homing equipment, Serrate, was installed in Beaufighter aircraft of No. 141 Squadron, Fighter Command. These aircraft carried A.I. Mark IV for completion of interception. Serrate operations began in June 1943. The German *Himmelbett* fighter control organisation was then in full swing and from the start there were ample contacts with the *Lichtenstein* A.I. in use in the German night fighters. During the first three months of these operations, one successful combat resulted on the average from every eleven sorties dispatched or from every nine sorties completing a patrol. All except one contact—an initial visual—resulted from Serrate homing. Only rarely was an initial A.I. contact obtained on a presumed enemy and none of these contacts led to an interception.

During the second three months of the operations, up to November 1943, the success declined. One combat on the average resulted from every thirty-five sorties despatched, or from twenty-six sorties completing a patrol, in spite of the mounting experience and practice of the aircrews. The difference between results for the two periods was caused by several factors. For one thing, the *Himmelbett* system of night-fighter control had been dislocated by the introduction of Window by Bomber Command, and the looser form of control adopted by the Germans gave fewer opportunities for homing by Serrate aircraft. This difficulty emphasised the shortcomings of the Beaufighter aircraft of No. 141 Squadron which were no match in speed and performance with the newer types of German night-fighters. Interference from Window with the A.I. Mark IV equipment was also reported.

Another point was the forward beaming of the *Lichtenstein* which made the direction of flight of the enemy aircraft with respect to the Serrate aircraft a critical factor. There was a big reduction in Serrate range, when the target aircraft was flying away, from fifty miles obtainable in the head-on position, to ten. One of the most successful tactics of the Beaufighter was, therefore, after picking up a Serrate contact from astern, to allow the enemy aircraft to close until within backward cover of the A.I. Mark IV, and then to whip round and attack it from astern. The proportionately small number of crews responsible for the majority of the successful interceptions indicates how difficult Serrate tactics were at that time. One pilot (Wing Commander Braham) had nine out of twenty-three successes and two other crews had five each.

Transfer of Serrate Operations to No. 100 Group

In December 1943 responsibility for Serrate operations was transferred to the newly-formed No. 100 Group.[2] The Beaufighters of No. 141 Squadron were then being replaced by Mosquito II aircraft. Nos. 169 and 239 Squadrons were

---

[1] No. 100 Group Review of Operations—Part I, November 1943–May 1945.

[2] A.H.B./II HI/45—N.Q. No. 100 Group "Review of Operations" and "Reports of Activities," December 1943–April 1944.

also taken over to be re-equipped and trained with Serrate. The crews of these two squadrons were experienced in defensive night-fighting but needed training in long range navigation. During the following months from December 1943 to April 1944 No. 100 undertook a heavy task in the refitting of the three Serrate squadrons. They were all to be equipped with Mosquito II aircraft which were by no means in good condition and needed constant effort to keep them serviceable. The fitting of backward-looking A.I. was undertaken to increase the A.I. cover, and the adapting of the Serrate gear, and especially the aerials, to work in the Mosquitos gave considerable trouble.

With regard to operational tactics, there was little information available on which to base the night fighter plan. The system of control of enemy night fighters was changing and as yet the " Y " Service was unable to give rapid and adequate reconstruction of the enemy fighter movements and tactics. This, together with the efficiency of the German early warning service and the vast areas to be covered by British night fighters, made it difficult to calculate what would be the best disposition of the limited night fighter force to give maximum support to the Bomber Command force. Consequently a number of different types of patrol were tried as follows :—

(*a*) In the target area during and after the attack.
(*b*) In escort of the bomber stream.
(*c*) At fighter assembly beacons.

After only a few sorties within the target area it appeared that the first method was impracticable. The large number of Serrate contacts obtained made it generally impossible to follow up any one of them to within A.I. range, and even when this was achieved it was difficult to transfer the Serrate contact correctly to the A.I. tube. The same confusion of contacts resulted when operating in or close to the bomber stream. Although Serrate or A.I. contacts could sometimes be obtained on enemy fighters remote from the stream and flying towards it, by the time close contact has been made, the target A.I. blip became confused with the numerous bomber blips as the enemy aircraft entered the stream.

Patrols over the enemy assembly beacons proved at first not so profitable as had been hoped. The beacons and times of patrol were chosen from careful consideration of enemy fighters' movements in previous operations as revealed by intercepted signals traffic. Sometimes the enemy used beacons other than those forecast or he used them at unpredicted times. Even when both factors were guessed correctly, Serrate aircraft generally reported few contacts. One reason for this was the difficulty they had in finding the visual beacons, and another was evidently the A.I. silence on the part of the enemy when assembling. Moreover, the Mosquito observer was usually too pre-occupied with the Serrate equipment to have enough time for accurate navigation and the Mosquito aircraft was not equipped with facilities for homing to enemy radio beacons. On a few occasions during this phase of operations, Serrate aircraft did make contact with a group of enemy night fighters by means of either Serrate or more rarely, A.I. The great majority of interceptions were, however, of aircraft operating individually and remote from groups of aircraft.

The most successful type of patrol during this phase proved eventually to be in the target area after completion of the bombing raid. In most instances the Mosquitos patrolling the target area after bombing, reported many A.I. contacts of which they were able to recognise several as being almost certainly enemy aircraft. The number of Serrate contacts obtained there however was small. It appeared that some aircraft remained in the target area but without their A.I. on, and that these aircraft were preparing to land. It is interesting to note that among the first six enemy aircraft destroyed within the target area after bombing, two were single-engined with navigation lights on.

The lessening opportunity for Serrate homing in the first months of 1944 is shown by a comparison between initial contacts made by Serrate and by A.I. equipment. From December 1943 to April 1944 nearly twice as many successes resulted from contacts made initially by A.I. sets as from initial Serrate contacts. The figures for Serrate sorties operating on nights of major operations during this period are as follows :—

Sorties completing a patrol	220
Serrate chases leading to A.I. contact	44
Resulting successful combats	9
A.I. chases without previous Serrate	220
Resulting successful combats	17 + 1*

(* Initial contact was visual on a tail light.)

The chief reason for the small number of A.I. contacts obtained from Serrate chases was probably that the enemy fighters only used *Lichtenstein* to any extent when in the vicinity of the bombers, and the Serrate aircraft had difficulty in operating there owing to the saturation of their A.I. tubes.[1] At the beginning of the year the observations of the Serrate crews showed that the enemy fighters were sometimes using their A.I. at the beacons and when moving between beacons, but this practice soon became less common. The enemy fighters remaining in the target area after bombing were certainly not using their A.I. to any great extent. How much enemy fighters were deliberately limiting the use of their A.I. in order to avoid Serrate attacks was not known.

The fitting of backward-looking A.I. certainly made a considerable improvement, and between December 1943 and April 1944 nearly as many combats resulted from initial backward A.I. contacts as from initial forward A.I. contacts. Considering all operations in this period, one successful combat resulted on the average from every fifteen sorties despatched, or from every eleven sorties completing a patrol.[2] The scale of success was higher on nights of major bombing operations (main force attacks on targets in Germany) than on nights of minor operations (attacks on targets in France, Mosquito attacks and minelaying). When only nights of major bombing operations are considered, one successful combat resulted from every eleven sorties despatched or from every eight sorties completing a patrol.

It is an interesting point that the chance of an A.I. contact being converted to an attack was apparently much higher if the A.I. contact were obtained by a Serrate chase than if it were obtained directly. On the average one in five A.I. contacts following Serrate chases resulted in combats (this was approximately equal to the figure prior to December 1943). The reason for this is probably that in most cases an enemy aircraft with its A.I. operating would be looking for hostiles and consequently flying along reasonably steadily, making a good target for A.I. interception. Secondly, if A.I. contact were lost during the later stages of the interception it could often be regained after switching back to Serrate.

[1] No. 100 Group " Review of Operations "—November 1943-May 1945, paras. 16-20.
[2] A.H.B./11 H1/45, December 1943-April 1944.

The Serrate operation was undoubtedly causing the enemy considerable trouble.[1] Not only were enemy fighters being shot down but many others were being engaged in A.I. dogfights when they should have been attempting to intercept bombers. The enemy controllers were broadcasting frequent warnings to their aircraft to beware of the " long-range night fighters " (which would also include the Fighter Command intruders). The confidence of the German night fighter crews must have been seriously affected by the knowledge of the presence of hostile night fighters: every *Lichtenstein* contact they obtained might well turn out to be an offensively armed night-fighter instead of a heavy bomber. Nevertheless, the operation had considerable limitations, the chief of which was that no close escort of the bomber stream could be effected, due to the swamping of the A.I. Mark IV tube by masses of friendly aircraft. It was during these early months of 1944 that the enemy was achieving very considerable success at interception of Bomber Command aircraft en route. During March the night bombers suffered two of the heaviest losses they ever sustained. Seventy-two aircraft were lost out of a force of 810 when attacking Berlin on 24/25 March and ninety-six aircraft were lost out of a force of 795 when attacking Nurnberg on 30/31. Interception on the route in was the major cause of loss in each case.

Apart from being so easily swamped, A.I., Mark IV was not an efficient equipment against aircraft taking violent evasive action. More important still, interference by enemy jammers was becoming more and more serious when over enemy territory, particularly in the region of strongly-defended targets and near the bomber stream. It was clear that improvement in the standard of success of the bomber support operation could be expected only if a new form of A.I. could be obtained which could be used near the stream and be more efficient in following evasive action. Such an equipment was the 10 cm. A.I., Mark X which was not yet allowed to be flown over enemy territory because of the danger of it falling into enemy hands.

The equipment of the three Serrate squadrons consisted of rather old Mosquito, Mark II aircraft, which had already given of their best.[2] The exacting Serrate operations soon proved too much for these aircraft and the the number of abortive sorties was large. In February, it was decided to take a long-term view, which involved a temporary reduction of the operational effort, in order to give the Mosquito aircraft an overhaul and to re-fit with Merlin XXII engines. This policy soon began to bear fruit and in March the serviceability showed a remarkable improvement. The scale of effort of Serrate squadrons grew from 41 sorties in January to 175 in April.

Serrate Operations from March 1944 to D-day[3]

Between March and D-day, our bombers made a growing number of attacks against targets in France as a preliminary to the landing in Normandy. In March these attacks were almost unopposed by enemy fighters, but there was a tendency for the enemy to use certain fighter groups independently, which foreshadowed increased resistance. In April the attacks over France did meet with a somewhat greater opposition, and in May the fighter opposition became serious and the loss rate for the more strongly defended areas of

[1] A.H.B./II H1/45, paras 21–24. [2] *Ibid.*, para. 25. [3] *Ibid.*, paras. 28, 32.

enemy-occupied territory rose to 4·3 per cent.[1] From the point of view of high-level fighter support, the important factors in these operations against targets in France were :—

(*a*) Several attacks were made simultaneously against targets fairly close to each other, so that there was no well-defined bomber stream but rather an area over which bombers flew ;

(*b*) the attacks were of short penetration.

The changed bomber tactics made it practicable for Serrate aircraft to operate as escort to the bombing force, not only by flying parallel with the bombers, but also crossing and re-crossing their tracks. The escort was successful and during May eighteen enemy aircraft were destroyed and one damaged in the course of 212 sorties, an average of eleven sorties despatched per successful combat. The Serrate equipment played a greater part than hitherto in the successes. Twelve of the successful combats were from initial Serrate contacts, six from initial A.I., and one from an initial visual on an enemy aircraft illuminated by searchlights. One successful chase was carried out on Serrate alone, the enemy aircraft flying too low for A.I., Mark IV, to be used. On two occasions enemy fighters were attacked while they themselves were in the act of attacking bombers.

The escort plan was thus a great success, but certain other helpful factors should also be mentioned. The increasing skill of the crews certainly played a part and the good visibility conditions prevailing on certain nights may also have contributed. The fact that most of the patrols were short was an advantage, for crews could afford to be more persistent in their chases when there was plenty of petrol and time in hand. There was another possibility ; most of the operations in May took place in areas where German night fighters would not have had the experience of those based in Germany. A fresh offensive fighter plan tried was a sweep by Serrate aircraft prior to the attack over a wide area where enemy fighters might be flying in preparation for early interception of the bombers. These were, in most cases, not very profitable in terms of aircraft destroyed but the moral effect was considerable.

In May, a decision was made to equip Mosquito, Mark II, squadrons with Mosquito, Mark VI, aircraft, No. 169 being the first squadron to receive new aircraft. The old type A.I. installation proved unsatisfactory, and a great deal of test and experimental flying, as well as structural modifications to aircraft, was undertaken by No. 169 Squadron.

A successful installation was eventually designed and by the end of July all Serrate squadrons were re-equipped with Mark VI aircraft.[2] The important feature of the Mark VI was the drop tanks which could be carried, thereby increasing the radius of action and the time spent on patrol.

Airfield Intruders[3]

In the early part of April 1944 it was decided to extend the scope of No. 100 Group's bomber support activities by the inclusion of low-level Intruder operations over *Luftwaffe* airfields. The operations were carried out in close co-operation with Fighter Command (Air Defence of Great Britain) which had been operating low-level Intruders for a considerable time. It was hoped that the knowledge and experience of the enemy night fighter system that was

[1] A.H.B./II H1/45, May 1944. [2] *Ibid.*, July 1944. [3] *Ibid.*, paras. 26 and 27.

being gained by No. 100 Group through the growing Intelligence and through the operation of high-level fighters would help to increase the success of airfield intrusion, which our own experience in this country showed could be a very serious embarrassment indeed to night defensive operations. No. 515 Squadron were transferred to No. 100 Group from No. 11 Group equipped with Defiant aircraft. Their role in Fighter Command had been that of R.C.M. aircraft. They were at first re-equipped with Beaufighter Mark II aircraft for certain operations which never materialised, but afterwards re-equipped with Mosquito Mark VI aircraft without any form of radar. A period of intense training was undertaken to fit them for the role of low-level intruding, and in April they commenced "nuisance" intruding on enemy airfields, carrying high explosive and incendiary bombs. They were joined by No. 23 Squadron from the Mediterranean theatre, in June. This Squadron was also equipped with non-radar Mosquito, Mark VI aircraft. During the first few months of the operations of these two squadrons, only a small number of enemy aircraft was attacked, but their activities around enemy airfields were known to be a source of considerable worry to the enemy.

Use of Monica in A.I. Mark X Operations[1]

Efforts to acquire A.I. Mark X resulted in the arrival in No. 100 Group of two squadrons, Nos. 85 and 157, at the beginning of May 1944. A.I. Mark X, unlike Mark IV, had no backward coverage and from the point of view of the aircraft's own protection, some kind of backward warning equipment was necessary before it could be used on high level operations. In this rôle the tail warner would have the further purpose of enabling the Mosquitos to exploit offensively contacts obtained from the rear. To provide a quick interim fitting, Bomber Signals Development Unit (B.S.D.U.), the experimental unit of No. 100 Group, began a modification of Monica I. Until the tail warner was fitted, A.I. Mark X squadrons were trained for low-level airfield intrusions. This meant that they would eventually be in a position to play a dual rôle -either high level or low level work, which was to help considerably in the planning of bomber support operations.

Nos. 85 and 157 Squadrons officially began operations on D-day (5/6 June),[2] and until the end of June they carried out low level airfield intrusion. Towards the end of June, however, part of their effort was diverted to anti-flying-bomb work, and from 21 July until the beginning of September both squadrons were withdrawn from Intruder operations and moved to West Malling for full-time flying-bomb interception. The first airfield intrusion results with A.I. Mark X were very promising and it was found that at a height of 1,500 to 2,000 feet, A.I. contacts at ranges of five miles or so could be obtained and held. During June, from 176 sorties despatched, of which 131 were completed, thirty-eight A.I. contacts were reported, leading to the destruction of ten enemy aircraft and damage to three others. All these combats, save one of those leading to damage claims, resulted from sixty-two sorties flown between 11/12 and 16/17 June. A few high level sorties were flown by A.I. Mark X aircraft equipped with rearward warning equipment before the squadrons were taken over for anti-flying bomb duties, but the number was not sufficient for any definite conclusions to be reached concerning the potentialities of A.I. Mark X on high level patrols.

[1] A.H.B./II H1/45, May 1944. [2] *Ibid.*, June 1944.

Serrate Operations Subsequent to D-day

In June and July the number of Serrate contacts fell considerably.[1] In July only one in every ten sorties, on the average, reported a Serrate contact. In May it had been one per sortie, and in the early part of the year each sortie had been reporting a large number of contacts. This decline was due to the replacement of the *Lichtenstein* by the new German A.I. set, the *S.N.2*. The number of A.I. contacts obtained directly on enemy aircraft increased, however, in June and July, but on the whole the degree of success of the operation declined in proportion with the withdrawal of *Lichtenstein* by the enemy and for every aircraft destroyed or damaged eighteen sorties were required. The increased number of A.I. contacts obtained directly on enemy aircraft during June and July was due to the success of patrols over enemy beacons. In June the enemy was making more and more use of his assembly beacons in France and a round of these beacons proved to be the most profitable type of patrol for the Serrate squadrons. Many of the successes at the beacons were obtained before the enemy fighters had attempted to intercept the bombers, and so a valuable measure of direct support was thus given to the bomber operation.

By July, enemy jamming of A.I. Mark IV was a serious handicap. It was reported by most crews to be effective during the whole of the time they were over enemy territory, and particularly at the enemy coast and in the Ruhr area. Not only did it mean that a large number of contacts were not obtained at all, but frequently it prevented the successful follow-up of contacts which had been achieved. This added fuel to No. 100 Group's clamour for A.I. Mark X. The next two months, August and September, saw the eclipse of the Serrate/A.I. Mark IV operations.[2] The number of Serrate contacts obtained dropped practically to zero and at the same time it became increasingly difficult to achieve combats from A.I. Mark IV contacts. In August 331 Serrate/A.I. Mark IV sorties yielded nine successful combats. In September, 240 sorties yielded one successful combat. In September the frequency of A.I. Mark IV was altered in an attempt to evade the interference, with some slight success. The following table shows how the number of Serrate contacts decreased between May and September as *Lichtenstein* was withdrawn, and also how the enemy jamming of A.I. Mark IV made it more and more ineffective.

1944.	*May.*	*June.*	*July.*	*Aug.*	*Sept.*
Average number of Serrate contacts per sortie completed	1·1	0·2	0·1	0·02	0·005
Average number of A.I. contacts (without initial Serrate) per sortie completed	0·3	0·5	0·8	0·5	0·3
A.I. contacts per successful combat ..	9	9	10	16	60

Offensive Fighter Operations using A.I. Mark X

The decrease in the average number of contacts on enemy aircraft obtained with A.I. Mark IV by the three Serrate squadrons may have been partly due to the lack of enemy fighter opposition experienced by the bombers on many operations. In contrast, however, was the success achieved with A.I. Mark X by Nos. 85 and 157 squadrons when they returned to offensive fighter operations from anti-flying bomb operations at the end of August. During

[1] A.H.B./II HI/45, June–July 1944.
[2] *Ibid.*, August–September 1944.

September they took part in both high and low level patrols with good results. From a total of 167 high-level sorties they reported forty-seven enemy contacts leading to twelve successful combats. Patrols were flown over assembly beacons and in target areas after bombing, and escort of the bomber stream was also tried, flying from ten to fifteen miles wide of the mean track.

A number of contacts were also obtained on the rearward-looking Monica equipment carried by A.I. Mark X high-level intruders. It was found that these contacts could, in general, be evaded fairly easily but that it was often difficult to convert to a forward A.I. Mark X contact. Only about one-quarter of the total of Monica contacts reported were so converted. The main value of Monica was thus in prevention of attacks from the rear rather than as an additional interception aid.

Mutual Identification

With the growth in the number of bomber support fighters and the shrinking of the territory held by the enemy due to the Allied advance on the Continent, the waste of time caused by chases between friendly fighters became considerable, and there was clearly great need for some form of mutual identification.[1] It was decided to fit a modified form of I.F.F. Mark III in certain aircraft, and also the Type F infra-red identification system. The fitting began in May 1944 with the Serrate aircraft of Nos. 141, 169 and 239 squadrons and although fitting was not general for several months, the identification devices showed their great value immediately they were used.

Use of Serrate during Spoof Operations[2]

During Spoof operations employing airborne Mandrel screen and Window feint forces, Serrate aircraft and the low level intruders were also given a part to play in the deception. Serrate aircraft accompanied the diversionary forces in order to give the feint more realism and also to be in a position to intercept enemy fighters airborne in reaction to the feint. Serrate aircraft and low level intruders were also on occasion sent to patrol areas well away from the main attack in an attempt to deceive the enemy as to the area in which the attack could be expected.

Planning of Serrate Fighter Operations[3]

As the Allies advanced on the Continent, the No. 100 Group countermeasures and feint attacks became more effective and the German early warning system was of less value. The enemy was forced to limit the area of operation of his fighters, and in response to a threatened attack only those aircraft in the particular operational area would be used. No longer could reinforcements be flown in from great distances. This fact was of great assistance in planning the Allied supporting fighter disposition because the area of operation could now be safely limited. Also the reduction in the enemy early warning meant that a large part of the bomber route in and out could be considered safe. The " Y " Service in No 100 Group had, during the preceding months, become a highly-efficient organisation and the movements of the enemy night fighters were followed during the actual operation. A full reconstruction of the night's activities was available the following morning, on which the planning for the next night's operations could be based.

[1] A.H.B./II H1/45, August–September, 1944, para. 43.
[2] A.H.B./II H1/44, June 1944–March 1945
[3] *Ibid.*, paras. 47–50.

Later still, during the final rapid advance into Germany, with the consequent disorganisation of the enemy night fighter system, there was no opportunity for precise planning. The Mandrel aircraft were no longer used as a screen but were flown with the bombers in order to confuse the enemy plotting system as far as possible, and the fighters carried out mainly close escort of the bombers and attacks on the few remaining enemy airfields.

Perfectos

By June 1944 it was known that the enemy was fitting the *FuGe.25A*—a form of I.F.F.—in his night fighters for identification purposes and for use in the *Egon* system of fighter control.[1] It was thought that if an airborne interrogator for the *FuGe.25A* could be made and fitted with a directional aerial system, it could serve a similar purpose to Serrate with the added advantage of giving indications of range. Accordingly, the Bomber-Support Development Unit was instructed to modify an SCR. 729 (the American interrogator equipment for use with Mark III I.F.F.) so that it would transmit on a frequency of 125 megacycles per second and receive over a small band about 156 megacycles per second—the frequencies of the enemy's I.F.F. For an aerial system, the one designed by T.R.E. for use with another homing system known as Meerschaum was proposed in order to provide D.F. in azimuth. It was not possible to provide D.F. in elevation with this system, but this was not considered to be a serious disadvantage and the simple nature of the aerial allowed it to be installed in the Mosquito aircraft without any great modifications to the fuselage or wings.

The first model, developed for use with A.I. Mark IV, allowed the signals to be displayed on the A.I. tubes, and thereby still further simplified development since separate display units were not required. This model, which was given the code name of Perfectos I, was tested operationally in October 1944 with very encouraging results, and arrangements were made for it to be installed in aircraft of No. 169 Squadron.[2] The installation work was completed in November 1944. A number of Perfectos contacts were obtained in November 1944 and December 1944, at ranges generally of ten to fifteen miles, and occasionally more. A few were converted to A.I. Mark IV contacts, but no combats resulted.[3] This was due to the limitations of the A.I. Mark IV which was no longer suitable for bomber support work and was also at this time suffering severe interference over enemy territory. The value of Perfectos had, however, been established, and development of a model with separate presentation units which could be installed in Mosquitos fitted with A.I. Mark X was carried out. Perfectos II, the model for use with A.I. Mark X, was given satisfactory trials in January 1945 and was installed in aircraft of No. 85 Squadron during February 1945.[4] In March 1945, seventy A.I. Mark X Perfectos sorties were flown, with very encouraging results.[5] About thirty Perfectos contacts were obtained, five of which were converted to A.I., leading to three enemy aircraft destroyed and damage to one. The initial range of most Perfectos contacts was eight to fifteen miles, but one contact was reported at a range of fifty miles.

Perfectos was also installed in Mosquitos fitted with A.I. Mark XV (ASH or AN–APS4). In this case the signals were displayed as an alternative to tail warning signals on the Monica IX tube. The equipment was installed in

[1] B.S.D.U. File S.5194/Sigs.—100 Group Letter 100G/S.1201/4/Sigs. dated 30 June 1944.
[2] A.H.B./II HI/45, October 1944. [3] *Ibid.*, November–December 1944.
[4] B.S.D.U. File S.5194/Sigs. [5] A.H.B./II HI/45, March 1945.

No. 23 Squadron in March 1945, but by this time the enemy fighter activity had diminished considerably and no outstanding results were achieved. Perfectos was also used on a few occasions just before the end of hostilities by the Eighth United States Army Air Force in daylight operations. In this case, however, a separate and more powerful transmitter than that of the SCR. 729 was used. This gave a greatly increased range, contacts being obtained at almost 100 miles. The Bomber Support Development Unit was working on a similar equipment for night fighters, but it was not completed before the end of hostilities.

Serrate IV

In July 1944 the frequency and other details of the enemy's *S.N.2* A.I. became known and arrangements were made for the development of suitable homers. It was decided that as an immediate measure the Bomber Support Development Unit should produce a homer by modification of standard equipment, to be used until Hookah, the universal homer being produced by T.R.E., was ready. The homer for *S.N.2*, which became known as Serrate IV, was intended for use in Mosquito aircraft fitted with A.I. Mark X. The difficulties of presentation were overcome by adopting an aural method which gave the pilot indications of D.F. in the form of dots and dashes in a Lorenz beam. It was considered that this system might have advantage over the visual method as it would allow the pilot to carry out the homing side of an interception without having to watch the cathode ray tube, and without the assistance of the navigator, who could concentrate on looking for A.I. contacts.

For Serrate IV, it was proposed that the intermediate frequency stages of the V.H.F. R/T set should be used, together with a radio frequency unit covering the frequency of the German *S.N.2*, and aerials of the opposition type. This aerial was one designed by the Royal Aircraft Establishment for homing to enemy jammers of the British V.H.F. R/T. Operational trials with the first model of Serrate IV were carried out in August.[1] The aural presentation proved to be satisfactory, but it was found extremely difficult to pick out A.I. signals from among those from *Freyas* which were of greater signal strength, and which were spread over the whole frequency band, and the next step was to devise a means of reducing the interference from *Freya* signals. As *Freya* had a pulse recurrence frequency of 500 pulses per second, and *S.N.2* as far as it was known 290–300 and possibly 800 pulses per second, it was thought that this could be done by constructing a filter to pass pulse recurrence frequencies of 750–950. This would pass the third harmonic of 250–315 cycles per second, but the basic and all harmonics of 500 cycles per second would be rejected. The development of the filter proved extremely difficult but a model was eventually produced and satisfactory operational trials were carried out in December 1944. A few sorties were carried out by aircraft of No. 157 Squadron in January but no contacts were reported.

By this time it seemed that the enemy had moved to frequencies outside the range of the captured *S.N.2* equipment, and therefore beyond the scope of Serrate IV. Three equipments were accordingly modified to cover different frequency bands, and work was started on a new version—to be known as Serrate IVA—which, with interchangeable aerials, could be pre-set to cover a frequency band of about 5 megacycles per second within a frequency range of 70–105 megacycles per second. Success was achieved in February 1945, when a

[1] A.H.B./II H1/45, August 1944.

crew of the Bomber Support Development Unit destroyed two *Me.110s* with with the aid of Serrate IVA on a frequency of about 77 megacycles per second.[1] An intensified search was made both by aircraft and ground listening stations to determine the frequencies most used by the enemy for *S.N.2* and as a result the majority of the Serrate aircraft was set to operate on 103 megacycles per second, whilst the remainder were adjusted for operation on the other band of *S.N.2* frequencies—83 and 73 megacycles per second. By March 1945, Serrate IVA had been fitted in a number of aircraft in Nos. 141, 157, and 169 Squadrons. All these squadrons were equipped, or were in process of being equipped, with Mosquitos carrying A.I. Mark X. A further model—known as Serrate IVB—was produced, which could be used in the frequency range 103–119 megacycles per second. This enabled the Serrate equipment to cover what was considered to be the maximum possible frequency range for the *S.N.2*. The operational use of the equipment was, however, very small since the enemy night-fighter reaction at that time was falling off considerably and no outstanding successes were, therefore, achieved.

An installation, which combined Serrate IV with a Mandrel III jamming set modified to sweep over a frequency band of 60–120 megacycles per second, was also developed by the Bomber Support Unit. It was intended to jam the tail warning equipment which was being installed in enemy night fighters, and, it was believed, was enabling them to avoid interception. Fighters fitted with the combined homer/jammer were expected to be able to home to within A.I. range and then jam the tail warning radar of the enemy fighter, preventing it from taking effective avoiding action. The installation was known as Meerschaum II. A similar device known as Meerschaum I had had been developed previously for use against enemy bombers; it worked well but was not tried out operationally.

The numerical total of kills attributable to Serrate and Perfectos was not impressive in relation to the operational effort involved, but it would be misleading to judge their value by figures alone. The first stage in the Air War in Europe was the defeat of the German bomber offensive, after which the Germans were forced to put their main effort into defensive fighters to protect their country from Allied bombers. The offensive homing campaign carried the war a stage further by striking at the Germans' final defensive air weapon, the night-fighter, whilst operating over their own territory. The kills achieved may not have been very great in number, but they occurred with persistent regularity and had great deterrent effect.

Immediately before and after VE-day a good cross-section of the German Air Force's most experienced and reliable night-fighter pilots were closely questioned on the matter. They were unanimous that the Serrate Mosquito aircraft caused great consternation amongst the night-fighter crews who, hitherto the hunters, were now also the hunted.[2] Instead of being free to concentrate upon the bombers, they had to keep the closest vigil for the Allied fighters. Many crews refused to operate their I.F.F. for fear of being homed on, and on some occasinns this led to German night-fighters being shot down by their own flak. Captain Kramer (with twenty-nine "kills" to his credit) referred to the German night-fighters being thrown on to the defensive and even using *Duppel* (German Window) in self-protection. The bringing home

[1] A.H.B./II H1/45, February 1945. [2] A.D.I. (K) Reports Nos. 599/44 and 700/45.

to German night-fighter pilots that their airborne radar was being used as a beacon by Allied homing fighters was a finishing stroke to their morale.

GERMAN AIR-TO-AIR HOMING

The subject of radio silence has already been discussed in so far as it concerned denial to the enemy of early warning through the medium of the German Air Force Raid Tracking Service.[1] It would now be appropriate to consider the advantage the enemy derived from British aircraft radio transmissions by homing to them. The technical and tactical homing problems facing the German Air Force were substantially the same as those facing the Allied forces. In the main, however, German homing operations were employed defensively. The lead the Allies kept in the introduction of new radio techniques, and the ascendancy gained and kept in the air offensive with the help of many radio devices made homing operations of great potential importance to the enemy. The Germans therefore lost more than the Allies did by tardiness in the introduction of homing techniques, and it is of interest to study their attitude to this matter.

General Martini has stated that members of his staff often repeated a catch phrase " *Aller funkverkehr ist Landersverrat* " (" All radio traffic is treasonable ")[2] The *Luftwaffe* in general was well aware that a transmission of any type could be listened to by the Allies and D/F'd. It was therefore fully aware of the opportunities of homing to transmissions from Allied aircraft. When airborne counter-measures were taken against *Freya* stations, a German firm named *Kathen* developed an apparatus which would enable a German night-fighter to home to the jamming aircraft. The equipment was called *Freya-Halbe* (*Halbe* = half, signifying that it was a radar apparatus consisting of the receiver only without the transmitter) and was tried out at Werneuchen in 1943. The trials were successfully completed by about June of that year and it was then demonstrated to the authorities for use by the German Air Force night fighter units.

At that time, the German night fighter force was commanded by General Kammhuber, the creator of the Kammhuber Line,[3] whose night fighter organisation depended essentially upon closely ground-controlled aircraft operating in " boxes." He saw in air-to-air homing a powerful threat to his form of control. Being a strong opponent of all forms of free-lance methods, Kammhuber brushed aside air-to-air homing and insisted on strict adherence by his aircraft to the limits of their " boxes." Even with the discovery of Monica and the production of homers for it, Kammhuber maintained his stand and it was not until General Schmidt took command of the night fighter forces in November 1943 and encouraged free-lance methods, that D/F homing to transmissions from bombers was used operationally.

Although the technical experts were satisfied that air-to-air homers working on transmissions of metric wavelengths were successful, it took a long time to convert aircrews to their use. A prejudice against " new fangled gadgets " persisted and minor electrical troubles quickly discredited this form of equipment. Although *Naxos* the homer for H2S was available in January 1944, for the first three or four months comparatively little use was made of what proved to be an excellent homing device. In the meantime aircrews gained confidence in homers as results from *Naxos* increased, and reliance on all types of homing

[1] Part 2, Chapter 13, of this volume. [2] A.D.I. (K) Report No. 369/45.
[3] A broad chain of air defences across N.W. Europe.

equipment increased proportionately. Unfortunately for the enemy, this change came about too late for him to exploit our use of Monica which by then had almost ceased to be used.

After the change of policy brought about by General Schmidt, experimental receivers known as *X-Halbe* were designed, capable of adaptation to any metric wavelength that might be used by the Allies. In addition, one of the operational requirements for A.I. stated after 1943 was that it should be possible for its transmitter to be switched off and for its receiver then to be capable of use as a D/F air-to-air homer to any airborne jammer. *Naxos* and *Korfu Z* homers which covered the 1·5 centimetres to 20 centimetres wave band, already existed.

As R/T and W/T jamming intensified, free-lancing in general and homing into the bomber stream in particular became even more widely used in spite of the disadvantage that none of the homers employed could enable the fighter to home to an individual bomber within a stream. The ability of homers such as *Naxos* to pick up bombers at as great a range as 100 miles often proved a disadvantage in that it led to useless chases. Estimate of range had to be by deduction and even with experienced crews this was not a reliable method. Both for reasons of limited supply and of the need for special skill in using homers, it was normal for enemy night-fighter leaders to do the homing, leading their formation into the British bomber stream to a point where each fighter could resort to the individual use of his own A.I., assisted by visual contact, to complete the interception. Leaders have, however, testified to the difficulty of keeping their formation together by night.[1]

Use of Receiver of *S.N.2* for Homing to Jammer Aircraft[2]

Several attempts were made to use the specially adapted receiver of the *S.N.2* A.I. equipment to home to Allied aircraft jamming the *S.N.2* but few successes were obtained owing to the lack of range presentation. It was found that to home successfully, gain had to be reduced considerably in order to avoid chasing distant aircraft. Nor were the orders of the *Luftwaffe* High Command helpful, for in the belief that jammer aircraft could be quickly and easily replaced, they ordered that only bomb-carrying aircraft were to be attacked.[3]

Freya-Halbe[4]

The *Freya-Halbe*, officially known as the *FuGe.221*, was designed in early 1943.[5] When free-lance tactics were eventually permitted at the end of 1943, it was intended to employ the twenty-five of these sets which had been manufactured, but when they were required it was found that the makers had used various parts of them for the manufacture of other apparatus and that the sets had thus virtually been consumed as spares. *Freya-Halbe* was therefore never used in operations.

Rosendahl-Halbe

The first Monica set obtained by the Germans was recovered from a British bomber which had been shot down over Rosendahl in Holland. The *FuGe.221A*

[1] Air Scientific Intelligence Report No. 109.

[2] A.D.I. (K) Report No. 370/1945.

[3] A.D.I. (K) Report No. 416/1945, para. 166.

[4] Part 2, Chapter 8, of this volume for reference to anti-homing devices for Mandrel airborne jammers.

[5] A.D.I. (K) Report No. 369/1945.

which was subsequently developed for homing to Monica was accordingly named after this town. It seems that this homer gave good D.F. until within four kilometres of the target, after which the D.F. became unreliable. For this reason the introduction of *Rosendahl-Halbe* was delayed.[1] The Germans ultimately discovered that the polarisation of the receiver aerials was at 90° to that used by the bombers and it was assumed that this was the cause of the bad D.F. For technical reasons it was not found possible at first to re-orientate the aerials of the homer in order to obtain the right polarisation, and by the time these difficulties had been overcome the use of Monica by the Royal Air Force had ceased.

Flensburg

The *Flensburg* homer, officially called *FuGe.227*, was another attempt to solve the problem of homing to Monica transmissions.[2] The D.F. properties gave some trouble but the set was adequately selective and could discriminate between a number of signals by tuning both the r.f. and p.r.f. controls. *Flensburg* was used to a limited extent in German Air Force night fighter operations but came into use too late to be of maximum value. The use of homers was then, however, well confirmed in principle and the next step was to extend the scope of the *FuGe.227* to cover the entire wavelength band of the Mandrel screen and of other *Freya* jammers.[3] The various forms of *Flensburg* homers designed were as follows :—

Flensburg I, 1·3 to 1·75 m. ..	against Monica.
Flensburg II, 1·7 to 2·6 m. .	against *Freya* A and B band and *Jagdschloss* jammers.
Flensburg III, 2·3 to 3·8	against *S.N.2* and *Freya C* jammers.
Flensburg IV	against *S.N.2* and *Freya C* jammers.
Flensburg V, 25 cm. band	against 25 cm. radar jammers.
Flensburg VI, 50 cm.	against *Wurzburg* jammers.

These homers were considered to be a successful solution to the airborne jammer problem except for objections to the high aerodynamic resistance of the aerials on the longer wavelengths. *Flensburg* equipment continued to be fitted up to November 1944 although by then it had almost ceased to be used by aircrews carrying it.[4] At one time attempts were made by Luftwaffe squadrons to remove parts of the homer from their aircraft in order to save weight, but a sharp reprimand from high quarters caused the equipment to be restored.

Trials with a *Flensburg*-fitted Ju. 88 Aircraft

The story of the landing in Suffolk on 13 July 1944 of a *Ju.88* aircraft fitted with *Flensburg* has already been related.[5] At that time, although it was understood that *Flensburg* was a homer for Monica it was not clear whether it was used for homing into the bomber stream generally or for seeking out individual aircraft. The *Ju.88* aircraft had only just been fitted with the equipment and the crew had not been fully instructed in its operation. A practical test of the *Flensburg* as fitted in the *Ju.88* was arranged, using a few Monica-fitted aircraft as targets. The trials were flown from the Royal Aircraft Establishment, Farnborough. At the same time the Operational Research Section at Bomber Command investigated whether Monica was still having any

[1] A.D.I. (K) Report No. 369/1945. [2] *Ibid.*, para. 16. [3] *Ibid.*, paras. 17–18.
[4] A.D.I. (K) Report No. 700/44. [5] Part 2, Chapter 12.

influence on the loss-rate of the bomber force. Briefly the first trials showed that *Flensburg* was capable of homing to an individual Monica operating amongst others from a distance of 50 miles. The trials carried out had been against a few aircraft only, each carrying Monica tuned to a slightly different frequency, and there were good hopes that by modification it would at least be possible to prevent *Flensburg* from being effective against an individual Monica. It was intended to vary the pulse recurrence frequency and to set all Monica transmitters on exactly the same radio frequency as far as technically possible.

It was then found necessary to arrange for much more comprehensive trials of the proposed modifications to Monica. In conjunction with the Operational Research Section the R.C.M.staff of Bomber Command planned a test involving the flight across England of a miniature bomber force. The route was Cambridge–Gloucester–Hereford–Cambridge, in a height band of 15,000–18,000 feet at a speed of 140 knots, and the timing was arranged to simulate the normal concentration of a bomber force under operational conditions. In addition, half the aircraft were to discharge Window, Type MB, at the rate of one bundle per minute on the last leg of the route. The *Ju.88*, with a specially competent radar operator aboard, was to make approaches to the bomber stream to determine the effectiveness of *Flensburg* against Monica with pulse frequency sweeping and all transmitters tuned to the same frequency, and also the value of Window, Type MB, against *S.N.2*.

The trials as planned were approved and the orders were framed in such a way as not to disclose to the aircrews taking part that a Monica homing test was to be carried out. On 30 August 1944 the trial took place with a total of seventy-one aircraft. In brief, the results showed that *Flensburg* homed efficiently to Monica, and that Window, Type MB, was completely effective against *S.N.2*. Using *Flensburg* it was possible to home into the stream from at least 45 miles away and then to select an individual aircraft and complete the interception. On the other hand, any attempt to intercept by means of *S.N.2* alone was frustrated by Window, Type MB, except at the head of the stream. This was an interesting result in itself, and it confirmed that the rate of discharge chosen for Window MB, which had been arrived at immediately the purpose of *S.N.2* became known and before any tests were done, was adequate.

On the basis of this trial flight, the Air Staff accepted the recommendation to discontinue the use of Monica, which was finally withdrawn from operation on 12 September 1944. It had already been restricted by reason of the plotting risk and of the need for maintaining strict radio silence during the approach to enemy territory. The attempt to make Monica a satisfactory tail-warner, however, did not end there. During the winter of 1944/45, No. 5 Group in Bomber Command produced a modification which enabled the radio frequency of the transmitter-receiver unit to sweep continuously through a given range; this prevented *Flensburg* from homing effectively to an individual transmitter but it could not prevent homing from a distance to a general concentration of Monica transmitters.

Centimetric Wavelength Homers[1]

The first centimetric wavelength homer produced for the German Air Force was called *Naxos* and known officially as *FuGe.350*.[2] It was a detector set able to receive all transmissions on the 8–12 centimetre waveband but it could not

[1] A.D.I. (K) Report No. 367/1945. [2] A.D.I. (K) Report No. 369/1945, para. 21.

discriminate between different wavelengths in the band. The problem of designing a set to home to a beamed transmission rotating at sixty revolutions per minute such as produced by H2S was first tackled in March 1943, some two months after the Germans discovered that the Royal Air Force was employing H2S. Little progress was made until an engineer hit upon the idea of obtaining continuous presentation of the signals received by employing aerials rotating about twenty times faster than those of the transmitter. The *Luftwaffe* Signals Staff was so impressed with the ease with which it was possible to home to a slowly rotating beam such as that of the H2S, that one of the requirements for the German Air Force equivalent of H2S, called *Berlin A*, was that its rate of rotation in searching should be very high to ensure that the *Naxos* solution to the homing problem could not be employed against it.

The first trials with *Naxos* were flown in December 1943 at Werneuchen and the first operational *Gruppe* to be equipped with the set had it installed in all their aircraft by 25 January 1944. The real value of *Naxos* was first appreciated by German aircrews in the early summer of 1944 when the increase in Allied jamming of ground-to-air communications had made it most difficult for them to find the bomber stream by those means.[1] The picture obtained by *Naxos* was not discriminating enough, however, to enable a fighter to track down one individual bomber unless the target were well separated from others in the stream. On the other hand *Naxos* made it easy to locate the bomber stream generally, which at that period was the main preoccupation of the German Air Force. A rough estimate of range could be gained if the height at which the bombers were flying was known, since by climbing and noticing at what height the H2S signals ceased to be heard, the fighter could judge the approximate distance of the target bomber.

First news of the introduction of *Naxos* began to trickle in from *Luftwaffe* prisoners in mid-July 1944.[2] The first German night-fighter *Gruppe* to be equipped with *Naxos* was completely fitted by the end of January 1944. *Naxos* training was done at Weneuchen where a captured Liberator aircraft and a *Ju.88*, both equipped with H2S were used as target aircraft.[3] The first aircrews to be trained at this school all went into *Gruppe II*, and after they had become proficient this formation became known as the *Schwerpunkt Gruppe* (Centre of Gravity Group), a term denoting a unit which, on the expectation or first warning of a raid, was positioned as near as possible to the expected track of the main bomber stream. *Gruppe II* continued in this rôle until the American attack on Quakenbruck on 8 April 1944 when all the *Naxos* equipped aircraft were destroyed, and for a time the *Gruppe* had to operate without *Naxos*: a good example of the value of direct air action as a counter-measure. It was not until 7 July that replacements of *Naxos* fitted *Ju.88* aircraft began to arrive.

Naxos Construction[4]

The *Naxos* aerial was housed in a plexiglass dome, flippantly referred to as the "Cheesedish Cover," some 40 or 50 centimetres in diameter and protruding above the top of the fuselage midway between the tail unit and the trailing edge of the wings. The aerial consisted of two metal-sheathed cylindrical units,

[1] A.D.I. (K) Report No. 369/1945, paras. 25 and 26.
[2] A.D.I. (K) Report No. 407/1945, para. 36.
[3] A.D.I. (K) Report No. 599/1944. [4] A.D.I. (K) Report No. 580/1944.

each about ten to fifteen centimetres apart on either side of a porcelain insulator. They were connected at their base by a horizontal rod, to the centre of which was fastened a vertical rod, coupled in turn to an electrically-driven turntable. The presentation unit consisted of a single cathode ray tube some twelve centimetres in diameter. When the apparatus was switched on, a circular trace appeared near the perimeter of the tube and when aircraft using H2S were within *Naxos* range, a series of dots, one for each aircraft picked up, appeared on the trace. The position of a dot on the trace indicated the position of the target aircraft. The range of the *Naxos* equipment depended upon the relative heights of the fighter and the target bomber. When the former was 1,000 metres below the latter, the range was 50 kilometres and when 2,000 metres below, the range was 100 kilometres.[1]

Naxos Homing Technique[2]

In a homing operation, the German radio operator obtained the height of the bomber stream from the broadcast commentary and closed in usually well below the height given. He then endeavoured to keep on the fringe of the cone formed by the H2S transmissions, gaining height and closing with the target at the same time. The reason for this technique was to avoid having his presence betrayed by an indication on the H2S screen. When the first *Naxos* contact had been made, the commentary was again referred to in order to confirm that the target belonged to the main bomber stream and was not a decoy.

When homing to a formation of bombers, amongst which was a number using H2S, each aircraft transmission appeared on the presentation screen of the *Naxos*. In order to select an individual target, the operator decreased gain so as to eliminate all signals except that of the nearest bomber. As the fighter closed with the target, gain was progressively decreased so as to keep only the target dot on the screen. This dot widened and spread round the circular trace until, when the fighter was directly beneath the target, the trace formed a complete circle. The procedure accordingly gave the fighter an excellent point of vantage for use of an upward firing gun. Frequently the final stage of approach was effected mainly by use of A.I. Although a few German aircrews claimed that a very experienced crew could complete an interception by the use of *Naxos* alone, it was generally considered that the function of *Naxos* was for homing to within A.I. range.[3]

---

[1] A number of variants of Naxos were produced, as follows:—

"*Naxos Z*" (Z = *Uzulanplug* = Target Approach): the original homing device operating in the 8–12 centimetre band. It could not differentiate between frequencies in the band, so that if there was more than one H2S aircraft in the vicinity, the presentation was confused

"*Naxos ZR*" (R = *Ruckwarts* = Backwards): This employed aerials both above and below the aft part of the *Ju.88* and served as a backward warning device for the approach of British night fighters using Mark VIII or Mark XA.I. on the 9-centimetre wavelength

"*Naxos ZX*" (X = X-band): This was a 3-centimetre version of the original "*Naxos Z*" and operated on the 2·5 – 4-centimetre band.

"*Naxos RX*". This was a 3-centimetre version of the "*Naxos R*" and was used as a tail-warner against 3-centimetre A.I.

"*Naxos ZD*": This was a combined homer for both the 9- and the 3-centimetre bands. The 3-centimetre aerials rotated on the same axis but above the 9-centimetre aerials.

[2] A.D.I. (K) Report No. 580/1944.

[3] A.D.I. (K) Report No. 580, para. 81, and A.D.I (K) Report No. 620/1944.

Naxos—Shadowing Technique

Mention has already been made of the use of the more expert crews as leaders, each being responsible for homing the less experienced crews into the bomber stream. One feature of this technique was shadowing the bomber stream. Up to mid-August 1944 in *II/N.J.G.1*, the *Naxos*-equipped aircraft flown by the *Gruppen Kommandeur* was employed as a shadowing aircraft to home to H2S transmissions of the incoming bombers and to report their position and composition to the *Gruppe*.[1] The shadowing aircraft—called the *Fuhrer* or sometimes *Aufklaner* (Reconnaissance)—took off at the first indications of a Royal Air Force attack before the remainder of the Gruppe, and homed to and remained with the bomber stream. The method of reconnaissance reporting varied, but was usually by V.H.F. R/T from the leader to Division headquarters in a special code which changed from day to day. The leader thus reported course, height and, as far as possible, composition of the bomber force. The Division in turn passed such information as was necessary to the night-fighter *Gruppen* under its control and the information was received on the airfield loud-speakers. When the night fighters took off to intercept the bombers they were not always in direct communication with the leader but usually received guidance from him by way of the ground control. In all cases, however, once the fighters had been conducted into the bomber stream, the leader aircraft was informed and each fighter thereafter operated individually, assisted by flares dropped by the leader.

Single-Engined *Wilde Sau* Fighters with Air-to-Air Homers[2]

Single-engined *Wilde Sau* night-fighter aircraft employed on free-lance operations were equipped with a homer called *FuGe.16Z* for homing to navigational radio beacons. They used this equipment also for homing to British jammer aircraft in bomber streams. As with most homers, this one gave no indication of range or height, and pilots had to depend upon general information supplied by ground control.[3] *Me.109* and *F.W.190* aircraft were equipped with *Naxos* for similar free-lance operations against Royal Air Force H2S aircraft. In the *F.W.190* the *Naxos* aerial dome was fitted to the after part of the sliding portion of the cockpit cover.

Infra-Red Homers—*Kiel*[4]

A most interesting feature of the enemy homing programme was the development of an infra-red air-to-air homer equipment for homing to bomber exhausts, known as *Kiel*. It was alleged to have a range of five to six kilometres on twin-engined fighters, which is considerably greater than anything achieved with infra-red by the Allies. There were few models of this equipment in operation by the time of the German capitulation in Europe. The moon and burning targets proved to be an embarrassment, and the use of *Kiel* in the neighbourhood of the target area was made impossible by the interference. It seemed that this form of homing nevertheless had great possibilities in the matter of suitability for homing to individual aircraft. Constructionally *Kiel* was simple and consisted essentially of a photo-cell detector placed at the focus of a paraboloid reflector which was arranged to scan in the manner of centimetric A.I. aerials. The photo-cell operated a cathode ray unit which provided the normal form of presentation.

[1] A.D.I. (K) Report No. 599/1944. [2] A.D.I. (K) Report No. 426/1944.
[3] A.D.I. (K) Report No. 416/1945, paras. 148–150.
[4] A.D.I. (K) Report No. 336/1945.

Counter-measures against German Air Force Homers

The best counter-measure against German homer operations was the greatest degree of radio silence compatible with effective operational use of all airborne radio equipment. The enemy was thus deprived as far as possible of the means on which his tactics depended. Radio silence measures were directed equally against the night-fighter and against the German raid tracking service.[1] The best effect was achieved by consideration of radio silence, jamming, and spoof transmissions combined in such a way as to outwit the enemy air defence system as a whole.

---

[1] *See* Chapter 13 of this volume.

CHAPTER 15

THE EMPLOYMENT OF RADIO COUNTER-MEASURES IN FEINT BOMBER ATTACKS—SPOOF

The employment of radio counter-measures in feint bomber attacks provided a fresh approach to the tactical problems of the Bomber Offensive. The technique became known as Spoof, and as carried out by aircraft of No. 100 Group in Bomber Command it was a very great factor in reducing the power of the German Air Defence. The full-scale introduction of Spoof was only effected after some delay caused by misgiving as to the wisdom of allowing aircraft to be diverted from the bomb-carrying role to the special force necessary to perform the operation.

Many devices of a technical and non-technical nature had been employed in the endeavour to minimise bomber losses. The raiders approached the target by indirect courses, feinting at other possible targets on the way in order to mislead the defences. Bomber aircraft were concentrated in time and space in order to saturate the radar and anti-aircraft guns and thus reduce their effectiveness. Such tactics were successful for a time, but by a readjustment of defensive methods the Germans were able to a great extent to overcome their effect. Individual radio counter-measures against certain radar and communications equipments enabled the Allies to neutralise or nullify the advantages they gave. This use of counter-measures, however, merely denied the services concerned to the enemy, and the Germans regained the initiative by changes of equipment, frequency, or tactics.[1]

Spoof was the co-ordinated use of several radio counter-measures, combined to produce a calculated deception of the enemy's raid reporting system, and employed in conjunction with the tactics of the main bomber force. It aimed generally at inducing the Germans to commit their fighters to engage an imaginary simulated raid at a place or time remote from that of the genuine bomber attack, but was also used in a variety of ways, including the causing of false alerts to fatigue the enemy's defences.

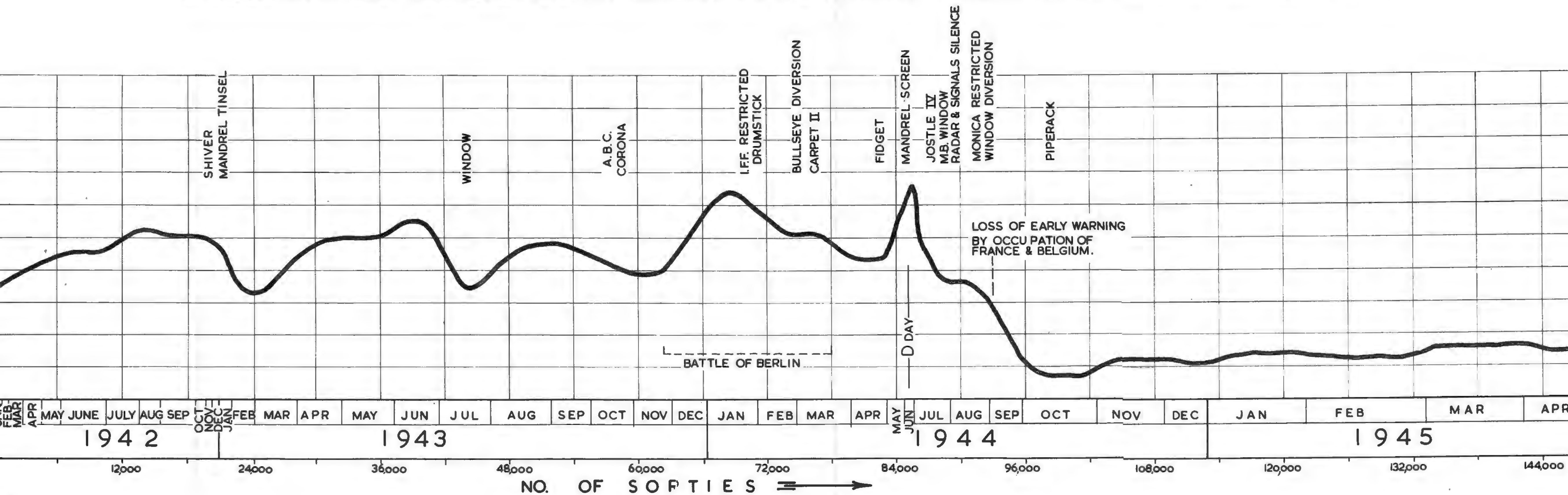
Moonshine

Mention has already been made[2] of an airborne radar responder called Moonshine tuned to be responsive to enemy *Freya* early warning stations, and designed to produce on the cathode ray tube of *Freya* equipment a multi-aircraft echo from each individual Moonshine transmitter. By this means a small, widely dispersed formation of Moonshine-fitted aircraft could appear to the enemy as a large bomber force. This spoof device could be most effective in areas in which the enemy relied entirely on *Freya* for early warning. It had, however, certain limitations in use. The Moonshine response was limited to about five miles in length which corresponded approximately to a daylight bomber raid.[3] To simulate a night operation, however, a much more extended

[1] The Bomber Command Loss Rate against German targets is shown at Diagram 8.
[2] Part 2, Chapter 7, of this volume.
[3] A.M. File R.C.M./155/Tels. 2, Parts 1 and 2, Encl. 129A.

DIAGRAM SHOWING BOMBER COMMAND LOSS RATE ON GERMAN TARGETS

PERCENTAGE LOSSES ON GERMAN TARGETS BY NIGHT JAN 1942—APRIL 1945 ARE CALCULATED FOR EACH 3000 SORTIES.
INTRODUCTION OF EACH R.C.M. DEVICE & OTHER IMPORTANT FACTORS AFFECTING THE LOSS ARE SHOWN AT THE APPROPRIATE DATES.



response would be required, and this would enable the deception to be unmasked by D.F., as all the responses would have the same bearing. Moonshine was not suitable, therefore, to simulate night operations. Furthermore, the Moonshine aircraft were not in general flown nearer to the enemy territory than 30 miles for fear of the deception being detected by the *Wurzburg* radar.

It was decided on 11 May 1942 that No. 11 Group should exercise full operational control of Moonshine aircraft and should be advised technically by No. 80 Wing who would be responsible for the maintenance and setting up of the special equipment.[1] Air Ministry (A.I.4) provided Headquarters, No. 80 Wing with the details of enemy radar stations and made arrangements for this information to be kept up to date from day to day.

It was planned to use Moonshine for the following purposes :—

(*a*) To create an enemy reaction at a place and time suitable for our fighters to engage at a tactical advantage.

(*b*) To draw enemy fighters away from the day-bomber attacks which were then being made over enemy-occupied territory.

In order to cover up the inherent limitation of Moonshine just mentioned, operations had so to be designed as to induce the enemy to despatch their fighter aircraft before the feint force had reached the 30 miles limit.[2] In some circumstances, Moonshine aircraft were to lose height steadily soon after setting course for the point of rendezvous, so that by the time they reached the 30 miles limit they would be at an altitude of 3,000 to 5,000 feet. They were then to fly fast down to sea-level and return on selected tracks at sea-level while other aircraft gained a great altitude and swept a carefully selected area. This was intended to lead the enemy radar and observer corps to confirm the reports they would probably by then have given. During the sweep the aircraft engaged on it were to spread in order to increase the area, and hence the number of stations by which they would be reported. Occasionally a few bombers were to be included in the sweep. They were to make a shallow penetration and to drop a few bombs in order to reinforce the spoof. It was further planned that, on occasions, No. 11 Group would despatch a small escort of fighters with the Moonshine aircraft with the objects of :—

(*a*) Helping to fortify the impression that fighters were joining up at the rendezvous.

(*b*) To give life to the fake echoes.

(*c*) To orbit the Moonshine aircraft in order to reduce the possibility of the spoof being unmasked by D.F. methods.

(*d*) To maintain some echoes after the Moonshine aircraft had returned.

(*e*) To confirm the impression given to enemy radar and observer corps stations that real aircraft were actually flying.

(*f*) To protect the Moonshine aircraft.

The first occasion on which Moonshine was used was on 6 August 1942[3] when eight Moonshine aircraft (Defiant aircraft of No. 515 Squadron), accompanied by a monitoring aircraft, took off from Northolt at 1904 hours and orbited over Portland from 1952 to 2003 hours before returning to base. These aircraft entered the enemy radar detection zone on the outward journey

[1] H.Q. No. 11 Group File 11G/S.600/1/Ops. and A.M. File R.C.M./155/Tels. 2, Part 1.
[2] A.M. File R.C.M./186/Tels. 2, M.S. [3] A.M. File R.C.M./121/Tels. 2, Part 1.

16 miles south-west of Middle Wallop at 1925 hours and left it near Southampton on their return at 2025 hours. The enemy fighter force which took off as a result of this flight was plotted as 26-plus aircraft, which was believed to be a maximum effort for the sector concerned. The enemy balloon barrage at Cherbourg was raised.

In order to confirm whether the enemy's reaction was, in fact, due to Moonshine, a similar flight was carried out on 12 August between the hours of 1108 and 1245, but this time without using the Moonshine apparatus. No enemy aircraft was airborne for action against this sortie and no balloon barrage activity was reported. Moonshine was from then on used for operational purposes. In all, Moonshine was operated 29 times, 26 of which were successful in creating an enemy fighter reaction at the time and place planned. On the three other occasions no enemy reaction was observed—on two when the weather over the enemy aerodromes was unfit for flying and on the other, during the Dieppe operation, when it was impossible to plot the enemy reaction owing to jamming and it was probable that the whole available enemy fighter force was engaged on the major operation.

The following are examples of the effects produced. Of these (*a*) was one of the best results produced, (*b*) and (*c*) were usual average reactions and (*d*) was one of the least successful.

(*a*) 2 October. Attack by 12 Boston aircraft on Le Havre. Main formations consisted of a total of 132 British fighter aircraft. The enemy reaction was 16.

Diversion.—The Moonshine diversion consisting of 72 aircraft, including the nine Moonshine Defiants, produced a reaction in the St. Omer and Courtrai areas of 50 enemy aircraft.

(*b*) 20 August.—Attack on Amiens by 12 Fortress aircraft.

Main Formations.—Consisted of 264 British fighter aircraft. The bombers had a clear run to the target. Total enemy reaction 83.

Diversion.—The Moonshine Defiants joined with 128 fighters in the Beachy Head area. Enemy reaction 60. They then joined with 76 fighters in the Clacton area. Enemy reaction 100.

(*c*) 17 August.—Attack on Rouen by 12 Fortresses.

Main formations.—Consisted of 180 aircraft. Enemy reaction 78.

Diversion.—The nine Defiants joined with three Fortresses and 97 Spitfires over Walton-on-Naze area. Enemy reaction 144 plus.

(*d*) 7 September.—Attack on Rotterdam by 36 Fortresses.

Main formations.—60 British aircraft. Enemy reaction 48.

Diversion.—108 British aircraft including the Defiants. Enemy reaction 30.

No. 11 Group Intelligence analysed sixteen of the Moonshine operations and calculated that they had caused an unstated number of enemy fighters to be airborne for a total of 837 minutes—an average of 52·4 minutes per operation. A further analysis of nine operations by No. 11 Group Intelligence produced an average of 65 enemy aircraft airborne by the Defiants as opposed to the

41·8 enemy aircraft produced by the main formation and its fighter escort. A further analysis carried out by No. 11 Group Intelligence gave the following comparisons :—

(*a*) "Circus" 220 (2 October 1942)—58–70 per cent. of the enemy's available forces were airborne.

(*b*) "Circus" 224 (9 October 1942)—63–81 per cent. of the enemy's available forces were airborne.

(*c*) "Rodeo" 101 (11 October 1942)—a sweep by Defiants—92 per cent. of the enemy's forces available were airborne.

(*d*) "Circus" 227 (15 October 1942)—59 per cent. of the enemy's forces available were airborne.

144 plus enemy aircraft were reported against the diversion on 17 August 1942. The enemy control initiated action as soon as the Defiant formation left Clacton. An extract from the official report for that day gives the following :

> "This operation stirred up German reaction on a considerable scale. Aircraft of the N. Section of the Pas de Calais were airborne by 1720 and the recall to one wing was heard at 1747. The raiders were designated as bombers, main formation, second formation, and withdrawal cover. An announcement sent out by control at 1730, and notable for its departure from the usual jargon, reported bombers at 2/3,000 feet, covered by fighters in serried mass. Control's analysis of the attacking force was not clearly laid out : the formations were often inaccurately labelled and it was only in the latter stages that control avoided confusion by concentrating on the movement of only one of the formations."

Moonshine was operated for the last time on 22 November 1942, after which date No. 515 Squadron was required exclusively for R.C.M. operations of another kind in support of Bomber Command. When it again became available for Moonshine operations, the frequency band of the enemy early warning system had extended considerably beyond the coverage of the Moonshine equipment and it was considered impracticable to produce the equipment required to cover all the enemy's frequencies.[1] Furthermore the immunity of the German 53 centimetre G.C.I. from Moonshine limited the usefulness of those aircraft.

The use of Moonshine was always restricted by precautions to ensure that it should never fall into the hands of the Germans. It is important as an example of the use of radio deception to secure a tactical advantage. Moonshine was, however, a relatively minor feature in comparison with the much greater scale of feint achieved by the employment of radio counter-measures in support of Bomber Command in the later stages of the War.

The Beginning of Spoof Raids in Support of the Night Bomber Offensive

After the use of Moonshine in 1942 to simulate a decoying force of day-bombers, more than a year elapsed before attempts were made to draw German defensive fighters away from the night bomber force by means of planned dummy attacks. It became apparent during 1943 that it might be possible to induce the enemy to commit his defensive night-fighters to action by the threat from a dummy raid, provided that the threat was aimed at an area

[1] A.M. File R.C.M./121/Tels. 2, Part 1.

containing important or vulnerable targets. If this could be achieved, the feint would have the valuable result of enabling the main bomber force to complete its task with greatly reduced losses.

Between October 1943 and February 1944, Berlin was frequently and heavily raided. The enemy accordingly became sensitive to threats against the Berlin area, and by February it was considered that his reaction in defence of it was almost automatic. This finally convinced Bomber Command that feints should be begun.[1] The first Bomber Command feint attacks were made by training aircraft, and although radio counter-measures were not used at first, the German dependence upon radar was exploited.[2] The object was to alert the German early warning radar organisation in order to draw night-fighters against an imaginary raid in an area remote from that in which the main attack was intended. The feint forces did not actually make an attack, nor were they even exposed to combat, as the plan ensured their withdrawal at a safe time and distance from the enemy coast.

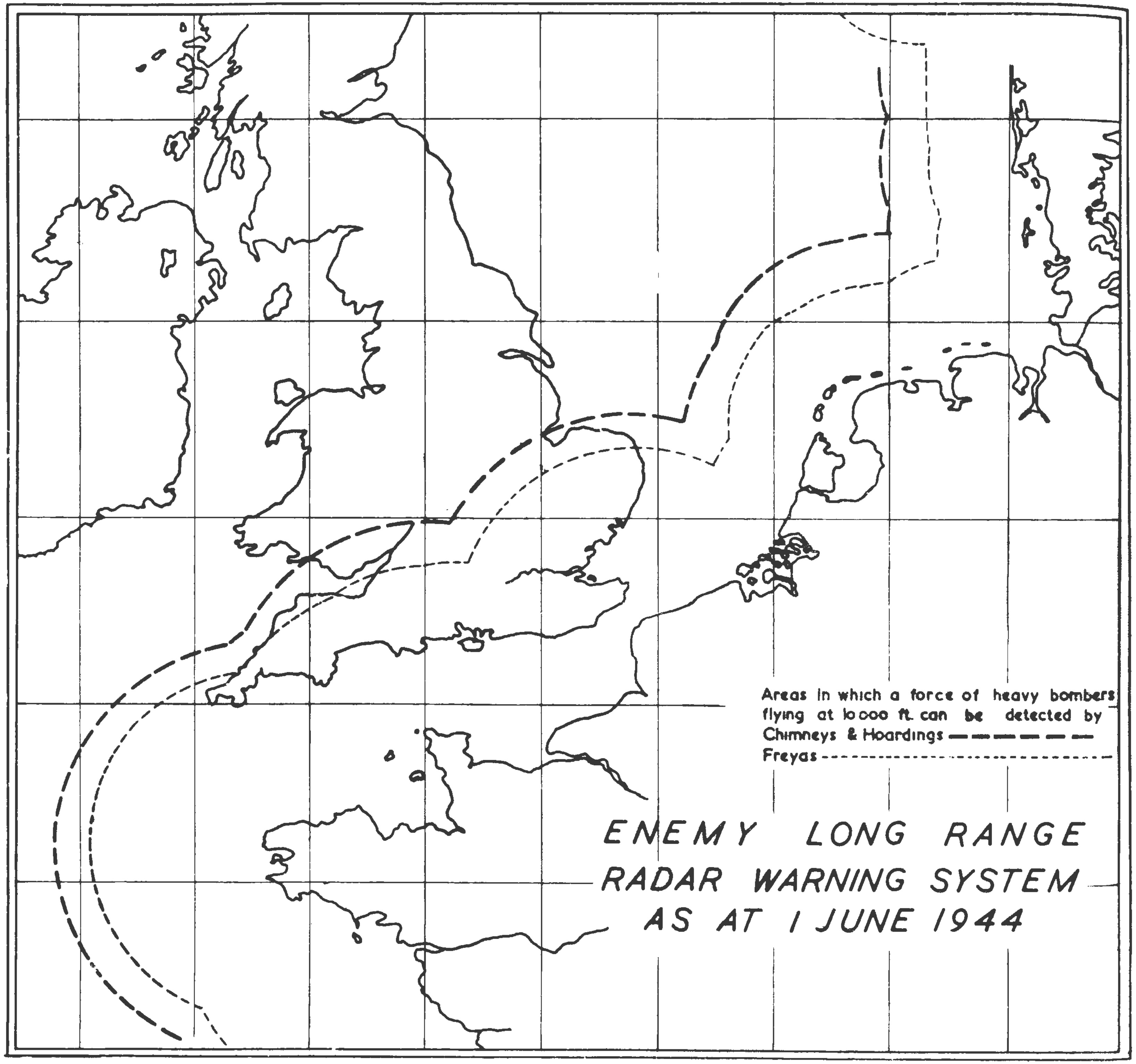
The mounting of these feint attacks was made possible by the existence of the large operational training establishment in Bomber Command at the beginning of 1944. Many of the aircraft were four-engined types used by Heavy Conversion Units (H.C.U.s) and flown by crews in the last stage of training before entering operational squadrons. The H.C.U.s in the Command could together muster from 150 to 200 aircraft and they provided the feint forces, augmented on occasions by Operational Training Unit (O.T.U.) aircraft. One of the regular night flying exercises at the O.T.U. stage was a long flight *en masse*, usually flown round the British Isles. An incidental object of this exercise was to keep British air defences in practice and when this was included in the programme, the flight was known as a Bullseye.

The Bullseye Feint

The ruse first tried on the night of 20/21 February 1944, was to route the Bullseye force out over the North Sea as far as 54° 30′ N., 05° 00′ E., from which point it returned to the Humber. The bomber force was to cross Northern France and Southern Germany to attack Stuttgart on the same night. The movement of both forces was timed to bring the Bullseye force well into radar view of the enemy before the real attack could be plotted. The plan worked well. The enemy despatched practically the whole of his available night-fighter force to the area of Southern Denmark to await what was evidently supposed to be an imminent attack on Berlin or some other target in the area about which he was particularly sensitive. The Germans realised their mistake only when the Bullseye force turned for home and the main bomber force was reported to the north-west of Strasburg. The fighters in Southern Denmark were immediately ordered to Augsburg to intercept—an impossible task, as the distance was 400 miles. In the meantime the bomber force reached Stuttgart with 598 aircraft and delivered a heavy attack for the loss of only nine bombers, compared with the 78 aircraft lost against Leipzig the night before. The success of Bomber Command in this attack in February 1944, set the Germans a new problem. They had now not only to contend with radio counter-measures in all the many forms hitherto experienced, but they also had to recognise the difference between a feint and the real attack.

---

[1] A.M. (A.I.4 (f)) Reports PEARL/ZIP/TAC/N.11 and 15.
[2] The German long-range radar warning system is shown at Diagram 9.


Areas in which a force of heavy bombers flying at 10,000 ft. can be detected by
Chimneys & Hoardings
Freyas
ENEMY LONG RANGE RADAR WARNING SYSTEM AS AT 1 JUNE 1944

Later, feint raids on the same lines were successful in varying degrees, but it was not until the liberation of North-West Europe allowed greater freedom for the manœuvre of feint forces that the enemy was reduced to the point where he was compelled to hold his fighters back until he felt certain of the real attack. Until the German retreat across France began, the only area in which Bullseye forces could safely operate was over the North Sea towards Heligoland. As this was also the best, and indeed the only practicable routeing for the bomber force when attacking targets north and east of Berlin, there was not very much scope for the Bullseye feint technique. Nevertheless, considerable success was achieved on some occasions and in general the Germans became exceedingly nervous about committing night fighters until the situation was entirely clear to them.

