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COMMUNICATION PLATFORM PAYLOAD DEFINITION STUDY FINAL REPORT

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Volume II - Technical Report

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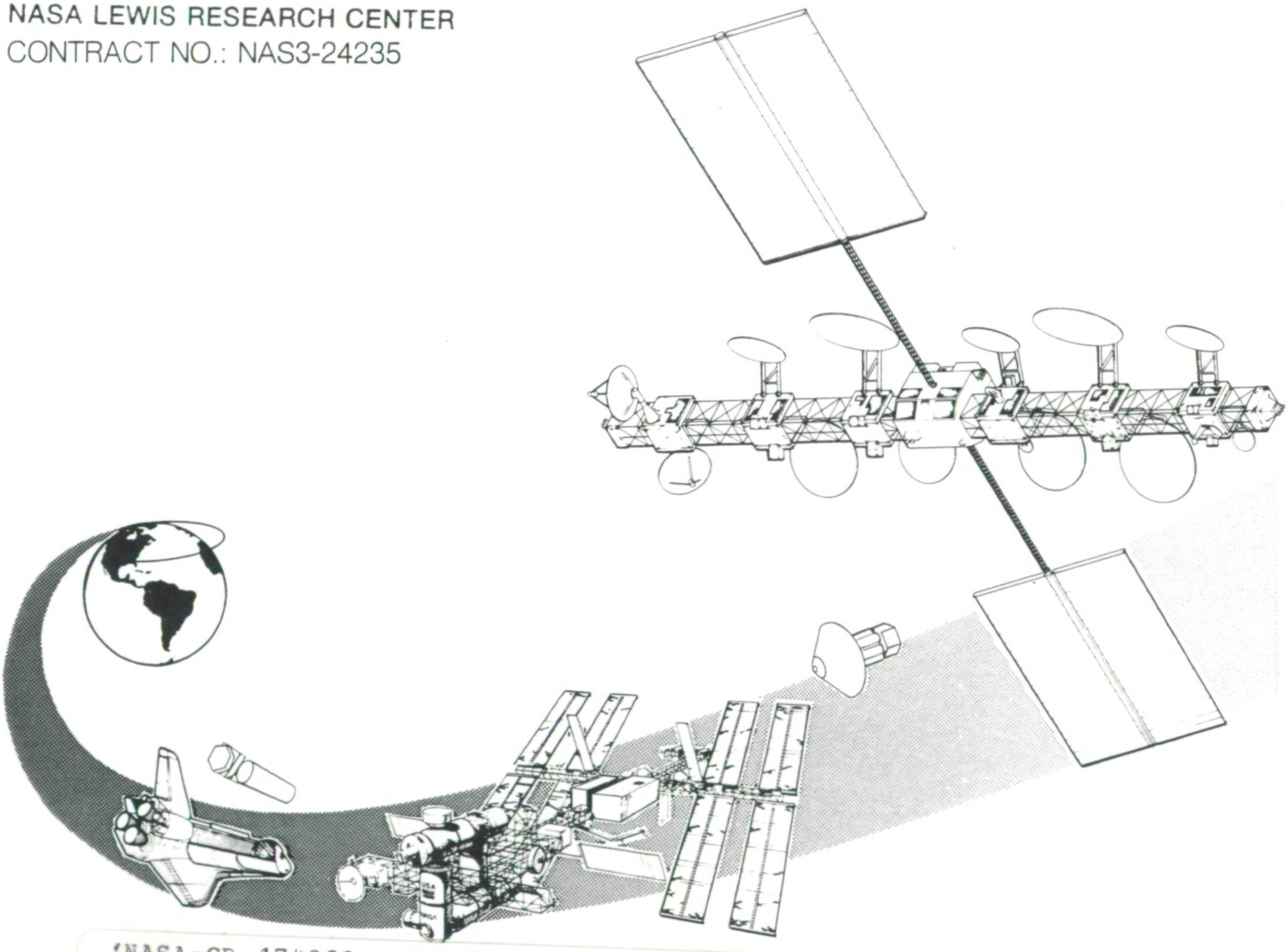

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16. Abstract

This is the Ford Aerospace & Communications Corporation Final Report for the Communication Platform Payload Definition (CPPD) Study program conducted for NASA Lewis Research Center under contract No. NAS3-24235.

This report presents the results of the study effort leading to five potential platform payloads to service CONUS and WARC Region 2 traffic demand as projected to the year 2008. The report addresses establishing the data bases, developing service aggregation scenarios, selecting and developing 5 payload concepts, performing detailed definition of the 5 payloads, costing them, identifying critical technology, and finally comparing the payloads with each other and also with non-aggregated equivalent services.

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SECTION INDEX

1.0 OVERVIEW

1.1 NASA STUDY CONTRACT

This Volume II, Final Technical Report, presents the composite results of the "Communications Platform Payload Definition Study" performed under the NASA-Lewis Research Center contract with Ford Aerospace & Communications Corporation, NAS3-24235. The overall study period of performance was June 1984 though July 1985.

This study was accomplished as a joint effort of Ford Aerospace and Satellite Systems Engineering (SSE). SSE provided the satellite user expertise in the service aggregation scenarios and also provided evaluation and adaptation of the traffic models for the various services. The SSE user interpretation was based upon experience in supporting DBSC's planned domestic DBS service as well as in dealing with a number of domestic band international users in defining the communications needs and economic viability of satellite communication.

The Ford Aerospace Study Manager was Dr. Edward M. Hunter. The study management at NASA-Lewis was directed by William A. Poley.

1.2 STUDY OBJECTIVES

The specific goals of the Communications Platform Payload Definition Study are as follows:

- Determine types of geostationary communications payloads applicable to a large platform, circa 1998
- Provide concept system architecture
- Provide payload concept and description

- Provide comparisons including estimated cost and technology risk
- Identify high payoff technology

In the context of this study, "large geostationary facility" means a very large (i.e., greater than 5,000 pounds) satellite, a platform, or a cluster of satellites colocated at a single geostationary orbit slot. "Communications payload" refers to those subsystems which provide voice, video, or data communications services. Not included in the "payload" are subsystems providing the functions of attitude control, stationkeeping, and power generation.

The study evaluated the impacts of new traffic forecasts and estimates of the new services to be provided in order to provide NASA with answers to the following questions:

- Is the existence of one or more large scale geostationary facilities, each consisting of a payload providing a single communications service or a variety of communication services, desirable in the mid to late 1990s?

- If so, what are the most viable operational systems (payload, spacecraft, transportation, and space operations) for that time frame?

- For those operational systems, what enabling and supporting technologies are required prior to implementation and, in particular, which of those technologies is of high technical and/or economic risk?

1.3 GUIDELINES AND CONSTRAINTS

The scope of this study was controlled by several NASA directed as well as contractor recommended guideline and constraints. Among these were:

- Utilization of 1998 operational technology (mature status 1993)
- No in-orbit payload assembly
- Minimum system lifetime of ten years
- Conformance to "anticipated" regulatory requirements
- "Baseline" configurations limited to communications payloads only
- Institutional issues ultimately not a barrier
- Must be economically feasible
- Must be based on demonstrated need
- Accommodate user/operator requirements

In addition to the above constraints Ford Aerospace added the constraint that "Baseline" configurations be constrained to rigid reflectors for FSS and DBS

The various communications service aggregation scenario configurations were to include at least two "baseline" systems and at least two "variations". The coverage and frequency planning for each is as follows:

a. Baseline Requirements

- Up to CONUS coverage
- U.S. domestic FSS and DBS services only
- C/Ku/Ka frequency bands

b. Variation Requirements

- Service coverage area up to entire western hemisphere (WARC region 2 + Intelsat)
- Additional services: mobile (land, sea, air), data collection, others
- Intersatellite link capability to international satellites or other non-U.S. satellites or platforms

The various scenario configurations were to be based upon either of the following two launch concepts:

- Launch Concept 1: up to a maximum single shuttle launch of combined spacecraft and upper stage with a spacecraft weight of up to 12,000 pounds

- Launch Concept 2: allows a separate spacecraft (without upper stage) of size and weight up to a full shuttle launch capability (65,000 pounds)

1.4 STUDY APPROACH

The NASA SOW organized the study into an orderly sequence of tasks. These tasks support the study outputs by successively accomplishing:

Task 1: Assemble a data base consisting of traffic models, market forecasts, technology forecasts, criteria for selection and evaluation, and cost estimating methodology to be used for the remainder of the study tasks.

