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CIRCULARLY POLARIZED ANTENNA for 2500 to 3500 MEGACYCLE FREQUENCY RANGE

BY

M. Heusinkveld, Ens., USNR
H. F. Carlson, CRE, USN

Report R-2512

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BuShips Problem S877R-C

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BuShips Problem S877R-C

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ABSTRACT

1. This report describes the development of an antenna for the MBE jamming system. The MBE equipment consists of a jamming transmitter, a monitoring receiver, and an antenna system, the purpose being to jam enemy radar signals in the range of 2500 to 3500 megacycles while simultaneously monitoring the enemy signal being jammed.

2. The antenna system consists of two directional antennas, one for transmitting and one for receiving. These are mounted on the same axis so that they rotate together, and are driven by a servo drive system controlled from some remote point. Each antenna consists of a dipole with a parabolic reflector twelve inches in diameter, having a beam width of approximately 20 degrees at the half power points. The polarization is roughly circular, maximum ellipticity being 1.65 (ellipticity being expressed as the ratio of maximum to minimum voltage intensity). This polarization is produced by the use of a wire grating spaced about an eighth wave length from the solid parabolic reflector. Maximum coupling between the two antennas is 72 decibels down from direct connection. With this low value of coupling the jamming signal from the transmitter will be less likely to jam the receiver as it monitors the enemy signal. Antenna to transmission line matching is moderately good, the standing wave ratio being not greater than 2.3 on the 50 ohm line.

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TABLE OF CONTENTS

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PLATE 10. Characteristics of circularly polarized antenna with dipole fed from below.

PLATE 11. Characteristics of circularly polarized antenna with dipole fed from below and with additional reflecting element.

PLATE 12. Relative field intensity pattern of MBE Antenna at 2600 megacycles in horizontal plane.

PLATE 13. Relative field intensity pattern of MBE Antenna at 2600 megacycles in vertical plane.

PLATE 14. Relative field intensity pattern of MBE Antenna at 3000 megacycles in horizontal plane.

PLATE 15. Relative field intensity pattern of MBE Antenna at 3000 megacycles in vertical plane.

PLATE 16. Relative field intensity pattern of MBE Antenna at 3400 megacycles in horizontal plane.

PLATE 17. Relative field intensity pattern of MBE Antenna at 3400 megacycles in vertical plane.

PLATE 18. Blueline print showing details of MBE antenna.

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INTRODUCTION

1. This work was done in accordance with Bureau of Ships letter S-S67-5 (920-Ab), S-920-010147, under Problem S877R-C. (See reference 1) The entire equipment developed under this problem consists of a jamming transmitter, a monitoring receiver, and an antenna system. The purpose of the equipment is to jam enemy radar signals in the range 2500 to 3500 megacycles while simultaneously monitoring the enemy signal being jammed. This report describes the development of the antenna system only.

ANTENNA SYSTEM

2. The antenna system consists of separate transmitting and receiving antennas mounted on opposite ends of a housing containing the antenna drive mechanism. The two antennas are directional, each having a beam width of about 20 degrees at the half-power points. A parabolic reflector 12 inches in diameter is used to obtain the desired directivity. The two antennas are rotated together so that they are simultaneously trained on the same enemy position. Radio Frequency coupling between the two antennas was kept low so that the transmitted signal would not jam the receiver while the receiver was monitoring the enemy signal. For good jamming and receiving coverage the polarization of both antennas was made circular.

POLARIZATION

3. A circularly polarized wave is considered as being composed of two vectors at right angles to each other and at right angles to the direction of propagation of the wave. One of these vectors lags the other in time phase by 90 degrees, so the effect at any point as the wave passes is that of a vector of constant amplitude with time, but rotating in the direction of polarization at the radio frequency rate. In this respect a circularly polarized wave differs from a plane polarized one, in which the direction of polarization remains constant. It is this difference which makes circular polarization preferable to plane polarization for jamming purposes; since it will induce a voltage in the enemy antenna for any polarization of the enemy antenna. A simple dipole antenna can be placed in any position in the plane perpendicular to the direction of propagation of a circularly polarized wave and the energy received will be the same. If the polarization of the wave is not exactly circular the receiving antenna can be rotated in this plane and the voltage induced in it will not be exactly constant but will have maximum and minimum points, depending on the angle of the receiving antenna in the plane. This factor is the criterion used in determining how nearly circular the polarization is.

DEVELOPMENT AND RESULTS OBTAINED:

Polarization

4. Two methods of producing the circularly polarized radiation were

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tried in this project. In one method, phase delay was introduced at the radiating elements; in the other method it was introduced at the parabolic reflector.

5. In the first method shown by Figure 1, Plate (1), one dipole is an eighth wavelength farther from the reflector than the other, and the two dipoles are perpendicular to each other. Due to the eighth wavelength of transmission line, the voltage wave from the farther dipole will lag that from the nearer dipole by an eighth wavelength as the two components are radiated from the dipoles. This voltage wave from the farther dipole will lag an additional eighth wavelength as it travels back past the nearer dipole, the resultant wave thereby becoming circularly polarized. The combined wave travels back to the parabolic reflector and is projected into the beam. This method was tried but the polarization obtained was far from being circular, and varied rapidly with frequency. For this reason this was not prosecuted.

6. In the second method the dipole and reflecting elements are oriented as shown by Figure (2), Plate (1). The plane-polarized energy is radiated back from the simple dipole to the reflecting wire grating and the solid reflector. The wire grating reflects a component of the radiation having voltage intensity parallel to the wires, the component of radiation with perpendicular voltage intensity passing through. This perpendicular component travels to the solid reflector and back through the wire reflector, a total path of a quarter wavelength, thereby lagging the parallel component by a quarter wavelength. If the dipole is at an angle of 45 degrees with the wires of the grating the energy will be equally divided between the two components, and the components in the beam will be 90 degrees out of phase, thus constituting the circular polarization.

METHODS OF FEED

7. When this project was begun the general plan for the antenna arangement had not been decided; consequently several variations of the antenna were developed. Two methods of feed were used, one through the back of the parabolic reflector, as shown in Plate (2), and the other from below and in front of the reflector, as shown in Plate (4). In each case work was done both with and without directive elements near the dipole.

8. Plate (2) shows the antenna fed through the parabolic reflector without additional elements while Plate (3) shows the antenna with additional directive elements added. Plates (8) and (9) shows some of the results obtained from these two antennas respectively. In these plates the ratio of maximum to minimum voltage intensity gives the ellipticity of the polarization produced, as explained in Paragraph (3). In addition to producing polarization more nearly circular, the antenna with the directive elements produced field intensity patterns with smaller side lobes than the antenna without these directive elements.

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9. Plate (4) shows the antenna fed from beneath and to the front without additional elements while Plate (5) shows the antenna with this same type of feed but with a reflecting element added. Plates (10) and (11) show the standing wave ratios and the ellipticities of the polarization of the two respectively. At the time of the writing of this report the reason for the discrepancy between the standing wave ratios of the Laboratory model and the manufacturer's model shown on Plate (11) had not yet been found. The polarization obtained from the two models were practically identical. As before, the reflecting element decreased the size of the side lobes. Since in the method in which the dipole was brought up from underneath and to the front the dipole could remain motionless as the reflector was rotated around it and no rotating joint nor moving cable was necessary, this antenna with the reflecting element was the one chosen for the MBE System. Relative field intensity patterns for MBE antenna are given on Plates (12) to (17) inclusive. In this report all values are given in relative voltage rather than in relative power, and direction of intensity refers to direction of voltage intensity or direction of electric vector rather than magnetic.

COUPLING BETWEEN ANTENNAS

10. Coupling between the two antennas was found to depend to a considerable extent on the "bazookas", or radio-frequency suppressors on the transmission line supports of the dipoles. It was found that fins on the outside of the drive mechanism housing as shown by Plate (7) decreased this coupling. Without these fins the maximum value of coupling over the frequency range was about 54 decibels down from direct connection between the transmitter and receiver cables. When these fins were added this maximum value of coupling was reduced to a value of about 72 decibels down.

11. When a metal sheet was placed in front of the antenna system to simulate some nearby interfering object, the coupling between antennas was considerably increased. When both antennas were arranged to give the same phase rotation considered as transmitting antennas, the coupling between the two was considerably less than when they were set to give opposite phase rotation when used with this metal sheet as the interfering object. Direction of rotation of the polarization of this type of antenna can be reversed by rotating the wire grating through an angle of 90°, this amount of rotation again placing the wires at an angle of 45° with the axis of the dipole.

Beam Shift

12. Difficulty was encountered in projecting the radiated beam straight forward from the reflector. In some arrangements the beam would be shifted as much as eight degrees to the right or left of the axis of the reflector, this deviation varying with frequency. As explained in the preceding paragraph,

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it was desirable to use the same phase rotation in the two antennas. As a result of this, since one antenna was to be mounted ri ht side up and the other upside down, if the beam from one antenna would be deviated to the right, the other would be deviated to the left, and the two antennas would not be trained on the same target. Through experimentation a setting was found in which the beam remained quite well centered in the horizontal plane. In the vertical plane it was necessary to tilt the parabolic reflector back by 2 1/2 degrees to make the mean direction of the beam over the frequency range more nearly horizontal.

Gain

13. Measurements gave values of gain for this antenna of some ten or twelve decibels over a plane-polarized isotropic source, although these measurements were unreliable because the values could not be repeated with reasonable accuracy. Since with circular polarization the energy is divided into two equal components, the gain as determined by measuring voltage intensity with a plane polarized test antenna will include only one half of the radiated energy at that point. From a total energy standpoint, the measured values of ten or twelve decibels would be increased by three decibels, this correcting for the apparent loss of gain due to the circular polarization.