O.T.U. Spoof Force Combined with a Window Force

By the end of June 1944 the possibilities of Bullseye in its original form were fairly exhausted. The main disadvantage of the simple O.T.U. spoof technique was the need for the unarmed force to turn back before reaching the enemy coast, which limited the period during which it appeared as a threat. At this stage the long-overdue radio counter-measure form of spoof was introduced to give to Bullseye a short new lease of life, and to feint bomber raids generally an effectiveness which they retained and progressively improved up to the end of the war in Europe. The addition of a small Window force which flew outward with the Bullseye and carried on when the latter had to turn back, removed the main weakness of the original Bullseye feint.

Window in its original role as a G.C.I./early-warning radar "jammer" had demonstrated that the German radar was unable to distinguish between the echo from a genuine aircraft and one from a bundle of Window. This element of deception, as opposed to mere jamming by saturation, offered the most promising possibilities. By employing a small force of aircraft to drop Window according to a pre-determined pattern, it became possible to simulate to radar ground stations the approach of a bomber force comparable in size to the large scale Bomber Command raids, the presence of which would inevitably cause major German air defence forces to be committed to action. This stratagem was first used on the night of 14/15 July 1944, the small Window dropping force consisting of only about six heavy bomber aircraft. Thus was inaugurated the Special Window Force of No. 100 Group which was to play an important part in future operations.

The best method of employing Window-dropping aircraft was not arrived at without much calculation and deliberation.[1] When the Air Officer Commanding, No. 100 Group, after considerable time spent in working out the Window spoof theory, formally placed his proposals[2] before Headquarters, Bomber Command, on 11 May 1944 he advocated that 15 aircraft disposed in three lanes five miles apart, with a 20-mile interval between aircraft in each lane, each aircraft dropping Window of both the *Wurzburg* and the *Freya* varieties at the rate of 20 units (each equivalent to one aircraft) per minute, would appear as a mass of 800 aircraft. This represented a startling economy in aircraft, but involved complicated weaving by the aircraft in azimuth and elevation in order to fill the gaps that would otherwise appear between the lanes of Window, and also to give the correct appearance of depth. Headquarters,

[1] Part 2, Chapter 9, of this volume.
[2] H.Q. No. 100 Group File 100G/TS. 1210/Sigs.

Bomber Command, on the other hand, advocated the employment of 25 aircraft flying in a more straightforward deployment and representing about 400 aircraft.[1]

Employment of Window in Feint Air Attack

The dropping by a special force of aircraft of a carefully calculated and steadily maintained quantity of Window in such a way as to simulate formations of bomber aircraft was probably the most important radio counter-measure of the whole war. Used in conjunction with the Mandrel screen it became a feint tactic of very great value in the bomber offensive.

Different types of Window spoof were developed as follows[2] and in this order of appearance :—

(*a*) Combination of a small special Window force with an O.T.U. Bullseye force.

(*b*) Window spoof force. This consisted of a somewhat larger force of special Window aircraft by themselves. It thus dispensed with the O.T.U. aircraft which by May 1944 had become ineffective.

(*c*) Window spoof force with Mosquito fighters. The addition of Mosquito fighters at the head of the Window spoof force increased the resemblance of the spoof force to a real raid. It also provided the Mosquitos with an excellent opportunity to attack the German fighters airborne against the spoof threat. This was done by fanning out when the Window force turned back.

(*d*) Window spoof force with Mosquito fighters and Mosquito bombers. The enemy attached much importance to reports of bombs having been dropped as indicating that a raid was genuine. Bomber Command exploited this by combining the last-mentioned type of spoof with Mosquito bombing missions.

The Window force was generally employed in one or more of three different ways. Either it simulated a separate bomber force acting independently, or it accompanied the main bomber force and broke away from it, or, thirdly, it saturated an area on the route or around a target. Combinations of one or more of these tactics were frequently employed during one night's operation, much care being taken to avoid repetition.

The first method, the simulation of a separate force, was used with the dual object of attracting fighters based in the area in which the Window force operated and drawing them away from areas in which bombing raids were being made. It was also used on nights when no major raids were planned, in order to cause unnecessary activity by night fighter controls and their flying units, thus increasing wastage and undermining the morale of crews and controllers.

The second method, the splitting of routes by means of a breakaway by a Window force, was designed to lay a false trail for the confusion of fighters attempting route interception or to divert others which were being directed to possible targets. This tactic was particularly useful for the protection of bomber forces which had to make deep penetrations over enemy territory.

[1] No. 100 Group File TS. 1210/Sigs. and H.Q.B.C. O.R.S. Report No. S.148 (Bomber Command File B.C./S.28806/1/O.R.S., 11 April 1944).

[2] A.M. (A.I.4 (f)) Report PEARL/ZIP/TAC/N.11 of 22 November 1944.

[3] *Ibid.*, July 1944–May 1945, and No. 100 Group " Review of Operations."

The Window force normally left the main force at one of its turning points, often to continue on a straight path towards a possible alternative target.

The third method, the saturation of an area with Window, was used principally in the Ruhr when it was accepted that there was little likelihood of deceiving the enemy as to the area in which operations were intended; the object of saturation was to conceal the identity of the actual target for as long as possible.

The three methods must be considered in relation to the particular conditions in which they were employed. The separate feint force, operating in an area away from bombing attacks, might have only limited choice of areas in which to operate. On nights when a number of targets was attacked, these areas were often restricted to those parts of Germany where the weather did not allow a bombing force to go with any great hope of success. Consequently an enemy who made intelligent use of his own meteorological information could discount them in advance. On the other hand, the saturation method, which showed most satisfactory results, was employed in an area which was geographically ideal—the Ruhr, where there were many likely targets only a few minutes flying time inside enemy territory. The enemy, seeing an attack developing in that direction, had only a very short time in which to decide exactly where the attack was to fall. This method was not usefully employed in any other area, mainly because conditions were not suitable.

Mandrel Screen

The Mandrel screen technique which had been in abeyance for about twelve months was brought into use again by No. 100 Group on the night of 5/6 June 1944. Its use had previously been discontinued as a result of the Germans spreading the frequencies of their early warning radar beyond the capabilities of the jamming equipment then available.[1] This disability having now been overcome, Nos. 199 and 803 Squadrons were equipped, and from this time onwards the No. 100 Group airborne Mandrel screen gave cover to Bomber Command's raids, screen aircraft being disposed at 80 miles from the enemy coast with pairs of aircraft of No. 199 Squadron spaced at intervals of 28 miles, jamming the entire *Freya* frequency band (70–200 megacycles per second), and aircraft of No. 803 Squadron halfway between them, covering the frequency band of the enemy long-range narrow beam stations (120–140 megacycles per second).[2] Thus the narrow beam stations were covered at intervals of 14 miles and the *Freya* stations at intervals of 28 miles. These intervals were designed to prevent the enemy radar stations from seeing between adjacent jammer centres, thereby effectively reducing the range of German early-warning radar to about 30 miles. The use of the Mandrel screen was, however, somewhat limited because of its interference with army and navy communications, and screen operations in the English Channel were therefore normally precluded.

On three occasions in June the screen was operated close to the enemy coast but it was concluded[3] that this probably enhanced the chances of the German Air Force radar to see through or behind the screen, as the distance between the stations of the screen was determined relative to the beam width of the enemy's early-warning radar. A problem was set early by the shortage of aircraft for screen operation. The need to fly the aircraft of No. 199 Squadron

[1] *See* Chapter 8 above for origin and further details. The " Mandrel " screen was started on 5 December 1942, using Defiant aircraft of No. 515 Squadron, Fighter Command.

[2] No. 100 Group " Review of Operations."

[3] *Ibid.*

in pairs in order to cover the *Freya* frequency band made heavy demands on the squadron[1]. Furthermore, the need to put up the screen for spoof purposes on nights when the main bomber force was resting, was an additional drain on aircraft and crews.

At first each pair of aircraft in the screen tried to keep station together by visual means; but this was found to be either very difficult or impossible on most occasions. A plan for station keeping was accordingly worked out by the navigation section at North Creake. In this, known as the "Racecourse" pattern, the aircraft flew circuits up and down selected Gee lattice lines perpendicular to the enemy's coast. The first circuit was ten miles long, rate one turn being made at both ends of the straight legs, and each circuit being adjusted according to wind conditions to take exactly ten minutes. The aircraft of each pair started at opposite ends of the circuit in order to maintain a strong average jamming intensity over all frequencies. A very high standard of flying and navigation was called for, especially as the Stirling aircraft always flew at their maximum operational height, often in cloud. Some Gee chains were jammed by the Mandrel, so that there was then no means of windfinding once the Racecourse pattern had been started. Many of these difficulties were overcome when Halifax aircraft were substituted for the Stirling aircraft, but this change did not occur until March, 1945. This screen technique was not peculiar to spoof operations only, but was the usual one for straightforward jamming operations also. Flying as they had to in such a methodical manner, Mandrel aircraft would indeed have been relatively easy prey to enemy fighters fitted with *Freya-Halbe* homers had they been used extensively.

During July 1944 No. 100 Group's Mandrel screen was operated on five occasions when a mass bomber raid was not intended, the purpose being to cause the German Air Force defences unnecessary and wasteful activity[2]. It was hoped that these dummy raids would not only tire the enemy, but would result sooner or later in the defences failing to react efficiently on the night of a genuine Bomber Command raid.

Employment of Mandrel with Window Spoof Force

For feint attacks to be wholly successful they had to contain, ostensibly, all the ingredients of a genuine bomber raid. Airborne Mandrel jammers had been brought into use against the German early warning and G.C.I system in December 1942, and thereafter were regularly employed in Bomber Command aircraft. A Window spoof force without support of this kind would soon have raised doubts in the minds of the enemy as to its validity. At the same time, it could be used skilfully to enhance the general effect. During August the Mandrel screen occasionally moved forward whilst jamming, to give additional protection to an approaching force, and also intentional "breakdowns" of the screen were so arranged as to give the German early-warning radar a glimpse of the Special Window Force coming through it[3]. Both devices worked successfully and demonstrated how flexible was the new weapon.

Evidence was soon forthcoming from Intelligence sources to show that the Mandrel screen was being effective[4]. An example is taken from the raid on

[1] No. 100 Group "Review of Operations" and Narrator's interview with the Officer Commanding, No. 199 Squadron.
[2] No. 100 Group "Review of Operations," July 1944.
[3] A.M. (A.I.4 (f)) Report PEARL/ZIP/TAC/N, August 1944.
[4] *Ibid.*, PEARL/ZIP/TAC/N.6.

Sterkrade, on the night of 16/17 June 1944, which began crossing the enemy coast at 0045 hours. German fighters from Belgium, Holland and North-west Germany were airborne 33 minutes before this, at 0012 hours. An early reaction of this kind was not unusual but when fighters were airborne so early it was usual for the enemy fighter controls to issue a series of plots on the Royal Air Force bombers as they flew out over the Norfolk coast until it was clear which route they were taking. A concentration of plots would next appear where the fighters were in a position to intercept the bombers. It was therefore noteworthy that on this particular night the fighters were not given plots on the bombers until the raid began to cross the enemy coast. In confirmation of the enemy's apparent ignorance of the movement of this raid was an intercepted wireless message from the Brussels safety service main station, passed to an aircraft believed to be operating from Eindhoven. It was sent when fighters were being ordered to assemble at beacon K, south-east of Deelen, at 0012 hours, and stated that a danger of air attacks had been announced covering a wide area from Northern France to the Frisians and inland as far as the Ruhr.

The absence of plots or the lateness of their commencement and their intermittent nature from that date, together with confusion of control orders, testified to the effect of the Mandrel screen upon the German Air Force defences. During the last week of June, messages indicating the tracks of the bombers were intercepted on four nights[1]. On the remaining nights, no attempt was made to issue either a track or information of bomber movement, as had been customary, over England.

On the night of 21/22 June, Bomber Command did not employ the Mandrel screen.[2] The bombers, en route for Schölven and Wesselin, were first plotted only a few miles from the Norfolk coast, then across the North Sea and over the Dutch Islands, almost to the targets. The two raids crossed the Dutch Islands together, then divided to follow a northerly and a southerly route. As a result of this, the enemy was not compelled to choose a suitably-placed beacon and to concentrate there, but was able to hold his fighter force in being until he was quite clear as to the intention of the bombers, and then to direct groups of fighters directly into the bomber stream. Thirty-seven Lancaster aircraft of the southerly stream and eight of the northerly raid were lost on this occasion, and it is interesting to notice that the former raid passed nearer to airfields where most of the enemy night fighters were concentrated (Eindhoven, St. Trond, Cologne and Florennes). Events of this night contrast sharply with those of the night of 16/17 June, just related, and bring into relief the efficacy of the Mandrel screen in its new role.

Despite the advantages already gained, R.C.M. spoof was still being handicapped by lack of radio silence. It was only because the Allied invasion of Europe had dislocated the hitherto efficient German raid tracking service[3] that tell-tale radar transmissions by Bomber Command aircraft were not disclosing all the positions of main force bombers which the spoof was designed to protect.

During June and July 1944 when the German raid tracking service was struggling to reform itself inland, it did occasionally recapture its old efficiency in plotting the bombers by listening methods, as for example on 27/28 June.[4]

---

[1] A.M. (A.I.4 (f)) PEARL/ZIP/TAC/N.7.

[2] *See* Diagram 10 for diagrammatic illustration of the raid mentioned.

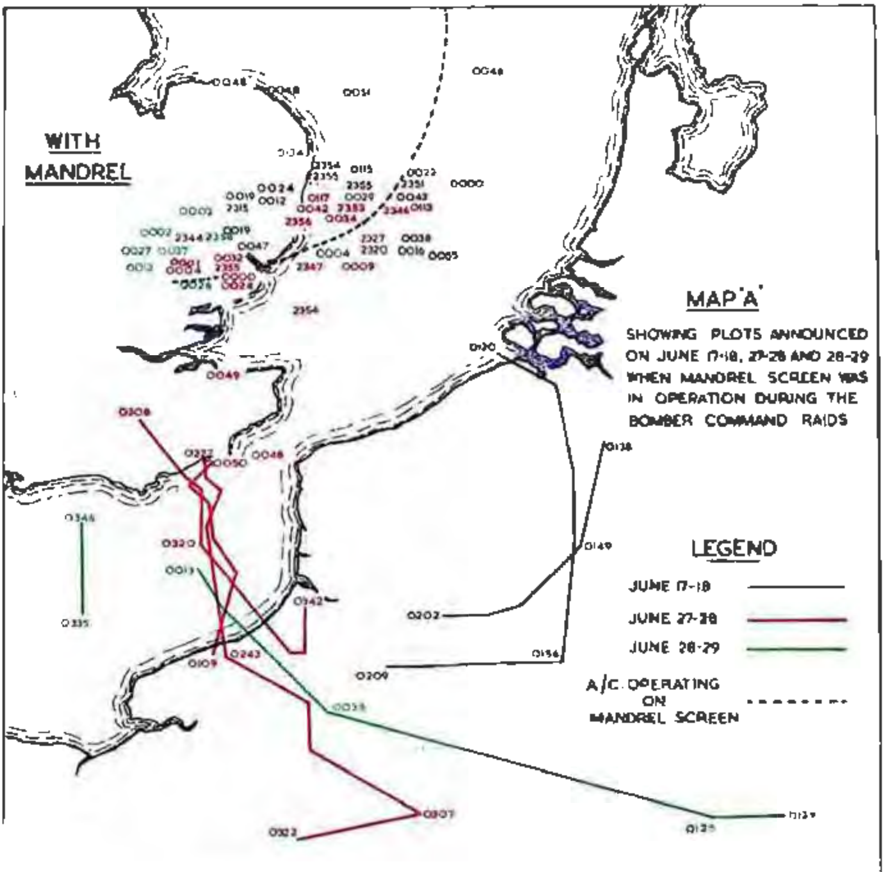
[3] *See* Part 2, Chapter 13, of this volume.

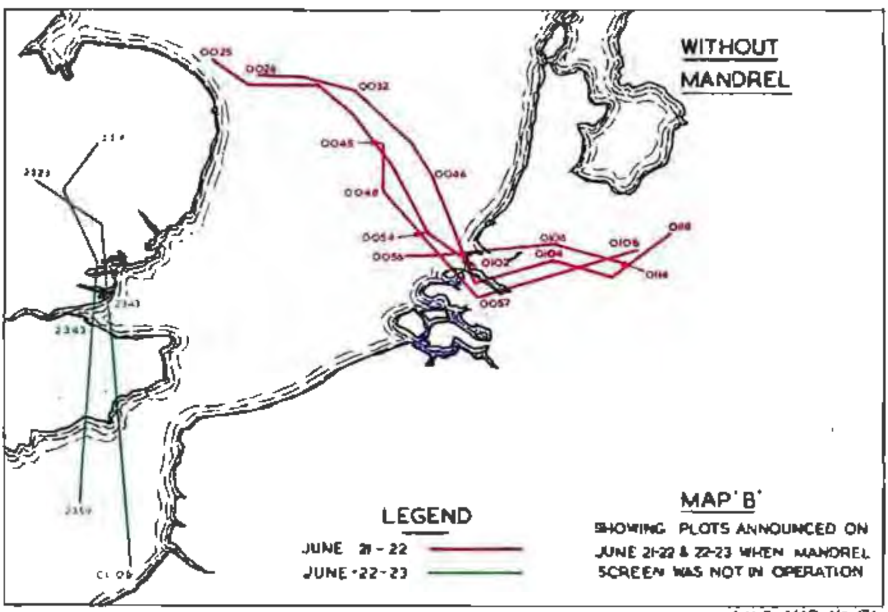
[4] A.M. (A.I.4 (f)) PEARL/ZIP/TAC/N.7.

SECRET

DIAGRAM 10

PLOTS ON BOMBERS FROM GERMAN LISTENING & RADAR SERVICE





A.H.B. MAP No. 474

SECRET

On that occasion, although the Mandrel screen and Window spoof were in operation, the German night-fighter control began to receive scattered plots of the bombers over Essex and off Harwich. A good track plot began to develop from the Hastings area and this was continued across the Channel and beyond the French coast.

On the following night the enemy raid tracking service issued only one plot before midnight—at 2358 hours in a position east of Cambridge. At 0012 hours the Mandrel screen was put up, and yet one minute later the service began broadcasting a series of plots. A number of scattered ones were given over East Anglia, and a track which started in mid-Channel was carried across France as far as Toul.[1]

R.C.M. spoof was thus employed under considerable disadvantages until radar silence was imposed upon the bomber force on 28/29 July 1944 to be effective during the early stages of their outward journey. All the more significant, therefore, was the success obviously achieved by spoof in the meantime. While it is probable that eventually the enemy came to understand how the Mandrel screen and Window forces were operated, he could rarely afford to ignore them, nor could he be certain that a feint attack was all he had to fear. There can be no doubt that, due to the favourable tactical situation after the German retreat to the Rhine, which allowed the Mandrel screen and the Window force considerable freedom for manœuvre, these particular stratagems played a great part in deluding and confusing the enemy.

Features of Window/Mandrel Spoof Operations

Operation of the Special Window Force became almost a day-to-day feature of the general air offensive after its first appearance on the night of 14/15 July 1944 and it is worth while to give a few more detailed examples of its employment. Originally the Force was made up from all available spare heavy aircraft of No. 100 Group, rarely amounting at first to more than ten in number.[2] Even so it achieved considerable success from the outset. At that time the Force operated only over the sea and turned back when still a short distance from the enemy coast. At the same time, the Mandrel screen continued to be used with great effect, having been strengthened during July 1944 by the addition of some Fortress aircraft of No. 214 Squadron. Towards the middle of the same month it became a well-established tactic to combine Window with Mandrel for spoof purposes.

The Mandrel screen was used on sixteen nights of the following month—on several occasions over south-east England to give cover to bomber attacks on the Pas de Calais area. It was found that, when other targets in France were chosen, the mere presence of the screen in front of the Pas de Calais was sufficient to hold fighters in that area.

On the night of 17/18 August 1944, No. 100 Group achieved one of its most outstanding successes with the spoof force, a big attack on Kiel and Stettin having taken place on the preceding night. No major bombing raid took place on the night mentioned, but the Window Force strengthened in numbers by a Bullseye force and covered by a Mandrel screen, headed towards North Germany. The Window aircraft flew almost to the Schleswig coast and created in the mind of the enemy an impression that the previous night's attack was

---

[1] *See* Diagram 10.

[2] No. 100 Group "Review of Operations," November 1943–May 1945, and A.M. (A.I.4 (f)) PEARL/ZIP/TAC/N Reports, July 1944–May 1945.

to be repeated. No less than twelve squadrons of enemy fighters were deployed against the Windowers. A still more important result of this feint attack took place on the following night when the main force actually bombed Bremen by a route similar to that previously taken by the spoof force. The enemy, thoroughly deceived, assumed this to be another spoof and left it entirely unopposed by night-fighters.

With the advance of the Allied armies further into Europe, September 1944, there were new developments in Window/Mandrel spoof technique. For the first time, the spoof force was employed over Europe. It could now be advanced nearer to the heart of Germany with comparative safety, delaying still further the detection of the main bomber force by the enemy radar. This handicap was additional to the loss of radar stations and observer corps posts in territory from which the Germans had recently been driven. A fresh problem was the possibility of the enemy seeing behind the screen which now often operated east of the Hague, which was still in enemy hands. In order to guard against this, the length of the screen was increased and the more northerly part was bent back so as to smother sightings from Holland. At this time No. 171 Squadron was formed at North Creake, equipped with Halifax aircraft and fitted for either Mandrel or Window roles.

It became increasingly evident in September 1944 that the spoof attacks were having great success. Enemy controllers were becoming more and more susceptible to deception even to the extent of seeing a spoof attack where none existed[1]. As an example, on the night of 11/12 September a small minelaying force in the course of a secondary operation in the Baltic evoked heavy fighter reaction, which however made very few contacts. It was evident that the enemy had taken the minelayers to be forerunners of an attack on the Berlin or Stettin areas. Another successful night was that of the 13/14 of the same month when a Window force, feinting at Karlsruhe, brought a heavy force of the *Luftwaffe* post-haste down to Southern Germany although no main force was operating.

As the enemy became more competent in seeing through the Window, it became necessary to increase its density, although owing to the shortage of specialised spoof aircraft, this was only achieved by robbing Mandrel and other jamming forces.[2] About the same time the practice was begun of following a feint attack by a genuine attack on the same target, the latter being timed to open just when the enemy had decided that the first was a feint, and that the night's work was over. By February 1945 this had become a confirmed practice and the part was played by the 492nd Bombardment Group, United States Army Air Force, equipped with Liberator aircraft and trained both in night bombing and Pathfinder technique. Their rôle was to make bomb attacks in conjunction with Window forces and this was done with good effect.

The depth of main force penetrations increased during the month, making it still more difficult to stage a convincing feint because the distances to be covered over enemy territory made the differences between main and feint attacks more obvious. However, some success was restored by Windowing lavishly at turning points in order to mask the new direction of the force. So much importance was attached to the accuracy of navigation by the Window force that in February 1945 two navigators were attached to each Window station solely for

[1] A.M. (A.I.4 (f)) PEARL/ZIP/TAC/N Reports.
[2] No. 100 Group " Review of Operations," November 1943–May 1945.

the purpose of analysis and checking the navigation logs of Window aircraft. It was shown that even a single Windowing aircraft helped to confuse the enemy controllers and it was made a rule, accordingly, for aircraft to complete patrols on dead reckoning when radio aids-to-navigation failed. Until then it had been considered that an individual aircraft off track was liable to give the enemy a true indication of the nature of the nearby force. The advantages of added confusion were now, however, believed to outweigh this consideration. On one occasion an aircraft which had failed to receive a recall to base completed its sortie alone and was plotted throughout by the enemy as a force of 20 to 30 aircraft.

Towards the end of March it became the custom to split the Window force and to operate the Mandrel aircraft in the dual rôle of Mandrel and Window. By this means, with the co-operation of the 492nd Group (U.S.A.A.F.), it was possible to make several feint attacks simultaneously in different directions and areas, as for example, on the night of 20/21 March when no less than three feint attacks were made in support of the main force attacking Bohlen. One Window force left the main stream shortly after crossing the front line and made for Kassel, which was bombed. Further on, when closer to the true target, another Window force broke off and bombed Halle. The third feint force was provided by the Mandrel screen which, after the passage of the bombers, re-formed into a Window force and attacked Frankfurt with flares.

The heavy spoof aircraft worked throughout this month at maximum effort. In the course of feint operations, more than two hundred tons of Window were dropped in addition to over five hundred tons of bombs. On one particular operation, for example, each aircraft discharged nearly two tons of Window. This was all done by hand in full flying kit, under conditions of extreme cold and using oxygen ; a strenuous task when the automatic launching machine was not available.

When the feint forces operated in a different area from the main force, the Command wind-broadcast was usually of no value to the feint forces. A No. 100 Group wind-broadcast was therefore instituted in March 1945, the wind-finder being normally an H2S aircraft of the Mandrel screen which found and broadcast wind velocities for areas between base and patrol for the benefit of Window and Mandrel aircraft.[1] This was done immediately jamming had begun, by which time the presence and position of the aircraft could no longer be concealed from the enemy. It proved successful : on the first night of the scheme, a Window aircraft carried out a Window patrol entirely on dead reckoning based upon broadcast wind velocities and, at the estimated time of arrival, the aircraft was within five miles of base.

Authority for the feint force to be increased to a size compatible with its usefulness and responsibilities was only slowly forthcoming, but in April 1945 the Mandrel squadrons Nos. 171 and 199 were increased by four aircraft each.[2] On several occasions a small force of about twenty to twenty-four heavy bombers was allocated from either No. 4 or No. 6 Group to support the Window force. The old Liberator aircraft of No. 223 Squadron had shown themselves to be too slow to keep up with the British bombers, and they were replaced during the month by Fortress aircraft. Later in the month, when the frontage of the Allied

[1] No. 100 Group " Review of Operations," 1945. [2] *Ibid.*

armies was constantly moving, the Mandrel screen formation was discarded and instead, these aircraft flew on three occasions with the main bomber force, with uncertain effect. Only one important operation was undertaken by No. 100 Group spoof aircraft during May 1945. On the night of 2/3 May eighty-two four-engined aircraft—a record number for the Group—took part in a Mandrel/Window feint in the Schleswig area,[1] one of the few remaining strongholds of the enemy. Kiel was attacked by Pathfinder aircraft at the same time. Little fighter opposition was encountered, probably due to the disorganisation of enemy plotting by the feint attack.

German Radio Counter-Measures against Window and Mandrel

While the Germans were remodelling their night-fighter interception technique, their scientists and radio technicians made great efforts to enable radar stations to discriminate between bomber aircraft and Window echoes.[2] The first step was to introduce new *Freya* frequencies in bands less susceptible to Window and Mandrel. Additional *Freyas* were installed to operate in the 150–200 megacycles per second frequency band, some being in the Allied I.F.F. band of 158–186 megacycles.[3] These stations were able to see through Window and Mandrel interference, and although they were not numerous enough to provide a complete picture of the night-bomber movements, they vitiated to some extent Allied Window/Mandrel spoof and jamming cover.

Intelligence reports indicated that German G.C.I. stations continued to be manned after Window had rendered them ineffective, and that they were held in readiness for instant action should the opportunity again arise. Earphones were fitted to the giant *Wurzburgs* in order that operators could listen to the audio characteristics of radar echoes received. It was found that the propellers of a genuine bomber aircraft produced a characteristic hum in the earphones which did not accompany the echoes from Window, but this distinction could only be heard when the bomber was at close range. Nevertheless the *Nuremburg* procedure, as the new acoustical method was termed, was a factor of some account. Furthermore, two electronic discriminators were produced at the same time for discriminatory purposes,[4] the *Wurzlaus* and *Taunus*. *Wurzlaus* took advantage of the fact that echoes from bombers were fast moving, whereas those from Window moved slowly over the display. Use was made of the Doppler principle, the precise frequency of the echo received from a moving target being varied by an amount proportionate to the speed of the target along the line of sight. The display on the cathode ray tube showed the faster-moving target producing an echo which extended on both sides of the time-base. In the *Taunus* system an electrical circuit controlled the size of the echo according to the " suddenness " with which it was received. This had the effect of splitting up the ragged serrated blips and enabling an echo from any aircraft within the Window cloud to be distinguished.

After the value of both *Wurzlaus* and *Taunus* had been somewhat enhanced by a subsequent modification called *Fakir*, the German authorities considered them jointly to be about 80 per cent. effective against Window. This figure was arrived at from theoretical calculation, however, and in practice, after allowance had been made for technical and operating inefficiencies, the

---

[1] No. 100 Group " Review of Operations," 1945.

[2] H.Q. No. 100 Group File 100G/TS. 1260/Sigs.

[3] Minutes of Sub-Committee of Tactical Counter-Measures to Enemy Night Fighter and A.A. Gun Defences, 3 March 1944.

[4] H.Q. No. 100 Group File 100G/TS. 1260/Sigs., Encl. 9A.

equipments were about 50 per cent. effective, except against the thickest Window clouds, when they were apt to prove unsatisfactory. A more effective German counter-measure than *Wurzlaus*, *Taunus* and *Fakir* was the development of a policy of wide frequency dispersal, higher power, and a more concentrated beaming of early-warning radar, made possible mainly by the adoption of higher frequencies.

The German development plans for early-warning radar in 1944 and early 1945 showed that they were then fully alive to the threat of Window and electronic jamming.[1] Technical counter-measures to such jamming would automatically equip them against spoof which involved Window and Mandrel. Thus when the war in Europe ended the Germans were about to introduce early-warning radar stations of greater range and of far greater discrimination. Amongst them, of particular note, were *Michael-B Jagdschloss* (600 megacycles per second–200 kilowatt), *Forsthaus Fk.* (1,200 megacycles per second–70 kilowatt), and *Forsthaus Z.* (3,300 megacycles per second–100 kilowatt).

T.R.E. made careful calculations as to what effort would be required to operate Window and electronic jammer spoofs in the face of these new stations.[2] It appeared that, with every aircraft of the bomber force dispensing Window at the highest useful rate (one unit per pulse width), the protection given to the bomber force against any of these new radar stations would be of doubtful value, as in all cases the first 30 or 40 aircraft could be accurately plotted even at a range as great as 45 miles. To provide such a Window concentration as this would have involved each aircraft dispensing Window at a rate of seven and a half pounds per minute for each frequency band to be covered. Thus for every hour over enemy territory, each aircraft would have to carry a weight of approximately 450 pounds for each frequency; or 1,350 pounds if all three types of radar were in use simultaneously.

Electronic jamming in the main force would have involved the use of sufficient equipment in every aircraft to provide self-protection, and since the ground radars would be unlikely to use continuous rotation, automatically tuned jamming equipment would hardly have been effective. It would in that case have become necessary for every aircraft to carry a special operator with manually tuned jammers and panoramic receivers. It was therefore unlikely that effective Window spoofs against any of these radar stations would be practicable unless more than 100 Window aircraft could be made available for each force. Similarly, operation of Mandrel with the spoof force would involve a prohibitively large diversion of aircraft. It thus appears that had the war continued for some months beyond V.E. day, Window/Mandrel spoof in its customary form might well have become an uneconomical operation. On the other hand, the only known alternative—direct action with fighter-bombers against the early-warning stations—was amply demonstrated in combined operations to be almost equally problematical.

Exhaustive post-war trials, in which the German Air Force night fighter defence system was operated under Allied supervision and control against large-scale Allied bomber forces supported by spoof forces, enabled the Allies to " see " and " hear " the effects of R.C.M. on the German early-warning and raid-tracking radio stations. Although this was a somewhat academic test,

[1] A.M. A.D.I. (Science) Report, 11 April 1945.

[2] T.R.E. Memorandum 5.M.112/M.R., 1 May 1945, in H.Q. No. 100 Group File 100G/TS. 1252/Sigs.

it proved conclusively that the Allied radio spoof devices were, technically, just about as effective as they were designed to be. That they were equally effective tactically is adequately borne out by reactions of the *Luftwaffe* night-fighter control to them and by post-war interrogations of the German staffs concerned.

Nevertheless, when the war ended, the latest centimetric technique had endowed radar early-warning and raid-tracking services with a new lease of life in the face of the most advanced contemporary radio spoof devices. It seems, therefore, that the 1939–1945 War left the Royal Air Force with a most important and urgent need for further research into and development of this form of radio warfare. That this would be a profitable field for research was clearly demonstrated by the fact that the diversion of a number of bombers from the main bomber force for radio spoof purposes effected a marked overall economy in both aircraft and aircrews, and increased the effectiveness of the bomber offensive in Europe to a proportionate degree.

CHAPTER 16

THE OPERATION OF MOBILE RADIO COUNTER-MEASURE UNITS OF No. 80 WING IN NORTH-WEST EUROPE, 1944-1945

The diminution of German long-range bomber activity during the latter half of 1944, combined with the landing in north-west Europe and the rapidity of the Allied advance on the Continent, called for an expansion of the ground R.C.M. organisation for bomber support. In September 1944 proposals were made by Headquarters, No. 100 Group for the establishment of ground R.C.M. units in Western Europe.[1] The equipment and personnel for this commitment were, in general, to be obtained from the resources of No. 80 Wing and from those units previously formed for Operation "Neptune" whose use in a defensive role had ceased due to the Allied advance. The units, which would be in mobile form, were to be used against the enemy's early warning and night fighter control systems to supplement the airborne radio counter-measures already being carried out by Headquarters, No. 100 Group. The following radio aids employed by the enemy were to be countered:

(*a*) Radar early warning.

(*b*) Fighter control communications system.

(*c*) Aircraft Interception (A.I.).

(*d*) M/F Beacons.

These proposals were submitted to Air Ministry by Bomber Command, and were agreed by Supreme Headquarters Allied Expeditionary Force.[2] Supreme Headquarters was much concerned as to the effect of the jammers on their communications and a comprehensive study of the problem was carried out by the S.H.A.E.F. Mutual Interference Committee,[3] which resulted in certain frequencies being barred for jamming operations.

Meanwhile, discussions had been taking place between representatives of Headquarters No. 100 Group and No. 80 Wing to determine the composition of the Continental element of No. 80 Wing. It was decided that this was to consist of a mobile headquarters (administrative and operational) to operate six Communication Jamming and eight Radar Jamming Units. The Communication Jamming Units were to be formed from existing Mobile Meacon Units expanded with S.J. (V.H.F. Jamming) Units, and the Radar Jamming Units to be formed by converting existing but redundant Ground Mandrel stations. It was also planned to incorporate those units employed in a defensive role against rockets when they could be released.

The Headquarters on the Continent was to be known as Headquarters No. 80 Wing (Main), the Communication Jamming Units as Mobile Signals Units, Type S.C. Nos. 80 to 85, and the Radar Jamming Units as M.S.U.s, Type S.F., Nos. 70 to 77. *The units already on the Continent were Advanced*

[1] No. 80 Wing File T.C.3075/Sigs. [2] No. 80 Wing File S.3076/Sigs. [3] No. 80 Wing File 80W/M/TS/3155/3/Air.

Headquarters No. 80 Wing, Nos. 60 to 62 M.S.U.s, Type S.R. (Watcher/Monitor Units) and Nos. 40 and 46 M.S.U.s, Type S.J. (V.H.F. Jamming Units).[1] The two latter were ultimately re-formed into three units, M.S.U.s, Type S.J., Nos. 51 and 53, when incorporated in the Continental element for Bomber Support, and were later augmented with Nos. 50, 54 and 55 Units from the United Kingdom. Communication Unit No. 5328 M.S.U., Type D attached to Advanced Headquarters was to be absorbed into Headquarters 80 Wing (Main).

The S.F. Units were to be deployed at intervals of 20 to 30 miles along the Western Front from Eindhoven in Holland to the Swiss border, and the S.C. Units at intervals of 60 to 100 miles along the same front.[2] With this disposition it was anticipated that each Radar Jamming Unit would be capable of dealing simultaneously with at least three enemy G.C.I. stations within a range of not more than 50 miles. It was expected that the S.C. Units would be effective against German high-power Central European and Big Screw beacons when their distance from the night-fighter aircraft was equal to the distance from the night-fighter to the beacon, and against low-power Little Screw beacons when their distance from the night-fighter aircraft was equal to three times the distance from the night-fighter to the beacon. When not used for jamming medium frequency W/T traffic being broadcast from beacons (Fidget), the Communication Jamming Units were to be used for meaconing or mimicking these beacons, thus depriving the enemy of their use as navigational aids.

In the high frequency band, six 1-kilowatt Army type No. 16 transmitters were to be used to jam night-fighter control on high frequency and these transmitters were, for convenience, to be operated from the Communication Jamming Units. However, when H/F jamming operations on the Continent were ultimately banned by S.H.A.E.F. these transmitters were omitted from all S.C. Units, except the first to be deployed. Against the enemy 100-watt R/T transmitters, it was considered that the No. 16 transmitter available would be effective until its distance from the enemy control station was more than twice the distance of the control station from the night-fighter being jammed.

In the very high frequency band, 24 T.U.4 transmitters of 500 watts power were to be provided and operated from the Communication Jamming Units, four transmitters being allotted to each S.C. Unit. The operation of these jammers would be limited by their ability to receive the enemy ground station, but provided this could be heard, it was expected that jamming would be effective until the distance between the enemy night-fighter and the jammer was more than twice the distance of the night-fighter from its control station.

---

[1] Details of these units were as follows —

(a) Mobile Signals Units, Type "S.C", Nos 80 to 85, each comprising three M/F Meaconing channels (M.24 transmitters), one H/F Meaconing channel (Type 1190 transmitter) and four V.H.F. Jamming channels (T.U.4 transmitters). No 80 Unit was also equipped with one Army Type 16 set for H/F jamming.

(b) Mobile Signals Units, Type "S.F.", Nos. 70 to 77, each comprising nine channels (plus two spare) covering a frequency band 20–600 megacycles per second (G.M.C., T.1659A, 1636 and RUG transmitters)

(c) Mobile Signals Units, Type "S.R.", Nos. 60 to 62, each comprising three watcher channels and D/F.

(d) Mobile Signals Unit, Type "S.J.", No. 50, comprising one 50-kilowatt GRQ/1 transmitter. Mobile Signals Units, Type "S.J.", Nos. 51 to 55, each comprising two 15-kilowatt V.H.F. jammer channels (M.R.T./1 transmitters).

[2] No. 80 Wing File S.3076/Sigs.

Five 15-kilowatt Small Cigar Units (10 Transmitters) and one 50-kilowatt Unit (Type GRQ/1) were to be considered for use in the V.H.F. band, should these transmitters eventually be released from the "Big Ben" (Rocket) commitment.

The rapid supply of the intelligence with respect to enemy transmissions to night-fighter aircraft was essential if the jamming of these communication channels was to be applied immediately.[1] Intelligence for the S.C. Units was to be provided on a minute-to-minute basis by the "Y" organisation, augmented by Nos. 364 and 365 Wireless Units, already on the Continent. There was considerable doubt whether this arrangement would be adequate to keep the operational Headquarters of No. 80 Wing (Main) and its associated S.C. Units fully and immediately informed, mainly on the score of distance and the restricted communications between the United Kingdom and the Continent. Headquarters No. 100 Group pressed strongly for the expansion of the "Y" detachments on the Continent, but it was eventually decided that, in view of the extensive watcher system existing in England, sufficient information of the enemy M.F., H.F. and V.H.F. channels could be supplied provided good land-line communications could be established with the Operations Room of No. 80 Wing (Main). No. 364 Wireless Unit would also supply intelligence mainly on the V.H.F. channels direct to No. 80 Wing (Main) as already intended.

The supply of minute-to-minute intelligence to the S.F. Units did not arise since these units were equipped with their own watching apparatus. This was the practice which had been successfully employed with the original ground Mandrel Units. It was decided therefore that it would be sufficient to supply these Units with a general directif as to the type of signal they were to search for and jam, the jamming to be applied without further authority.

The operational control of jammers on the Continent was to be vested in Headquarters No. 100 Group, but Headquarters No. 80 Wing (Main) was permitted to operate independently on information available to them from the "Y" organisation. Headquarters No. 100 Group was to be notified of all action being taken. Local control of operations at Headquarters No. 80 Wing (Main) was to be effected from an Operations Room situated at a site most convenient for communications to all Units. This site was also to be the headquarters of the whole organisation. Provision was made for the use of a Mobile Operations Room which, together with mobile offices, was constructed in three articulated trailers. A considerable staff was planned for the Operations Room which was to be fitted with the usual display boards, plotting table and telephones. Owing to the possibility of jammers on the Continent seriously interfering with Allied communication channels, S.H.A.E.F. placed the jamming organisation under the direct control of Headquarters, 2nd Tactical Air Force to enable them to exercise power of veto if transmissions proved to be causing interference.[2] Headquarters, 2nd T.A.F. represented the British 21st Army Group for the same purpose A comprehensive system of communications was essential for the successful dissemination of intelligence and for operational control.[3] Telephone or teleprinter tie-lines were to be provided where possible. W/T, using the simplest possible code where security was not important, was to be used as a stand-by.

---

[1] No. 80 Wing File S.3076/Sigs. [2] *Ibid.*
[3] No. 80 Wing File 80W/M/S.3155/4/Air.

Siting

At the conclusion of the planning stage, and whilst units were being mobilised, two officers from Headquarters No. 80 Wing proceeded to the Continent on 4 December 1944 to select sites for Bomber Support Communication and Radar Jamming Centres. After a short liaison visit to S.H.A.E.F., during which it was decided as a preliminary measure that definite siting should only be conducted in the northern (British) sector of the front, the party, accompanied by a representative of S.H.A.E.F., carried out a tour of this zone. Sites for the Units comprising the first phase of the operation were selected and clearance for their use obtained. Suitable accommodation for a Main Headquarters was requisitioned three kilometres south of Verviers, but the German counter-offensive which was launched at this time enforced the abandonment of the project. As a result, a search was made for alternative accommodation for Headquarters No. 80 Wing and the "Y" Service in the Brussels area. Siting for units to be established within the southern (American) sector was carried out as required prior to the arrival of the units concerned.

The first part of the Continental Ground Jamming organisation consisted of Headquarters No. 80 Wing (Main), No. 80 M.S.U. Type S.C. (Communication Jammer) and Nos. 70 and 71 M.S.U.s Type S.F. (Radar Jammers) which landed at various ports in France and Belgium and completed concentration at Wenduine, on the Belgian coast, on 15 January 1945.[1] This site was already in use as Advanced Headquarters No. 80 Wing, which had been set up for the defensive Big Ben organisation, and proved invaluable as a transit centre where all Units could be overhauled if necessary after the channel crossing.

No. 80 S.C. Unit was deployed as soon as snow and icebound road conditions allowed at Uden in Holland. No. 70 S.F. Unit was deployed at Leende and No. 71 S.F. Unit near a site of No. 80 M.S.U. Meanwhile, since it was essential that the operational Headquarters should be as near as possible to No. 364 W.U. situated south-east of Brussels, a search in the Brussels area disclosed a suitable site for Headquarters No. 80 Wing (Main), namely the Chateau Brifaut at Schepdael, eight miles west of Brussels. This building had apparently been used by the enemy as a signals intelligence interception station and had ample accommodation with excellent telephone connections to Brussels, undamaged except for the telephone exchange.[2] Work was immediately put in hand to make the chateau ready to accommodate Headquarters and the latter moved in on 9 February. The phasing in of units from United Kingdom took place at short intervals, the units being concentrated and inspected at the transit centre, and thence deployed at their respective sites.

Medium Frequency Operations

No. 80 S.C. Unit became operational on 18 February and radiation was first authorised by Headquarters No. 100 Group on 21 February. For the remainder of the month its three M.24 transmitters were employed on meaconing, Mimic, Fidget and Special Fidget. Special Fidget entailed a modification to the normal meacon circuit whereby the incoming signal was made to control a local oscillator so that, whereas during the "mark" condition of keying the incoming signal became the drive for the transmitter (normal meaconing action),

[1] No. 100 Group "Review of Operations," January 1945, and A.H.B./II H1/45, January 1945.

[2] No. 100 Group "Review of Operations," February 1945.

during the "space" condition the transmitter was driven by the local oscillator. In addition the oscillator was keyed in dots, thus producing a mutilating effect whenever the enemy beacon to which the meacon station was tuned commenced to send morse signals. It was essential, of course, that the frequency of the local oscillator drive was identical with that of the incoming signal, and this was achieved by adjusting the oscillator to give a zero beat with it, reduction of receiver gain enabling both signals to be heard at the same time.

No. 81 S.C. Unit became operational at Bree on 3 March 1945,[1] No. 82 S.C. Unit on 31 March in the Geldern area and No. 83 S.C. Unit on 9 April in the Julich area. It was evident after the first five weeks of operation that the meaconing and jamming was proving a nuisance to the enemy. Excellent radiation took place on meaconing and Mimic, and monitoring reports from Headquarters No. 80 Wing (Main) showed that W/T traffic being passed by beacons could not easily be read through the Fidget jammers. Special Fidget operations ceased at the end of March 1945. This method of jamming had proved unreliable as it was dependent on the enemy signal being received clear of interference, and interference had proved excessive at all units. Moreover, Fidget action was frequently being taken by Headquarters No. 80 Wing (Rear) on the same beacon, thus making Special Fidget impossible to operate.

Nos. 84 and 85 S.C. Units were deployed near Coblenz and in the area west of Worms respectively during the month, but the break-through across the Rhine was advancing so rapidly that Headquarters No. 100 Group ordered the withdrawal of these Units before they became operational. No M.F. operations took place after the night 26/27 April 1945.[2]

High Frequency Operations

No H.F. operations were carried out on the Continent as S.H.A.E.F. and Headquarters, 2nd T.A.F. stated that jamming of this band could not be tolerated due to the extensive use made of these frequencies by Allied Army and Air Forces.

Very High Frequency Operations

All S.C. Units were provided with 500 watt T.U.4 transmitters for jamming German V.H.F. fighter control channels, but the authority from Headquarters No. 100 Group to use these could not be given until March 1945. This frequency band (38 to 42·5 megacycles per second), however, was invariably completely jammed by airborne jammers during operations, and few signals were heard.[3] Moreover, as the traffic requiring to be jammed was mostly German R/T with occasional W/T, and as no German-speaking operators were available in the Wing, the identification of suitable signals to jam was difficult. Occasional signals were passed to Headquarters Operations Room by No. 364 W.U., which had German-speaking operators, and these signals were then "told" to S.C. Units. A total of sixty signals were jammed by Nos. 80 and 81 Units during March and twenty-seven signals were jammed by Nos. 80, 81, 82 and 83 Units in April, but in many cases the evidence on which jammers were brought up was slight, due to causes mentioned above.

---

[1] No. 100 Group "Review of Operations," March 1945.
[2] A.H.B./II H1/45, No. 100 Group "Review of Operations," April 1945.
[3] No. 100 Group "Review of Operations," March 1945

Nos. 40 and 46 M.S.U.s Type S.J. (three transmitters each) were released from their defensive rôle against rockets in March and were re formed at Wenduine into Nos. 51, 52 and 53 M.S.U.s Type S.J., each Unit comprising two 15-kilowatt small Cigar transmitters. Nos. 54 and 55 M.S.U.s Type S.J. were deployed at Leende and full power tests were carried out on two transmitters to enable them to be adjusted to cover between them the frequency band 38 to 42·5 megacycles per second.

The high power (50 kilowatt) GRQ/1 transmitter of No. 50 S.J. Unit, was installed and tried out for the first time on the night 21/22 March, the transmitter being located at Wenduine, and having a half-rhombic aerial system beamed on Dusseldorf. Several tests were carried out with this transmitter during the month, but it was found that the range was too great for jamming to be effective over the Ruhr with the transmitter sited on the Belgian Coast. It was found that a high degree of mismatch occurred in the transmitter tuned circuits when being frequency modulated over the whole German night fighter V.H.F. band. Headquarters, No. 100 Group therefore approved modifications to enable the transmitter to cover the frequency band 40 to 42·2 megacycles per second only and the move of the transmitter nearer to the Ruhr. It was now intended that the lower half of the band should be covered by one or more small Cigar transmitters (15 kilowatt) which were already designed for a 3 megacycles spread. Work was proceeding on these lines and the GRQ/1 had been moved forward to the Leende area in Holland when all operations ceased.

Radar Jamming Operations

On 18 February, Headquarters, No. 100 Group ordered radiation from S.F. Units for the first time.[1] Instructions were given to Nos. 71 and 70 Units (located near Uden and Leende respectively) to jam all signals heard within the band 70 to 200 megacycles per second and 430 to 600 megacycles per second (*i.e.*, the German *Freya* and *Wurzburg* bands). Only signals having pulse recurrence frequencies of 25, 500 and 1,000 cycles per second were to be jammed. The limitations of p.r.fs. were relaxed on the following day to permit a 10 per cent. latitude on either side of p.r.fs. 25, 500 and 1,000 to allow for possible inaccuracies of measurement and variations in p.r.f. from those actually used by the enemy. The 10 per cent. tolerance allowed proved an accurate estimate as many signals which fell within this tolerance were covered from the night of 19/20 February. All signals jammed throughout the operations on the Continent were confined to the *Freya* band. No *Wurzburg* band signal was heard.

No. 72 M.S.U. Type S.F. became operational near Neerglabeek on the 25 February. Early in March, due to the Allied advance, it was apparent that Nos. 70, 71 and 72 S.F. units were rapidly becoming too far behind the front line to be effective against enemy radar, and consequently these units were moved to positions near Schaephuysen, S'hertogenbosch, and Julich respectively.[2] No. 71 Unit moved on 31 March. No. 72 Unit became operational on its new site with No. 83 Unit nine miles north-east of Julich on 2 April 1945.

Meanwhile No. 73 Unit became operational on the old German *Knickebein IV* site at Kleve on 25 March, and No. 74 S.F. Unit west of Bonne on 27 March. It is a matter of interest that the aerials of No. 73 S.F. Unit were suspended from

[1] No. 100 Group " Review of Operations," February 1945. [2] *Ibid.*, March 1945.

the large rotatable gantry of the German *KN.4* station, thus giving additional height and enabling this unit to remain effective for a longer period than the remainder. *KN.4* was the equipment whose activities in June 1940 began the *Knickebein* threat which resulted in the institution of R.C.M. and the formation of No. 80 Wing.

No. 75 S.F. Unit moved up to the site occupied by No. 81 S.C. Unit, preparatory to moving to the Durembach area. Owing to the rapidly-changing military situation the site became too far to the rear and a siting reconnaissance in the Worms area was carried out. The unit became operational on 13 April 1945 but was ordered to be withdrawn on the same day, as the military advance had progressed so far by this time as to make operations in this area useless.[1]

Special Investigation Watches

Early in February an order was received from Headquarters, No. 100 Group, for a watch to be kept for *S.N.2* (enemy A.I.) signals. It was known that modifications had been made to the *S.N.2* equipment which extended its working frequency from a narrow band in the vicinity of 90 megacycles per second to a possible band from 65 to 110 megacycles per second.[2] Information was required on the extent of the new band and whether some frequencies were more commonly used than others. No. 62 S.R. Unit was despatched to a site near Leende and carried out watches nightly from dusk to dawn. Reports were despatched to Headquarters, 80 Wing (Main) and forwarded to No. 100 Group. These were analysed, and disclosed information which had hitherto not been supplied from the normal signals intelligence sources. Owing to the close proximity of No. 70 S.F. Unit to this site, considerable interference was experienced during operational periods and a move to the south-east was therefore agreed. Further deployments were made as the front line moved forward, but each change of location was kept to such a distance that the unit could operate every night. On 1 March[3] a move was made to Tongres, on 4 March to Jonckeur, on 17 March to Aachen, on 22 March to Kendenich, and on 31 March to Sinzig. No. 60 S.R. Unit was also deployed to carry out this watch and was sited near Vught after a short period of operation near Uden. Analysis of logs of these watches was not carried out by No. 80 Wing, but all logs were forwarded to Headquarters, No. 100 Group.

Instructions were received from Headquarters, No. 100 Group, early in March to watch for *Bernhardine* transmissions and instructions were given to Nos. 60 and 62 S.R. units to carry out a watch for these enemy signals in the frequency band 30 to 33·2 megacycles per second. All signals heard in the band other than from local Allied transmissions were logged and reports forwarded to Headquarters, No. 100 Group for analysis and comparision with information also being obtained from investigational flights by aircraft of No. 192 Squadron.

Operational Control

The ultimate control of jammers on the Continent was vested in Headquarters, No. 100 Group, with Headquarters, 2nd Tactical Air Force, exercising a measure of control in cases where jammers might cause interference with essential Allied communications. Certain frequencies were barred for jamming purposes and a

[1] No. 100 Group "Review of Operations," April 1945.
[2] *Ibid.*, February 1945. [3] *Ibid.*, March 1945.

daily report was required by Headquarters, 2nd T.A.F., on the jamming which had been carried out, in order that any reports received by them of unusual interference could be examined to determine whether such jamming was caused by No. 80 Wing operations. A jamming organisation in the vicinity of signals centres is inevitably suspect, but suspicions fortunately proved unfounded.

Tests were arranged in conjunction with Headquarters, No. 85 Group, to ascertain the effect of radar jammers as follows :—[1]

(*a*) The effect of transmissions on anti-aircraft radar interrogator trace, and whether I.F.F. responses could be seen through interference from jammers (if any).

(*b*) Whether the aircraft transponder was apparently triggered by No. 80 Wing jammers so that it saturated and gave uncertain responses.

(*c*) Whether the aircraft transponder was apparently triggered by jammers to the extent of becoming a jammer itself on the I.F.F. frequency.

(*d*) Effect of jammers on interrogation of Mark VIII A.I. aircraft by Mark X A.I.

(*e*) Effect of jammers on interrogation of Mark X A.I. aircraft by Mark VIII A.I. aircraft.

(*f*) Effect on observation of known A.I. beacons. Difficulties (if any) in homing to various beacons.

Only one of these tests was successfully carried out and this showed that no serious interference was experienced by anti-aircraft radar when interrogating I.F.F. in aircraft.[2] As a result of this report permission was granted by Headquarters, 2nd T.A.F., to operate jammers in the I.F.F. band (157 to 187 megacycles per second) which had previously been barred. The remaining tests were abandoned because of the difficulty of co-ordinating flight trials. No restrictions other than a bar on the jamming of Gee frequencies were placed on No. 80 Wing operations in the V.H.F. bands.

Procedure for M.F. and V.H.F. Control at Headquarters, No. 80 Wing (Main)

Information on beacon activity was received by telephone from No. 364 W.U. and from the Headquarters Monitor Section. The information was written on a pad and handed to a W.A.A.F. (Clerk S.D.) supervisor. The latter displayed the information on the display board by hanging up a suitable plaque showing the type of beacon and the details of frequency and call sign. The Operations Officer then gave the order to the W.A.A.F. supervisor as to what action should be taken. The latter then hung up further plaques showing the site or sites concerned, the number of transmitters and type of action to be taken, thus displaying the orders to be passed to the jamming units. Other W.A.A.F. personnel, manning head-and-breast-set telephones in direct communication with jamming units, kept watch on this display board and passed the order to the units concerned. When a unit had been given an order, the order was displayed on the board in white lettering on a black background. When the unit reported that the order was in force the plaque was turned over, showing black lettering on white ground. Thus the Operations Officer at all times had a full display of what beacons were active and what action had been ordered or was being carried out.

[1] File 80W (M) S.3155/6/Air, Encl. 21A.

[2] File 80W (M) S.3155/3/Air.

Radar Jammer Unit Control at No. 80 Wing

No direct control of S.F. units was carried out from the Headquarters Operations Room as these units were self monitoring, but in the early stages of their operations, every signal which a S.F. unit jammed was reported by telephone and full details were logged. As no useful purpose was served by this minute-to-minute reporting, and as the available telephone lines and operators were fully occupied with instructions to the S.C. units, S.F. units were later instructed to render a complete report of their activity at the end of operations.

Careful thought was given to the method by which the Bomber Command operational period for the night should be made known to all units. It was arranged that the times should be received from Headquarters No. 100 Group by teleprinter in high grade cipher using a code word in the message followed by the times. The information was then relayed to the units concerned in high grade cipher.

Intelligence

It had been planned that all M.F. intelligence required for operations should be received from the " Y " organisation, together with information from 364 W.U. located on the Continent at Genval (20 miles south of Brussels). Communications were organised for this purpose. Further intelligence was to be passed to Headquarters, No. 80 Wing (Main) Operations Room from Headquarters, No. 100 Group Operations Room.

Headquarters, No. 80 Wing (Main), had an important requirement for information about the activity of German beacons, and especially the times at which they began to radiate W/T instructions to night-fighters. The German beacons radiated according to a call sign and frequency rota which changed periodically. It soon became apparent that to obtain this information rapidly enough for useful action to be taken by the S.C. units, a monitor section at Headquarters, No. 80 Wing (Main), was necessary in order to overcome the unavoidable time-lag in obtaining the information from the United Kingdom through the existing channels of communication. A monitor section was therefore established in the Chateau Brifaut consisting of 15 receivers, each of which was allotted a portion of the M.F. band in which to search for enemy beacons.[1] Call signs and frequencies of the beacons were analysed in conjunction with their locations and it became a simple matter for the operators to identify the beacons active and report them to the Operations Room. The necessary details of a German beacon transmitting instructions by W/T were thus made available and the Operations Room could order radiation (meaconing, mimicking or Fidget) from S.C. sites as necessary. A further function of the monitor section was to provide information concerning any jammers which were not correctly tuned to the enemy signal. Such monitoring was carried out both for the Continental transmitters and for those being used for jamming under control of Headquarters, No. 80 Wing (Rear).

The information required for V.H.F. jamming consisted of details of German R/T and W/T transmissions between 38 and 42·5 megacycles per second, the enemy night-fighter V.H.F. band. To obtain this, German-speaking operators were necessary, but as they were not available to S.C. units the information was supplied by No. 364 W.U. As has already been stated, comparatively little

[1] No. 100 Group " Review of Operations " (A.H.B./II H1/45).

V.H.F. jamming was carried out because the V.H.F. band was adequately jammed by airborne jammers.[1] Occasionally signals could be read through the jamming and were reported by 364 W.U. and a ground jammer was ordered to radiate. S.C. units were also given permission to jam independently if they heard German R/T in the band.

Radar Jamming

It was not possible to provide minute-to-minute intelligence for the operation of the S.F. Units because this would have required a very large number of watcher units in view of the limited range at which the enemy radar signals could be heard. S.F. Units were therefore self-monitoring and were instructed to jam within certain limits of frequency and pulse recurrence frequency. They were provided with a frequency spectrum to assist them to identify signals of doubtful origin.

Provision of D.F. Equipment

The value of D.F. equipment was realised for identifying friendly from enemy signals, and also for fixing the position of enemy stations by combining the bearings supplied by two or more units to give a point of intersection. Such information would be valuable to Headquarters No. 100 Group, and would also enable the Operations Room to allot the jamming of particular signals to the S.F. Units most suitably placed for the task. For these reasons a D.F. equipment was planned for each S.F. Unit. The Marconi D.F.P.5 set was tried out but proved too insensitive for the purpose. Two H. Adcock D.F. aerials were constructed for use with the Type S.27 receivers and the first set of aerials was issued to No. 61 M.S.U. Type S.R. (a watcher unit), which was despatched to operate in the vicinity of No. 73 Unit. On test, an accuracy of $\pm 5°$ was obtained for the 150 megacycles aerial and $\pm 10°$ for the 75 megacycles aerial. The second set of aerials was issued to No. 62 M.S.U. Type S.R. but this unit could not be deployed before operations ceased. A full test of a system of D.F. installed at each S.F. Unit was therefore not carried out.

Communications

Rapid communications were important. A landline system was essential for successful ground R.C.M., but little hope had been held out by S.H.A.E.F. for its provision, due to heavy Allied commitments in the field. The arrival of additional Air Formation Signals Units however, secured the provision of a reasonably efficient landline system. There were many interruptions during the early stages but these difficulties were overcome by the attachment of an Air Formation Signals Unit to Headquarters No. 80 Wing (Main) at Schepdael.

Telephones were provided by Air Formation Signals to all units when possible, but the rapid advance and the limited number of trunk lines available made this not always possible. Where telephones were not supplied W/T was used. Headquarters No. 80 Wing (Main) used an M.F. broadcast channel which was watched by all M.S.Us. It proved most satisfactory and all M.S.Us. received instructions without delay by this means. The M.S.Us. also had an H.F. channel of much lower power which was continuously manned by those units not in telephone communication. It was used for acknowledgements or queries. Some interference was experienced, but eventually a frequency (2,560 kilocycles

[1] No. 100 Group "Review of Operations."

per second) was allotted which gave reasonable reliability. The inevitable drawback of using W/T was the delay involved in cyphering and decyphering. This delay was minimised by the use of a special code developed for the use of No. 80 Wing (Main) from the Bomber Code. This code was only used, however, when the considerations of speed outweighed those of security.

The Withdrawal of No. 80 Wing (Main) from Europe

With the virtual cessation of hostilities in Europe at the end of April, Headquarters, No. 80 Wing (Main) was instructed by Headquarters, No. 100 Group on 4 May to withdraw all units to Wenduine in preparation for their return to U.K. and by 13 May all units had concentrated at the Transit Centre. Headquarters closed down at Schepdael at 1600 hours 11 May and withdrew to Wenduine.[1] Embarkation at various ports in France and Belgium took place between 13 and 16 May. The destination in the United Kingdom for both Headquarters and units was No. 100 Group airfield at Swanton Morley, Norfolk.

Disbandment of No. 80 Wing

Concurrently with the return of Headquarters, No. 80 Wing (Main) and units from the Continent, steps were taken to close down the remaining sites in the United Kingdom and to dispose of the very large amount of equipment of all types belonging to the Wing. In view of the number of stations built almost on a permanent basis, many with high masts, this task proved lengthy, but by the middle of August all outstations had been cleared, and on 22 August 1945 the main body of Headquarters No. 80 Wing left Radlett for Swanton Morley, thus joining up with Headquarters, No. 80 Wing (Main) and its mobile units.

During this closing-down period arrangements were made by Air Ministry and Headquarters No. 100 Group for the formation of a peace-time R.C.M. organisation, which in part was to be built up from personnel and equipment of No. 80 Wing which disbanded on 24 September 1945. The new organisation was to be known as The Radio Warfare Establishment and formed at the Royal Air Force Station, Watton.

[1] No. 100 Group " Review of Operations " (Summary).

PART III

RADIO COUNTER-MEASURES IN SUPPORT OF COMBINED OPERATIONS

PART III

INTRODUCTION

Large scale amphibious operations of the type launched against Sicily and Italy, Normandy and the South of France offered considerable scope in the use of radio counter-measures. The chief task was that of helping to achieve tactical surprise, partly by neutralising the enemy's means of detecting the attacking force during concentration and approach, and partly by simulating threats in areas remote from the chosen place of landing.

The counter-measures employed were generally the same as those previously used in defensive and offensive air operations. The choice and planning of them for amphibious assault purposes depended on the main tactical plan of which they naturally formed a part. Preparation was made in great detail and the counter-measures were supplemented by direct air attack on the enemy radio stations required to be neutralised.

CHAPTER 17

RADIO COUNTER-MEASURES IN SUPPORT OF OPERATION "HUSKY"

After the collapse of France in 1940 there had arisen the threat of a rapid German advance through Spain to the western gateway of the Mediterranean. From December 1940 accordingly, Mr. Churchill had been seeking a means of rousing and assisting the French in North-West Africa to resist German control. Allied control of that territory, with or without French co-operation, was an urgent requirement but until the United States of America entered the War in December 1941, the British were neither strong enough to convince the French that they had a good chance of survival, nor to take over north-west Africa by force without French co-operation.[1] On the entry of the U.S.A. into the War, however, a new impetus was given to the British plan, until in July 1942 it was decided to occupy north-west Africa, by force if necessary, in order to forestall a similar German occupation in force and to safeguard the western gateway.

This landing (code name "Torch") was planned to be made on 8 November 1942 coincident with an offensive by the Eighth Army from El Alamein to Tunisia which would contain the main German forces in North Africa. When the Allied forces landing in this operation had become firmly established, they would be required to drive towards Tunisia to support the Eighth Army. Caught in the pincer movement, the Axis forces in North Africa were finally defeated by 13 May 1943 and there followed an Allied landing in Sicily (under the code name of "Husky"[2]) on 10 July 1943. This landing was followed by landings on the Italian mainland in Calabria on 3 September, and at Salerno on 9 September 1943 (under the code name "Avalanche"). There followed a bitter contest in Italy in which by degrees the Allies established themselves in that country, until by August 1944 they were ready to mount an invasion of Southern France from the Italian theatre in support of the main Allied campaign in north-west Europe. The final Mediterranean landing, originally called "Anvil," went under the code name of "Dragoon."

Radio Counter-Measures in Mediterranean Landing Operations

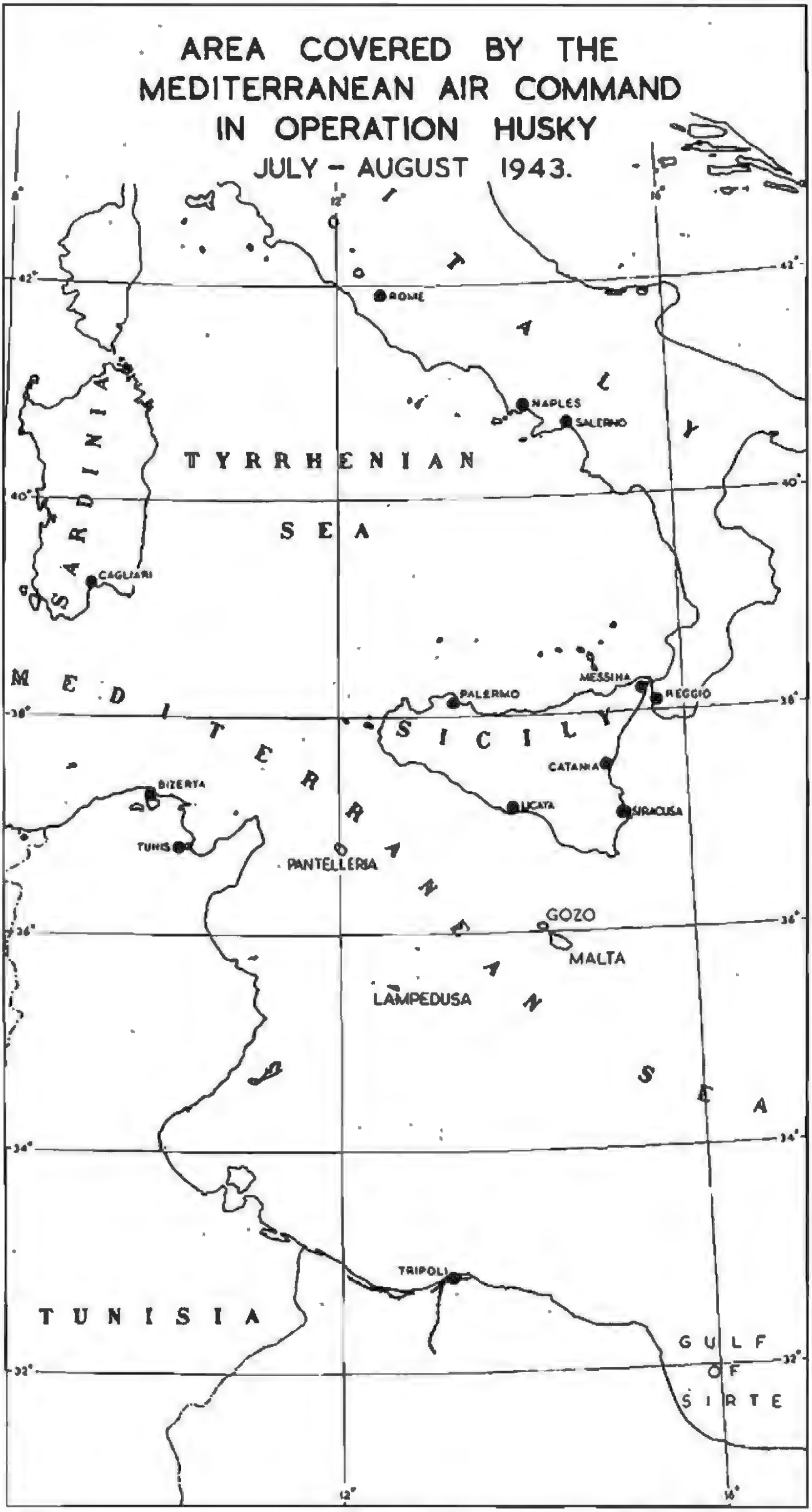
When operation "Torch" was in the planning stage, R.C.M. was in the early throes of development. At that time R.C.M. was primarily a technique for defence and, like the Home Chain of radar stations, was fairly static in conception, consisting of Meacons, navigation beam "deflectors," high-power, long range R/T and radar jammers and similar devices. The impending landing in north-west Africa could not be assisted by such equipments based on Allied territory, nor were the landing beaches going to be in range of enemy radar cover and radio aids-to-navigation based on the continent of Europe. There was accordingly no call for radio counter-measures.

In the Allied landing in Sicily, however, the situation was different and gave ample scope for the exercise of R.C.M. by both belligerents. Sicily and the mainland of Italy were defended by a well-equipped enemy force of all arms,

---

[1] *See* Royal Air Force Narrative "Operation Torch," prepared in the Air Historical Branch, Air Ministry.

[2] Air Ministry File C.32153/46.



AREA COVERED BY THE MEDITERRANEAN AIR COMMAND IN OPERATION HUSKY JULY – AUGUST 1943.

A.H.B. 1. MAP No. 485.

having a network of early-warning radar, aircraft fitted with A.I. and A.S.V., and a very comprehensive R.C.M. organisation of its own which was strong in jammers. Furthermore, enemy early warning radar and R.C.M. jammers gave a fair degree of cover against Allied air movements over Malta and Tunis and were powerful factors to be reckoned with. For the first time, therefore, R.C.M. became an integral part of a major Allied landing and, hence, an important precedent for the forthcoming landing in north-west Europe.

R.C.M. Plan for "Husky"[1]

In order to appreciate the R.C.M. plan for the invasion of Sicily it is necessary to have a broad picture of the air plan.[2] Preparatory measures for the main operation included the following :—

(*a*) Neutralisation of enemy air forces.
(*b*) Development of Malta and Gozo as bases for fighter support.
(*c*) Occupation of Pantellaria as a fighter base for support of the assault.
(*d*) Occupation of Lampedusa as a base for convoy protection purposes and for air/sea rescue and R.D.F. facilities.

Eight simultaneous sea-borne assaults were then to be made on 10 July 1943 with the object of capturing airfields and secondary ports in south-west Sicily on a 90-mile coastline between Licata and Syracuse. Fighter protection for all landings was to be given from Malta and Pantellaria.[3] British and American landings during the night 9/10 and on the following night were to be supported by airborne landings from North African bases.

The operations involved the convergence and co-operation of a number of major Allied formations widely separated geographically, and presenting a complication of command and control.[4] The enemy, on the other hand, was operating on internal lines, compactly. The Air Commander-in-Chief was to control air operations from a "Command Post" (C.P.) and the Commanding General, North African Air Force (N.A.A.F.), was to control that force from the same post, where staffs were to be combined. Advanced Headquarters, North African Strategical Air Force (N.A.S.A.F.), North African Tactical Air Force (N.A.T.A.F.), and North African Coastal Air Force (N.A.C.A.F.), were to be established near C.P.[5] The Air Officer Commanding, N.A.T.A.F. (controlling Desert Air Force, and XII Air Support Command (A.S.C.)) was to command all forces providing direct support to British and American assaults. When air forces first became established in Sicily, they were to be controlled operationally by the Air Officer Commanding, Desert Air Force. Later the Commanding General XII A.S.C. would control air forces operating with the 7th Army and the Air Officer Commanding the Desert Air Force those with the 8th Army, both subordinate to N.A.T.A.F.