Task 2: Using the data base and criteria select at least six service aggregation scenarios for development and evaluation. Hold an informal briefing at NASA LeRC to review the scenario ranking and select scenarios for further development.

Task 3: Develop payload concepts for four of the service aggregation scenarios developed in Task 2.

Task 4: Develop four detailed payload system configurations for the concepts developed in Task 3, and define the payload to the component level.

Task 5: Provide a system cost estimate and identify cost drivers for the payload configurations.

Task 6: Identify both enabling and supporting technologies critical to the eventual implementation and operation of each of the concepts.

Task 7: Provide system comparisons between the communications payloads.

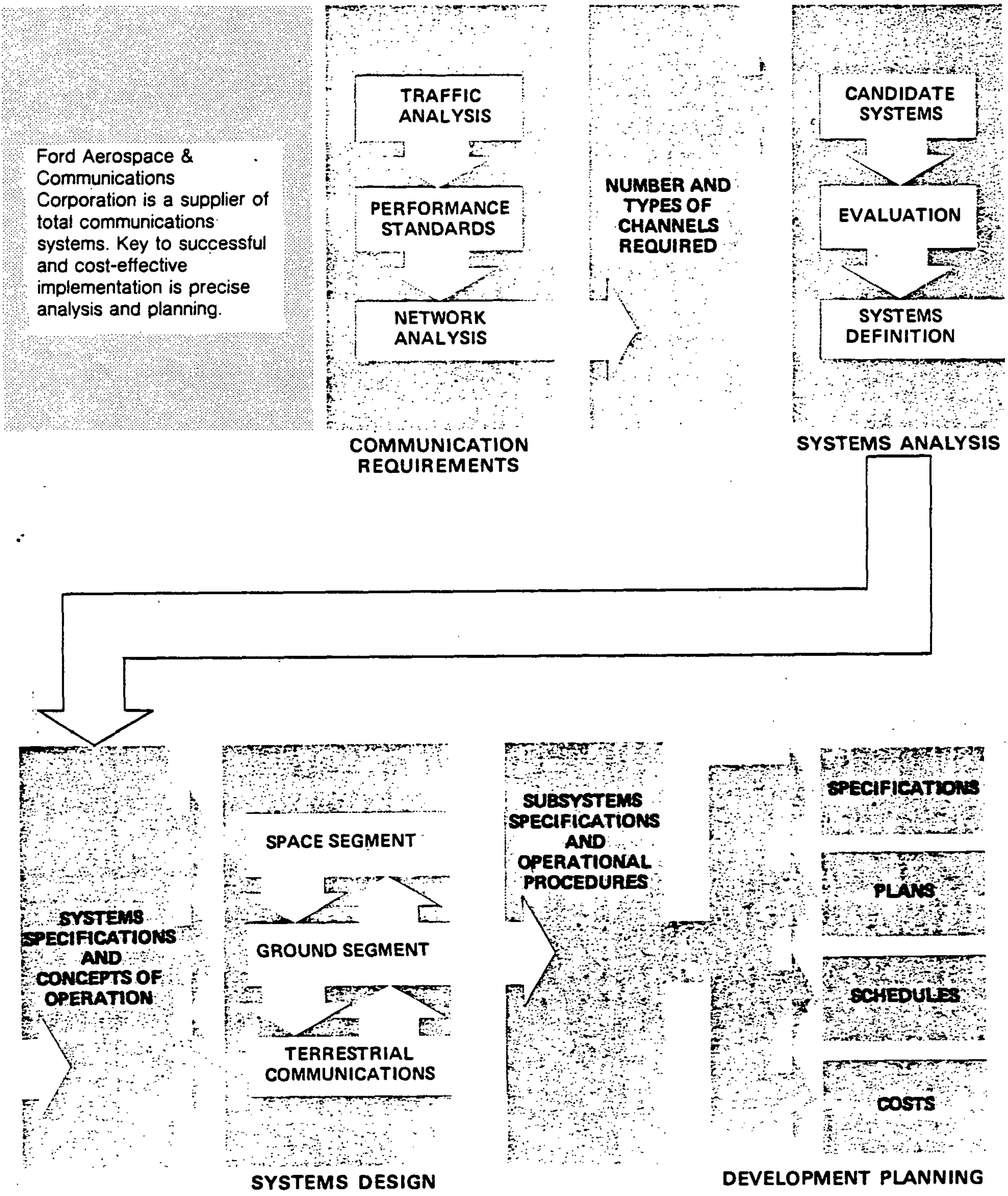
Interim presentations were made at NASA Lewis Research Center on 27 September 1984 and 7 February 1985, and the final review presentation was held on 16 July 1985. Three additional interim review meetings were held at Ford Aerospace in Palo Alto, California as well as a bus study contract interface meeting.

The general methodology which was utilized to generate the development planning information on performance and costs is shown in Figure 1.4-1. The traffic analysis, performance standards and network analysis leads to overall communications requirements expressed in number and types of channels. The systems analysis effort then postulates candidate systems, evaluates, and defines selected concepts. The systems design effort provides hardware definition of space and ground segments which serves as the basis for costing and other development planning outputs.

1.5 SUMMARY DESCRIPTION

Several satellite demand forecasts have indicated a growing pressure on arc/spectrum resources. More efficient use of this scarce resource will be required to meet projected demands in the year 2000 and beyond. In addition, economic pressure from terrestrial systems such as fiber optics will require a significant reduction in per-circuit costs in order for satellite systems to remain competitive, especially for point-to-point high density routes.

Figure 1.4-1 Development Planning Methodology



Ford Aerospace & Communications Corporation is a supplier of total communications systems. Key to successful and cost-effective implementation is precise analysis and planning.

In the point to multi-point applications such as DBS and data gathering, the satellite should have a natural advantage over land distribution systems. However in the U.S. the existing land based distribution system is extensive and already in place and will be very difficult to replace.

A potential solution to these problems is the use of large geostationary platforms which can provide significant improvement in the communications capacity of an orbital slot as well as economies of scale.

This study describes several scenarios which provide an increasing capability to serve projected Region 2 traffic. Briefly these scenarios are:

- A medium capacity CONUS FSS and medium power DBS capability
- A high capacity medium and high power video distribution capability
- A high capacity CONUS FSS capability
- A complementary pair of satellites with the high capacity CONUS FSS capability above and in addition, incorporating intersatellite links to "European" and "Asian" platforms to carry all Region 2 international traffic, plus providing all non-U.S. domestic coverage in the Western Hemisphere, as well as all maritime service in the Western Hemisphere.

The first three scenarios are sized such that the platform, upper stage and fuel can be carried to low earth orbit (LEO) with a single shuttle launch; the last scenario would require multiple shuttle launches with in-orbit assembly of spacecraft and upper stage, and/or fueling at the Space Station or GEO servicing.

For each scenario, this report describes the various payloads, antenna requirements, hardware implications (including on-board processing) and modulation/access methods. Finally, the advantages and disadvantages of each scenario are discussed relative to such factors as launch considerations, institutional barriers, reliability, and economics.