Mechanical Construction

14. The final antenna system weighs approximately 140 pounds. The overall length with the domes in place is 48 inches and the diameter to the outside edges of the fins is about 23 inches. The parabolic reflector has a diameter of 12 inches and a focal length of 4 inches from the center of the dipole. A reduced blueprint of one of the antennas is given on Plate (18).

15. The antennas are driven together by an electric motor with a selsyn control system in the housing between the antennas, electrically connected to an external control unit.

16. The transmission line supporting the dipole consists of the outer brass tube and an RG-8/U cable with its vinyl covering and copper braid stripped back. The cable and brass tube were chilled in dry ice until the polyethylene had contracted enough more than the brass to allow the cable to be inserted into the tube. When this line was warmed back to normal temperatures a tight fit resulted. The radiating element to be connected to the inner conductor of the transmission line was then attached by the use of a sleeve pushed over the inner conductor and under the polyethylene dielectric by heating with a soldering iron, and subsequent soldering.

Discussion

17. This antenna represents a compromise among the various requirements

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as to polarization, pattern, coupling between antennas, impedance, and mechanical details. Coupling between antennas could be decreased and polarization could be made more nearly circular by moving the parabolic reflector nearer the dipole, but this would decrease the gain and increase the size of the side lobes.

18. The distance between the wires of the reflecting grating was found to be not critical. In this antenna they were set one-half inch apart, and five-eighths inch from the solid reflector. The lucite strip perpendicular to these wires, shown in Plate (5) was used to give the wires adequate mechanical support. It had some effect on the pattern and the polarization of the antenna.

19. Pictures of the final antenna system are given on Plates (6) and (7). Plate (7) shows the plastic domes used to keep out the weather. These domes were made of laminated glass cloth phenolic three sixteenths of an inch thick. It was found that these domes decreased the gain an amount varying erratically with frequency between zero and two decibels.

CONCLUSIONS

20. The final antenna developed here covers the frequency range 2500 to 3500 megacycles with a maximum standing-wave ratio of about 2.3.

21 At maximum ellipticity the ratio of maximum to minimum voltage intensity is about 1.65.

22. Maximum coupling between antennas is about 72 decibels.

23. Beam width for the various planes, direction of intensity, and frequencies average about 20 degrees.

ACKNOWLEDGEMENTS

24. Dr. A. V. Haeff, Coordinator of the general S877R-C project, suggested the use of the wire gratings for producing the circular polarization and gave many other useful suggestions. Mr. R. J. Violette of NRL, outlined the method for making the solid dielectric line. Mr. T. E. Haneley of NRL developed the fins which decreased the coupling between antennas.

REFERENCES

1. BuShips ltr. S-S67-5 (920-Ab), S-920-010147 of 8 Sept 1944 to Dir. NRL: Request for Assignment of Problem S877.R-S.

Original data recorded in NRL Log Books 4168 and 5367.

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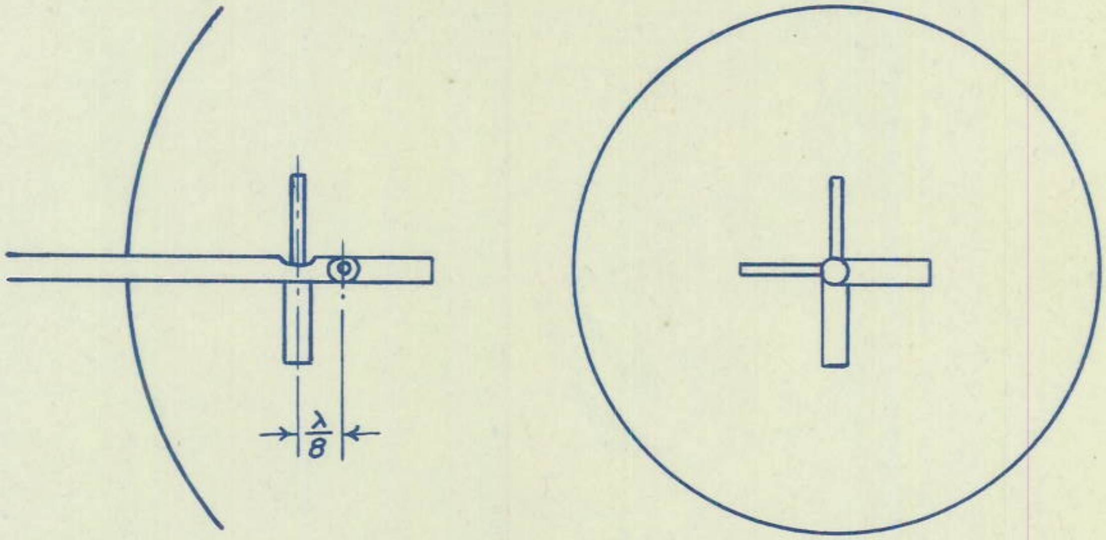

Circular Polarization Produced at Dipoles

Fig. 1

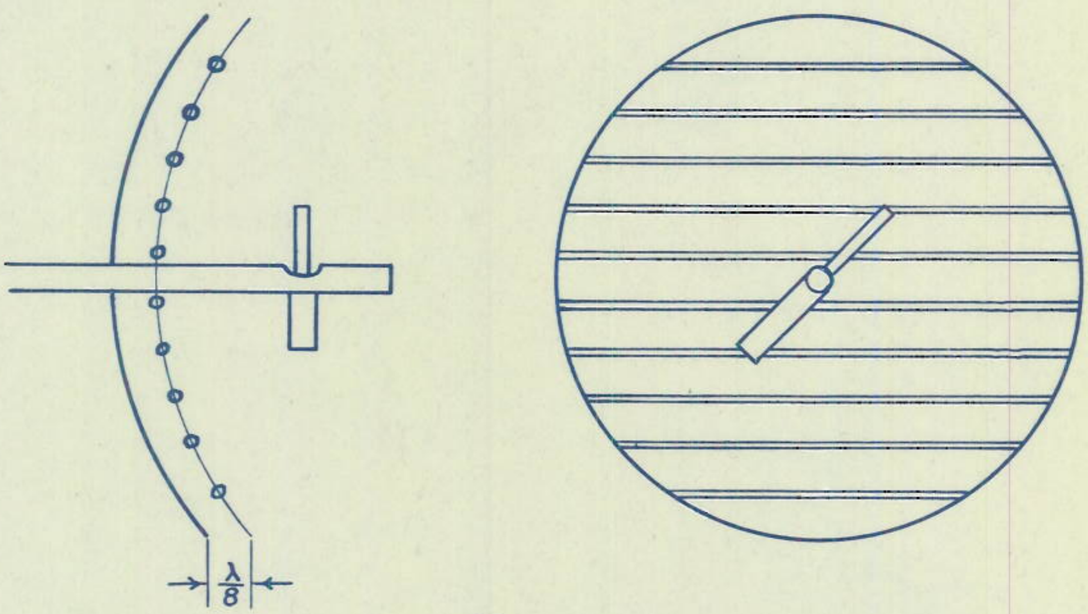

Fig. 2

Circular Polarization Produced at Reflector

[redacted]	NRL - Special Development Section M.H. April 18, 1945	PLATE I

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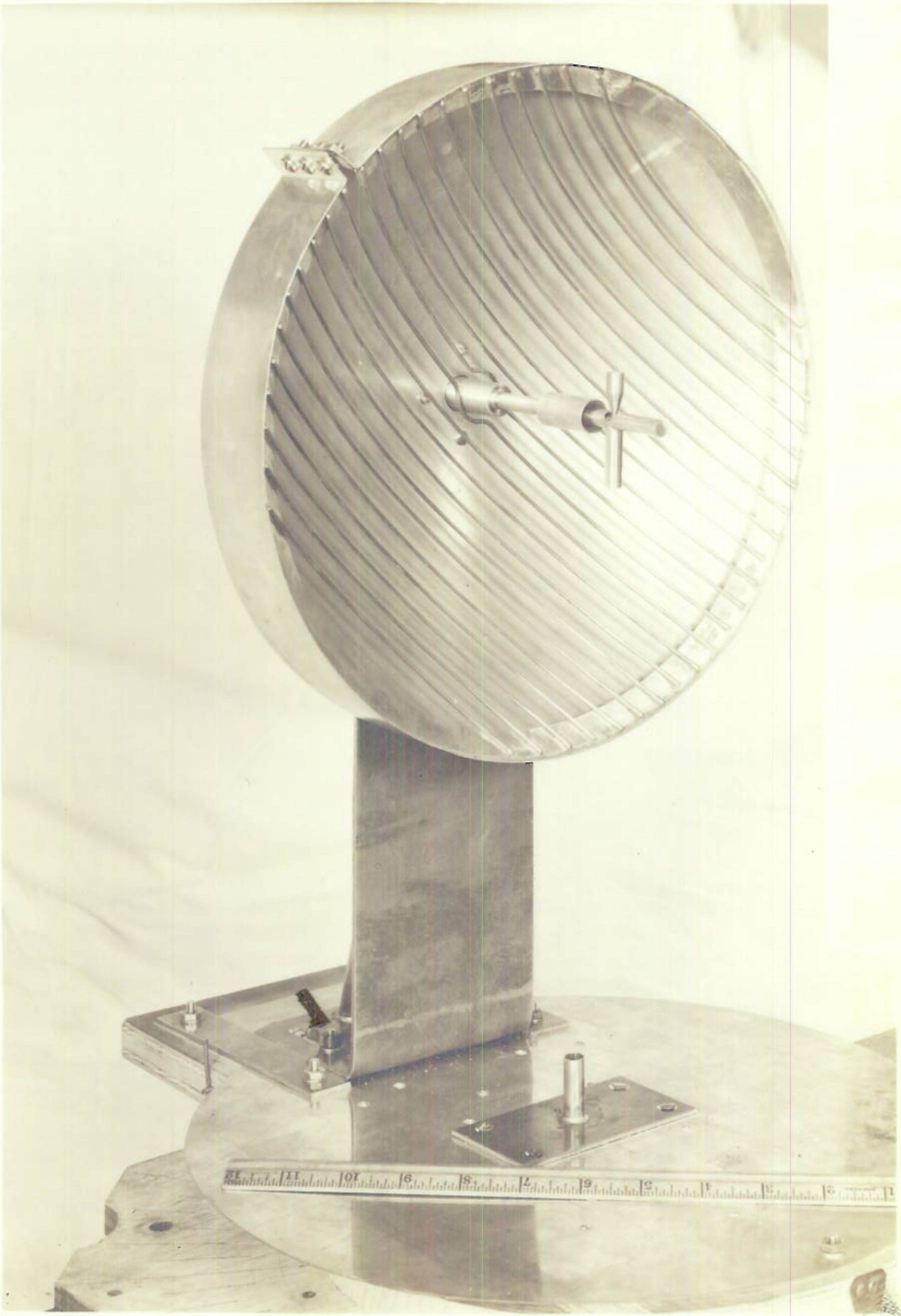

DECLASSIFIED CIRCULARLY POLARIZED ANTENNA FED THROUGH THE BACK OF THE PARABOLIC REFLECTOR.