Success depended to a great extent upon tactical surprise as to the points and times of Allied landings in Sicily.[6] It was therefore the Supreme Allied Commander's (General Eisenhower's) plan to attempt to convince the Axis forces that his intention was to make a two-pronged assault in the Balkans and the

---

[1] *See* Diagram 11.
[2] For details *see* North African Air Force Headquarters Report (23rd S.C.O.R.U.), Part I, para. 2.
[3] Headquarters, M.A.A.F., "Outline, R.C.M. Plan—Operation 'Husky'," in A.H.Q. Malta File M.S. 5386/Sigs., Encl. 78A.
[4] A.M. File C.32153/46, page 10, para. 3.
[5] Headquarters, N.A.A.F. Report (23rd S.C.O.R.U.).
[6] Air Ministry File C.32153/46, Encl. 1A.

South of France by an imaginary "12th Army" from the Middle East and by General Patton's American forces from North Africa: a difficult feint to make convincingly, having regard to the distance of actual and potential fighter bases from the landing beaches.

It was at once obvious that achievement of surprise could be helped by the use of radio counter-measures of a kind capable of jamming enemy early-warning radar by which the enemy would otherwise get several hours warning of the approach of Allied sea convoys, together with a track of its progress. It was realised that cover of this kind had to be complete in any given area to be worth while, since, if only a small proportion of the early warning network were left immune, it would be able to "peep behind the screen" and render useless the jamming of the rest of the network, from the point of view of securing tactical surprise. This necessitated the neutralisation of enemy stations in Sardinia as well as in Sicily.

One hundred per cent. success was considered too much to hope for in the jamming of early warning radar, and it was decided to rely mainly upon destruction of enemy stations by air attack, but to supplement that by airborne jamming, employing Mandrel and Carpet. In order to complete neutralisation of early-warning cover, Rug[1] and Type 91 transmitters were to be used against enemy coastal ship-watching stations. Force 343 (destined for the Western beaches) was to have Rug fitted in United States Navy ships, and Force 545 (destined for the eastern beaches) was to have Type 91 jammers fitted in its Royal Navy trawlers.

Furthermore, it was desired by the same means and at the same time to jam enemy early-warning radar and G.C.I. equipment in order to neutralise the air defence against the Allied air offensive and, especially, against the airborne forces which were destined to play a major rôle in securing Axis lines of communications between the Straits of Messina and the enemy's southern and south-eastern beach defences. The operation of Mandrel and of Carpet for the protection of troop-carrying aircraft presented no problem from the point of view of co-ordination between the Services. On the other hand the operation of Carpet to protect shipborne forces together with Rug and Type 91, required co-ordination. It was calculated that airborne Carpet could be used to conceal from the enemy the size of convoys from a range of about 45 miles from the enemy coast and thereafter to prevent accurate plotting and gun-ranging down to a range of about seven miles.

The timing of the attacks against enemy radar stations and the initiation of R.C.M. action was of the greatest importance.[2] Premature action was liable to disclose the direction and object of our attack, and also to give the enemy sufficient time to make good material damage caused by direct air attack and sufficient time also to overcome R.C.M. interference.[3] Consequently it was decided to delay air attack to the latest possible time before the landings, consistent with the preservation of tactical surprise.

Plan of Air Attack[4]

Although the Allied attack against enemy radar was not technically a radio counter-measure, the two operations were so closely related as to justify some

[1] Naval shipborne early warning radar jammers.

[2] The Commanding General, North African Air Forces, was made responsible for initiating and co-ordinating action against enemy radar stations.

[3] A.H.Q. Malta File M.S. 5386/Sigs., Encl. 78A. [4] *Ibid.*

account of the former. It was intended to attack radar installations at Alghero and Pulla, in Sardinia, on D —6 day, at Palermo, Marsala, Passaro and Catania on D —3 day, and at Licata, Cape Scaranida, Passalo, Cape Passaro, Syracuse and Noto, as late as possible on D —1 day. From then onwards to D-day airborne forces were to disable other radar stations in the areas in which they were dropped.

Mandrel Plan[1]

Mandrel for Operation "Husky" was available in Nos. 420, 424 and 425 Squadrons on a scale of six aircraft per squadron for Mandrel screen operations. For use against the German G.C.I. system, it was installed on a scale of four aircraft in every night-bomber squadron. Six Royal Air Force Mandrel aircraft were ordered to patrol at equally spaced intervals at 8,000 to 10,000 feet, 30 miles off the coast of Sicily from Marsala to Catania. Transmissions were to begin 30 minutes before the leading troop-carrier aircraft crossed the coast of Sicily, and this screen was to be maintained until first light on D-day. Mandrel aircraft were permitted to carry bombs and to attack targets in Sicily after completion of their Mandrel patrol.

Carpet Plan

As a further cover for the airborne landings, twelve aircraft equipped with Carpet and Mandrel were to precede the leading troop carrier aircraft and to patrol at 500 to 1,000 feet at a distance of seven to eight miles from the coast of Sicily on the main line of approach, from 30 minutes before the leading troop-carrier aircraft was due to cross the coast of Sicily, and they were to maintain transmissions until all troop carrier aircraft had so crossed.[2] Thereafter these aircraft were to patrol between 500 and 1,000 feet, equally spaced between Licata and Syracuse. Patrolling would continue until 0400 hours on D-day and both Carpet and Mandrel transmissions were to be maintained throughout the flight.

For shipping cover, four groups of six Carpet aircraft were each to precede the convoys until seven and eight miles off the Sicilian coast. These groups of aircraft were to patrol between 500 to 1,000 feet at equally spaced intervals between Licata and Syracuse. Because of the great difficulties of aircraft recognition, aircraft were to be at all times at least five miles ahead of the leading ship in the convoys and during the final stages to break off to the flanks of the assault and to continue transmissions there. These operations required most careful co-operation with the Royal Navy during the planning stages.

Rug and Type 91 Plan[3]

It was originally intended that the Rug jammers should cover the western approach primarily allotted to American forces, and that the Type 91 jammers should cover the remaining approaches, which were primarily allotted to British forces. But on 3 May 1943 when the Supreme Commander changed his plan and threw all his effort into the south and south-eastern assault, the Rug and Type 91 effort were similarly amalgamated and became, of course, a naval responsibility.[4]

[1] A.H.Q. Malta File M.S. 5386/Sigs., Appendix "B."
[2] H.Q. N.A.A.F. Letter A.P.O. 650 U.S. Army, 4 July 1943.
[3] File H.I.F./R.A.F./207/1/Air (P).
[4] A.M. File C.32153/46, page 10, para. 3.

The problem of immunising Allied R.C.M. aircraft from being fired at by Allied ships has already been mentioned. The low altitude prescribed for the R.C.M. aircraft made them extremely vulnerable to small arms fire should they wander over the convoys, and naval gunners were apt to fire whenever there was the slightest doubt as to identification. The problem of keeping the prescribed distance ahead of or to the flank of a moving convoy while flying to and fro alongside the convoy, on a multi-leg track in darkness and without suitable radio aids-to-navigation, was indeed a difficult one for the R.C.M. aircraft. The Air Officer Commanding, Mediterranean Air Command, acquainted the Naval Liaison Officer, Headquarters, Force 141, with the nature of the R.C.M. patrols, pointing out that they should be fairly easy to recognise on ships' radar plots from the nature of their tracks and by the fact that the low-flying aircraft would be four-engined (Fortress B-17F type), and asking for steps to be taken to ensure that these aircraft would not be fired upon.[1] The Royal Navy and United States Navy agreed to this request provided that the aircraft would keep well away from the convoys and would move clear of the beaches by 2330 hours on the night D-1/D-day at latest.[2] The absence of jamming cover for ships thereafter was accepted.

Meacon Plan[3]

It was intended to form two mobile Meacon stations, Nos. 21 and 22 M. Units, in No. 80 Wing at Radlett from experienced Meacon men of that Wing, and to deploy one at Bordj Menaiel (35 miles east of Algiers) and the other on the Cap Bon Peninsula, respectively, with a view to meaconing enemy M.F. radio beacons and M.F. and H.F. aircraft D.F.[4] These two stations were to be reinforced by a third, No. 20 M. Unit, from Middle East Command (Heliopolis), to be located near Benghazi. No. 21 M. Unit was to be responsible for action against beacons on Sardinia and along the west coast of Italy and Southern France, together with aircraft meaconing against aircraft using the M.F. and H.F. D.F. system covering this area, and including Sicily for this purpose. No. 20 M. Unit was to be responsible for action against beacons in Crete, in Greece (including the broadcast station at Athens) and along the south coast of Italy, together with aircraft meaconing action against aircraft using the M.F. and H.F. D.F. system covering this and again including, for this purpose, Sicily. Pending installation of No. 22 M. Unit on its allotted site, both Nos. 20 and 21 M. Units were detailed to cover beacons within Sicily in so far as they were within radio range. No. 22 M. Unit was to assume this responsibility as soon as it was ready.

It was stressed that it would be the primary function of all stations to Meacon homing signals from convoy-shadowing aircraft in their respective areas whenever such procedure was heard to be in operation. A special watch was to be established on one channel at each station solely for this purpose whenever the local convoy position was such that the procedure was likely to be adopted. No. 380 Wireless Unit (W.U.) was to inform No. 21 M. Unit on this matter, and local Naval units were made responsible likewise for No. 20 M. Unit. For these operations, all Meacon stations were placed under operational control of Headquarters, North African Air Force.

---

[1] File H.I.F./R.A.F./207/1/Air. [2] A.H.Q. Malta Signal A.S.4, 8 July.
[3] Diagram 12. [4] H.Q. M.A.C. Letter S.8656/Sigs., dated 17 May 1943

DISPOSITION OF BEACONS AND MEACONS IN THE MEDITERRANEAN

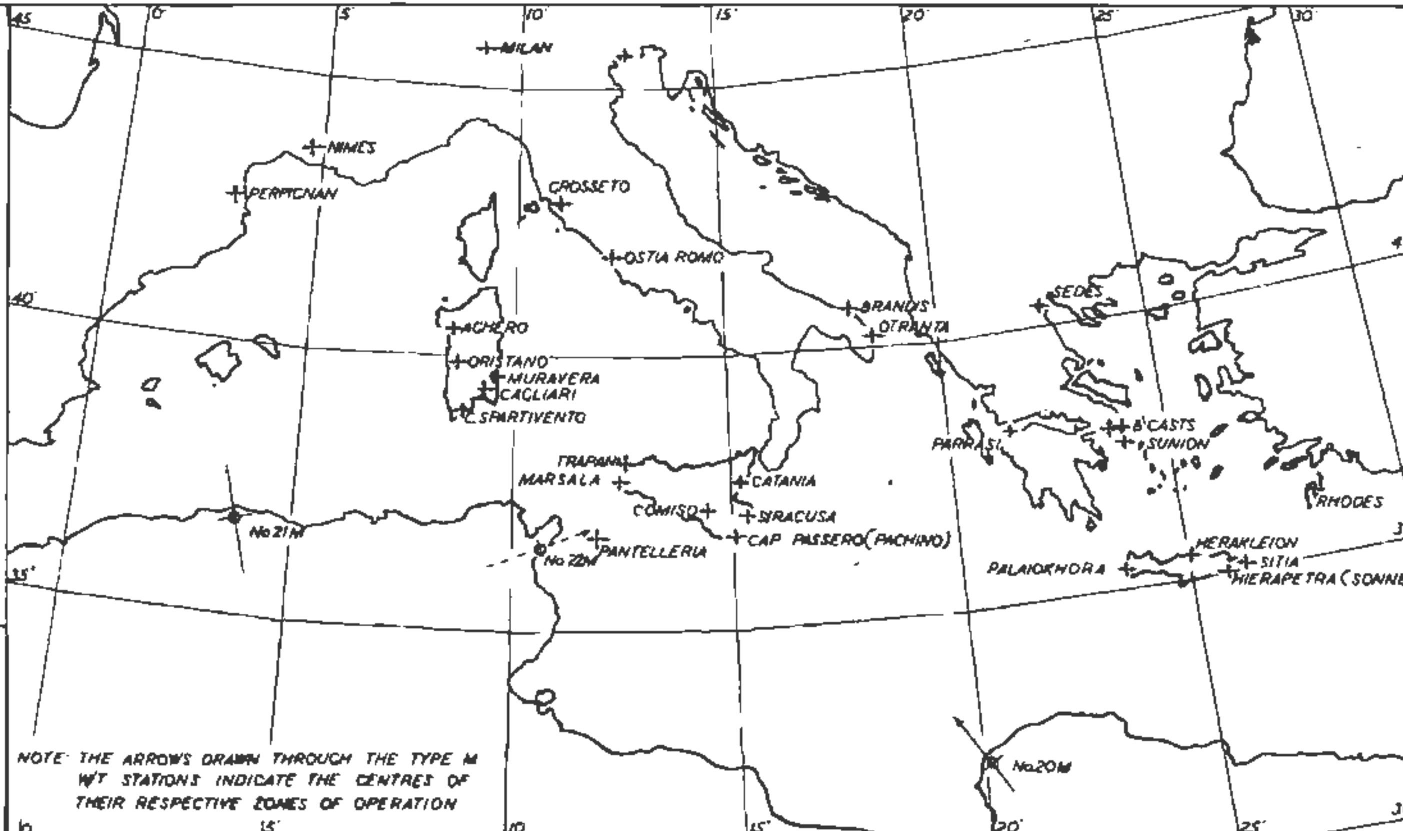


DIAGRAM 12

SECRET

A.H.B.I. MAP NO. 123

Assessment of Results

In general, R.C.M. operations went according to plan, but there was no real effort to record, collate and then analyse results either at the time or later when prisoners, enemy station logs, and all relevant documents fell into Allied hands. Indeed, the official report complains that there was too much demand on prisoner of war interrogation generally to result in any light being shed on this question. There was, moreover, no real planned Intelligence/Operational Research Section drive to investigate this important matter and to assess properly the effects of R.C.M. Instead, the key Signals staff officers were either dispersed to other commands upon completion of the landings or were heavily engaged in preparation for and conduct of the next operational phases.

Meacon Stations

The operations of Nos. 20, 21 and 22 M. Units were routine in nature and varied greatly in results and, of course, according to enemy activity, which was, on the whole, somewhat less than anticipated. The interception logs of the three stations show that on several occasions both enemy ground D.F. stations and co-operating aircraft being meaconed were in considerable difficulty, being frequently unable to take a reliable bearing.[1] Whether this was due to the meaconing was, unfortunately, never determined, but the circumstances were such as to suggest strongly that it was. As a number of aircraft distress incidents culminated from failures to establish effective D.F. service, it seems that the operation of the three M. Units was worth while. They were disbanded on 4 November 1943.

Result of Air Attacks

Between 5 July and 8 July, inclusive, one hundred and thirty-one 500-lb. bombs were dropped against the enemy early-warning radar, but investigation revealed that no damage had been sustained by any *Freya*, Chimney or *Wurzburg* Stations.[3] Those stations which were put out of action ceased operating because of damage to their operations hut.

Result of A.B.C. Mandrel Jamming

An observer aircraft took off shortly before the jamming began in order to observe the effect, and flew north from Cap Bon at an altitude of 10,000 feet.[3] Unfortunately no *Wurzburg* observations could be made, but continuous watch on the *Freyas* was kept. When the jamming commenced it was noticed that several unusual things occurred at the *Freyas* Stations. At least one enemy radar station shut down completely ; a new frequency of 143 megacycles per second appeared and the pulse repetition rates were increased from approximately 500 to 1,000 cycles per second. These were symptoms that the *Freya* system was at least being considerably affected by the Allied jammers.

R.C.M. had made its first large-scale appearance in support of Combined Operations. Although it had done so somewhat inconclusively, such evidence as there is suggests that it had been successful. At least the Allies had gained valuable experience in a new field, and that was to stand them in good stead when the time came to embark on the liberation of north-west Europe.

---

[1] O.R.B.s for Nos. 20, 21 and 22 Meacon Units—appendices operating logs.

[2] A.M. File R.C.M./155.

[3] *See* Combined Communications Board Counter-Measures Committee, R.C.M. Board Library 141.

CHAPTER 18

RADIO COUNTER-MEASURES IN THE ALLIED LANDING IN NORTH-WEST EUROPE

By the time the full-scale planning of the landing in Normandy was in progress, the technique of radio counter-measures had been established and its effectiveness, especially in the offensive, was well understood. Much thought had already been given to this type of operation, and in August 1942, No. 80 Wing had worked out an R.C.M. plan for a projected Operation " Round Up " intended to be directed against north-west France. The scheme included the use of Window, Mandrel, Moonshine, Carpet, Jostle, Meacons, and the navigational beam jammers Aspirin, Bromide and Benjamin, although some of these devices were not then in use. By 1944, tbis plan was well out of date, but it was valuable as a starting point for planning for the forthcoming operation.

The strength of the Allied Air Forces supporting operation " Neptune," as the landing was called, was such that Allied air superiority was assured.[1] The Allies were accordingly anxious to bring the German Air Force to battle in order to inflict the maximum casualties, but nevertheless wished to avoid giving the Germans any opportunity to retaliate effectively. It was therefore planned to use R.C.M. in the following circumstances during the assault :—

(*a*) To prevent the enemy obtaining early warning of, and accurate plots on, approaching surface forces.

(*b*) To prevent enemy coastal batteries from using radar-controlled gunfire against surface forces.

(*c*) To support airborne operations by—

- (i) Reducing and confusing the enemy's early warning system, thus delaying both the arrival of fighters amongst troop carriers and the alerting of the threatened dropping zones.
- (ii) Interfering with enemy fighter control R/T, thus affecting both the movement of night fighters into the area of operations and the vectoring of intercepting fighters.
- (iii) Producing diversionary threats and thereby dividing the enemy's available fighter effort.

(*d*) To delay the movement of enemy reserve ground forces by producing threats of apparent assaults, both airborne and seaborne.

Air Attacks on Enemy Radio Installations Prior to the Assault

Although direct air action against enemy radio stations is not a counter-measure effected by radio means, it nevertheless should be considered part of the general radio counter-measure plan which aims at denying to the enemy the benefits of his radio services as a whole. The programme of air attacks on selected enemy radio stations as a preliminary to the landing was intended to

[1] Air Signals Report on Operation " Neptune," Planning and Assault Phase.

lower the morale and efficiency of the operators, and thereby to increase the effects of the electronic jamming to be applied later. It was also hoped to destroy the very long-range radar installations which, partly on account of their narrow beam width, would be most difficult to jam. Thirdly, the attacks were intended to damage as far as possible those radar sets which were in position to overlook the approach of the assault forces both surface and airborne.

The density of the German early warning radar stations was such that there were major sites, each containing an average of three pieces of equipment, situated at ten to eleven mile intervals along the coast between Ostend and Cherbourg.[1] This chain, it will be remembered, was backed by an inland system of lesser density. It was decided, as a security measure, to attack two radio stations outside the assault area for every one attacked within that area.[2] To that end, all information concerning enemy radio stations covering the vital area available to all services was collated. A section of the Air Ministry Branch D.D.I.4[3] was attached to Headquarters, Allied Expeditionary Air Force, for several weeks before D-day for the purpose of providing expert advice on the enemy radio targets and on the results of our air attack upon them.[4] Much valuable work was done by this section and the tactical surprise achieved when the landings were made was due very largely to successful destruction of most of the enemy radar warning stations on the Channel coast during the preceding weeks.[5]

Abdullah

In view of the relatively small target offered by enemy radar stations to bomber aircraft, and because of the need to make the attack during the initial run-up to the targets in the face of their considerable light anti-aircraft defences, it was decided to equip at least the leading aircraft with a homing device tuned to the transmissions from the target stations. A homer called Abdullah was consequently adapted for this purpose and fitted to six Royal Air Force Typhoon aircraft of a specially formed flight.[6]

Typhoon and Spitfire aircraft of the Allied Expeditionary Air Force flew some 1,700 sorties in attacks on radar installations, which were pressed home with the utmost determination. Dive bombers dropped over one thousand two hundred 500-lb. bombs, and in low level attacks over three thousand five hundred 60-lb. rocket projectiles were fired. In addition the sites and equipment were sprayed with many thousands of rounds of cannon shell and machine guns. As a result, seven of the extra-long-range installations were destroyed, including all six south of Boulogne, and at least fifteen other installations were rendered completely unserviceable.[7] In addition to this destruction, the morale and efficiency of the enemy radar operators were lowered by these Allied attacks to such an extent, indeed, as to cause them to close watch on the approach of Allied aircraft. It was therefore assumed that these attacks had reduced the efficiency of the enemy early-warning system in the vital area to a point at which R.C.M. and Spoof were likely to have the maximum effect.[8]

[1] A.E.A.F. File A.E.A.F./S.13052.
[2] Allied Expeditionary Air Force File A.E.A.F./S.13052.
[3] Deputy Directorate of Intelligence.
[4] Air Staff Operational Monograph No. 1 (C.S. 22270).
[5] A.H.B./II E/85 -A.D.I. (Sc.) Report " Intelligence on Enemy Scientific Development."
[6] A.E.A.F. File A.E.A.F./S.13163.
[7] A.H.B. IIE/85.
[8] A.D.I. (Science) Report on " The Radio War."

Chimneys

The most important enemy long-range radar installations to be destroyed were the Chimneys.[1] A trial of the effectiveness of 60-lb. rockets against this type of station was made by No. 11 Group aircraft on a Chimney in the Ostend area on 16 March 1944. The attack, made in two waves by aircraft of No. 198 Squadron, was a complete success, at least four hits being obtained on the aerial supporting cylinder. This compelled the enemy to dismantle the entire station and a new aerial system was seen to be still in process of reconstruction on 9 May and again on 24 May. It was therefore evident that the equipment, which had taken a year to construct, could not be made serviceable in less than three to four months. Many similar attacks were made on other Chimneys and by D-day not one of the four installations south of Boulogne was in operation.

Hoardings

The form of attack appropriate to Hoardings was difficult to decide and rockets, cannon fire and bombs were all tried.[2] Of the three large Hoardings in the vital area, by D —4 one had been made unserviceable by cannon fire and another by a combination of all three forms of attack. The only surviving one was not thought likely to be able to help the enemy because of its situation.

Freyas[3]

Because of the small target presented by the *Freya* and its relatively high susceptibility to electronic jamming, it was not made a primary objective in the majority of attacks. At least one *Freya*, however, that at Cap de la Percée, suffered a direct hit by a rocket projectile and a number of other *Freyas* also suffered to varying extents. Machine-gun bullets were stated by some prisoners to have been most effective in damaging the apparatus.

Giant *Wurzburgs*

Rockets and cannon were found to be highly effective against Giant *Wurzburg* stations. At least five of these stations are known to have been seriously damaged necessitating replacement of major parts, and it is believed that many others were damaged to a considerable extent.

Small *Wurzburgs*

Because of their small size, and their mobility and quantity, the Small *Wurzburgs* with their very limited range were not considered to be useful targets but at least one was destroyed incidentally in the course of air attack on a neighbouring target.

Coast Watchers

These installations were also relatively invulnerable to air attack but pilots claimed many strikes on them and air photographs suggested that a good deal of damage had been done to them.

W/T Stations

A number of W/T stations of importance were attacked by Bomber Command. These attacks were examples of precision bombing and, so far as can be judged, completely achieved their object. Much of the credit for this goes to the Oboe

[1] A.E.A.F. File A.E.A.F./S.13052. [2] Air Signals Report on Operation "Neptune."
[3] For details, *see* Air Signals Report on Operation "Neptune."

technique. The W/T station at Boulogne/Mt. Couple, for instance, contained about sixty transmitters. The first attack was unsuccessful, but two nights later on 31 May/1 June in an attack by over 100 aircraft, at least 70 heavy bombs were put on the target which measured only 300 yds. by 150 yds. After this attack only three transmitters remained serviceable.

The W/T station at Beaumont Hague/Au Ferre was also attacked on the night of 31 May/1 June 1944 by about 120 aircraft. Although the main concentration of bombs fell just outside the target area, an adequate number scored direct hits. The attack on the Dieppe/Berneval-le-Grand W/T station was adjudged to be completely effective. Most of the eight or nine blast-wall protected buildings received direct hits and the remainder suffered so many near misses that their operational value was greatly diminished. In addition, the aerial masts appear to have been completely demolished and the two dispersed sites were also hit.

An important W/T station at Cherbourg/Urville Hague was attacked on the night of 3/4 June by 99 aircraft. Once again Oboe was employed and the results were remarkable, the centre of a very neat bomb pattern coinciding almost exactly with the centre of the target area. The buildings and aerial system were annihilated and the site rendered unsuitable for rebuilding without a huge preliminary effort in levelling and filling craters. This station proved to be a German " Y " station and its loss doubtless caused serious inconvenience to the enemy.

Enemy Jammers

Air attacks on enemy early-warning radar and W/T stations were not the only counter-measures of this form.[1] Encouraged by the success they believed to have achieved in support of the escape of the *Scharnhorst* and *Gneisenau* from Brest, the Germans had increased their jammer stations. They were a prospective danger to the Allied landing forces, for they could have neutralised the night-fighter control ships and jammed the Gee Chain upon which a large part of the Allied air forces depended for navigation. The jammers were found to be clustered in five large groups and, with the use of Oboe, Bomber Command destroyed them. Attacks were also made by Mosquito aircraft of the British Second Tactical Air Force against a *Knickebein* navigational aid station at Sortosville on 3 May 1944, in which a 500-lb. bomb scored a direct hit within the circular track of the station.

The cumulative effect of these attacks was of great value in the Allied assault. At no time on the night of D –1/D-day were more than 18 per cent. of the previously available enemy radio installations working. For a part of the night only 5 per cent. were operating and the task of applying electronic counter-measures to the remainder of the system was simplified.

Machinery of Radio Counter-Measure Control

The application of radio counter-measures in support of Operation "Neptune" carried greater possibilities of interference with the Allies' own radar and communications than ever before. At a vitally critical time a vast number of radio installations of all kinds and all services were to be crowded

[1] A.D.I. Science Paper " The Radio War."

into the small area of sea and land in the assault area, and in the air above it. The chances of mutual interference alone were very serious, apart from deliberate counter-measures.

In view of the experience of Bomber Command in offensive radio counter-measures, and of the part which they were to play during the period of the landing, the Chief Signals Officer, Bomber Command, was made responsible for the R.C.M. Plan for D-day.[1] He and his working committee were in close co-operation with the Air Signals Officer in Chief, Allied Expeditionary Air Force, to this end. Special arrangements were necessary to provide advice on the problem of mutual interference. A Mutual Interference Sub-Committee[2] of the Combined Signals Board was accordingly set up under the chairmanship of the Air Signals Officer-in-Chief, A.E.A.F. to ascertain the technical limitations in this respect. It operated through a Technical Working Sub-Committee under the chairmanship of the Group Captain Signals Plans, Headquarters, A.E.A.F.

It still remained to set up machinery to ensure adequate control of R.C.M. with regard to its effect during the assault and to have expert advice close at hand for commanders in the field. Control of R.C.M. from H −30 to H-hour was vested in the Allied Naval Commander, and from H-hour onwards, in the Air Commander-in-Chief A.E.A.F.[3] They were advised by a Combined Counter-measure Advisory Staff at Stanmore under the Director-General of Signals, containing one member from each of the Services, and drawing opon the Mutual Interference Sub-Committee for technical information of a detailed nature. Obviously such a committee, sitting inland at Stanmore, was not in itself well situated to advise commanders in the field. An Interference Advisory Staff was accordingly put at the disposal of the Signals Officer-in-Chief of 21 Army Group, Portsmouth, with a further similar staff each for the Chief Signals Officer, 1st U.S. Army, and Chief Signals Officer, 2nd British Army, at the bridgehead.[4]

There was some dispute as to whether the measures taken to prevent chaos in the ether to our own forces were too elaborate and comprehensive, but the magnitude of the problem and the bogey of this unknown factor were adequate reasons for a generous provision.[5] The fact is that this machinery achieved its aim : its first estimation as to the restrictions needed was good, although many matters of detail arose for clearance in the light of experience later in the field.

Radio Counter-Measures against Early Warning and Fighter R/T Control Stations

Direct air assault on the enemy radar stations had been so effective that a relatively easy task was left for Allied radio counter-measures in comparison with that normally presented in the night-to-night support of the strategic bomber offensive. But in this instance, in which deception was of more importance during the initial stages of the invasion than provision of cover to the ground forces from air attack, radio counter-measures had to be wholly effective over selected large areas. One peep behind the screen by a single immune enemy radar station might well have nullified the entire counter-measure effort.

---

[1] A.H B./IIE/76—" War in the Ether."
[2] Air Signals Report on Operation " Neptune "—Appendix " F " of Section IX.
[3] *Ibid.* [4] Air Signals Report on Operation " Neptune."
[5] A.H.B. IIE/76.

The main purpose of R.C.M. immediately preceding and during the assault was as follows :—

(*a*) To protect ports of embarkation by depriving the enemy of the assistance of his radio aids-to-navigation. This was the rôle of ground R.C.M. stations in 80 Wing.

(*b*) To provide cover for the airborne forces and to simulate the landing of airborne troops elsewhere in enemy territory.

(*c*) To cover the approach of surface forces against early detection and against radar-controlled gunfire.

R.C.M. operations in the air involved over a hundred aircraft of Bomber Command. The diversion plan aimed to delude the enemy into believing that we were attempting landings on the beaches near Cap D'Antifer and Boulogne. This was to be achieved by two combined naval and air operations known as "Taxable" and "Glimmer" respectively. Meanwhile, R.C.M. cover for the entry of the airborne forces which were being landed in two distinct areas east and west of the main assault beaches was to be maintained by means of a Mandrel barrage covering the whole range of enemy coastal early warning frequencies, supplemented by feint landings away from the area of actual operations. Further, to cover the airborne forces and also to lend realism to the feint landings at Cap D'Antifer and Boulogne, a curtain of V.H.F. jamming was to be put down between the area of the actual assault and the direction from which the enemy fighter reaction was expected. There were thus the following five distinct R.C.M. tasks :—[1]

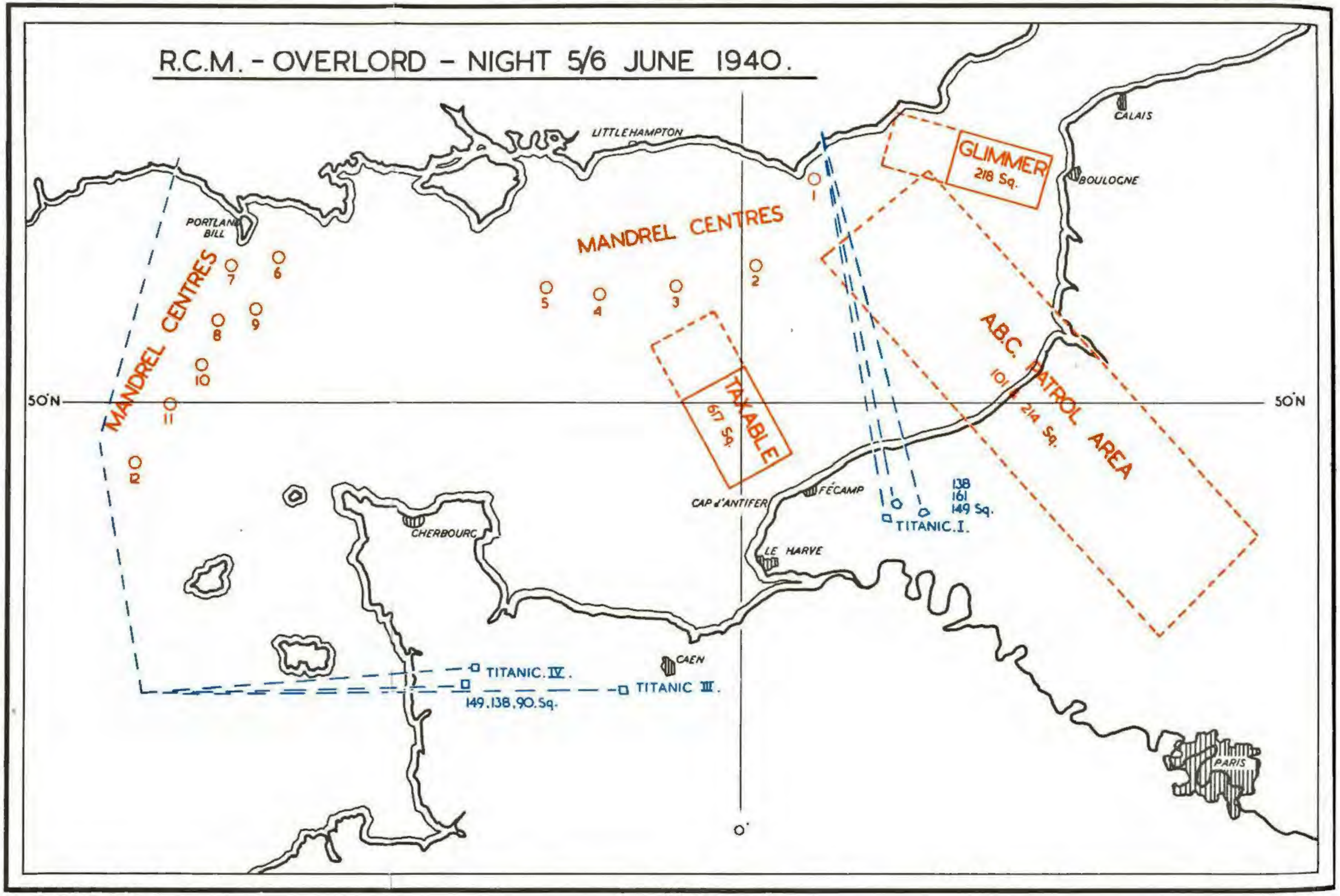
(*a*) "Taxable"	..	A combined naval/air diversion against Cap D'Antifer.
(*b*) "Glimmer"	..	A similar diversion against Boulogne.
(*c*) Mandrel	..	Jamming barrage to cover airborne forces.
(*d*) A.B.C. ..	..	V.H.F. jamming support for "Taxable" and "Glimmer" and cover for airborne forces.
(*e*) "Titanic" I, III and IV.		Feints for airborne forces.

Operation "Taxable"

The Naval plan for "Taxable" involved the simulation of a convoy approaching Cap D'Antifer at 7 knots on a 14-mile front.[2] Eighteen small ships were to be used in co-operation with aircraft dropping bundles of specially prepared Window in such a manner as to give the appearance on the enemy's coastal *Wurzburg/Seetakt* radar equipment of a large convoy of ships approaching. The effect was to be heightened by our ships towing balloons fitted with reflectors designed to give radar echoes of the kind normally associated with big ships, the whole being elaborated by Mandrel type jamming intentionally of sufficiently low intensity to allow the enemy radar just to see the spoof convoy through it.

No. 617 Squadron[3] was selected for this rôle, which presented two practical problems, namely, a method of creating and sustaining surface-vessel echoes by means of Window dropped from these aircraft, and a flying technique that

[1] Diagram 13.
[2] Air Signals Report on Operation "Neptune," paras. 38–44.
[3] O.R.B. for No. 617 Squadron, June 1944.



C.B.H. 18466- Wt. 13814 - Dd.G.5071 - 1000 - 6/50

fp

would give an effective ground speed of only seven knots advance of the Window spoof. A solution to those problems was propounded by T.R.E. and trials made in the north of Scotland proved conclusively that it was possible to produce upon radar equipment similar to that used by the enemy the illusion of slow moving vessels, by means of Window ejected from aircraft.

The type of manœuvre adopted by the aircraft was to fly in elongated orbits of which the major axis was perpendicular to the coast, each orbit being slightly more advanced than the preceding one. The rate of advance of successive orbits was thus adjusted to equal that of the convoy simulated. In Operation " Taxable " 24 miles had to be covered. The aircraft were disposed in two lines, four abreast, forming a box 12 miles wide and 8 miles deep over the naval " convoy " area. A total of thirty orbits, each gaining ·82 nautical miles on the previous one, was made by No. 617 Squadron over a period of three and a half hours. Eight different sized bundles of Window were used and they were discharged consistently from a height of 3,000 feet at a rate of twelve bundles a minute throughout the three and a half hours of the operation. This system prevented diffusion of the Window and yet allowed time for echoes to appear on the enemy radar warning devices. The Window was discharged on a schedule which caused the echoes seen on the enemy radar to be maintained on the correct line of approach, while growing in size as the imaginary convoy drew near to the coast. The Southern Gee-Chain was employed for the very accurate navigation required, the " B " lattice being used for tracking and the " C " lattice for positioning. As a precaution against the effects of fatigue and the danger of failure, two navigators and an extra Gee set were carried in each aircraft.

In order to allow time for the intensive training required for operation " Taxable " No. 617 Squadron[1] was taken out of the line on 7 May, and was ready for the operation on 31 May. A suitable ground radar station was established at Flamborough Head against which the squadron was able to test and perfect the technique involved for the operation in conditions exactly similar to those obtaining in the actual " Taxable " area.

Operation " Glimmer "

The execution of Operation " Glimmer " was allotted to No. 218 Squadron,[2] and intensive training was carried out between 20 and 31 May. The operation was similar to " Taxable " but the method of execution differed in the following respects :—[3]

(*a*) Fewer orbits were necessary as the distance across the channel to Boulogne was less than that to Cap D'Antifer.

(*b*) The Gee cover in the " Glimmer " area was inadequate for the high degree of accuracy required. It was therefore decided to use the High Street G—H beacon for tracking and the south eastern Gee chain for positioning.

(*c*) Only six aircraft were employed as compared with the sixteen for " Taxable " and as no relief aircraft were used, each aircraft carried two pilots, three navigators, four Window crew and an additional Gee receiver for positioning.

---

[1] O.R.B. No. 617 Squadron, May 1944.
[2] Details will be found in O.R.B., No. 218 Squadron, for May and June 1944.
[3] Air Signals Report on Operation " Neptune," para. 45.

Support of Airborne Forces[1]

There was an Army requirement for aircraft to drop dummy paratroops in certain areas. The number of aircraft available for this was limited and so it was decided to use Window to make each aircraft appear to the enemy radar to be a considerable force. The diversionary aircraft approached the enemy coast on a course adjacent to that of the Allied airborne forces, but broke away close to the enemy coast to approach the diversionary dropping zones. The operation was divided into several sections known as "Titanic I, III, and IV," and was designed to saturate and confuse those enemy sites which were best located to provide the enemy with intelligence of the movements of the real forces, and to divide any available fighter effort between the real and the diversionary forces. In addition, bomber forces were routed, whenever possible, in such a way as to assist in the saturation and confusion of the radar sites referred to above.

" Titanic I "

This phase was carried out by fifteen aircraft of No. 3 Group[2] which had the two-fold task of discharging large quantities of Window, Type M.B. and N., to deceive the *Freya*, *Seetakt* and *Wurzburg* coastal watching installations, and of dropping dummy paratroops in the area behind Cap D'Antifer and Le Havre.[3] The object of this operation was to delude the enemy into believing that this was a main airborne forces dropping area.

" Titanic III and IV "

These operations were similar to " Titanic I " but were further to the west. Nineteen aircraft of No. 3 Group were allotted to this task.[4] Leaving the south coast just west of Portland Bill, they were routed almost due south behind a Mandrel screen flown by Nos. 199 and 803 Squadron, turning in due east, so as to pass south of the Channel Isles and south of the Cherbourg Peninsula, the " Titanic III " force destined for the Caen area and the " Titanic IV " force to a zone just south west of Carentan.

The method employed in dropping Window was to discharge two bundles of Type M.B.[5] every twelve seconds and one bundle of Type N every six seconds. This had the effect of magnifying the " Titanic " force, as seen on the enemy radar, twenty-fold. In addition Window, Type O was discharged at the rate of three bundles per minute by main force aircraft employed in bombing targets to the east of the assault area. The object of this was to cause general confusion to enemy radar on the coastal belt between Le Havre and Cap D'Antifer–Fécamp.

Electronic R.C.M.

Many types of electronic jamming equipment were employed as countermeasures, Mandrel and Carpet being extensively used against ground radar stations and A.B.C. against the enemy's V.H.F. fighter control system.[6]

It was suggested that the most efficient method of screening Allied surface forces would be to drop large quantities of Window from aircraft flying at 20,000 ft.

[1] Air Signals Report on Operation " Neptune," para. 46.
[2] O.R.B. of H.Q. No. 3 Group for May and June 1944.
[3] Air Signals Report on Operation " Neptune," para. 48. [4] *Ibid.*, paras. 49–50.
[5] Chapter 9 of Part 2 above, for further details of various types of Window.
[6] Air Signals Report on Operation " Neptune," para. 51.

By the time this fell into the beams of the enemy's ship-watching radar it would be sufficiently dispersed to produce an interference level so high that Allied shipping could not be seen through it. This scheme was not accepted because the Royal Navy had decided to fire upon all aircraft within range, and because Allied shipborne radar would have been seriously jammed by the Window. It was decided therefore to use electronic methods for the purpose of jamming enemy *Seetakt*, *Freya* and *Wurzburg* equipment which would be used by him for detecting surface forces and for controlling gunfire against them. Shipborne Mandrel and Carpet jammers were used for this purpose. As the German very long range reporting radar had been effectively destroyed by air attacks, it remained to counter the *Freya* chain, which might be expected to pick up the approach of our airborne forces at a range of about seventy miles.

No. 199 Squadron[1] of the Royal Air Force, aided by aircraft of No. 803 Squadron of the United States Army Air Force, was designated as the Mandrel barrage and screen squadron and was fitted with Mandrel equipment capable of covering the entire known *Freya* frequency range. It was not possible, in view of the limited time available, to cover every spot frequency within this wide band, extending from 60 to 200 megacycles per second but as there were comparatively few spot frequencies in use between 170–200 megacycles per second, this band was dealt with by modified I.F.F. sets which could be monitored to required frequencies. As this involved finding the frequency of any *Freya* set looking at the aircraft, a special operator was carried to keep the four modified I.F.F. sets in each aircraft correctly set up. Mandrel radiation between 80–86 megacycles per second would have jammed Gee seriously, and the navigation of the air operation depended upon this Gee chain. The frequency range to be jammed by Mandrel was accordingly limited to 88–200 megacycles per second.

Because of the limitations of power supply, equipment and aerial spacing, it was found that single aircraft could not be so fitted as to cover the range. The difficulty was overcome by employing aircraft in pairs. Each aircraft was able to cover one half of the required range so that complete cover was provided by each pair, or "jamming centre." The object was so to dispose jamming centres as to provide a Mandrel screen which would reduce the effective range of a *Freya* to 30 miles.

Of the many considerations affecting the use of A.B.C., the following were the main ones :—[2]

(*a*) The direction from which enemy night fighters could be expected to attack.

(*b*) The R/T control system employed by the enemy.

(*c*) Whether A.B.C. jamming should be applied as for a normal bomber raid or whether a special patrol area should be organised.

(*d*) The possibility of using A.B.C. as a diversion to assist the operations "Taxable" and "Glimmer."

It was finally decided that No. 101 Squadron, reinforced by No. 214 Squadron, should patrol in the area shown on the map attached.[3] The objects of this patrol were to provide a protection screen of V.H.F. jammers between the

[1] O.R.B. No. 199 Squadron, May–June 1944.

[2] Air Signals Report, on Operation "Neptune," paras. 59–62.

[3] Diagram 13.

assault area and the direction from which enemy fighters could be moved into that area, and also to create the impression that the patrol was acting as top cover for "Glimmer."

No. 101 Squadron, each aircraft of which was fitted with three A.B.C. transmitters for spot frequency jamming in the 38–42 megacycles per second band, carried an extra crew member specially trained to apply A.B.C. jamming. In all other respects it was a normal Lancaster main force bomber squadron and the A.B.C. jamming operation was undertaken as an additional function. On the night of 5/6 June, twenty-four aircraft of No. 101 Squadron[1] and five of No. 214 Squadron operated, giving a total of 82 jammer transmitters on the 38–42 megacycles per second frequency band, each capable of radiating about 50 watts per channel. These aircraft patrolled the A.B.C. area between Dieppe and the mouth of the Somme for four and a half hours at heights between 24,000 and 27,000 feet.

R.C.M. against Enemy Radio Aids to Navigation

The task of conducting radio counter-measures against enemy radio aids-to-navigation, including, in particular, blind bombing aids, was allotted to No. 80 Wing.[2] It was intended that this wing should operate from stations in the United Kingdom just prior to and during the landings, and that it should detach R.C.M. echelons to operate in the bridgehead and in Europe during the subsequent advance. This mobile sub-formation of the wing was termed No. 80 Wing (Main).[3]

In view of the marked air superiority of the Allied air forces over the German Air Force, it was anticipated that the enemy would take full advantage of bad visibility cover for air attack upon the bridgehead and that he would depend upon radio aids to navigation, and especially upon blind bombing aids, for this purpose. The following aids were those concerned :—

Benito.
Knickebein.
Mobile Track Guides.
M.F. Beacons.
Sonne Elektra.
M.F. and H.F. D.F. Fixers.
Fighter Benito.
Fighter Bomber Control.

Mobile R.C.M. units were formed to counter all these aids and their function is described in more detail below.

The high power of many of these aids made it either difficult or impossible to jam them by means of transmitters based in the United Kingdom. It was therefore necessary to have jammers established on the bridgehead at the earliest opportunity.[4] On the other hand, the shipping capacity of the first convoys was severely limited and a very large number of enemy aids had to be covered. It was important to concentrate on only the most important aids and these were decided to be the enemy's blind bombing aids—Benito and

[1] O.R.B.s Squadrons Nos. 101 and 214 for June 1944.
[2] H.Q. 80 Wing Appreciation, 25 February 1944, and Operation Order, in Appendices "R" and "S" of No. 80 Wing Report.
[3] Part 2, Chapter 16, of this volume.
[4] H.Q. 80 Wing Appreciation, 25 February 1944, and Operation Order, para. 8.

Knickebein in particular.[1] There were fewer Benito track beam transmitters than range transmitters and the former were more easily jammed. It was consequently decided to jam only the track beams in the first instance, extending the R.C.M. operations as quickly as the build-up of units on the bridgehead would permit. In this connection the plan[2] provided for mobile units to move to the Continent in three echelons as follows :—

(*a*) First Phase. The first echelon to land on D + 7 to provide limited R.C.M. cover of the bridgehead against accurate enemy blind bombing aids. This echelon to be attached to No. 83 Group for administration. It became operational near Bayeux on 19 June 1944.

(*b*) Second Phase. The second echelon to land, when port facilities were available, to provide R.C.M. cover for the port. In this phase the first and second echelons to be attached to No. 85 Group for administration.

(*c*) Third Phase. The third echelon to land at a later stage of the operations when it became necessary to provide R.C.M. (meaconing) against enemy navigational aids. The units to be attached to No. 85 Group for administration.

As soon as Advanced Headquarters, No. 80 Wing, was established on the Continent, liaison communications with Headquarters, No. 83 Group, were installed.[3] By this means, plots of enemy aircraft movement were obtained from Headquarters, No. 83 Group, for purposes of co-ordination of such movements with beam activity. It was found that No. 80 Wing jammers on the Continent rarely interfered with other operational radio activities, an ample testimony to the effectiveness of the preliminary work done by the Mutual Interference Sub-committee of the Combined Signals Board and by the contributors of the Interference Advisory Staff and the Combined Counter-measure Advisory Staff at Stanmore.

It was necessary to combine the use of the R.C.M. Watch Organisation based in the United Kingdom with that of the limited facilities at the bridgehead. Consequently operational control of the No. 80 Wing detachment remained with No. 80 Wing with a proviso that the Air Force Commander on the Continent could exercise overriding control in the event of R.C.M. operations interfering with his communications. This arrangement also facilitated the integration of tactical R.C.M. requirements in connection with the landings with R.C.M. operations in support of strategic bombing which at this time, although it temporarily changed its direction somewhat, nevertheless continued to conform with the long-term strategic plan.

R.C.M. Stations Operating from the United Kingdom[4]

Cigar was installed at Brighton to jam enemy fighter R/T on the frequency band 38·5 to 42·3 megacycles per second and was effective over a large part of Northern France. In view of its high power (fifty kilowatts) and the risk of interference with radio services in England, this transmitter had not been used before. Eighteen ground Mandrel stations were installed at Ventnor to jam enemy early-warning *Freya* stations in the bridgehead area in the frequency

[1] H.Q. 80 Wing Appreciation, 25 February 1944, and Operation Order, paras. 12, 22B, 24, 25.
[2] *Ibid.*, para. 3.
[3] Air Signals Report on Operation "Neptune," para. 80.
[4] *Ibid.*, para. 75.

band 70 to 220 megacycles per second. As the distance of these transmitters from the enemy coast was excessive, their effectiveness was problematical. The equipment was considered likely to be more nuisance to Allied radio than to that of the enemy and so was not used for the assault.

Numerous Aspirin stations on the south coast of England were used effectively against *Knickebein* beams intended as blind-bombing aids. Similarly No. 80 Wing operated Benjamin successfully against the enemy Benito blind-bombing system which he attempted to employ in air attacks on south coast harbours. Although Cigarette and Special Cigarette stations on the south coast stood by throughout for operation against enemy fighter R/T control, the need for their use did not arise.

Royal Air Force Meacon stations were continuously active against enemy M.F. beacons and the *Sonne Elektra* system, which all enemy multi-seater aircraft used, and against the enemy H.F. D.F. service. Enemy aircraft which might have attacked the ports of embarkation or concentration areas were thus deprived of navigational assistance while operating within the Meacon zone.

Effect on the Enemy

The various components of the R.C.M. were closely inter-dependent, and the results can best be summarised by giving an indication of the enemy reaction to the plan as a whole.[1] The first and most important fact is that the Germans did mistake the Glimmer convoy simulation for a genuine threat and, furthermore, they believed that the A.B.C. patrol was cover for operations in the Somme area. Consequently the enemy took action with searchlight and guns against the imaginary convoy. In the filter room at Stanmore, it could be seen that the greater part of the German night-fighter force was sent into the A.B.C. area, obviously under the impression that here was the main bomber stream of a major attack. On arrival in the area, the night-fighters found that they were subjected to serious jamming on their R/T communications channel. They returned towards their control points and appear to have received instructions to continue hunting in the supposed main bomber stream. Sporadic fighter activity continued in the A.B.C. area between 0105 hours and 0355 hours. Nos. 101 and 214 Squadrons had between them a total of seven combats as well as a number of visual contacts on enemy fighters, and claimed one night fighter as destroyed and two damaged.[2] One aircraft of No. 101 Squadron was shot down into the sea but all of the crew were subsequently rescued.

The enemy also sent a number of E-boats against Glimmer, which from all points of view was a successful spoof operation. No. 218 Squadron completed Glimmer exactly to schedule with no casualties. The Taxable convoy simulation, although it was accurately flown, drew only slight attention from the enemy. Shortly before the main "Overlord" operation commenced, enemy coastal radar activity was checked and found to be less than usual, due no doubt to the extent of damage recently inflicted by Allied air attacks. The Mandrel screen flown by Nos. 199 and 803 Squadrons undoubtedly jammed effectively those stations which remained active.

The "Titanic" operations also went exactly to schedule and drew some reaction from the enemy. Two Stirling aircraft were lost on "Titantic III."

[1] Air Signals Report on Operation "Neptune," paras 43–70.
[2] O.R.B.s for Nos. 101 and 214 Squadrons, June 1944

The simulation was watched by radar in England and was seen to give an excellent picture of a large force of low-flying aircraft. There is now ample evidence that these operations delayed the reactions of the enemy ground forces to the real airborne operations. When the war was over the head of the German Signals Corps maintained, on interrogation, that although his radio installations suffered considerable damage from bombardment prior to D-day, there were still sufficient left to maintain a service.[1] Similarly the Chief of the *Luftwaffe* Intelligence claimed to have foretold the approximate place of the Allied landings, but that his advice was ignored by the High Command.[2] It is easy to claim not to have been deceived after the event. The fact remains that tactical surprise was achieved in a very great measure by the main force, and this despite the magnitude of the operation and the vast electronic organisation at the disposal of the Germans for gaining information of the assault.

---

[1] Air Ministry Weekly Intelligence Summary (A.M.W.I.S.) No. 308, page 49.
[2] *Ibid.*, No. 325, page 7.

CHAPTER 19

RADIO COUNTER-MEASURES IN SUPPORT OF THE ALLIED LANDING IN THE SOUTH OF FRANCE (OPERATION ANVIL/DRAGOON)

The Allied Chiefs of Staff decided at the conference called Quadrant in September 1943 to plan an assault on Southern France to coincide approximately with the main landing operation in Normandy.[1] It was calculated that the former would assist the latter in several ways. It would contain a considerable portion of Axis forces in France and Italy in the South of France and so lessen resistance to " Overlord " and it would put a considerable Allied force on a flank of the German lines of communication and would open alternative ports and routes by which to reinforce the Allied northern forces. Finally, it would stiffen the operations of the French *Maquis* against the enemy.

On 12 June 1944 it was decided that final plans for operation "Anvil"[2] should be produced and that the operation would consist of an amphibious assault mounted from North Africa, Corsica, Sicily and Italy against Southern France, east of Toulon, with the object of seizing a suitable port as a base and subsequently advancing towards Lyon and Vichy, or westward to the Atlantic coast, as determined by developments. The ultimate object was to join the Allied forces operating in Northern France.

The army forces to take part in operation "Anvil" were planned to be one U.S. corps, two French corps and an airborne force consisting of British, U.S. and French airborne formations.[3] The main assault was to be launched at H-hour on D-day by three U.S. divisions between Cap Cavalaire and Agay, the left flank to be secured by a landing of French commandos near Cap Negre. An airborne force was to be dropped in the Argens valley between Le Muy and Carnoules, and later a French parachute regiment might be dropped in localities held by the *Maquis* from about D +5 to D +10. On the night of D −1, a Special Service force was to be landed immediately after dark on the islands of Port Cros and Levant with the object of neutralising the enemy defences on these islands in order that shipping might enter the Bay of Cavalaire. The forces for the operation were to be placed under the command of Major-General A. M. Patch, Commanding General of the VII U.S. Army.

The naval forces planned to take part in the operation were a composite task force comprising 4 battleships, 2 heavy cruisers, 14 light cruisers, 11 aircraft carriers, 105 destroyers and numerous supporting craft, cargo ships and assault craft.[4] Their tasks were to establish the army forces ashore on the beaches selected, to make diversionary movements outside the assault area, to land commandos and Special Service forces at selected landing points and to provide carrier-based aircraft to augment the scale of fighter cover over the beaches and shipping lying offshore and to observe for naval gunfire. The Naval

[1] A.H.B./II J1/90/29A, Encls. 31B and 16A, para. 2.
[2] A.H.B./II J1/90/34 (Signals Report on Operation " Dragoon "), para. 2.
[3] *Ibid.*, para. 3. [4] *Ibid.*, para. 4.

Commander for the operation was to be Vice-Admiral H. K. Hewitt, U.S. Navy, Commander 8th U.S. Fleet, and during the period of the operation he was to use the title " Naval Commander Western Task Force ".

The air forces available comprised the Mediterranean Allied Tactical Air Forces (M.A.T.A.F.) and the Mediterranean Allied Strategical Air Forces (M.A.S.A.F.)[1] M.A.T.A.F. included American, French and British formations and squadrons containing day and night fighters and fighter-bombers, medium and light bombers, tactical reconnaissance aircraft and troop carriers. The strategical forces consisted of American and Royal Air Force heavy day and night bombers, medium night bombers and long-range escort fighter aircraft. In addition, certain day and night fighters, anti-submarine, shipping reconnaissance and strike squadrons and air/sea rescue aircraft and launches under the Air Officer Commanding, M.A.C.A.F., were to be employed in support of the operation, while certain tactical air forces were to be operating solely in support of the Italian campaign, and two United States photographic reconnaissance squadrons were to meet requests for photographic reconnaissance from Commanding Generals of the XII T.A.C. and M.A.S.A.F.

Air Force Tasks[2]

The task of the air forces was broadly sub-divided as follows :—

(*a*) to neutralise the enemy air forces,

(*b*) to provide air protection to the assault convoys, the assault and to subsequent operations,

(*c*) to prevent or effectively retard movement of enemy forces into the assault area,

(*d*) to assist the assault and subsequent operations of the ground forces by air action,

(*e*) to transport and drop airborne troops engaged in the operation, and

(*f*) to support operations by the *Maquis* by air action and air supply.

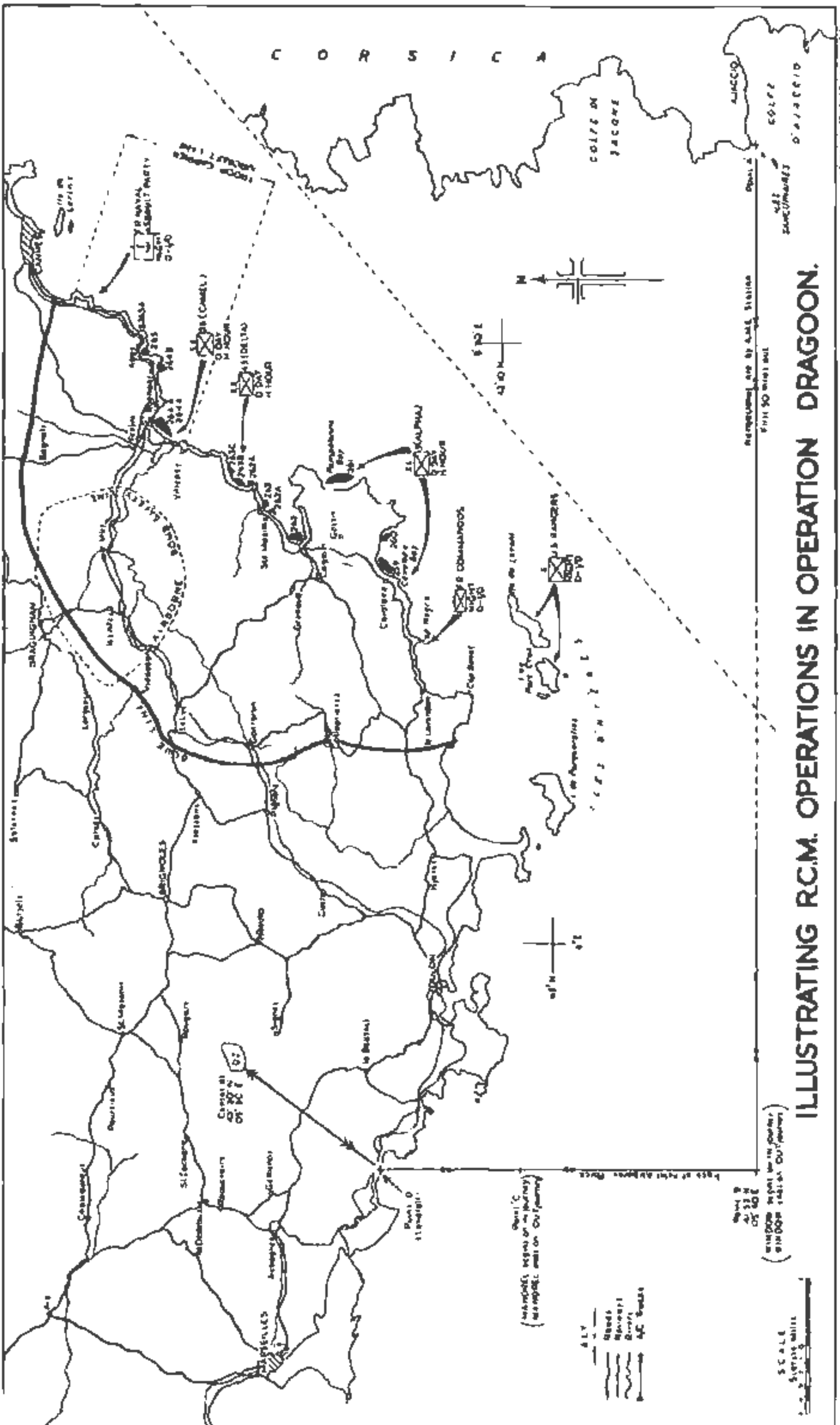
These tasks were in addition to the normal air commitments of the air forces in M.A.A.F., such as long range strategic bombiug, support of the battle in Italy, and operations over the Balkans. Also, air forces were to be allocated certain tasks in support of the cover plan and diversionary operations.

Radio Counter-Measures Plan for Operation " Anvil "/" Dragoon "

The R.C.M. planning staff was, of course, an integral part of the signals planning staff, generally, for " Anvil "/" Dragoon." It was fortunate to have at its head an experienced R.C.M. officer from No. 80 Wing in the United Kingdom and who had planned the radio counter-measures for operation " Husky." [3] This staff moved from La Marsa to Algiers on 4 December 1943, and on 8 July 1944 to Caserta (Italy)[4] in order to be alongside Allied Forces Headquarters, Commander-in-Chief Mediterranean, Commander United States Naval Forces North-West African Waters, and Headquarters VII Army,

[1] Combined Operations H.Q. Bulletin Y.42, Operation " Dragoon," page 2.
[2] *See* II J1/90/34, para. 6. [3] *See* Part 3, Chapter 17, of this volume.
[4] A.H.B./II J1/90/34, para 12 refers.

DIAGRAM 14



ILLUSTRATING R.C.M. OPERATIONS IN OPERATION DRAGOON.

and to remain with them during their moves. The planning staff was thus remote from the executive staff, a disadvantage which was outweighed by the advantages of proximity to certain other headquarters and which was largely overcome by frequent liaison visits to the executive staffs.

Plans were sufficiently advanced by February 1944[1] for them to be referred for more detailed examination to the lower formations. By the end of March, plans were advanced enough for decentralisation to lower formations and for co-ordination to be effected with other Services as far as was possible in the absence of firm advice on the air plan and the probable date of D-day. In the first week of July it was decided that the operation would take place about the middle of August.[2] Obviously a more precise date would, for the time being, have to await events in Northern France. The benefit of having completed an outline plan and preliminary co-ordination so early before the event was, however, not to be enjoyed by the R.C.M. Staff. Receipt of preliminary reports on the large-scale R.C.M. operations in Operation " Neptune " made it evident that developments in R.C.M. technique and production of R.C.M. equipment had taken place which were not known in the Mediterranean theatre.[3] It was, therefore, decided that the Senior Signals Planner should visit the United Kingdom as soon as possible after the launching of Operation " Overlord " to find out how R.C.M. had been employed in that operation and to what extent similar employment in operation " Dragoon " was possible. Unfortunately, the visit could not take place until 28 June 1944, which left very little time for the production of detailed R.C.M. plans and the procurement of equipment to implement them or training required to carry them out. It was evident that assistance would be required from experienced personnel in the United Kingdom and that all delays entailed in submitting R.C.M. plans to various staff sections for approval should be cut down to a minimum. It was accordingly decided to set up an inter-Service R.C.M. Planning Board with Air Staff representation to produce detailed plans. Some assistance was forthcoming from the United Kingdom ; experienced R.C.M. personnel[4] were sent out arriving at Headquarters, Mediterranean Allied Air Forces, on 20 July 1944. Ultimately their assistance proved invaluable, and without it practically no effective radio counter-measures could have been carried out in the time then available.

The counter-measures against the enemy early warning radar and fighter control organisation in Northern Italy and Southern France were to be effected in three main phases, the scheme being similar in broad outline to that adopted during the invasion of Northern France.[5] These phases were :—

Phase " A " .. Direct action against enemy radar installations.

Phase " B " .. Radio counter-measures in support of diversionary operations, and

Phase " C " .. Radio counter-measures against enemy radar and radio for the protection of Allied convoys, airborne forces and assault craft.

---

[1] A.H.B./II J1/90/34, para. 13 [2] *Ibid.*, para. 14. [3] *Ibid.*, paras 39 and 40

[4] These representatives from the United Kingdom were Dr. Cockburn from the Telecommunications Research Establishment, Major Tait from Headquarters, Allied Expeditionary Air Force, and Squadron Leader Ricketts of Air Ministry, D.D.I.4.

[5] The Radio Counter-Measures Plan for Operation " Anvil "/" Dragoon " is given in full at Appendix No. 17. Diagram 14 refers.

Direct Air Action against Enemy Coastal Radar[1]

Co-ordination of this programme among the interested Services proved to be very difficult, since the interests of the Navy, the Army, the Air Forces and " A " Force (responsible for the cover plan) were conflicting at all stages. The cover plan called for maximum effort in the Gulf of Genoa area right up to D-day, and dispersal of attacks in any other area along the whole length of the coastline from the Spanish border to the eastern limit of our front in Italy; the effort of the air forces was limited with maximum demands on it immediately preceding D-day and therefore called for concentrated attacks on targets vital to the assault with no dispersal of effort; the Navy called for maximum air effort against coastal defence batteries; the Army were interested primarily in surprise and, therefore, called for maximum support to the cover plan but also effective action against coastal defences. It was finally decided that no attacks on coastal batteries or radar stations would take place before D —5 and that, even then, the attacks would be dispersed along the whole coastline.

Diversionary Operations and R.C.M.[2]

In furtherance of the cover plan, which was aimed at leading the enemy to believe Genoa was the threatened area, a small diversionary operation was planned on the right flank of the main assault forces. The force was to consist of two gunboats and several personnel tenders and motor launches to be routed within enemy radar range towards the Gulf of Genoa, then to swing at the last moment westward to bombard the Nice/Cap D'Antibes area. No air forces were to be involved in this diversion and the R.C.M. was to consist mainly of shipborne jammers covering coast watchers and coastal gunnery radar frequencies.

The main diversionary operation was planned to simulate a large-scale attack on the left flank of the actual assault forces timed to go in a few hours before H-hour, simulate a withdrawal to the main assault anchorage and repeat the operation the next night and again a few days later. The naval force involved consisted of a destroyer and a small number of personnel tenders and motor launches. Detailed planning of the R.C.M. to support this operation involved close liaison with the naval personnel involved. This was made difficult by the air signals planning being carried out at Caserta and the naval planning in Naples. Ultimately, an agreed course and disposition of the diversionary forces was settled after considerable discussion and was a compromise between Air and Naval requirements.

The R.C.M. in support of the diversion consisted of shipborne jammers to cover coastwatchers and coastal gunnery radar frequencies. In addition, the ships towed reflector balloons to confuse coastal radar, and were fitted with A.S.V. Moonshine to deceive enemy airborne A.S.V. reconnaissance by giving a response compatible with a much larger force. The fitting of the A.S.V. Moonshine was to be carried out by a special team of T.R.E. scientists. To complete the simulation of a large convoy, Window dropping by aircraft orbiting over the diversionary force and keeping station on it was planned in a manner similar to that employed in operation "Overlord". This was to be carried out by A.S.V. Mark III Wellington aircraft of No. 36 Squadron making parallel orbits six miles by two miles, dropping specially packaged Window from a

[1] II J1/90/34. Signals Report on Operation " Dragoon," para. 41.
[2] *Ibid.*, paras. 41–45.

height of 3,000 feet. The orbit was to move forward one and three-quarters miles each time giving an apparent rate of advance of 12 knots to an illusory convoy 10 miles wide by 6 miles deep. The convoy simulation was to last a total of seven hours, being limited by navigational problems and shortage of available Window.

To simulate an airborne operation in support of this diversion and also to provide a diversion for the actual airborne operation, simulation of a large troop carrier force was to be carried out on the night of D/D –1 in the inland area north-east of the Baie de La Ciotat. This was to be undertaken by five C–47 aircraft using Window to simulate a force of some 200 aircraft and dropping dummy paratroops and rifle fire simulators over the dropping zone.

Methods of Attack on Enemy Radar[1]

Some of the main difficulties in attacking targets as small as early-warning radar stations have already been discussed in connection with Operation "Neptune". The Operational Research Station of Allied Expeditionary Air Forces had made a detailed study of this problem of air attack upon German early-warning radar in Northern France, and this information was placed at the disposal of the air and R.C.M planning staffs in the Mediterranean theatre.[2] For example, it had been found that 670 single bomb attacks would be required to ensure a 75 per cent. hit on a Hoarding type of enemy radar station.[3] Thus the air effort required to disable the extensive early-warning screen along the coast between the Spanish and Italian borders can well be appreciated. Airborne jamming would be far more economical in so far as it could be employed effectively. Since, however, it was essential to ensure that no part of the radar chain should be able to give sufficient information of the approaching landing forces to endanger success, reliance could only be placed on a combination of direct air attack, jamming, and spoof.

Clearly, economy and efficiency could only be achieved in dealing with such minute targets by the closest liaison between the air and R.C.M. staffs on the one hand and Intelligence on the other. The following Intelligence facilities[4] were therefore placed at the disposal of Headquarters, M.A.A.F., and collated there for this purpose :—

(*a*) Information from "noise-watchers" and investigational flights.

(*b*) Combat films from striking aircraft.

(*c*) P.R.U. photographs of equipment before attack.

(*d*) Pilots' reports.

(*e*) Relevant intelligence from other sources.

(*f*) Information as to the exact time of proposed attacks.

(*g*) Notification of change of plans as to time and point of air attacks.

Method of Simulating a Diversionary Amphibious Force by Window-laying Aircraft

The diversionary feint attacks planned for "Anvil/Dragoon"[5] lent themselves admirably to the employment of Window in a manner similar to that adopted for operations "Glimmer" and "Taxable." The problem of navigating the

[1] *See* Part 3, Chapter 18, of this volume.
[2] A.H.B./II J1/90/34, para. 41 refers.
[3] *Ibid.*, Appendix "E" R.C.M. Instruction for Operation "Anvil," Annexure "A"
[4] *Ibid.* [5] *See* Part 3, Chapter 18, of this volume.

Window aircraft was, however, different from "Taxable" and "Glimmer" in that the Allied Italian Gee chain did not provide cover over the operational area, nor was G-H available. It was anticipated that the required degree of accuracy could be achieved by use of AN/APS-15, H2S or A.S.V., Mark III. Whereas in Operation "Neptune" Window aircraft used Gee lattice pinpoints for marking the area covered by the convoy, in operation "Anvil/Dragoon" the ships comprising the feint convoy force were used as reference points for navigation. This method had much to recommend it, as the Window laying itself had to be done in relation to those same vessels, so that automatic provision was made for any unpredicted diversion of the convoy from planned course and speed. It followed that the limits, and in particular, the front of the feint convoy had to coincide with those of the real convoy, frontal flank marker ships being used as reference points.

Window Force Required[1]

It was calculated that three aircraft equipped with centimetre radar and P.P.I. presentation could lay sufficient Window to simulate a convoy with a frontage of ten miles and a depth of six miles, representing several hundred ships, for a period of four hours. As the simulations could only be maintained during the hours of darkness, a maximum of six aircraft would be required for each diversion. As Nos. 36 and 458 Squadrons were experienced in night-flying G.R. operations, were equipped with A.S.V., and were not required for a more important rôle, it was decided to draw this Window force from them. In the event, the task fell upon No. 36 Squadron.

Naval Co-operation[2]

Window alone would have been inadequate as a radio counter-measure for this feint. The diversionary convoy consisted of some 20 to 25 small vessels accompanied by a destroyer. These vessels were carrying equipment designed to jam enemy radar, in much the same fashion as the real convoy, and yet to leave a sufficient part of the enemy radar screen immune in order to afford it just enough view of the Window feint to be deceived by it. In addition, certain of the vessels were equipped with Moonshine R.C.M. equipment to present the appearance of a large convoy to enemy aircraft equipped with A.S.V. should they be used to reconnoitre the sea areas of operation. The general aim was to simulate a convoy of 400 to 600 ships.