1.6 ORGANIZATION OF FINAL REPORT

The final report describing the findings of the Communications Platform Payload Definition Study is contained in three volumes. Volume I, Executive Summary, CR-174928, provides a brief overview of the payload descriptions and key findings. Volume II, Final Technical Report, CR-174929, provides the detailed information on the study data base (Task 1), aggregation scenario development (Task 2), payload concept development (Task 3), payload definition (Task 4), cost estimates (Task 5), critical technology (Task 6), and system comparison (Task 7).

Additional supporting detail is contained in Volume III, Addendum to Final Technical Report, CR-174930. This includes descriptions of traffic models, traffic surveys, satellite and ground system profiles, and payload details for all developed scenarios.

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2.0 DATA BASE

2.1 OVERVIEW

The purpose of task 1, Initialization and Data Base Development, was to develop the foundation material required to support the subsequent study tasks 2 thru 7. NASA provided references 1 through 7 as the initial data base. During the study, references 8 through 53 were compiled and used in various phases of the effort. A summary of the task outputs included:

- Overall study and task constraints
- Communication service aggregation scenario selection criteria.
- Payload concept evaluation criteria.
- Traffic forecasts and distribution models.
- Forecasts of space and terrestrial plant-in-place.
- Communications technology forecast.
- Cost estimating methodology.

This material was presented to NASA Lewis Research Center, Cleveland, Ohio, in a Task 1 Review held on 27 September 1984.

The data base information has been organized into the following sections of this report:

Traffic Forecasts (Section 2.2)

This Section contains the forecast of communications traffic for the categories of A) U.S. Domestic B) Non U.S. Domestic C) Regional Services D) International Traffic (Region 2 to other regions) and E) Maritime. A breakdown of fixed services (voice, video and data), direct broadcast and mobile is included. The approach to this subtask was to utilize the NASA supplied models of U.S. commercial traffic supplemented by other models developed by Ford Aerospace and it's associate contractor

Satellite Systems Engineering, Inc. (SSE). The results of a survey of industry, performed by SSE, on traffic requirements is included as Appendix D.

Traffic Distribution Models (Section 2.3)

The section addresses the distribution patterns of the traffic projected in Section 2.2 The projections were based upon use of the NASA FSS model, the Intelsat FSS model, and others developed for this study. Supplementary material is also included in Appendices A, B, and C of Volume III of this report.

Space and Terrestrial Supply Forecast (Section 2.4)

This section defines the availability of spacecraft transponders and terrestrial terminals over the period from present up to 1998. Additional detail on satellite system models is included as Appendix E to this report.

The space segment estimates include the number of satellites, orbit locations, and traffic carried. The terrestrial segment estimates include information on the traffic carried, transmission mode split, numbers of earth stations serving the space segment, ranges of sizes and types of earth stations, and frequency bands utilized.

Selection Criteria and Constraints (Section 2.5)

This section summarizes the overall study and task constraints imposed by NASA, defines the service aggregation scenario selection criteria, defines the payload concept evaluation criteria, and addresses other general constraint issues including a) institutional barriers b) regulatory considerations and c) insurance issues.

Additional Task 1 material related to payload servicing forecasts and communications technology forecasts is presented in Section 7 of this report.

2.2 TRAFFIC FORECASTS

2.2.1 Introduction and Summary of Traffic Demand vs Supply

2.2.1.1 Approach to Traffic Forecast

The purpose of the traffic forecast subtask of Task 1 was to assemble, develop, and/or synthesize traffic forecasts and models required by the study and not furnished by NASA. This information was supplemented by a NASA provided synthesis (Ref. 8) of the results of the most recent Western Union (Ref. 1 and 2) and I.T.T. (Ref. 3) demand studies, completed in the summer of 1983.

The requirement for a large space platform is ultimately dependent on the anticipated need from the end users, not only to enable optimal design of the platform but also for the continued justification of the requirement for the communications payload.

There is certainly no dearth of demand studies for communication satellites in the next 15-20 years. There are forecasts that have been produced on a regular basis to be sold to the industry at large. There are forecasts that have been produced on a contract basis to support FCC application and business plans of would-be satellite operators. There are also forecasts that have been produced under contract to NASA, or other government agencies, in support of various programs. As might be expected, the methodologies and assumptions used by the various demand studies have varied considerably, resulting in some dramatically different results, but, until very recently, almost all forecasters agreed in their assessment of almost exponential growth in the demand for satellite communication, with no slowdown in sight. The only perceived constraint to this growth was not a slackening of demand, but rather the saturation of the orbital arc and an inability to build and launch enough satellites fast enough to cater to the demand.

The most obvious recent proof of the optimism is the number of applications for FSS licenses received at the FCC in November 1983. If all of the satellite systems currently authorized and pending at the FCC were approved (and financed), the number of commercial C and Ku-band satellites in orbit would grow from 18 at year-end 1983 to 32 by year-end 1985, 78 by year-end 1990, and 111 by year-end 2000 (assuming one for one replacement at the end of the expected design life and no new systems). Already, one of the November 1983 applicants, American Satellite, has proposed a Ka-band package in their planned system, and in December 1983 Hughes Communication became the first company to propose a commercial all Ka-band satellite system.

Despite these events, in recent months there has been some uncertainty heard in the forecasting world. One recent demand projection, the report of Working Group A-1 (WGA-1) of the FCC advisory Committee on Space WARC '85 (Ref. 10) was somewhat more cautious in it's outlook for the satellite communications industry.

WGA-1 used two different approaches to develop their demand estimates, the average of which was 10% lower than Western Union's (1983) demand projections and 25% lower then I.T.T.'s (1983) demand projections.

The most probable stimulus for this more cautious view of future growth in satellite demand is the current "buyers's market" for satellite transponders. There are a number of transponders available on operational satellites and many more available on satellites to be launched in 1984 and 1985 (especially GTE's G-Star and Spacenet Systems). With the supply of transponders about to double in the next 2-3 years, some hard questions are beginning to be asked about those demand studies predicting virtually unlimited growth.

This temporary shifting in the satellite marketplace should be seen as the natural result of two factors:

1. A predictable slowdown in growth of the two major applications that spurred the growth of the commercial satellite industry in the 1970's - point-to-point heavy trunking telephony and cable TV distribution

2. Slower than expected growth in some of the newer services that were expected to drive satellite demand in the future - video conferencing, DBS, and private corporate networks

With the fairly rapid introduction of both SSB-AM microwave and fiber optics into the terrestrial transmission systems (and the related decision by AT&T to keep most of their long-distance voice traffic off their satellite), it has become obvious that high density point-to-point traffic does not exploit the true advantages of satellite transmission, especially when there is a substantial terrestrial infrastructure in place. Voice will continue to be a major component of satellite demand but in the context of many smaller networks and with emphasis on remote locations and lower density traffic.

The distribution of video signals from a network center to cable franchises is a natural use of satellites, and this application provided the spark that ignited the growth of the commercial satellite industry. But the cable T.V. industry is also in a period of reshuffling, facing competition from new technologies such as LPTV, MDS, private cable, etc, and weeding out of some of the poorly managed and conceived programming services (eg, CBS cable, the Entertainment Channel, etc). In the long run, the television industry will continue to be a major user of communication satellites, as the recently announced satellite interconnection plans of the three commercial TV networks illustrate.

The reasons for the slower than expected growth in some of the newer services are ultimately cost-related. Almost all video conferencing so far has been full broadcast quality, using an entire transponder. Until most video conferencing can be compressed into less bandwidth (ie, 1.544 Mb/s or even 56 kb/s) with acceptable quality, the costs of video conferencing will be inhibiting. Similarly, the growth of private corporate networks has been hampered by the high cost of earth stations and accompanying equipment. The advent of DBS has been slowed by regulatory hurdles and the uncertainty over the optimal mix of cost and sophistication in the sky and cost and sophistication on the ground.