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PLATE 2

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CIRCULARLY POLARIZED ANTENNA FED THROUGH THE BACK OF
THE PARABOLIC REFLECTOR, WITH ADDITIONAL REFLECTING ELEMENTS.

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PLATE 3

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CIRCULARLY POLARIZED ANTENNA FED FROM BELOW.

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PLATE 4

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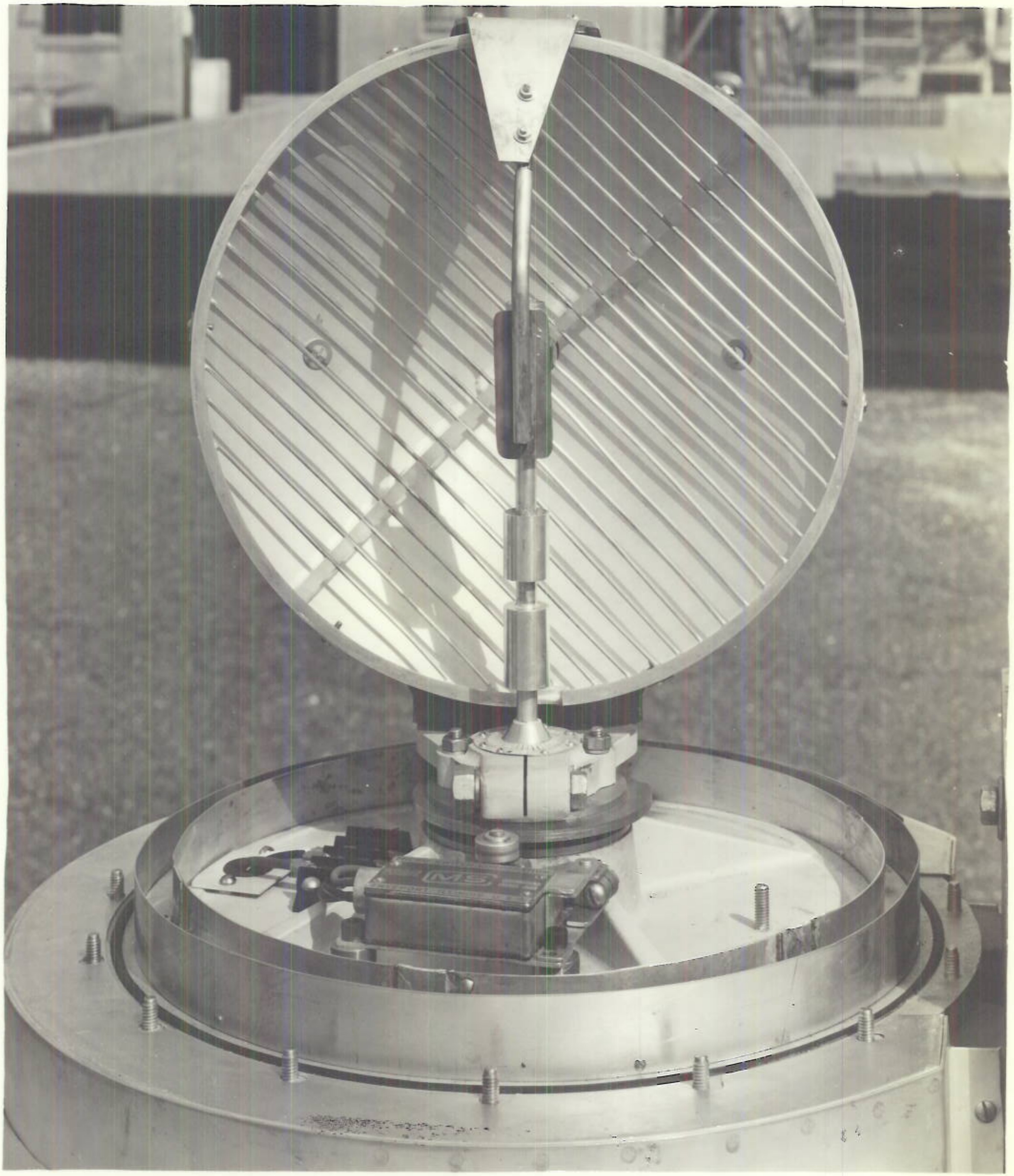

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CIRCULARLY POLARIZED ANTENNA FED FROM BELOW,
WITH ADDITIONAL REFLECTING ELEMENT.

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PLATE 5

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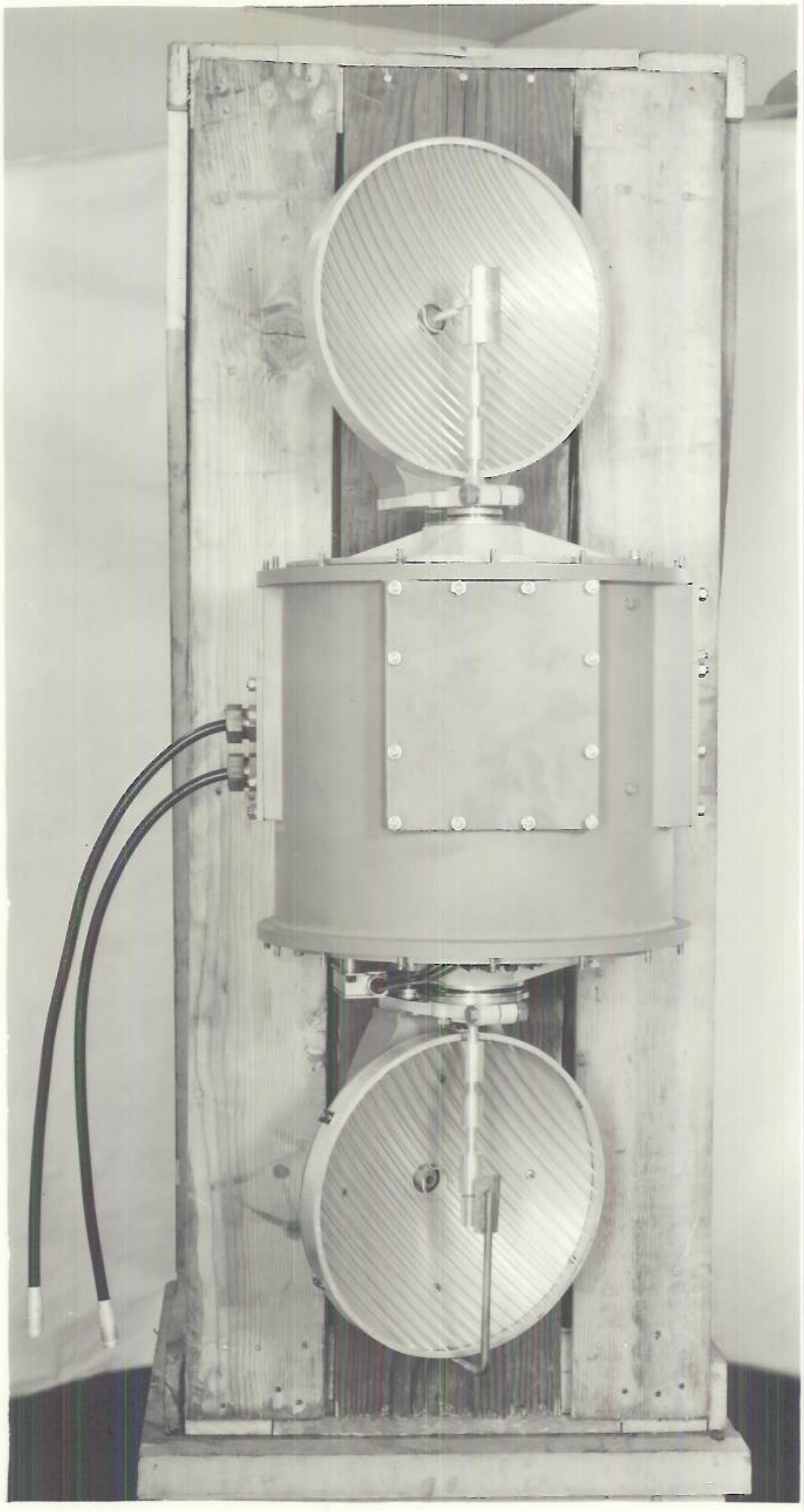

DEVELOPMENTAL MBE ANTENNA SYSTEM WITHOUT WEATHERPROOFING DOMES.