Technique of Window-laying

It had been found that bundles of Window were only successful for simulating shipping during the first 6 to 10 minutes of their fall, after which each bundle became too dispersed to afford further deception, although still effective as a jamming device.[3] Each bundle had therefore not to be visible to enemy radar for a longer period than 6 to 10 minutes, and to achieve this, a dropping height limitation of 3,000 feet was imposed. In order to preserve the appearance of a convoy the Window screen had continually to be renewed before each bundle had dropped below the enemy radar screen. To accomplish this, each dropping aircraft had to complete each orbit in seven minutes. It was decided to employ

[1] A.H.B./II J1/90/34, Appendix "E," Annexure "C," paras. 6, 8, 9.
[2] H.Q. M.A.A.F. C.M.F.—O.R.S. Report No. N.20 (Appendix "G") to A.H.B./II J1/90/34.
[3] A.H.B./II J1/90/34 O.R.S. Report on Convoy Simulation of "Window" (Appendix "G").

three elongated orbits along the direction of the convoy, with the six tracks spaced at two mile intervals. These spacings and the dropping rate of 15 bundles per minute were calculated on the basis of enemy beam widths and pulse lengths to make the whole orbit pattern merge into one solid mass when viewed by enemy radar. At closer range it was anticipated that the separate orbits might be resolved, but this risk was accepted for the sake of giving a life-like appearance of a convoy made up of six lanes of ships. This arrangement,[1] then, would produce a simulated convoy with a frontage of ten miles, and a length determined by the seven minute orbit time and the speed of the aircraft employed. Since the Wellingtons flew with an indicated air speed of 130 knots, this represented a convoy approximately seven miles long.

When a ship approached a shore-based radar station from long range, the echo and the rate of growth of the echo were, at first, both very small, but as it passed into " radio optical " range, the echo size and rate of growth increased rapidly until very large responses were achieved at close range.[2] The behaviour of aircraft responses differed markedly from this as, for normal flying heights, they were larger at long range, had a much more uniform rate of increase and did not achieve such high values at close range. It was, therefore, necessary to employ Window bundles of graded sizes to be used at different ranges from the enemy coast in order to simulate reality in this respect. The bundles and ranges at which they were to be used were worked out by T.R.E. taking into account the probability of anomalous propagation conditions, and suitably bundled materials were supplied by Air Ministry for the operation. Very small bundles were to be used at long range from the coast gradually increasing as the range diminished, maintaining the same dropping rate throughout. The effect was to simulate a smooth growth of the "convoy" response from zero to its maximum value without showing any serious discontinuities.

Differences between Simulation in "Dragoon" and "Overlord"

In the particulars mentioned so far, the operation was following closely along the lines of two similar diversionary operations employed in the landings in the north of France, but partly because of the different conditions and partly due to the fact the T.R.E. considered that the accuracy attempted in "Overlord" was unnecessarily high, a number of changes were introduced. In " Overlord," a much longer convoy was simulated and it was considered necessary to vary the type of bundle employed between the back and front of each orbit according to the distance of the aircraft from the enemy coast. In " Dragoon," because of the shorter " convoy " and because of the relaxation in accuracy requirements, this variation was omitted and, as the " convoy " moved forward, only a general periodical increase in bundle size, appropriate to the mean distance from the coast, was employed. The difference in method of navigation has already been mentioned. The fact that this simulation called for a turn through about 80 degrees in approaching the enemy coast, was another strong point in view of the A.S.V. method employed in this instance.

Training[3]

It was hoped that the squadron would be able to train for this operation over a period of two weeks, and experience has shown that this would have been most desirable but, owing to difficulties in withdrawing the squadron from other

[1] *See* A.H.B./II J1/90/34, Appendix "G," para. 7.
[2] *Ibid.*, para. 8.
[3] *Ibid.*, paras. 16–21.

urgent commitments, only four or five days training were possible. A Type 14 ground radar (3,000 megacycles per second) set was moved to a suitable site on the coast near Reghaia (near Algiers), the base for No. 36 Squadron, and arrangements were made with the Royal Navy to place three vessels at the disposal of the squadron as practice marker vessels. These were a trawler and two motor launches, which were instructed to patrol along east and west courses four miles apart within the coverage of the Type 14 for aircraft at 3,000 feet during the practice periods. (The range on small ships from this site was insufficient to permit continuous observation of the marker vessels.) Practices were begun by day and later continued by night, and it was possible to allow each crew at least one night sortie of two hours to practice orbiting and station keeping, in addition to day practices.

Practice Window was dropped at a rate of 15 bundles per minute during one-half to two-thirds of each run and it was thus possible to observe the orbit shapes and general quality of station keeping on the P.P.I. of the Type 14 station. The combination of P.P.I. presentation with the high resolving power of the Type 14 prevented this equipment being useful in studying the effectiveness of the Window laying as a deceptive measure. This problem had been thoroughly studied with the aid of captured and simulated enemy radar in U.K. in preparation for "Overlord," and it was considered that the recommendations on dropping rates, sizes of bundle and spacing of orbits could be accepted without further experiments. It was possible in this way to form some opinion of the relative merits of the crews and to study the problems of handing over to a second detail while still maintaining the orbits. Not only did No. 36 Squadron gain valuable practice from these exercises, but important lessons were learnt. It was found that the A.S.V. response from the motor launches and other small vessels was insufficient, even in a calm sea, and would therefore be unsatisfactory for use with a rough sea. It was accordingly decided to fit corner reflectors to the three marker ships and a Lucero beacon to the centre marker ship. Owing to the shortness of time, however, it was unfortunately not possible to incorporate either of these aids to navigation. This convoy-simulation problem has been written somewhat fully here because of the relative novelty and importance of the technique.

The Employment of Moonshine[1]

Three different Moonshine sets were employed, differing mainly in frequency cover, thus:—

(*a*) 540 to 590 megacycles per second—designated "H.F."
(*b*) 89 to 95 megacycles per second—designated "M.F."
(*c*) 75 to 85 megacycles per second—designated "L.F."

Only in the H.F. band had this equipment ever been used before successfully, so that an atmosphere of experiment surrounded the operation of the others. Six motor launches were involved in the fitting programme. It was found that the wardroom was the only place capable of accommodating the sets and for this purpose a large table was built and fitted along the entire length of the wardroom, together with a shelf above it. Each ship installation comprised two H.F. sets and one M.F. or L.F. set and, because of the shortness of time available, was a very improvised arrangement.

[1] A.H.B./II J1/90/34, Appendix "F." Report on Fitting and Operation of "Moonshine."

Prior to unpacking for fitting, the equipment had suffered some 400 miles of road travel, six weeks in storage, and 2,000 miles of air travel with consequent loadings and unloadings, packing and unpacking. Hence it was not surprising that few of the sets worked on first being tested, but all original faults were cleared just in time for the convoy operation.

Plan for Airborne Diversion[1]

It has been mentioned that an airborne diversion, so arranged as to simulate five waves of troop carriers, was to be a part of the cover plan, with the aim of diverting enemy forces away from the main Allied assaulting force. Five Dakota aircraft, each simulating a serial of troop carriers by means of continuous dropping of Window, were to approach the Baie de La Ciotat area from the south from a point outside the enemy radar detection range. These aircraft were to proceed to a dummy drop zone (D.Z.) north-west of Toulon and to drop 500 miniature parachute dummies. They were then to withdraw on a reciprocal bearing, continuing the use of Window until again outside enemy radar range. This diversion was to simulate a force of approximately 200 aircraft flying in normal troop carrier formation of five serials each of 40 aircraft.

The aircraft were provided by No. 216 Squadron and each was to carry 1,200 Units of Window type N and 600 Units of type CHR-1 (Rope) and 100 dummy parachutes.[2] Galera was chosen as the loading airfield. Aircraft were to be there by 0900 hours D −1 and upon completion of loading, were to proceed to Ajaccio by 1700 hours D −1, which airfield was to be the base of operation. Flying at 1,000 feet above sea- and ground-level and at an indicated air speed (I.A.S.) of 140 miles per hour on a four-legged course, the drop was to be made from 600 feet above the D.Z., both types of Window being dispersed continuously from a point 90 miles south of the intended landfall on the inward journey until again reaching the same point on the return. Type N was dropped at the rate of one unit every six seconds, and type CHR-1 at one unit per 12 seconds.

Associated Mandrel Jamming[3]

In order that the diversion should be as realistic as possible, Mandrel jamming was associated with the Window dropping. But this jamming had to be skilfully left incomplete; just sufficiently to enable the enemy radar to get such a glimpse of the Window force as would suffice to confirm the belief that it was a genuine airborne force. The commencement of Mandrel jamming was arranged to be deferred until 10 miles south of the landfall on the inward flight to the dummy D.Z. and timed to cease at the same point on the return flight. This arrangement was calculated to maintain the reality of the diversion during the period when the aircraft had to gain altitude for crossing the coast, with the consequent change in appearance of the Window column. Headquarters, M.A.A.F., provided for every coastal radar on both sides of the diversion force to be neutralised by Mandrel jammers from a separate source, in order that these radar stations should not be permitted to "peep behind the screen", and thereby spoil the illusion.

The five Dakota aircraft had to be diverted from transport duties for this diversionary operation[4] and this was done on D −3 so as to have time for special

[1] A.H.B./II J1/90/34, Appendix "H" and Annexure, H.Q. M.A.T.A.F. Operational Instruction No. 8.
[2] *Ibid.* [3] *Ibid.*, Appendix "H," Annexure, para. 12. [4] *Ibid.*, Appendix "H."

overhaul and repair. The four-legged course, together with an absence of normal radio aids-to-navigation in the operational area set quite a stiff task for the Dakota navigators, especially as accurate track- and time-keeping were necessary. As normal dead-reckoning and astro-navigational methods would not alone have been accurate enough for the purpose, it was arranged for the controller at A.M.E.S. Station No. 8001, by means of an SCR. 299 type station, to give course corrections out to 50 miles and a ground speed check at this point. Thereafter navigation was to be continued by dead-reckoning, astro-navigation being impracticable on such short legs. The controller was to call any aircraft that deviated appreciably from its track on the first leg of the outward journey and to indicate the sign and extent of the deviation.

Airborne Mandrel Jamming Screen[1]

Airborne jamming by Mandrel as a supplement to the main air attack upon the enemy coastal radar network in support of the naval and troop carrier aircraft was to be flown continuously from 0030 until 0600 on D-day. It was to be maintained by forty type ZN/APT-3 transmitters installed in eight aircraft of the No. 34 S.A.A.F. Squadron, M.A.S.A.F. The transmitters were to be tuned in accordance with the latest reconnaissance information as to what frequencies the enemy was operating. The aircraft were to fly on four different patrol lanes approximately 40 miles from the enemy shore and at altitudes from 9,000 to 11,000 feet.

Air Action against Enemy Radar

In general, the R.C.M. operations went accurately to plan. Signals intelligence of enemy radar was collected by ground watcher stations under the Command Signals Intelligence Officer and the Beaver station and Investigational Squadron under the control of the Chief Radar Officer. Information from these sources was co-ordinated and issued in the form of a monthly report, but it was deemed necessary for the day-to-day intelligence required during progress of attacks on radar stations to set up a small group in Corsica at Headquarters No. 63 Fighter Wing to control all the investigational work and analyse the results. This group was in touch with M.A.T.A.F. who were mainly responsible for the attacks on enemy radar. The high accuracy D.F. Ping-Pong equipment ordered from the United Kingdom to implement intelligence information did not become operational until D –1 day.

Because of cover plan requirements, attacks could not start before D –5 and, in fact, occasioned by bad weather conditions on D –5, they did not start until D –4. Attacks were carried out by fighter and fighter-bomber aircraft under M.A.T.A.F., and escort fighters of the United States XV Air Force. Of a total of twenty-two sites attacked nine were probably unserviceable on D-day. This does not appear to be a very satisfactory result but it must be remembered that the sites to be attacked were spread out from the Spanish border to Italy and further that, in the actual assault area between Toulon and Nice, it was claimed only one *Wurzburg* and one *Seetakt* remained undamaged on D-day. Results were nevertheless disappointing because of several factors, the chief of which were lack of oblique photographic cover, lack of training in radar recognition on the part of the pilots and, of course, the shortness

[1] A.H.B./II J1/90/34, Appendix " J." Report of Fitting and Operation of Airborne " Mandrel."

of the period in which attacks were permitted. It was hoped that prisoner-of-war interrogation would yield information on the efficiency of the direct action programme, but because of the huge numbers of prisoners captured it was found impossible to conduct interrogations and practically no information from this source was obtained.

Efficacy of Moonshine Diversions[1]

One of the allotted ships did not participate because of engine trouble. On both days (14 and 16 August) a large number of signals, characteristic of enemy airborne radar, were received and enemy aircraft were observed flying close to the ships, coincident with strong signals being received on the Moonshine receivers.

In the ten H.F. sets only one fault developed. This was in the transmitter of H.F. No. 9 which failed at 2200 hours on the first night. It was still unserviceable on the second night, but on test afterwards it worked again satisfactorily without the fault being found.

The M.F. situation was not satisfactory. Several faults developed, the first set going unserviceable towards the close of the first operation at 0310 hours. Only one L.F. set took part in the first operation and two in the second. The only failure was one on the first night, which was soon rectified. In addition, two of the petrol-electric sets gave some trouble, but otherwise the equipment in general functioned well.

Mandrel Operation[2]

Except that one aircraft returned early with petrol trouble (quickly replaced by a spare aircraft), the operation went on without untoward incident. On 31 July one of the No. 34 Squadron aircraft which had been allotted to this operation, was ferried to No. 4 Base Signals Unit at Maison Blanche for prototyping of the special Mandrel equipment. This was satisfactorily completed by 4 August, whereupon the aircraft was ferried back to its base. By 12 August, nine more aircraft had been ferried to the Base Signals Unit. All but one were so fitted and a party sent from No. 4 B.S.U. to the operational base, Celore, completed the final installation. The final tuning and checking was done at Celore. The aircraft were stacked on patrol lines in such a way as to rule out the possibility of collision. Three aircrews reported some evidence of transmitter failure during flight but, on check after landing, only one transmitter proved to be faulty, due to an unserviceable valve.

Window (Convoy Simulation) Operations[3]

In the event a shortage of Window made it necessary to curtail the dropping to 0400 hours, when the withdrawal was beginning. It was felt, however, that it would have been impossible to continue the deception beyond that point, as the convoy then did too large a change of course to make it possible to maintain a suitable pattern. Various alternative drop patterns were considered carefully for use during this critical phase, but no adequate solution was found. It was convenient to cover the seven-hour period in two details, the change-over occurring at 0100 hours on the turn. There was a seven-minute overlap of

[1] A.H.B./II J1/90/34, Appendix " F." Technical Report on " Moonshine " Equipment, paras. 4–7.

[2] *Ibid.*, Appendix " J." Airborne Mandrel in Operation " Dragoon."

[3] *Ibid.*, Appendix " G," paras. 28–43.

Window-laying on the relief and the second detail orientated its orbits on the new bearing. This was possible because the formation of shipping was rectangular (almost square) and the turn was about 90°. Navigation lights were used during the take-over period.

Each detail consisted of four aircraft, three Window-laying and one reserve. The reserve was briefed to take any of the three rôles and patrolled a few hundred feet above the centre position. A W/T code was arranged to call for the relief, and any aircraft requiring to be relieved was asked to attempt to complete another full orbit before leaving patrol. The second detail was instructed not to approach nearer than ten miles to the enemy coast, as height-measuring radar could expose the deception at very short range. Since the vessels were to proceed close in-shore, it was necessary for the aircraft at this stage to range themselves on the shore and maintain their stationary orbits in this way. They were each provided with large-scale maps of the coastline and allotted marker points for homing. This method proved to be very satisfactory.

The fact that first rendezvous was made with the shipping before dark proved to be of considerable assistance. There were, in fact, no clearly defined marker vessels. Station-keeping had to be carried out on the rectangular shipping formation as a whole. The presence of a destroyer in the group was a great help, and each detail was briefed concerning the position in which it must expect to find the destroyer relative to the rest of the "convoy." It will be seen from the above that the accuracy achieved fell very far short of that achieved in "Overlord" and probably fell somewhat short of the standard which had been hoped for in this operation. It is nevertheless felt that it was within the tolerances, and that any deficiencies would probably be masked by the jamming screen from the surface vessels.

Window/Mandrel (Airborne Diversion) Operation

Five aircraft took off from Ajaccio at five-minute intervals and made an accurate landfall in the centre of the Baie de la Ciotat. Average landfall dispersion did not exceed five miles, which, after an over-water flight of 250 miles on dead reckoning, is considered to be excellent. Weather was good except for low stratus cloud off the coast. Actual wind was 90° off that predicted but was, however, fortunately very light. No opposition was encountered except for a single incident of red tracer fire from Ciotat observed by the last aircraft. The bombing of Toulon and Marseilles were observed by all aircraft, with fires seen at the latter and heavy *flak* bursts at Toulon.

Aircraft were over the drop zone from 0349 to 0419 hours. Dummies and fire simulators were dropped from 600 to 700 feet above land at a speed of 110–120 miles per hour. The actual drop of dummies took an average of 30 seconds and the many flashes, coloured lights and small explosions observed by all aircraft after the first drop, indicated that simulators and dummies functioned properly.

Window was laid during the entire 100-minute period between the turning point and the drop zones without incident. The six-man re-supply crew proved adequate for this without undue fatigue, even though packages were being opened and dropped every six seconds during the entire period. All aircraft returned safely to base. Crews afterwards testified to the usefulness of the aid to navigation given by A.M.E.S. No. 8002 both on the outward and the return flight.

As nearly perfect as was the airborne diversion operation itself, the real criterion was, of course, the protection it gave to the main airborne operation,[1] which went as follows. The first wave dropped exactly as planned at 0430 hours with the exception of some 450 troops who landed outside the dropping zone near Le Luc. The second wave, due to drop at 0430 hours, was cancelled because of the weather, but they went in as late as 1200 hours and were well concentrated in the dropping zone. By last light they were well established and working down to join the 36th Division. The main glider force went in at 1810 hours wholly successfully. This highly satisfactory result, coupled with the fact that only one C.47 aircraft and three gliders became casualties before reaching the dropping zone, testifies to the efficacy of the diversionary airborne operation, as well as to that of the fighter escort.

Although accurate assessment of the effectiveness of the R.C.M. programme is not possible, it appears from interception of enemy broadcasts that the diversionary operation on the left flank deceived the enemy and forced him to withhold from the main assault area a large proportion of mobile reserves to meet the imaginary threat aimed at the Toulon/Marseilles area. It can also be said that the degree of tactical surprise achieved was due in some measure to the radio counter-measures employed by both ships and aircraft. The airborne diversion also appeared to have been successful in that Berlin broadcast that "thousands of enemy paratroops were dropped in an area north-west of Toulon," a statement which was corrected some five hours later, when it was stated that the paratroops had been found to be only dummies. The following excerpt from Allied Forces Headquarters Weekly Intelligence Summary is of interest in this connexion :—

> The progress of operation in Southern France has greatly exceeded expectations . . . though the Germans were not taken by surprise by the actual fact of an Allied landing, their Intelligence was much at fault, both as to the exact timing and as to the target area . . . reliable (enemy) reports, supported by troop dispositions at the time of the invasion, indicate that Genoa was regarded as the most probable objective with the Sete/Narbonne coast as a favourite alternative . . . the full force of the Allied assault was accordingly met by a single low-established division supported by the coast defence and static forces in the assault area . . . this despite the presence of mobile troops stationed between Marseilles and Toulon which were apparently ordered to remain in their assigned sectors.[2]

[1] Combined Operations Headquarters Bulletin Y/42, Operation "Dragoon," para. 9.
[2] A.H B./J1/90/34. Signals Report on Operation "Dragoon."

KNICKEBEIN

Knickebein was the name given by the Germans to a radio navigation aid employing a narrow beam which could be directed to any desired position with an accuracy of 0·1 degree and which could enable the pilot to reach a target area under conditions of bad visibility.

Aerial System

The aerial system used in the early installations consisted of two arrays containing an angle of 165 degrees, each comprising two stacks of eight vertical centre-fed full wave-length aerials with reflectors. These operated on fixed frequencies of 30 and 31·5 megacycles. They were carried on a framework which was capable of rotation about a central vertical axis, the weight being taken on bogies running on two concentric sets of rails, one at the perimeter and a smaller set near the centre. The framework supporting the arrays was 315 feet in length and 100 feet high. These arrays radiated interlocked dots and dashes on an audio frequency of 1,150 c.p.s. as complementary signals, so that along the equi-signal line a continuous note was heard, while at points to one side of the equi-signal dots were heard and on the other side dashes would predominate. Discrimination in determining the equi-signal gave the effect of a " beam ". The rate of keying was 60 per minute and the ratio between the length of dot and dash was 1/7.

In the later installations the size of the arrays was reduced to two arrays of two stacks of four full wave-length aerials with reflectors ; this enabled a lighter carriage to be used with a single circular track 100 feet in diameter. The overall width of the aerial system was 139 feet. These installations were fitted with large diameter tubular aerials instead of wire, thus enabling them to be used over the band of frequencies 30 to 33·3 megacycles without loss of efficiency. The same angular displacement between the two arrays was retained.

Beam Width

The effect of reducing the number of elements in the arrays resulted in a widening of the " beam ". From a document and diagram captured in July 1940 the width of the equi-signal in the first installation was given as 0·3 degree, and this width was confirmed by air tests. Tests carried out on the later installations showed that the beam width was approximately doubled. Air tests confirmed the positions of the beams, and showed that they were sensibly the same for the smaller installations, although changes of frequency caused a small displacement.

Knickebein Ranges

The following table from a captured document shows the normal ranges which the Germans expected to obtain using the standard aircraft blind-landing receiver, *Fu.Bl.*1 (*E.Bl.*1) :—

Height of Aircraft.	*Range.*
100 metres	100 Km.
500 metres	160 Km.
1,000 metres	210 Km.
2,000 metres	230 Km.
3,000 metres	330 Km.
4,000 metres	375 Km.
5,000 metres	410 Km.
6,000 metres	430 Km.

Positions of *Knickebein* Installations

Thirteen *Knickebein* installations were identified and photographed. The positions of these and the dates on which they were first photographed and were heard to transmit are given in the attached table. Three of these, Stollberg, Kleve and Lorrach Holstein were large installations and were all on German territory.

They were evidently erected at the beginning of 1940 or earlier for use against targets in France and England when the collapse of France was not expected. The installation at Lorrach Hollstein was not discovered until May 1944.

Knickebein Beam Predictor

The earliest form of predictor consisted of copies of the German diagram made on transparent material so that they could be placed on small maps and adjusted until the characteristic dot or dash signals obtained by the listening stations fitted the pattern ; the direction of the main equi-signal line then showed the setting of the beam.

As the number of *Knickebein* and listening stations increased this method became unwieldy and a more compact form of predictor was introduced. It consisted of a baseboard carrying a number of cards, one for each *Knickebein*, and a pivot card with the beam pattern drawn on it. The cards had the names of the listening stations arranged in a vertical column with lines drawn to a degree scale at the bearing of the stations from the particular *Knickebein*. Having determined which *Knickebein* was active by D/F and the frequency on which it was operating, the characteristic received (*i.e.* dot, dot edge, dash, dash edge or equi-signal) was inserted against the station, recording it with chinagraph pencil. By rotating the beam pattern, the setting of the main beam could then be read off from the degree scale. The average accuracy of the predictor was of the order of one or two degrees, but it was often possible to obtain a setting to an accuracy of 0·5 degree.

A third model, using the same principle but with the rotating pattern replaced by a sliding pattern in the manner of a slide-rule, was brought into use in the last year of the war. By laying out the beam settings on a map for two or more *Knickebeine* obtained in this way, it was possible to obtain an intersection and so determine the target or turning point for an attack.

KNICKEBEIN

		Place.	Frequency. (megacycles)	Position.	First Photograph.	First Heard.
LUFTFLOTTE 2	*Kn.* 1.	Klepp, Stavanger	30 or 31·5	58° 46′ 10″ N., 05° 37′ 30″ E. ..	29. 9.40	—
	**Kn.* 2.	Stollberg	30	54° 38′ 42″ N., 08° 56′ 42″ E. ..	1. 9.41	—
	Kn. 3.	Julianadorp..	33·3	52° 54′ 40″ N., 04° 43′ 00″ E. ..	10. 3.41	November 1940
	**Kn.* 4.	Kleve	31·5	51° 47′ 24″ N. 06° 06′ 12″ E. ..	15.10.40	June 1940
	Kn. 5.	Bergen-op-Zoom	31·5 or 33·3	51° 27′ 03″ N., 04° 18′ 02″ E. ..	24. 9.41	October 1941
	Kn. 6.	Mt. Violette	30 or 31·5	50° 37′ 05″ N., 01° 40′ 58″ E. ..	21. 6.41	May 1941
LUFTFLOTTE 3	*Kn.* 7.	Greny	30 or 31·5	49° 57′ 42″ N., 01° 17′ 30″ E. ..	1.10.40	August 1940
	Kn. 8.	Mt. Pincon	30 or 31·5	48° 58′ 22″ N., 00° 37′ 13″ W. ..	17. 6.41	May 1941
	Kn. 9.	Beaumont-Hague	30 or 31·5	49° 40′ 29″ N., 01° 51′ 16″ W. ..	18. 9.40	August 1940
	Kn. 10.	Sortosville-en-Beaumont .. .	30 or 31·5	49° 25′ 04″ N., 01° 42′ 32″ W. ..	3. 7.41	May 1941
	Kn. 11.	Morlaix	30 or 31·5	48° 40′ 00″ N., 03° 43′ 50″ W. ..	4. 1.41	October 1940
	**Kn.* 12.	Lorrach Holstein	—	47° 38′ 01″ N., 07° 45′ 54″ E. ..	13. 5.44	—
	Kn. —.	Noto, Sicily	—	36° 55′ 44″ N., 14° 58′ 45″ E. ..	5. 8.42	—

Note 1.—*Knickebein* marked * were the large type.

Note 2.—Numbers were those used from 1941 onwards. Frequencies were those used before the multiple frequency scheme in 1941 was introduced.

WIRELESS INVESTIGATION AIRCRAFT UNITS

Investigation flights for the identification of enemy radio aids and the testing of the counter-measures taken against them have played a very important part throughout the operations of No. 80 Wing. From June 1940, when the recently disbanded Blind Approach Training and Development Unit (B.A.T.D.U.) reformed at Boscombe Down, until the cessation of hostilities in May 1945, the Airborne Unit underwent many changes in title and establishment but its primary function, support to the Wing both in a defensive and offensive role, remained unchanged. Brief details of the history of the Unit, together with a short account of the various types of work undertaken, are given below.

Blind Approach Training and Development Unit

The Blind Approach Training and Development Unit reformed at R.A.F. Boscombe Down on 18 June 1940 for the purpose of investigating the *Knickebein* beams known to be operating from Western Europe as a radio navigational aid.

Wireless Intelligence and Development Unit

After the formation of the special R.C.M. Section within the Directorate of Signals the B.A.T.D.U., which was operationally controlled first by Air Ministry and later by the newly formed No. 80 Wing, was renamed the Wireless Intelligence and Development Unit on 14 October 1940, and in December 1940 became No. 109 Squadron.

No. 109 Squadron

In February 1941, coincident with the offensive attacks against the beam transmitters in the Cherbourg Peninsula, a "striking flight" was added to the establishment, and in August of that year, in preparation for the greatly increased scale of activity expected during the coming winter, the Squadron was reorganised with an increased establishment to a total of three flights, employed respectively on the development of Oboe technique, investigations for T.R.E. and the "Y" Service, and R.C.M. investigation flights.

No. 1473 Flight

The Squadron operated until July 1942 when the R.C.M. investigation flight became known as No. 1473 Flight, the remainder of the Squadron being transferred to other duties unconnected with No. 80 Wing. In June 1943 changes in aircraft and personnel establishments were made to enable the flight to undertake a number of commitments which, due to aircraft limitations of height, speed and range, had previously been deferred.

No. 192 Squadron

Finally, with the formation in December 1943 of Headquarters 100 Group, and the growing need for investigation in connection with offensive R.C.M., No. 1473 Flight became part of No. 192 Squadron whose activities both in an offensive and defensive role continued until the end of the European campaign.

The work undertaken by the Unit at various stages of its history is described below, mentioning various enemy aids and the part played by the Unit in the development of appropriate counter-measures. Brief details are also given of certain work undertaken by the Unit for formations other than Headquarters No. 80 Wing.

Knickebein

The first task allotted to the re-formed B.A.T.D.U. was the identification and plotting of the *Knickebein* beams operating from Western Europe in the 30 megacycles per second band. For this task the aircraft were fitted with S.27 receivers, the first beam being identified and plotted on 21 June 1940. Subsequently, numerous test flights were carried out to determine the efficacy of the various early forms of counter-measures devised, both British and captured German airborne equipment being employed.

During the early development of the *Knickebein* system, routine flights were made during enemy operations against this country in order that the beam settings might be obtained and passed to the Operations Room, Headquarters No. 80 Wing. At a later date it became possible to determine these settings from observations from the ground watcher organisation, but flights to test the efficiency of Aspirin action and to assist in the identification and determination of the radiation pattern of the new *Knickebein* beams as these become operational, were continued at intervals until 1944, when, during the final phase of long-range bomber activity against this country numerous flights were undertaken by No. 192 Squadron to test the jamming of *Kn.* 8 and 10, in use during the large-scale attacks on London. During these later flights pilots were briefed to fly out towards the source of the signal until it could be identified as free from jamming and then to return down the beam along the equi-signal until jamming action made this impossible. Reports on these flights showed varying results, but in the main, a general confusion of signals for many miles beyond the coast was observed.

Ottokar

Beam signals in the 30 megacycles per second frequency band alternating with German R/T were first intercepted in January 1944. The transmissions appeared to originate from the Den Helder area and it was suspected that *Kn.* 3 was being used in a defensive role as an aid to German night fighters. Numerous flights subsequently made by No. 192 Squadron confirmed this fact.

Ruffians

With the anticipation in September 1940 that the enemy intended to make use of a second beam system in the 70 megacycles per second band, an experimental jammer, consisting of a modified gun-laying radar transmitter was set up at Harpenden and air tests commenced immediately to determine the range at which this counter-measure might prove effective. By October 1940 the W.I.D.U. had identified a new system of beams from Calais, Cherbourg and Le Havre areas, thus confirming information already received from the " Y " Service and other sources. Routine flights were made nightly to determine the frequency and position of approach beams, the information obtained being relayed to the Operations Room, Headquarters No. 80 Wing, in order that counter-measure action might be taken. These flights, undertaken during periods of enemy activity and often under hazardous flying conditions, provided vital information often unobtainable from other sources.

Further flights were undertaken to assist the Scientific Analysis Section then investigating the complex Ruffian System which consisted of an elaborate beam pattern. The pinpointing at night to a degree of accuracy required for this work was a most exacting navigational task. Flights were also made for T.R.E. with the dual purpose of (i) estimating Ruffian field strength and (ii) testing the efficiency of Bromide (counter-measure) action.

Attacks on Cherbourg Ruffians

In November 1940 flights were made to ascertain whether it was possible to determine with a degree of accuracy sufficient for bombing purposes the " cut-out " when flying over the beam transmitters in the Cherbourg Peninsula. In view of the successful results of these tests a decision was made to take offensive action against these transmitters. The first attempt was made in November 1940 during one of the heavy raids on Coventry ; but the smallness of the target made this an exceedingly difficult task, and although direct hits could not be established, a measure of success was obtained in that during this and many subsequent attacks the Ruffian transmitters ceased radiation for a considerable period. The attacks were continued until the summer of 1941, the establishment of No. 109 Squadron being increased in February of that year to include a striking flight for offensive purposes. The main objectives were those Ruffians situated in the Cherbourg Peninsula but attacks were also made during May 1941 against the Ruffians at Morlaix.

Extensive investigations were carried out to devise more accurate methods of determining the target and experiments were made in the use of (i) luminous marker bombs, and (ii) a narrow beam system similar to the German *Knickebein*. Attacks against the Ruffian transmitters were discontinued before either of these systems was developed sufficiently to enable it to be used operationally but narrow beams were employed extensively at a later period and played an important part in the "Trinity" Operations.

Benito

Although the properties of this enemy beam system and the method of using it were not fully understood until April 1941, signals in the 40 megacycles per second frequency band had been intercepted by aircraft of B.A.T.D.U. during a routine investigational flight in the autumn of the previous year. By December 1940 the system had been established as consisting of a form of beam plus some method of ground control; flights by No. 109 Squadron gave two pinpoints on a beam in Norfolk and indicated the Poix area as a possible source of the transmission. Observations during this and subsequent flights suggested also that some form of visual presentation was used. In May 1941 flight tests were made to determine whether it was possible to interpret the signals aurally or by cathode ray tube when pinpointing the setting of the beam; attempts to utilise a captured German receiver ("Y" *Gerät*) were made but proved unsuccessful. Routine flights to investigate new Benito beam and range transmissions as these occurred were made by aircraft of No. 109 Squadron and No. 1473 Flight during the period 1941–1943. Tests were also made to estimate the efficacy of counter-measures Domino (Meaconing of range tone) and Benjamin (jamming of Benito beam).

Meacons

The Meacon scheme was ready for operation in July 1940 and air tests were made immediately by the B.A.T.D.U. to test the efficiency of the first Meacon station at Flimwell (Tunbridge Wells). By September of that year numerous flights had been carried out and results obtained, showing errors varying from 9 degrees to 59 degrees, had established the system as highly satisfactory. Air tests continued during the building up of the Meacon organisation and comparative field strengths of German beacons and R.A.F. Meacon stations were obtained.

Fidget

With the introduction in April 1944 of Fidget as a counter-measure against the passing of instructions to enemy night fighters by Big Screw high-power beacons, flight tests made by aircraft of No. 192 Squadron over enemy territory provided valuable evidence of the success of the scheme.

Elektra/Sonne

Evidence of the *Elektra* system consisting of a fan of equi-signal beams separated by alternate dot and dash sectors was first obtained in August 1940 and flights were inaugurated immediately to investigate this new navigational aid. These tests were invaluable in establishing the beam pattern of *Elektra* 1 (481 kilocycles). A captured map obtained several weeks later confirmed in every case of the accuracy of the results obtained. Meaconing action was taken immediately against the *Elektra* system, air tests being carried out to determine at what range this counter-measure was effective; periodical flights were also made to confirm the characteristics of the new *Elektra* as obtained by ground stations and to assess the effects of Meaconing. With the introduction in February 1943 of *Sonne*, a development of the *Elektra* principle enabling this aid to be used by aircraft or submarines to obtain bearings, flights were made during March of that year to confirm ground observations made on *Sonne*. Results indicated that *Sonne* provided a most useful and easily employed navigational aid of which use might advantageously be made by Coastal Command aircraft. A further series of air tests was carried out to determine the area over which Meaconing would be effective.

Activity in Connection with Allied Transmissions

Miscellaneous activities by the Airborne Unit in connection with allied transmissions in the medium frequency band included the following:—

(*a*) Flights to investigate enemy interference with the Splasher system.

(*b*) Examination of the effective range of Allied radio range installations.

(c) Investigations of a prisoner-of-war statement suggesting that good bearings were obtainable on the supposedly masked Droitwich B.B.C. transmission.

(d) Flights to investigate the possible use of certain unsynchronised B.B.C. transmissions as a navigational aid to enemy aircraft launching flying bombs.

R/T Jamming

Flights to investigate the possibility of jamming enemy R/T in the 38–42 megacycles per second frequency band were instigated in the autumn of 1942. In April 1943 tests were made of transmitters proposed for Cigar barrage jamming in this band, and to ascertain in particular the interference caused to S.B.A. beacons on adjacent frequencies. Flights were also made during the summer of 1943 to investigate the effectiveness of Cigarette, a development of Cigar, for the purpose of jamming control instructions to enemy fighter bombers over this country.

Operation "Trinity"

This operation, which took place in December 1941 consisted of the offensive use of a beam-ranging device, somewhat similar to the Benito system, for the precise blind-bombing of the German battleships *Scharnhorst* and *Gneisenau* and the cruiser *Prinz Eugen* then lying in Brest dockyard. Although under the operational control of H.Q. No. 3 Group the formation of the requisite organisation and the control of the technical side of the operation was vested in H.Q. No. 80 Wing. A narrow beam apparatus whose development had just been completed by Messrs. Standard Telephone & Cables, Ltd., in co-operation with H.Q. No. 80 Wing was utilised to give "line", and a ranging device, known as the Broody Hen was supplied by T.R.E.

No. 109 Squadron had been associated with the development of both these devices having carried out all the flight tests. Special operators from this squadron were accordingly chosen to operate the S.27 type receivers fitted for the reception of the beam signals, and the Broody Hen equipment used for ranging. The squadron also supplied pilots highly skilled in beam flying to act as second pilots in the aircraft.

Jamming of Tank Communications

During the autumn of 1941 preparations were made to jam the enemy's tank-to-tank V.H.F. communications (28–34 megacycles per second band) during the expected offensive in Libya. Barrage jamming from aircraft was considered to be the only practicable method and No. 109 Squadron was given the task of designing manufacturing and fitting into six "tropical type" Wellingtons the special aerial equipment to be used in conjunction with standard aircraft sets modified for this purpose. This work was carried out in a remarkably short period and after flight trials the aircraft proceeded to Egypt, one of the crews being composed of No. 109 Squadron personnel and the whole party being under the command of an officer from H.Q., No. 80 Wing. These aircraft were extensively used during the opening phases of the Libyan campaign and an appreciable measure of success was achieved.

Airborne W/T Station

During December 1942, at the request of H.Q. Fighter Command, extensive tests were carried out by No. 1473 Flight on a Whitley aircraft equipped as an airborne signal station and designed for use in combined operations overseas to act as a Flying Repeater Station to relay by W/T, messages to distant stations, as an emergency ground station for use in forward areas and as a semi-permanent Group Signals Station.

Miscellaneous

Miscellaneous activities undertaken by the Unit included the following :—

(a) Tests of the effects of Barrage Balloon cables on V.H.F. beams.

(b) An investigation to determine whether the terminal equipment at submarine cable stations radiated waves capable of being used as position indicators.

(c) Window trials.

(*d*) Tests undertaken for A.D.G.B. to investigate the ultimate range and jamming susceptibility of their new high powered R/T ground transmitter unit.

(*e*) Investigation of Oboe jamming for the Pathfinder Force.

(*f*) Observation flights in connection with the use of Starfish (decoy fires).

APPENDIX No. 3

GERMAN MEDIUM FREQUENCY NAVIGATIONAL AIDS AND COUNTER-MEASURES APPLIED

Beacons

At the outbreak of the European war, the enemy possessed some 24 medium frequency radio beacons throughout Greater Germany. Those beacons were used for navigation by the German Air Force, and by March 1940 the number in use had increased to 46, the new beacons being mainly located along the German western frontier. In addition to the beacons, several German broadcast stations had recognition letters superimposed on their programmes, and were used as beacons. Advances by the enemy through Denmark, Norway, Holland, Belginm and France resulted in the movement of most of the Western German beacons to new locations throughout the occnpied countries, the use of several captured broadcast stations, and the erection of several higher powered beacons along the European coast from Norway to Bordeaux.

The development of beacons had been followed by the " Y " Service from the early days of the war. It had been established that all beacons operated on certain frequencies in the band 176–600 kilocycles per second. Transmission was in the form of a call sign followed by a 20-second continuous note for ease of direction finding. All call signs were of five characters (figures and letters). Addition of the figures in the call signs, known as " totals," was found to be the key to a rotation of " totals " and frequencies, each beacon using a different " total " and frequency on each day of the month. Changes of " total " and frequency were made at midnight German time. Such rotations became known as " Systems " of which immediate information was required, particularly when changed, for the successful application of Meaconing. The supply of this rapid intelligence played a very important part in the operational control of counter-measures throughout the war. The limited resources of the " Y " Service were often unable to supply immediate information on new call signs and frequencies when a new system was introduced. If the enemy had used a " hatted " method of distributing his call signs and frequencies the efficiency of radio counter-measures would probably have suffered considerably.

The navigational use of beacons and broadcast stations now included homing, fixing of turning points and offensive bombing operations against the United Kingdom. It was therefore decided by Air Ministry to take offensive radio counter-measures, and deny the use of these stations to enemy aircraft, whilst nearing or flying over this country. The Experimental Department of the Post Office had been working for some time on a scheme by which any " 5th column " radio beacon, which might be operated in the larger towns of this country, could be re-radiated by another transmitter away from the town, thus preventing enemy aircraft homing to the beacon. This system was described by the Post Office as Meaconing.

It was decided to erect a number of stations along the south and east coasts of this country. Each station was to be equipped with three channels, each of which would be able to receive, amplify and re-radiate an enemy beacon. On 14 August 1940, three Meacon sites were completed and ready to take counter-measures. A Control Centre had been set up and the immediate interchange of information between the " Y " Service and the Control was possible. The system of changing call signs and frequencies had been broken down and it was also possible to recast ensuing sets of call signs and freqnencies. Information as to the power of each beacon was compiled from measurements taken at the Air Ministry Research Station, Great Baddow. Headquarters, Bomber Command were taking advantage of the information on beacons, their aircraft often using them for navigation. Arrangements were made that all beacons in the occupied countries should be subject to Meaconing with the exception of a limited number required by Bomber Command during any particular operation.

The allocation of Meacons against beacons was made from a knowledge of the beacon activity, of the enemy intentions in raiding this country or the actual raid in progress, the power of Meacon transmitters, and the area over which each Meacon transmitter would affect the bearings of beacons of different power. Care had to be taken that the Meacon was not "in transit" with the beacon and raiding force. Certain technical difficulties had to be taken into consideration. A Meacon site with three channels could not operate any two channels with a frequency spacing of less than 20 kilocycles per second; one channel could not radiate near the harmonic of another; certain differences in frequency (I.F. of Meacon receiver) caused interaction; also one type of receiver would not cover the band 400-500 kilocycles per second.

Elektra

During August 1940 the enemy introduced a new type of navigational aid in the form of an *Electra* Beam. The first of these was located at St. Peter, N.W. Germany, and operated on 481 kilocycles per second. This type of beam was Meaconed in the same way as the G.A.F. beacons but a Meacon site receiving dashes was most suitable.

On 1 September 1940 the disposition of the enemy M/F navigational aids was as follows:—

Norway	2 beacons and 4 broadcast stations.
Denmark to N. France (*Luftlotte 2*)	15 beacons, 3 broadcast stations and 1 *Elektra* beam.
France (*Luftlotte 3*)	21 beacons and 4 broadcast stations. One high power beacon at Cherbourg was reported by "Y" Service to have a power of 20 kW.

This formidable array of navigational aids had to be countered by an increasing but still insufficient number of Meacon channels. Careful allocation of these channels was made against the beacons most likely to be used during any particular raid. Speed of intelligence in advising the activity or inactivity of the beacons was very important.

On 1 December 1940 the first complete change of system of call signs and frequencies of the beacons occurred. Such changes did not affect the recognition letters sent by broadcast stations or the frequency of the medium frequency beams. The change introduced a new set of frequencies in the band 176–600 kilocycles per second together with short word call signs mainly of four letters. Call signs and frequencies changed between the beacons once per day, during the hours of daylight, and at different times each day. The reason for this change seems to have been firstly to avoid changes of call sign and frequency at night when the German Air Force were operating, and secondly on security grounds. Forecasting of call signs and frequencies was now impossible and proved a serious handicap to counter-measures since effective Meaconing depended upon a knowledge of the call sign, frequency and location of the beacon. A period of delay was inevitable while the "Y" Service intercepted and fixed the beacons as they became active.

By the middle of December 1940 it became apparent that the new system comprised 4 rotas of call signs and frequencies, each rota being employed for one day. Once the daily change of rotas had taken place and the new rota established all that was necessary was to have the activity of the beacons followed. Pre-operational planning and allocation of Meacons was again possible with a marked increase in efficiency. The 4 rotas continued to be used until 31 March 1941.

During this period the number of high-power coastal beacons which operated outside the rotas had increased from one to five. Also in December 1941 a new *Elektra* near Bayeux (France) operated on 296 kilocycles per second, and on 8 March another new *Elektra* at Stavanger operated on 319 kilocycles per second. Broadcast stations in Germany had been formed into synchronised groups but several in occupied countries still operated as beacons during periods of activity. Indications of activity were sometimes obtained by hearing the broadcast stations commence keying recognition letters.

To counter each of the higher-power beacons, *Elektra* and broadcast stations it was necessary to employ more than one Meacon channel against the enemy beacon to be masked. This multiple Meaconing introduced several technical difficulties such as " sing round " between sites. Charts were therefore prepared by the G.P.O. showing which Meacon sites, by reason of their rejection angles, were suitable to work together.

The term " Rejection Angle " as applied to a Meacon installation denotes the bearing of the line joining the receiver to the transmitter site and, for practical purposes, includes the 45-degree sector on either side of the line. Successful Meaconing cannot be carried out from within these sectors owing to the impossibility of rejecting the re-transmission from the local transmitter and the resultant " sing round " effect. In the case of multiple Meaconing unless the sites are chosen with care as regards their relative rejection angles, " sing round " can be caused by one Meacon transmitter driving another member of the group in operation instead of the enemy signal. Use of the G.P.O. charts referred to above, combined with practical experience, enabled this new application of Meaconing to be used successfully and, in general, the use of two sites was found to be sufficient. In the case of the high-power beacon at Cherbourg which was at first much used by the enemy, the area of effective Meaconing had to extend over the whole of the south of England and as many as five of the highest-powered Meacons available were used.

Meaconing strength and tactics seemed to be worrying the enemy. Many references to the failure of D/F equipment were being intercepted by the " Y " Service. Enemy aircrews were frequently lost and crashed or landed their aircraft in this country with no idea as to where they were. Several instances occurred of aircraft flying around a Meacon looking for the airfield which they knew was near the beacon being covered. Some discovered their mistake, others were either shot down or crash landed.

On 1 May 1941, a Spanish broadcast station at La Coruna radiated a carrier after midnight when normal programmes ceased. This transmission was continued until the morning when programmes were again radiated. The station was obviously being used as a beacon and captured maps showed bearings marked off up the west coast and western approaches of England. Meaconing counter-measures were taken.

Changes of Enemy Beacon " System "

On 1 April 1941 another complete change in call sign and frequency system took place. Five new rotas were introduced, rotas being changed daily during the hours of daylight. 1 September 1941 saw the introduction of yet another new set of 6 rotas. Up to this time the battle between medium frequency navigational aids and counter-measures had mainly been on the basis of the number of aids and the power used. The enemy must have watched the Meaconing and realised that after a call sign and frequency change some time elapsed before all Meaconing was again fully applied. On 10 October 1941 he took advantage of his discoveries and introduced a complicated system of 20 rotas with 6 changes of rota each 24 hours, during the hours of darkness. Two-letter call signs were now employed and a few changes made in the set of frequencies in the 176–600 kilocycles per second band. The high-power fixed-frequency beacons were now reduced to four. Reduction of power of several inland beacons near airfields was also noticed. Owing to range, Meaconing was difficult on these lower-powered beacons but was continued in case attempts were made to use them over this country.

The " Y " Service increased the number of direction finding stations engaged on beacon work but it was difficult to reduce the period of delay, before re-allocation of Meacon channels had been made, to below 15 minutes. Various forms of autonomous working were considered but owing to the importance of the Meacon being correctly placed geographically, in relation to the beacon, indiscriminate Meaconing was not attempted.

Early in November 1941 the system in use was broken down. A different two-letter call sign was used for each frequency in each of the 20 rotas. A chart was prepared listing the frequencies down one side and all the call signs for each frequency recorded in 20 columns, each column being a rota. The sequence of rotas was "hatted" but with an accurately frequency calibrated receiver it was possible, after each change of rota, to intercept two or three beacons, measure their frequency, and find the rota they fitted.

On 14 November 1941 an instruction was issued to all Meacon sites containing the chart of rotas and describing how the rota in use could be determined. Further charts were issued which allocated Meaconing of the various beacons to the most suitable Meacon sites under each rota. It had always been considered advisable not to Meacon continuously any beacon from one site; knowledge of the position of the Meacon might in certain circumstances enable it to be used as a beacon. The allocation charts described above varied the Meacon site for the beacons operating within the system, but not the Meaconing of fixed frequency beacons, *Elektra* beams or broadcast stations. Two charts were, therefore, prepared and each one was brought into use at irregular intervals.

The new method of Meacon control relieved the control centre of much work in passing instructions. More attention than had been possible in the past was paid to finer points. The efficiency of the organisation improved to the extent that all beacons were being re-Meaconed within an average of three minutes from a rota change.

During November, the *Elektra* near Bayeux was last heard and on 11 November 1941 a new *Elektra* on 291 kilocycles per second was plotted in the Brest area. Another change was the high-power fixed frequency beacon on the Island of Schenvren; this beacon now worked alternatively with a new high-power beacon just south of Dunkirk. The change was probably made because Bomber Command had decided after some airborne tests that enemy beacons could safely be used over the Continent when defensive Meaconing was being carried out in the United Kingdom. Enemy beacons had proved to be of considerable value to R.A.F. aircraft.

The efficiency of the new Meacon Control Scheme seems to have been proved by another change in the beacon system on 20 December 1941. This time 20 rotas of wedded call-signs and frequencies were employed, 15 changes of rotas taking place daily, 12 of the changes being during the hours of darkness, at 45 to 70 minute intervals. The constant use of one call sign for each frequency prevented rota identification without D/F facilities. New allocation charts were issued to all Meacon sites and each rota numbered. As soon as the "Y" Service had discovered the rota number in use, this was passed by Meacon Control to each Meacon site. This system saved full instructions having to be given over the telephone and full Meaconing was effected within 5 to 10 minutes of a rota change.

The beacon system again changed on 1 April 1942, selected frequencies in the band 176–600 kilocycles per second and changing two-letter call signs being employed; 15 changes of call sign and frequency took place daily, mostly during the hours of darkness. The "Y" Service allocated every D/F Station they could possibly spare to the fixing of beacons. This was later helped by a partial breakdown of a corrupt sliding scale of call signs and frequencies. Fifteen to 25 minutes were now taken before all beacons in the system were effectively Meaconed after a change. Autonomous working or self direction finding by the Meacon sites was again considered but the D/F loops available were not thought to give sufficiently accurate bearings at night. Tests were, however, carried out certain Meacon stations being made responsible for covering selected beacons whatever their call sign or frequency. The Meacon stations were advised of the bearings of the beacon to be covered and searched the band until that beacon was discovered. Some slight success was achieved being partly helped by the inactivity of beacons not directly connected with flights or raids by enemy aircraft, and in a tie-up by "Y" Service between German W/T and beacons which enabled forecasting of beacons activity to be made. The existence of several beacons whose bearings from Meacon stations were rather close did not help this scheme.

On 1 June 1942 another system of 20 rotas with wedded two-letter call signs and frequencies was introduced. Changes of rotas during operational periods now took place as frequently as every 25 minutes. Self-fixing of beacons by Meacon sites, combined with instruction from the Meacon Control on information from "Y" Service, enabled Meaconing to be continued. Considerable reductions in beacon power made Meaconing difficult but at the same time must have made it very difficult for enemy aircraft operators to obtain bearings. Such frequent changes of rotas must also have made it necessary for long lists of beacons with call signs and frequencies to be carried. Re-shuffles of the call signs and frequencies in the 20 rotas took place on 10 July, 1 August, 18 August and 7 September.

On 15 September 1942 there was yet another complete change in the beacon systems. All beacons including those on fixed frequencies now operated in the narrow band of 500 to 600 kilocycles per second. This denied the use of enemy beacons to British aircraft whose receivers did not cover this band and was one example of enemy defensive measures being introduced. The number of beacons in the western coastal strip was now reduced to 19. The new system was made up of three programmes, each programme covering ten days and containing ten rotas of call signs wedded to frequencies. Rotas changed at midnight daily and contained ten sub-rotas of changes of call sign and frequency to beacon locations, these ten changes being spaced out over the 24 hours. Repetition of programmes was in irregular order but once the new programme was identified all rotas were repeated in the same order as when the programme was previously used. Frequent inactivity of many beacons left gaps in the rotas but forecasting on a limited scale became possible.

During October 1942 a new *Elektra* on 316 kilocycles per second was heard and fixed at Quimper (France), and on the 11th of the month the *Elektra* at Stavanger changed frequency from 319 to 297 kilocycles per second. On 31 December 1942, there was a slight change within the three programmes previously used, wedded call sign and frequency rotas remained the same but the sub-rotas of beacon locations were changed. At this time there were six broadcast stations in Norway operating as beacons. A broadcast station in North Holland was sometimes heard superimposing recognition letters, and two stations in France were more frequently active. Meaconing action was always taken during likely or actual periods of enemy activity.

A return to a 20-rota system was made on 1 February 1943, two-letter call signs being wedded to frequencies in the 500 to 600 kilocycles per second band. Fifteen changes of rota took place daily but forecasting was possible as the rotas were changed in the same order as that of the beacons in Central Germany employed some months earlier. New sets of rotas were introduced on the 8th and 16th of the month. On 26 February 1943 the *Elektra* on 316 kilocycles per second at Quimper changed to a *Sonne*. This station was the first to adopt this new form of Medium Frequency navigational aid. Meaconing proved an effective counter-measure.

On 1 March 1943 another complete change in beacon locations and operating procedure took place. Beacon locations were now arranged in 14 groups, each group comprising three sites located at the points of a triangle with roughly 50 to 80 mile sides. Ten of the groups were spaced along coastal areas between Southern Norway and Bordeaux. The other 4 groups operated further inland in France. The call signs were now three figure groups which were the same as the actual frequency being employed. The frequency band 500 to 600 kilocycles per second was used with the exception of two frequencies near 250 kilocycles per second. The three sites of each group operated on the same frequency throughout March, each site radiating in turn for 15 minutes. The sequence of rotation around the sites was changed 10 times per day, more frequently during the hours of darkness than in daylight. A further general reduction in the power of the beacons was noticed, this often making interception and identification difficult. Each of the various bomber and reconnaissance units of the G.A.F. appeared to be allocated certain beacon groups which only became active when aircraft of the unit were in the air. Indications of enemy activity and units concerned thus became possible by observing the activity of beacon groups.

On 1 April 1943, further changes were made. The fourteen groups were divided up as follows :—

(*a*) Nine groups interchanged frequencies ten times per day at the same time as the change of sequence of rotation of sites within each group.

(*b*) Four coastal groups in Holland and France increased the number of transmitters at each mast site to three. Four sets of three frequencies rotated around the groups with ten changes per day. Each set of frequencies rotated around the mast sites.

(*c*) One group in the Cherbourg area remained on a fixed frequency.

Several changes in *Elektra* and *Sonne* transmissions took place as follows :—

8.4.43. *Sonne* on 481 kilocycles per second at Petten first heard.

10.4.43. *Elektra* on 297 kilocycles per second at Stavanger last heard.

19.4.43. *Sonne* on 297 kilocycles per second at Stavanger first heard.

27.4.43. *Elektra* on 481 kilocycles per second at St. Peter last heard.

6.5.43. *Sonne* on 297 kilocycles per second at Stavanger changed to 319 kilocycles per second.

18.5.43. *Sonne* on 303 kilocycles per second at Lugo (Spain) first heard.

24.6.43. *Sonne* on 297 kilocycles per second at Arles (South France) first heard.

On 1 July 1943, eleven of the beacon groups added a further site and the period of operation of each site was reduced to ten minutes. During August a new practice arose of *Sonne* stations changing to *Elektra* transmission during periods of enemy activity over this country. Such changes did not affect Meaconing but were often one of the indications of enemy activity.

25.8.43. *Sonne* on 306 kilocycles per second at Bayeux first heard.

8.8.43. *Elektra* on 291 kilocycles per second at Brest last heard.

30.9.43. *Sonne* on 311 kilocycles per second at Seville (Spain) first heard.

In December "Radio Paris" broadcasting station, which had not been used as a beacon for some long time, was again heard superimposing recognition letters. The group system continued in operation until 6 February 1944, but on the nights of 21/22 and 29/30 of January one site of each group operated continuously during a period of enemy activity over this country.

On 6 February 1944 the group system was practically abandoned. Two groups, one in the Cherbourg area and the other in South France, remained in operation on fixed frequencies. All beacons were withdrawn from the Brest peninsula and a limited number operated in two systems. Nine beacons in Southern France used word type call signs wedded to frequencies and thirteen beacons in the western coastal area used the figures of their frequency as call signs. Rotas now only changed once per day at 1100 G.M.T. The power of the beacons remained at a low level and offensive use appeared to have been abandoned. The use of these beacons in a defensive role is described later in this Appendix.

On 26 February 1945 the *Sonne* on 316 kilocycles per second at Quimper changed frequency to 325·5. After the Allied landing in North France there was a slight increase of beacons in North France but as the beacon locations were overrun they were not replaced at other locations. During air launched Flying Bomb attacks on this country use of beacons which were operating in a defensive beacon system was made. *Elektra* and *Sonne* transmissions in enemy held territory continued to operate until the end of the war. Meaconing action was taken whenever the German Air Force took offensive action.

"Meaconing" of the German Wireless Safety Service Organisation

One of the wireless services of the German Air Force was a network of high grade direction-finding stations, which operated in the 150 to 600 kilocycles and 3 to 6 megacycles per second bands. This organisation became known as the "Safety Service" and its functions were to assist any aircraft in distress and unable to find its position by any other means. Communications between aircraft and ground control stations was carried on in a simple "Q" code. When told to do so the aircraft transmitted long dashes whilst the ground stations took their bearing, the bearings were then passed to the Control and a "fix" given to the aircraft in a coded map grid reference. The Safety Service was independent of all other W/T organisations such as airfield "Homing." From listening observations of the operating by the ground personnel they appeared to be highly skilled and capable.

After the German occupation of Western European countries the Safety Service was extended so that any aircraft flying over the United Kingdom or Western Approaches could be given assistance. As radio counter-measures against navigational aids used for attacks on the United Kingdom became more effective a new use for the Safety Service Organisation was found ; instead of being rather an "S.O.S." organisation, it now started giving "fixes" to aircraft operating over this country. The Safety Service Organisation used one frequency in each of the M/F and H/F bands. The call signs were grouped so that a Control Station would have a three-letter call sign and each outstation under that Control would use the same three-letter call sign with an additional letter to identify the outstation. Six Control stations were set up along the coastal area between Denmark and Bordeaux and each Control had two or more outstations.

The threat of the use of the Safety Service Organisation to assist bombing had been considered and specially sensitive Meaconing equipment had been designed. This equipment was known as Aircraft Meaconing (A.C.M.) and by a lucky coincidence became operational at the first Meacon site to be fitted with Medium Frequency equipment on 7 December 1940. On the following day the Service was in fact used as expected, and some 20 aircraft called for "fixes" whilst over this country.

A.C.M. circuits were originally constructed so that the receiver normally operated with the continuous wave oscillator "on," and the enemy signals could be heard by the operator. A switch was provided which cut off the oscillator and switched the output of the receiver to the Meacon channel for Meaconing. This arrangement meant that the operator was unable to follow the traffic whilst Meaconing was in progress, and resulted in the Meacon being switched "off" intermittently, to be sure the aircraft was still radiating its signal for D/F. It was feared that the above conditions would enable the enemy to detect Meaconing, and also that more effective Meaconing could be provided if a monitor receiver was available. A monitor receiver was, therefore, provided and fitted so that during Meaconing the headphones of the operator were switched over to this receiver and the enemy transmissions heard via the Meaconing transmitter. Results so obtained were excellent and further improvement in the A.C.M. became possible with these monitor receivers insofar as the complete aircraft transmission, including calling the ground station, could be Meaconed and the enemy thus prevented from obtaining bearings on any signal radiated by the aircraft.

The operators required for A.C.M. had to be highly skilled in Meaconing signals of varying frequency and strength and of short duration. A morse speed of at least 20 words per minute and full knowledge of operating procedure was required to follow the enemy transmissions. Valuable assistance was rendered by the "Y" Service, firstly by the loan of two officers who trained the operators on No. 80 Wing sites, and later by a short course.

Meacon Control at H.Q. kept the A.C.M. stations informed of all changes in the enemy organisation ; they also issued plotting maps showing the position of the enemy D/F stations with compass degrees marked around them, the German Air Force coded map grid and a list of "Q" codes used and their meaning. Each A.C.M. operator was therefore able to follow the enemy plotting and judge the effect his Meaconing was having on such plotting. Meaconing strength could then be increased or decreased as necessary.

All A.C.M. work was analysed at Meacon Control, intercepted bearings passed by the enemy outstations to his Control ; "fixes," stations Meaconing, and Fighter Command radar or Royal Observer Corps plots were all available and whenever an aircraft flying over the country was Meaconed, errors of up to 200 miles in the position given were noted. Aircraft approaching or flying away from the country were affected in a less degree according to their distance from the Meaconing stations. Meaconing was causing the enemy control stations to instruct aircraft to repeat their transmissions for check bearings. Many doubtful bearings and "fixes" were being given and delay and confusion resulted.

By April 1941, an alternative frequency was introduced so that if unable to obtain a good "fix" on the first frequency the aircraft changed to the alternative frequency. The four A.C.M. channels then available were divided to cover both frequencies. During May 1941, the alternative frequency was changed each night but remained between 410 and 430 kilocycles per second. The new frequency was quite easy to find in this narrow band.

During the summer of 1941, Meaconing equipment to cover the high frequency band and on which the Post Office had been working for some time was installed at certain Meacon sites. Aircraft operating over the Western Approaches, or using this band as an alternative to the M/F band whilst flying over this country, were effectively Meaconed.

In August 1941, A.C.M. operators reported that after the aircraft had been sending its long dashes for bearings for a few seconds it switched off for about a minute, and then switched on again. After a careful watch it was discovered that during this minute of silence the aircraft was radiating its long dashes on another frequency; sometimes this second transmission was identified by the aircraft sending its call sign once at the beginning of the new transmission and sometimes no call sign was sent. Some of the A.C.M. sites were set up on this new alternative frequency, the operator being provided with a receiver with which he could monitor the main frequency. The enemy soon found it just as difficult on either frequency to give the aircraft " fixes."

His next move was to introduce a number of different alternative frequencies, a different frequency being used each night. Combined efforts of the " Y " Service and A.C.M. stations usually resulted in the alternative frequency being discovered as soon as one aircraft used it. Meacons were then ready for all the following aircraft. The use of alternative frequencies continued until July 1942 when, instead of all the stations in the Safety Service Organisation operating on one main frequency, they split up so that each control station and its outstations had their own frequency. Sufficient A.C.M. channels were available for two to cover each frequency. The enemy gained nothing by dividing the Meaconing strength. A disadvantage he now suffered was that the aircraft had to change frequency to contact different control stations, and did not always choose the best one to minimise the effects of Meaconing.

The enemy gave up the battle in August 1942, after which date his aircraft only used the Safety Service when over the Continent, all transmissions being on considerably reduced power and often the ground stations instructed the aircraft to reduce power even further. On the few occasions when aircraft attempted to obtain " fixes " over or near this country they were Meaconed. It seems that whenever the ground control stations suspected Meaconing they would only give doubtful " fixes " and bearings and often none at all. Airfield " homing " frequencies were also watched and when aircraft were any distance from the airfield and signals were sufficiently strong to Meacon, such action was taken.

Various odd attempts to use the Safety Service Organisation were made, the A.C.M. sites dealing with the activity as it arose. The most interesting attempt to use the Safety Service Organisation to assist bombing was on the night of 4/5 June 1943, when the Control station at Villacoublay controlled five aircraft of *III K.G.6* on 367 kilocycles per second and gave them " fixes " together with bearings and times to their targets, a procedure similar to that employed on V.H.F. with fighter-bombers. Each aircraft appears to have been given its own target since incidents were reported from the Warminster, Leamington, Aldershot, Maidstone and Gravesend areas. The precise targets were not determined however. " Fixes " given to the aircraft differed by distances up to 40 miles from the pinpoints at corresponding times as shown on the Records Research track charts. The discrepancies were probably caused by Meaconing and no similar attempts to use the Organisation were again made.

Defensive Use of Medium Frequency Beacons by German Air Defence

For the successful defence by fighter aircraft against air attack over a large area it is essential not only that the detection and estimate of strength, composition and direction of the attacking force should be possible but that, when obtained, this information should be available to each aircraft responsible for interception. In addition, although it is desirable to have fighters airborne at operational height it is advisable to have these waiting at pre-arranged positions for easy vectoring towards an attacking force at the most opportune moment.

The enemy therefore provided a low power M/F beacon near to each G.C.I. site over which each aircraft to be controlled could circle until operational instructions were passed. After each sortie or interception the fighter was able to "home" to this low powered beacon and circle until new instructions were issued. These beacons, known as G.C.I. or Little Screw beacons, employed a power of some 100 watts only. Airfields were also equipped with low power beacons of the same type which were employed to aid "homing" to airfields when patrols were completed.

As the Allied raids increased in intensity the German Air Force turned its attention more and more towards defensive action. So many fighters were made airborne during each operation that individual ground control of all of them became impossible, the majority of them being left to make their own interceptions using information broadcast in the form of a running commentary. This meant that large fleets of fighters would need to navigate and rendezvous all over the Reich and occupied Europe and some navigational aid had to be provided. Central European High Power Beacons, previously used for internal transport and training duties, were utilised for this purpose. In addition high powered beacons were provided in areas of Western Europe not adequately covered by the Central European Beacons. These were known as Big Screw Beacons and operated with a power of approximately 1·5 kW. After take-off, each fighter could rendezvous with the many other aircraft by "homing" to a pre-arranged Big Screw or Central European Beacon and there circle awaiting general instructions or information. This system enabled large numbers of aircraft to be directed to waiting areas suitably disposed for intercepting an attacking force, by directing them from beacon to beacon as more detailed information became available on the course of the attacking bombers. Associated with certain Big Screw and Central European Beacons were low powered beacons known as *Bruderfunk-Feuer*. Each of these was located near a Big Screw or Central European Beacon and made use of the same call sign. The purpose served was, however, never determined.

As already stated, for the fighter aircraft to make successful interception it was necessary for the aircrew either to receive explicit instructions as to the direction in which to fly or to have up-to-date information available as to the whereabouts and direction of the attacking bombers. In either case good ground to air communication was essential and this was normally achieved on H/F or V.H.F. until Allied radio counter-measures made these communication channels unreliable. Early in 1944, therefore, commenced the policy of using the Big Screw and Central European Beacons for broadcasting brief details of the location and direction of the attacking forces. The information was given in W/T, the normal beacon keying being suspended for the short duration of the message. Operating details of beacons are summarised in Table 1 to this Appendix. In addition to the beacons outlined above, two high power beacons were installed during January 1944 in the Ruhr and were used solely for passing tactical W/T traffic to night fighters. These were known to the Germans as *Paule* and *Achmed*. They each made use of a fixed call sign and frequency and were situated at Dortmund and Dusseldorf respectively.

When, at the beginning of 1944, the use of beacons for passing tactical W/T messages was observed steps were taken to institute counter-measures in the form of Fidget. This was first employed on 28 April 1944 when action was taken against three beacons, and by January 1945 Fidget had increased to such an extent that it was often applied to as many as twelve enemy beacons simultaneously during an attack by Bomber Command. Mimicry was also introduced against Big Screw and Central European Beacons which were still acting as such to make navigation of night fighters from waiting area to waiting area more difficult.

Table I

Types of Beacon.	Purpose.	Power.	Frequency.	Call Sign.	Remarks.
G.C.I. (Little Screw).	Rendezvous for individual control.	Low power, 50 to 100 watts.	32 frequencies within band 200–1,200 kc/s. Changed daily, several beacons sharing common frequency.	Fixed for each location. Usually 2-letter call sign.	
Safety Service Airfield Beacons.	"Homing" to airfields after operation.	Low power, 50 to 100 Watts.	As for G.C.I. beacons and included in the same rota.	3-letter call signs identical with the local Safety Service D/F Organisation ; changing twice weekly.	Some of these have been known to pass tactical W/T traffic. A number of airfield beacons did not operate on the G.C.I. frequency rota but always made use of fixed frequencies.
Big Screw ..	Rendezvous in force ; large scale waiting areas ; also used to pass tactical W/T traffic.	1 to 1·5 kW.	200 to 600 kc/s band. Frequency wedded to call sign, changed twice daily.	4- or 5-letter call sign wedded to frequency which changed twice daily.	Each Big Screw and Central European shared a common frequency within the 26 frequencies available.
Central European (O.B.D.L.).	As for Big Screw.	500 watt to 1 kW.	As for Big Screw.	4- or 5-letter call sign wedded to frequency which changed twice daily.	A different set of call signs was used by each type of beacon but in each case the call sign was wedded to the frequency.
Bruderfunk-Feuer		Low power	Fixed.	Same as currently used by associated Big Screw or Central European Beacon.	Situated very near to a Big Screw or to a Central European Beacon.

APPENDIX No. 4

OPERATIONS ROOM—ORGANISATION AND PROCEDURE

When No. 80 Wing was first formed its operational commitments were limited to the following radio counter-measures :—

(*a*) Meaconing—to re-radiate enemy beacons used by the enemy for navigation over the British Isles.

(*b*) Aspirins—to jam enemy *Knickebein* beams, which were radiated on two fixed frequencies (30 ; 31·5 megacycles per second) used for blind area bombing.

An operations room was set aside at Aldenham Lodge. Under the Commanding Officer, a Duty Wing Commander was in control of operations, assisted by an Operations Officer and two junior officers each in charge of the Meaconing and Aspirin sections, respectively, the latter being known as the Headache Control Officer. In addition, a Scientific Analyst was present to aid the Duty Wing Commander in determining the azimuth of each *Knickebein* beam detected. The duties of the Operations Officer and each of the sections are described below.

The Operations Officer was in charge of the Operations Room and supervised the duties of all sections, warning the Commanding Officer, Duty Wing Commander and officers in charge of sections immediately activity was indicated. During an operation, close contact was maintained with each section and information was obtained from H.Q., Fighter Command, as to the general air situation. In addition the Operations Officer was responsible for passing information to outside formations intimately concerned with the Wing activities, *e.g.*, advising the Duty Air Commodore at Fighter Command of beam settings which indicated a probable target, also the Duty Group Captain at Air Ministry of the general situation.

Headache Control

Throughout the hours of darkness all Aspirin jammers radiated dashes on the frequency on which they had last been instructed to radiate. This radiation was continuous except for pre-arranged breaks of ten minutes duration three or four times each night. These breaks were known as listening periods and enabled all jamming sites equipped with receivers together with special listening sites situated round the coast, to listen on 30 and 31·5 megacycles per second for any enemy signals which might be active. After each listening period each site reported by public telephone to Headache Control the characteristics of any signal heard. Nil reports were required.

Four clerks (special duties) were responsible for receiving these reports, logging them and subsequently charting them in a form suitable for a later detailed analysis. In addition, each report was displayed for immediate analysis. Display was by means of maps showing the location of each listening site—a separate map being used for each frequency. As each site reported, a coloured pin, representing the characteristic heard, was inserted in the appropriate map at the position of the reporting site.

Reference to the maps showed those *Knickebein* beams which were active and enabled the azimuth on which each beam was set to be determined by the Duty Wing Commander and Scientific Analyst. Additional maps were prepared as and when new *Knickebein* frequencies came into operation.

As the settings of each beam became apparent they were indicated on a further map by means of coloured cords. Any beam intersections thus became evident and probable targets illustrated. This map was known as the Aspirin map since, besides showing beam settings, it displayed all Aspirins and the frequency on which they were radiating. Coloured flags, each colour representing a particular frequency, were used in this display. As *Knickebeins* were swung on to different targets it was therefore possible to observe any dangerous gaps in jamming caused by the new disposition and to order a suitable jamming cover.