What is occurring now in the satellite industry is a more critical assessment by users of the advantages and disadvantages of satellite communications, compared to other transmission media. And what is now becoming clear to users is that the major operational advantages of satellites are in point-to-multipoint, and multipoint-to-multipoint applications. It is in these applications that the instant networking feature of a satellite network becomes most dramatic. In the next decade and beyond, the industry will understand better these market (and economic) realities, leading to rapid growth in those areas where satellite communications are most suited.

It is projected that the new growth areas will come from the following:

- <u>Video Conferencing</u> - Analysts still believe that video conferencing will have a major impact on future demands for network capacity. As video conferencing costs fall due to economies of scale in the provision of service and the transition to all-digital service (leading to more efficient compression techniques), demand for the service will grow dramatically. Combined with the continued rise in the cost of travel and the increased productivity by not travelling, video conferencing should evolve into a major component of demand in the next 25 years.

- CPT-CPT - Often the most expensive and difficult component of any transmission system is the local distribution link. Direct satellite links between customer premise terminals (CPT) offer the opportunity to avoid local distribution problems entirely. As earth station prices continue to decline and more efficient transmission modes (eg, thin-route TDMA) are introduced, this option becomes cost effective to a larger number of users. I.T.T. (Ref. 3) foresees CPT-CPT traffic as 20% of the total satellite market by the year 2000, while W.U. (Ref. 2) estimates this application as 25% of the total satellite market by 1990. Another report forecasts growth in thin route earth station sales revenues from $3 million in 1981 to $175 million in 1991, reflecting an annual compound growth rate of 50%.

- Personal Computer Networks - As the personal computer market continues to grow, there will be a burgeoning need for low-volume data communication links direct to the telephone line. A recent study predicted growth in household ownership of personal computers with modems from almost none in 1982 to nearly 5 million in 1985. It also predicted the number of electronic mail users expanding from 10,000 in 1982 to almost a million by 1986. Much of this communication can be handled over the telephone local lines, but there will be an increasing need for visual and graphic forms of communication, requiring more bandwidth than the local telephone companies can supply.

- DBS - Depending on whom you believe, DBS represents nothing less than the next generation of TV program delivery or nothing more than an idea whose time has come and gone. In theory, DBS is the most natural application for satellites, with millions of small, inexpensive ground stations instantly connected in a network via a very powerful satellite. The major drawback to DBS in this country is not the DBS technology itself, but a well entrenched broadcast and cable industry with billions of dollars of plant in place. There is an initial potential market of 10-20 million homes for DBS in the next 10 years or so, and if DBS systems gain a foothold, the cable industry will find it hard to compete when the time comes for upgrading or replacing their existing plant. The key to the success of DBS is the need to reduce the costs of building and launching these larger, more powerful satellites.

- Mobile Satellites - With the coming boom in cellular radio, there will be a sizable market for connecting those areas outside of SMSA coverage, including rural and offshore areas. There is already an application for a commercial mobile satellite system on file at the FCC, and Canada has plans to build a mobile satellite for its own national needs.

- Data Gathering - Essentially the mirror image of DBS (multipoint-to-point), this is an application that has so far been used mostly for earth remote sensing and weather monitoring, but holds much promise for such labor-intensive services as meter reading, security monitoring of businesses and homes, oil well management, and myriad other uses. Already the Association of Rural Utilities is considering the use of satellites for the reading of gas and water meters outside of major cities. The potential for these types of services is enormous.

What is common to all of the above-listed services is the requirement for sophisticated satellites using large antennas, high-powered transmitters, and sensitive receivers. What also is common is the need for these communication services to be offered at competitive prices. And the most obvious way to help keep the price of such services down is to take advantage of the economies of scale inherent in placing various communication packages on a large space platform.

The methodology utilized to establish the traffic forecast included the following steps:

a. Conduct a literature search of all existing forecast data, both international and domestic.

b. Conduct a series of industry surveys to fill in the gaps of existing forecasts with special emphasis on both the user community and those services not addressed by the forecasts (eg, data gathering, private computer networks, etc).

c. Convert the traffic data base into meaningful units, eg,

   (1) Data - bits per second (b/s)
   (2) Video - channels
   (3) Voice - circuits
   (4) Mobile satellite - circuits
   (5) Data gathering - b/s

d. Quantify traffic data base in terms of types of usage and distribution of traffic. The temporal and spatial distribution of the flow of communications is needed for optimal system design. This distribution would vary with the service offered and included the following traffic allotment as appropriate:

(1) By earth station
(2) By SMSA
(3) By other defined region
(4) By CONUS

2.2.1.2 Summary of Traffic Demand vs Supply

This section summarizes the overall demand/supply for communications traffic in Region 2. The traffic data base is based upon the following:

a NASA Model for CONUS FSS and CPS
b SSE estimates for DBS
c Mobile estimates based on GE forecast
d Maritime estimates based on Inmarsat forecast
e International and intra Region 2 based on INTELSAT Forecast of August 1984
f Non-U.S. domestic Region 2 from various sources
g Forecast extrapolation based on Ford Aerospace/SSE estimates

The orbit spares philosophy has significant impact on supply/demand projections. This study has added the following factors to demand in order account for sparing requirements:

U.S. Domestic	None
Non-U.S. Domestic & Regional	50%
International	50%

The following assumptions were used in determining the sparing factor:

a. U.S. domestic sparing factor is probably in the 20-30% range, however the U.S. domestic traffic base addresses satellite addressable traffic only, and it was felt the traffic actually carried via satellite would reduce the demand by approximately the same percentage as sparing requirements would add to demand.

b. Non-U.S. domestic and regional traffic requires conservative sparing philosophy because of critical importance of national telecommunication network infallibility and lack of alternative spacecraft to which traffic could be rerouted.

c. International traffic also requires conservative sparing philosophy because of international agreements and requirements of sophisticated switching on board the satellite.

A summary of demand versus supply projection for the various satellite communications services follows:

A. Demand/Supply for Fixed Satellite Services

The summary shown in Table 2.2.1-1 represents the aggregation of demand from voice, video and data services. Demand summaries have been converted to equivalent 36 MHz transponders to show projected demand vs. supply in the same unit. Conversions were made according to the capacity loading factor in Table 2.2.1-5.

Table 2.2.1-1

Fixed Satellite Services

(In Equivalent 36 MHz Transponders)

	1990		2000	
	U.S.	Non-U.S	U.S.	Non-U.S
Supply	1048	384	1951*	574**
Demand	1024	182***	2150	270***

* Assumes constant growth from 1995

** 1995 Estimate

*** Including 50% sparing factor

B. Demand/Supply for Non-Fixed Satellite Services

Table 2.2.1-2 compares the best estimate of supply for U.S. and Non-U.S. DBS, mobile and maritime services. Transponders are equivalent, but for each service (i.e. voice, video, data) a separate conversion factor was used.

Table 2.2.1-2

Non-Fixed Satellite Services

DBS (In Channels)
(In Equivalent 36 MHz Transponder)

	1990		2000	
	U.S.	Non-U.S	U.S.	Non-U.S.
Supply	10	0	42	12*
Demand	24	0	50	20

Mobile Services
(In 4 MHz Transponders)

Supply	3	1	6	1*
Demand	23	0.2	75	2

Maritime Services
(In Equivalent Inmarsat 2nd Generation Transponders)

Supply	3	3*
Demand	1	2

* - 1995 Estimate

2.2.1.3 Breakdown of Summary Satellite Demand

This section details the component segments of the summary satellite transponder demand projected in Table 2.2.1-2.

Highlights of the demand forecast include:

1. Little change from NASA - provided U.S. FSS demand model.
   -- Outstanding issue -- effect of fiber optics
2. Non-U.S. FSS features moderate to high growth, based on current and projected traffic.
3. DBS (includes high power and medium power services not addressed by NASA model) shows low to moderate growth.
4. Mobile services have very high demand in U.S.(based on G.E. forecast) and low demand elsewhere
5. Maritime services show moderate growth (based on Inmarsat projections)

A summary of projected traffic demand as a function of communications mode follows:

A. <u>Fixed Satellite Demand</u>

Table 2.2.1-3 shows the breakdown of US Domestic fixed satellite service demand for voice, video, and data segments (Ref. 8) is the source for this demand.