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PLATE 6

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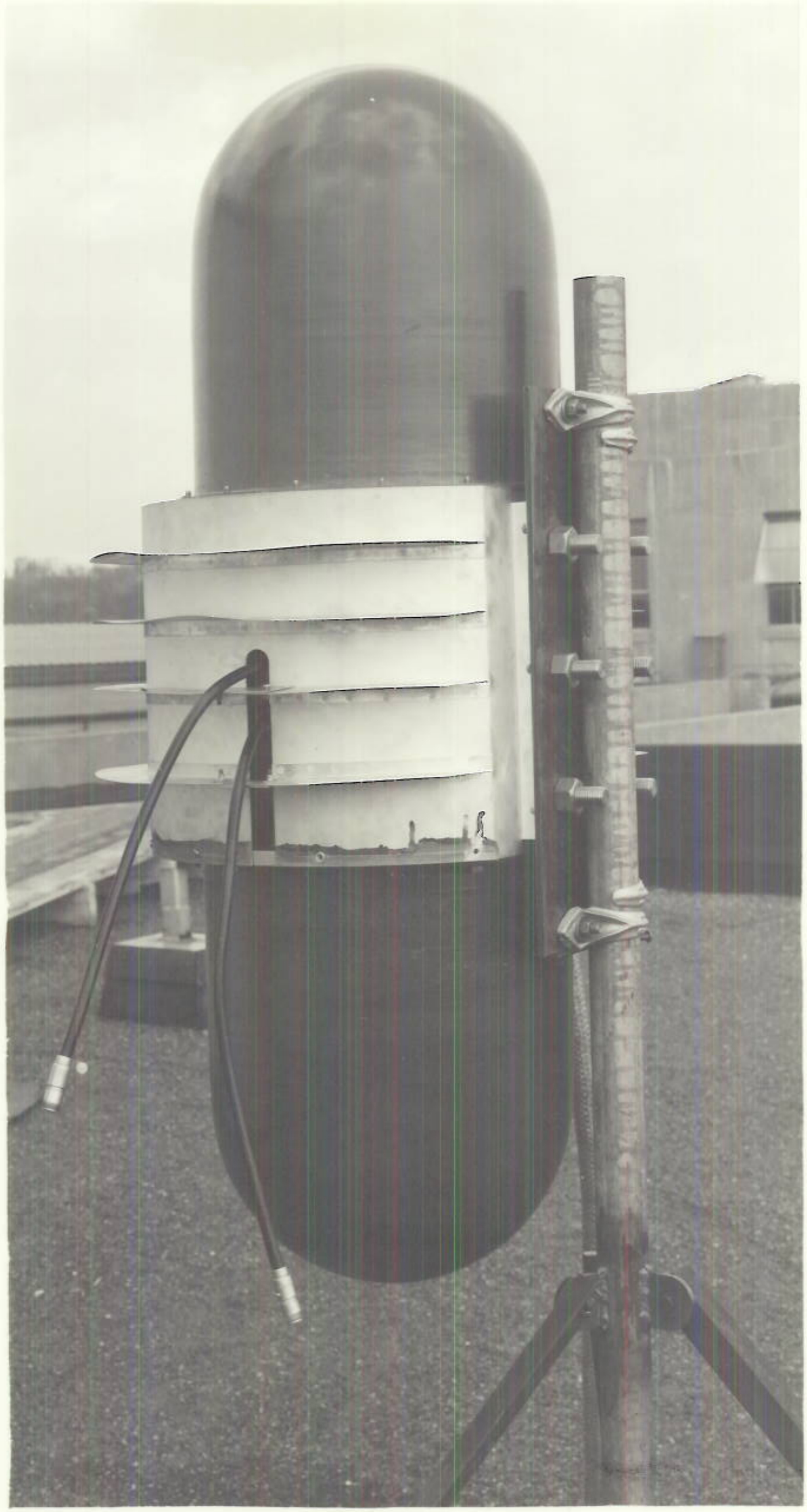

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FINAL MBE ANTENNA SYSTEM WITH WEATHERPROOFING DOMES IN PLACE.

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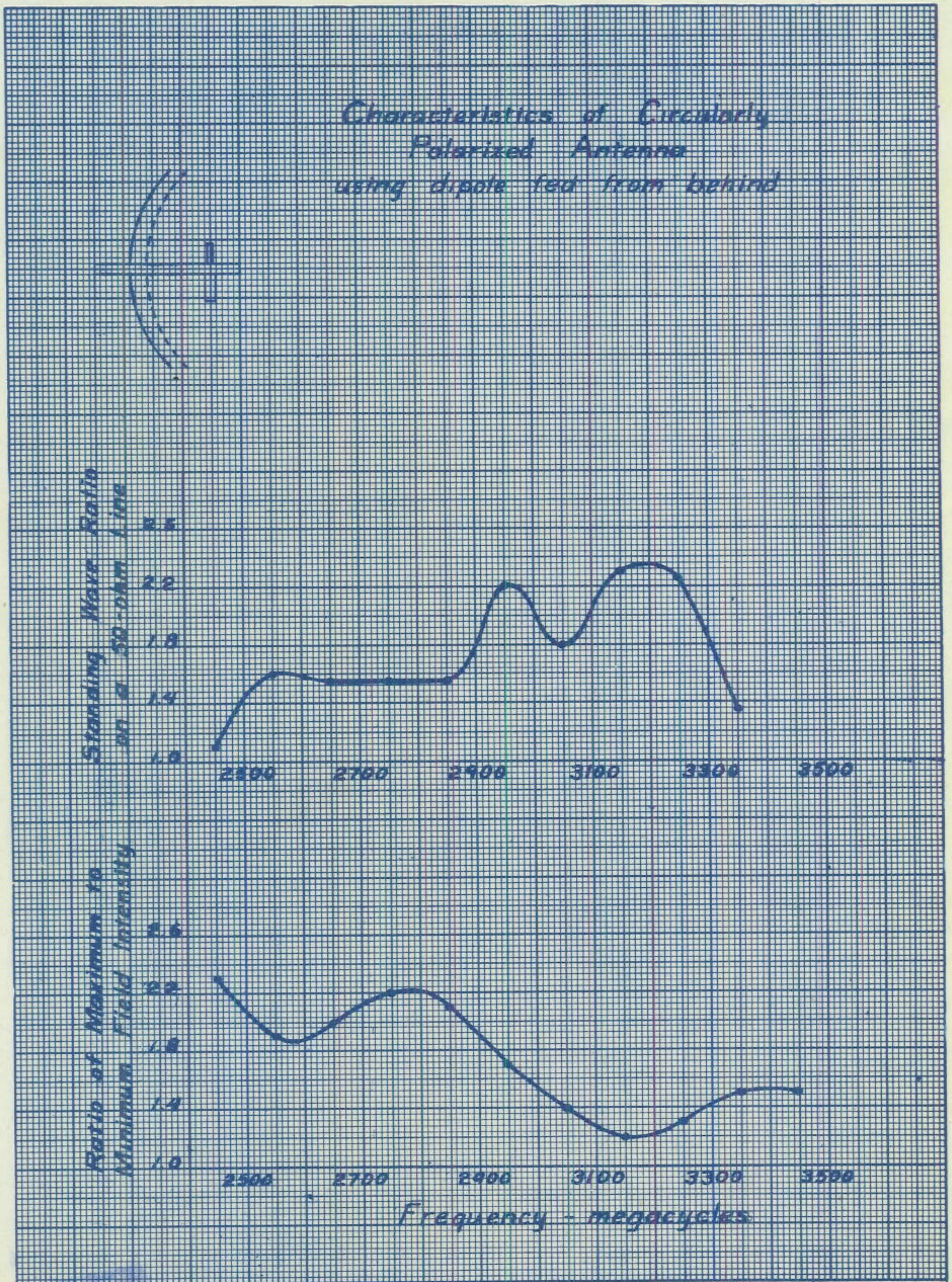

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	M.H. October 6, 1944	

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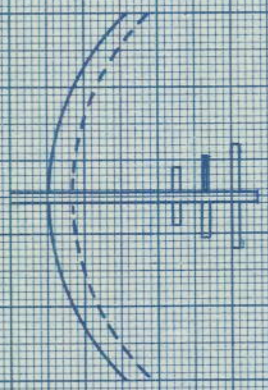
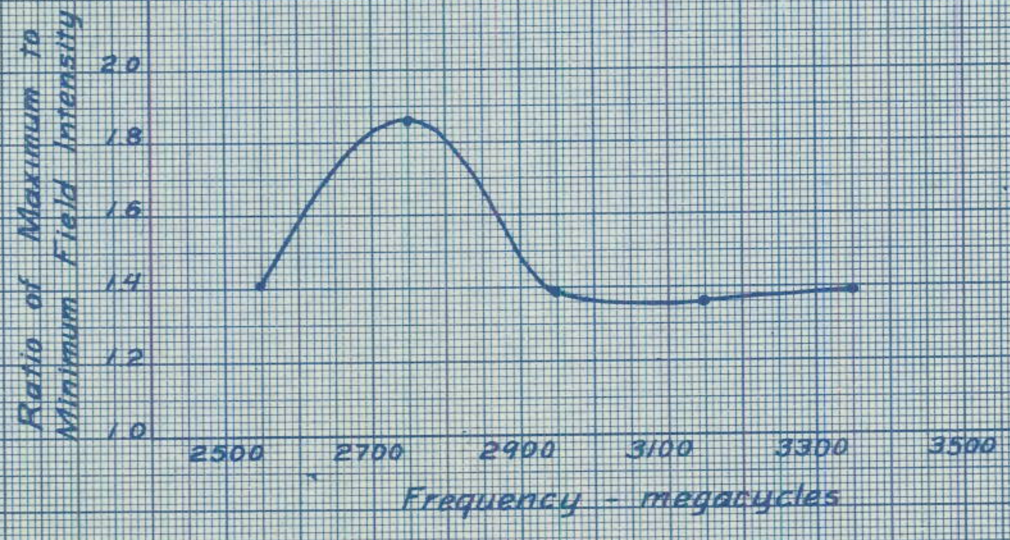
Characteristics of Circularly Polarized Antenna