It was the duty of the Headache Control Officer to organise the above work, supervise and ensure that reports were quickly and accurately received, logged and displayed, and to order a redistribution of jamming if required. In addition the Headache Control Officer organised under the general direction of the Duty Wing Commander and in conjunction with the Commanding Officer of No. 109 Squadron, any investigation flights which might be necessary. After each flight the crew would be interrogated by telephone tie line and a preliminary report submitted to the Duty Wing Commander and Scientific Analyst.

The enemy Ruffian type beams were at this time coming into use, operating on frequencies between 66·5 and 75 megacycles per second. Suitable receivers had been installed at certain listening sites, where a watch for this type of signal was continuously maintained. Reports were made to Headache Control where they were logged and charted for future analysis. No counter-measure was yet ready and the work was of an investigational nature. Many of the investigation flights organised by the Headache Control Officer were in connection with this activity.

Meacon Control

This section was responsible for all R.C.M. against enemy M/F aids and consisted of a Meacon Control Officer assisted by four clerks (special duties). Information concerning enemy beacon activity was obtained from the " Y " service at Cheadle and a tie line was installed for this purpose. Enemy beacons interchanged call-signs and frequency at intervals in accordance with a pre-arranged rota. As each change took place it was necessary for the " Y " service to establish by D/F the source of each enemy call-sign heard. This information was passed to Meacon Control immediately it was determined, and was logged by a clerk S.D. In addition a beacon activity sheet was maintained which had provision for planning the distribution of counter-measures.

All enemy beacon and counter-measure activity was displayed on a map of the British Isles and western Europe. On this map the position of each Meacon station with its rejection angle was shown and given a reference letter. Every Meacon transmitter available at each site was numbered. Thus, Flimwell had the reference "A" and its four transmitters were numbered "A1 ", "A2 ", etc. These references were printed on large headed display pins and stuck into the map at the appropriate Meacon site, thus showing what transmitters were available. As each enemy beacon became active a small coloured pin was inserted at its location on the map.

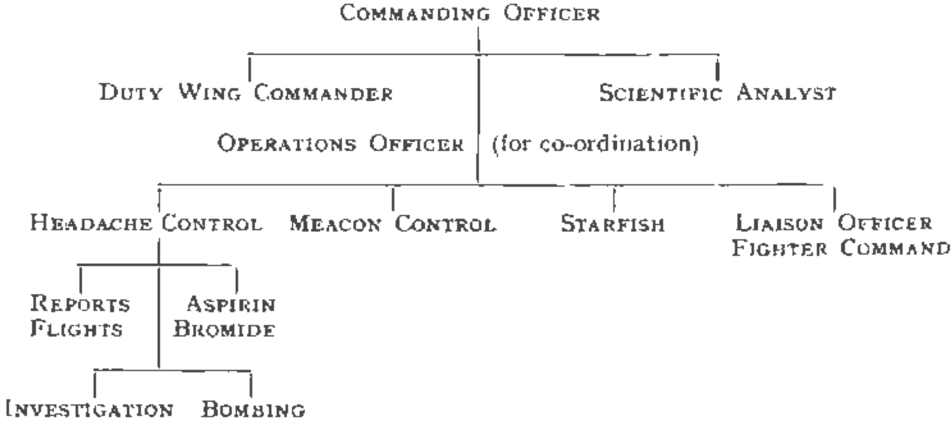
When a Meacon site was ordered to cover a beacon its call sign and frequency were given and the transmitter number to be employed was specified. The appropriate transmitter reference pin was then removed from its previous position and stuck on the map at the position of the enemy beacon. A list of the relative powers of Meacon transmitters at each site was displayed for easy reference so that discrimination could be used when allocating cover of beacons of varying operational importance, or power.

It was necessary for the Meacon Control Officer to remain familiar with the current air situation, particularly the route by which enemy aircraft were approaching the target or were likely to approach, bearing in mind the *Knickebein* beam settings. This was to avoid choosing a Meacon site so placed that it was on the bomber route in line with the target and the enemy beacon. In view of the small number of Meaconing transmitters available, discrimination had to be used in taking R.C.M. against those beacons, which from their disposition, seemed of most use to the enemy. R.C.M. was vetoed on certain enemy beacons which were to be used by Bomber Command aircraft and this information was received each evening and displayed by a clerk S.D.

Expansion of the Operations Room

By the end of October 1940 the first Bromide (jammers of Ruffian type beams), was in operation, and during November and December the operational activities of the Wing grew apace. Mobile watcher sites operated on the south coast to pinpoint quickly and accurately the position at which Ruffian beams from Cherbourg crossed the coast ; Bromide jamming was active, the jammers being dispersed to afford cover of major target areas ; a few high power Aspirins with rotatable aerial arrays to enable jamming to be directed towards the beam intersections had become available; Glowworm (later known as Starfish) had become operational; blind bombing by the use of Benito beam and range signals was coming into use and counter-measures were being planned. The Meaconing of aircraft requesting fixes had also been instituted.

With this increase in commitments the operations room had to be expanded. This was achieved by placing Meacon Control in an adjoining room and removing part of the intervening wall. The organisation of the work was based on the following general plan :—



It will be seen that the general organisation remained the same, but with the addition of the new section Starfish. Modifications were chiefly made within sections as set out below.

Headache Control

This was divided into subsections dealing with incoming information such as reports of enemy signal activity, and outgoing orders such as redistribution of Aspirin jamming and the ordering of Bromides to radiate. The reports were handled as outlined previously except that reports of Ruffian activity were taken in duplicate, the copy being handed to the Scientific Analyst direct for immediate study.

Aspirin

In addition to the display already mentioned, displays were instituted for each Aspirin having a rotatable aerial array, showing a compass rose with a pointer to indicate the setting on which the transmitter was radiating. One Clerk S.D. was responsible under the direction of the Headache Control Officer for telephoning all orders to Aspirin sites and keeping up to date all displays of this section.

Bromide

A small display board was installed showing Bromide transmitters. Against each transmitter provision was made for hanging a plaque giving the frequency on which it was required to radiate. As each Ruffian frequency became active the Headache Controller under the direction of the Duty Wing Commander decided what jamming should be instituted, and displayed this by hanging the appropriate frequency plaque opposite transmitters which were to radiate. A Clerk S.D would then telephone each site required, and pass instructions to radiate giving the transmitter number and the frequency to be used. The Headache Control Officer, who still continued to organise investigation flights, also interrogated by telephone crews of No. 109 Squadron aircraft on return from bombing Ruffian beam transmitters on the Cherbourg Peninsula. A preliminary report was then prepared and submitted to the Duty Wing Commander and the Scientific Analyst.

Meacon Control

As stated above, this section was now installed in a room adjoining the main operations room. Its method of control remained the same, but its duties were growing as more and more Meaconing sites became operational. In consequence of the earlier success of Meaconing considerable use was being made by the enemy of their safety service network. Only one frequency was employed and special equipment was installed at Henfield to Meacon the aircraft radiations. Speed and the very special nature of the work required that this Meaconing should be autonomous. The Meacon Control Officer was fully informed as to the action taken from information supplied from Cheadle and Henfield. To increase power and to make Meaconing even more efficacious, enemy beacons were double-Meaconed. Technically this introduced considerable complications in Meaconing due to interaction, and to enable suitable sites to be chosen, a chart devised by the G.P.O. was used. Clerks S.D. were beginning to understand increasingly the intricacies of the work, and as additional facilities became available, and as more commitments devolved on Meacon control, some of the allocation of the necessary Meaconing was placed in charge of a Senior Clerk S.D., general indication only coming from the Meacon Control Officer.

Starfish Control

This section was manned by a single officer, but in the evening before any major operation took place, it was possible to send a Clerk S.D. to this section to assist in taking routine serviceability and weather reports from all Starfish sites. During an operation Starfish Control came under the direct orders of the Duty Wing Command of the Commanding Officer. It was necessary for the Starfish Controller to be completely conversant with the existing air situation and probable line of approach towards any estimated target. This information was obtained by liaising with the Operations Officer and the Headache Controller. Advice could also be sought from the Scientific Analyst for precise information regarding beam settings. As evidence accumulated, contact was continually maintained with Starfish sites or their local control in the areas affected, arrangements made with the G.P.O. trunk supervisor for calls to the affected areas to be connected with immediate priority and a very intimate knowledge of local weather conditions thus obtained. As the operation developed and bearing in mind all information at his disposal, the Starfish Controller would prepare a plan showing all evidence and details of site possibilities, for the Duty Wing Commander or the Commanding Officer and only on their instructions were such orders passed to a site. Q.L.s and other dummy lighting were controlled by the Starfish Controller on his own authority using his intimate knowledge of the general air situation.

A card index was maintained giving details and all relevant information concerning each site under Starfish Control. A map of the British Isles was displayed showing the disposition of all sites with cross reference to the card index; in addition large-scale maps were available of the area of each Starfish so that the location of each site could be studied in detail when preparing to set off a dummy fire.

Communications

During February 1941 arrangements were made whereby trunk sub-lines to main watcher sites were left permanently connected and voice-operated relays were fitted so that contact could be made immediately the receiver was lifted. This was to speed up reports and enable Bromides to be given new frequencies as quickly as possible. This innovation was necessitated by the enemy making sudden changes in his Ruffian frequencies, during an operation, in an attempt to avoid the Bromide jamming.

Expansion due to Benito

During February 1941 counter-measures to the Benito system were instituted, first in the form of Domino and later in the jamming of Benito beams with Benjamin jammers. A further subsection of Headache Control was therefore introduced to deal with order and display for Benjamins similar to that instituted for Bromides. Domino action was instituted by the Headache Controller or Duty Wing Commander personally by advising the Domino sites of enemy ground station frequencies which were to be covered. The subsequent operation of Domino was handled independently by the site concerned, although liaison was maintained with the Headache Control Officer or the Operations Officer to enable Benito traffic and action taken to be correlated with aircraft tracks. It had already been found that many of the telephone calls dealing with intelligence information and reports from outside formations concerning signal activity could be handled only by officers. This became even more obvious with the introduction of Benito and its counter-measure Domino. It was, therefore, necessary for the Operations Officer to assist the Headache Controller by dealing with many of the telephone calls which the latter was too busy to take. In fact the Headache Controller and the Operations Officer began to work more and more as a team, the Operations Officer taking over the organisation of flights, and many of the telephone calls on Benito and Domino.

Introduction of Enemy Aircraft Plotting Table

To relieve the Operations Officer of the frequent telephoning with the Liaison Officers of Fighter Command, a plotting table was installed and a Clerk S.D. was engaged continuously plotting tracks of enemy aircraft as passed from the Liaison Officer. Reference to this plotting table gave all the latest information available concerning enemy air activity, and more detailed plots could be obtained on any tracks of particular interest. Meacon Control made slight changes in the method of display although the general principle remained. The modification was chiefly in the nature of equipment used in order to avoid damage to the display map caused by continual insertion of pins. Hooks were fitted in the map at any position where display would be required and small ivorine tallies, which could be hung on the hooks, were used instead of the display pins.

It was sometimes found that enemy beacons were operating on reduced power which did not give sufficient drive to permit a Meacon site to operate without self-oscillation. In this event a Meacon site might be instructed to " stand-by " until conditions were more favourable. This situation was indicated by hanging a green tally over the transmitter tally where it was shown against the beacon location.

Transfer of the Operations Room from Aldenham Lodge to Newberries

During the summer of 1941 it was appreciated that Aldenham Lodge was no longer capable of housing the rapidly expanding administrative and technical staffs as well as the operations room. Crowding was so severe that the security of the highly secret work dealt with in the operations room was liable to be jeopardised. A new operations block was therefore decided upon and a nearby house—" Newberries "—was chosen for this purpose.

It was also appreciated that in many ways the organisation of control required re-planning to increase speed in assessing enemy signal activity and the speed of application of counter-measures. This was very necessary as it was anticipated that during the coming winter months the enemy would increase the scale of his attacks and try to overcome radio counter-measures by maintaining radio silence as long as possible and by employing rapid frequency changes. It was therefore decided to examine the existing methods of control and to develop new systems and lay-out where desirable. Due to the unsuitable nature of the rooms available at Aldenham Lodge, sections of the operations room were unavoidably too dispersed. Displays which were quite useful to the sections concerned could not be seen from any central position. The result was that the Duty Wing Commander or any other officer desiring to appreciate the work as a whole was required to make a tour of inspection, and officers were continually moving about the room trying to pick up the threads of the work of individual sections as related to their own particular function.

Headache Control was the most hard worked and most rapidly expanding section, but its co-ordination was breaking down with the glut of new commitments. Telephone calls were being duplicated unnecessarily by using three distinct sub-sections (Aspirin, Bromide and Benjamin) since all these types of transmitters were often available on the same sites. This disadvantage would obviously be aggravated as the enemy brought into use his extended *Knickebein* service which could employ any of the 34 frequencies in the band 30 to 33·3 megacycles per second. This innovation would prevent automatic radiation by Aspirins and implied that *Knickebein* and Aspirins would need control similar to Ruffians and Bromides. Starfish Control also required to be in a position where continued reference could be made both to the plotting table and to the Starfish records and displays. The experience of Clerks S.D. engaged on Meacon Control had increased to such an extent that it was considered possible to leave the work in their hands with only cursory supervision by an officer.

It was decided therefore to introduce considerable modifications in both display and procedure immediately the new accommodation was available. With this object in view the new operations room was planned and became operational on 19 October 1941.

Improved Meacon Control

As mentioned above, Meacon Control could be operated with only cursory supervision and this section was made comparatively independent of the rest of the operations room. General direction was made the responsibility of the Operations Officer and a display was evolved which enabled the Controller and Operations Officer to see at a glance details of enemy beacon activity and the state of countermeasures applied. The display method consisted of a board divided into two sections :—

(i) Transmitter Availability and Allocation Board, and
(ii) a Beacon Activity Board.

The plaques used on this board were sufficiently large so that details shown thereon could be seen from a considerable distance.

The "Y" Service reported the location, callsign and frequency of each beacon as it became active. This was recorded as already described and in addition a plaque showing the location of the beacon by name, was hung in the Beacon Activity section of the Display Board. On allocating a beacon to a Meacon site, a beacon plaque, similar to the one displayed in the Beacon Activity Section, was hung in the appropriate site column of the Availability Section against the correct transmitter number. A white ivorine disc was hung on top of this plaque to indicate when allocation had been made. This disc was removed when the site reported that it was re-radiating satisfactorily. If satisfactory Meaconing could not be achieved, and a site was instructed to stand-by pending more favourable conditions, a green disc was hung over the allocation.

The number of sites dealing with aircraft Meaconing had considerably increased and operators at these sites were given standard frequencies to watch and cover when possible. These allocations were displayed by a frequency plaque against the site A.C.M. channel. Transmitter numbers commenced at 12. This was to make a definite distinction from V.H.F. transmitters whose numbers commenced at one, and thus avoid possible misunderstanding at sites which incorporated both Meaconing and V.H.F. jamming transmitters. A map was displayed showing the location of all enemy beacons. Each Meacon site was also shown together with its angle of rejection. This map was used for reference purposes when arranging allocation but as all personnel on Meacon Control were familiar with the details shown, reference to this map was seldom necessary.

Records were maintained as follows :—

(*a*) Beacons Activity Log.—Beacon names, callsigns and frequencies, times of activity as reported by "Y" Service.

(*b*) Meacon Transmitter Sheets.—One sheet was maintained for each Meacon transmitter available. On these were recorded all allocations and radiation details. This information was afterwards transferred to a daily record book for permanent record.

Starfish Control

The organisation of this section remained the same as at Aldenham Lodge except that it was more conveniently situated. The Starfish Officer was near the Controller for consultation and discussion, whilst having easy access to his maps, site records and a clear view of the plotting table which was maintained as at Aldenham Lodge.

Headache Control

The remaining and major part of the Operations Room was devoted to countering enemy V.H.F. aids and considerable modification was made both in the methods of display and control. It was divided into two sections—incoming information known as " Reports ", and outgoing orders for implementing counter-measures, known as " Orders ". Co-ordination was maintained by the Operations Officer and the Scientific Analyst who assessed the information received from " Reports " and passed it on to the Headache Controller for " Orders ".

Report Section

The Report Section was manned by a total of five Clerks S.D. under the direct supervision of the Operations Officer. Three of these Clerks S.D. were engaged continuously in receiving by telephone reports dealing with signal activity, the fourth was engaged maintaining a permanent log of all such reports received, whilst the other Clerk S.D. charted the information for future analysis. No display was employed but all reports were taken in duplicate, each report giving the following information :—

Origin of Report : Originator's initials : Recipient's initials : Time Report received.

Signal frequency in megacycles : Time heard : Modulation frequency employed : Characteristic (*i.e.* dots, dashes, continuous note and carrier, etc.) : Keying speed : D/F bearing if available.

These reports were handed to the Clerk S.D. engaged on logging who retained the carbon copy and immediately passed the original to the Operations Officer.

The Operations Officer filtered all reports, passing any which had *Knickebein* or Ruffian characteristics to the Scientific Analyst who gave the final decision as to what beams of this type were active, and their source. This information was passed to the Controller for counter-measure action. The setting on which each beam was directed and if possible the estimation of target was also obtained and passed to the Operations Officer for forwarding to Fighter Command. The Controller and Starfish Officer were also informed so that suitable modificatinn or adjustment could be made in preparation of counter-measures.

All Benito type signals, both beam and range, were assessed by the Operations Officer, the source of each being determined from D/F bearings obtained by No. 80 Wing sites together with bearings obtained from the " Y " Service organisation at Kingsdown. It was not possible to estimate targets from Benito beams and the information which was passed to the Controller for action was merely as follows :—

(*a*) Benito beam : Signal frequency : Source.

(*b*) Benito control : (or range) : Signal frequency : Source.

In addition, by liaising with the Kingsdown " Y " Service, the Operations Officer was able to supply information to the Controller concerning Benito aircraft operating, the frequency on which the aircraft radiated, and the position of the aircraft. The Operations Officer also advised Fighter Command of any Benito beam and range signal active on their source.

Orders

In addition to maintaining general control of all operations in the room, the Controller directed personally all activities through the " Orders " section.

Two main display boards were employed :—

DIRECTIVE—Maintained by the Controller personally and known as " Controller's Order Board ".

EXECUTIVE—Known as " Orders Board ".

Controller's Order Board

The design and lay-out of this board, which was installed on the Controller's dais, showed those enemy signals which were active and the allocation of counter-measures required. Although the board had main divisions to distinguish *Knickebein*, Ruffian, Benito Beam and Benito Control, the principle of display was the same throughout and will be described in detail as applied to the *Knickebein* section of the board. The Board was divided into columns each representing a known *Knickebein* site, the respective headings being " *Kn. 1* ", " *Kn. 2* ", " *Kn. 3* ", etc. Horizontal lines drawn across the board intersecting the vertical columns provided small sections which would contain a display plaque, two pins being fitted in each section on which these plaques could be hung and easily visible from the opposite side of the room.

As each enemy signal became active a plaque showing the radio frequency employed was hung at the top of the appropriate column. The frequency plaque was printed on both sides, black on white background and white on black background respectively. In the column beneath each frequency, plaques showing sites and transmitters required for counter-measures were then displayed. Display of the frequency plaque as black on white background indicated that sites were to be ordered to line their transmitters up on the frequency specified and then stand by for further instructions. As soon as radiation was required the Controller turned the frequency plaque over so as to be white on black background. This enabled preparation to be made for speedy and effective jamming and yet postponing actual jamming until all information likely to be of use for analysis and advice to other defensive organisations could with safety be obtained.

" Orders " Section

This Section was manned by four Clerks S.D., each having a telephone extension from the Operations P.B.X. Action taken was displayed on the " Orders " boards making use of plaques similar in design to those used on the " Controller's Orders Board " *i.e.* printed on both sides. Four boards were used, each showing jamming sites available in a particular area. Each board was divided into main vertical sections to distinguish between Aspirin, Bromide and Benjamin transmitters. As each board was further divided by vertical and horizontal intersecting columns it was possible to display by means of removable plaques the type and numbering of transmitters available in each frequency band opposite the site which was printed at the left of each horizontal column.

The Clerks S.D. engaged on " Orders " observed any directions displayed on the Controller's Order board, contacted the sites required and passed appropriate instructions in the following form :—

> " Orders here. On Transmitter 1, line up and stand-by on 31.3. The time is now 2125."
>
> *Or*
>
> " Orders here. On Transmitter 1, radiate 31.3. The time is now 2125."

The details of instruction passed were logged for permanent record and by hanging a display plaque showing the frequency allocated on top of the appropriate transmitter on the " orders " board the action taken could be indicated to the room at large. " Standby " was shown with frequency printed black on white background, whilst " Radiation " was shown on the reverse side. Each Clerk S.D. was responsible for one board and therefore for a particular number of sites. Familiarity with the name of these sites enabled discrimination to be used while watching the " Controller's Orders Board " and avoided unnecessary duplication in telephone calls.

As instructions had been given to outstations concerning the normal modulation frequency, keying speed and mark-space ratio to be employed when jamming as an Aspirin, Bromide or Benjamin, it was unnecessary for " Orders " to specify these details when passing orders to sites, consequently telephone calls were very brief. There was at this time one exception to the rule. Some of the Benjamin jammers were used to jam Benito Control when a modulation would be used consisting of jumbled morse signals recorded on a single tape. This tape was known as the " M " tape. When required it was indicated on the Controller's Order Board immediately beneath the frequency by means of a plaque printed capital " M ". " Orders " would then instruct an outstation as follows :—

> " Orders here. On Transmitter 8, radiate 43.0, 'M' for 'Mike' Tape ".

It will be noticed that no provision was made on the " Orders " Board for Domino. This was handled by the Controller who personally communicated with the outstation concerned.

Extensions to hand instruments were provided as follows :—

Meacon Control	3
Reports	4
Operations Officer	2 (one scrambler)
Orders	4
Starfish Control	2
Plotting	1 (magneto ringing and normally tied to Fighter Command).

In addition Meacon Control made use of a tied line, magneto ringing, to H.Q. receiving room, responsible for checking the efficiency of Meaconing.

There was, however, no provision which would enable the Controller of Operations Officer to monitor or break into any telephone conversation being held on any of the operations room extensions. Any query which required the Controller's attention necessitated the call being transferred by the P.B.X. The Controller wishing to amend any order being passed to an outstation by a Clerk S.D. had to attract the Clerk's attention by shouting. This proved a particular disadvantage when everybody was fully occupied during busy periods.

V.H.F. Jamming Control—First and Second Line Jammers

Although large-scale enemy attacks did not materialise it became obvious that with the large increase in the number of Benito and *Knickebein* transmitters, there would be insufficient jamming transmitters available to cover all the targets which might be attacked. A change of jamming policy was therefore adopted in 1943 which aimed at preventing enemy aircraft using beams accurately anywhere over the country. This was known as "area jamming" as distinct from "target jamming" and is dealt with fully elsewhere. The procedure ensured that one, or in some cases two jammers suitably deployed to cover a particular enemy transmitter site would cover the country with a jamming signal comparable in power to the equi-signal zone of any beam.

Control of V.H.F. jamming changed in conception slightly as a result of this innovation. Having established which jammer, by itself, was capable of providing the most effective area cover of a particular enemy transmitter, the Controller always ensured that this jammer was ordered to radiate first, it being quickly brought on to frequency and thus made fully effective. Any other jamming transmitters which were available were subsequently ordered on in support. These functions were known as *first* and *second line cover* respectively.

The technicalities and organisation of monitoring have been described elsewhere and until this time did not materially affect the operations room. Immediately the principle of first and second line cover was adopted, however, it became imperative that first line cover be allocated priority in monitoring, every facility being given to monitoring sites by withholding the second line jammers until the first line cover had been effected.

It was therefore arranged that the transmitter specified on the Controller's Orders Board at the top of each frequency column would be the first line cover and would be treated as "priority." This expression was used by "Orders" when contacting the outstation concerned, which would repeat the word "priority" to its monitor site. This ensured preferential treatment over any second line jammer which the monitor site might be dealing with on other frequencies. Immediately monitoring was completed the monitor site advised "Reports" that a certain transmitter had been monitored on to the enemy signal specified. This information, coming to the Operations Officer in the normal way with other reports, was passed to the Controller who could then order on second line jammers. These second line jammers would already have been instructed to line up and stand by in accordance with the instruction displayed on the "Controller's Orders Board." To cope with this more complicated display, *e.g.* 1 transmitter to radiate while others were standing by, it was arranged that any transmitter plaque hanging at an angle (by one pin only) indicated "standby."

The enemy, endeavouring to avoid the effects of jamming, delayed radiation of his beam and navigational aids until his aircraft had reached the British coast. As this practice developed, still further speed was required in effecting counter-

measures. One of the chief difficulties encountered was the delay at outstations in effecting large changes in V.H.F. transmitter tuning but this was overcome by introducing a new control procedure.

Each transmitter, whether Benjamin or Aspirin, was allocated a basic frequency to which it was always tuned pending operational instructions. Basic frequencies were chosen such that all sites, particularly those responsible for first line cover, would have a transmitter available already tuned within ·5 megacycles of any likely enemy signal frequency within the *Knickebein* or Benito bands. A map was prepared on which was displayed all the jamming sites, the position of each being shown by a circle divided into segments. In each segment was indicated the reference number of a particular transmitter, the number being in a colour code which defined its " basic frequency." This display was situated near the Controller's Order Board so that as each enemy signal became active the Controller was able to select the transmitter most adjacent in frequency and situated at the site which was known to be suitable for first line cover. Transmitter operators were therefore able to commence radiating on the desired frequency very quickly without the need for major changes in coupling and aerial matching.

The V.H.F. display system was expanded to provide for Cigarette jamming, when Fighter Bomber and *Egon* controlled attacks were introduced, but the principle remained the same. The procedure, information flowing into the Operations Officer, who passed it on to the Controller, also continued. The control of all subsequent V.H.F. counter-measures introduced became less and less the responsibility of No. 80 Wing Headquarters, outstations operating autonomously, or on direction from other formations. For example :—

(i) Meerschaum was ordered by No. 11 Group Filter Room Controller via No. 80 Wing Controller.

(ii) Briar " H " and Briar " R " were withheld until Air Defence of Great Britain gave orders to proceed when the Controller directed the outstations concerned. In the case of Briar " H " the operations room kept the outstation informed of the position of the leading aircraft and suspected target area. Otherwise the tactical operation was handled locally with information passed direct from the " Y " Service.

Ground Mandrel used defensively in connection with *Egon* controlled attacks was an exception to normal procedure. The Controller ordered this counter-measure to " barrage-jam " immediately aircraft plots indicated that an attack was developing.

With the inception of Operation " Overlord " all V.H.F. jamming radiation was dependent upon approval by the Allied Expeditionary Air Force, whose responsible representative was at H.Q. A.D.G.B. No change in No. 80 Wing operational procedure was necessary except that before any frequency was jammed " Orders " contacted the A.E.A.F. representative by tied line and obtained approval. It was soon apparent that harmonics of jamming transmitters in this country were not causing the anticipated interference to communications concerned with " Overlord " and control procedure reverted to normal.

After D-day the enemy opened his " V " weapon campaign. These were first of all ground-launched from the Pas de Calais area and a percentage carried a small M/F transmitter. This was to enable enemy D/F stations to check accuracy of aim and wind variation. Meaconing of the signals was instituted, the control being situated at Ditchling. As all the bases suitable for launching flying bombs against this country were captured, the enemy began to launch them from aircraft coming from north-western Germany over North Sea. The use of beacons to aid the aircraft in determining the correct launching point was countered by Mimicry. Action taken was shown on the Meacon display board as for Meaconing except that a yellow disc was hung over the allocation. The procedure remained the same as for Meacon Control but the instructions to sites were passed in the following manner :—

" On your Transmitter 12 Mimic 248 on 248 kilocycles."

Big Ben

This operation involved H.Q. Operations Room only so far as correlating information and keeping interested branches such as A.I.2 (g) advised. The work was handled entirely by the Operations Officer.

Bomber Support Operations

From the Spring of 1942 onwards, the Operations Room and No. 80 Wing outstations were responsible for certain Bomber Support Operations. These duties were incorporated in the normal work of sections of the Operations Room. In many cases the work merely entailed forwarding to sites instructions received from higher formations such as H.Q. Bomber Command. The support provided was in two forms, navigational aids and radio counter-measures. These are set out below in the order in which they were introduced, and in each case the way in which control was dovetailed into the defensive organisation is described.

Splasher

The overall times for Splasher to operate each night were passed by Bomber Command who also signified by means of a code letter the degree of importance attached to the operation. The Operations Officer informed each site when it would be required. Sites changed frequency and call sign at irregular intervals in accordance with a scrambled schedule. Meacon Control decoded this scramble and displayed the frequencies, in numerical order, on a Splasher Display Board, a plaque indicating the name of the appropriate site being shown against each frequency. In addition, the transmitters engaged on Splasher at each site were shown by a plaque printed Splasher hung on the Meacon Control Display in the Transmitter Availability and Allocation Section.

Availability and Allocation Section

The Controller, bearing in mind the relative effort by the enemy and by Bomber Command, had to decide whether these beacons were a danger or an asset. Consideration also had to be given, since Meacon equipment was used for Splasher, whether Splasher should be cut to enable important enemy signals to be Meaconed. The Controller was aided in the decision by the category of importance given by Bomber Command when requesting Splasher.

Enemy interference with Splasher, either by Meaconing or by imitations, was countered by "mutilation." A Monitor D/F site was provided at Aldington where every Splasher transmission was kept under constant surveillance. Immediately enemy interference was detected Meacon Control were advised by tied line, *e.g.* "Mutilate 248 kilocycles." Meacon Control, by reference to the Splasher Board, identified the Splasher site and passed Aldington's message to the appropriate site verbatim. The site then distorted its call sign on the specified frequency so that aircrews were immediately advised not to use that particular beacon. When interference ceased Aldington advised Meacon Control—"Return to normal on 248 kilocycles," which was again repeated to the site verbatim. Each message received from Aldington was logged and frequencies being mutilated were shown by coloured discs hung over the appropriate frequencies on the Splasher Display Board.

Oboe Narrow Beams

These beams were maintained and operated entirely by No. 80 Wing personnel. H.Q. Bomber Command specified when they would be required, and the azimuth on which they were to be set up. The Operations Officer encoded Bomber Command's requirements and passed the instruction by telephone to the sites concerned. No display was used but the details were recorded in the Operations Officer's diary.

Oboe–Splasher II

This was a means of passing operational instructions to Oboe aircraft on M/F. Its primary function was to distract the enemy's attention from the two master channels on M/F used for control of Oboe aircraft. Modified Meacon equipment was used, two Meacon sites being connected. Operational times required were advised by H.Q. No. 8 Group and immediately before and throughout the operation liaison was maintained between the Operations Officer and the two master stations at Trimingham and Winterton. This was to ensure that H.Q. No. 80 Wing synchronised with H.Q. No. 8 Group throughout the operation. Transmitters engaged on Splasher II were indicated on the Meacon Display Board by red Splasher plaques hung on the Transmitter Availability and Allocation Section. This was merely to show that the transmitters were not available for other commitments.

Radio Counter-measures

Ground "Mandrel"

Overall times required were passed by Bomber Command to the Operations Officer who recorded the details in the diary and forwarded the times to the outstations concerned.

Grocer

This was requested by H.Q. Bomber Command who gave the Operations Officer the azimuth on which the installation should be set up together with the overall times of operation. This information was encoded by the Operations Officer and passed to the site concerned by telephone.

Cigar

Overall times required were passed by H.Q. Bomber Command. Depending on enemy night fighter reaction Cigar could be used in two ways :—

(*a*) Barrage of the whole *FuGe 16* band by 15 transmitters at Sizewell.

(*b*) Several of the jammers radiating on specified frequency.

Normally the operation was handled by the Operations Officer. It necessitated liaison with the "Y" Service, who gave information as to the frequencies being employed by enemy night fighters.

When activity was on a large scale, Cigar was ordered to "barrage," but when reaction was small the active frequencies were more heavily jammed by concentrating several transmitters on to each frequency. No display was necessary. The Cigar installation at Sizewell could not be effective on bomber routes south of Calais. Use of high power Cigar transmitters on the south coast was vetoed as it was feared too much interference would be caused to friendly communications. For bomber routes south of Calais, therefore, Cigarette transmitters, if available, were employed, and the normal method of displaying action required and orders given was used.

Fidget

The "Y" Service advised Meacon Control immediately any enemy beacon began sending W/T traffic. Meacon Control allocated the beacon to a Meacon transmitter instructing the site concerned. "On Transmitter 12 jam Fidget, call sign "BEATE" on 248 kilocycles." Meacon Control recorded the action taken both in the Beacon Activity Log and on the appropriate Meacon Transmitter Sheet. Action taken was also displayed on the Meacon Display Board as for Meaconing, except that a red disc was hung over the allocation plaque.

Rayon

In a further effort to improve ground to air communication and direction of night fighters, the enemy made use of a *Knickebein* type beam near Den Helder. This signal would change from its normal beam characteristics to sending R/T instructions to night fighters. The usual frequency was 31·2 megacycles per second. A high power jammer modulated with "S" tape—a record of a mixture of German-speaking voices—and fitted with a directional aerial, was installed in Norfolk. Reports indicating that Rayon was required were received by the Operations Officer from outstations in the normal way and the Controller was informed. Counter-measures required and ordered were displayed as for *Knickebein* and Aspirin, except that the modulation was indicated on the "Controller's Order Board" immediately beneath the frequency by a plaque printed "S."

Re-planning of Operations Room

In the latter part of the War, the absence of enemy attacks against this country together with the continual stepping up of the British air offensive resulted in a complete change in the operational function of No. 80 Wing, resulting in its main activity being devoted to Bomber Support. By the end of 1944, the enemy defences had been pushed back so far that ground-based V.H.F. counter-measures from this country in support of Bomber Command were no longer required. This aspect of Bomber Support was being covered very effectively with airborne equipment and with the deployment of ground-based jammers in Western Europe.

With the exception of Special Mandrel on the east coast, dealing with new *Freya* equipment operating between 32–38 megacycles per second the use of ground-based Mandrel in this country had ceased. Grocer had been abandoned with the enemy's A.I. change of frequency, and Rayon was rarely required with the disappearance of the appropriate enemy signals. Splasher II had been discontinued and Cigar was hardly ever required. Fidget, however, had become increasingly important as the enemy developed the system of using beacons for communicating instructions or information to his fighters. Meacon Control, which had for a long time been the "poor relation" of the Operations Room, became the most important section. As attempts were made to extend the effect of Fidget further and further east, the number of enemy beacons on which information was required increased until the existing Meacon Display system became inadequate.

In replanning the Operations Room on offensive lines it was necessary to evolve a system of display boards to show the following information :—

(*a*) Indication of Bomber Command routes and feints so that counter-measures could be applied with most effect.

(*b*) Indication of the number of night fighter beacons active as such or for passing control traffic, their location in relation to the bomber routes, and their call sign and frequency.

(*c*) Allocation of counter-measures, either Mimic or Fidget.

(*d*) Meaconing of enemy long-range navigational aids such as *Sonne*.

In addition, provision had to be made to meet the following new commitments :—

(*a*) Running commentary on operations to H.Q. No. 100 Group to co-ordinate Bomber Support by No. 80 Wing (Rear) and No. 80 Wing (Main).

(*b*) Monitoring of Fidget and Mimic.

(*c*) Introduction of H.F. Fidget to aid Drumstick.

(*d*) Receiving reports from watcher sites on V.H.F. with particular reference to *S.N.2* and I.F.F. used by intruders.

(*e*) Analysing reports received with a view to jamming any transmitter of the *Knickebein* or *Bernhardine* type which might be used by flying bomb launching aircraft.

To obtain a quick and general appreciation of the offensive operations for the night, a display map, edge illuminated and covering an area extending from the British coast to the east of Berlin, was provided. On this map the intentions of Bomber Command and airborne R.C.M. aircraft could be plotted. In addition, the position of all M/F beacons which might be used by the enemy in the defensive operation was indicated by different coloured electric pea lamps which could be switched on or off from a remote panel.

Meacon Control

This department was now sub-divided as follows :—

(*a*) *Meacon Reports Section*.—Responsible for receiving and displaying reports of enemy beacon activity—was manned by two Clerks S.D. A display board, known as the Meacon Reports Board, was provided. Each horizontal column was devoted to one beacon, whilst reading from left to right, the vertical columns being as follows :—

(i) Reference number of beacon.

(ii) Function—to indicate whether active and for what purpose.

(iii) Location of beacon.

(iv) German code name of beacon.

(v) Frequency.

(vi) Call sign.

(vii), (viii), (ix) Allocation and type of counter-measure to be applied.

Each section of the board was provided with pins on which could be hung a plaque bearing the information to be displayed. The enemy beacons with which counter-measures were concerned operated on systems of wedded call signs and frequencies. These systems were known so that immediately one beacon became active the system was established and the call sign and frequency of every other beacon could be displayed. The change of system took place at regular intervals and before each night's operation it was possible to display the call signs and frequencies on which each beacon would operate should it become active. In the three columns reserved for counter-measure display, plaques showing each Meacon site and transmitter number could be hung in accordance with the allocation planned. To distinguish between the three types of counter-measures, coloured discs hung on top of the allocation had the following significance :—

Red	Fidget.
Green	Mimic.
Nil	Meacon.
White	Standby.

Each Clerk S.D. was provided with a pad of proformae on which could be noted all details reported. These were known as "Reports Forms" and were designed to reduce writing to a minimum.

(*b*) *Meacon Orders Section*—responsible for issuing instructions to outstations. A display board was provided similar to the Transmitter Availability and Allocation Section of the earlier Meacon Control Display. It was, however, extended to include the availability of transmitters at No. 80 Wing (Main) and the use of coloured discs was modified to be in line with that employed on the Meacon Reports Board described above. It was further arranged that display plaques should be double sided, black on white to show orders given, and white on black to show orders had been carried out. A further modification was introduced, where possible, to indicate the allocation by means of beacon numbers corresponding to the reference numbers on the Meacon Reports Board. In this Section also, pads of proformae known as "Orders Forms" were provided for the two Clerks S.D. carrying out the duties of "Meacon Orders." On these forms notes could be made of all orders issued to sites and all radiation details as they were obtained.

(*c*) *Meacon Recording Section.*—This Section was provided with a large cardex panel fitted with record sheets each referring to one particular beacon and on which all details of beacon activity and the counter-measures applied could be permanently recorded throughout each 24 hours. One Clerk S.D. was responsible for the duties, the required information being obtained from the Meacon Reports forms and Meacon Orders forms passed continually from the respective sub-section of Meacon Control.

Over all these sections an N.C.O. presided. The duties of the Meacon Control N.C.O. were as follows :—

(*a*) Under the direction of the Controller, ensuring that all appropriate counter-measures were applied.

(*b*) Liaising with H.Q. No. 100 Group to ensure that action taken by No. 80 Wing was appreciated and in conformity with action taken by No. 80 Wing (Main).

(*c*) Receiving teleprinter reports from No. 80 Wing (Main) giving details of M/F counter-measures applied on the Continent and ensuring that such action was displayed on the Meacon Reports Board.

(*d*) Operating the display map switchboard to indicate beacon activity.

So many enemy beacon transmitters were at this time used for passing instructions or commentaries to their fighters that it was found that "Y" Service was unable, whilst still carrying out its many other duties, to observe each beacon continuously and thus be certain of knowing immediately when any of them changed function to sending W/T traffic. It was decided therefore to make use of all M/F receiver sites within the Wing to provide an additional check. This is one of the reasons for the expanded section of Meacon Control dealing with incoming information. The effectiveness of this step was immediately established when it was found that the source of the first intimation that these beacons were operating as communication channels, was distributed evenly between No. 80 Wing outstations and Cheadle. Of course, without D/F, this additional source of information could only be employed whilst the enemy continued to use his existing systems of beacon call sign and frequency allocation. Any change would have necessitated relying again entirely on Cheadle until they were able to establish the new method.

A chart was prepared and distributed to all No. 80 Wing outstations showing the method by which wedded call signs and frequencies were related to beacons in each system employed. There were twelve such systems and these were numbered 1–12. Immediately the system number was established by Cheadle D/F all outstations were advised by Meacon Control thus—" System No. 6 in force ". Outstations then watched the M/F frequency band and reported immediately any of the specified beacons becoming active as such or for passing intelligence. The charts referred to the beacons by reference numbers corresponding to those shown on the Meacon Reports Board. With these charts at all outstations it was therefore possible for Meacon Orders to pass instructions giving beacon reference numbers instead of giving the call sign and frequency. Time on the telephone was thus reduced. The use of the beacon number on the Meacon Order Board, when showing allocations made, assisted cross-reference to the Meacon Reports Board, and reduced writing on " Reports " and " Orders " forms.

Knowledge of the proposed bomber route enabled the Controller to estimate with some degree of accuracy which of the enemy beacons were most likely to be used for passing traffic. It was therefore possible to concentrate the outstation listening watches. This was implemented by issuing instructions through Meacon Control to " Guard " the selected beacons, thus: " Meacon Control—Guard Beacons, 2, 8, 9, 10 and 11."

Even when beacons were being used as such it was sometimes considered that justifiable annoyance could be caused to enemy night fighters and navigators upset by employing Mimic. Unfortunately, the operation had repercussions in that the signal strength of Mimic in this country, compared with that of the enemy beacon being covered, prevented any observation of changes in the beacon function. Whenever Mimic was used, therefore, frequent cuts were made at specified times to enable checks to be made on the enemy beacon activity. Since it was necessary to inform all listening stations including " Y " when each Mimic would be cut, a schedule of staggered cutting times, each column being given a reference letter, was produced and circulated to all concerned. It was then only necessary for Meacon Control to allocate a letter to each Mimic and notify all concerned of the appropriate letter. This again saved considerable time on the telephone. The cutting time letter was indicated on the Meacon Reports Board by a plaque hung on any vacant column opposite the appropriate beacon.

General considerations of Control which had to be considered during each operation included the following :—

(*a*) The number of counter-measure transmitters was insufficient to deal with every enemy beacon which might possibly be active. Discrimination was therefore necessary. In an offensive operation, however, discrimination might give the enemy prior warning of the area of attack.

(*b*) In order to be effective against far distant beacons the power of jamming was increased by using two or three transmitters. This aggravated the situation in (*a*) above.

(*c*) Some of the transmitters available had certain frequency limitations which again complicated allocation.

(*d*) Some of the counter-measure sites were located near friendly Safety Service D/F Stations whose frequencies were adjacent to those of enemy beacons which might be covered. In such cases counter-measures had to be applied from sites as remote as possible from the Safety Service D/F Station.

As the operation was offensive in character, planning enabled many of the difficulties mentioned above to be overcome.

Immediately the system on which the enemy beacon would operate was established, the Controller would plan an allocation of counter-measures against what were considered to be the most dangerous enemy aids. This plan took into consideration frequency limitation of equipment and reduction of interference to friendly channels. Having decided on the allocation which would create the greatest difficulty to the enemy when attempting to oppose the Bomber Force, the following steps might be taken by the Controller :—

(*a*) Withhold Mimic, keeping planned allocation on stand-by and concentrate all effort on Fidget as and when beacons changed to sending traffic or until the bomber stream had emerged from the Mandrel screen and the *area* of attack was already divulged.

(*b*) Reduce any double or treble cover on important beacons and use transmitters so released to Mimic beacons remote from the planned attack. Immediately the extra cover was required on the important beacons, they were re-allocated in accordance with the origical plan, thus ensuring that no technical difficulties would hold up the operation.

To disguise from the enemy any such signs of planning, similar procedure would be adopted even when no major raid was planned, and only No. 100 Group aircraft were operating. It was found that by adopting this planned method, much of the operation could be left to the Meacon Control N.C.O., tactical changes of plan being the responsibility of the Controller.

There was one further complication which was encountered and which involved monitoring of Fidget jamming. Enemy signals were so weak that they were inaudible at Meacon site receivers once their own transmitter site was radiating. Monitoring therefore had to be centralised at a site remote from any of the counter-measure outstations. It was decided to install this Monitor Section in the Operations Room itself where Monitor operators could observe what was required and where operators were immediately available for explicit detailed instructions from the Controller.

Each receiver operator responsible for a small section of the M/F band was provided with split headphones—one earpiece being connected to the receiver output whilst the other was connected to a telephone line. The telephone microphone was fitted to a flexible stand so that it could be moved to a position near the operator's mouth. A switch circuit provided for returning the split headphones to normal, *i.e.* both connected to the receiver output, and connecting the telephone line to a normal hand telephone set. This arrangement had the advantage that, whilst monitoring a transmitter on to an enemy signal, the monitor operator could hear the jammer moving on to frequency whilst conversing with the transmitter operator and advising him what frequency adjustments were necessary.

It was found, however, that where several transmitters were required to Fidget one frequency, considerable time was wasted in the Monitor Section trying to establish which Fidget station was off frequency. The following procedure was therefore adopted :—

> The most powerful transmitter of a group allocated to Fidget one beacon was instructed to " Master Fidget." This implied that the Master Fidget would continuously key a callsign allocated to that outstation. Immediately it had been monitored, the keying would be mutilated except for 30 seconds during every five minutes. Meanwhile, the remaining outstations of the group allocated to the same beacon would be instructed to " Slave Fidget " the Master Fidget. The Master Fidget gave sufficient signal strength for any Slave Fidget to hear the callsign and to adjust frequency so as to be on the zero beat. Each Slave Fidget station also used its callsign continuously but mutilated except for 30 seconds every five minutes. An occasional check by the Slave Fidget ensured that it remained on zero beat with the Master. In this way, as any drift in frequency by the Master Fidget was corrected by the Monitor Section, all the Slave Fidgets followed suit and reduced the work required by the Monitor Section.

Any Slave Fidget, however, which failed to make the necessary frequency corrections was quickly identified by its callsign and brought into line by the Monitor Section.

The whole of the above work can be summarised as follows :—

(*a*) " Y " established the beacon system and notified " Meacon Reports ".

(*b*) " Meacon Reports " advised Controller and all sites of Beacon System and set up callsigns and frequencies on Meacon Reports Board accordingly.

(*c*) Bomber Command and Group intentions received and plotted on Display Map.

(*d*) Controller prepared plan of counter-measures and directed N.C.O. in charge of Meacons accordingly.

(*e*) Controller advised Guard beacons to all sites via Meacon Control.

(*f*) " Meacon Reports " received information of various beacons becoming active from " Y " and outstations. The details were displayed and noted for the information of Recorder.

(*g*) N.C.O. i/c Meacons operated switchboard to display active beacons on map and made allocation on Meacon Reports Board in accordance with prepared plan.

(*h*) " Meacon Orders " instructed outstations in accordance with details on Meacon Reports Board.

(*i*) Outstations telephoned Monitor Section for checking.

(*j*) Outstations reported to " Meacon Orders " when radiating, giving aerial circuit and other radiation details. These details were noted for information of the Record Section and display altered accordingly.

H/F Control

As in Meacon Control, it was planned that this Section would be provided with facilities for receiving and displaying information on enemy signal activity both from " Y " Service (in this case via No. 100 Group) and from the No. 80 Wing listening organisation. Provision was also made for displaying counter-measures which might be ordered and for permanently recording all details of the Section's work.

As it was anticipated that No. 80 Wing (Rear) might become responsible for several existing types of H.F. Bomber Support counter-measures such as Drumstick, Corona, H.F. Jostle and Special Tinsel, arrangements were made to allow for display of these activities and for the rapid expansion of the H/F Control Section on the lines of Meacon Control. Cessation of hostilities, however, occurred before No. 80 Wing undertook any of these commitments. A limited number of transmitters which could operate effectively on the H/F band, 3–6 megacycles, were available within the Wing, however, and, with effect from 20 March 1945, these transmitters were used to support Drumstick. The operation was known as H/F Fidget.

As to the display board provided, this was only used for H/F Fidget. The Control procedure described below therefore will assume that the board only provided for the display of the following information :—

(*a*) *H/F Fidget Reports and Allocation* which displayed the frequency, callsign, and type of each enemy signal reported active and the jamming transmitters allocated to cover each signal.

(*b*) *Transmitter Availability, i.e.* every H/F Fidget transmitter available to the Wing. Since all these transmitters could be equally well be used on M/F by Meacon Control, some indication had to be provided to show for which department each transmitter was available. This was achieved by covering the appropriate transmitter plaque with a further plaque reading M/F when earmarked for Meacon Control. (The Meacon Control Board displayed H/F plaques for all transmitters earmarked for H/F.)

(*c*) *Bomber Command Restricted Frequencies* which were frequencies used by Bomber Command for Communication purposes, and were therefore not to be jammed.

The activities came under the direct supervision of the Operations Officer, assisted by H/F Reports and H/F Orders, manned by one Clerk S.D. respectively. This was adequate to deal with the limited duties existing at the time. Monitoring of H/F Fidget was most important and, as in the case of M/F activity, a Monitor Section was installed in the Operations Room equipped with three H/F receivers and employing the split headphone technique previously described.

Reports of enemy H/F activity concerned with running commentary or control for night fighters were passed to " H/F Reports " by No. 100 Group and by the H/F Monitor Section. The information included the frequency, call sign, and if possible, whether running commentary or control, and by which particular *J.D.* or *Gruppe*. All details were recorded in a log for permanent record and immediately displayed in the first three columns of the H/F Fidget and Allocation Display Board.

The Operations Officer directed " H/F Orders " to allocate a specified jammer to cover each signal. " H/F Orders " contacted the site specified and passed the necessary instructions, at the same time removing the appropriate transmitter plaque from the Availability Section of the Board and hanging it against the enemy signal to be covered. The plaque, printed on both sides, would be displayed black on white background to indicate that the instruction had been passed and would remain thus until the site reported that it was radiating in accordance with the instructions. The plaque would then be reversed to appear white on black background.

Meanwhile, the H/F Monitor Section would search for the signal reported so that the jammer could be monitored on to it as quickly as possible. When each jammer was monitored, the site would be transferred to " H/F Orders " so that radiation details could be obtained to complete the log entries dealing with the enemy signal concerned. Knowledge of the function of each enemy signal enabled control to utilise the few jammers available to the best advantage.

V.H.F. Control

As already mentioned, Special Mandrel was the only active ground-based V.H.F. counter-measure controlled by No. 80 Wing (Rear) in support of Bomber Command. This was handled autonomously by the Special Mandrel Monitor Station during the overall periods ordered by the Controller, who in turn received the directions from No. 100 Group. A continuous watch was maintained, however, by the No. 80 Wing V.H.F. watcher sites for any enemy signals which might become active. Particular attention was paid to signals of an *S.N.2* type which might indicate intruder activity. Any signals observed were reported in detail to the Operations Officer via V.H.F. Reports Section (which now consisted of only one Clerk S.D.). Careful analysis of all these reports was carried out by the Operations Officer to distinguish *S.N.2* type signals from any radiated from friendly G.L. and other radar stations which were very similar in character.

Although a number of G.M.C. transmitters had been modified in preparation for countering *S.N.2*, none of these was deployed until the enemy had already carried out large-scale intruder attacks. On the other hand No. 100 Group were providing facilities at aerodromes for barraging the whole *S.N.2* band when necessary. Therefore any *S.N.2* type signals observed were immediately reported by the Operations Officer to No. 100 Group as warning.

All the remaining V.H.F. organisation was in readiness for defensive operations. Because the threat of V.H.F. navigational aids against this country, however, was by now insignificant, the V.H.F. counter-measure organisation was proportionately reduced, but the Operations Room procedure was basically the same.

APPENDIX No. 5

TYPICAL R.C.M. NIGHT OPERATION 8/9 MAY 1942

As an attack became apparent R.C.M. was instituted and an example of how this was put into effect as the operation developed is illustrated below in diary form. This has been compiled after reference to the Operations Officer's Diary, Starfish Controller's Diary, Meacon Control Logs, V.H.F. reports, charts and jamming logs for the night of 8/9 May 1942.

2208 Cheadle report to Meacon Control that enemy beacons changed to system 10 at 2200 hours. Re-allocation of Meaconing instituted.

2209 No sign of enemy air activity.

2210 Reports being received of Benito Beam active on 42·8 megacycles per second, source—Cherbourg. Ruffians active on 71·1 megacycles per seconds, 70·5 megacycles per second and 68·0 megacycles per second, all from Cherbourg. Reports to S.I. (1) for analysis. Control advised and preparing suitable R.C.M. on standby.

2215 Upper Heyford contacted and two flights (Nos. 1386 and 1387) arranged to investigate any Ruffian Beam which may become active and to report on effectiveness of jamming. Advised of present frequencies. Routes and other details passed to No. 80 Wing Liaison Officer, Fighter Command, for clearance.

2216 Lorenz type signal reported by Radlett Receiving Room on 33·025 megacycles per second. All other watcher sites contacted but none of these can hear the signal.

2220 Bolt Head watcher site reports the line to their D/F site at Bolt Tail is U/S. G.P.O. already advised.

2220 A further Ruffian Beam active from Cherbourg on 73·7 megacycles per second. Reports to S.I. (1) for analysis. Controller advised and preparing suitable R.C.M. Still no sign of enemy air activity. Flights advised.

2230 All Starfish sites have reported "serviceable" except S.F. 10 (C), which is hand-operated only and would take 20 minutes to get going, and S.F. 11 (K), which reports Trunk Sub. line U/S. Weather over whole country is good with good visibility.

2230 Carrier on 65·75 megacycles per second reported active, source—Boulogne. S.I. (1) and Controller advised.

The present Ruffian position is :—

4 beams from Cherbourg	..	70·5, 68·0, 71·1 and 73 megacycles per second.
Carrier from Boulogoe	..	68·75 megacycles per second.

S.I. (1) is now obtaining reports from Southbourne Mobile Unit so that final analysis is possible.

2230 Delabole report modifications to G.M.C. transmitter No. 6 now completed and eqnipment available for operations.

2230 Splasher sites all active as instructed.

2235 Bolt Head report the line to D/F site now O.K.

2236 73·0 megacycles per second now inactive.

Reports being received of carrier on 70 megacycles per second occasionally keying Ruffian type signal, source—Cherbourg. S.I. (1), Controller and Flights brought up to date.

2243 Louth report failure on R.C.A. transmitter being used for Splasher. Fault being investigated. Radlett Receiving Room advised. Louth are still radiating Splasher on three frequencies.

2250 68·0 megacycles per second from Cherbourg now off. S.I. (1) Controller and Flights advised.

2251 Sidmouth report dots on 31·8 megacycles per second. No bearing available. All watcher sites asked to check but signal only heard by Sidmouth. No action taken.

2252 Signal activity at present is as follows :—

Cherbourg	..	42·8 megacycles per second.	Benito Beam.
		70·5 megacycles per second.	Ruffian.
		70·0 megacycles per second.	Ruffian.
		71·1 megacycles per second.	Rnffian.
Bonlogne	..	68·75 megacycles per second.	Carrier.

No jamming has been instituted yet and there is still no enemy air activity.

2306 Receiving Room, Radlett, report Louth R.C.A. transmitter again audible on Splasher.

2310 Cheadle report to Meacon Control that enemy beacons are now working on system 8. Re-allocation of Meaconing being arranged.

2310 71·1 megacycles per second Ruffian now inactive. Controller and Flights advised.

2315 74·5 megacycles per second Ruffian from Boulogne now reported active. S.I. (1) receiving report. Controller allocating R.C.M. in readiness. Flights advised.

2320 Louth report R.C.A. transmitter has been temporarily repaired and is serviceable to-night. Full overhaul and repairs will be carried out to-morrow.

2323 First plots of enemy aircraft on table—two raids 30 miles south of Dunkirk, flying north.

Controller orders Benjamin jammers to radiate on 42·8 megacycles per second. Still no sign of Benito range signal.

Controller orders Bromide jammers to radiate on 70·0 megacycles per second and 70·5 megacycles per second. Radlet Receiving Room advised of jammers ordered on.

2325 Cherbourg Ruffian on 72·5 megacycles per second now active.

Boulogne Ruffian on 74·0 megacycles per second now active.

Carrier on 68·75 megacycles per second now keying as Ruffian Beam from Boulogne. S.I. (1), Flights and Controller advised.

Controller arranging cover for 73·5, 74 and 68·75 megacycles per second but holding back until sufficient reports are available for S.I. (1) to analyse setting.

2330 Four enemy aircraft now plotted.

2331 31·8 megacycles per second now reported off. This signal was heard by Sidmouth only.

2331 Home Security reports via Liaison Officer, Fighter Commaod, fire 25 miles S.W. of Norwich. This is the remains of one started by enemy action during the last raid. Starfish Controller advised, who is contacting Norwich Local S.F. Control for further details.

2332 Controller now orders jammers to radiate on 73·5 megacycles per second. Receiving Room, Radlett, advised.

2334 Cassel Benito range ground station active on 42·4 megacycles per second. Controller advised. Parliament Hill Domino ordered to standby on this frequency. No Benito aircraft heard yet.

2345 Raids mentioned above now heading north of Dutch Isles. Starfish Controller liaising with Starfish site on East Coast. There is no sign of *Knickebein* activity.

2347 Beacon Hill Domino also brought to standby on 42·5 megacycles per second. Benito Ground Station.

2358 Present signal activity position :—

Ruffians Cherbourg	..	73·5 megacycles per second. Jammed.
		70·5 megacycles per second. Jammed.
		70·0 megacycles per second. Jammed.
,, Boulogne	..	74·0 megacycles per second. Jamming withheld.
		74·5 megacycles per second. Jamming withheld.
		68·75 megacycles per second. Jammed.
Benito Cherbourg	..	42·8 megacycles per second. Beam. Jammed.
		42·5 megacycles per second. Conttol. Domino standing by.

S.I. (1) advises that complete set of Ruffians are active and laid in Norfolk area. D.A.C., Fighter Command, and D.G.C., Air Ministry, advised.

2358 " Y " Service, Kingsdown, confirm no Benito aircraft heard yet.

2359 Starfish Controller concentrating liaison with sites in Norfolk.

0002 Benito Beam reported on 43·0 megacycles per second, source—Cassel. Controller orders jammers to radiate on 43·0 megacycles per second. Receiving Room, Radlett, advised.

0005 Controller orders Bromides to jam 74·0 megacycles per second.

0010 Cheadle report enemy beacons on system 12 at 0005. Re-allocation of cover instituted.

0018 Four enemy aircraft left enemy coast near Dutch Isles flying N.W. as far as latitude of Norwich, then turned West.

0020 67·25 megacycles per second. Ruffian Beam active from Boulogne. Controller orders Bromides to jam 67·25 and 74·5 megacycles per second. Receiving Room, Radlett, advised. Final analysis by S.I. (I) indicates beams laid in Norwich area.

0030 There are now three enemy aircraft coming in towards Norwich.

0035 Parliament Hill report hearing an aircraft B.D. calling the Ground Station T.2.

0040 First enemy aircraft has crossed Norfolk Coast. All jammers are radiating.

0043 Starfish Controller in contact with Norwich get report that flares have been dropped about 3 miles S.E. of City, just South of Starfish Site 43 (B).

0050 Parliament Hill report aircraft re-radiating 42·5 megacycles per second. Benito range signal. Domino action taken.

0052 Aircraft now concentrating on Norwich.

0057 Norwich report to Starfish Controller flares and fire South of City; also H.E. dropped.

Instructed Local Control of set off Short Starfish 43 (B) at Bramerton. About eight enemy aircraft now approaching from East.

0105 Cheadle report enemy beacons changed to system 13.
Meacon Control re-allocating cover.

0106 Norwich report to Starfish Controller that Site 43 (B) Short Starfish was set off at 0102. No report of any more flares.

Flares and bombs dropped South of Norwich. Will advise if 43 (B) is attacked.

0110 There are now approximately 16 enemy aircraft approaching Norwich from East and North-East.

0118 There are now 10 enemy aircraft over Norwich and nine more coming in.

0120 Flights report jamming effective.

0125 Starfish Controller cannot raise Norwich Starfish.

0140 Scole Splasher ordered to cut. Bomber Command advised.

0140 Starfish local Control at Norwich now contacted on tieline.

Norwich exchange evacuated and forgot to switch over to emergency board.

Norwich report eight H.E.s and one U.X.B. collected within 800 yards of Short Starfish 43 (B).

About 30 bombs dropped in vicinity of Norwich, mostly in outskirts. Fire reported at Stoke Holy Cross but no fires in Norwich. Enemy aircraft appear to be between Norwich and coast but are wandering.

0148 There are still seven enemy aircraft near Norwich. Remainder have gone home.

0155 There are now three enemy aircraft crossing coast on way home. There appear to have been some 30 enemy aircraft involved in tonight's raid.

0200 Table now clear.

0210 Beacons changed to system 7 at 0200.
Cover re-allocated.
Bromides switched off as Ruffians became inactive.

APPENDIX No. 6

No. 80 WING LIAISON SECTION AT HEADQUARTERS, FIGHTER COMMAND

Formation of the Liaison Section

In September 1940, the No. 80 Wing Liaison Section, composed of four Technical Signals Officers on a 24 hours watch-keeping basis, was installed in the Fighter Command Operations Room, at Stanmore, in the position adjoining the War Time Control of the Radio Transmissions Section.

The primary duty of the section was to pass to Headquarters, No. 80 Wing, at Garston, and from 14 October 1940, at Radlett, all available information concerning hostile tracks appearing on the Fighter Command Operations Room table, and to pass to the Fighter Command Air Staff information from H.Q. No. 80 Wing which might be of assistance to them in the defence of the country from air attack.

The Fighter Command Operations table received its information from R.D.F. and Observer Corps sources, and purported to show all aircraft, both hostile and friendly, approaching or flying over the United Kingdom. As time went on and hostile air attacks developed, the duties and responsibilities of the section increased and varied.

Amalgamation of No. 80 Wing Liaison Section with the Radio Control Section

At the end of November 1940 the No. 80 Wing Liaison Section, and the Radio Control Section composed of four A. & S.D. officers who had previously been under the control of the Chief Air Raid Warning Officer, were amalgamated—two officers being retained from each section. The section continued to be so constituted until April 1941 when it was decided that it could effectively be manned by four A. & S.D. officers, and it was so constituted until its final termination in June 1945.

Liaison Section Log

It was the duty of the Liaison Officer to record in the section's log all items of information passed to and received from H.Q. No. 80 Wing, and elsewhere, during his watch, and it is largely from these logs that this account is taken. The first item appears on 24 September 1940, shortly after the section had taken up its position in the Operations Room.

No. 80 Wing Investigation Flights

The Airborne Units of No. 80 Wing carried out investigational flights in connection with its radio counter-measure organisation. Details of these flights were received from H.Q. No. 80 Wing and passed by the Liaison Officer to the Fighter Command Operations Officer, to those Fighter Group Filter Controllers concerned, if they were crossing the coast, and to the Movement Liaison Officer. It was the duty of the Liaison Officer to pick out these flights, when possible, on the table, and to pass to H.Q. No. 80 Wing at the time any information required as to position, height and speed. The Liaison Officer either kept or obtained tracings of the tracks of these flights if so requested by H.Q. No. 80 Wing. He also obtained from Fighter Command permission for any proposed flights over prohibited and other special areas.

Discrimination of Information

In the early days before No. 80 Wing operated its own listening stations most information concerning enemy beams was passed by the " Y " Service to the Liaison Officer, who in turn passed it to H.Q. No. 80 Wing.

On 27 September 1940, the Liaison Officer was ordered to send daily by teleprinter a signal to the Duty Staff Officer, Whitehall, with copies to O.C. No. 80 Wing, and the D.D. of S. " Y," Air Ministry, stating particulars of beams identified, giving origin, bearing, frequency, times on and off, general outline of counter-measures taken by No. 80 Wing, the period covered, general information of investigation flight reports, unusual characteristics and observations, and a list of M/F beacons meaconed and those left for Bomber Command. This responsibility was, however, taken over by H.Q. No. 80 Wing as soon as its organisation was sufficiently equipped to undertake it.

The Liaison Officer continued to receive a report from H.Q. No. 80 Wing before 0500 hours daily, of the hostile beams active and the counter-measures taken during that night. This was presented to the Duty Air Commodore each morning for inclusion in his report, together with a report of any Starfish employed during the period, giving the general situation, the type of Starfish used and the time on.

Headache Report

The Liaison Section sent a report by teleprinter to H.Q. every twelve hours, giving a résumé of all enemy activity during the period and any other operational information of interest to the Wing. The report was sent at 0700 and 1900 hours daily, and was called the Headache Report.

On 28 September 1940 it was decided that the Liaison Officer should pass to the Duty Air Commodore at Fighter Command the following beam information :—

(*a*) Time on. (*c*) Point of origin.
(*b*) Frequency. (*d*) Time off.

On 30 November 1940 the Liaison Officers were instructed to keep a special watch for possible aircraft of *K.G. 100* and *K.G. 26*. These aircraft generally preceded the main attack, and at that time approached from the Brest and Channel Islands areas. It was their practice to fly on a meandering course to within about 20 to 30 miles of their target, and then to fly absolutely straight to it. The Liaison Officer was, on numerous occasions, able to pick out enemy aircraft of the above type, and to give early warning to H.Q. No. 80 Wing that they were on their way. Negative beam information was also passed to Fighter Command from H.Q., *e.g.* " 80 Wing has reason to believe that *K.G. 100* will NOT operate to-night."

On 30 November 1940 it was laid down that the Liaison Officer would also, between 1500 and 2359 hours, pass to the Duty Night Operations Staff Officer, in addition to the Duty Air Commodore, the Naval Liaison Officer, the Duty Intelligence Officer and the Anti-Aircraft Liaison Officer, all information of suspected or confirmed beams, and other information concerning targets received from No. 80 Wing. On 13 December 1940, the Admiralty asked to be informed of suspected enemy targets in this country as early as possible, to enable their Bomb Disposal Squads to be despatched well in advance.

Security of Information

It was found by the Air Ministry that this distribution of information of such a highly secret nature was too wide and was, by some means, actually reaching certain authorities in the actual target areas before the attack took place. It was therefore decided on 26 February 1941 that the Liaison Officer should only give his beam information to the Duty Air Commodore by day, and by night to the Duty Night Operations Staff Officer. The Duty Air Commodore's Instruction No. 18 of 3 June 1941 again stressed the secrecy of this beam information and continued similarly to restrict the distribution.

The Duty Air Commodore's Instruction No. 19 of 9 August 1941 limited distribution to the C.-in-C., S.A.S.O., D.N.S.O., Anti-Aircraft Liaison Officer and the Group Commander concerned or his representative. This distribution continued for some long time, until beam information was finally authorised to be passed by one Liaison Officer to the Duty Air Commodore, the No. 11 Group Filter Controller (if the beam passed through their areas), the Intruder Controller (during hours of darkness), A.A. Command Intelligence and " Y " Service Liaison Section at H.Q., Fighter Command. A record was kept by the Liaison Officer in addition to the log entry, of the time, type of beam approach, target and remarks under the heading B.A. (Beam Activity).

There is no doubt that this target information service was of great assistance to the Air Staff at Fighter Command, especially in the days when No. 80 Wing knew long beforehand what the target was likely to be. As time went on, the enemy must have become aware of some of the workings of this organisation, when he adopted the practice of not bringing up his radio aids until just before, or during, an attack.

Daylight Enemy Reconnaissance Aircraft

No. 80 Wing were especially interested in the tracks of any enemy reconnaissance aircraft during the daytime which might give some indication of the target for a coming night attack. These raids were told through to No. 80 Wing in detail as they proceeded, and were often associated with the testing of the enemy's navigational radio aids.

Interpretation of the Plotting Table

During all raids, it was the duty of the Liaison Officer to outline on the tie-line to No. 80 Wing, in addition to giving every track from its start to its finish, the progress of the raids and the apparent intentions of the enemy. It was not unusual for two or more lines of approach to be developing at the same time. Ability to assess the table could only be acquired by experience, and it would have been possible for an inexperienced observer to have given an altogether incorrect summary of the position as appearing on the table. Early anticipation of the intention of the raiders was of special assistance to the Starfish Controller, and saved him from needlessly lighting decoys.

In order that a Liaison Officer should have the complete operation picture in his mind, it was found expedient for one officer to be on duty for the whole of each night, and this practice was adopted. It was not possible for the table to give a completely accurate picture of the position at any given time, and in assessing the table all available extraneous information, height, speed, number of aircraft, weather, had to be taken into consideration to give a bearing on the intentions of the enemy, and to result in the accurate interpretation of the table. It was not an infrequent occurrence, during times when a large number of friendly bombers was going out or returning, for a number of hostile aircraft to appear on the table for the first time overland. It was on such occasions that the Liaison Officer had to keep an especial watch, especially for his radio control commitments. At the end of each phase of hostile activity, the Liaison Officer gave a résumé of that phase to the Operations Officer at H.Q. No. 80 Wing.

Throughout the war, the Liaison Section " told " to No. 80 Wing the tracks of well over 100,000 hostile aircraft. This figure does not include those plotted over the Normandy beach-head from D-day onwards. No. 80 Wing was interested in these tracks in connection with some of their commitments, and all such tracks appearing on the Fighter Command Operations table were " told." Owing to the large number of aircraft present, most of the plotting had then to be of the area variety. This form of plotting, although inevitable, made accurate assessment of the position extremely difficult. No. 80 Wing was particularly interested to see the effects of their counter-measures on the enemy tracks, and the Liaison Officer immediately informed the Controller whenever such success was apparent. During very prolonged periods without hostile attacks, the Liaison Officer " told " dummy raids to H.Q. in order to keep the plotters in training.

MAIN DUTIES OF THE LIAISON SECTION

Tracings of Hostile Tracks

Fighter Command kept, during the whole of the war, tracings of all hostile tracks appearing on their Operations Room table. Composite tracings of these tracks were prepared by Intelligence and sent to No. 80 Wing. As these composite tracings did not reach there until several days after the raids they recorded had taken place, the Liaison Officers made their own small tracings during each raid, showing the times, number of enemy aircraft, general lines of approach, targets, any unusual features, homeward tracks, etc., and for the sake of completion all beams active during the activity. These small maps were sent over each morning following enemy night activity to No. 80 Wing by D.R.L.S. thus permitting an immediate analysis without waiting for the composite phone enquiries, and were undoubtedly of great assistance.

Ministry of Home Security

The Ministry of Home Security Liaison Officer sat next to the Liaison Officer in the Operations Room, and passed to him, as it was received, all available information concerning hostile flares, fires, high explosives, and other incidents reported. The Liaison Officer immediately passed this information to No. 80 Wing who were thus able to follow the trend of the raids, and the success or failure of each attack. A special "Fighter Priority" was instituted in August 1942, whereby all incidents were reported by special lines to Fighter Command with the minimum delay.

Information concerning fires was similarly received from the Fire Control via the H.S.L.O., and passed to No. 80 Wing for use by the Starfish Controller.

After the night's activity had concluded, the Liaison Officer passed to No. 80 Wing a complete list of all incidents during the period. This was followed up by the daily "Green Form" issued by the Ministry of Home Security.

The Liaison Officer obtained from the Key Points Intelligence Branch, a department of the Home Office, a complete map of all potential targets in the United Kingdom. This map, which was kept up to date, enabled No. 80 Wing in conjunction with the hostile tracks to anticipate the less important targets the enemy might attack.

The Liaison Officer passed every night to No. 80 Wing from the Fire Control via H.S.L.O., reports of any fires not due to enemy action which showed a light visible from the air and might be used by the enemy as beacons in the event of a raid. The Liaison Officer also obtained from the H.S.L.O. reports of any crashed enemy aircraft or captured crew. No. 80 Wing was thus assisted in their quest for hostile radio equipment, and sometimes information bearing on the success of their counter-measures was obtained.