Table 2.2.1-4 combines all estimates of FSS demand that were considered for traffic between Canada-U.S.-Latin America; Canada-Latin America; Intra Latin America; Atlantic Ocean Region (AOR); and Pacific Ocean Region (POR). Figures are taken from a combination of sources including the August 1984 Intelsat

Table 2.2.1-3

U.S. Domestic Fixed Satellite Demand
(Voice-Half Circuits, Video-Channels, Data-Peak Hr. Mb/s)

	1990	2000
Voice	1,831,000(654)	6,849,000(1522)
Video-Broadcast Ch.	158(79)	233(78)
-Video Conf.	1,971(56)	8,225(176)
Data	12,687(235)	26,945(374)
TOTAL TRANSPONDERS*	(1,024)	(2,150)

* Equivalent 36 MHz Transponders

Table 2.2.1-4

Total Non-U.S. Domestic, Regional, And International FSS Demand
(Voice-Half Circuits, Video-Channels, Data-Peak Hr. Mb/s)

	1990	2000
Voice	148,823(53)	332,361(74)
Video	144(57)	274(91)
Data	461(9)	1,081(15)
TOTAL TRANSPONDERS*	(119)	(180)

* Equivalent 36 MHz Transponders

database (Ref. 9), various applications for satellite and fiber optic services e.g., (Ref. 20), past traffic trends and other secondary industry sources.

Raw estimates have been converted into equivalent 36 MHz transponders according to the capacity loading of Table 2.2.1-5.

Table 2.2.1-5

Capacities Per Equivalent 36 MHz Transponder* Year

ITEM	1985	1990	2000
1/2 Voice Cir**	1200	2800	4500
Broadcast Video Channels	1	2	3
Data Mb/S***	36	54	72

* Use of small terminals will limit capacities

** Weighted average voice channels for all applications

*** Includes video conferencing

B. Direct Broadcast Satellite Demand

Table 2.2.1-6 shows the summary of direct broadcast satellite demand for the combined U.S. Domestic, Canadian, and Latin America/Caribbean regions ie. WARC Region 2.

Table 2.2.1-6

Direct Broadcast Satellite Demand
U.S. Domestic, Canada, Latin America & Caribbean Region
(in Channels)

	1990	2000
LOW	12	32
BEST	24	70
HIGH	32	96

C. Mobile Satellite Demand

Table 2.2.1-7 shows the projected mobile satellite demand for years 1990 and 2000.

These figures were based upon the General Electric study done for NASA(Lewis) (Ref. 15) and the Canadian Phase B market study done for Telesat. The U.S. portion represents over 90% of demand. No market demand is foreseen for Latin America and Caribbean by the year 2000. The potential market for radio determination and positioning services are reflected in these numbers.

Table 2.2.1-7

Mobile Satellite Demand
U.S. Domestic, Canada and Latin America
In Users and (4 MHz Transponders)

	1990	2000
Voice (2 way)*		
U.S.	217,000 (9.0)	1,130,000 (47.0)
Non U.S.	2,000 (0.1)	20,000 (1)
Voice (1 way)**		
U.S.	557,000 (12.0)	1,245,000 (26.0)
Non U.S.	6,000 (0.1)	60,000 (1)
Data (Low Speed)***		
U.S.	175,300 (2.0)	205,000 (2.0)
TOTAL TRANSPONDERS	(23.2)	(77)

* 24,000 Users per Transponder
** 48,000 Users per Transponder
*** 96,000 Users per Transponder

The conversion from number of users to requirements for 4 MHz transponders were based on the following assumptions taken from mobile satellite applications:

- One 4 MHz transponder can be divided into 800 5 KHz channels
- Each channel can accommodate 30 two-way voice users, 60 one-way voice users or 120 (low speed) data users.

Applicants for proposed mobile services believe there will be more demand for low speed data than is reflected in these estimates.

2.2.2 U.S. Domestic Traffic Forecast

This section provides detail on the fixed service, direct broadcast, and mobile service traffic demands for the U.S. Domestic Traffic.

2.2.2.1 Results of Industry Survey

There are no changes in the fixed services forecast from the NASA Communications Traffic Synthesis. SSE did not analyze video or voice traffic estimates. However further analysis was provided for demand for data services in the following categories: remote job entry, inquiry/response, timesharing, point of sale, videotext/teletext, telemonitoring, and secure voice. It was assumed that these 7 categories included all of the 'new' services for which SSE attempted to quantify demand.

A series of industry surveys were conducted, with emphasis on those companies likely to be telecommunications users in the above categories. (See Appendix D for a list of industry survey respondents and analysis of those responses.) Major trends revealed were: integration of services; high demand for remote job entry (RJE) and telemonitoring mostly satisfied by mobile satellites; timesharing growth captured largely by fiber optics; and more long haul traffic in inquiry/response, and in point of sale transactions. It is not expected that these developments will significantly alter the NASA traffic data base.

2.2.2.2 Fixed Satellite Demand (U.S. Domestic)

Table 2.2.2-1 summarizes the voice, video, and data segments of the U.S. domestic fixed satellite demand.

Table 2.2.2-1

Fixed Satellite U.S. Domestic Demand
(Voice-Half Circuits, Video-Channels, Data-Peak Hr. Mb/s)

		Year 1990	Year 2000
Voice		1,831,000	6,849,000
Video			
	Broadcast Channels	158	233
	Video Conferencing	1,971	8,225
Data		12,687	26,945

2.2.2.3 Direct Broadcast Satellite Service (U.S. Domestic)

Direct broadcast services considered were from either medium or high powered satellites. (Channel estimates reflect zonal coverage; i.e., half-CONUS channels). 65% of U.S. T.V. households (approximately 87 million) are presently cable (half of these homes are actual subscribers); it is probable that 25%

will remain uncabled due to high installation costs per mile. A limited market for DBS exists in cabled areas since about 50% of current systems are only 12 channel systems.

The only real competition to DBS in non-urban areas is from the backyard TVRO market, receiving C-band video. However, because of scrambling, 2° spacing and legal uncertainties, the fully saturated market for C-Band TVRO's is estimated at 2 million. Of first round DBS licensees, only Comsat's Satellite Television Corporation (STC) actively started building it's high powered DBS system, although it is unclear exactly what type of services it will provide. Dominion Video, USSB, and DBSC are still in the process of securing financing. Four second-round applicants have also received authorization to construct direct broadcast satellites.

While system costs are high, and DBS may eventually be offered on medium powered satellites rather than high powered ones, the market for DBS seems to exist for 2 systems by the end of the decade and about 4-5 systems by the year 2000.

A summary of the direct broadcast traffic demand is shows in Table 2.2.2-2.

Table 2.2.2-2

Direct Broadcast Satellite Demand (U.S. Domestic)
(In Channels)

	1990	2000
LOW	12	32
BEST	24	50
HIGH	32	64

2.2.2.4 Mobile Satellite Service (U.S. Domestic)

The Mobile Satellite Service (MSS) encompasses three main service categories: a) mobile radio telephone b) other voice services (include commercial and public radio, and voice service to oil and gas companies and the trucking industry), and c) low speed data services (alpha - numeric messaging, dispatch, position surveillance, etc.) The two main quoted market studies for mobile services are the traffic model prepared by GE in June 1983 for NASA Lewis and subsequently referenced in the Mobilsat application (Ref. 15) and the market study prepared for NASA in November 1982 by ECOSYSTEMS International and subsequently referenced by Skylink, and used as the traffic base model for the TRW contract under NASA Lewis (Ref. 25). The GE traffic base was used by SSE as the best traffic base for mobile services. The ECOSYSTEMS forecast fell in between the 'conservative' and 'likely' scenarios of GE. (i.e., 179,000 potential mobile users in 1990). The main uncertainty in GE traffic base is the assumption that there will be no land-based mobile radio outside of SMSA's.