with dipole fed from behind and with additional reflecting elements





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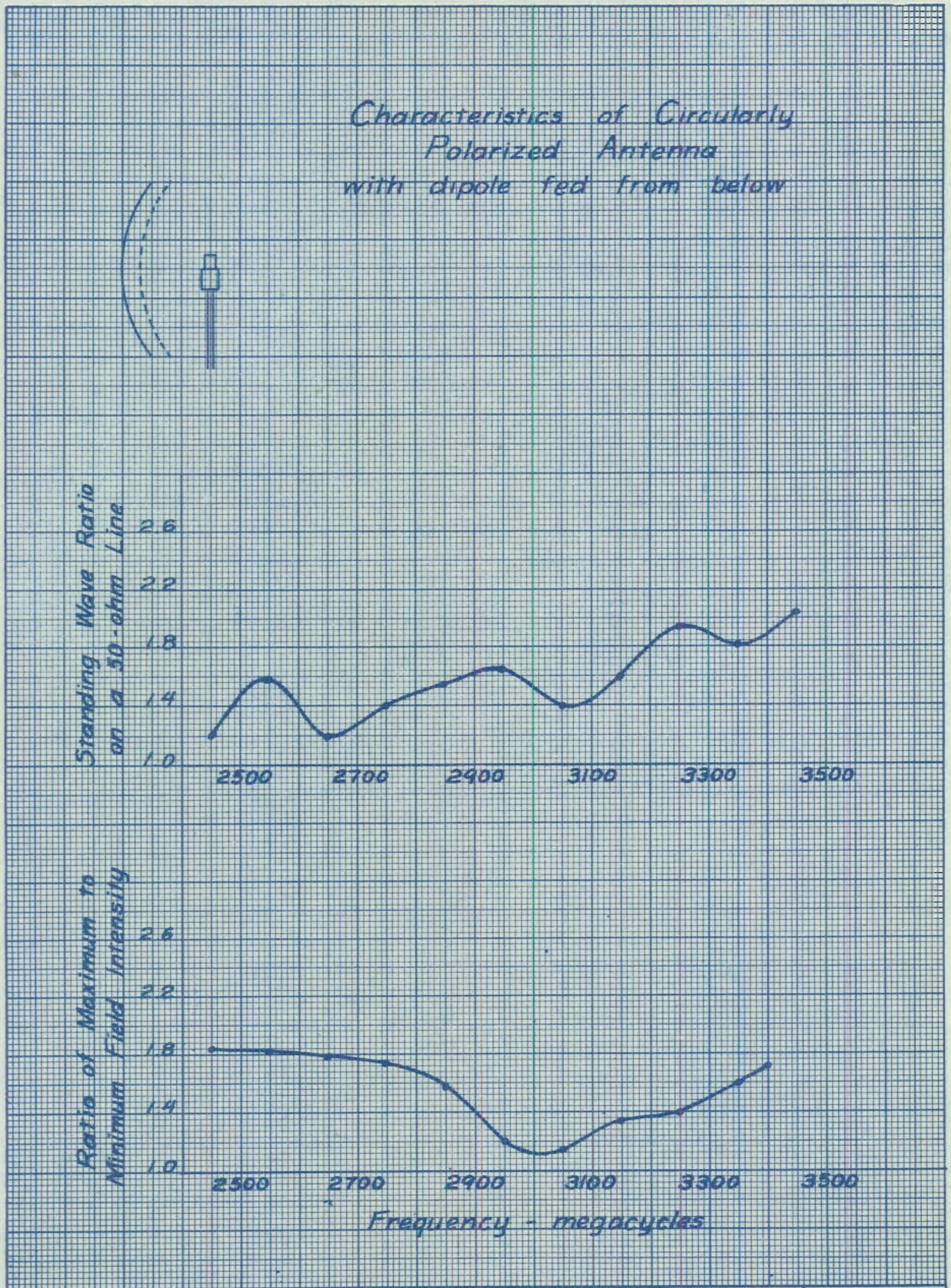

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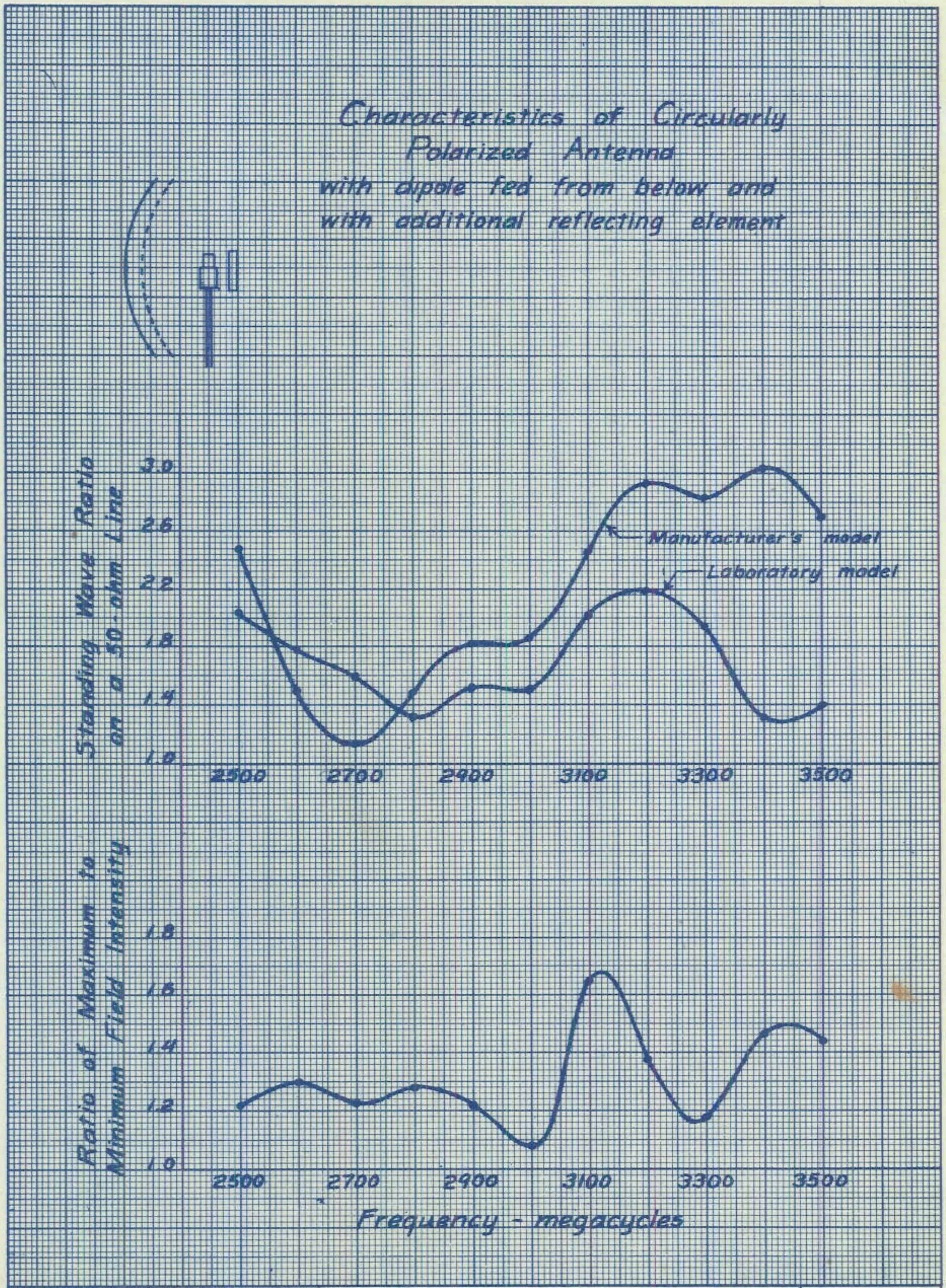