Weather Reports

H.Q. No. 80 Wing relied on Fighter Command for its weather reports. It was the Liaison Officer's duty to see that a dawn to dusk and dusk to dawn, weather forecast was despatched by the Meterological Section to No. 80 Wing by teleprinter. These reports were frequently also passed by telephone by the Liaison Officer to No. 80 Wing. In addition, the Liaison Officer, on request, passed particular weather conditions, both here and on the Continent, which were obtained from the six-hour chart in the Operations Room. Weather was often required by No. 80 Wing for their investigational flights, and was then specially obtained by the Liaison Officer from the Duty Forecaster. During the invasion period, frequent weather reports were requested and obtained.

Cloud Forecasts

On 4 April 1942 the G.A.F carried out three successful single aircraft raids, at intervals of about 30 minutes, on the Brockworth Factory and airfield near Gloucester during daylight, taking advantage of the cloud conditions existing at the time. On 5 April 1942 the Director-General of Signals issued instructions that radio counter-measures similar to those then employed by night should be employed during the daytime.

In May 1942, in order to reduce wastage of valves anticipated by a 24-hour service, it was decided that only under certain cloud conditions would daytime counter-measures be initiated. The Liaison Officer and Duty Meteorological Officer at H.Q. Fighter Command were ordered to co-operate, and it was arranged that the Liaison Officer should obtain from the Duty Forecaster at 0500 hours, for onward transmission to No. 80 Wing, a forecast when pre-frontal altostratus cloud or stratocumulus cloud was expected for that day. On days when no operational cloud was expected negative reports were obtained.

England and Northern Ireland were divided into nine areas. A copy of the area map was held at No. 80 Wing, and the various districts were referred to by the number in their respective areas. On days when a warning was given, special hourly maps were maintained by the Forecaster, in order that the Liaison Officer might be kept informed of the cloud movements. It was the Forecaster's duty to inform the Liaison Officer of any change in cloud conditions not covered by the forecast. The Duty Air Commodore was instructed to advise the Liaison Officer in cases of doubt of difficulty.

In October 1943, it was arranged that the Duty Forecaster should advise the Liaison Officer, for onward transmission to H.Q., when frontal cloud conditions existed at night. This was very useful, in view of the enemy's growing practice of bringing up radio aids at the last minute.

"Albino" and "Mutton"

The Liaison Officer passed to H.Q. prior warning of the balloon operation "Albino," and the aerial mine operation "Mutton," primarily to prevent investigational flights from being sent over prohibited areas, or those likely to be affected. At the request of No. 80 Wing, the Liaison Officer, on a few occasions, successfully arranged for "Mutton" to be postponed so that it did not interfere with vital and specially arranged flights.

Smoke Screens

In order that the Controller and Starfish Controllers at No. 80 Wing might be in possession of the full picture of defensive measures taken against the enemy during an attack, the Liaison Officer obtained and passed to the Wing the times and sites of all smoke screens laid. This information came via the H.S.L.O., when smoke screens were under Home Office control, and from the Operations Officer at H.Q. Fighter Command, from 1 April 1943, when the R.A.F. took over the control of smoke screens and allocated their operation to A.A. Command.

Bomber Programme

Each morning, the Liaison Officer passed to No. 80 Wing the number of bombers, targets and casualties of Bomber Command for the preceding night.

"Y" Section at H.Q. Fighter Command

A close liaison was maintained between the Liaison Officers and the "Y" Liaison Officers. In this way, much useful information was passed to No. 80 Wing as to enemy units likely to operate, bases, beacons, and areas of operation. It was suggested in 1942 that the two sections should be amalgamated. The Officer Commanding No. 80 Wing raised strong objections, informing H.Q. Fighter Command that the results obtained from his counter-measures organisation depended largely on the efficiency of his Liaison Section which must operate as a separate entity.

No. 80 Wing had a direct line to Cheadle in order to obtain essential information immediately, but there were numerous occasions when the Liaison Officer obtained the information via the "Y" Officer at H.Q., Fighter Command, before it had been passed by Cheadle to No. 80 Wing.

"Trinity"

Briefly, this was an operation at the end of 1941 for the bombing of the German warships at Brest with the aid of approach beams. The Liaison Officer gave, from No. 80 Wing, prior details of these attacks to the Duty Air Commodore and the Operations Officers could be informed. The Duty Air Commodore also informed the A.O.C. No. 10 Group in order that certain R.D.F. equipment in his Group which was found to interfere with the operation could be switched off.

During the attacks, the Liaison Officer "told" to No. 80 Wing the complete tracks, where possible, of all the aircraft taking part in the operation, from the time they left their bases until their return. Tracings of these tracks were made by the Liaison Officer at the time and sent to No. 80 Wing.

R.A.F. Intruder Aircraft

Soon after the R.A.F. Intruder Operations commenced, it was found advisable that the Intruder Controller should be informed as early as possible of the target likely to be attacked by the G.A.F., so that the intruder targets could be chosen as early as possible. It was therefore arranged, on 27 June 1942, that all No. 80 Wing information should be passed via the Liaison Officer and the Duty Air Commodore to the Duty "Y" Officer, who passed it, together with any "Y" information, to the Intruder Controller. This roundabout method was abolished eventually, and No. 80 Wing information was passed direct to the Intruder Controller.

Washtub

At the beginning of 1942, the enemy began to interfere with the R.A.F. M/F beacon system. Before the multiple beacon system could be worked out to counteract this interference, the B.B.C.s aid was sought. Droitwich V unsynchronised was made available to Bomber Command as a beacon. It afforded excellent "homing" facilities for aircraft within 150 miles, and being of such high power could not be easily jammed in the districts of the United Kingdom to which Bomber Command aircraft wished to navigate. On request from Bomber Command through No. 80 Wing, the Liaison Officer advised the Senior Control Room Engineer, at the B.B.C. when the transmitter was required. The transmitter, however, always remained liable to be closed down by the Radio Control Officer in the event of hostile raids making this advisable.

Fighter Command Bullseye Operations

From about July 1942, Bomber Command, in conjunction with Fighter Command and A.A. Command, carried out practice interception exercises at night. In order that No. 80 Wing investigational flights should not be confused with aircraft taking part in these exercises, the Liaison Officer passed to Headquarters particulars of them beforehand.

Interference with R.D.F.

Early in 1942, the enemy started to interfere with R.D.F. This interference varied in intensity, and was usually experienced before and/or during an attack in the South-East of the operational area of No. 11 Group. No. 80 Wing was interested in such interference, inasmuch as it indicated future enemy aircraft activity and enabled them to be ready with their counter-measures, especially as it had become the frequent practice of the enemy not to bring up his radio aids until the very last minute. Interference was, however, not always accompanied by raids, "spoof" interference being quite a normal practice.

It was the Liaison Officer's duty to obtain from the Fighter Command Operations Officer and/or the No. 11 Group Filter Room Controller notification of any interference, its extent, and stations affected. This was immediately passed to No. 80 Wing who were notified as soon as it had ceased. Before 0645 hours daily, the Liaison Officer obtained from the No. 11 Group Filter Room, for onward transmission to the Director of Telecommunications, via No. 80 Wing, all interference occurring during the preceding 24 hours. This information comprised the periods within which each interference took place, and the extent each station was affected. The codeword for interference was "Visitors." This interference continued until the middle of September 1944.

Starfish

When a Starfish was ordered off by the Starfish Controller at No. 80 Wing, details of the time, type and location were passed to the Liaison Officer, who passed them to the Duty Air Commodore in writing and to the H.S.L.O. verbally. The Starfish Controller required times when areas in which their Starfish were ignited received "Red" and "White" warnings from the Air Raid Warning Sections. This information was obtained by the Liaison Officer and passed to No. 80 Wing on the following day, when requested.

The Liaison Officer had an elaborate wall map, showing all the decoys it was proposed to employ in connection with the Normandy invasion. He was to be responsible for operating this map during the invasion and for keeping No. 80 Wing informed of the decoys employed. This map, however, was never brought into operation, and was returned to Colonel Turner's Department.

Meerschaum

In February 1944, it was known that enemy aircraft raiding this country were equipped with backward looking A.I. (*Neptun Gerät*) by which they were able to detect the presence of intercepting fighters. A scheme was worked out for jamming this device by special group equipment located at certain C.H., G.C.I. and certain No. 80 Wing stations. Immediately enemy aircraft likely to raid this country were plotted on the No. 11 Group Filter Room table, the Duty Controller passed the following message to the Liaison Officer: "Meerschaum on." The Liaison Officer passed this message immediately to the No. 80 Wing Controller who was responsible for passing all executive jammer messages to the jamming units located on No. 80 Wing Sites. The counter-measure was concluded by the passing of: "Meerschaum off" by the No. 11 Group Filter Controller and onwards in a similar manner. The operation continued until 14 May 1944.

Fighter Command Ops. 3 Conference

From March 1944, the Liaison Officer attended the Ops. 3 Conference each morning at 0915 hours, at which the hostile activity for the preceding night was discussed. The Liaison Officer furnished the Conference with full details of any hostile beam or beacon activity which had taken place during the period, and any Starfish data. The Liaison Officer on duty during the period prepared comprehensive details of the enemy operation, including a list of flares which usually preceded an attack at that time, in addition to the No. 80 Wing information.

"Bareback"

In May 1944, the B.B.C. transmitters at Washford and Brookman's Park were made available between 2330 and 0600 hours daily for counter-measures against German instructions to aircraft emanating in W/T from Calais I, which operated on frequency of about 583 kilocycles. As soon as the Liaison Officer had any indication of impending air raids against the United Kingdom, it was his duty to advise the Duty "Y" Officer who in turn advised Kingsdown. Immediately Kingsdown received this warning, they passed the following advice to the Senior Control Room Engineer at Broadcasting House: "Operation 'Bareback'—B.B.C. Transmitter stand by." When the transmitters were actually required, Kingsdown gave the Senior Control Room Engineer the following immediate message: "Operation 'Bareback'—Control required." The Senior Control Room Engineer then connected the key lines and held the transmitters ready for radiation when required. At the end of the raid, or when the Liaison Officer considered a raid unlikely, he passed this message to the Duty "Y" Officer "'Bareback' country clear." The transmitters were then stood down, or if the Liaison Officer anticipated further raids shortly, he requested "'Bareback' to stand by." As all the transmissions on this operation were short and intermittent, it was not thought that enemy aircraft could make use of them as navigational aids. This operation was finally merged into the operation called "Dartboard."

"Dartboard"

Under this operation, the P.I.D.'s transmitter Aspidistra at Crowborough, Sussex, and the B.B.C.'s transmitter, Moorside Edge 3, near Huddersfield, were made available to Bomber Command for jamming German medium frequency broadcast instructions to night fighters.

The Liaison Officer was only concerned in this operation by reason of his Radio Control duties. In the event of enemy raids occurring while Aspidistra was radiating continuous programmes for "Dartboard," the Radio Control Officer could close it down in the normal way. As soon as Aspidistra received "close down" instructions from the Senior Control Room Engineer, they immediately ceased programme radiation and handed over the transmitter to Kingsdown, so that the latter might key in the short bursts necessary to jam enemy fighter instructions. The need for strict control of the Radio Control Officer of programme transmission is obvious, since Aspidistra was a very powerful beacon in a most dangerous situation. The keying of "Dartboard" in short bursts did not deprive Bomber Command of its use, and was of doubtful use to the enemy.

Flying Bombs (Diver)

Between 13 June 1944 and 29 March 1945, 8,804 flying bombs were plotted, 5,605 crossed the coast and 2,302 reached the target area. Of these, 753 were air-launched, 526 crossing the coast and 106 reaching the target area.

In order to Meacon these flying bombs fitted with W/T apparatus the Liaison Officer passed to No. 80 Wing, and to Ditchling also when that station was operating, the following information concerning each of all these flying bombs during each phase :—

(*a*) First plot and time.

(*b*) Track.

(*c*) Crash pin-point.

(*d*) Time of crash.

(*e*) Home Secretary details of damage and casualties.

Every three hours the Liaison Officer also passed a complete list of flying bombs during that period, giving—

(*a*) Raid number.

(*b*) First plot.

(*c*) Landfall.

(*d*) Fate.

(*e*) Time.

The Liaison Officer gave in his 12-hourly report details of each phase of flying bombs during the period. Details required were—

(*a*) Times of phase.

(*b*) Number despatched.

(*c*) Number crossing the coast.

(*d*) Number reaching the Greater London area, and

(*e*) Claims by :

(i) Fighters,

(ii) Guns, and

(iii) Balloons.

During the air-launched attacks, tracks of the parent aircraft, if plotted, were passed.

Wind Speeds

To enable No. 80 Wing to work out the possible drift of flying bombs caused by wind, the Liaison Officer obtained from the Duty Forecaster at H.Q., Fighter Command, the wind states at surface, 2,000 feet and 5,000 feet every three hours. This was passed to No. 80 Wing from 24 June 1944 onwards.

Rocket Projectiles (" Big Ben ")

At 1843 hours on 8 September 1944 the first rocket projectile arrived in this country at Chiswick. Between this date and 1654 hours on 27 March 1945, when the last one fell at Orpington, some 1,115 were reported by the Ministry of Home Security.

Many of these projectiles were radio controlled, consequently an R.C.M. organisation was set up at Beachy Head. The Liaison Officer passed to No. 80 Wing, from the H.S.L.O. and the Scientific Observer in the No. 11 Group Filter Room, all the crash points, and firing points of these missiles, as they were received. Details of damage, craters and casualties were at first passed in detail, but this was found unnecessary, and damage information was only passed on request after 13 February 1945.

A.E.A.F.

During the time that A.E.A.F. maintained a Signals Security Section at Stanmore (*i.e.* from February 1944), the Liaison Officer passed to that Section each morning a copy of his Duty Group Captain's report of any beam active during the previous 24 hours, and counter-measures taken.

The Liaison Officer also obtained, from 4 January 1945, from the " Y " branch of the A.E.A.F. a report each afternoon of any strategic or mine-laying operations undertaken by the G.A.F. over the Continent on the preceding night. Details required were—

(*a*) Time.

(*b*) Scale of attack.

(*c*) Target (bombing or mine-laying) and, if possible,

(*d*) Type of aircraft and Unit employed.

This information was passed to No. 80 Wing between 1400 and 1500 hours daily.

Coastal Command Operations

In February 1945 No. 80 Wing became interested in any Coastal Command operations over the area from Norway to Dover which might invite hostile reaction. The Liaison Officer therefore obtained from the Coastal Command Liaison Officer, between 1700 and 1900 hours daily, details of all such operations orders for the coming night. This information was then passed by Scrambler telephone to No. 80 Wing.

APPENDIX No. 7

WAR-TIME CONTROL OF RADIO TRANSMISSIONS

Formation of Sub-Committee for the Control of Radio Transmissions

In 1936, the Committee of Imperial Defence formed a Sub-Committee called the Control of Radio Transmissions Sub-Committee. This Sub-Committee on which all interested parties were represented, was under the chairmanship of the Director of Signals, Air Ministry, and its object was to inquire into the action necessary in the event of war to prevent radio transmissions in the United Kingdom, with special emphasis on broadcasting, from being a definite aid to navigation to the enemy.

Radio Control Decisions

The Sub-Committee decided that all wavelengths between 200 and 10,000 metres with radiated power of over 500 watts would constitute a danger, and would have to be controlled. This involved stations operated in the United Kingdom by

(*a*) the G.P.O. ;

(*b*) Cable and Wireless, Ltd. ;

(*c*) the Admiralty ;

(*d*) the Army ;

(*e*) the R.A.F. ;

(*f*) all Civil Aviation ;

(*g*) the Home Office (*i.e.*, the Police) ; and

(*h*) the British Broadcasting Corporation.

It was decided that broadcasting should be suspended during enemy raids on the United Kingdom, aud that all other stations should also be closed. Lists of the stations which the Sub-Committee recommended to be closed in the event of raids were prepared.

The Admiralty reserved to itself the right to break silence in the event of Naval needs making this imperative.

Cable and Wireless, Ltd., were, in fact, at no time affected during the war for the reason that no enemy aircraft was ever found whose D/F apparatus operated on wavelengths used by Cable and Wireless, Ltd., namely between 2,000 and 10,000 metres. It was, however, thought in December 1940 that their transmitter at Ongar might be assisting the enemy, but this suggestion was finally discredited.

All Civil Aviation wireless was taken over by the R.A.F. and became part of the Service M.F. D/F organisation, and was as such liable to control.

Admiralty Beacons

The coastal radio beacons operated by the Admiralty were suspended on the outbreak of war. The Admiralty subsequently were allowed to restore the services of certain of these beacons covering the North-Western Approaches, which were found to be essential for marine navigation. Where possible, the beacons brought into service came under control—some, however, were too remote and without telephone or R/T facilities, and were therefore Meaconed by No. 80 Wing to prevent their being used by the enemy over vital land areas, or operated on an " on request " basis only. By the end of 1944 all West Coast beacons were operating.

French Broadcasting Stations

A scheme to control the French broadcasting stations was introduced but this did not in practice prove satisfactory, and was soon dropped.

Recommendations of the Sub-Committee were finally approved by the Committee of Imperial Defence, and are briefly summarised as follows :—

(*a*) Broadcasting should be synchronised.

(*b*) The Air Ministry should be responsible for the control of radio transmissions.

(*c*) Lists of all stations likely to be affected should be prepared.

Formation of Radio Control Section

The above recommendations and a decision by the Air Ministry to delegate the authority for the issue of executive close-down instructions to Headquarters, Fighter Command, led to the formation of the Radio Control Section in the Operations Room at Headquarters, Fighter Command, in September 1939.

The Section was composed of four A. and S.D. officers on a 24-hours watch-keeping basis, and came, until November 1940, under the control of the Chief Air Raid Warning Officer.

Amalgamation of Radio Control Section with No. 80 Wing Liaison Section

In November 1940, the Radio Control Section was amalgamated with the No. 80 Wing Liaison Section, but the responsibility for the control of radio transmissions remained vested in Fighter Command.

Transmitters Controlled by No. 80 Wing Liaison Section

The following transmitters were controlled by the No. 80 Wing Liaison Section :—

(*a*) All B.B.C. high-powered transmitters. (The remaining lower powered transmitters were closed by the British Broadcasting Corporation itself on an alert being sounded in the area in which the transmitter was situated.)

(*b*) All Naval transmitters and coastal beacons.

(*c*) All Police transmitters.

(*d*) All G.P.O. transmitters.

(*e*) All R.A.F. beacons, mobile and otherwise, and the M.F. D/F organisation.

(*f*) From November 1942 the transmitters, known under the code word of Aspidistra belonging to the Political Intelligence Department which had been installed near Crowborough in Sussex for propaganda purpose.

Communications

The Section was provided with tie-lines to the British Broadcasting Corporation's Control Centre in the basement of Portland Place, and to its stand-by Control Centres at Maida Vale, Wood Norton in Worcestershire, and at Aldenham in Hertfordshire. Except for test purposes, on very rare occasions only was it necessary for the Radio Control Officer to communicate with the stand-by by Control Centres.

Close-down Instructions to B.B.C. Control Room

The Control Room at Portland Place was under the direct control of a Senior Control Room Engineer who was under instructions to accept all close-down orders from the Radio Control Officer without comment. The Senior Control Room Engineer was able to switch off any transmitter practically simultaneously with his instructions from Fighter Command.

A remarkable liaison was established between the Radio Control Officers and the Senior Control Room Engineers, and it would be fair to state that on less than a half-dozen times during nearly six years did any misunderstanding arise.

Orders for Control

All close-down messages from the Radio Control Officer were passed in a prescribed form, viz., " Fighter Command speaking—awake—close (*e.g.* Brookman's Park 1) Clodat," and to open " Fighter Command speaking—awake—reopen (*e.g.* Brookman's Park 1) Clodat." During the period that Fighter Command ceased to exist under that name, the title Air Defence of Great Britain was, of course, snbstituted.

In the event of the code word Clodat becoming compromised, reserve code words Castop or secondly Kerbit were provided by Signals, Air Ministry. It was never, however, necessary to use either reserve code word.

Radio Control Section Records

A record was kept by the Section's Duty Clerk of all closing and opening times and tallies were put on a wallboard containing all current stations in their respective groups which were subject to control. It could therefore be seen at a glance what stations were closed at any moment. As time went on, experience was gained, and an excellent system was evolved both for recording and displaying close-downs.

B.B.C. Synchronised Groups

On 1 September 1939, the British Broadcasting Corporation divided their transmitters subject to control into three synchronised groups, viz. :—

North Home. *767 kilocycles per second (391 metres).*	*South Home.* *668 kilocycles per second (449 metres).*	*Foreign.* *804 kilocycles per second (373 metres).*
Lisnagarvey.	Moorside Edge.	Brookman's Park.
Westerglen.	Droitwich.	Moorside Edge.
Burghead.	Brookman's Park.	Westerglen.
Stagshaw.	Washford.	

Irish Free State Transmitters

Shortly after the outbreak of war it was found impracticable, chiefly on account of telephone difficulties, to attempt to request the Irish Free State to close their 100 kilowatt transmitter at Athlone, so spoilers were erected by 9 December 1939 by the British Broadcasting Corporation at Penmon (2 kilowatts), Clevedon (2 kilowatts) and Redmoss (1 kilowatt), and these spoilers came under Fighter Command control.

This system, however, proved unsatisfactory, since Redmoss in particular gave good signals for navigational purposes over the North Sea, and Penmon also was dangerous owing to its close proximity to Liverpool. Further, the cost of the organisation proved out of proportion to the donbtful benefit derived from it. The system was therefore abandoned on 3 February 1941.

Arrangements were concluded on 8 October 1940 with the Irish Free State whereby they themselves ran spoilers in Cork and Dnblin. Later, on 18 March 1941, an additional spoiler, designed to protect the Belfast area, was installed by the British Broadcasting Corporation at Ramsey in the Isle of Man. These three spoilers operated successfully until 29 February 1944 when they were discontinued, due to diminishing enemy air activity over the British Isles.

B.B.C. Transmitter Danger Areas

Synchronisation fails as a safeguard against enemy navigational use when enemy aircraft come within a certain distance of any high-powered transmitter. Theory and tests indicate that for aircraft loop D/F the unprotected area usually lies within the field strength contour wherein the local transmitter gives a signal of four times or more of that of the combined fields of the other members of the group. Therefore in order to prevent the enemy from being able to D/F, areas were worked out and marked on maps showing the four to one contour, *i.e.* the area round a synchronised transmitter in which a hostile aircraft could D/F on that transmitter. These areas varied during night and day, due to propagation effects, and it was therefore necessary to work out two areas of danger for each transmitter, one for use during daytime and the other for use during the night.

At the beginning of the war a number of mica templates was prepared with the danger areas of the transmitters it was required to control cut from them. A framework was erected on the balcony overlooking the Operations Table at Fighter Command. During the daytime the mica templates containing the daytime danger areas were slipped into the framework and the Radio Control Officer could, by looking through these templates, see the areas on the table in which the enemy could D/F on the transmitters which each particular area surrounded. Night danger area templates were also prepared and similarly used.

It was the duty of the Radio Control Officer to close down the transmitter whenever a hostile aircraft was plotted inside the danger area of that transmitter.

As time went on, the Radio Control Officers familiarised themselves with these areas, and did not have to use the mica templates. It was always left to the discretion of the Radio Control Officer, bearing in mind all the circumstances existing at the time, *e.g.* prevailing weather, scale of the attack, direction of hostile tracks, whether a particular transmitter should be closed or not.

The rule, however, grew up that transmitters should not be closed during a programme of extreme national importance, *e.g.* a speech by the Prime Minister, unless in the opinion of the Radio Control Officer, with his knowledge of the table, it was of paramount importance to close the transmitter.

The rule also grew up and was finally laid down on 15 October 1941 that transmitters should not be closed during News periods ; but here again this was left to the sole discretion of the Radio Control Officer. In addition, it became the practice to re-open closed transmitters for the News periods.

Radio Control Officers were always to assume that all transmitters were operating for 24 hours each day, regardless of published programme schedules.

In choosing the site for a transmitter, regard must primarily be paid to the public whom the transmitter is intended to feed, and it is for that reason that all high-powered broadcasting transmitters are to be found adjacent to thickly populated industrial areas, which in their turn were the area in which the enemy was most interested. Unless a system had been evolved to deprive the enemy of navigational aid from broadcasting, the enemy would have found himself in possession of a radio aid of great value in locating the precise areas to which he wished to navigate.

Increase of Transmitters by the B.B.C.

The British Broadcasting Corporation, as time went on, greatly increased the number of its transmitters, which in turn resulted in a far greater number of synchronised groups. This increase made the task of the Radio Control Officers more difficult in as much as the number of danger areas to be watched was increased. It was found impossible to continue the mica template method of ascertaining the danger areas.

Preparation of Transmitter Field Strength Maps

In about August 1940 50-mile circles round the broadcasting transmitters were taken to be the danger areas. This method continued for some time, but was found to involve unnecessary closings. Areas were therefore worked out based on the four to one field strength principle, and imposed on some ten two-sided gridded maps of the area shown on the Fighter Command Operations Room Table (one side for use at night and the other by day). Each map contained all the synchronised transmitters in each group.

As time went on, even this method proved unsatisfactory and was impossible to handle. So finally, in March 1944, the Air Ministry evolved a more simple method of reducing the danger areas to handy maps. Each large square of the Fighter

Command grid was divided into 25 smaller squares, and in each square were written the numbers of the transmitters that should be closed in the event of an enemy aircraft flying over that small square.

At that time no less than thirty-four high-powered transmitters, divided into some ten gronps, were under the Radio Control Officer's control, and it can easily be seen that it would have been physically impossible for him to carry on without some such guide, especially as he had his No. 80 Wing Liaison duties to perform.

The United Kingdom was divided into two halves, North and Sonth, and three maps were prepared for each half, for Condition "A," Condition "B" and Dartboard respectively.

Condition "A" was used when the P.I.D. transmitter Aspidistra was radiating synchronised with Brookman's Park 3 in Group "E." Condition "B" was used when Aspidistra was radiating unsynchronised outside Group "E." The Dartboard map was used when Aspidistra and Moorside Edge 3 were being used by Bomber Command for jamming German Medium Frequency broadcast instructions to their night fighters under an operation the code word for which was Dartboard.

The repeated re-grouping of the British Broadcasting Corporation's transmitters, and their closing by the Radio Control Officers, made the enemy distrust them as reliable aids to navigation, and there is no evidence of the attempted general use by the enemy of any of the British Broadcasting Corporation's transmitters for navigational purposes, although one or two transmitters are mentioned in Prisoner-of-war reports.

Flying Bomb Alerts

It has previously been said that the British Broadcasting Corporation closed its low powered transmitters whenever an alert was sounded in the area in which the transmitters were located. When the Flying Bomb attacks started it was, of course, unnecessary to close down for alerts occasioned by the Flying Bomb. It therefore became the duty of the Radio Control Officer to advise the Senior Control Room Engineer whenever a Flying Bomb attack was developing and the area likely to be affected. The Senior Control Room Engineer did not then close the low-powered transmitters unnecessarily, and the public was not deprived of its broadcasting service.

High Power Transmitter, Patrington—Control Precautions

On 12 Febrnary 1943 a very high-powered transmitter of 600 kilowatts on a frequency of 200 kilocycles per second (1,500 metres) was opened by the British Broadcasting Corporation at Patrington near Hull and was known as OSE 5·5. It was synchronised in Group "L" with Droitwich and Daventry V. Owing to its position and high power, it was necessary to devise special rules for the closing and/or reducing the power of the transmitter. In the event of a hostile or X-raid appearing north of the line Harwich–Dutch Islands, the Radio Control Officer would instruct the Senior Control Room Engineer to reduce the power of OSE 5·5 from 600 kilowatts to 400 kilowatts, thus cutting down over the North Sea the relatively large unspoiled area given by its 600 kilowatts. OSE 5·5 had similarly to be cut to 200 kilowatts if a hostile aircraft entered the danger area bounded by the Wash and Newcastle, and to be cut completely if hostile activity occurred in the Hull area, or if such activity was judged by the Radio Control Officer to be imminent. Further, if large scale hostile activity took place in other areas coincident with a major activity in the Hull area the complete Group "L" would be cut. Hostile activity in the Midlands–Glonccster danger area also necessitated the cutting of the complete Group "L."

A single high-powered transmitter, *i.e.* one of five kilowatts or over, was never allowed to transmit alone in any synchronised group. If the Radio Control Officer had closed all the high-powered transmitters but one in a particular group, it was the duty of the Senior Control Room Engineer to close it together with all the remaining low-powered transmitters not subject to control as a "consequent" shut-down. The Radio Control Officer was not concerned with this "consequent" shut-down, and had to issue closing and re-opening orders withont regard to it.

Introduction of Horizontally Polarised Aerials

There was another method beside frequency synchronisation for preventing enemy aircraft from navigating over the United Kingdom by the aid of British Broadcast Stations. This was by employing aerials radiating horizontally polarised waves, which are unsuitable for aircraft loop D/F. Start Point S.21 is an example of a high-powered station so adapted. Even this type of transmitter came under the control of the Radio Control Officer (owing to the possibility of some residual vertical polarisation appearing fortuitously due to aerial " out of balance " effect), but being a propaganda transmitter had not to be closed unnecessarily. The nature and extent of the enemy activity and prevailing weather were the governing factors, bearing in mind that high-powered stations may be a very dangerous beacon in industrial areas. The distance of each transmitter from nearby towns was contained in the Radio Control Officers' instructions.

During the war the Radio Control Section gave orders to the Senior Control Room Engineer to close down transmitters on no less than 3,555 occasions.

Admiralty

At the beginning of the war, all long and medium wave W/T stations belonging to the Admiralty were placed under the control of Fighter Command. Individual close-down areas were, however, never prepared for the Admiralty stations which were all closed by the Radio Control Officer under an omnibus order when he considered the scale of enemy attack warranted it. The order to close was passed by the Radio Control Officer to the Naval Liaison Officer in the Operations Room at Fighter Command in the following terms :—" Fighter Command speaking. Request close W/T stations Clodat." Re-open instructions were similarly passed with the word " re-open " substituted for " close."

In December 1943 two seaborne radio beacons belonging to the Admiralty called Scarweather and Nab, situated in the Bristol Channel off Swansea, and off the Isle of Wight respectively, were also brought under Fighter Command control. In practice close-down instructions were only passed when an attack of exceptional size was taking place, or when the Radio Control Officer had special reason to suppose that the enemy wished to obtain some navigational aid from these Admiralty stations. As time went on, the Admiralty carried out most of its transmissions on frequencies lower than those covered by the enemy's D/F apparatus, and synchronised its high-powered station at Cleethorpes as a further safeguard, in case the enemy extended the frequency range of his sets. Between 150 and 200 closings were made during the war.

Police

At the beginning of the war, all Home Office W/T stations were placed under the control of Fighter Command. Experience showed that this precaution was unnecessary and, on 20 September 1940, the control was removed and never re-imposed.

General Post Office Transmitters

At the outbreak of war, the following G.P.O. medium or long wave W/T transmissions were put under the control of Fighter Command :—

Leafield, Rugby, Portishead, Cullercoats, Humber, Land's End, Niton, North Foreland, Portpatrick, Caernarvon, Ongar, Parkeston Quay, Stonehaven, Seaforth, Wick, Sheigra, Callon Head, Tiree, Sanday and North Ronaldshay.

This control was maintained until the end of the War in Europe, but the list of stations was from time to time amended.

The Radio Control Officer was provided with an " Awake " line to the Supervisor in charge of the London Trunk Exchange, and passed an omnibus close-down instruction in the following terms when he considered that hostile activity demanded it. " Fighter Command speaking—awake—close down all stations—Clodat." The stations were re-opened in a similar manner by substituting " re-open " for " close down."

In the event of the destruction of the London Trunk Exchange, it was provided that close-down instructions would be relayed by the Duty Air Raid Warnings

Officer at No. 9 Group to the Supervisor in charge of the Birmingham Trunk Exchange, but it was never found necessary to resort to this alternative. When the Air Raid Warning Section at No. 9 Group was closed about March 1944, it was not considered necessary to provide any other alternative arrangements.

The Radio Control Officer did, in fact, close down all the G.P.O. stations when raids of exceptional size were taking place against the United Kingdom. Over 100 closings were made during the war.

The intermittent traffic of the G.P.O. was not inconvenienced by omnibus closures. There was not sufficient traffic to warrant synchronisation, but the G.P.O. was ready to adopt such a system if closings had proved too heavy. If Fighter Command did not issue close-down instructions and enemy activity occurred in the vicinity of G.P.O. stations, it was left to the G.P.O. to close down and re-open at their discretion, dependent on the extent of the enemy air activity. When close-down instructions had been issued from Fighter Command they could only be re-opened by Fighter Command.

M.F. D/F Organisation and R.A.F. Beacons

The M.F. D/F organisation can be divided under two headings :—

(*a*) D/F security and identification systems, and

(*b*) Radio beacons.

D/F Security and Identification System

This system provided two aircraft navigational services, Security, the provision of navigational aid to aircraft in the form of bearings and fixes, and Identification, the establishment of identity of friendly aircraft returning to the British Isles.

The two services consisted of twelve separate D/F sections, each comprising two or more D/F receiving stations. Each station had its own M.F. transmitters for communicating with aircraft, and for passing bearings and control messages between D/F stations, when landlines were not available.

Two sections employed synchronised transmitters to prevent the enemy from using their signals for navigation. The original intention had been to synchronise all the sections, but the provision of landlines was not possible.

It was the general rule that D/F sections should not be closed down by the Radio Control Officers, except on occasions of vital emergency, when it was considered that the denial of navigational aid to enemy aircraft was of such vital importance in the interests of national security as to justify depriving British aircraft of their security service. This decision required the weighing-up of such factors as the extent of the enemy raids, the number of friendly bomber aircraft in the air at the time, and the prevailing weather conditions.

The synchronised sections radiated simultaneously when passing messages to aircraft, and therefore offered no navigational aid to the enemy at distances greater than 30 to 50 miles from the transmitters. When hostile aircraft appeared within this range of any synchronised transmitter, it was the duty of the Radio Control Officer, if he considered it necessary, to close down the transmitter—in which event the other transmitters in the group continued to transmit.

Special attention had to be given to the transmitters at Barton near Manchester, and Borough Hill near Daventry, owing to their high-power and locations. Close-down areas for these two stations only were held by the Radio Control Section.

If it should happen that enemy aircraft were reported within 30–50 miles of all transmitters in any section, a decision had to be made as to whether the circumstances justified closing the whole section, and so depriving those of our aircraft, to whom the section had been allotted, of navigational aid. The route by which close-down instructions had to be passed was set out opposite each station in the list held by the Radio Control Section. It was the duty of the Radio Control Officer to advise the Duty Signals Officer at Bomber Command whenever any transmission of the M.F. D/F organisation was closed, so that alternative arrangements could be made to provide navigational assistance. The closing of transmitters in the non-synchronised sections was only resorted to in conditions of emergency. During periods of raids, however, instead of completely closing any section, the Radio Control Officer might, at his discretion, take the following action to restrict to a minimum the aid that the transmitters were likely to offer to enemy aircraft :—

(a) Instruct the D/F control station to use a transmitter in its section remote from the area of the enemy raids, and/or

(b) Instruct the D/F control station to restrict its transmissions to aircraft to the absolute minimum during the period of the raid.

Control messages were passed in the following form :—"Awake—close down (restrict) . . . transmitter Clodat."

Radio Beacons

A radio beacon service was available to provide navigational facilities additional to the M.F. D/F organisation. The Radio Control Officer held a list of the radio beacons (static and mobile) which were subject to his control. The decision to close was taken in the light of prevailing circumstances. The Duty Signals Officer at Bomber Command had to be advised whenever a radio beacon was closed and the rules were more stringently applied to beacons used for training aircraft only.

Eventually it was found inadvisable to close down the M.F. radio beacons as with increasing numbers of airborne aircraft there was now insufficient time to plan alternative arrangements. A security scheme was thereupon evolved whereby beacons were grouped and allocated for use to a changing schedule, so that enemy aircraft could never be sure from which site any transmission was coming at a particular time. It would have been possible for the enemy to break down this change-over system, but there is no evidence that he was successful or even tried. The Radio Control Officer, in practice, very seldom closed down radio beacons, except the one at Borough Hill, in view of their paramount importance to Bomber Command, and they were finally removed from Control.

The M.F. transmitter at Borough Hill which, as stated above, was used both as a beacon and in the M.F. D/F organisation, was always a source of great apprehension to the British Broadcasting Corporation, owing to its high power and close proximity to their Daventry transmitters, which were used for the Empire and Overseas Services.

The Daventry area was, of course, one in which the enemy was highly interested, and the Borough Hill beacon, unless controlled presented an admirable help to the enemy. Borough Hill was closed down whenever an enemy aircraft came within its unspoiled area on instruction to the Senior Control Room Engineer. Eventually, to overcome the British Broadcasting Corporation's apprehension, and to avoid the frequent close-downs, the transmitter was re-sited near Hull, and replaced the one in the Borough Hill organisation. Eventually the Director-General of Signals released all the R.A.F. M.F. D/F organisation from the Radio Control Officer's control, largely on account of the difficulties inherent in control.

Aspidistra

In November 1942, His Majesty's Government Communication Centre acquired from Messrs. R.C.A. in the United States of America, and erected underground near Crowborough in Sussex, one of the highest powered M.F. transmitters in the world. Incidentally, this station, as a whole, with its high power of 750 kilowatts, marks a step forward in design and equipment of a broadcasting station in this country. It operated on a frequency of 804 kilocycles per second (373·1 metres) and was sponsored by the Political Intelligence Department for propaganda purposes. This transmitter, and its subsequent off-shoots, came under Fighter Command control. The transmitter soon took on the additional duty of radiating normal Ministry of Information propaganda, synchronised in Group " E " on 804 kilocycles per second with the British Broadcasting Corporation's Brookman's Park 3 and Moorside Edge 3. For the last four months of the war in Europe, the propaganda programme was carried by Aspidistra alone, unsynchronised, except for short periods when it was used for the Political Intelligence Department's purposes, when Brookman's Park 3 was brought up to carry the propaganda programme. As far as the Radio Control Officer was concerned, Aspidistra was closed by close-down instructions to the Senior Control Room Engineer similar to those issued to the British Broadcasting Corporation.

From 24 April 1944, it was the duty of the Radio Control Officer to advise Aspidistra via the Senior Control Room Engineer of impending enemy air raids on the United Kingdom, and so assist them with various other commitments.

B.B.C. Monitoring Station at Tatsfield

From time to time, especially after the Americans came into the War, the Senior Control Room Engineer reported from Tatsfield interference from friendly sources to some of their programmes. The Radio Control Officer obtained the frequency and callsign of the offending transmitter, and passed them to the Operations Officer at Headquarters No. 80 Wing who in turn advised the offender. This service was much appreciated by the British Broadcasting Corporation.

APPENDIX No. 8

RUFFIANS AND THE "X" *GERÄT*

The Ruffian system of beams in conjunction with the "*X*" *Gerät* was an elaborate system by which selected targets could be bombed completely blind with a high degree of accuracy.

In its simplest form which is shown in Fig. 1, the system required an approach beam to enable the pilot to maintain a straight course to the target and two cross beams aligned so as to cut the approach beam (P) and (Q) a fixed distance apart and at a fixed distance from the target (X). The time taken to pass from one cross beam to the other along the line of approach gave the ground speed of the aircraft, and this in conjunction with the position of the second cross beam (Q) relative to the target gave the correct instant for bomb release (R).

This process was carried out automatically by a "clock" in the aircraft. A description of the clock is given later in this Appendix.

Since the beams used in the system were very narrow (about 0·05 degrees) and therefore difficult to identify, a more elaborate arrangement of beams was used by the Germans. A schematic lay-out of this is given in Fig. 2. From the diagram it will be seen that a wide (or coarse) approach beam (about four degrees) was provided with a narrow (or fine) approach beam laid approximately up the centre of the coarse beam. A second fine approach beam was also set up probably as a stand-by to the first in case of failure or other reason. A coarse cross beam was also provided and set up to cut the approach beam (O) approximately 30 kilometres before the first fine cross beam to give warning that the aircraft was approaching the "run-up" to the target. Finally a third fine cross beam was used as a stand-by to the second fine cross beam, both of these being adjusted to be 15 kilometres from the first fine cross beam and five kilometres from the target when measured along the approach beams. All these seven beams operated on a different radio frequency. They were modulated at two kilocycles per second and keyed at a rate of 120 per minute with a dot/dash ratio of 1/7.

Two receivers were provided in the aircraft each with its own aerial and with "kicking" course meters, one for the pilot and one for the observer, and it was the duty of the wireless operator to tune these to the frequencies required. These receivers had selective audio filters adjusted to a frequency of two kilocycles per second with a tolerance of 50 cycles per second. At a later date, in an attempt to overcome jamming a supersonic modulation was added to the system and alterations to the receiver were made to accommodate this.

At the beginning of an operation the receivers would be tuned to the frequencies of the coarse approach and coarse cross beams respectively, the aircraft having been flown from base by dead reckoning in the direction of the target. As soon as the observer reported that he had reached the coarse cross beam, the pilot of the aircraft at its correct operational height would manœuvre his aircraft until his indicator showed that he was in the coarse approach beam. The wireless operator would then retune the pilot's receiver to the frequency of the fine approach beam along which the pilot would fly at a constant airspeed and height towards the target.

Meanwhile the wireless operator would have tuned the observer's receiver to the frequency of the first fine cross beam. As soon as the course meter or indicator showed that the aircraft had reached the first fine cross beam the observer pressed a key on the clock which set it in motion. The observer's receiver was then retuned to the frequency of the second fine cross beam, and again as the indicator showed that the equi-signal was reached, the observer pressed the key on the clock a second time.

The clock had now received two impulses in a certain period of time during which the aircraft had made good exactly 15 kilometres. From this the ground speed was worked out automatically, and the clock having already been adjusted for a known height and type of bomb, released the bombs electrically at the correct instant for these to hit the target.

Although Figs. 1 and 2 show each transmitter radiating a single beam, this was not in fact the case. Each transmitting array produced a fan of beams.

In the case of the coarse beam a flight test, in which an aircraft of No. 109 Squadron flew round a transmitter at the Cherbourg site at a radius of very approximately 10 miles, showed that there were two pairs of equi-signals, the angles between these being about 40 degrees and 140 degrees respectively. Fig. 3 shows the diagram which was obtained from the flight tests and also a theoretical diagram of the radiation from two aerials spaced a half wave-length apart when excited in and out of phase. These were in sufficient agreement to suggest that this type of array was being used.

From an analysis of a large number of flight tests and ground observations the approximate pattern of the radiation of the fine approach and cross beams was determined. The general pattern is shown in Fig. 4 (*a*) from which it will be seen that there were pairs of beams separated by 10 to 15 degrees, the separation between beams being two to four degrees. Dashes were received in the narrow zone and dots in the wide zone. The angles between the beams did not remain constant, but there appeared to be limits beyond which they did not extend. It was believed that the reason for this pattern was to avoid ambiguity between the various beams when the observer switched over from the coarse cross beam to the first fine cross beam and again from the first to the second fine cross beam.

It was found that both the coarse and fine approach beams were always the right-hand beam of the pair, *i.e.* with dots to the right and dashes to the left when considered from the aspect of an aircraft flying away from the source. The coarse and fine cross beams, however, were left beams, *i.e.* the aircraft received dots before dashes as it crossed these beams when flying along the approach beam. At a later stage in the use of Ruffians the second fine cross beam was changed to a right beam.

It was fonnd possible from photographs obtained by the Photographic Interpretation Unit to make a rough sketch of the structure of a Ruffian station and to obtain some approximate dimensions.

The length of the structure carrying the aerials for the fine beams was of the order of 16 metres and that of the cross arms near each end about one metre. These cross arms probably carried the aerials and reflectors, the length giving a spacing of the right order for the frequencies which were used.

No evidence could be found from photographs of aerials capable of producing the coarse beam. It was possible that these were mounted on the same structure near the centre.

A distance of 16 metres between aerials gave a spacing of 3·5 to 4 wave-lengths for the frequency band of 66·5 to 75 megacycles if the aerial system were a fixed and rigid one. The effect of this resulted in an increase of angular separation of the equi-signals with change of frequency.

A theoretical diagram of the radiation from such an aerial system was made for aerials excited in and out of phase. It was found that if the aerial current were made deliberately unequal during alternate periods of excitation a radiation pattern could be produced which would give values of angular separation of equi-signal zones similar to those obtained from test flights and ground observations of fine beams. Fig. 4 (*b*) shows the pattern of such a system with reflector.

Although there is no evidence except from the photographs that such a simple aerial system as described was in fact used, the practical and theoretical results were sufficiently similar for it to have been considered.

There were three groups of Ruffian stations. They were sited near Calais, Cherbourg and Morlaix. In the early phase of the war the Calais transmitters were always used as cross beams with the Cherbourg transmitters providing the approach. The station near Morlaix was used only for approach purposes with the Cherbourg and sometimes the Calais transmitters supplying the cross beams. In the later phase of Ruffian activity in 1943 the Calais transmitters operated as approach beams on occasions.

A table attached gives the location of the arrays in each group and the code name which was given to them. In the early phase these arrays were spaced sometimes several miles apart, but later they were regrouped so as to be within a hundred yards or so of each other.

The " X " *Gerät* " Clock "

The ground speed registering the bomb release mechanism consisted essentially in a high grade clock mechanism on which the equation involved in this method of blind bombing is semi-automatically worked out and the stick of bombs released automatically at the correct moment before the target, using the second fine cross beam as a datum line.

It has already been explained that the distance between the first and second fine cross beams was adjusted to mark off a distance of 15 kilometres along the length of the fine approach beam and that the second fine cross beam crossed the approach beam at a distance of five kilometres from the target, a ratio between the two lengths of three to one.

It will be appreciated then that if a constant speed stop-clock mechanism is arranged to drive two independent pointers, one of which moves at an angular velocity of one-third that of the other, and if both pointers are originally set in coincidence with the slower moving pointer allowed to move for the time taken by the aircraft in passing from the first to the second cross beam, when it is stopped and the normal speed pointer allowed to move, both pointers will again be in coincidence when the aircraft passes over the target. The aircraft is assumed to have made good a constant speed during these times.

If now the slower moving pointer does not start in coincidence with the normal speed pointer but is originally set back by an angular amount corresponding to the length of the horizontal plot of the bomb's trajectory in the absence of air resistance, according to the height from which it is to be dropped, the two pointers will come into coincidence at a point before reaching the target from which the bomb, if then released, will just reach the target neglecting resistance.

It will be noted that as the slower moving pointer has been set back it will pass the constant speed pointer once during the 15 kilometre run. This coincidence of the two pointers has no significance.

The effect of air resistance is to shorten the horizontal plot of the bomb's trajectory thus requiring a longer run after passing the second cross beam. Allowance can be made for this by slightly reducing the speed ratio of the slower moving pointer to the constant speed pointer so allowing it to move a greater angular distance before being stopped at the second cross beam. If now in addition the two pointers are provided with electrical contacts a circuit can be completed on the pointers reaching final coincidence which can be used for the automatic release for the bombs.

The effect of the first coincidence noted above, whilst the slower moving pointer is moving during the 15 kilometre run, can be overcome by providing a master switch is not closed until this pointer has reached its final position. In actual practice three pointers were provided, the third normally moving locked to the slower speed pointer but set back initially by the amount required to allow for the bomb's trajectory.

The clock mechanism was contained in a drum with a Perspex window mounted in a location convenient for operation and observation by the observer. The clockwork was wound by means of a spindle through the lower end and there were two setting knobs projecting through opposite sides of the case. The operating press lever was also mounted on the side midway between the two setting knobs.

Three concentrically mounted pointers moved over the main dial which was engraved from 0–120 in divisions and half-divisions (numbered at every tenth division). These pointers were painted black, green and red respectively, the black being undermost, the green in the middle and the red on top. The green pointer was shorter than the other two which were of equal length. The large black and red pointers carried contacts near their tips which, when they coincided, completed the bomb release circuit.

The green pointer was driven by the clock through a variable speed friction gear; the gearing ratio between this pointer, the slower moving pointer noted above, and the red being set initially by means of one of the two adjustment knobs and the setting indicated by a small red pointer moving over a scale graduated every 0·5 from a ratio of 1·5 to 4. The variable speed friction disc also operated as a clutch device, allowing the green pointer to be disconnected from the clockwork drive and locking it.

The red pointer was driven directly by the clock again through a clutch and moved continuously so long as the clockwork was released and the appropriate clutch allowed to engage.

The black pointer was frictionally locked to the green in such a manner that the black could be preset to a definite position on the dial, whilst the green was held in position; thereafter the two pointers moved as one with the preset angular displacement. The second adjustment knob was used for this setting operation.

The starting and stopping of the clock and the operation of the two pointer drive clutches was controlled by a cylindrical cam which was rotated one step each time the operating lever was pressed. On the completion of a full sequence of operations the pointers were returned to their initial position by stop clock mechanism ready for a second run.

The sequence of operations during a bombing run in so far as this clock was concerned was as follows, it being assumed that the black pointer had been set to the appropriate dial reading for the height at which bomb release was to take place and that the speed ratio between red and green pointers had been adjusted, both in accordance with a card of tables provided :—

(a) On hearing the first fine beam the observer pressed the operating lever of the clock mechanism. This released the clockwork, engaged the clutch of the variable speed gear and fixed the safety locks of the adjusting knobs. The green and black pointers then commenced to move together.

(b) On hearing the second fine beam the observer again pressed the lever. This disengaged the clutch of the variable speed gear so stopping the green and black pointers and, the ground speed having now been registered on the dial, the clutch of the red pointer was engaged and this pointer now commenced to move over the dial towards the black one. At the same time the main switch of the bomb release circuit was closed.

(c) On the red pointer reaching the black pointer the bomb release circuit was completed through the contacts and the observer could now press the lever a third time so stopping the clockwork.

(d) Pressing the control lever a fourth time disengaged all drive clutches and locks thus allowing the pointers to fly back to their original positions.

Two different sizes of clock were captured, one ten inches in diameter and a later improved model seven inches in diameter. In the later model there was an additional small scale and pointer to indicate the running time of the clock. The scale was engraved up to four hours.

Ruffian Beam Predictor

From a knowledge of the radiation pattern of equi-signals obtained from practical and theoretical considerations a Ruffian beam predictor was devised.

Although the handling of this was a much more difficult process than that of the *Knickebein* beam predictor owing to the very complicated nature of the beam patterns, it is found on many occasions to be of value in obtaining beam and target settings.

The predictor consisted of a baseboard, with two rotatable discs and a card with the listening stations arranged in a vertical column with lines drawn to a degree scale at the bearing of the listening station from the Ruffian transmitter. The top rotating disc was engraved with the radiation pattern of the equi-signals for the frequency band of 66·5 to 75 megacycles per second. Coarse beams were marked on one half of the disc and fine beams on the other. As it was found that the angular spacing of the equi-signals from the different beam arrays in the system was not exactly the same, interchangeable rotating discs were provided. Also, since in the early use of the system the arrays were separated by a few miles, the bearings of these from the listening stations differed. A rotatable disc below that carrying the radiation pattern was therefore provided so that the correct bearings from the particular Ruffian transmitter to the listening stations were obtained. A separate instrument was required for each group of arrays.

Having determined the group to which the particular signal belonged by D/F or by frequency discrimination, the method of use consisted in marking the card in chinograph pencil with the characteristics (dot, dot edge, dash, dash edge, or equi-signal) received alongside the particular listening station, a separate column being used for each frequency.

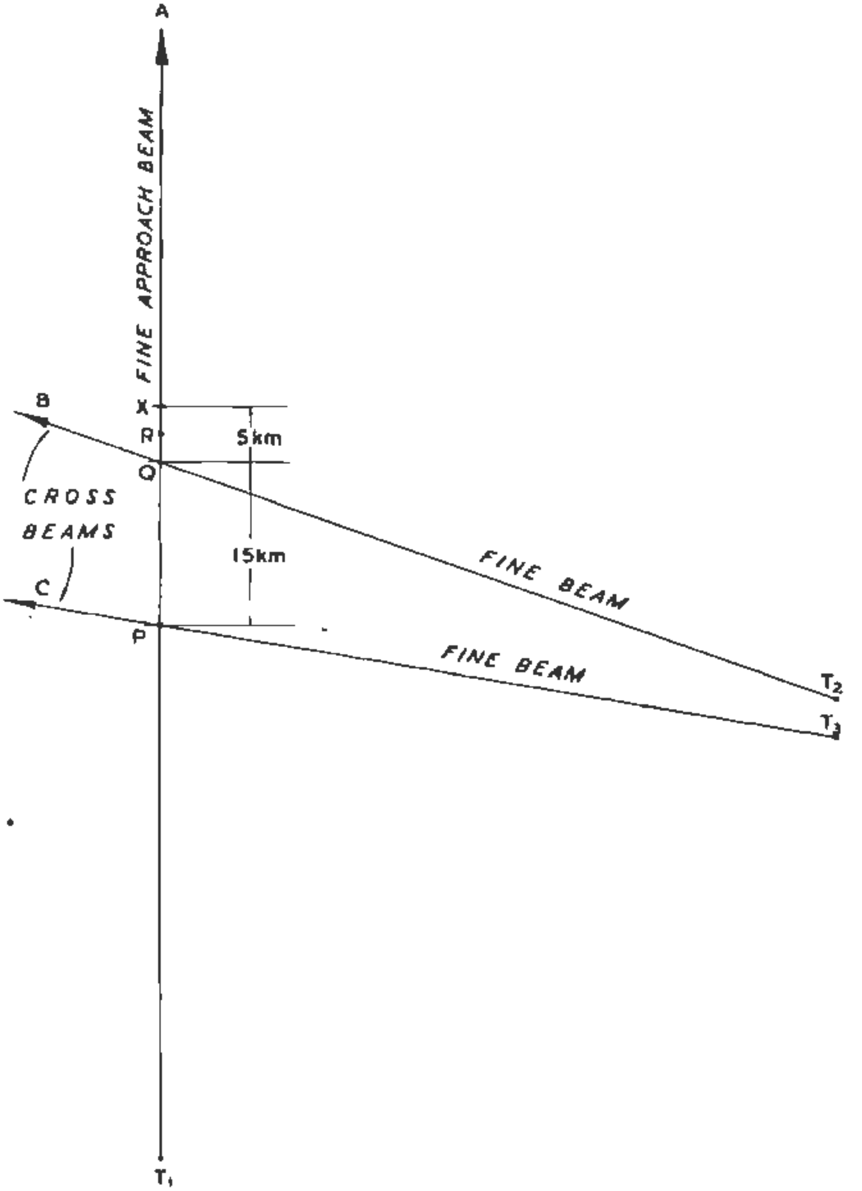
By a study of the characteristics and by rotating the upper disc, it was usually possible to select which one of the three or four frequencies of a group was radiating a coarse beam. In the case of the approach beams this gave a rough indication of the line of approach, and it enabled the main fine beam to be determined and a more accurate value for the beam setting to be obtained.

Having obtained the line of approach, if the cross coarse beam and its setting could then be determined, a rough indication of the target was obtained since it was known that the coarse beam was set approximately 50 kilometres from the target. This enabled the main fine cross beams to be identified, thus giving a more accurate setting for the target.

POSITIONS OF "*RUFFIAN*" TRANSMITTERS

CALAIS AREA

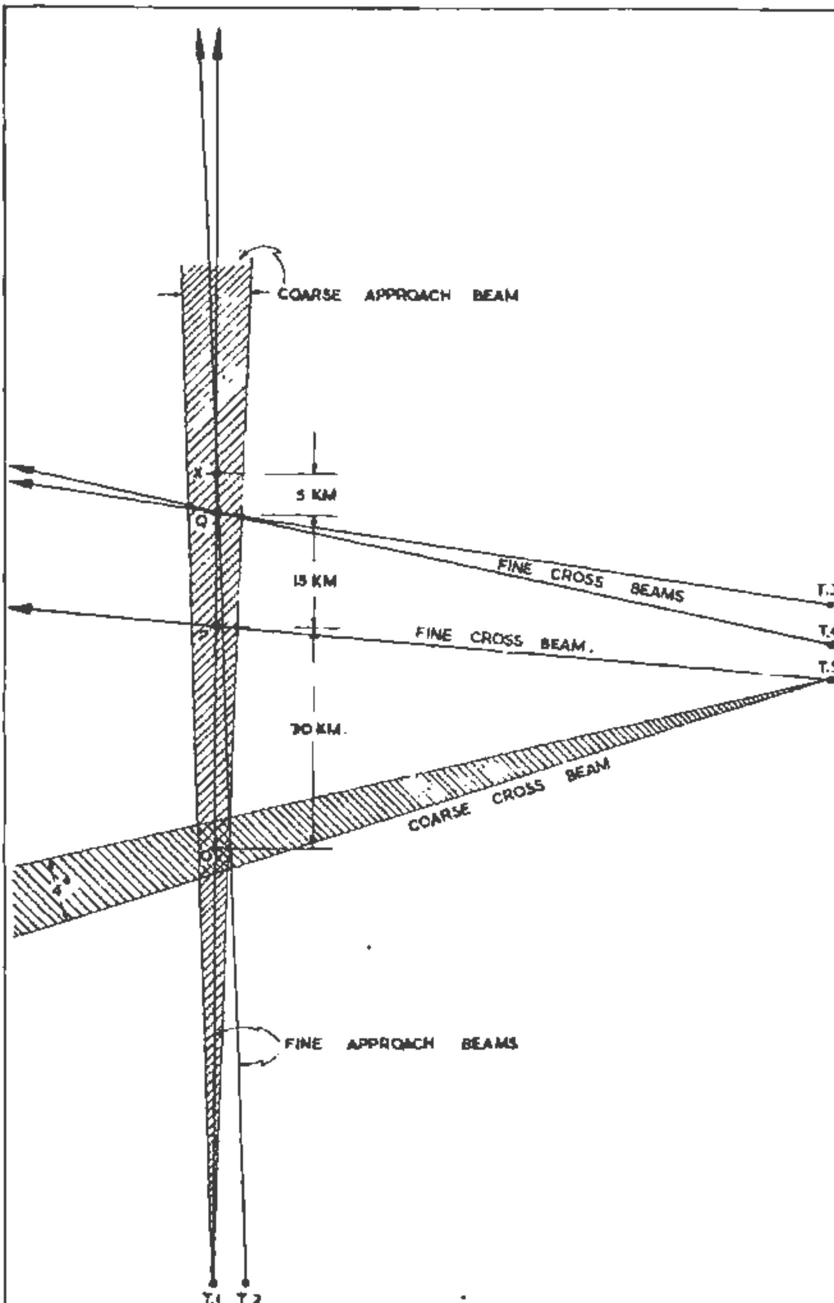
1940–41	*HIMMLER*	Coarse and Fine	50° 52′ 19″ N., 01° 42′ 19″ E.
	RIBBENTROP	Fine	50° 52′ 20″ N., 01° 42′ 26″ E.
	HESS	Fine	50° 50′ 25″ N., 01° 38′ 32″ E.
1942	*LEY*	Coarse and Fine	50° 50′ 14″ N., 01° 38′ 01″ E.
	GOEBBELS	Fine	50° 50′ 21″ N., 01° 38′ 21″ E.
	HESS	Fine	50° 50′ 25″ N., 01° 38′ 32″ E.



FUNDAMENTAL PRINCIPLE OF THE RUFFIAN SYSTEM

APPENDIX 8.
FIG. I.

AHB(1) DIAG N°107



SCHEMATIC LAY-OUT OF RUFFIAN SYSTEM.
Showing Main Beams Without Side Lobes.

APPENDIX 8.

FIGURE 2.

A.H.B. DIAG. No 110

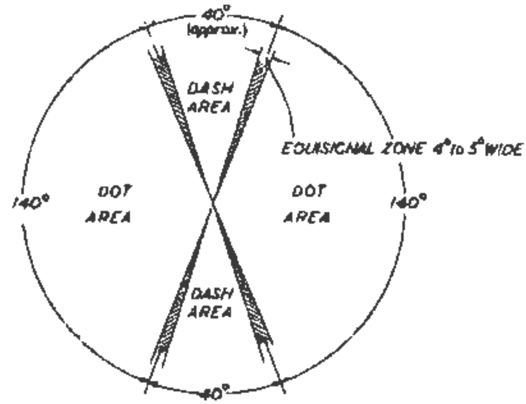
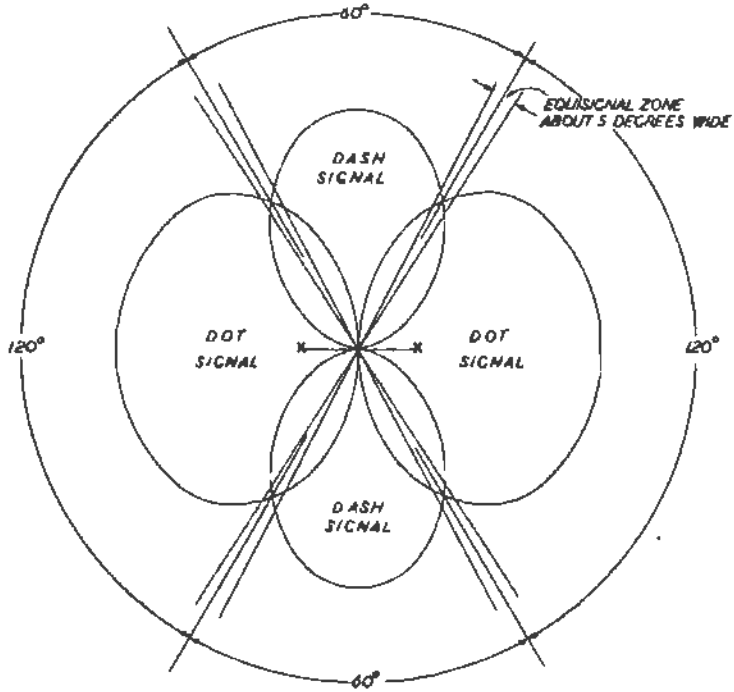


DIAGRAM OBTAINED FROM FLIGHT TEST Fig. 3(a)



THEORETICAL DIAGRAM OF 2 AERIALS SPACED λ/2 APART
EXCITED IN & OUT OF PHASE Fig. 3(b)

RUFFIAN SYSTEM RADIATION DIAGRAMS OF COARSE BEAM	APPENDIX B. FIG. 3.

A.H.B.I DIAGRAM No. 115

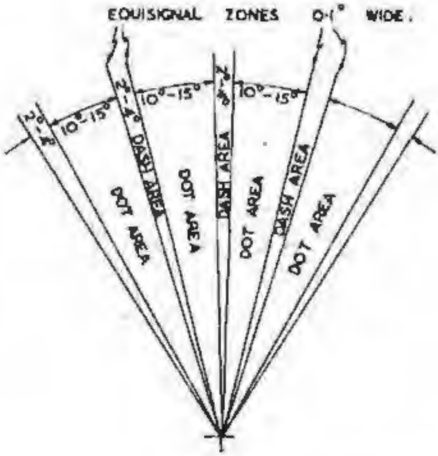


FIG. 4A.
DIAGRAM OBTAINED FROM FLIGHT TEST.

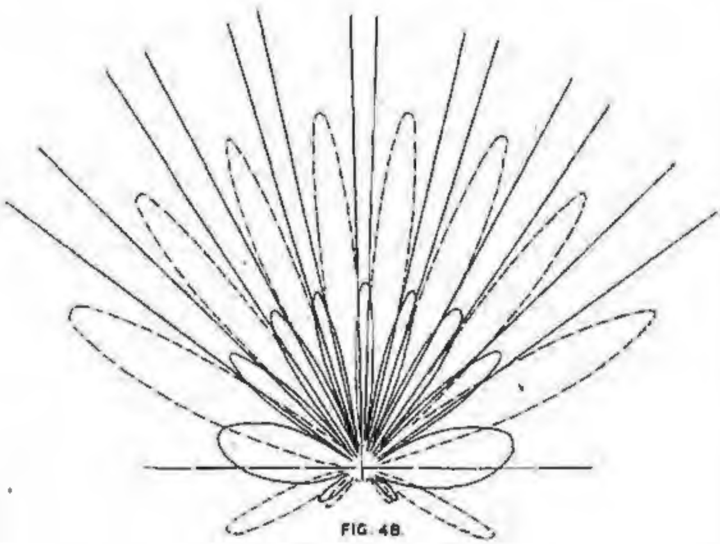


FIG. 4B.

2 AERIALS SPACED 4λ APART
EXCITED IN & OUT OF PHASE
WITH REFLECTORS.

[FULL LINE = IN PHASE
DOTTED LINE = OUT PHASE]

GENERAL PATTERN OF THE RUFFIAN SYSTEM.	APPENDIX 8. FIGURES 4A & B.

A.H.B. DIAG. No. 117.

CHERBOURG AREA

1940–41	*GOERING*	
	Coarse and Fine	49° 41′ 51″ N., 01° 55′ 38″ W.
	HITLER	
	Coarse and Fine	49° 42′ 19″ N., 01° 51′ 25″ W.
	GOERING	
	Coarse and Fine	49° 41′ 51″ N., 01° 55′ 34″ W.
1941–42	*HITLER*	
	Coarse and Fine	49° 41′ 52″ N., 01° 55′ 32″ W.
	QUISLING	
	Fine	49° 41′ 54″ N., 01° 55′ 29″ W.

MORLAIX AREA

	SHIRACH	
	Coarse and Fine	48° 24′ 58″ N., 03° 53′ 22″ W.

APPENDIX No. 9

BENITO AND THE "*Y*" *GERAT*

A new system for the blind bombing of selected targets was first observed to be in use over England in November 1940, stations in the Cassel, Cherbourg and Poix areas being employed. Stations were also used at Mont de Boursin, St. Valery, Commana, Montdidier and Stavanger. This system was given the code name Benito. Basically, the system made use of a single beam to enable each aircraft fitted with the "*Y*" *Gerät* to remain on course to the selected target together with a method of ranging to enable a ground control station to order the release of bombs at the correct position. Using the "*Y*" *Gerät* equipment Benito operated in the frequency band 42·2 to 47·8 megacycles per second. Any description of Benito involves two distinct subjects, viz., "Benito Range Measurement" and "Benito Beam," and this distinction is adopted in the following explanation.

Benito Range Measurement

Range measurements in the Benito system relied on the measurement of the phase difference which existed between a tone radiated by a ground station and the same tone on its return when re-radiated by an aircraft. The following equipment was therefore required :—

(*a*) A ground station transmitter which operated on a frequency in the band 42·2 to 45 megacycles per second.

(*b*) An airborne receiver (*Fu.Ge. 17*) tuned to the frequency of (*a*).

(*c*) An airborne transmitter operating on a frequency in the band 46 to 47·8 megacycles per second and which could be modulated by the audio-output of the airborne receiver. The power of this transmitter was of the order of five watts.

(*d*) A ground station receiver tuned to the frequency of the airborne transmitter.

(*e*) A phase analyser at the ground station for comparing the phase of the outgoing and returning modulation.

The manner in which this equipment was disposed and the method of operation is illustrated in schematic form in Fig. 1.

Since the signal travels to the aircraft and back at a speed of 3×10^8 metres per second the distance travelled in one complete cycle of the modulation frequency (f cycles per second) is $\frac{3 \times 10^8}{f}$ metres. Any phase difference which exists is a measure of the proportion of one complete cycle and if this phase difference is θ degrees, then the distance travelled by the signal is $\frac{\theta}{360} \times \frac{3 \times 10^8}{f}$ metres.

Half of this total distance which the signal has travelled gives the range of the aircraft returning the signal to the ground station thus :—

$$\text{Range of aircraft} = D \text{ metres} = \frac{\theta}{360} \times \frac{3 \times 10^8}{2f} \text{ metres.}$$

An ambiguity occurs if the phase shift is 360 degrees or more, but this ambiguity can be resolved by employing a lower modulation frequency.

Phase shift could be measured easily to within two degrees, and the following table gives the accuracy of range measurement for various modulation frequencies and the ranges at which ambiguity occurs for each modulation frequency :—

Modulation Frequency.	*Accuracy of Ranging.*	*Range at which Ambiguity Occurs.*
10,000 cycles per second	·083 kilometres	15 kilometres
3,000 cycles per second	·280 kilometres	50 kilometres
300 cycles per second	2·8 kilometres	500 kilometres

It will be observed that by using a modulation frequency of 10,000 cycles per second (which was that normally used for fine measurement) range could be measured very accurately to within 83 metres whilst measurement using a 300 cycles per second modulation could resolve any ambiguity as to which multiple of 15 kilometres was being measured with the higher modulation.

By taking bearings on the aircraft radiations the ground station could vector the aircraft to the beam as it approached the target area and thus avoid the necessity for flying along a narrow beam for a long period. All instructions passed to the aircraft, including the bomb-drop signal, were radiated by the ground station ranging transmitter using R/T or morse. The ranging tone was sometimes, but not always, discontinued while the instructions were passed.

Benito Beam

The beam station was situated near the ranging station and employed an aerial array mounted on a rotatable turntable. The output of the transmitter, amplitude modulated at 2,000 cycles per second, was keyed to produce dashes at 180 per minute with a mark-space ratio of 8 : 1. This keyed output was fed to the aerial array, the elements of which could be phased so as to produce two sets of alternating lobes, which overlapped. Aerial phasing was switched in synchronism with the transmitter keying to take place in the middle of each dash. This gave a very narrow main beam or equisignal zone with numerous weaker subsidiary beams on each side.

The beam was therefore of the Lorenz type except that the equisignal consisted of dashes 180 per minute with a mark-space ratio of 8 : 1 instead of the usual continuous note. The first or second half of each dash would become relatively weaker as an observer facing the transmitter moved to the left or right of the equisignal zone until eventually the mark-space ratio would appear to be 4 : 5. This is illustrated in Fig. 3. The high keying speed made aural analysis almost impossible and the apparent change in the mark-space ratio accounts for the many reports of either dots or dashes which were received in the early days.

The "*Y*" *Gerät*

It was therefore necessary for the aircraft to carry a form of mechanical analyser for interpreting the characteristics of the beam. This instrument, the *Fu.Ge. 28A*, was known as the "*Y*" *Gerät*. Briefly, the apparatus operated as follows :—

(*a*) A motor-driven switching mechanism on the analyser was kept synchronised with the beam transmitter switching by the short breaks in the transmitted signal, *i.e.* the space after each dash.

(*b*) This switching mechanism provided for the rectified voltage produced by each half dash to charge two equal condensers in series but with opposite polarity. The relative strength of each half dash therefore decided the relative charge on each condenser.

(*c*) The resultant voltage across the condenser network as a whole was, therefore, positive, negative or zero, depending on the relative strength of each half-dash. The resultant voltage, used to control the grid of a valve, decided the position of the pointer on the anode current meter of this valve relative to a mean or standing current position. The mean position of the meter needle was arranged to indicate "ON" course, whilst any movement displayed the angle and direction "OFF" course.

It will be appreciated from the foregoing description of the Benito system that it was more versatile than any bombing aid previously encountered. Some of the ways in which it was possible to use the system being—

(*a*) One beam and one range station operating aircraft, *i.e.* ranging them along the beam.

(*b*) Vectoring over a target using two or more range stations on a wide base line.

(*c*) Intersection of two or more beams over the target as with *Knickebein*.

Domino

In view of the high degree of accuracy which could be obtained by the ranging system and since the first two of the above possible methods of operation relied entirely on the accuracy of range measurement, it was decided that the first counter-measures should be directed against this part of the system. The very nature of the ranging system laid itself open to the application of subtle counter-measures. A study was made of the economics of using subtle as opposed to crude jamming methods at a time when the need for conserving material and trained personnel was paramount, and it was decided that the employment of subtle methods difficult for the enemy to detect would delay his conversion to new systems or the development of anti-jamming devices.