In addition to the forecast of traffic for the MSS, there is an application pending at the FCC by Geostar for a satellite system offering service in the radio-determination area. Geostar, in recent conversations, has alluded to an overall market of approximately 9 million users by 1995. Each user would have a pocket calculator-sized terminal capable of receiving and sending brief alpha-numeric messages, and would be able to be constantly positioned by the Geostar computer facility to a distance of a few meters. This number appears extremely optimistic, and the inability of the Geostar system to offer voice services is, in our view, an inhibiting factor to its potential for operation.

SSE concluded that the demand for messaging and positioning services is more accurately reflected by the Mobilsat estimates, and that such services are more likely to be carried on a satellite such as Mobilsat or Skylink.

Table 2.2.2-3 summarizes the expected mobile satellite demand for voice and data for the time period of 1990 and 2000.

Table 2.2.2-3

Mobile Satellite Demand (U.S. Domestic)
(In Number of Users)

		1990	2000
DATA		175,000	205,000
VOICE	(1 way)	557,000	1,130,000
	(2-way)	217,000	1,245,000

2.2.3 Non U.S.Domestic Traffic Forecast

This section details the traffic forecast for Canada and the Latin America/Caribbean areas for FSS, direct broadcast and mobile services communications segments.

2.2.3.1 Fixed Satellite Service

Canada Voice Traffic:

The traffic demand projections listed in Table 2.2.3-1 were based on actual traffic carried on Anik C Ku-Band (5 city node) for switched services plus Anik D C-band for Northern services. This includes data traffic, expressed in equivalent voice grade channels. Very little private network service is currently carried via satellite. Telecom Canada has adjusted overall switched voice traffic growth forecasts downward and only small growth is seen in switched services via satellite.

Future growth is projected in various private line services, including: high speed data (by Globe & Mail newspaper; Mobile Oil), ISDN, off-shore communications, and other private network users. Increased competition between Telecom Canada and CNCP telecommunications is likely to spur growth. Thus, overall voice traffic carried via satellite will double between 1985 - 1990 (approximately 14% per year), and then triple between 1990-2000 (approximately 12% per year).

Table 2.2.3-1

Canada Voice Traffic (Non-U.S. Domestic)
(Half-Circuits)

1985	1990	2000
10,000	20,000	60,000

Latin America & Caribbean Voice Traffic:

The projected demand shown in Table 2.2.3-2 is based on analysis done by Working Group A-1 of FCC Space WARC 1985, Advisory Committee (Ref.). Projections were made on expected requirements of the nine countries that are likely satellite users for domestic traffic The working group considered demographic and economic variables; regression analyses were also performed to forecast long distance telephone calls, and ultimately the number of circuits required. It was assumed that countries in these areas would place a larger proportion of circuit growth on satellites, due to lack of extensive terrestrial infrastructure. Voice projections also include some data traffic.

Table 2.2.3-2

Latin America/Caribbean Voice Traffic (Non-U.S. Domestic)

(Half-Circuits)

	1985	1990	1995	2000
Argentina	167	725	1315	1830
Bolivia	60	138	220	314
Brazil	13,974	20,904	29,684	40,574
Chile	446	1,001	1,689	2,574
Colombia	341	1,712	3,254	4,840
Ecuador	60	138	220	314
Mexico	2,423	7,916	14,037	20,797
Peru	35	80	128	179
Venezuela	45	240	491	803
TOTAL	17,550	32,881	51,038	72,193

Canada Video Traffic:

The Canadian Video Demand shown in Table 2.2.3-3 is based on actual traffic on Anik during period of 1975-1983. A stable rate of growth for video service is expected due to slower growth for pay T.V. A strong demand for provincial educational television is not expected to materialize. Approximately half of the video services serve the Arctic region and half are for program distribution by T.V. networks. Little, if any videoconferencing is currently carried on Anik. Nonetheless, interest in video is high, and the projected demand reflects moderate needs by the private sector over the next 15 years.

Table 2.2.3-3

Canada Video Traffic (Non-U.S. Domestic)
(Channels)

	1985	1990	1995	2000
Broadcast T.V.	33	40	50	60
Videoconferencing*	0	5	10	30
TOTAL	33	45	60	90

* Expressed in Broadcast Quality Video Channels;
1 Broadcast Channel=20 Videoconferencing Channels.

Latin America/Caribbean Video Traffic:

Intelsat traffic and video projections to 1985 were used on the base for the video traffic projected in Table 2.2.3-4. Steady growth in Latin America is expected for video distribution channels. Requirements in Mexico, Brazil, Venezuela and Colombia account for most of the demand in 1984 and will continue to dominate demand. This estimate tracks towards the low end of the PANAMSAT forecast (which doesn't include video forecasts for Mexico and Brazil). Video traffic is expected to be carried on the Brazil and Mexican domestic satellite systems (and any other future or regional satellite systems) and is included in the above estimate.

It is not expected that there will be a large demand for domestic videoconferencing in this region. A minor demand for videoconferencing is included in the above forecast.

Table 2.2.3-4

Latin America/Caribbean Video Traffic
(Non U.S. Domestic)
(Channels)

	1985	1990	1995	2000
Broadcast TV	15	24	33	40
Videoconferencing*	0	1	3	5
TOTAL	15	25	36	45

* Expressed in Broadcast Quality Video Channels; 1 Broadcast Channel= 20 Videoconferencing Channels.

2.2.3.2 Direct Broadcast Service

Canada Direct Broadcast Traffic:

The primary market for DBS in Canada is in rural areas and in the North; however, these areas are already accommodated by Ku-band video on Anik C. In addition, all major and secondary cities in Canada are cabled, and initial pay-T.V. efforts of last year were not very successful (4 of 7 services failed). In view of these developments, the prospects for DBS in Canada are not very bright with nominal traffic forecast as shown in Table 2.2.3-5.

The Canadian government has taken a go-slow approach on DBS and the market for DBS in Canada does not appear to be firm. A more optimistic forecast would show up to 10 DBS channels by the year 2000.

Table 2.2.3-5

Canada Direct Broadcast Traffic (Non-U.S.Domestic)
(Channels)

1990	2000
0	10

Latin America/Caribbean Direct Broadcast Traffic:

No traffic forecast for these areas currently exists. The only data sources are inputs from various countries at RARC '83. DBS is a natural application for many countries in this region, given the lack of competitive nationwide terrestrial distribution systems. However, the number of T.V. sets is extremely low, and the costs of a DBS system will be extremely high.

The most likely video distribution system will be direct to community antenna, via low-to-medium powered satellites. Countries that are candidates to build such systems are Brazil, Argentina, Colombia,Venezuela, Chile, and several countries in the West Indies. We believe that fixed satellites will carry most of the DBS-type traffic, and have already included that traffic in the FSS estimates. A nominal number of DBS channels that could be offered by a higher powered satellite system, probably in Brazil or Mexico are projected in Table 2.2.3-6. A more optimistic outlook show up to 16 DBS channels by the year 2000.

Table 2.2.3-6

Latin America/Caribbean Direct Broadcast Traffic
(Non U.S. Domestic)
(In Channels)

1990	2000
0	10

2.2.3.3 Mobile Satellite Service

The projected demand for mobile satellite service to Canada and Latin America/Caribbean is given in Table 2.2.3-7.