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	M.H. March 23, 1945	

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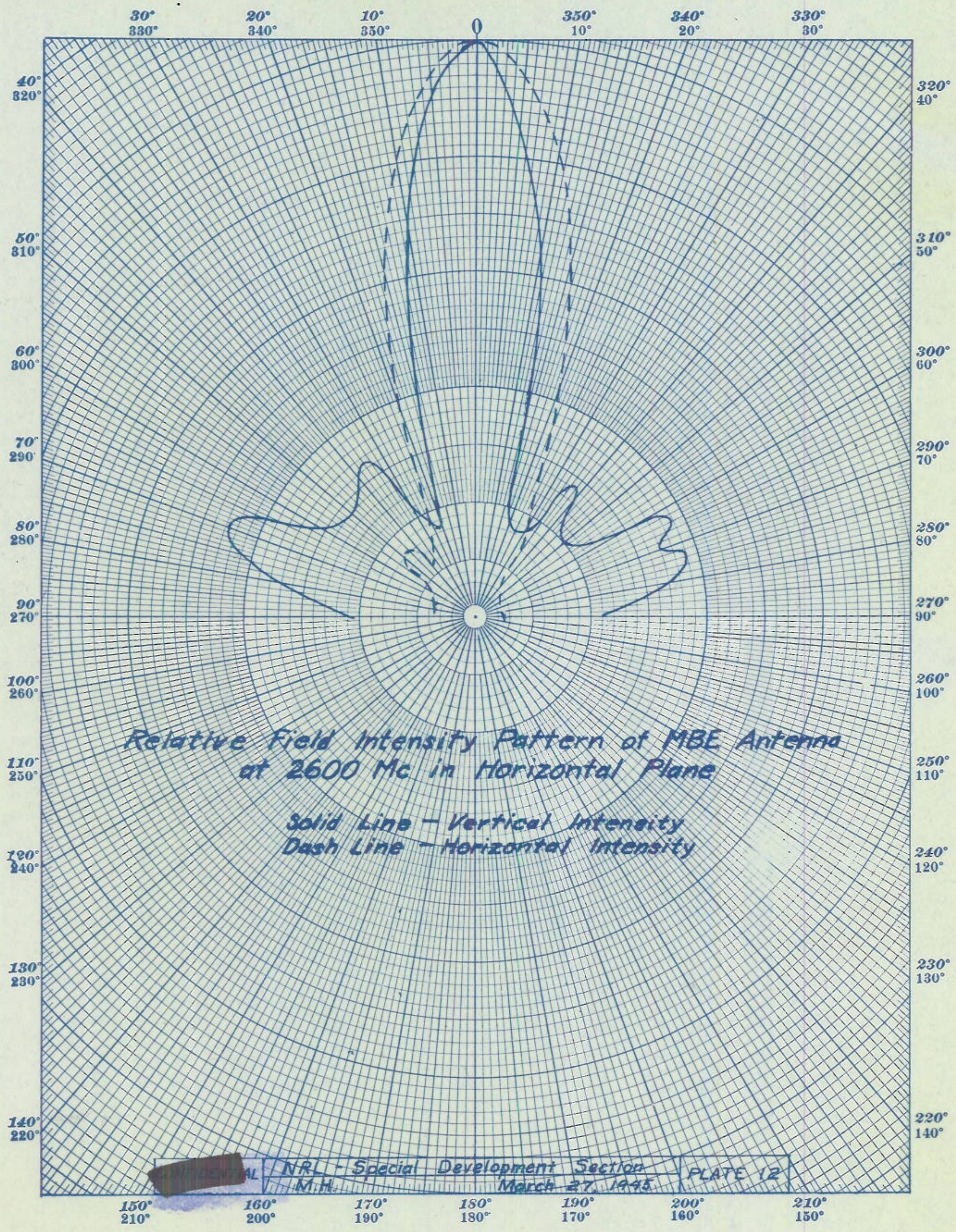

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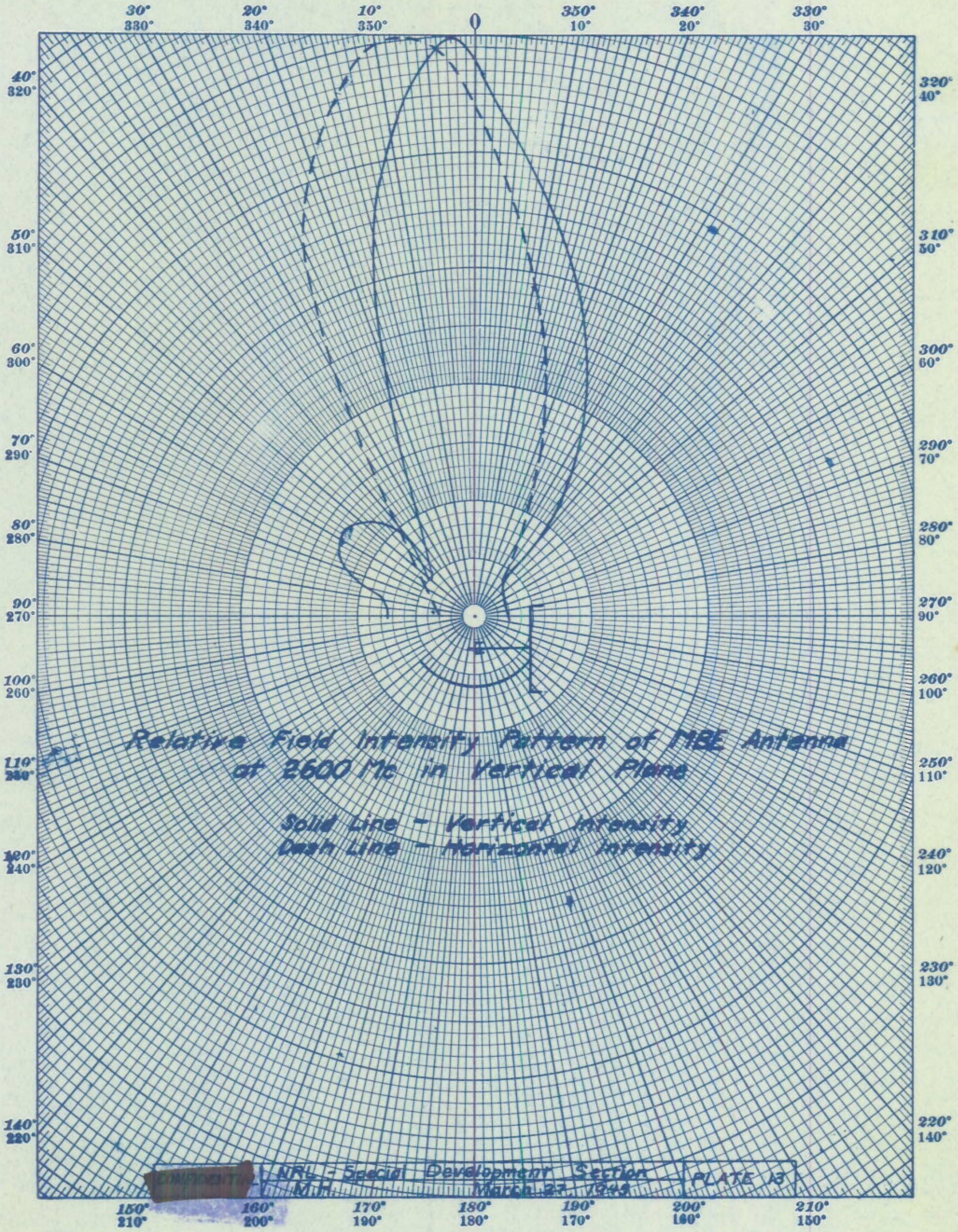

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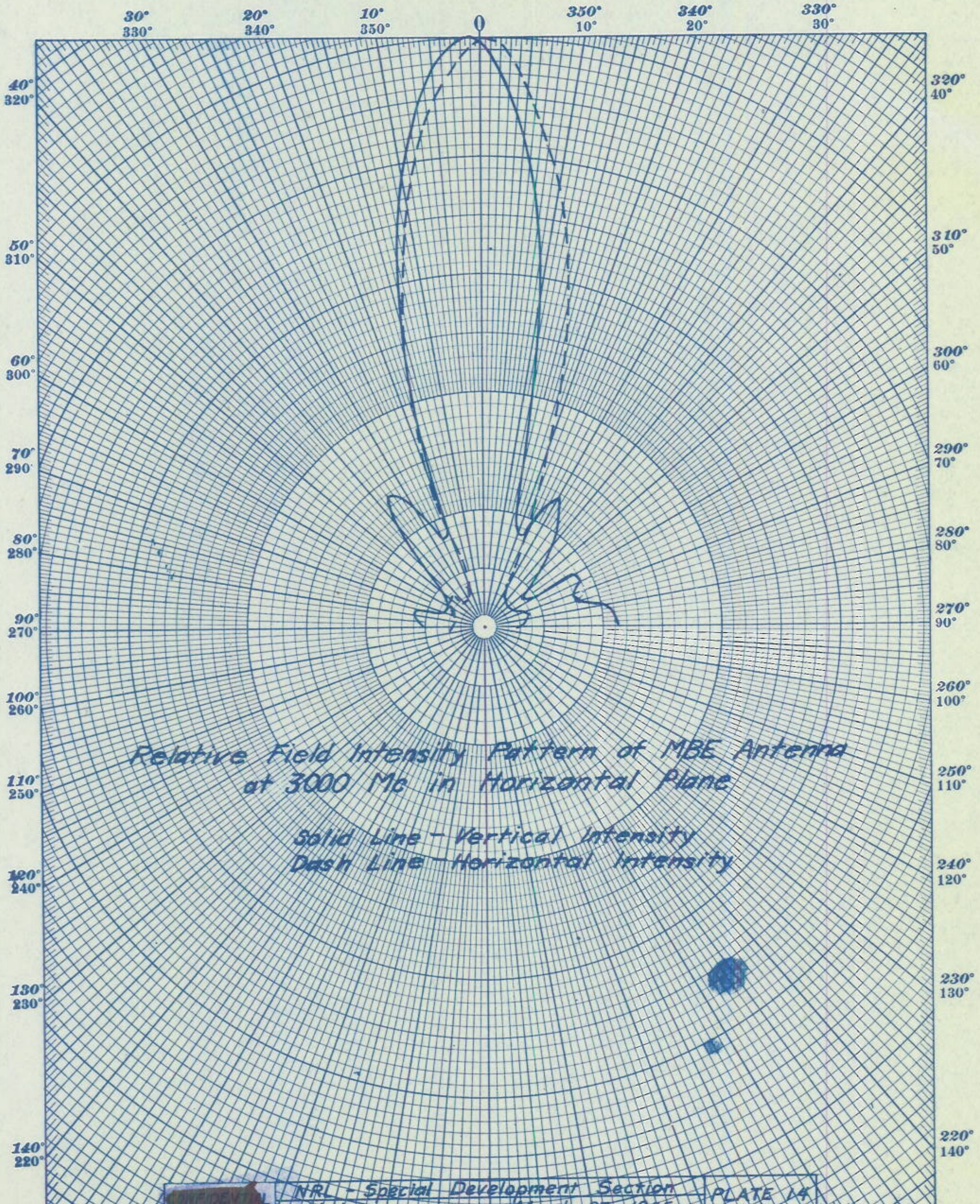