Subtle counter-measures, under the code name of Domino were accordingly introduced in February 1941 and operated as described below. As each aircraft re-radiated the ranging tone received from its ground station, it was detected by the Domino receiver site and the tone so obtained was used to modulate a Domino transmitter tuned to the same frequency as the enemy ground station. The enemy aircraft therefore received two interlocked ranging tones simultaneously but of different phases owing to the different distances which each had travelled, consequently the re-radiation from the aircraft was modulated by a tone whose resultant phase, due to the combination of the two signals received, was in no way directly related to the true distance of the aircraft from its controlling ground station. The ground control station would therefore obtain incorrect range measurement. For the subtlety of this Domino system to be retained, it was necessary to ensure sufficient attentuation in the system for the aircraft receiver to be energised mainly by its own control station. If this were not the case then the Domino transmitter would continue to energise the aircraft receiver (by "singing round") even when the enemy control station had ceased radiation. The Domino system would then be divulged.

The first Domino station to be operated was situated at Alexandra Palace in North London, using the B.B.C. Television Sound Transmitter, and its associated receiver site was located nearby at Highgate. It was primarily designed to protect London from Benito aircraft operating with the Cassel control station.

A schematic diagram indicating the layout of the system, and how it dovetailed into the Benito network, is given in Fig. 2. Provision was made whereby an artificial phase shift could be introduced on the tone received from the aircraft to increase the errors caused by the enemy range measurement and an analysis of this principle, among others, is made in a mathematical paper on the subject produced by T.R.E.

The Domino installation was also provided with a tone source which could be used to generate a replica of the enemy ranging tone on occasions when, due to interference or weak signals received from the aircraft, it was impossible to implement the subtle Domino method. This procedure of jamming was only put into effect as a last resort and after the enemy had become aware that counter-measure action was being carried out. A full technical description of the apparatus at Domino sites is given by T.R.E. in the following papers issued in October 1941 :—

(*a*) General Description of Domino Installation.

(*b*) Technical Information of Domino Operations.

(*c*) Domino Operator's Instructions.

Benjamin

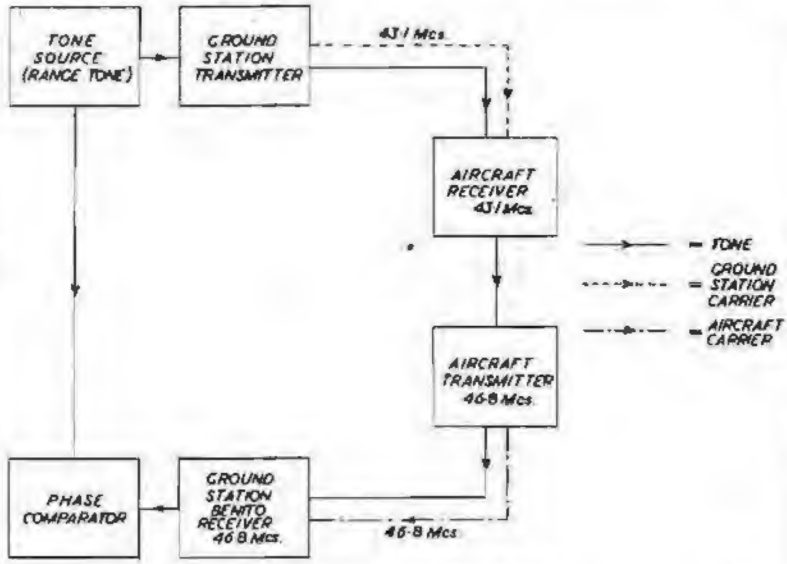
Attention was then directed towards applying counter-measures to the beam signals and various transmitters were earmarked for this purpose. Although analysis of the beam signals heard had indicated the wave form of the keying, it was not until an enemy beam mechanical analyser was found in a crashed aircraft in May 1941, that the type of jamming signal could be designed on a scientific basis.

It was decided to adopt a drifting dash method of jamming produced by radiating dashes similar to those of the enemy beam, but with a slower keying speed. Such a system would produce a variable intensity of dashes received by the aircraft, and would also make the synchronising break in the enemy keying appear to be irregular. In this way the synchronising device on the *Fu. Ge. 28A* beam analyser would be upset and thus make the system inoperative. This type of jammer, known as Benjamin, keyed dashes at 160 per minute, and was modulated at 2,000 cycles per second. Benjamin jammers were installed near important target areas and first came into operation on 27 May 1941.

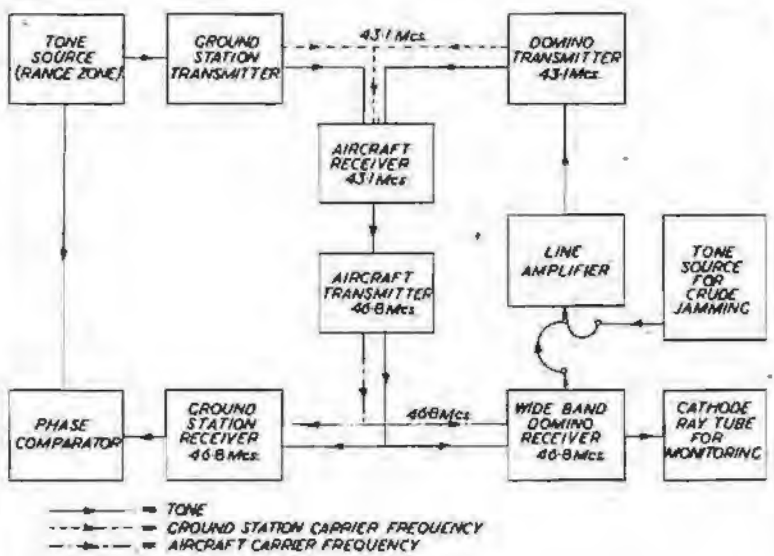
It became apparent that the existing method of target jamming, which required several jamming transmitters for each enemy channel, made it possible for the enemy to outbuild the defensive organisation. An expansion of the Domino scheme to a total of 14 stations was considered, but in view of the complicated nature of the Domino equipment required, it was decided to adopt a programme of crude jamming the Benito communications channel by using transmitters available within No. 80 Wing.

Tests were carried out and it was decided that jamming should take the form of recordings of scrambled morse using Marconi-Stille tape reproducers of which an ample supply was available. It was also decided to discontinue the system of target jamming hitherto employed and to concentrate on providing, where possible, one transmitter of sufficient power and suitability located to deal with each of the enemy beam or range transmitters. It was estimated that this method would prevent the enemy signals being used as an accurate aid anywhere over the British Isles. This system of allocating jammers was known as "area jamming."

Reference to Fig. 3 shows that the signal strength or power of the enemy signal in the equisignal zone of the beam is much less than it is a few degrees off course. This point was taken into consideration when deciding what power would be required for a jammer to prevent accurate use of the beam. The redistribution of transmitters and where necessary the erection of high gain aerials designed by T.R.E. to ensure distribution of the maximum possible power over the desired area was therefore put into effect. Although this scheme was itself capable of frustrating the enemy's use of Benito it was appreciated that in practice a certain amount of secondary jamming would be desirable. This was provided near important targets.



BENITO RANGING PROCEDURE — Fig. 1



'DOMINO' SCHEMATIC IN RELATION TO 'BENITO' RANGE — Fig. 2

OPERATIONAL METHOD OF BENITO SYSTEM	APPENDIX 9 FIGS. 1 & 2

A.H.B.I. DIAGRAM No. 118

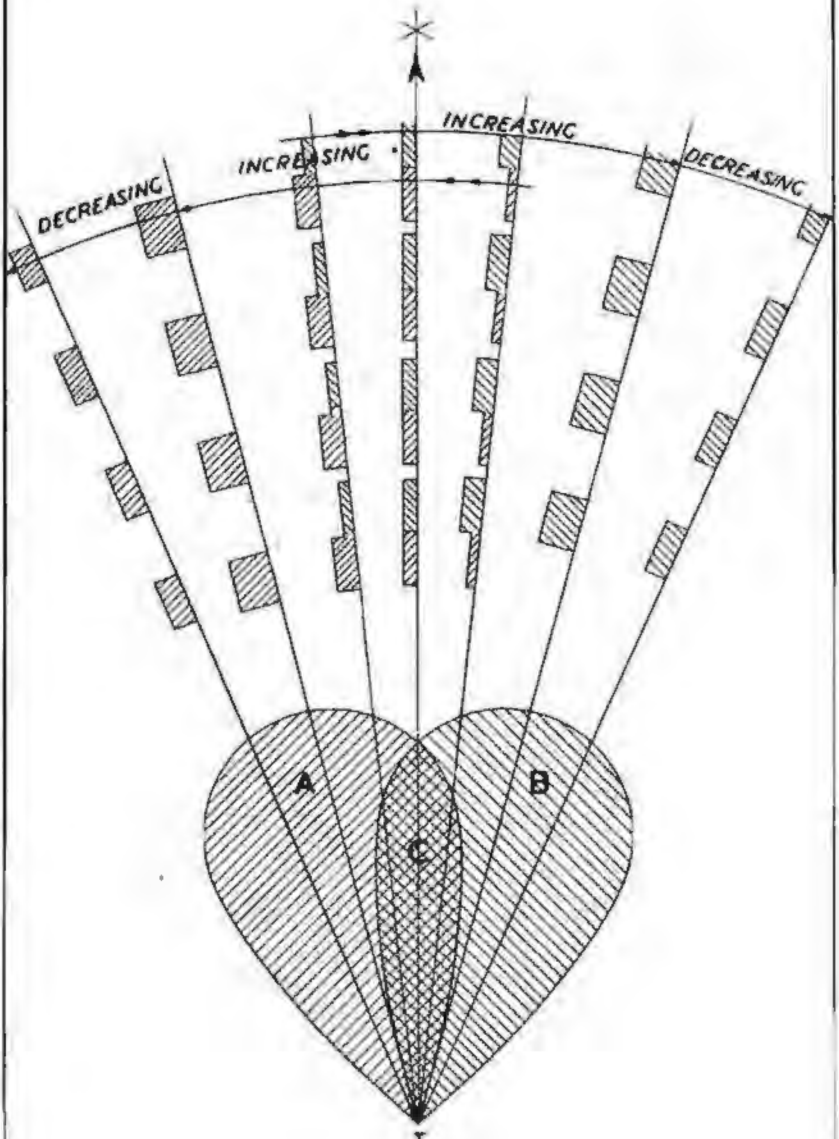


DIAGRAM OF BENITO BEAM SYSTEM

APPENDIX 9 Fig. 3

A.H.B.I DIAGRAM No. 119

Fighter Benito

Finally, no description of Benito would be complete without mentioning its application to enemy Fighter Control which was first observed in August 1942 being used over Holland. Only the range technique was used and employed frequencies in the band 38·4–42·3 megacycles per second. Vectors were given to the fighters by the ground control station after measuring the range and using ordinary D/F methods to locate the fighter which carried the receiver/transmitter type *Fu.Ge. 16 ZE* or *Fu.Ge. 16 ZY*. In the case of Fighter Benito a standard practice was adopted whereby the ground station frequency and its associated aircraft transmitter frequency were always separated by 1·9 megacycles per second.

In Western Europe it was the practice for the ground stations to radiate on the upper half of the *Fu.Ge. 16* band whilst the aircraft re-radiated the ranging tone employing frequencies in the lower half of the *Fu.Ge. 16* band. Owing to the distance involved the ground station transmissions could not be heard in this country with any certainty but by making use of the knowledge of the above-mentioned 1·9 megacycles separation a ground-based jammer in this country could be tuned to cause interference to the enemy aircraft receiver. The jamming employed aimed at preventing the operational messages and instructions being received by each aircraft and for the purpose transmitters using directional aerial arrays concentrating the jamming towards the east were situated at Sizewell on the east coast of England. This operation was known as Cigar.

APPENDIX No. 10

ORGANISATION OF No. 80 WING OUTSTATIONS

R.C.M. installations involved the erection of a large number of very small outstations throughout the country often situated in remote districts. As the number of personnel manning these stations was usually small, and mainly technical, it was obviously uneconomical to make these units self-contained with domestic and administrative staffs. Consequently it was decided to billet all ranks with subsistence on local householders.

This arrangement was not entirely satisfactory since a difficulty arose with the accommodation and feeding of the watch-keeping personnel. In the case of certain outlying stations it was only possible for these airmen to have one hot meal a day, the remaining meals, which could easily be heated on the site, being provided by the householder. Except for the mobile units despatched to Western Europe and for certain large outstations formed in the last year of the war, in connection with Big Ben operations, the personnel of all stations of the Wing were accommodated and fed under these private billeting arrangements.

Normally administrative, clothing and barrack services for small outstations are obtained by attachment to a reasonably near parent station. For security reasons this was not acceptable in the case of No. 80 Wing. Consequently, besides providing for technical supervision, it was necessary to devise an organisation capable of meeting all the administrative and provisioning requirements for outstations spread over an area extending from the north of Scotland, North-East England, and throughout the whole of the country south of the Humber and including South Wales.

To meet these technical requirements, and as very few of these outstations had resident officers, it was necessary to maintain at Headquarters a relatively large staff of visiting technical officers who were made responsible for the supervision of the various jamming equipments in the outstations. At first the delegation of this responsibility was made in respect of the function for which the equipment had been provided, such that an officer was responsible either for Aspirins, Bromides or Meacons respectively. This however was changed with the introduction of the Area Scheme. Moreover in view of the small staff of Administrative and Equipment Officers available it was necessary that the technical officers should frequently undertake such duties, particularly with regard to technical and barrack equipment. Clothing was issued by employing an Equipment Officer continuously touring the country with what virtually amounted to a mobile clothing store. This organisation could not be considered wholly satisfactory and in April 1941 it was decided that the area to be administered had become too large for one central Headquarters at Radlett. Consequently the so-called Area Organisation was commenced with resultant decentralisation of administration.

The Area Scheme was at first principally confined to technical supervision and administration, though this, by the very nature of the outstations, had to include many normal administrative functions which later grew in volume as the general organisation of the Wing became stabilised. At this early stage, however, each Area Headquarters consisted of an Area Officer and an Area N.C.O. who now took on duties of visiting the outstations of their areas and were responsible for all the technical equipment, regardless of the type of equipment or function. These Area Officers and N.C.O.s were assisted in the case of special equipment by specialist officers from Wing Headquarters. Siting, installation and opening of new outstations was in all cases the duty of Wing Headquarters, such a station not being handed over to the Area concerned until it was fully established.

The functions of Area Headquarters steadily grew as it became necessary to decentralise more and more the administrative and equipment responsibilities of Wing Headquarters. Area Headquarters staffs had necessarily to be increased to cope with the growing administrative duties until finally the establishment of a typical staff comprised the following officers and other ranks :—

1 S/Ldr.	(Sigs. G).
1 W/O	W/O (Admin.).
1 Cpl., 1 A.C. ..	Clerk (G.D.).
1 Sgt., 2 A.C.s ..	Equipment Assistants.
1 F/Sgt.	W/Op. (Area Technical N.C.O.).
3 A.C.s	D.M.T.

The final development consisted in the complete decentralisation of equipment stores, each Area Headquarters then dealing directly with the appropriate Maintenance Unit for all stores and equipment other than that peculiar to the Wing.

Diag. 4 shows the boundaries of the six Areas into which Great Britain was finally divided under the Area Organisation. Except for very minor modifications, these boundaries were not materially altered from the commencement of the scheme. The six Areas were known as the Northern, the Eastern, the Midland, the South Eastern, the Southern and the South Western Areas, with Area Headquarters at Marske, Braintree, Hagley, Windlesham, Ashmansworth and Fairmile respectively.

The following were the Police Stations in which small emergency jamming transmitters were installed during the summer of 1940 :—

> Pickering, Cleethorpes, Wisbech, East Dereham (later moved to Reepham), Eye, Epping, Whitstable, Uckfield, Chichester, Wimborne Minster, Newton Abbott, Glastonbury.

The following were the No. 60 Group Stations in which Watcher operations were carried out, on a lodger basis, during 1940 :—

> Staxton Wold, Ottercops, West Beckham, Bawdsey, Dover, Hawkinge, Swanage, Douglas Wood, Hillhead, Pevensey, Stenigot, West Prawle, Drone Hill, Stoke Holy Cross, High Street, Canewdon, Poling, School Hill, North Foreland, South Foreland and Portland (three Naval Stations), Peterhead, Hartley, Coverack.

APPENDIX No. 11

R.C.M. EQUIPMENT

V.H.F. Transmitters Used by No. 80 Wing in Quantity

(*a*) *Diathermy with H.F. Drive and A.F. Power Supply.*—A simple push-pull clinical Diathermy oscillator using H.F. 300 valves, modified for frequency and provided with a drive circuit and a modulation unit. Modulation was obtained by supplying H.T. from a power pack at 1,150 cycles per second.

(*b*) *Diathermy with Crystal Drive, Type No., Drive Unit, Type 8.*—As immediately above but with crystal and doubler drive and Thyratron keying device (dots or dashes): spot frequencies, 30·0, 31·5 and 33·29 megacycles per second. A half-wave dipole attached to a suitable chimney was used with the above equipments when first installed.

(*c*) *Diathermy (modified). Type No., Drive Unit, Type 8.*—The clinical Diathermy P.A. stages were eventually returned to the manufacturers for reconditioning and return to the hospitals and replaced by a special P.A., using the same valves (H.F. 300) and certain components, manufactured by Messrs. Peto-Scott. The critical crystal drive, now provided with alternative variable frequency M.C. drive, was still used. Spot frequencies 30·0, 31·5 and 33·29 megacycles per second or continuously variable 28–34 megacycles per second. Output approximately 150 watts carrier.

Peto-Scott, Type No., Drive Unit, Type 9.—Similar in circuit to Diathermy but with separate P.A. stage power supply giving greater outpnt and assembled as one consolidated rack unit: frequencies as before; carrier output approximately 300 watts.

S.T. & C., Type No. T.112.—Standard early pattern S.T. & C., S.B.A. transmitters modified for keying and mounted in impressed vehicles; spot frequencies 30·0, 31·5 and 33·29 megacycles per second with small adjustment as first, later modified to cover with three changes of crystal, 29–34 megacycles per second: output 500 watts carrier. Five fixed S.B.A. beacons (S.T. & C. or Lorenz) of similar pattern were also used during 1940–41. A single half-wave dipole, approximately half-wave from the ground, was used with the normal S.B.A. equipment feeder.

G.M.C., Type No. T.1388.—Modified from Army gun-laying radar transmitter, GL/Mark 1. After various tests using different repetition notes, with and without keying, and with and without additional modulation it was ultimately decided to modify these transmitters for normal C.W. operation with automatically keyed grid modulation the tone being obtained from external A.F. oscillators. Except for changes in wave band coverage and the incorporation of many minor improvements dictated by experience and for special operations, this general pattern was continued in all the many G.M.C. transmitters ultimately supplied to the Wing. A "J" matched half-wave dipole approximately half-wave from the ground was the standard aerial used although a simple Sterba array had been employed in the first instance, aligned on to the target to be protected. Elevated cage aerials were used for Cigar. The rated carrier output varied from 600–750 watts over a frequency band, in the final model, of 20–75 megacycles per second.

S.W.B.8, Type No. T.1277, Type No. T.1491, S.W.D.11, Type No. T.1278.—Standard H.F. communication transmitters modified in wavelength coverage and provided with anode modulation and tone source equipment together with special adjustable automatic keying devices. Twin rotable ½ wave tuned aerials, with or without parasitic reflectors, were the standard aerial equipment used in the mobile versions of these transmitters in which the frequency coverage was 29–34 megacycles per second increased later to 48 megacycles per second in the case of S.W.B.8 and 28–36 megacycles per second in the case of S.W.B. 11. Certain static S.W.B. 8's were converted to cover from 38–48 megacycles per second and were used with half-wave dipoles on 60-foot lattice masts. The carrier output power was 1·8 kilowatts in the case of S.W.B. 8 and 5·5 kilowatts in the case of S.W.B. 11 transmitters.

S.W.B. 4, Type No. T.1281, Type No. T.1493.—Two early Marconi television transmitters modified to cover 38–48 megacycles per second and 42–48 megacycles per second respectively and provided with anode modulation and tone source equipment together with special adjustable automatic keying devices. They were used with half-wave dipoles on 60-foot lattice masts. The rated carrier output was 1·4–1·6 kilowatts.

T.U. 4, Type No. 1284, Type No. 1284A (Tropical).—This was the first transmitter specially designed for R.C.M. purposes and built on a production basis. The original requirements, not in all cases completely obtained, which were considered to be universally applicable to all known enemy radio aids, were as follows :—

(*a*) R.F. Cover.—20–120 megacycles per second continuously variable. It was obvious a number of bands with coil change would be required inside the total coverage but frequency change was to be easy and rapid within any one band.

(*b*) A.F. tone generator to give full modulation 100–10,000 cycles per second.

(*c*) Keying.—Unit to provide keying rates of 50–200 per minute (dashes or dots).

(*d*) Mark-space ratio to be continuously variable from 1 : 1 to 12 : 1.

(*e*) R.F. setting accuracy to 0·007 per cent (five kilocycles at 60 megacycles per second) from calibration cards to be provided.

(*f*) R.F. stability to 0·015 per cent. (10 kilocycles at 60 megacycles per second) over normal temperature range after five minutes run.

(*g*) A frequency stability to 1 per cent.

(*h*) Keying and mark-space ratio to 1 per cent.

In the models as finally produced the requirements were slightly modified in accordance with the experience gained with the prototype.

(*a*) The total R.F. cover was reduced to 27–100 megacycles per second.

(*b*) Twin tone sources were provided enabling simultaneous modulation to be produced at from 100–30,000 cycles.

(*c*) A keying note of 60–200 per minute was obtained.

(*d*) The mark-space ratio was continuously variable from 1 : 1 to 7 : 1.

(*e*) The average carrier power output ranged from 600 watts to 1,000 watts.

(*f*) These transmitters were in all cases fitted in Brockhouse trailers with a quarter-wave aerial mounted on the roof, adjustable for frequency from inside the van body.

G.E.C. 100 A.M., Type No. 1264.—These transmitters were originally produced for police purposes but were handed over to No. 80 Wing after modification for use as low power universal transmitters covering the band 27–120 megacycles per second. Keying and modulation were as for the T.U.4 except that only a single tone was available covering from 100 to 10,000 cycles per second. The variable speed mark-space ratio keying device was a separate component and not incorporated in the transmitter proper. A "J" matched half-wave dipole was used with the static models and a quarter-wave dipole on the roof of the vehicle in those cases where the transmitter was mounted in a vehicle. A suitable P/E power unit (Peters 1·5 kilowatts) was installed in the mobile vehicles, making these entirely self-contained units.

U.S.B.2, (H.P.) Type No. T.1298, (H.P.) Type No. T.1298A, (H.P.) Type No. T.1307, (L.P.) Type No. T.1336, (L.P.) Type No. T.1492.—There were two forms of this transmitter (a high power model and a low power model) both of which were based on a series of S.B.A. transmitters in hand by Messrs. Marconi for South Africa. The general characteristics were, on the whole, similar to those of other general purpose R.C.M. transmitters, but covering a smaller range, being : R.F. coverage 29–80 megacycles per second for the high power transmitter and 29–48 megacycles for the low power transmitter ; variable keying speed 60–180 ; variable mark-space ratio 1 : 1 to 7 : 1 ; single audio tone 200–3,200 cycles per minute. A five-eighths wave tuned vertical aerial was used. The rated carrier output of the high power model varied between 2·0 and 3·0 kilowatts, and was approximately 600 watts in the case of the low power model. The various type numbers refer to changes in valve types, necessitated by difficulties of supply and to other small modifications.

Single V.H.F. Transmitters or V.H.F. Equipment designed for Special Purposes. H.M. Signal School Bromide.—An emergency 500-watt transmitter produced at short notice for the Ruffian threat; covered the band 65–75 megacycles per second with alternative modulation frequencies of 1,150 and 1,500 (later modified to 2,000) cycles per second and dot or dash keying at 120 minute, the mark-space ratio being 7 : 1.

Grocer.—A jammer against enemy A.I. in the 480–505 megacycles per second frequency band, having a beam aerial system which was set in azimuth to cover the bomber stream. Monitoring was carried out from a near-by site using a panoramic receiver, and separate rotatable aerial, scanning the band 475–515 megacycles per second. The transmitters, two to each monitor as originally laid out, were spaced about 100 feet apart and each fed into an independent paraboloidal mirror mounted on a turntable on a gantry erected above the respective transmitter hut. The frequency of each transmitter was remotely controlled, by means of push buttons, from the monitor site so that the jamming signal could be laid completely over the enemy signal by a visual method. Each transmitter consisted of an R.F. self-oscillator having tuned lecher cathode output and grid lines, using four V.T. 99 valves in push-pull (diagonally opposite tubes in phase). Tuning was achieved by a variable grid capacitance in the R.F. stage operated by a tuning motor controlled by the push buttons at the monitor. The common anodes of the valves were driven by a power amplifier fed from a noise modulator, the noise being produced by a crystal detector having a D.C. voltage applied in the direction of greatest impedance. Each transmitter was capable of delivering 100 watts R.F. power through open wire feeders to horizontal slot radiators, giving vertical polarisation. Each mirror was divided into a top and bottom section and had a total vertical aperture of 40 feet, giving a five-degree beam width and a gain of about 700, the whole structure weighing about 10 tons.

Tuba.—American A.500B and A.500C.—A V.H.F. transmitter designed for use against A.I. in the first instance, the A.500B model covering roughly the same band as Grocer, namely 480–510 megacycles per second and the A.500C model with certain electrode modifications covering 330–600 megacycles per second. Cavity resonator tubes known as Resnatrons or Sloan-Marshall tubes Type 1c and Type 21, respectively, were used for obtaining the power which was 18 kilowatts modulated in the case of the Type 1c tubes and 38 kilowatts in the case of the Type 21 tubes. These tubes were completely demountable, and as was to be expected with such a new technique directly applied for field use in mobile units a large number of teething troubles was experienced. The first unit, however, with Type 1c tubes carried out about 100 hours on operations with one failure only, but owing to its limited frequency range was restricted in scope. The later units with Type 21 tubes were never used operationally. Various types of aerial fed by 16-inch wave guides were tried from an experimental net "horn" produced by flaring out the last 150 feet of wave guide to 30 feet high and six feet wide to rotatable wide-band "Hog Horns" designed by R.R.L. These were half "cheeses" and were found to be much easier to handle over the whole frequency band from 330–600 megacycles than the original T.R.E. "cheeses" which, though only designed for the original limited frequency, were very sensitive to small frequency changes.

Elephant Cigar.—American A.3600 R/T Jammer.—This transmitter designed for R/T jamming consisted of a pair of resonant line oscillators each capable of being tuned over a frequency range of approximately 30–50 megacycles per second and each having a carrier output of 50 kilowatts. Each oscillator employed a tuned grid, tuned cathode circuit, tuned by means of shorting bars and two Type 880 water-cooled valves in push-pull. The cathode lines were made of 2-inch copper tube, the line itself forming one lead of the filament circuit and a heavy rubber insulated cable running through the centre of the tube, the return. Each oscillator was frequency modulated by means of a "wobbulator" which consisted of a motor-driven four-bladed rotary loop (inductance) placed between the shorted ends of the grid lines, and which gave a frequency sweep at about 400 cycles per second, depending on the mean frequency of the oscillator, between two megacycles at 30 megacycles per second and 4·5 megacycles at 50 megacycles per second. Vertically stacked triple cage dipoles on 105-foot wooden towers fed in parallel were used, with wire netting screens to increase the forward gain. For Big Ben operations it was necessary to modify this equipment to cover down to 18 megacycles per second and to provide tone amplitude modulation. The reduced frequency was obtained by fitting condensers at the high frequency ends of the grid and cathode lines and using the " wobbulator " as a manually operated tuning control. This control, in conjunction with a variation of the additional grid condenser, enabled the oscillator to be tuned over five megacycles per second without switching off for adjustment of the shorting bars. The modulation was obtained by utilising the modulator of a T.U. 4 transmitter, the modulation voltage being introduced into the grid bias circuit of the oscillator to give Class " C " grid bias modulation.

Briar " H ".- This was a method, produced by No. 60 Group, of using a Type 12 radar station for spoiling the effective control of the enemy *Freya* stations used for ranging in his *Ruebezahl* bombing system. In this method a receiver was tuned to the 125 megacycles per second frequency band and received the pulses from the *Freyas* concerned. These pulses were then widened to about 100 microseconds, squared, modulated at 200 kilocycles per second, delayed for an appropriate period and finally re-transmitted to the *Freya* on 156 megacycles per second, thus covering about 10 miles of the trace which could be adjusted to cover the target area.

Briar " R ".—A second method devised as a counter-measure to *Ruebezahl* which consisted in a modification to A.S.V. Mark II transmitters in order that these could be used to trigger the *Fu.Ge. 25A* equipment in the enemy aircraft at a rate sufficiently high to prevent any useful response being obtained by the interrogating *Freya* station. Four transmitters, each using a simple dipole aerial system, were intended to be installed at each station. One experimental station only was completed and this was never used operationally.

" J " Beams.—The narrow beam equipment was produced originally in an endeavour to achieve some satisfactory means of guiding bombers to small targets, in particular such targets as the Ruffian beam stations which were being attacked by No. 109 Squadron using the techniques described in Appendix 2. It was in other words to be a British *Knickebein*. Besides the operational results to be achieved it was also proposed to use the " J " beam system, as it was called, as a " spoof " scheme to cover the early phases of Gee. This was to be implemented by aligning the beams on the targets to be attacked in any given operation.

The prototype, of which two were produced, the second incorporating the experimental experience of the first, consisted of an aerial system mounted on a G/L cabin which was rotatable on a turntable, the transmitter, a T.U.3 (T.1254) being in the hut. The aerial system consisted of three concentric half-wave dipoles spaced 0·95 wavelengths apart and fed from the bottom, the two outer aerials being 180 degrees out of phase with the middle aerial keyed 67½ degrees from a vector at 90 degrees to the two outers. After a lengthy period of experimental development the first prototype was used for Trinity operation. An improved equipment based on the lessons of the two prototypes was later produced in which the aerial system was mounted on a separate rotatable cabin, the transmitter being a standard T.U.4 (T.1284) in the usual Brockhouse trailer. The new phased array system could also be steered electrically over a few degrees and consisted of a four-element array, the central component consisting of two aerials spaced fore and aft along the centre line of the beam path. A number of these improved equipments were produced and used in conjunction with Oboe operations as well as for the original " spoof " purposes.

Alexandra Palace.—B.B.C. Television Transmitters.—Sound Transmitter.—This transmitter was modified to provide a high power transmitter for use in the London area in connection with the Domino scheme in the band 42 to 45·5 megacycles per second. The associated receiver site from which the necessary enemy audio tone was obtained and where the monitoring equipment was installed was in the first place at Swains Lane (an emergency B.B.C. station) a mile or two from Alexandra Palace, but was later moved to a more suitable site on Hampstead Heath (Parliament Hill). The normal sound circuit aerial system on the tower at Alexandra Palace was used. The modification required and the provision of the necessary receiving equipment were carried out by the B.B.C. The carrier power was rated at approximately 3·5 kilowatts.

Vision Transmitter.—This transmitter and its aerial system were modified to provide a high efficiency *Knickebein* jammer, capable of rapid frequency change over 34 channels, adjacent channels being separated by 1,000 kilocycles in the band 30 to 33·3 megacycles per second. Sixteen channels could be covered simultaneously from the one transmitter. The various channels were obtained by modulating a carrier fixed at 31·65 megacycles per second by means of 17 H.F. oscillators each giving two channels, any eight of which could be selected at will and plugged to the input of eight mixers. The frequencies of these oscillators were 50, 150, 250, 350 kilocycles per second and so on up to the total number required. The carrier was thus situated in frequency midway between the frequencies of the two middle channels in the band required. The carrier was not suppressed but did not actually serve any useful jamming purpose. Three audio-frequency oscillators were provided each covering a separate audio-frequency band and adjustable as required. Any one of these three oscillators could be selected to modulate any of the eight H.F. oscillators selected for use at a given time. All channels were keyed simultaneously. The carrier power of the transmitter was four kilowatts, and modulated with a single H.F. oscillator gave one kilowatt peak power per side-band available. This transmitter was also later modified to cover the bands 38–42, 42–46, 48 megacycles per second, as required when used against the enemy Benito system.

American G.R.Q./1 Transmitter.—This transmitter was originally obtained for the " Big Ben " operation for use on a static site, but was never used for this purpose and was ultimately mobilised for use in western Europe on Bomber Support. The transmitter consisted of a high-power push-pull oscillator using two Type 8009 water-cooled valves producing a 50-kilowatt carrier over a frequency range of 20 to 55 megacycles per second. The oscillator itself consisted of a double Hartley circuit with an untuned grid and adjustable feed-back condensers. Adjustment of variable condenser for fine tuning. An electronic keying unit was provided to produce I.C.W., the number of pulses per second being controlled by an ordinary A.F. oscillator, the whole unit being capable of adjustment from 100 to 15,000 pulses per second. Power supply was obtained from three D/E 62 K.V.A., 230-volt, three-phase, 60-cycle alternators run in parallel.

The transmitter could be operated into either a balanced or an unbalanced load and was actually used with portable half Rhombic aerials. The design of these could of course, be varied according to requirements but in the first instance, for " Big Ben " purposes, two separate aerials each with four wavelength limbs giving a beam width of 30 degrees in azimuth were provided to cover the full band, one cut to 25 megacycles per second and the other to 50 megacycles per second. An absorption loading line was connected at the remote end of the aerial giving an input impedance substantially constant over the full frequency band. This line, disconnected from the aerial at the remote end and directly connected to the transmitter at the near end was used as a dummy load.

American M.R.T./1 Transmitters.—These transmitters were designed originally for R/T jamming and were, in general, similar to the Elephant Cigar but using air-cooled valves and having an output carrier power of 15 kilowatts. Later for " Big Ben " purposes, a modulator and tone source were added and modifications made similar to those for Elephant Cigar. Each transmitter unit consisted of an oscillator cabin, a power and modulator cabin and a petrol/electric power source and when mobilised these three components were mounted on to three 3-ton vehicles. Single, wide-band, cage, dipole aerials, mounted on portable 70-foot towers were used in the first place but these were later exchanged for portable full Rhombic aerials supplied from U.S.A.

Mandrel, Type No. T.1431.—The first transmitter employed was designed by T.R.E. and consisted of a single V.T. 62 master oscillator valve and two V.T. 62 valves in push-pull as a power amplifier stage. These transmitters were used in batteries of six to cover the requisite " barrage " band and had only semi-variable frequency control by means of lecher shorting bars. On account of the wide frequency band required (up to ± 1 megacycle per second) series modulation was employed, thereby necessitating a 2,000-volt high tension supply. The noise jamming signal in these first models was produced by means of a conventional neon striker time base circuit generating three independent and random frequency saw tooth wave forms. These were amplified in a wide band amplifier and distributed from a cathode follower output circuit to the inputs of the modulators on the individual transmitters forming the barrage. The original aerial array consisted of two vertical dipoles, spaced horizontally, half a wave apart, to each transmitter. Each pair of dipoles was mounted in front of an electro-static screen, 13 feet long by eight feet high, the whole assembly for one unit consisting of six arrays in a line of three vertically spaced pairs. Various methods of mounting the arrays were tried, ranging from telegraph poles to light collapsible masts, but eventually the most successful solution found, in order to withstand the severe coastal gales experienced, was the employment of standard two-inch steel scaffolding which could be erected, braced as required, to form a hoarding without the necessity for concrete foundations. The waveband covered by this original barrage system was 118 to 128 megacycles per second and the power output of each transmitter was rated at 10 watts, fed through twin screened feeders (duradio 11) to the aerial screen system and estimated to be concentrated by the latter into a 60 degree sector.

With the increase of the enemy *Freya* operational frequencies over wider bands and with the requirement to cover other radar transmissions from 30 to 600 megacycles per second it was necessary to modify the first transmitters, to add additional transmitters to the unit, and to revert to spot frequency monitored jamming as opposed to the original fixed barrage.

Mandrel, Type No. T.1636.—The T.1431 described above was modified into a push-pull tunable self-oscillator circuit with a frequency range of 90 to 160 megacycles per second but retaining the same modulation and power supply arrangements. The noise jamming signal was now obtained, both for this and all other *Mandrel* transmitters described later, except the G.M.C., from a cold cathode photo-electric cell and electron multiplier (R.C.A. valve, Type No. 931A) excited by means of a pea lamp whose brilliancy could be controlled. The simple dipoles were now replaced by wide-band cone dipoles.

Mandrel, Type No. T.1659 and T.1659A.—These transmitters were standard T.1131 transmitters modified to cover 50 to 90 megacycles per second (T.1659) and 90 to 100 megacycles per second (1659A). The estimated power output of these transmitters was 10 watts and suitable cone dipoles and screens were used as for transmitter, Type Y.1631.

Mandrel Rug Transmitters.—American APQ/2. –This airborne type of transmitter was used for the frequency bands from 160 to 600 megacycles per second. The unmodified form was used for the bands 200 to 530 megacycles per second, and two modified forms for covering the bands 160–200 megacycles per second and 530 to 600 megacycles per second. The estimated power output varied from 10 to 15 watts and again suitable cones and screens were employed.

Mandrel, G.M.C., Type No. T.1388.—Normal G.M.C. transmitters with vertical "J" matched dipoles were provided for the frequency bands down to 30 megacycles per second, gas discharge tube noise generators being employed.

Carpet.—Six modified Admiralty Type 91 transmitters were provided at the Dover Mandrel site for use against aircraft coastal radar operating on 53 centimetres. These were locally monitored for R.A.F. purposes. They were employed for training of personnel as a component of the existing Naval South-East Coast Jamming Screen against gun-laying radar and ultimately handed back as a Unit to the Naval authorities at Dover.

Type 651.—A twin transmitter and monitor jamming equipment specially designed for shipboard use against H.S. 293 radio-controlled glider bombs. A battery of ten units (20 transmitters) was installed on a coast site for possible use against rockets but it was never used operationally.

Purple.—Army Wireless Set No. 16.—A specially designed equipment for mobile field jamming operations in the band 0·86 to 7·5 megacycles per second. The circuit was simplified to give rapid tuning facilities and consisted of a single valve oscillator giving about 2 kilowatts power into a 46-foot telescopic aerial when modulated. Unmodulated carrier or carrier amplitude modulated by single-tone or multi-tone oscillators, a microphone or a gramophone pick-up could be used.

R.C.A. 50-kilowatt Transmitters at Crowborough (*H.M.G.C.C.*) (*Loaned to Air Ministry by the B.B.C.*).—These were originally normal short-wave broadcast transmitters operating on the B.B.C. Overseas Service. As obtained, they were crystal controlled, with two separate channels, having separate exciters with a common P.A. When modified the crystal drive units were discarded, only the modulators and P.A.s being retained. In order to obtain very rapid tuning over a wide frequency band of approximately 30 to 70 megacycles per second, the P.A.s were converted to self-oscillators, operated in push-pull with lecher tuning and D.C. motor drive for the tuning arms. The output was taken from the cathodes, the anodes being tied to ground so far as R.F. was concerned. The valves used in both P.A. and anode modulator stages were water-cooled R.C.A., Type 880s, operating with 12,000 volts on the anodes. As planned for "Big Ben" operations these transmitters were in the first instance controlled from the Eastbourne site by means of a remote control system. This system, operated over either G.P.O. landlines or over an ultra-short wave (5,000 megacycles per second) radio link giving eight separate channels for speech or control, was designed to tune the transmitter over its full range, and to switch the main H.T. on or off. This was accomplished by sending tone to line from a B.F.O. situated at Eastbourne Control, a 1,000-cycle note operating the driving motor in one direction and a 2,000-cycle note driving it in the reverse direction. The audio tones were fed to a discriminator, where they were rectified and amplified by a D.C. amplifier, the output of which was fed to a D.C. generator having a special field to give current of the desired polarity to operate the tuning motor. This motor was of very high speed and could sweep the lechers in a matter of seconds. A 300-cycle tone was used to operate the Post Office relay which controlled the main H.T. relay of the transmitter. In order to indicate to Eastbourne Control the frequency to which the transmitter was tuned, a telemeter was installed there, controlled by the output of a photo-electric cell, the amount of light falling on the cell being governed by the position of the lecher-tuning arms.

The following M/F and H/F Transmitters have been used for Meaconing and Special Purposes.—In general these are standard transmitters with small modifications only in connection with the drive circuits.

Type.	Frequency Range in kilocycles.	Mast Height in feet.	Mast Spacing in feet.	Type of Aerial.	Type of Earth.	Normal output power into Aerial.
G.12 (T.1259) ..	110–1,200	—	—	—	—	2·0 kilowatts
G.12A (T.1302)..	150–6,000	150	250	2-wire T	30-wire radial	2·0 kilowatts
G.12B	150–1,200	150	300	2-wire T	12-wire radial	1·5 kilowatts
G.12E (T.1197)..	150–1,200	150	250	2-wire T	12-wire radial	1·2 kilowatts
G.12F (T.1331) ..	150–6,000	150	250	2-wire T	12-wire radial	1·7 kilowatts
TFM.1 (T.1210)	160–1,020	—	—	—	—	100 watts
TEM.1 + Amp. (A.1262).	190–1,050	150	250	3-wire T	36-wire radial	3·0 kilowatts
TEM.2 (T.1212)	160–1,050	70	220	4-wire T	12-wire radial +4 mats	250 watts

Type.	Frequency Range in kilocycles.	Mast Height in feet.	Mast Spacing in feet.	Type of Aerial.	Type of Earth.	Normal output power into Aerial.
RCA. (T.1206) ..	150–1,050	70	220	4-wire T	12-wire radial +4 mats	500–750 watts.
T.77	150–1,200	70	220	4-wire T	12-wire radial +4 mats	200 watts
T.77+Amp. (A.1111).	150–550	150	250	4-wire T	12-wire radial +4 mats	2·5 kilowatts
M.11 (T.1267 ..	150–600	100	300	2-wire T	8 mats	2·5 kilowatts
M.24 (T.1261) ..	(*a*) 150–600 (*b*) 150–1,000	100	190	2-wire T	8 mats	2·5 kilowatts
T.1087	3,000–6,000	70	—	54 feet 6-wire vertical cage.	12-wire radial +4 mats	350 watts

Western Electric, Type 407A-3 Broadcast Transmitter.—This transmitter consisted of a crystal oscillator operating into a three-stage R.F. amplifier; a three-stage audio frequency amplifier; a modulated amplifier having two Type 342A water-cooled valves in parallel and a final power amplifier using two Type 298A water-cooled valves in a high efficiency Doherty circuit, giving an unmodulated carrier output of 50 kilowatts. The output of the transmitter was designed to feed the aerial by means of a 100-ohm nitrogen gas-filled coaxial feeder. For speed of erection, however, the down lead of the aerial was brought through the roof of the transmitter, building, its 40-ohm impedance being matched to the 100-ohm output from the transmitter by means of a T network built externally to the transmitter and adjacent to the power amplifier unit. Owing to the complexity of tuning the power amplifier no attempt was made to tune the transmitter over a large frequency range. Instead a variable frequency master oscillator was used as an alternative to the crystal oscillator and it was found that by this means the transmitter would operate from 1,170 kilocycles per second merely by swinging the frequency of the master oscillator.

APPENDIX No. 12

RADIO COUNTER-MEASURES AGAINST "BIG BEN"

Introduction

The launching of long range rocket projectiles (" Big Ben ") against this country and Allied targets on the Continent took place during the period September 1944 to March 1945 and a total of over 3,000 incidents was reported. This total, which does not include abortive launchings, consists of 1,115 rockets launched between 8 September 1944 and 27 March 1945, against England, and 2,050 between 14 September 1944 and 28 March 1945, against Continental targets.

In July 1944 No. 80 Wing was directed by Air Ministry to prepare to apply radio counter-measures against " Big Ben " after the remains of a long range rocket had been found in Sweden which had apparently been launched experimentally from Northern Germany. These remains were found to include parts of various types of radio equipment in damaged condition, and the organisation of radio counter-measures was for some time restricted practically to whatever could be done in the light of information obtained and surmised from an examination of these relics, as very little other intelligence was available on the radio used in connection with " Big Ben."

General Counter-measures against " Big Ben "

The radio counter-measures adopted formed only a part, of course, of the variety of counter-measures—offensive and defensive—which were planned and applied against "Big Ben." The principal offensive counter-measure specifically aimed at " Big Ben " was air attack against rocket launching and storage sites, centres of production of rockets' components and propellant fuels, and related transport facilities. The salient defensive counter-measures were an elaborate warning system and an R.C.M. organisation neither of which were in fact brought into full use. A complex system of special radar stations provided the warning information. It claims to have detected every rocket launching which was followed by an incident ; also many others, and, in association with a sound ranging system, provided data from which launching areas were computed. Fall of shot was observed by various organisations, the most accurate of which was flash spotting by an Army Field Survey Unit.

Aim of R.C.M. against " Big Ben "

The formation of a plan for the provision of effective radio counter-measures against "Big Ben" was dependent upon sufficient intelligence being available to enable tolerable estimates to be made of the types and purposes of the radio used in the rocket and that on the ground for its control. Such intelligence was not initially available.

It was assumed that the radio used in and with the rocket would be designed to direct it so as to follow a desired trajectory in elevation and azimuth, to obtain a desired range, and perhaps to cause the detonation of the war head if air bursts were required.

It was therefore the aim of these radio counter-measures to prevent or interfere with the proper functioning of such radio devices and, if possible, to cause the rockets to be misdirected so as to miss their targets and preferably to fall harmlessly or, better still, to cause injury to the enemy.

Intelligence on Radio used with " Big Ben "

The intelligence available on " Big Ben " radio prior to the operational use of rockets against this country was confined mainly to that obtained from examining the relics of the Swedish incident and surmises made thereon ; no signals identified with or suspected of being associated with " Big Ben " were heard. These relics indicated the presence of various pieces of damaged and incomplete radio equipment, namely :—

- (*a*) A receiver-transmitter (hereafter called " Rx-1 " and " Tx-1 ") linked together with a common oscillator, the receiver being capable of being pre-tuned in the frequency band 18·8–27 megacycles per second and the transmitter being pretunable over 45–54 megacycles per second. When operated together, the operable band was seen to be more limited, but the exact band and the principles of co-operation of the two sets were not initially clearly determined.
- (*b*) A receiver (hereafter called " Rx-2 ") type E.230 (a type already known as being used in the H.S. 293 radio controlled glider bomb) : capable of being pre-tuned to any spot frequency in the band 47–50 megacycles per second, also suspected of having been used in a version operating on frequencies down to about 40 megacycles per second.
- (*c*) A receiver (hereafter called " Rx-3 ") with a pretunable coverage of 46–53·5 megacycles per second.

(*d*) Some components which, it was thought, might indicate the presence of a transmitter (hereafter called "Tx–2") working somewhere in the band 30–100 megacycles per second.

(*e*) A box with spaces for 12 valves and some associated resistances and condensers.

(*f*) A box containing five plug-in generators then found operating in the band 6·5–11·5 kilocycles per second tunable to ±0·5 kilocycle by varying associated inductances and five plug-in modulators; later suspected of being associated with Rx–3.

Very little other intelligence necessary to the development of an R.C.M. system against "Big Ben" radio was available beyond tentative estimates such as :—

(*a*) Range of rockets which might be up to about 200 miles.

(*b*) Launching sites which might be anywhere on the Continent within 200 miles of targets in the United Kingdom.

(*c*) The projectile was likely to be fired at an angle of elevation of about 70 degrees, its inclination gradually changing to about 45 degrees under full drive.

(*d*) That wireless control of the rocket was likely to be exerted during the first 10 miles of flight, the duration of which might be between 45 and 70 seconds.

It was speculated that the purposes of the equipment referred to above might be intended respectively to provide :—

(*a*) Indications of range, on Benito ranging principles by comparing the phase relationship of the modulation of a signal transmitted by the radio control on the ground and a re-radiation of that modulation on another frequency, from the rocket.

(*b*) Azimuth and elevation control comparable to that in the H.S. 293 glider bomb.

(*c*) Possibly for control of fuel throttles to cut off fuel or to vary the rockets' speed, or perhaps to cause detonation of its war head.

In the next few months little further intelligence came to light although the examination of remains of rockets landing in this country showed that some of them contained radio equipment, but that in these cases only two types of set were in fact installed; and for a considerable period after about the middle of October, wireless control does not appear to have been used at all, reliance being placed instead upon an "integrating accelerometer."

Planning of Radio Counter-measures

Acting on the foregoing assumptions, it was decided that means should be provided to apply R.C.M. :—

(*a*) Primarily on the 19–25 megacycles per second and 40–55 megacycles per second frequency bands.

(*b*) Using plain carrier or modulation (A.M. or F.M.) with tone or noise.

(*c*) Employing maximum possible power.

(*d*) When rocket signals were heard but if not intercepted when rocket launchings (flash) were reported.

(*e*) From bases as far forward as practicable.

(*f*) Aimed towards any areas still available to a retreating enemy within 200 miles from London.

(*g*) On the assumption that up to 20 signals (whether genuine or false might not be immediately perceptible) would be active simultaneously.

In early July, it was estimated that rocket attacks on a limited scale were imminent; it was therefore necessary to prepare, as quickly as possible, to apply such few radio counter-measures as were thought might be of some possible effect and which could be set up by the use of existing equipment with hastily made modifications, and to expand the R.C.M. organisation from this very limited beginning as rapidly as availability of " Big Ben " intelligence, special equipment, suitable personnel (requiring training), and the elaboration of suitable operational procedures, would allow.

The provision of the ground based R.C.M. system in the United Kingdom was planned in three successive stages, the advancement of which was to proceed as rapidly as the limitations mentioned above would permit. In each stage the search for enemy signals was made by all the available effort of the " Y " Service and No. 80 Wing resources, and was controlled from a jointly run operations room devoted exclusively to " Big Ben " radio intelligence and R.C.M. Control. The R.C.M. transmitters were operated and controlled by No. 80 Wing.

In addition to investigation aircraft of No. 192 Squadron, specially equipped aircraft up to a total of four squadrons to operate under Headquarters No. 100 Group were also planned to be equipped with search receivers and jamming transmitters.

The initial stage of the ground R.C.M. organisation to be working by 23 August 1944—involved the following :—

(*a*) *Radio Intelligence and R.C.M. Watch* (*Search and D/F*).

Beachy Head (Eastbourne).	" Y " Service and No. 80 Wing Joint Control.	Eight search and two D/F sets, cathode ray tube analytical and photographic equipment.
Gorleston (Yarmouth).	" Y " Service Outstation.	Three search and one D/F.
Capel (Dover).	" Y " Service Outstation.	Three search and one D/F.
Beach Farm (Lowestoft).	80 Wing Outstation.	Three search and one D/F.
Eagle's Nest (Dover).	80 Wing Outstation.	Three search and one D/F.
Southbourne.	80 Wing Outstation.	Three search and one D/F.
Worth Matravers.	80 Wing Outstation.	Three search and one D/F.

(*b*) *R.C.M. Control and Monitor.*—Beachy Head—with tie lines to all receiving and transmitting outstations and Headquarters No. 80 Wing.

The second or interim stage—to be working by the beginning of September—was to extend the foregoing facilities as follows :—

(*a*) *Radio Intelligence and R.C.M. Watch.*—As for initial stage.

(*b*) *R.C.M. Control.*—The erection of a new building at Beachy Head with much increased facilities including 15 sets of receivers each equipped with auxiliary cathode ray tube visual presentation, extended tie lines enabling two-way speech and tone transmission for transmitting stations, and " Big Ben " alarm circuits operating two-way between No. 11 Group Filter Room, Beachy Head and Radlett.

(*c*) *R.C.M. Transmitters.*

The third or final stage, to be working by about the end of September, was to provide much more special receiving and high-power transmitting equipment, and a more complex control organisation.

(*a*) *Radio Intelligence and R.C.M. Watch.*—As for preceding stages augmented by (*b*) below, and controlled by Canterbury instead of Beachy Head.

(*b*) *R.C.M. Control and Monitor.*

(i) Control at Canterbury (replacing Beachy Head).

(ii) Two associated sub-controls at St. Margaret's Bay near Dover for Hope Point, Whitfield Tower and Crowborough.

(iii) Landline system linking controls, sub-controls, receiving and transmitting sites by two-way speech (over 200 circuits) and high-fidelity tone lines (about 100 circuits).

(iv) St. Margaret's " A " and " B " to be provided with a total of about 60 receivers fitted with auxiliary cathode ray tube presentation, landline circuits for speech and high-fidelity tone (up to 16 kilocycles) connecting receivers and transmitters (each manned by an operator), on which circuits controllers in Operations Control Room and supervisors at transmitting stations could also monitor and speak at will.

(v) " Big Ben " two-way warning system between No. 11 Group Filter Room and R.C.M. Controls at Canterbury and St. Margaret's Bay.

(c) *R.C.M. Transmitters.*

Provision of Radio Counter-measures

The plan in the three stages mentioned above was not in fact implemented in full due to the rapid advance of Allied forces across France and Belgium into Holland. By the beginning of September, stages I and II of the plan had been substantially carried into effect to the extent that equipment was in place and operable and a sufficient quantity of personnel had been found, although the efficiency of the system had never been tried operationally and only very limited trial transmissions (essential to operational efficiency) were possible due to security considerations.

By the end of August arrangements had been made for the provision, at varying dates in September and October, of all the transmitters, receivers, auxiliary gear and telephone circuits and personnel required to achieve Stage III. Most of the receiving equipment and the 25 transmitters, types AN/GRQ–1, A–3600, AN/MRT–1 and modified R.C.A. were provided and promised from American sources.

In view of the military situation then prevailing, early in September No. 80 Wing was directed by Air Ministry to stop all work on the following components of Stage III :—

Canterbury	Ops. Control.
St. Margaret's	" A " and " B " sub-controls.
Whitefield Tower	Transmitting station.
Crowborough	Four of the six transmitters.

The result was a modified final stage having :—

(a) *Radio Intelligence and R.C.M. Watch.*—As planned for Stage II.

(b) *R.C.M. Control.*—As planned for Stage II.

R.C.M. Control Facilities

The R.C.M. control facilities for the final stage were planned as follows :—

(a) A receiver for searching and monitoring was provided for operation in conjunction with each R.C.M. transmitter, and landline circuits were arranged to link any receiver with any transmitter.

(b) The Control Station at Canterbury was connected by landlines to the receiver–monitor sub-control stations " A " and " B " at St. Margaret's Bay which were in turn associated with the R.C.M. transmitting stations at Hope Point, at Whitfield Tower and Crowborough, respectively.

(c) Receiving equipment was provided at the Canterbury Control Station for analytical purposes and to enable general observation of " Big Ben " signals and R.C.M. activity. Sufficient receivers were arranged at St. Margaret's " A " and " B " to provide for one to be associated with each R.C.M. transmitter at Hope Point, Whitfield Tower, or Crowborough as the case might be. Each receiver was provided with a panoramic adapter enabling the visual display on a cathode ray tube of signals active within 100 or 500 kilocycles on either side of whatever the frequency might be to which the receiver was tuned ; audio oscillators, wavemeters and other ancillary equipment were also available.

Landline circuits and P.B.X.s were specially arranged by the G.P.O. to provide the following facilities :—

(*a*) Two-way speech between control stations (Canterbury and St. Margaret's), and to transmitters.

(*b*) Two-way speech between controllers and receiver-monitor operators at control stations and supervisors and operators at transmitting stations.

(*c*) Transmission of receiver output (" tone ") at the control to the sub-controls and vice versa and from either to transmitters ; these tone circuits would cover frequencies between about 100 and 16,000 cycles.

(*d*) " Speech " and " tone " lines were separate ; receiver and transmitter operators were supplied with head and breast sets. The receiver operator's phones were switched so that they could either be used with both listening to the receiver, or " split " so that one remained associated with the receiver while the other was used for intercommunication with the controller and/or transmitter operator. The transmitter operator's phones were similarly " split " to allow intercommunication with the transmitter supervisor without losing touch with the receiver-monitor at the associated control station.

(*e*) Although each receiver was arranged so that it would normally be associated with a particular transmitter, arrangements were made whereby any receiver could be associated with and " drive " any transmitter or any number of transmitters.

(*f*) Personnel in charge of transmitter watches could call and speak to any operator and vice versa and all calls by operators could be listened to and broken into by personnel i/c watches.

A plan for inter-station landline provisions planned for Stage III, including those required during the change-over from Stage II, was drawn up. Further information on the telephone circuits facilitating control is included in a G.P.O. Memorandum dated 25 July 1945 referring to the facilities provided by the Post Office Engineering Dept., a copy of which is attached to this Appendix.

The control arrangements at Beachy Head in the intermediate stage were arranged in the same general way as, and formed the prototype for, the final scheme. The two salient differences were :—

(*a*) The " tone " lines to transmitting stations were only of normal telephone fidelity (going up to about 3,000 c/s).

(*b*) A radio link was provided between Eastbourne and Crowborough using a pair of Army Type 10 equipments. This link which employed pulse communication methods on centimetric wavelengths provided six two-way circuits. The transmitters at Crowborough were specially modified to be remotely tunable by the application of various audio tones from Eastbourne. Thus the radio link could be used in lieu of landline to enable

(i) two-way speech ;

(ii) transmission of receiver output to transmitter to aid manual tuning and/or as a modulation source ;

(iii) remote control of transmitter tuning.

A two-way " Big Ben " warning circuit was provided between No. 11 Group Filter Room, Stanmore (the focal point of reports of " Big Ben " radar observations) and the control and sub-control stations, and to Headquarters No. 80 Wing, Radlett. This warning operated a special bell and a lamp signal and was acknowledged by reply signal (lamp) plus speech circuits if required. Circuits to the Scientific Officer at Stanmore were also provided for intelligence purposes. The " Big Ben " warning bell signals were immediately acknowledged by the Controller. It was also arranged (but did not occur) that warnings should be passed to No. 11 Group Filter Room from Canterbury or St. Margaret's stations if signals were observed which were thought to connote launching activity.

R.C.M. Operational Procedure

Each receiver operator would search a pre-determined band either covering or falling within the range allocated to his associated transmitter. The main considerations governing the width of this band were the length of time it would take him to search it thoroughly, and the time it would take to adjust his associated transmitters and start radiating. The aim was to be able to transmit against a recognised signal in preferably 10–15 seconds and certainly not more than 30 seconds. Generally the band did not exceed 250 kilocycles per second.

Each operator was briefed upon the types of signal that were known not to be of interest, and was instructed to report any other type immediately to the Officer or N.C.O. i/c his Watch. This report was made by flashing the Controller, reporting the frequency of the signal and, if required, passing tone to line to enable the signal to be heard and assessed by the Controller. If the Controller wished to speak to an operator (*e.g.* to ascertain information regarding signal activity in the band being watched or to order some change in search) he could do so by flashing the operator, who would then " split " his headset and reply.

On instructions by the Controller (which might also be given on receipt of a " Big Ben " warning) or, if a signal was of a recognised kind which should be covered forthwith by R.C.M. transmission, the operator contacted his " twin " transmitter operator, the action taken being as follows : –

(*a*) If the transmitter was remotely tunable the receiver operator tuned the transmitter (after carefully " centering " the suspected signal on his oscilloscope) so that the R.C.M. transmission covered the suspected signal.

(*b*) If the transmitter was only locally tunable, then the receiver operator would give the transmitter operator the frequency concerned and pass the receiver output (with B.F.O. on) to line, so that the transmitter operator could bring his transmitter to bear by swinging it across the suspected signal and hearing his signal cross over. The R.C.M. transmission would also be audible and visible to the receiver operator who would coach the transmitter operator, each using the " split " headphones. In the event of the usual transmitter being unserviceable then the transmitter supervisor would allocate the task to the next most suitable equipment.

(*c*) Where modulation was required, this was supplied either from a local audio oscillator at the transmitter or from the receiver-monitor station by the tone line, using either a local oscillator or the modulation of the suspected signal.

(*d*) If it was desired to use different or additional transmitters, this was done by the use of changeover arrangements at the monitor P.B.X. and jack fields at transmitter P.B.X.

Rocket Radio Apparatus

Rockets began to fall in this country on 8 September and broken parts of wireless sets and components were recovered from several of them. From initial examinations it appeared that operationally launched rockets did not include more than two types of wireless equipment, as follows :—

(*a*) A crystal-controlled receiver-transmitter operating on about 30 megacycles and 60 megacycles per second, transmitting on exactly double the received frequency, suggesting use for velocity or ranging data by " doppler " method with plain C.W. signals.

(*b*) A receiver working on about 52 megacycles per second associated with a complex filter system such that specially modulated receiver signals might, through a procession of switches and relays operate various controls within the rocket such as those governing fuel supplies and/or directional control surfaces.

The salient observations made from the initial examination of remains of some " operational " rockets were therefore :—

(*a*) The " ranging " receiver-transmitter appeared to operate on approximately 30 and 60 megacycles per second and not on about 20 to 24 and 46 to 54 megacycles per second for the former of which ranges the SWB.11 transmitters had been modified.

(*b*) The second receiver operated at about 52 megacycles per second but the form of jamming required needed further study in view, among other things, of the inclusion of complex filter circuits.

(*c*) There was no evidence of the presence of (or use for) the E.230 receiver or second transmitter.

United Kingdom Based R.C.M. Operations against " Big Ben "

Fourteen " Big Ben " incidents were reported between 8 and 15 September. R.C.M. transmissions were made in respect of several of these launchings and also in respect of some " Big Ben " alarms which did not result in reported incident. These transmissions were all very brief, mainly consisting of five-second bursts of radiation in the 50 megacycle region and their speculative aim was to interfere if possible with the fuel supply control of the rocket. Some suspected and otherwise unidentified signals in this band had been heard contemporaneously with launchings and alarms.

All ground-based R.C.M. transmissions were stopped with effect from 15 September 1944 in order to avoid any possibility of their interference with the search for signals associated with rocket control. (It may be observed that airborne R.C.M. transmissions continued for a time after that date.)

So far as is known, no signals were thereafter identified as being connected with " Big Ben " control either during September and October (after which the " integrating accelerometer " was introduced) or towards the end of the rocket offensive when a further use of radio control was reported as being suspected.

Continental Based R.C.M. against " Big Ben "

After the attempt to cross the Rhine at Arnhem had been unsuccessful and it appeared that the rocket offensive might be continued against this country and against Allied targets on the Continent, arrangements were made to send a mobile R.C.M. formation to operate on the Continent in conjunction with No. 105 M.A.R.U. (subsequently expanded under S.H.A.E.F., into No. 33 Wing which also included No. 365 W.U. of the Signals Intelligence Service).

For this purpose an Advanced No. 80 Wing Unit was established at Wenduine on the Belgian coast between Ostend and Blankenberghe and various units were deployed for operations as stated below :—

Unit.	*Function.*	*Equipment.*
H.Q. Echelon of No. 60 M.S.U., Type " S.R."	R.C.M. Control.	Simplified display and landline equipment and point to point W/T working with H.Q. No. 80 Wing, Radlett.
Nos. 60 and 61 M.S.U.s, Type " S.R.".	Search/Monitor.	Receivers (with auxiliary C.R.T. visual indicators, audio oscillators, etc.) for search and to cover R.F. band 20·80 megacycles per second with ample margin each end (to operate in conjunction with No. 365 W.U.).
No. 62 M.S.U., Type " S.R.".	Search/Monitor.	Used mainly for listening reconnaissance in advanced areas as close as possible to enemy territory and launching sites.
Special Mobile Unit.	Transmitter.	Jostle IV equipment to cover 18–24 or 28–32 megacycles per second frequency bands for use against Rx–1.
Nos. 40 and 46 M.S.U.s, Type " S.J." (subsequently reformed).	Transmitter.	Each three transmitters, Type AN/MRT–1.

Although a total of 2,050 " Big Ben " incidents on the Continent were reported as occurring between 14 September 1944 and 28 March 1945, as the occasion for the use of these Units appeared to become less and less probable, they were diverted for use on the Bomber Support R.C.M. role of H.Q. No. 80 Wing (Main); they were, however, available for use against " Big Ben " operations. Actually they were not required beyond keeping some listening watches.

Results of Technical Investigation

The radio devices in at least the later versions, if not all of the rockets, were stated not to be primary controls, but devices to apply secondary, refined corrections to the basic control equipment which itself provided sufficient accuracy to hit a target the size of London from a range of about 200 miles. Thus the successful jamming of the radio equipment would not have served to deprive the enemy of the general use of this weapon.

After several months of extensive study of specimens of both types of radio equipment recovered from rockets, both R.A.E. and T.R.E. pronounced the view that the proper operation of each type might be effectively upset by the reception of sufficiently strong and accurately tuned C.W. jamming signals; these views were a departure from earlier opinions to the effect that accurately modulated signals might be required from which harmonics and side band effect were eliminated.

The conclusion that C.W. jamming might be effective (which incidentally was not reached until late in the rocket offensive) would have helped to mitigate the difficulties of effective application of R.C.M. against the rocket, but nevertheless several other serious problems remained. The salient among such problems were :—

(*a*) The enemy could select the R.F.s of the signals in the 30 and 50 megacycles per second frequency bands.

(*b*) He could site his transmitters at points over a very wide front, deep in enemy territory and in valleys or otherwise screened and directed upwards so that ground signals were very unlikely to be audible to us. The re-radiation from the rocket (on 60 megacycles per second band) might be audible but only for so brief a period that jamming transmissions in response to it would have to be practically automatic to be quick enough to be useful.

In these circumstances effective R.C.M. would have required high-power barrage transmissions covering the bands available to the enemy, by groups of transmitters spread over all areas of territory across which the enemy might choose to fire rockets, and these radio barrages would have had to be made to transmit either permanently or immediately whenever a radar warning was received; in the latter case it is assumed that the reception of such warnings by the R.C.M. Control would prove to be fully reliable. Undoubtedly such barrages would have caused serious interference to other services, particularly tactical ground formations.

Conclusions

The enemy succeeded completely in preventing the effective use of R.C.M. when he produced control means for his rockets which operated with sufficient accuracy without the use of radio aids.

The enemy succeeded in making it very difficult successfully to apply R.C.M. against his temporary use of radio in " Big Ben " operations. He achieved this, *inter alia*, by—

(*a*) high security on details of the device generally and particularly of the radio used prior to actual operations, thereby depriving Allied intelligence of sufficient information to design in advance an R.C.M. system complete in essential detail;

(*b*) using equipment which, if likely to fall into our hands, was also likely to be severely mutilated when so doing;

(*c*) placing reliance in V.H.F. signals of very brief duration which were difficult to pick up and identify (particularly from ground stations);

(*d*) using radio equipment which, at least on initial examination, appeared to require complex and precise counter-transmissions to be effective.

The provision of an effective system of counter-measures required the highest possible efficiency in the inter-service general and technical intelligence system, and the closest liaison and most rapid transfer of all available intelligence and technical appreciations thereon between the general and technical intelligence staff, the scientific and production staffs and the service operational units concerned in the application of all forms of counter-measures.

So far as R.C.M. equipment is concerned the most effective system was shown to be one in which—

(*a*) the control of R.C.M. transmitters was exercised from the point at which the radio search was carried out ;

(*b*) R.C.M. transmitters were remotely controllable from the Ops. Control point in as many as possible of the following ways :—

R.F. tuning.
Switching and keying " on " and " off."
Form of modulation.
Power transmitted.
Direction of propagation.

If remote R.F. tuning were not available, then circuits should be provided for speech and transmission of the output of search/monitor receivers to jamming transmitters to enable the transmitter operator to tune with rapidity and precision.

The combined control of the radio intelligence and radio counter-measures at operational formation level served the purpose of both functions best, indeed their separation would not have produced satisfactory results. It is therefore considered essential that these functions should be combined at all levels under a unified authority charges with full responsibility for both.

To meet threats such as this application of radio skeleton R.C.M. systems are required in which the facilities for flexible control are available. " Universal " receivers and visual watching aids are required covering whatever frequency bands are expected to be detectable, and " universal " jamming transmitters are required capable of covering any frequency within technical reach, and having remote controls mentioned above, and equipped with associated aerials systems which are equally easily adjusted to efficient performance.

Finally, airborne jamming is frequently the most effective against V.H.F. but may require to be associated with ground based R.C.M. Control.

Stage/Function.	Radio Intelligence and R.C.M. Watch.	R.C.M. Control and Monitor.	R.C.M. Transmitters to operate in band 19–25 megacycles.	40–55 megacycles.	Remarks.
Initial Stage I. Operable end August.	Beachy Head improvised building. 2 "Y" Service } Outstations for radio search. 4 No. 80 Wing. }	Beachy Head improvised building. Tie lines to all receiver and transmitter Outstations. "Big Ben" radar warning from No. 11 Group F.R.	Brighton 1—50 kW. Flimwell 1—8 kW. 1—2·5 kW. 9—0·5 kW.	Brighton 1—50 kW. Flimwell 1—2·5 kW.	Transmitters not capable of operating at all points in band due to inherent design and the aerials available.
Totals	7 stations with D/F, about 30 receivers.	1 control station ..	2 stations 12 TX.s	2 stations 2 TX.s	
(Interim) Stage II. Operable early September.	Beachy Head new specially equipped building. 6 outstations as for Stage I.	Beachy Head new specially equipped building. Tie lines to all RX and TX sites for tone and speech specially arranged for control. "Big Ben" radar warning.	Brighton 1—50 kW. Flimwell 4—8 kW. 1—2·5 kW. up to 20—0·5 kW.	Brighton 1—50 kW. Flimwell up to 5—2·5 kW. Hope Point 20—1 kW.	
Totals	7 stations with D/F, about 40 receivers.	1 control station ..	2 stations up to 26 TX.s	3 stations up to 26 TX.s	

Stage/Function.	Radio Intelligence and R.C.M. Watch.	R.C.M. Control and Monitor.	R.C.M. Transmitters to operate in band 19–25 megacycles.	40–55 megacycles.	Remarks.
Final Stage III. To be operable end September/early October.	Canterbury and St. Margaret's Bay, backed up by stations in Stage II as required.	Canterbury control St. Margaret's Bay "A" and "B" sub-controls. One RX for each TX and L/L circuits for each. Specially arranged for control. "Big Ben" radar warning.	Hope Point 20 TX.s	Whitfield Tower 15—50 kW. 14—15 kW. Crowborough 6—50 kW. Hope Point 20—1 kW.	*If required, pending installation of 50 kW. TX.s at Whitfield Tower and Crowborough.
TOTALS	10 stations	.. ..	1 station 20 TX.s	3 stations 55 TX.s	*Plus 40—1 kW. TX. if required.
Actual state of provision when orders given to cease work on scheme.	As at Stage II	As at Stage II	Brighton 1—50 kW. Hope Point 20—8 kW. Flimwell 1—2·5 kW. 9—0·5 kW.	Brighton 1—50 kW. Crowborough 2—50 kW. Hope Point 20—1 kW. Flimwell 1—2·5 kW.	Search-Monitor Control and sub-controls at Canterbury and St. Margaret's Bay under construction. Transmitter installation commencing at Whitfield Tower.
TOTALS	7 stations with D/F, about 40 TX.s	One control station ..	3 stations 31 MX.s	4 stafions 24 TX.s	

Copy

MEMORANDUM DETAILING THE FACILITIES PROVIDED BY THE POST OFFICE ENGINEERING DEPARTMENT IN CONNEXION WITH THE WARNING ARRANGEMENTS AND COUNTER-MEASURES TAKEN BY THE SERVICES AGAINST THE V.2 ROCKET ATTACK DIRECTED AGAINST SOUTHERN ENGLAND BY THE GERMAN ENEMY IN 1944/45

Shortly after Intelligence revealed that the enemy was planning an attack on this country with rocket projectiles the Ministry of Home Security consulted the Post Office Engineering Department with the object of obtaining co-operation in the provision of a supplementary warning scheme. Subsequently the Air Ministry formulated a request for special communication facilities to assist in the defeat of this new weapon by radio counter-measures.