The projections are based on results from both Phase A and Phase B market surveys for Telesat Canada. Major portions of usage are slated for Northern Canada which is outside of the Trans-Canada telephone system. The latest design of the Canadian MSAT is for a one satellite, 2-beam system, with capacity of approximately 10,000 users. At this point, no L-band paging, positioning or alpha-numeric messaging is slated to be carried on the satellite. Canada would still like to have a joint satellite with the U.S., but is getting impatient with lack of FCC approval for such a project. If necessary, Telesat believes there is enough business for a dedicated Canadian satellite.

Table 2.2.3-7

Canada, Latin America/Caribbean Direct Broadcast Traffic
(Number of Users)

1990	2000
2,000 (2-way)	20,000
6,000 (Push to talk)	60,000

2.2.4 Regional Services Traffic Forecast

This section details the traffic forecast for the regional services in the following 3 categories:

a. United States to/from Canada
b. United States to/from Latin America/Caribbean
c. Intra Latin America/Caribbean

2.2.4.1 Regional Service - U.S. to/from Canada

Terrestrial links currently carry 95% of the traffic between the U.S. and Canada. This is not expected to change significantly over the next 20 years. At present, there is very little U.S. - Canada commercial voice, video or data traffic via satellite, but Telesat has been negotiating reciprocal agreements with U.S. carriers, including American Satellite, SBS and Equatorial.

Many industry sources believe fiber optic transmission systems will be extensively utilized for this traffic. Any satellite traffic would largely be customer-premise-to--customer-premise for private networks. Based on the interest shown by the carriers, we see this as a slowly emerging market, and the traffic projections shown in Table 2.2.4-1 reflect this view.

Table 2.2.4-1

U.S./Canada Fixed Services Traffic
(Regional)
(Voice - Half Circuits, Video-Channels, Data-Peak Hr. Mb/s)

	1990	2000
VOICE	2,000	10,000
VIDEO	5	10
DATA	10	25

2.2.4.2 Regional Service - U.S. to/from Latin America And Caribbean

The voice traffic projections shown in Table 2.2.4-2 are from the 1984 Intelsat traffic data base, and are also consistent with PANAMSAT projections. While traffic is exclusively that between earth stations in the Intelsat system, we believe these numbers are sufficiently 'soft' to include expected growth in private line traffic. The projected voice traffic also includes some data.

Table 2.2.4-2

U.S./Latin America And Caribbean Voice Traffic
(Half-Circuit)

1990	1995	2000
13,280	19,424	28,702

The video traffic projections shown in Table 2.2.4.3 are based on a Satellite Communications Procurement Index developed by PANAMSAT, and on current traffic. Almost all video traffic will be TV distribution from major cities to provincial centers. Little demand is projected for videoconferencing.

Table 2.2.4-3

U.S./Latin America And Caribbean Video Traffic
(Channels)

	1990	1995	2000
Broadcast T.V.	6	11	20
Videoconferencing*	0	1	2
TOTAL	6	12	22

* Expressed in Broadcast Quality Video Channels;
1 Broadcast channels = 20 Videoconferencing Channels.

2.2.4.3 Regional Service - Intra Latin America & Caribbean

The voice traffic projections of Table 2.2.4-4 are from the 1984 Intelsat traffic data base, and are also consistent with PANAMSAT projections. While traffic is exclusively that between earth stations in the Intelsat system, it is believed that these numbers are sufficiently 'soft' to include expected growth in private line traffic. The voice traffic also includes some data.

Table 2.2.4-4

Intra-Latin America & Caribbean Voice Traffic
(Half-Circuit)

1990	1995	2000
3,048	4,575	6,650

The video traffic projections of Table 2.2.4-5 are based on a Satellite Communications Procurement Index developed by PANAMSAT, and on current traffic. Almost all video traffic will be TV distribution from major cities to provincial centers. Little demand is seen for videoconferencing.

Table 2.2.4-5

Intra-Latin America & Caribbean Video Traffic
(Channels)

	1990	1995	2000
Broadcast T.V.	6	11	20
Videoconferencing*	0	1	2
TOTAL	6	12	22

*Expressed in Broadcast Quality Video Channels;
1 Broadcast channels = 20 Videoconferencing Channels.

2.2.5 International Traffic Forecast

This section details the voice, video and data traffic forecast for communications between Region 2 and other regions. The information is divided into two segments, namely the Atlantic Ocean Region(AOR) and the Pacific Ocean Region (POR).

2.2.5.1 Atlantic Ocean Region (AOR)

The Atlantic Ocean Region voice traffic projection of Table 2.2.5-1 is based on the 1984 Intelsat traffic data base. This covers all trans-Atlantic traffic between North and south America to Europe and Africa. There are two countervailing factors which tend offset each other, leaving the Intelsat projection as the 'best guess': 1) the positive effect of competitors to Intelsat in the satellite industry and; 2) the negative effect of fiber optic cables (TAT-8 and TAT-9).

Table 2.2.5-1

Atlantic Ocean Region Voice Traffic (International)
(Half Circuits)

1990	1995	2000
53,942	77,995	117,630

The Atlantic Ocean Region video traffic projection of Table 2.2.5-2 is based on the current Intelsat leases for international video, PANAMSAT traffic projections and the Walter Hinchman Study prepared for Intelsat. The 1983 base figure is 5.5 Intelsat transponders leased for video. High growth is projected to include both program transfer and videoconferencing (expressed in equivalent broadcast-quality T.V. channels).

Table 2.2.5.2

Atlantic Ocean Region Video Traffic

(Channels)

	1990	1995	2000
Broadcast T.V.	10	20	30
Videoconferencing*	5	10	30
TOTAL	15	30	60

*Expressed in Broadcast Quality Video Channels;
1 Broadcast channels = 20 Videoconferencing Channels.

The three elements of data traffic considered are: current traffic carried by ORC's(i.e. telex, telegraph & low speed data); current data traffic carried over voice-grade circuits; and IBS type traffic. The forecast of Atlantic Ocean Region voice traffic shown in Table 2.2.5-3 is based on estimates of International Business Services (IBS) from Intelsat plus projections of growth for gateway Intelsat data traffic. It is assumed that 1 voice grade channel = 3 telex bearers; 1 telex bearer = 24 telex channels; and 1 voice grade channel = 64 kb/s.

Table 2.2.5-3

Atlantic Ocean Region Data Traffic

(In Mb/s)

1990	1995	2000
190	410	880

2.2.5.2 Pacific Ocean Region (POR)

The Pacific Ocean Region voice traffic projection shown in Table 2.2.5-4 is based on the 1984 Intelsat traffic data base (Ref. 9). This forecast covers all trans-Pacific traffic between Canada, the U.S., and Mexico to Eastern Asia and Oceana.

Table 2.2.5-4

Pacific Ocean Region Voice Traffic
(Half Circuits)

1990	1995	2000
13,672	22,132	37,186

The Pacific Ocean Region video traffic projection shown in Table 2.2.5-5 is based on Intelsat's current video channel leases (5.5). The traffic is largely composed of U.S. - Australia and U.S.- Japan TV distribution and videoconferencing. The videoconferencing component of demand is expressed in equivalent broadcast quality TV channels.

Table 2.2.5-5

Pacific Ocean Region Video Traffic
(Channels)

	1985	1990	2000
Broadcast T.V.	6	10	15
Videoconferencing*	0	2	10
TOTAL	6	12	25

* Expressed in Broadcast Quality Video Channels;
1 Broadcast Channel = 20 Videoconferencing Channels.

The Pacific Ocean Region data traffic projection shown in Table 2.2.5-6 is based on the estimate of demand cited by International Record Carrier's in support of Pacific Ocean fiber optic cable request to the F.C.C. There is currently no IBS forecast for the Pacific Ocean Region. The P.O.R. voice traffic is estimated to be approximately 10% of Atlantic Ocean Region (A.O.R) voice traffic for 1990 and 20% by 2000.