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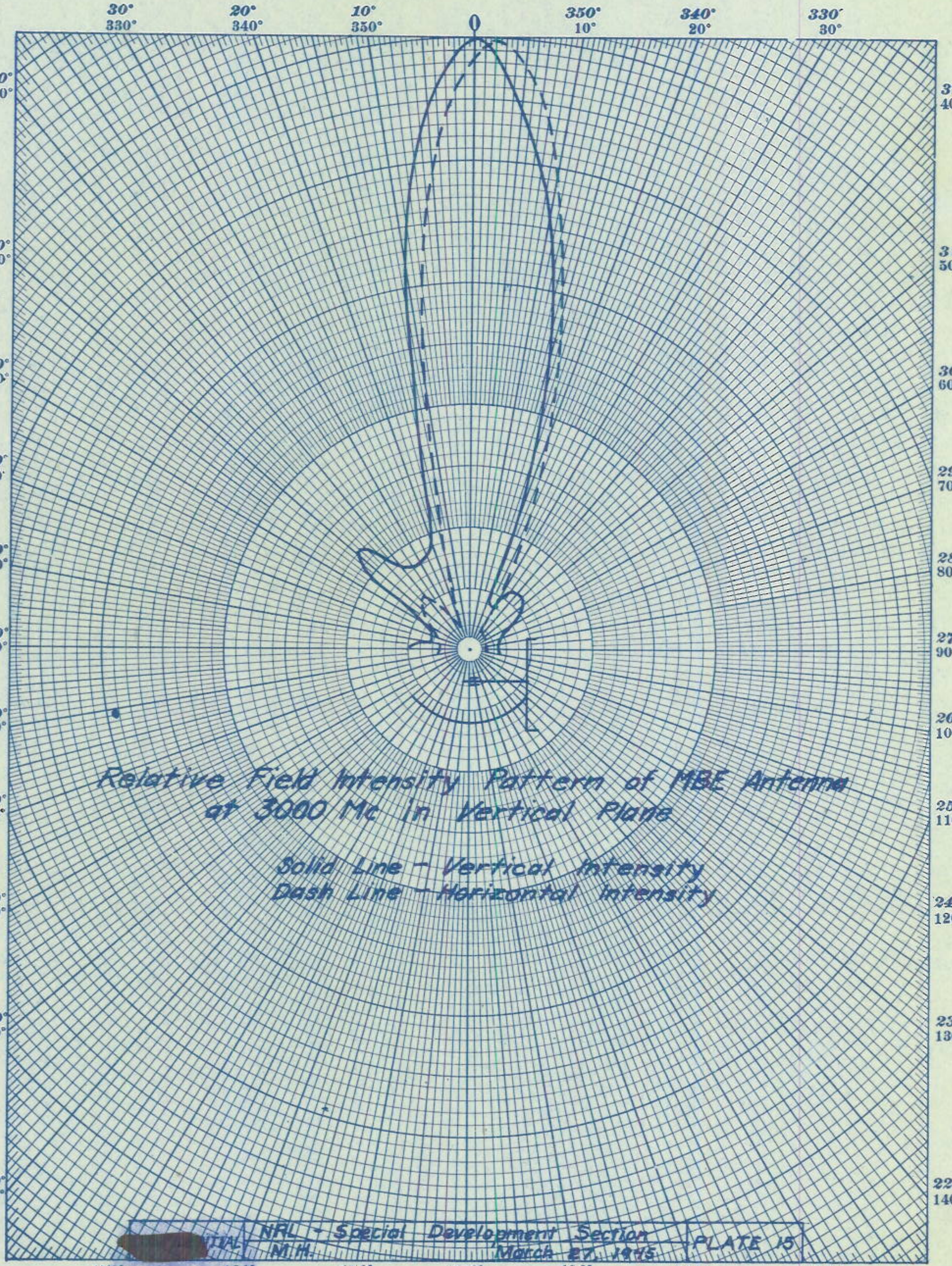

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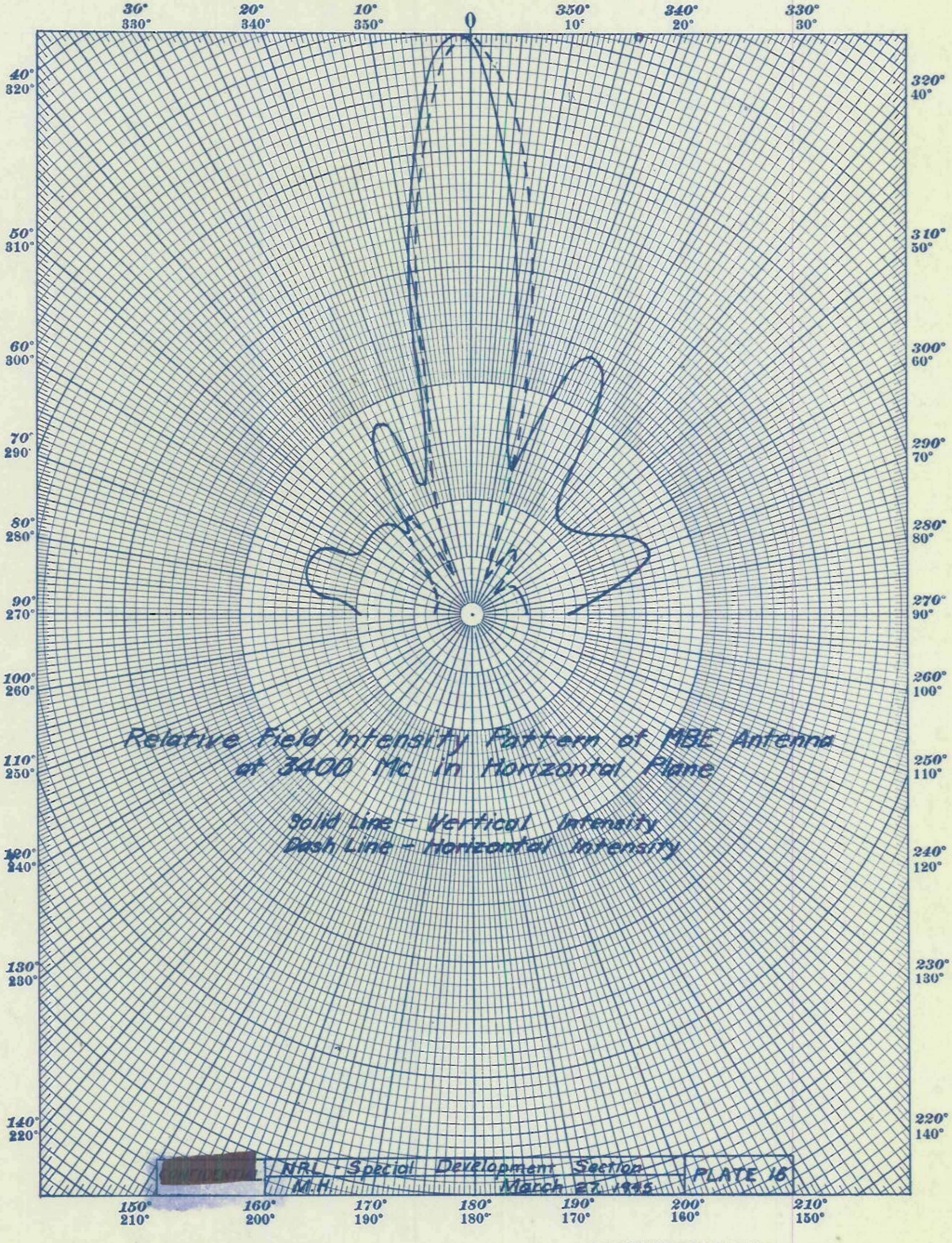