In June 1943, at the request of the Ministry of Home Security, the Post Office Engineering Department initiated development of a remotely controlled public warning system, the warning devices to be located at London A.A. gun sites with the control situated at Fighter Command. In its initial form the warning consisted of Klaxon hooters fitted in the Command Posts of twenty-one London gun sites and controlled by the operation of an iron-clad mains type switch situated adjacent to the Filter Room Controller at Stanmore. In view of the limited range of the Klaxon type hooters, it was arranged that Bofors guns would fire blank ammunition on receipt of the hooter signal. These arrangements were completed in August 1943 but as no attack developed the scheme was abandoned in favour of a much improved and more ambitious scheme.

In September 1943 a total of 165 sites were chosen in and around London, the locations in the main being the A.A. and Balloon sites, though some 30 Police Stations were also utilised to give the requisite coverage. At each site the Post Office Engineering Department provided a small relay set, which was controlled from equipment installed at G.O.R., Brompton Road. This equipment at G.O.R. was in turn directly controlled by a master switch adjacent to the Controller's position at Stanmore. Operation of the master switch at Stanmore actuated the G.O.R. equipment which radiated signals simultaneously to each of the 165 sites where the local relay sets provided the requisite conditions for firing four maroons and one rocket. Elaborate precautions were taken to ensure that working parties, faults, etc., could not simulate the Stanmore signal thereby originating false firing conditions. Precautions were also taken to prevent similar false operation between G.O.R. and each site, although in this case the precautions were not so extensive, since false operation at individual sites, while serious, was not so vital as similar occurrence at all sites. The operation of the master switch at Stanmore was to be undertaken by the Controller on receipt of a bell signal local to the Filter Room. This bell signal was controlled from pendant bell pushes fitted above the plotters' positions and operated by the plotters on receipt of a code word from the distant radar station.

Tests carried out in 1943 indicated that the time interval elapsing between the passing of the code word and the hearing of the maroon signal by an observer, stationed approximately one mile from a firing site, was 23 seconds.

A similar scheme was installed in the Portsmouth and Southampton areas, the site equipments in this case being controlled via Fareham G.O.R. from a separate master switch on the Controller's position and marked " Hampshire."

In December 1944 a further special requirement arose for the provision of a warning signal to be transmitted from Fighter Command to the L.P.T.B., Leicester Square. A simple scheme utilising 50-cycle signalling as adopted for remote control of sirens was used. Operation of a switch by the Filter Room Controller caused a lamp and buzzer signal to operate in the L.P.T.B. Control Room, whereupon standard safeguards affecting the under-water tunnels were undertaken by the Leicester Square staff. This scheme was used throughout the rocket attacks and proved very satisfactory. The supplementary public warning was never utilised due no doubt to Government policy.

In order to determine more accurately the sites from which rockets would be fired, the Air Ministry in July 1943 requested the provision of facilities for the synchronisation of time at Dunkirk and Ventnor C.H. Stations with the time given in the Filter Room, Stanmore.

Various schemes were tested and eventually it was decided to adopt an arrangement whereby "pips" of tone were transmitted from Stanmore over the plotting lines at times corresponding to 58, 59 and 60 seconds at the half-hourly and hourly periods. A warning tone transmitted exactly at 29 minutes and 59 seconds was also provided to prepare the Radar station observer for the time signal which followed. At the Radar station the time was recorded on a stop-watch, the watch being stopped at the 58th second, reset at the 59th, and restarted at the 60th second. The time transmitting equipment at Filter Room was driven from the Master pendulum (P.O. Clock No. 36) and good synchronisation was obtained between Filter Room and distant stations. In addition to the above facilities, a half-hourly and hourly battery pulse was transmitted to Ventnor and Dunkirk. This pulse was utilised via a relief relay to provide a strobe on the C.R.D.F. receivers. The above facilities were later extended to include all C.H. stations from Stenigot to Ringstead. Similarly tone signals were extended to all C.H.L. stations in the same area. The control equipment was provided in duplicate at Stanmore and Hillhouse Filter Rooms. The provision of the time synchronisation facility to Ringstead and Southbourne presented difficulties in that both these stations plotted to No. 10 Group Filter Room. A subsidiary equipment was installed at No. 10 Group and arranged to relay the signals from the timing equipment at No. 11 Group Filter Room. A further demand was received from the War Office for the transmission of the tone signals to all London area sites via the existing plotting lines. As these lines terminated at G.O.R., Brompton Road, it was necessary to provide a "slave" equipment at G.O.R. driven from the main equipment at Stanmore. Additional facilities were introduced to allow the "pip" generating oscillator at G.O.R. to be switched on just prior to the hourly and half-hourly periods.

As previously stated, the master timing equipment located at Hillhouse (and in duplicate at Stanmore) was driven from the P.O. Clock No. 36 which supplied impulses to drive the Filter Room clock. The Clock No. 36 had, by careful adjustment been regulated to an accuracy of seven seconds per week, and this was considered to be the best regulation that could be achieved with such a mechanism. It was stated, however, in January 1945 that a departure from standard time of up to seven seconds could not be tolerated and it was therefore decided that the master source of time should be G.M.T. in place of the Clock No. 36. A circuit was provided from the Central Telegraph Office to Stanmore over which the G.M.T. signals were transmitted at quarter-hourly intervals, the signals being in the form of six pulses of battery each of 200 M/S duration. At Stanmore (and at Hillhouse) an equipment was provided which suppressed the first three G.M.T. pulses, transmitted the last three as tone signals to all stations and in addition supplied a battery signal coincident with the last pulse.

In addition to the aforementioned facilities the Air Ministry, in July 1944, requested the urgent provision of special communication equipment to assist in combating the approaching rocket attack, by radio counter-measures. The facilities required consisted of linking by landlines, a receiver station at Beachy Head with three transmitter sites located at Brighton, Flimwell and Hope Point, but as contact by the radio station with any one of the transmitter sites had to be made with utmost rapidity, normal telephone switching arrangements were out of the question. Two speech circuits and six unidirection tone circuits were provided between the receiver station and each of the three transmitter sites. Specially designed equipment was installed to enable the Beachy Head radio operators to contact and transmit tone to one or more radio operators at the transmitting sites.

The control requirements at the receiver station were met by the provision of five-lamp signalling 30-line keyboards for Sub-Controller B, Sub-Controller C and the "Y" Officer. The speech circuits from all the transmitter sites and other operational speech circuits were terminated on all five keyboards with ancillary working. The telephone lines from the radio receiver operators were also terminated on all the keyboards. Thus all five officers had access to all lines, although under normal operational conditions each Sub-Controller dealt only with the transmitter site under his control. At each of the three Sub-Controller's keyboards, the six tone circuits from the respective transmitter site were each terminated on a cord and plug. All circuits on the keyboard had a jack termination as well as keys, and therefore it will be seen that any one of the tone circnits could be plugged into any of the radio receiver lines as required.

The radio receiver operators each had charge of two radio receivers and arrangements were made whereby the double headgear receiver, worn by the operator, could be switched by means of two keys to function as follows :—

(*a*) Keys 1 and 2 normal	telephones split ; left ear on to both radio sets in parallel and right ear to keyboard line.
(*b*) Key 1 " listen set A " Key 2 normal	Set A on to both ears. Set B disconnected.
(*c*) Key 1 " listen set B " Key 2 normal	Set B on to both ears. Set A disconnected.
(*d*) Key 1 normal Key 2 " set to line "	Left ear on to Set B ; Set A to line (*i.e.* " signals to line ") with right ear in parallel.
(*e*) Key 1 normal Key 2 " Set B to line "	Left ear on to Set A ; Set B to line with right ear in parallel.
(*f*) Key 1 " listen Set A " Key 2 " Set B to line "	Set A on to both ears. Set B giving signals to line.
(*g*) Key 1 " listen Set B " Key 2 " Set A to line "	Set B on to both ears. Set A giving signals to line.

At each transmitter site the six-tone and two speech circuits from the receiver station were terminated on a special control jack panel, consisting of 8 strips of 20 way jacks ; each circuit was terminated on the outer springs of the 20th jack and multipled to the inner springs of the remaining 19. This arrangement allowed for lines to 19 mobile transmitter vehicles leaving one jack for answering and monitoring purposes. Two circuits were cabled out to each transmitter vehicle, one for tone and the other for speech. The speech circuit was terminated in the vehicle on a normal Post Office Bell Set for signalling purposes and a Head and Breast plate telephone provided. Only one ear-piece of the telephone was connected to the speech circuit, the other being separately connected direct to the tone circuit. On the control panel, the two circuits from each transmitter vehicle were connected via the outer springs of the jacks. Insulating pegs were used for insertion in the jacks, and with pegs in all jacks (excluding of course the 20th jack which was the operating monitoring jack), no lines were connected. The method employed for connecting any vehicle to a tone or speech circuit was simply to withdraw the peg from the appropriate jack thereby allowing the inner springs to make contact with the outer springs and form the connexion. At the same time a warning lamp, associated with the jack from which the peg had been removed, was displayed, to indicate that the connexion had been made and to serve as a safeguard against two tone circuits being put in contact. The glow of two lamps or more in the same vertical row would have been an indication to the control operator that he had erroneously connected two or more tone circuits to the same transmitter vehicle. This novel method of connexion afforded a simple and rapid means of switching one or more transmitters to the speech and tone circuits. The method of signalling between the transmitter site and the receiving station was 17 cycles A.C., this being converted to a steady glow on the calling lamp at each end. The transmitter vehicle could signal the control panel on a lamp by operating the switch on the mouthpiece of the telephone, whilst the operator could in turn be called from the control panel by the bell ringing in the normal manner.

In summarising it will be seen that the provision of the above-mentioned equipment ensnred the following facilities :—

(*a*) The controllers at the receiver station had complete control of all landline communications and could at all times monitor on any circuit.

(*b*) It was possible for a radio receiver operator detecting certain signals, to pass these signals direct by landline to the ear of a radio transmitter operator and if necessary, monitor on the circuit whilst this was proceeding.

(c) The radio receiver operator could call and converse with any of the controllers and still retain control of both radio sets.

(d) Any controller at the receiving station could call a radio operator.

(e) At the transmitter site, the officer in charge had complete control of all circuits on the control panel ; he could arrange for the tone circuits to be connected to any transmitter vehicle or vehicles as required.

(f) The transmitter operator could call and be called from the control panel and converse with the officer in charge ; if necessary this conversation could be extended to the receiver station.

Coincident with the provision of equipment at Beachy Head the Air Ministry requested some extension of the warning signal scheme in operation at Filter Room, Stanmore. It was arranged, therefore, that the operation of any of the pendant bell pushes located above the plotters in the Filter Room should, in addition to producing a warning signal on the Controller's position, also cause the operation of a loud ringing bell at Beachy Head and a further bell at No. 80 Wing, Radlett. On receipt of a bell signal a key was operated at Beachy Head, causing a white acknowledge lamp to glow on the Filter Room Controller's keyboard ; this indicated that the signal had been correctly received at Beachy Head. In order to guard against signalling failures a separate speech circuit between Filter Room and Beachy Head was provided. This special circuit was connected to both the Controller and Scientific Observer's keyboards with outgoing calling and speaking facilities on both keyboards. Incoming calls, originated by ringing from Beachy Head were received only by the Scientific Observer. A further facility to permit Beachy Head to give an alarm signal to Filter Room, was provided, by fitting suspended bell pushes at Beachy Head ; operation of these bell pushes caused a lamp to glow on the Filter Room Controller's keyboard. At a later date this bell push scheme was rearranged at the Filter Room such that receipt of a signal not only lit the Controller's warning lamp but also extended signals to all C.H. sites where the incoming signal operated a strident buzzer. A similar signal was required to be transmitted to the G.L. sites, but line considerations made this impossible. An alternative scheme was agreed upon, such that upon operation of the bell push at Beachy Head, 900 cycle tone was transmitted to all G.L. sites for so long as the bell push was operated ; it was found possible to discriminate quite easily between this warning tone and the three-pip tone synchronising signal transmitted at half-hourly periods.

Whilst the installation of Beachy Head receiver station and the three transmitter sites was in progress, the advance of the A.E.F. across France reduced the need for radio counter-measures directed southwards across the Channel and the Air Ministry requested the urgent re-organisation of the system. The original scheme was proceeded with, however, in order to make use of the radio receiver and transmitter facilities already available. In the meantime, work was commenced on the revised scheme, but although most of the external cables were laid and repeater equipment provided, the installation of the internal equipment never progressed beyond the design stage. It may be of interest, however, to give a brief outline of the proposed scheme.

The Beachy Head Receiver Station and Flimwell, Brighton and Hope Point Transmitter sites were to be incorporated in the new "set-up," the following additional stations being provided :—St. Margaret's "A" and "B" Receiver Stations, Whitfield Towers and Crowborough Transmitter Stations. A further receiver station and main control for the network was to be set up at Kent College, Canterbury, which also was to exercise a limited control over a number of transmitters at Whitfield Towers. St. Margaret's "A" receiver station was solely to control transmitters at Hope Point ; Beachy Head receiver station was to control the transmitters at Flimwell, Brighton and some of those at Hope Point and Crowborough ; St. Margaret's "B" receiver station was to control the main transmitter at Whitfield Towers as well as some of those at Crowborough.

The two receiver stations "A" and "B" at St. Margaret's Bay were to be accommodated in two buildings approximately 50 yards apart on the cliff top ; each was to perform similar functions and would have been equipped to give similar facilities, the equipment at the Kent College receiver station would have differed only insofar as it was intended to instal a Conference Amplifier for

Conference facilities with the Controllers and Supervisors of all receiver and transmitter stations. The arrangements to be made at each station are described in the following paragraphs.

At each radio operator's position a receiving unit was to be installed; this consisted of a double headgear receiver, a desk microphone, a three position key KS labelled "Speak Transmitter" and "Speak Controller," a two position K.H.F., and a calling lamp. With both keys normal, the radio receiver output would have been connected to both ear-pieces of the receiver operator's headset and also to line, to the distant transmitter station. With key KS operated in the "Speak Transmitter" position, one ear-piece was to be left connected to the radio receiver output and the other ear-piece to be associated with the desk microphone to form a normal telephone circuit connected to the transmitter station; at the same time the radio receiver output would be disconnected from line and an engaged signal given to the Controller. With key KS operated in the "Speak Controller" position the radio receiver outpnt would have been left connected to one ear-piece and also to the transmitter line whilst the other ear-piece would have been associated with the desk microphone to form a "speaker" circuit to the Controller. A calling signal would also be given to the Controller. Key KHF would have merely served to connect the radio receiver output to a link to the change-over Panel for picking up a high fidelity circuit to the radio transmitter.

The Controller would have been provided with a 30-line lamp signalling keyboard for terminating miscellaneous private wires and local telephone circuits. In addition, a Control Panel—possibly to have been provided in duplicate for use of an assistant controller—would have been provided for monitoring the radio receivers' signals. This Control Panel would have been equipped for the termination of 20 receiver units; each radio receiver termination consisting of the following:—

(*a*) Jack permanently connected to the radio receiver output for visual monitoring by means of a cathode ray oscillograph.

(*b*) Engaged lamp to give an indication when the radio receiver operator was speaking to the transmitter (Key KS in receiver unit operated to Speak Transmitter position).

(*c*) Calling lamp to indicate that the receiver operator was wanting the Controller.

(*d*) A three-position key performing the following functions:—

(i) Position "Normal"	No connexion.
(ii) Position "Speak"	Disconnects one of the receiver operator's ear-pieces from the radio set and connects it to the Controller's speaking unit (the operation of the receiver operator's "speak" key completing the circuit for two-way conversation).
(iii) Position "Monitor"	Transfers the Controller's telephone circuit to a high impedance monitoring connexion enabling the Controller to listen to the radio receiver and transmitter operators while introdncing minimum loss to the circuit.

No design work in connexion with the transmitter sites had been commenced, although an outline of the probable facilities required had been received from the Air Ministry. It was understood that no alterations to the existing equipment were anticipated at Flimwell and Brighton; no decisions regarding Crowborough had yet been taken. At Hope Point and Whitfield Towers the main transmitters were to be in groups of three to a building and some additional in huts with two per hut. In a Control building a Supervisor would have had facilities to monitor by means of a control panel similar to that provided for the receiver controller, and to obtain full flexibility a change-over panel with a patching jack field for allocation of high fidelity circuits to the transmitters as required, would have been fitted. In addition, provision would have been made for a lamp signalling keyboard for termiuating miscellaneous circuits and a display panel to indicate when transmitters were "on the air."

The transmitter operators were to have facilities for—

(a) Speaking to the distant receiver operator.

(b) Speaking to the transmitter supervisor over a separate circuit. (Both-way signalling to be provided.)

(c) Modulating the transmitter by a signal coming over the normal line from the radio receiver.

(d) Modulating the transmitter by a signal coming over the H/F circuits from the radio receiver.

In each transmitter building or hut a small keyboard in charge of a Corporal was to be provided for monitoring on the transmitter-receiver lines ; a circuit from this keyboard to transmitter supervisor was also to be provided.

Warning facilities identical with those provided between Beachy Head receiver station and Filter Room, Stanmore, were also to be extended to the new receiver stations at Kent College and St. Margaret's " A " and " B."

As previously stated the external cables had already been laid prior to abandoning the scheme. The high fidelity circuits provided a moderately level response between 300 and 16,000 cycles and were provided by means of 20 lb. unloaded cable. All high fidelity circuits, excluding the St. Margaret's Bay–Hope Point were amplified, using Army Carrier Repeaters R.C.T. No. 2.

In conclusion the staff of the P.O. Engineering Department wish to place on record their appreciation of the help and active co-operation accorded to them by the officers and officials of the Air Ministry who, in the matter of transport and helpful suggestions, facilitated the rapid completion of all the work involved.

APPENDIX No. 13

MONITORING

The problems involved in the accurate monitoring of the various transmitters employed for radio counter-measures are second only in importance to the provision of the most suitable form of jamming or spoiling transmission likely to be most effective in dealing with the particular enemy radio apparatus against which action must be taken. Indeed these two requirements are intimately connected and in the ideal case are directly bound together, the solution of one involving the solution of the other. This ideal had only been achieved completely in one case, that of Meaconing, and partially in the case of Domino. In the former case, monitoring, by which is to be understood the tuning of the radio frequency of the jammer to the radio frequency of the signal to be jammed, in general to within a few kilocycles per second, together with similar action with regard to the audio frequency and other characteristics, does not arise as the enemy transmission as a whole is received and re-radiated without change. In the case of Domino (and provision was made for similar action in certain " Big Ben " projects) the audio signal only is re-radiated, the radio frequency requiring to be monitored. In all other cases of jamming the problem of ensuring that the radio frequency, the audio frequency, the keying rate (if keying is employed) and the characteristics of the keying, including the mark-space ratio, are correct, involves the setting up, either locally or at a distance, of an independent monitoring system capable of covering the necessary features to be watched.

This monitoring can be considered from two aspects. In the one case and naturally the more satisfactory, the monitoring station, besides hearing the transmitter to be monitored, can also hear the enemy station to be jammed, and in the second case where the jamming transmitter can only be monitored by reference to wave-meters and similar equipment, on information received from the Operations Controller. This second aspect cannot be considered true monitoring and was only resorted to when other means failed. It must be understood in this connection that when once an enemy signal has been satisfactorily covered neither the particular monitor concerned, nor any others within range, can hear the actual enemy signal.

Other jammers can, however, be monitored on to the same frequency and so long as no individual signals can be heard to either side of the jamming signals it must be assumed they are all in frequency.

Monitoring by special de-centralised stations was introduced with the advent of the area scheme of administration, but before this became necessary individual sites were required to attempt local monitoring, as will be described later, the whole system being watched, as far as was possible, by means of a central Headquarters Monitor Room at Radlett which was instituted as soon as the Wing was formed.

The different stages through which monitoring passed, in connection with Aspirins, Bromides and Benjamins, will now be described, followed by a description of special applications devised for certain definite purposes.

Crystal Control

Crystal control is not strictly speaking a method of monitoring but is included in order to complete the history of frequency control. The first transmitters used for Aspirin were fitted with Crystal control on one or other of three frequencies—30·0, 31·5 or 33·3 megacycles per second—thus permitting these transmitters to be kept ready for instant action and only requiring to be switched "on." This was particularly necessary in the case of the diathermy jammers installed at Police Stations and was rendered possible by the fact that at that time the *Knickebein* system employed international frequencies standardised before the war for blind approach purposes. In each case provision was made for minor adjustments in initial setting.

Local Monitoring

By this is meant the use of a receiver, adjacent to the transmitter to be monitored, which is tuned in to the signal it is desired to jam, with the local transmitter switched "off," and after carefully noting the dial settings and suitably reducing the gain, the adjustment of the transmitter into tune with this setting. This method was used on the early Aspirin sites, all jammers being periodically switched "off" at specified times in order that the enemy signal could be checked. At that time Aspirin jammers were brought into operation as a matter of routine during the hours of darkness and it was fortunate that in general the enemy beacons were tested during the day, thus allowing monitoring receivers to be set before operations commenced. As noted previously the enemy only used one of three frequencies, thus allowing the distribution of jammer frequencies to be pre-selected.

This method of monitoring was checked by a central monitoring section at Wing Headquarters where most of the enemy signals and the jammers themselves could be heard. This method of local monitoring could not be considered satisfactory owing to the large spread consequent on the proximity of the receiver to the jamming transmitter, and constant checking by the Headquarters section was essential. As experience was gained in this section, this method of centralised monitoring became the main control.

Centralised Monitoring

This method had become well stabilised with the advent of Bromides for which it was the only practicable solution, as in many cases the Ruffian signals could not be heard at individual transmitter sites, the frequencies involved could not be crystal controlled, and frequent and rapid frequency changes were required. The local transmitter control had now to depend on the use of wavemeters, a crystal pip controlled model being produced at very short notice by Messrs. G.E.C. for this purpose and also for use by the watcher stations along the coast ; these had now become a very important link in the scheme, not only for prediction of beam settings, but also for reporting the activity of the enemy stations and the frequencies on which they were radiating. As a result of the reports received from these watcher stations, a plan could be made by Operations Control and frequencies allotted to, or changed at, individual transmitters. These were immediately brought up on wavemeter settings and ultimately monitored by the Headquarters Monitor Section. As a number of transmitters was frequently employed against each enemy station concerned, this monitoring could only ensure that the jamming transmitters were all approximately on the same frequency, any station not in the general mush being steered by telephone instructions, up or down in frequency, until it was lost in this general noise. As Bromide and Aspirin jamming was almost invariably carried out by keying dashes at approximately the same rate as that employed by the enemy stations, individual transmitters were identified for monitoring purposes by a process of elimination, the suspected transmitter operator being instructed to send either dots or a continuous note. In addition watcher stations would report to Operations Room when jamming was not covering the enemy signal. These stations, on good reception sites along the coast and in many cases partially screened from jamming stations inland, were in general able to keep a continuous watch on enemy signals.

Centralised monitoring proved very successful during the early stage of the Wing's development. The expansion of activities resulted, however, in undue pressure of work, and with the introduction of the area scheme a number of monitor stations was established in various parts of the country. Monitoring could thus be decentralised by the allocation of jamming transmitters among these new stations, the central station continuing to maintain a general watch.

Decentralised Monitoring

These area monitor stations were situated on high sites and every effort was made to select locations from which as large a proportion as possible of the enemy beacons concerned could be heard, but they could not be expected to be so efficient as the coastal watcher stations. The procedure was now similar to that used with centralised monitoring insofar as transmitters were still instructed directly by the Operations Room as to frequencies, audio notes, keying rates, etc., and any immediate changes required, but at the same time, or as soon afterwards as possible, the area monitor concerned was also given the same instruction. If time permitted this instruction to the monitor was passed by Operations Room but when working under high pressure, time was not always available and individual transmitter sites would then call up their monitor and request checking of frequencies. In all cases transmitters were brought up immediately on receipt of instructions using their local wavemeters, the monitor checking the settings of the individual transmitters in turn, either in the best cases on to a receiver setting obtained from the enemy transmitter, or a setting obtained from other jammers or a crystal checked wavemeter.

Special Monitoring

In all stages of general monitoring as described above, plain audio methods were in use, the monitor discovering the frequency of the transmitter concerned in relation to the frequency required, by a process of searching on a calibrated receiver, checking against a crystal pip wavemeter, and passing instructions to the transmitter personnel by landline, the instruction being in the form " come up in frequency . . . kilocycles " or as the case might be. The method adopted for the identification of transmitters has been described above. In addition to the above, certain equipments installed for a special purpose were provided with their own monitor stations situated on suitable sites in the same locality as the transmitters. Under this heading can be included the counter-measures Domino, Mandrel, Grocer and " Big Ben."

In the case of Domino and Mandrel, monitoring for radio frequency was carried out by a process of " squealing in " in which, after the transmitter had been brought approximately on to frequency, the beat note received at the monitor between the jamming transmitter and the enemy signal was passed over a landline to the transmitter operator thus enabling him to adjust his transmitter very accurately on to frequency. Loud speakers could be used at the transmitter site for this purpose, as a public address system, leaving the operator free to move about without trailing wires. In Domino the transmission of the audio tone constituted a special system and as the received enemy audio tone was re-radiated, monitoring in the strict sense did not apply. In Mandrel noise only was radiated and other than checks for modulation itself no monitoring was required. A panoramic receiver was used for Mandrel on two sites, but, as available, was limited in frequency coverage.

In the case of Grocer and certain transmitters for " Big Ben," panoramic receivers or panoramoscope adaptors were employed at the monitor with electric motor controlled tuning devices at the transmitter. The transmitters in these cases were steered on to frequency by the monitor operator by means of a remote control system to the motor on the tuning device. Noise only again was radiated by Grocer but for the " Big Ben " transmitters arrangements had been made to re-radiate the enemy tone as with Domino had this become necessary. With all these special local methods of monitoring, reflectors or mirrors combined with suitable siting had to be utilised in order to overcome the excessive signal strength from the local jamming transmitter.

Although during the war the most obvious and simple forms of direct manual monitoring have been employed it is in the development of this aspect of R.C.M. that progress will be required, in the post-war period.

APPENDIX No. 14

SUMMARY OF POST-WAR REPORTS ON GERMAN AIR DEFENCES

At the outbreak of war, the Germans relied mainly on anti-aircraft guns (*Flak*) for defence against air attack. Fighters were normally employed in an offensive role and were rarely operated under control from the ground. A small force of night fighters also operated in conjunction with searchlights.

It was not known at this time whether the Germans employed radar as an aid to air defence but gradually information accumulated. It was learnt that eight early warning radar stations (*Freya*), operating on frequencies around 120 megacycles per second (2·5 metre wavelength) had been erected in the North and East Frisian Islands, but there was no radar equipment for the direction of A.A. fire or searchlights or for the close control of fighters.

The Development of Enemy Radar

The limited extent of this chain of stations was soon changed. The early warning system was expanded rapidly from the original eight stations and extended along the whole of the coastline held by the Germans. The *Freya* continued as the main equipment for this purpose until the summer of 1942, when a longer range installation —the *Wasserman* or Chimney—became available. This gave a range of 200–250 kilometres, as against the 80–120 kilometres of the *Freya*. This improvement was achieved by using an aerial array of greater gain, but it meant that the beam width of the Chimney was more narrow.

The *Freya* suffered from one disadvantage—that it could not read heights, but the deficiency was to some extent made good by the introduction of another installation known as the *Wurzburg*.

The *Wurzburg*, which made its first appearance in 1940, operated on a much higher frequency that the *Freya*—about 560 megacycles per second (53 centimetre wavelength)—and because of this it could be used with an aerial system producing a narrow beam which could be tilted in elevation or turned in azimuth. It was at once used for the direction of *Flak*, and later to control searchlights and to assist the operation of night fighters by plotting the aircraft involved in an interception. It was also introduced into the early warning system, where it helped to overcome the limitation imposed by the *Freya's* inability to read heights.

The *Kammhuber* Line

The night fighter system developed in the form of a continuous belt of combined searchlight and radar positions, which became known as the *Kammhuber* line after General Kammhuber, the General in charge of night fighters.

The *Kammhuber* Line developed rapidly and by the winter of 1941/42, it stretched from the Schleswig area over Kiel, Hamburg, Bremen, Ruhrgebeit, Arnhem, Venlo, to the Liege areas and beyond southwards, with a second belt for the protection of Berlin, covering the Gustrow–Stendal area and extending in the direction of Gardelegen.

Himmelbett

The limitations of the searchlight technique for directing night fighters were fully appreciated and attempts were soon made to use the *Wurzburgs*, and to introduce ground to air communication for the control of the night fighter throughout an interception: a further development in 1941 was the introduction into the *Kammhuber* Line of the Giant *Wurzburg* with its increased range of 40 kilometres.

The German scientists had not evolved a plan position radar presentation unit which would allow both the bomber and the fighter to be plotted by the same apparatus and it was necessary, therefore, to use two radar sets, one for plotting the enemy aircraft and the other for the night fighters. The plots obtained from the two sets were displayed on a special plotting table known as the *Seeburg Tisch*. This form of Ground Controlled Interception (G.C.I.) was called *Himmelbett*.

Another method, known as *Freya A–N*, used a *Freya* with an aerial system giving "split" D/F. In this system a switching device caused the aerial lobe to be swung from side to side and the signal to be displayed on the left or right of the time base according to the position of the lobe. The result was an echo which extended on either side of the time base, each side being equal when the equipment was accurately aligned on the aircraft or of different sizes according to the degree of misalignment. A very accurate indication of D/F was obtained in this way and if it were arranged so that both the bomber and the fighter were in the lobe, it was possible to control the fighter in an accurate interception. The system, however, called for considerable skill on the part of the controller and its use was discouraged by General Kammhuber in favour of the two *Wurzburgs* with the *Seeburg Tisch*.

The normal equipment of a G.C.I. station was:—

1 *Freya* (for search and A–N).

2 Giant *Wurzburgs*.

1 *Seeburg Tisch* (plotting table).

1 Ground-air transmitter.

1–2 low power radio beacons.

1 visual beacon.

In the spring of 1942, it was decided that the searchlights should be withdrawn from the *Kammhuber* Line and used by the *Flak* for the protection of special targets. Additional *Wurzburgs* were installed and *Himmelbett* took the place of the searchlights.

Aircraft Interception (A.I.)

At first, interceptions were carried out by "Catseye" fighters, but although during conditions of good visibility some success was achieved, it became obvious that some form of radar device was required in the aircraft. For this purpose the *Lichtenstein* B.C. was produced and the first four sets were installed in aircraft in February 1942.

The development of its operational use was at first delayed by its unpopularity with aircrews due to the reduction in aircraft performance caused by the large aerial arrays. Successes by certain crews, however, dispelled in some degree this dislike and by the end of 1942, A.I. used with *Himmelbett* control was the backbone of the German night fighter defence.

C.A.S. APPRECIATION ON EFFECT OF WINDOW ON THE CONDUCT OF BOMBING OPERATIONS (20 April 1943)

Effect on the Enemy R.D.F. System

The enemy R.D.F. system consisted broadly of four types of equipment :—

(a) *Freya*—which was an early warning system which might also be used for fighter interception.

(b) Large *Wurzburg*—which had a narrow beam and was mainly used for control of fighter interception.

(c) Small *Wurzburg* for the control of unseen fire from the ground.

(d) A.I. airborne equipment—for the completion of an interception when the aircraft was controlled by a large *Wurzburg* or for free lance interception when there were large concentrations of bombers.

A reasonable estimate in the opinion of experts was that the efficiency of the enemy R.D.F. systems described above would be halved by our use of Window.

In recent months it was believed we had succeeded in interfering seriously with the R/T ground control of enemy night fighters by jamming with Tinsel. As a result, the enemy had begun to use V.H.F. for ground control purposes, and this at present we were unable to jam. This new factor increased the need to introduce other methods, such as Window, to interfere with the enemy's radio defences.

It must be expected that in the course of time the enemy would evolve and bring into action some methods of counteracting the effect of Window. This was likely to be difficult, however, and it was considered that effective counter-measures could not be taken for at least six months.

Effect on Oboe, H2S and Monica when Used by our Bombers

Trials had shown that H2S was not adversely affected by Window and that the effect produced on Monica was not likely to reduce its efficacy seriously. There was no reason to suppose that Oboe would be affected. Our own principal radio aids to bombing were, therefore, generally unaffected.

Reduction in Bomber Losses Resulting from the Use of Window

The enemy were greatly expanding their night fighter defences which were already regarded as being responsible for 70 per cent. of our losses by enemy action. All available scientific counter-measures were required to minimise this increasing danger.

In 1942 our aircraft missing and destroyed by enemy action in bombing operations at night against Germany alone amounted to 5·06 per cent. of the sorties despatched. It was estimated that 80 per cent. of all our aircraft missing and destroyed on night bombing operations against targets in Germany were lost through enemy action. In those losses due to enemy action it was estimated that :—

(a) 70 per cent. were lost to night fighters and 30 per cent. to *Flak*.

(b) Of those lost to night fighters, 50 per cent. out of the 70 per cent. were probably lost to G.C.I., controlled interceptions and free lance A.I. fighters, and 20 per cent. to free lance Catseye fighters.

(c) Of those lost to *Flak*, some 20 per cent. out of the 30 per cent. were lost to radio-controlled ground defences, and 10 per cent. to visually operated ground defence.

If Window were employed on the lines planned by Bomber Command, it would be reasonable to assume that during its effective life our losses due to radio-controlled or A.I. fighters (50 per cent.) and to radio-controlled ground defences (20 per cent.) would be halved ; that is, 35 per cent. of the total aircraft lost through enemy action would be saved.

Of the 22,345 bombing sorties despatched against Germany at night in 1942, which constituted 81 per cent. of the total night bombing effort, 1,129 were missing or destroyed by enemy action. On the above calculations, had Window been employed (1,129 × 81 per cent. × 35 per cent.) = 316 bombers and aircrews would have been saved.

It was estimated that during the eight months beginning 15 May 1943 at least 32,500 bomber sorties would be despatched against Germany. This represented 70 per cent. of our estimated total bombing effort. Of these it was expected, on the basis of the 1942 casualty rate, that 1,625 aircraft and their crews would be lost. On the above calculation, Window should save 455 of these.

In 1942, one night bomber to every 20 despatched to Germany was lost, missing or destroyed by enemy action. If Window had been employed with the effect anticipated above, we should have lost one aircraft for every 28 sorties despatched. In heavy aircraft, allowing for the load displaced by Window material and an extra member of the crew to throw it out, the lower rate of loss would have resulted in each aircraft dropping in operations against Germany 182,000 lb. of bombs as opposed to 140,000 lb. or a nett gain of 42,000 lb., per aircraft.

At the present rate of loss the average experience of aircrews from Bomber Command amounted to some 15 operational sorties. With a lower loss rate which would result from Window the average standard of operational experience would rise. This average level of operational experience was a critical factor, and any increase would result in improvement in the operational efficiency of the bomber force as a whole.

Conclusions

The effect of Window on bombing operations in the remaining eight months of 1943 would probably be to save 455 aircraft and crews, raise the average operational experience of aircrews, increase considerably the overall efficiency, and generally raise the morale of the bomber force.

EFFECT ON OUR OWN DEFENCES OF THE USE OF WINDOW BY THE ENEMY

Window was not a practical counter-measure against our C.H. stations giving early warning of high flying aircraft, nor against G.L. Mark II which was the existing type of gun-laying apparatus. All other R.D.F. ground equipment, including C.H.L., and S.L.C., were vulnerable to Window. The new types of Mark VII and Mark VIII A.I. equipment, with which our night fighters were now being equipped, would be particularly affected.

Effect on Ground R.D.F. Systems

The introduction of the R.D.F. Type 11, Mark II equipment would improve to some extent the ability of our C.H.L. stations to operate through Window. Four of these Type 11 sets should be available by September 1943. To adapt these sets to the G.C.I. rôle, special height-measuring equipment was required. The equipment would not begin to be available until the autumn of 1943. By the end of 1943 there should be available 18 Type 11 sets, less height-finding equipment (for use as C.H.L.) and six sets with height-finding equipment for use as G.C.I.

Effect on our A.I. Systems

Experiments had shown that the American A.I. set S.C.R. 720 and our A.I., Mark IX, now under development, were capable of operating through Window. A.I., Mark IX, would not be available until the middle of 1944, but 50 S.C.R. sets were expected in this country by August 1943, and 200 sets by June 1944. It must be remembered, however, that considerable installation modifications and training problems would have to be solved before this equipment became operational.

Gains to the Enemy in the Use of Window over the United Kingdom

The Window principle was extremely simple and we could reasonably expect the Germans to know of it. Indeed, information suggested that they might be aware of the principle; they might therefore be withholding its use for the same reasons as ourselves, and particularly also because they were not in a position to undertake a substantial bomber offensive against us.

Thus, it would be realised that once Window was employed, the enemy might retaliate. He was already introducing a form of Monica in his night bombers which would inevitably reduce the effectiveness of our night fighters to a degree which could not at present be assessed. Should, however, he use Monica and Window together it was estimated that the effectiveness of our existing night defences in this country would be reduced by at least 80 per cent.

It should be remembered, however, that only small numbers of enemy aircraft attacking this country are, in present circumstances, being destroyed and that the scale of enemy attack was not likely to be increased. The benefit of the introduction of Window was not, therefore, likely to be great to the enemy in terms of numbers of aircraft saved.

Position in Overseas Theatres

The above factors were mainly applicable to the defence of the United Kingdom. As regards overseas, our R.D.F. ground equipment and A.I. were vulnerable to Window and no appreciable improvement could be expected until the end of 1943. It would thus be seen that the use of Window by the enemy would considerably reduce the effectiveness of the night defences of those ports and bases at which our vital resources would be concentrated, especially during the forthcoming operation "Husky" (Sicily); it might also increase the difficulties of our opposed landings. It was not considered, however, that the scale of enemy night effort in overseas theatres, and particularly in the Mediterranean, was likely to be as heavy as to make this a serious threat.

Advantages to be Gained from the Use of Window in the Present Strategical Situation

Germany was committed to land operations in Russia, Europe and the Mediterranean, and in consequence had at her disposal no strategic bombing force which could be counted a serious threat to this country. The present strength of German long-range bombers on the Russian front was so low that no further reduction was considered possible even though no serious offensive was undertaken against Russia during the summer of 1943. This precluded, therefore, the strengthening of the enemy bomber force on the Western or Mediterranean fronts, however much the Germans might wish to take advantage of the Window technique.

It was estimated that the enemy could at present maintain only 15–20 long-range bomber sorties a night against this country, the effort rising perhaps to 30 sorties during the summer. By conserving his force he might be able to produce a maximum effort of 150 long-range bomber sorties in one night, but this would entail the use of aircraft and crews from training units and double sorties by some of the aircraft. With the growing strength of our own night bombing and American day bombing, Germany was being forced to divert more of her aircraft manufacturing resources to the production of fighters, and this prohibited any expansion of her bomber force.

Moreover, the enemy had now clearly adopted a policy of giving fighters priority to the Western front at the expense of the Russian front and had embarked on a considerable programme of improvement and strengthening of his air defence system in the West. If this policy of substantially strengthening his night fighter forces and defensive system in the West was accomplished without our developing adequate counter-measures, our growing bomber offensive was our only means of striking directly at Germany and Germany's war potential. It was essential that it should be intensified and that its efficiency should be increased by all possible measures.

In the present strategic situation therefore, even considering overseas operations, there were the strongest reasons for increasing the effectiveness of our bomber offensive by the use of Window.

STATE OF READINESS TO EMBARK ON AND SUSTAIN WINDOW OPERATIONS

Bomber Command aircraft could be equipped for the launching of Window by hand by 15 May, and improved methods of mechanical launching were being developed on high priority.

A statement obtained from the Ministry of Aircraft Production showed the rate of production of Window material, as compared with the possible rate of expenditure during the next three months. From these figures, if the stipulated rate of expenditure of 380 tons a month (*i.e.* 38 tons a night for ten nights a month) was not exceeded, we could start using Window on 15 May. This would result in our reserve stock being reduced from its present figure of some 400 tons at the end of April to some 100 tons during the next three months. Thereafter, production would equal 380 tons per month. It was possible that more firms would by then have started working and that the 380-ton figure could accordingly be increased. This would enable a corresponding increase in our expenditure from mid-August onwards to be made. M.A.P. were not yet able to estimate what this increase was likely to be.

It should be noted, however, that the stepping up of production during the next three months would be dependent to some degree upon two conditions, viz. :—

(*a*) Immediate return of certain named specialists to the firms engaged.

(*b*) Division of certain skilled operatives in the paper and metal foil trades to the firms engaged.

According to M.A.P. the total number of individuals likely to be involved in these two transactions would not exceed 30.

Availability of Aluminium

It was estimated that if Window remained effective for eight months 5,000 tons of Window material would be expended in operations from the United Kingdom on night bombing raids. The weight of aluminium expended on this basis would be 1,670 tons. The stocks of aluminium in this country were not adequate to permit of this expenditure without affecting the production of aircraft.

In terms of Lancaster production the use of 1,670 tons of aluminium would be at the expense of 112 aircraft. In this same period it was estimated that we should save 455 by using Window, or a balance of 340 Lancasters.

Supplies of aluminium for Window would be a temporary requirement and should cease altogether as soon as a substitute could be found. The quantities required might also be materially reduced if cutting and bundling processes were improved. Aluminium was selected because it was readily obtainable in the form required without extensive experimentation which was ruled out by security considerations. These security considerations would be automatically relaxed as soon as Window operations were commenced and efforts over a wide field might then be made to find a suitable substitute for aluminium.

RECOMMENDATION

The use of Window would increase materially the effectiveness of our bombing offensive. The cost would be a possible increase in the effectiveness of the enemy's night bombing in this country and an increase in the difficulties of night air defence in overseas theatres. In the present strategic situation, however, the balance was overwhelmingly in our favour, and it was recommended that we should employ Window as from 15 May 1943. An early decision is desirable so that the necessary additional production might be initiated.

APPENDIX No. 16

BOMBER COMMAND POLICY LETTER EXPLAINING RESTRICTED USE OF RADAR DEVICES

From : Headquarters, Bomber Command.
To : Headquarters, Nos. 1, 3, 4, 5, 6 (R.C.A.F.), 7, 8 (P.F.F.), 91, 92, 93 and 100 (B.S.) Groups.
Date : 13 October 1944.
Ref. : BC/TS.32130/AIR/OPS.

The liberation of France, Belgium and part of Holland has brought about a considerable change in the war situation with regard to the strategic bombing of Germany. The situation, except in the extreme north, now resembles that which was envisaged at the beginning of the war, before the enemy overthrew France and the Low Countries. It is considered important that all concerned, including especially aircrew personnel, should fully understand the advantages and changes involved in the new situation, of which the following is a brief summary :—

(*a*) The enemy has lost the use of the extensive and highly efficient radar network which he had set up in France and the Low Countries, for the purpose of giving early warning of the approach of our bombers. He is therefore forced to rely on the less elaborate network in Germany itself and on his Observer Corps, with the result that, except in the extreme north, he is largely denied the early warning facilities which he used to enjoy. It is estimated that at present he cannot get warning of our approach from a distance of more than approximately 50 miles west of the German frontier. The enemy is building radar installations behind his western frontier and no doubt hopes, if he can stabilise the battle line, to recover some measure of his former facilities.

(*b*) The enemy's withdrawal has caused him to lose the elaborate G.C.I. organisation which he had set up in occupied territory. Whereas formerly an attack on Stuttgart would be noted by the enemy before it had crossed our coast and would be plotted accurately by him for a distance of 300 miles each way, it is doubtful nowadays whether he can plot the raid for more than about 100 miles each way. The part of the route during which his night-fighters can engage our bombers is even more restricted, since he does not permit his night-fighters to fly very close to or over territory occupied by us, for fear the devices with which they are equipped should fall into our hands.

(*c*) The enemy has had to withdraw his night fighter squadrons, with a few exceptions in the extreme north, well back into Germany. Here, the airfields are not as well equipped from an operational point of view as those which he has lost in occupied territory. No doubt he will embark on a programme of improvement, but for the present these airfields, particularly from the point of view of vulnerability and night operations, are many of them far from satisfactory.

(*d*) The German Night-Fighter Command and organisation, which was carefully and efficiently laid out, has had to be largely abandoned with the loss of occupied territory. The enemy has had to set up new headquarters, new plotting rooms and provide the required communications. There can be no doubt that it will be some time yet before this organisation will function as smoothly and effectively as the one which he has lost.

The effect of all these factors is to reduce the enemy's early warning of night raids, to make it more difficult for him to intercept us, especially on occasions when the penetration to Germany itself is not very deep, and thirdly, to force him to use a hastily improvised layout of night air defence, based on airfields which are not up to modern requirements. The result of this is to be seen in the greatly reduced loss rate from which the Command has suffered during night attacks on Germany in the last two months. In these circumstances, it would be surprising if the enemy failed to explore any method or device which held out a promise of modifying the situation in his favour. The obvious and outstanding thing to do, from his point of view, was to make use of the various radar transmissions, which we now make from our bombers, in order to plot the bomber stream and to home his fighters on to our bombers. By this means, he would largely discount the loss of his early warning system, and would be almost entirely independent of G.C.I. methods. He would also make most of our radio counter-measures ineffective, as he would be mainly independent of the transmissions which they are designed to jam.

There are three main sources of such radar transmissions : Monica, H2S Mark II, H2S Mark III, and (although at present in very small numbers) A.G.L.(T). By making use of these transmissions, the enemy can plot our bomber stream while it is yet at a great distance, thus avoiding the disadvantage which the pushing back of his radio location system has caused him. By carrying suitable devices in his night-fighters, he can home them into the bomber stream, though his power of homing on to individual aircraft differs with the type of transmission and will be dealt with in more detail later.

To deal first with the enemy's power of plotting the bomber stream at a distance by listening to our transmissions. Certain steps have been taken to obviate this by relying on the G-chain which will shortly be extended to provide a reliable cover well into Germany. There is no need to use H2S until the point is reached at which the raid would appear on his new radio location chain, *i.e.* approximately 50 miles from the German frontier. Since we are able to fly over friendly territory as far as this point, there is also no need to employ either Monica or A.G.L.(T). We can therefore deny him the use of our transmissions to give him early warning without any inconvenience to ourselves or loss of efficiency in our operations.

With regard to homing into the bomber stream, it is known that the enemy possesses two instruments—*Flensburg* which homes on to Monica, and *Naxos* which homes on to H2S. We are fortunate in having captured a *Flensburg* device and full-scale trials have been carried out with it. It has been found quite easy to home on to a bomber stream, in which a number of aircraft are employing Monica from a distance of 50 miles. It was also found possible to home on to individual aircraft using Monica and to make a visual interception without the use of any other means. For this reason it has been decided, for the time being, to discontinue the use of Monica until such time as it can be modified to prevent homing by means of the *Flensburg*. It might, however, be argued that the enemy possess an excellent A.I. (*SN2*) with which he can home on to individual aircraft from a distance of ten miles and that there is therefore no need to switch off Monica since this will not prevent the enemy homing but will deny the bomber warning of his approach. This would be true but for the fact that it has been definitely ascertained that the use of "M.C. Window" has a devastating effect on *SN2* and, *provided it is used as laid down in the instructions*, virtually makes it useless. It is not known how many night-fighters are equipped with the *Flensburg* device but it is thought a fair proportion now have it.

With regard to the *Naxos* device which is designed to home on to H2S Mark II, it is not known definitely whether a fighter can home on to an individual aircraft using H2S, and there is some evidence to show that this at present is not being done. The rate of loss of H2S and non-H2S aircraft on similar targets is carefully watched, and at present, taking the Command as a whole, the rate of loss of H2S aircraft is very slightly less than that of non-H2S aircraft. The difference, however, is not sufficiently great to be significant. The use of H2S therefore, as at present permitted, may allow a proportion of fighters to home into the bomber stream but probably will not assist them to home on to an individual bomber. It is practically certain that the *Naxos* cannot home on to Mark III H2S, and there is no evidence to show that the enemy possesses any devices which can do so.

To sum up, our present policy denies the enemy the free use of all his methods of long-range plotting, homing into the stream, and homing on to individual bombers, without loss of efficiency in our own operations with the one exception that the use of Mark II H2S over Germany may assist the enemy to home into the bomber stream. Judging by the lower loss rate now prevailing, it would not appear that this facility has as yet helped the enemy very much, but this point will be carefully watched and, if the situation should change, our policy with regard to the use of these transmissions will be reviewed.

Finally, the foregoing remarks broadly cover the situation as it is today, but it must be realised that it is fluid and not static. The enemy is continually trying new schemes and ideas, and it is necessary to be continually on the watch, and to modify our tactics to meet new threats. All this emphasises once more the extreme importance of every aircrew carrying out as exactly as possible the instructions laid down regarding radar silence, routeing, Window dropping, timing, etc. The more accurately the instructions can be obeyed, the more completely will the enemy's defence measure be neutralised and his attempts to shoot down our bombers frustrated.

(signed) R. SAUNDBY A/M
for Air Chief Marshal,
Commanding-in-Chief,
BOMBER COMMAND.

APPENDIX No. 17

RADIO COUNTER-MEASURES PLAN FOR OPERATION "ANVIL"/"DRAGOON"

Radio counter-measures in support of Operation "Anvil" will be effected in three main phases :—

Phase "A". Direct action against enemy radar installations.

Phase "B". Radio counter-measures in support of diversionary operations.

Phase "C". Radio counter-measures for the protection of convoys, airborne forces and assault craft.

PHASE "A"

Direct Action against Enemy Radar Installations

Direct attacks against enemy radar installations already form a part of the air offensive programme of Mediterranean Allied Air Forces. With immediate effect these direct action attacks are to be stepped up in intensity against coastal radar installations from the French/Spanish border in the west to the limit of our left flank in Italy in the east.

Disposition of Attacks

The general principle that attacks should be evenly distributed over this area should be adopted. It will be necessary, however, to cootrol the distribution of these attacks to conform to :—

(*a*) the overall cover plan ;

(*b*) day-to-day assessment of success of attacks ;

(*c*) overall pre-"Anvil" bombing programme.

It will be essential, therefore, that control of direct action be exercised by this headquarters in consultation with representatives of the Naval Task Force Commander who may request specific action against *Freya* installations likely to interfere directly with the assault forces.

Scale of Effort Required

The total number of coastal radar installations at present known to exist in the area under consideration is approximately 70 distributed over about 25 sites. Of this total approximately 50 per cent. have been accurately pinpointed and photographed. Priority accorded to photographic cover, interpretation and investigation flights is being raised and arrangements are being made for all information so obtained to be passed rapidly to the lower formations concerned. Arrangements are also in hand to procure from the United Kingdom high accuracy D.F. which will materially cut down the air effort involved in the area east of Toulon. West of Toulon the investigational effort involved will be found by the Ferret Squadron.

Detailed study of the type of attacks which will achieve the highest chance of success against the various types of enemy radar installations had been made in connection with "Overlord." From this an approximate estimate of the air effort required can be made but an accurate estimate must depend on a day-to-day review from photographic evidence and listening investigation of the success of these attacks.

PHASE "B"

Information

Final details of the tactical cover plan are not yet available but it is expected a decision will be made within the next few days. In the meantime, a reasonable estimate of the scale of effort involved in assisting a diversionary operation can be made. It will be assumed in these estimates that the diversionary forces will simulate an assault convoy covering an approximate frontage of ten miles to a depth of six miles and that diversionary operations requiring air support will take place on the nights of D-day — 1/D-day and D-day/D-day + 1.

R.C.M. Required for Naval Diversion

Simulation of the diversionary effort is required against enemy ground radar equipment and against enemy airborne radar equipment. In addition, jamming consistent with the simulated forces must be carried out. This last commitment is assumed to be entirely a naval one.

R.C.M. against Ground Radar

This will be achieved by dropping Window from a height of about 3,000 feet in the area of the diversionary forces to simulate in the enemy's ground radar presentation the approach of a deuse convoy at a plausible speed. This method was applied successfully in "Overlord" and can be repeated in operation "Anvil" although a different navigational method will have to be used.

The air effort entailed will be a maximum of three aircraft per diversion airborne throughout the period during which the diversionary forces are under enemy radar detection, which will, at the maximum, be a period of eight hours. At the maximum, therefore, a total of six aircraft per diversion will be required. The success of the operation depends entirely on the degree of training achieved and for this reason aircraft should be allocated and training begun forthwith.

R.C.M. against Airborne Radar

In this case the simulation will be achieved by the use of special Moonshine equipment carried in ships and will require special operators. Both the equipment and the operators are being obtained from the United Kingdom. Three ships will be required per division to carry this equipment. C.-in-C., Mediterranean has agreed to undertake responsibility for the installation of this equipment.

PHASE "C"

Introduction

The overall R.C.M. effort required to fulfil this protective role is entirely dependent on "H" hour. If the assault is timed to go in at or before first light, maximum protection by R.C.M. can be given, but maximum effort will be entailed. As the hour of assault is delayed after first light, so the degree of protection possible by R.C.M. will decrease, as will the R.C.M. effort required. In the limiting case where the assault forces cover the whole passage from the range at which radar detection is first possible to visual range in daylight, effective protection by R.C.M. is possible only in the absence of visual reconnaissance. It will be assumed that the airborne operation to be protected will be conducted during the hours of darkness and that the assault will go in at or before first light. A correspondingly smaller effort will be required if the assault is after first light unless effective smoke screen protection is to be provided.

Concealment of Airborne Forces and Convoys

In order to conceal for as long as possible the magnitude and direction of the approach of our airborne forces, an airborne Mandrel screen will be flowo about 40 miles offshore at about 15,000 feet, supplemented by Mandrel jamming from the Beaver station in Corsica. For this purpose, approximately ten aircraft will be deployed over a front of some 50 miles for a maximum period of four hours. This estimate is based on present known enemy radar cover. Should the enemy suddenly increase his radar cover by the use of frequencies outside the present limits of the band employed in this theatre the diversion of a special jamming squadron from the United Kingdom will be necessary. This Mandrel screen will also give protection against estimation by *Freyas* of the size of the shipborne forces.

Protection of Convoys and Seaborne Assault Forces

This will be achieved entirely by shipborne jamming equipment supplemented by the Mandrel cover achieved as a result of the Mandrel and Beaver operations outlined in the above paragraph.

Protection of Airborne Assault Forces

Airborne assault forces will be protected in the initial stages by the Mandrel screen. During the final stages of their approach to the main coastline, protection will be achieved by a diversionary airborne operation dropping dummy paratroops. By the use of Window the aircraft of this diversion will be made to simulate a force comparable with that necessary to drop a like number of real paratroops.

Final details of dropping zones for diversionary airborne forces will be decided when full particulars of the airborne operation are known. No accurate estimation of the air effort required can be made but it is not anticipated that any additional aircraft, over and above those which will be asked for to drop dummy paratroops, will be required since Window will be dropped from the same aircraft.

Airborne Cigar

If the enemy's night-fighter defence effort is considerable some diversion can be achieved by simultaneous bombing raids routed in the vicinity of the airborne forces and supported by air Cigar jamming to hamper the enemy's ground control of his night-fighters. Should air Cigar be used it will be necessary to provide the air Cigar jamming effort from United Kingdom.

For tactical surprise, the strategic bombers can be routed in time in such a way as to conceal to a great extent the lower flying airborne troop-carrying aircraft.

Issue of Operational Instructions

Action required to implement the air aspects of this instruction will be achieved through the medium of operational instructions issued by this headquarters.

APPENDIX No. 18

GLOSSARY OF TERMS

A.B. Scheme	R.A.F. masking (by Meaconing) of Lough Erne M.F. beacon on United Kingdom side.
Abdullah	R.A.F. airborne homer on to G.A.F. early-warning radar stations.
Albino	R.A.F. balloon operation. For defence of United Kingdom against bombers.
Album Leaf	Allied airborne Oboe, Mark II, repeater.
Anna Marie	G.A.F. N.F. R/T control by use of music-changes.
Anvil	Allied combined operation (later called "Dragoon") against S. France—launched 15 August 1944.
Ash	Allied A.I. Mark XV. American 3 cm. design—primarily for S.E. aircraft.
Aspidistra	(*See* Dartboard.)
Aspirin	R.A.F. jammer against *Knickebein*—H.P. V.H.F.
A.S.V.	R.A.F. airborne "air-to-surface vessel" search and homing radar.
Avalanche	Allied combined operations against Bay of Salerno—launched 9 September 1943.
B.A.B.S.	R.A.F. blind approach (responder) beacon system—200 M/cs.
Bagful	R.A.F. airborne "Y" receiver—automatic search and recording—24-hour endurance.
Bareback	Allied R.C.M. against *Egon* R/T control—H.P. M.F.—dislocated synchroniser.
B.B. Scheme	Scheme for masking (Meaconing) Admiralty M.F. beacons.
Benjamin	R.A.F. jammer against Benito course-keeping beams.
Benito	G.A.F. L.R. navigation aid—split beams for track—re-radiated pulses on phase-difference principle, for range measurement.

Berlin	G.A.F. A.I.—9 cms.—developed from H2S.
Bernhardine	G.A.F. radio aid to navigation.
Big Ben	G.A.F. V.2 rocket operations.
Big Screw	G.A.F. H.P. M.F. beacons for navigation/control of N.F.s.
Bildwandler	G.A.F. infra-red receiver.
Blonde	R.A.F. airborne "Y" receiver with Bagful facilities plus auto-analysis of signal to which tuned.
Boozer	R.A.F. tail-warning receiver against G.A.F. A.I.
Black Move	Plan for move of H.Q., No. 80 Wing, from Radlett to Worcester in an emergency.
Briar H.	R.A.F. R.C.M. against range-finding system of *Egon*—triggered by ground radar and re-radiated "mush" to jam C.R.T.
Briar R.	R.A.F. R.C.M. against *Egon* ground stations—modified A.S.V. Mark II transmitter on very high p.r.f.—broadcast jamming.
Bromide	R.A.F. jammer against Ruffian—converted G/L pulsed transmitter.
Broody Hen ..	R.A.F. navigational aid for Brest operations—airborne repeater (forerunner of Oboe)—using S.B.A. beams plus re-radiation.
Bruderfunk-Feuer ..	("Little Brother") L.P. G.A.F. beacon associated with Big Screw.
Bullseye	R.A.F. feint using training aircraft to simulate bomber raid.
Bumerang	G.A.F. code name for R.A.F. Oboe.
Carpet	R.A.F. jammer against G.A.F. ground radar—barrage jamming—ground and airborne versions.
Chimney	G.A.F. early-warning radar (alt. = *Wasserman*), range 200–250 kms.
Cigar (Ground) ..	R.A.F. jammer against G.A.F. V.H.F. R/T control of N.F.s—38–42 mc/s—H.P.
Cigar (Airborne) ("A.B.C.") ..	Airborne version of Ground Cigar.
Cigarette	R.A.F. jammer against V.H.F. R/T control of G.A.F. fighter-bombers 38/42 mc/s—Special Cigarette was employment of television transmitter at Alexandra Palace for same purpose.
Cousol	Name under which R.A.F. used G.A.F. *Sonne*.
Corkscrew	Allied operations against Pantellaria launched 11 June 1943.
Corona	R.A.F. jammer against H.F. R/T control of N.F.s—employed H.P. B.B.C. transmitters at Rugby and Leafield—also used for Ghost control.
Daisy	Form of jamming of A.S.V. Mark II resulting from deliberate enemy jamming or fault in A.S.V.
Dartboard	(First called Light-up) R.A.F. jammer against H.P. G.A.F. N.F. control on M.F. (commentary from Stuttgart)—used 800 kW. transmitter (Aspidistra) at Crowborough.
Deviator	R.A.F. R.C.M. to *Knickebein*—modified portable beam approach beacon for automatic re-transmission of *Knickebein* transmissions.
Diver	G.A.F. flying bombs, V.1—auto-M.F. transmissions from V.1 on which G.A.F. plotted track and impact point—R.A.F. Meaconing these transmissions.

Domino	R.A.F. R.C.M. to Benito—on V.H.F. Meacon principle to confuse range-finding.
D.R.	"Dead Reckoning"—mathematical process of applied navigation.
Dragoon	(Originally Anvil.) Allied combined operations against S. France—launched 15 August 1944.
Drumstick	R.A.F. H.F. jammer against G.A.F. aircraft control on 3/6 megacycles per second.
Duppel	G.A.F. form of Window.
Egon	G.A.F. L.R. navigation aid like Oboe—aircraft I.F.F. (*Fu. Ge. 25A*) triggered by *Freya* or *Mammut* combined with R/T control (originally called *Rubezahl*).
Elektra	G.A.F. L.R. navigation aid—split beams, fan-like, 5-degree sectors—481 kilocycles per second—keyed dot/dashes.
Fidget	R.A.F. R.C.M. against G.A.F. N.F. control by means of Big Screw (H.P.) beacons.
Flammefreya ..	G.A.F. interrogator against R.A.F. I.F.F. for measuring range and bearing.
Flensburg	G.A.F. airborne homer against Monica.
Freya Halbe	(*Fu. Ge. 221*) G.A.F. airborne homer against Mandrel.
Freya	G.A.F. early-warning ground radar on 120 megacycles per second band—no height-finding (*Wurzburg* for that).
Fakir	G.A.F. R.C.M. against Window—electronic anti-jammer.
G.C.I.	R.A.F. "ground-controlled interception" radar—rotating beam with P.P.I. presentation.
Gee	R.A.F. medium range radar aid to navigation—hyperbolic time-base principle.
Glimmer	Sea convoy operation in "Neptune."
Glow-worm	Original code name for Starfish (*see* below).
Ground Grocer ..	R.A.F. jammer against G.A.F. A.I. (*Lichtenstein*)—475–515 megacycles per second—automatic scanning and re-transmission.
Greenbottle	R.A.F. airborne homer for homing on to U-boat R.D.F.
Air Grocer	Airborne version of Ground Grocer—carried by Fortress aircraft and Mandrel aircraft—20 megacycles per second band, and also modified to jam *Wurzburg*.
H2S	R.A.F. airborne blind bombing and navigational aid radar—10 cm. and 3 cm. versions—scanning and P.P.I. presentation of ground features beneath aircraft.
Headache	R.A.F. R.C.M. operational control system—for control of all R.C.M. against *Knickebein*.
Himmelbett	G.A.F. G.C.I. system employing pairs of *Wurzburgs*, one concentrated on fighter and other on target aircraft, plotting both on a *Seeburg Tisch*.
Hoardings	G.A.F. early-warning ground radar.
Horchdienst	G.A.F. raid-tracking "Y" Service intercept stations—signals and radar listening.
Husky	Allied combined operations against Sicily—launched 10 July 1943.
Hyperbel	G.A.F. version of British Gee.
I.F.F.	R.A.F. airborne responder (transmitter-receiver) for enabling interrogator to distinguish between friend and foe.
Intruder	Operation of Allied long-range fighter free-lance into enemy territory.

"J" Switch .. R.A.F. jammer switch against G.A.F. S/L radar control—caused I.F.F. in bomber to "squitter"—believed to jam control.

Jostle .. .. R.A.F. airborne jammer against G.A.F. H.F. R/T fighter control (Jostle IV = V.H.F. jammer).

Kammhuber Line .. G.A.F. belt of N.F.s, S/L.s and A.A. defences across N.W. Europe—developed by General Kammhuber.

Karuso .. .. G.A.F. airborne R/T jammer against Allied R/T fighter control—100–150 megacycles per second.

Kiel .. .. .. G.A.F. infra-red airborne homer—for homing on to exhaust of bombers and as a warning receiver in U-boats.

Knickebein .. .. G.A.F. L.R. aid to navigation—split beam technique with intersecting beam at target—30 megacycles per second band.

Korfu Z .. .. G.A.F. homer receiver—20,000 to 15,000 megacycles per second.

Lichtenstein B.C. (*Fu.Ge. 202*) .. G.A.F. airborne A.I. on 490 megacycles per second band.

Lichtenstein S.N.2 .. G.A.F. airborne A.I. on *c.* 90 megacycles per second band.

Liquid Lunch .. R.A.F. forward-looking warner to indicate when aircraft being scanned by enemy or own A.G.L.T.

Mammut .. .. G.A.F. early-warning ground radar—*c.* 156 megacycles per second.

Mandrel .. .. R.A.F. jammer against G.A.F. early-warning radar—65–230 megacycles per second—ground and airborne versions.

Meacon .. .. Method of "masking" a radio beacon or beam by automatic reception and re-radiation of its transmissions on same frequency, same characteristics and synchronised, so as to induce D/F in use on the beacon to read a bearing between the real beacon and its Meacon transmitter (verb = meaconing).

Meerschaum .. R.A.F. homer/jammer against *Neptun*—air and ground versions.

Mimic .. .. Modified R.A.F. Meacon for use when enemy signal too weak to trigger Meacon—transmitter of latter caused to oscillate and then hand-keyed.

Monica .. .. R.A.F. tail-warning radar against G.A.F. A.I.—range 500/3,500 feet—frequency 223·5–227·5 megacycles per second.

Moonshine .. .. R.A.F. airborne responder, triggered by G.A.F. early-warning radar and indicating to the latter a large formation of bomber aircraft.

Mutton .. .. R.A.F. aerial mine operation against G.A.F. bombers attacking United Kingdom.

Naxos .. .. (*Fu.Ge. 218*) G.A.F. airborne homer on to S-band transmitters such as H2S—receiver also used by U-boats as a G.S.R. against centimetric A.S.V.

Neptun .. .. G.A.F. airborne tail-warner—*c.* 167 megacycles per second—presentations for pilot and observer—also used by U-boats as a search receiver against A.S.V.

Neptune .. .. Allied combined operations in the invasion of N.W. Europe 5/6 June 1944—that part of Overlord up to and including main landings.

Oboe	R.A.F. blind-bombing radar—ground controlled—responder on aircraft—Cat controls constant-range track and Mouse controls bomb release point—Mark I = metric: Mark II = centimetric: Mark III = multi-channel control.
Ottokar	G.A.F. navigational aid for N.F.s—V.H.F. beam (a modification of *Knickebein*) with V.H.F. R/T control on 30 megacycles per second band, using S.B.A. receiver in aircraft.
Overlord	Allied combined operations—invasion of N.W. Europe—launched 5/6 June 1944.
Peacock	Allied airborne repeater—improved Broody Hen.
Perfectos	R.A.F. airborne homer on to G.A.F. I.F.F. *Fu.Ge. 25A* used on *Egon* control.
Piperack	R.A.F. airborne jammer against G.A.F. A.I. (S.N.2).
Rayon	R.A.F. jammer against R/T channel of G.A.F. *Ottokar* N.F. control.
Rebecca	R.A.F. airborne interrogator for working on *c.* 200 megacycles per second radar responder beacons and B.A.B.S.
Red Queen	Form of G.C.I. incorporating Allied Airborne homer on to *Egon* aircraft.
Rosendahlhalbe ..	(*Fu.Ge. 221A*) G.A.F. aircraft homer on to Monica.
Rotate	G.A.F. "spoof" R.C.M.—H.P. recorded transmissions simulating rotating beacons on *Knickebein* frequencies.
Ruffian	G.A.F. L.R. aid-to-navigation—V.H.F. split beam (two narrow astride one wide)—*c.* 74 megacycles per second—used as an intersect of *Knickebein* for blind bombing release—accurate to within 10/20 yards over London—used in conjunction with receiver called "X" *Gerät*.
Rubezahl	Original name for *Egon*.
Rug	(Type 91) R.N. shipborne jammer against German low-angle early-warning radar.
Seeburg Tisch ..	G.A.F. plotting presentation for N.F. G.C.I. control.
Seetakt	G.A.F. early-warning ground radar.
See-Saw	Believed to be G.A.F. rotating H.F. beacon-experimental.
Serrate	R.A.F. airborne equipment for homing our fighters on to G.A.F. A.I. transmissions on *c.* 490 megacycles per second.
Shiver	R.A.F. jammer against G.A.F. radar S/L control—modification to I.F.F. to make it "squitter" when "J" switch made.
S.N.2	G.A.F. airborne A.I. (75–100 megacycles per second).
Sonne	G.A.F. L.R. aid-to-navigation—fanlike split beams on dot/dash principle, rotating through one beam segment (called Consol by R.A.F.).
Spanner	German infra-red receiver.
Splasher	Scrambled R.A.F. M.F. beam system—groups, each of four beacons, employing frequency switching.
Starfish	Allied decoy flare-fires—counter-measure to G.A.F. flare target markers.
Taunus . ..	G.A.F. anti-jammer modification to *S.N.2.* A.I. and to *Wurzburg*.
Taxable	Allied convoy operation in Operation Neptune.
Tinsel	R.A.F. airborne jammers against G.A.F., H.F., R/T, N.F. control—modification to T.1154 noise-modulated from microphone in engine nacelle. (Special Tinsel was a H.P. ground version.)

Titanic (I, III and IV).	..	Allied feint and airborne drops in Cherbourg Peninsula on 5/6 June 1944 ("Overlord").
Torch ..	..	Allied combined operations in invasion of N.W. Africa on 8 November 1942.
Trinity ..	..	Allied operations against German battleships, *Gneisenau* and *Scharnhorst* in Brest.
Washtub ..	..	R.A.F. unmasking of H.P., B.B.C. transmitter at Droitwich at selected times, to counter G.A.F. meaconing of R.A.F. M.F. beacon scheme (Washtub II = ditto at Start Point).
Wasserman ..	..	G.A.F., long-range, early-warning radar (*see* Chimney above).
Wilde Sau ..	..	G.A.F. technique for control of S.E. fighter by night against R.A.F. bomber stream—free-lance when once located in the stream.
Windjammer	..	G.A.F. ground-control by N.F.s by radar.
Window ..	..	R.A.F., R.C.M. against G.A.F. early-warning; fighter and S/L and A/A ground control and A.I. Metallised leaflet/strip reflector.
Wotan ..	..	G.A.F. blind-bombing aid—range measurement along a tracking beam by measurement of phase angle difference between outgoing and relayed signals.
Wurzburg ..	..	G.A.F., G.C.I., and S/L and A.A. control on 460–600 megacycles per second—range 200–250 Kms per second—height finding by tilt of parabolic mirror (Giant and small types).
Wurzlaus ..	..	G.A.F. R.C.M. Window—anti-jammer for G.C.I. and E–W, on doppler principle.
"X" *Gerät* ..	..	G.A.F. blind-bombing automatic receiver—used in Ruffian technique on *c.* 74 megacycles per second.
"X" *Halbe* ..	..	G.A.F. receivers capable of adaptation to any R.A.F. metric wavelength, for air-air homing.
"Y" *Gerät* ..	..	G.A.F. airborne receiver used in "Benito"—automatic "Course" and "Range" panel indicators.
Zahme Sau ..	..	Tame Sow—G.A.F. employment of T.E. N.F.s, under ground-control (*Himmelbett*), for long-range pursuit of Allied bombers.

Abbreviations used in Glossary

G.A.F.	..	German Air Force.	N.F.	..	Night Fighter.
G/L	..	Gun-laying.	S.E.	..	Single-engined.
H.F.	..	High Frequency.	T.E.	..	Twin-engined.
H.P.	..	High Power.	V.H.F.	..	Very High Frequency.
L.P.	..	Low Power.	E–W	..	Early-Warning.
L.R.	..	Long Range.	c.p.s.	..	Cycles per second.
M.F.	..	Medium Frequency.	Mc/s	..	Megacycles per second.
I.R.	..	Infra-Red.	Kc/s	..	Kilocycles per second.