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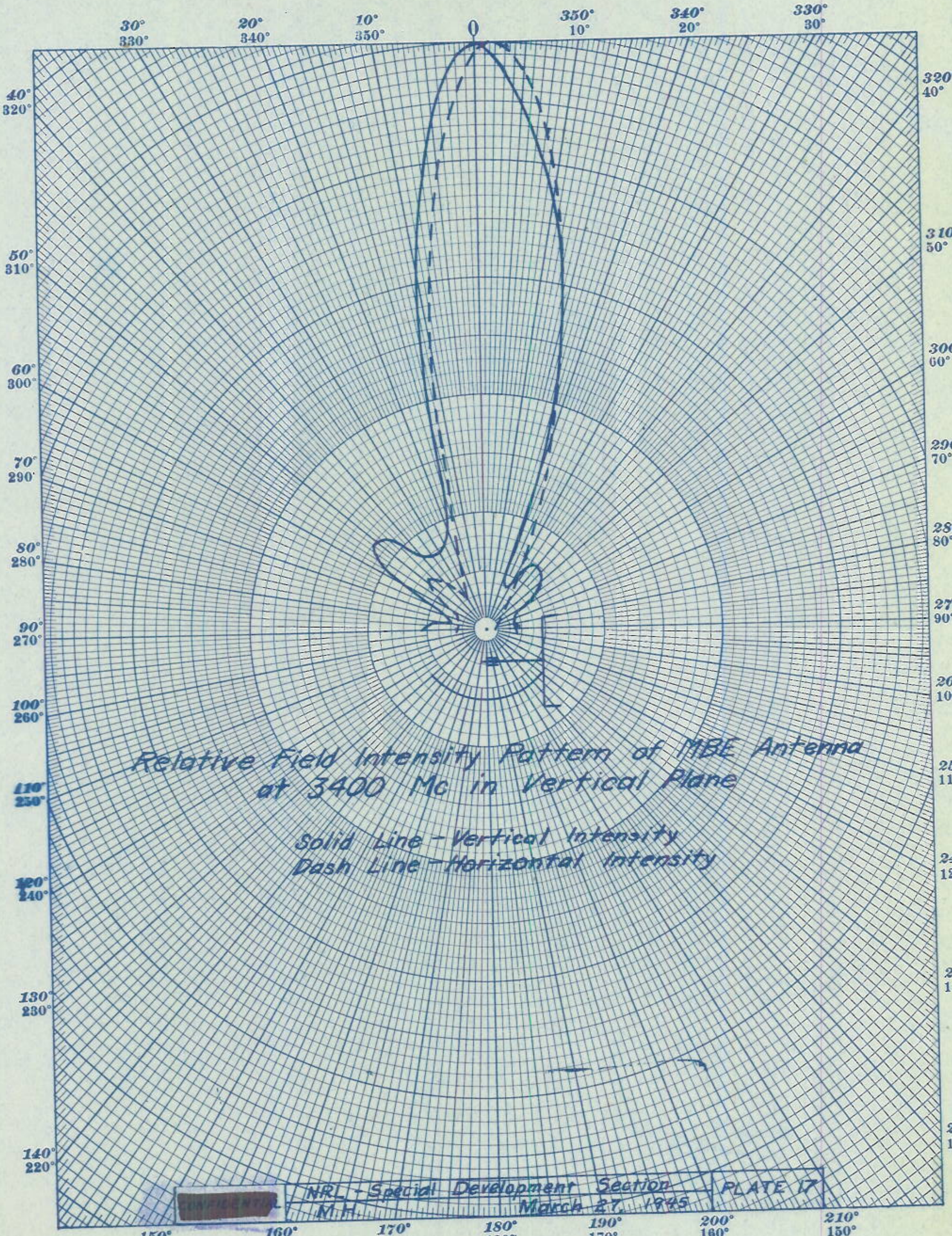

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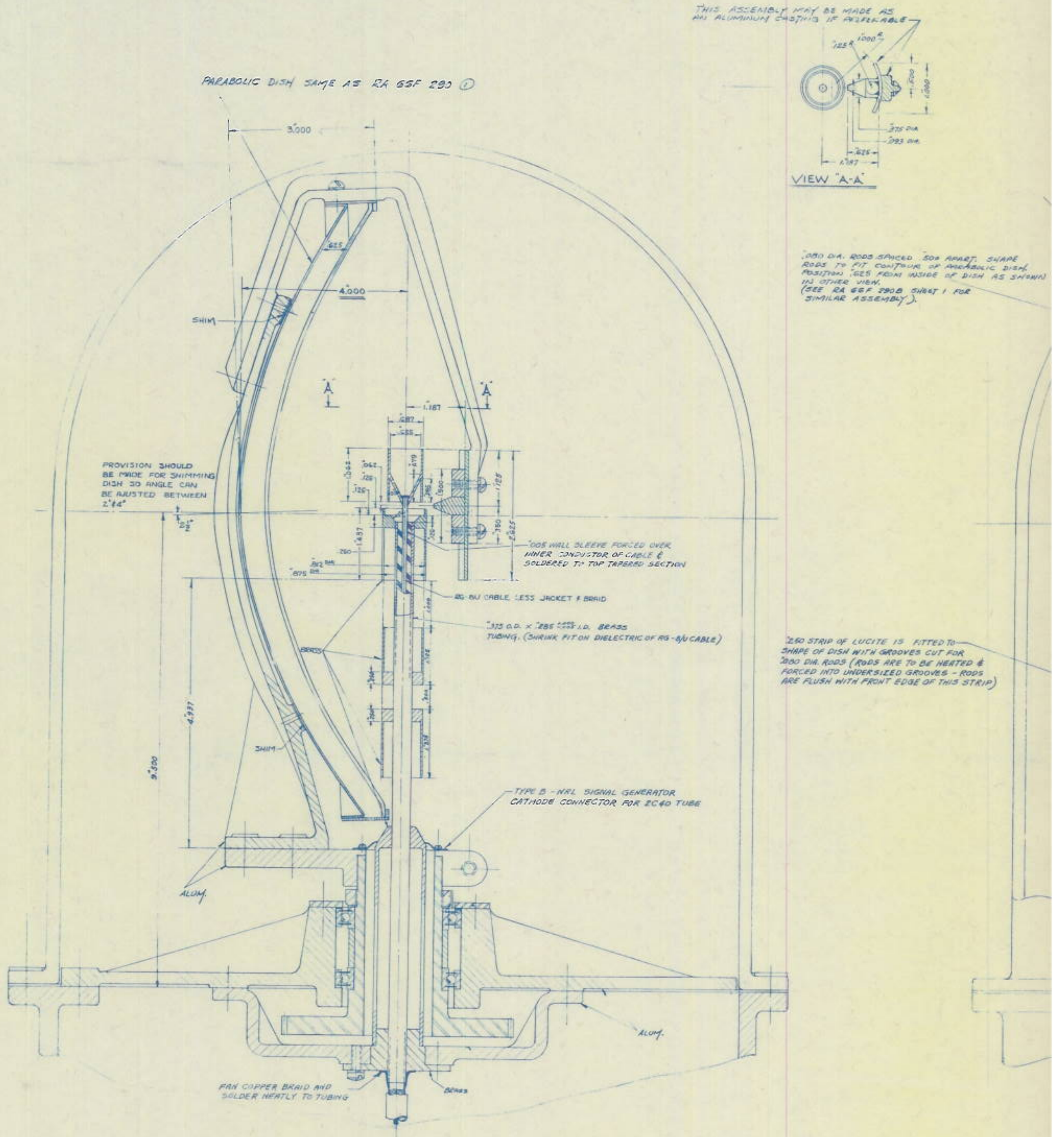

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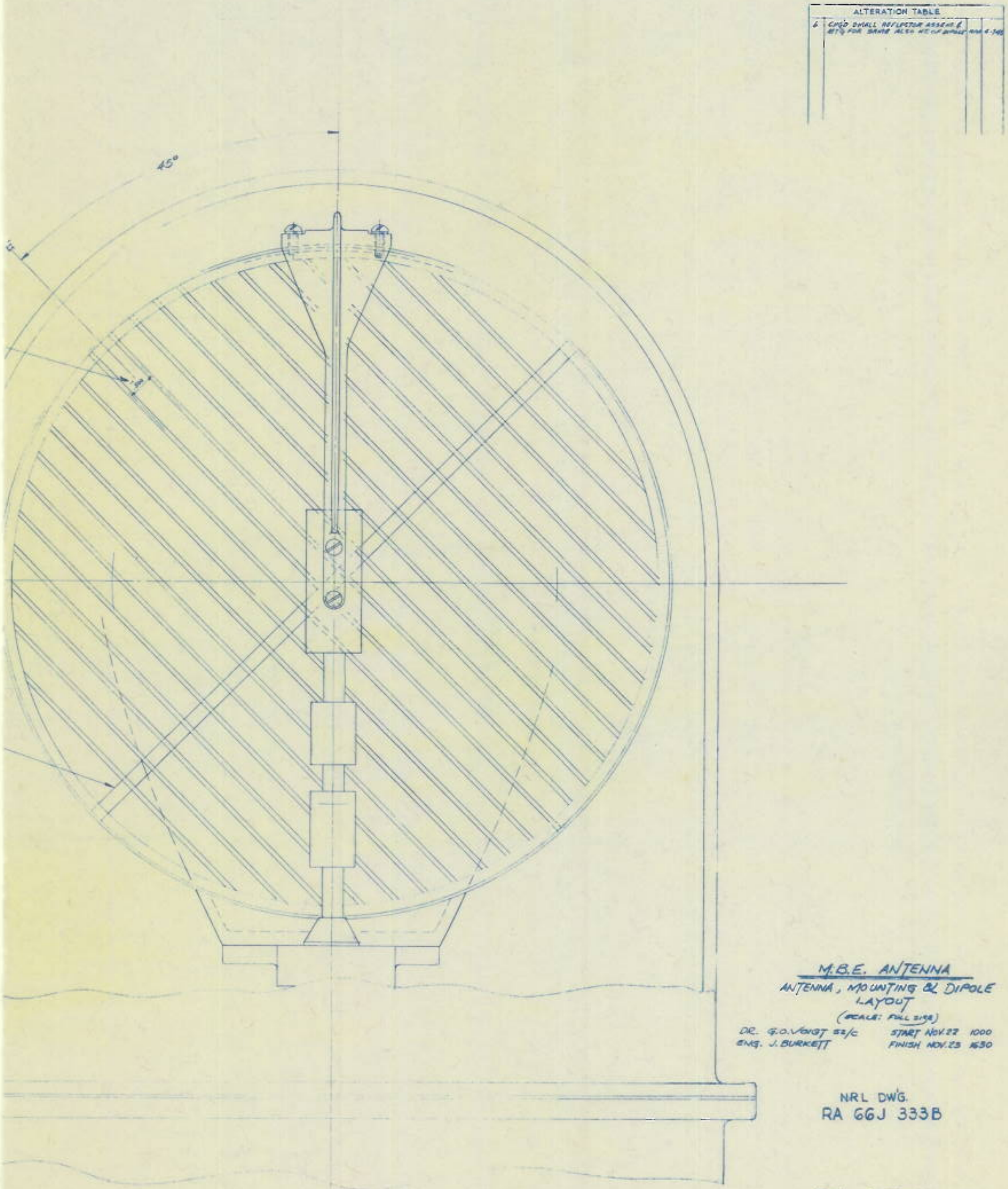

PLATE 18

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