Table 2.2.5-6

Pacific Ocean Region Data Traffic
(In Mb/s)

1990	2000
41	176

2.2.6 Maritime Services Traffic Forecast

The maritime traffic forecast of voice and data for Canada and Latin America/Caribbean as shown in Table 2.2.6-1 is based on the current Inmarsat traffic matrix, and forecasts for the second generation Inmarsat system. The "Nominal" Inmarsat traffic estimate is used as the traffic base. Traffic is split in following ways: 90% voice, 10% data; 80% A.O.R., 20% P.O.R. Development of significantly cheaper earth stations and more varied service offerings may spur maritime growth beyond estimates shown.

Table 2.2.6-1

Maritime Traffic From Canada And Latin America/Caribbean
A.O.R. & P.O.R.
(In voice-grade circuits)

1985	1990	1995	2000
72	147	245	307

2.2.7 Future Growth for Traffic Forecast to Year 2008

The growth in traffic for fixed satellite services is expected to follow the growth rates projected in Table 2.2.7-1. The growth rate for the decade of year 1990 to year 2000 is compared to that of the succeeding decade for each segment of FSS demand (voice, video and data) as well as for different geographic areas.

Table 2.2.7-1

Projected FSS Growth From Year 2000 To 2008

	1990-2000			2000-2008		
REGION	GROWTH RATE PER YEAR(%)			GROWTH RATE PER YEAR (%)		
Domestic	Voice	Video	Data	Voice	Video	Data
a)U.S.	14	15	8	10.5	11	6
b)Canada	7.5	7	-	6	6	-
c)Latin America, Caribbean,& South America	8	6	-	8	6	-
REGIONAL						
a)Canada-U.S.	7	-	10	6	-	7.5
b)U.S.-Latin America	12	14	-	12	14	-
c)Intra Latin America	12	14	-	12	14	-
INTERNATIONAL						
a)A.O.R.	8	15	8	8	11	6
b)P.O.R.	10.5	8	16	10.5	8	6

The total projected traffic demand for year 2008 for each of the types of services is shown in Table 2.2.7-2. The derivation of the video conferencing demand for trunking applications in detailed in Table 2.2.7-3.

Table 2.2.7-2

Projected Traffic for year 2008 by Type of Service

Type	Year 2008 Totals	
— Voice Trunking		
— Digital (60%)	9090	10^3 HVC
— Analog (40%)	6060	10^3 HVC
— Voice CPS	78	10^3 HVC
— Data Trunking	5336	Mb/s
— Data CPS	39907	Mb/s
— Video Conf. Trunking	37800 (1576	Mb/s or 10^3 HVC)
— Video Conf. CPS	2131	Mb/s
— Broadcast Video	537	Channels

2.3 TRAFFIC DISTRIBUTION MODELS

2.3.1 Approach

During the data base development, distribution models for the CONUS traffic and the Intelsat traffic were acquired from NASA

Table 2.2.7-3

Derivation of Video Conferencing Demand (Trunking)

	FULL		LIMITED		SLOW	
1-WAY	30		184		-	
2-WAY	76		5776		1748	
TOTAL	106	+	5960	+	1748	= 7814 CHANNELS

- o THROUGHOUT: 3 (FULL), 36 (LIMITED), 900 (SLOW) (36 MHz)
- o AVERAGE REQUIREMENT PER CHANNEL

$$\frac{81\ \text{MB/S}}{7814} \times \left(\frac{106}{3} + \frac{5960}{36} + \frac{1748}{900}\right) = 2.1\ \text{MB/S}$$

- o TOTAL 2008 REQUIREMENT

$$7814 \times 2.1 \times 1.11^{8} = 37800\ \text{MB/S}$$

and Intelsat respectively. It was also necessary to generate models for Canada, Mexico and Brazil since the projected 2008 demand exceeded the 4x reuse from C and Ku-band application. Use of population distribution data and domestic phone system distribution data were used to make a first cut approximations at the distribution matrix.

Section 2.2 discussed total traffic forecasts in several categories. However, in designing a payload - especially the beam coverages - the distribution of the traffic must also be considered. First, there is the well-known skewness of U.S.

traffic to the East; high frequency reuse in this area is a major objective of any payload design. The point-to-point nature of the distribution is important in those channels operating with analog modulation, and can also be used to optimize designs using SS/TDMA.

Distribution models were not developed for all traffic considered. As an example, broadcast video does not require a distribution. Domestic coverage for several South American countries - e.g., Columbia - could be provided by a single beam; hence distribution characteristics were not relevant.

The following subsections describe the distribution models used in this study.

2.3.2 NASA FSS Model

A tape containing data on a 316x316 matrix, representing the distribution traffic between 316 selected SMSAs, was provided by NASA at the beginning of the study The distribution was used for all U.S. domestic point-to-point requirements. Section 4.2.3.1.1 describes how the tape was processed in various ways for use in satellite loading programs. In particular, all traffic requirements between SMSAs whose distance was less than 400 miles were deleted from the original tape to obtain satellite addressable traffic.

2.3.3 Intelsat FSS Model

The Intelsat distribution model reflected actual satellite addressed traffic from gateway station to gateway station. This matrix then was used to generate intra Region 2 traffic as well as Region 2 to AOR and Region 2 to POR traffic matrices for application to the payload concepts discussed in Section 4.

2.3.4 Other Distribution Models

In three cases distribution models were developed as part of this study because the total year 2008 requirements of Section 2.2.7 indicated frequency reuse would be necessary to meet the demand in Canada, Mexico, and Brazil.

The basic approach used was to break each country into regions, such as provinces, and to use population estimates to obtain a distribution as follows:

Let P_i be the population the i^{th} region, and a_{ij} be the proportion of the total traffic between region i and j. Then:

$$a_{ij}=\frac{P_iP_j}{\sum\limits_k\sum\limits_l P_kP_l}$$

There were two modifications to this basic approach. First, for Canada only, a "proportionality matrix" was developed which adjusted the a_{ij} to reflect a "400 mile rule" (see Section 2.3.2). For example, New Brunswick is less than 400 miles in total extent, so all traffic from that province to itself was deleted. The modified formula is:

$$a_{ij}=\frac{t_{ij}P_iP_j}{\sum\limits_k\sum\limits_l t_{kl}P_kP_l}$$

where t_{ij} is the proportionality factor. The second adjustment was to inflate traffic to/from national capitals, or the regions in which they lie, by a factor of 10.

Tables 2.3-1 thru 2.3-4 indicate the various values used to derive the distribution matrices. The matrices (in terms of total demand) are contained in Appendix C. For Mexico, the fraction of population was estimated to be that shown in Table 2.3-1.

Table 2.3-3

Canada-Proportionality Matrix

Alberta	.2	.9	1	1	1	1	1	1	1	1	1	1	.8	1
British Col.	.9	.3	1	1	1	1	1	1	1	1	1	1	1	1
Manitoba	1	1	.2	1	1	1	1	1	1	1	1	1	.4	1
New Brun.	1	1	1	0	1	1	0	1	1	0	.5	1	1	1
Newf.	1	1	1	1	.2	1	1	1	1	1	1	1	1	1
NW Terr.	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Nova Scotia	1	1	1	0	1	1	0	1	1	0	1	1	1	1
Ont 1	1	1	1	1	1	1	1	0	.9	1	0	1	1	1
Ont 2	1	1	1	1	1	1	1	.9	.9	1	1	1	1	1
P.E. Is.	1	1	1	0	1	1	0	1	1	0	1	1	1	1
Que 1	1	1	1	.5	1	1	1	0	1	1	0	.7	1	1
Que 2	1	1	1	1	1	1	1	1	1	1	.7	.9	1	1
Saskwan.	.8	1	.4	1	1	1	1	1	1	1	1	1	.2	1
Yukon	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 2.3-1

Proportion Of Population By Region - Mexico

Area	% of Population
North Region	20%
Central Region	50%
South Region	30%

Table 2.3-2

Canada - Adjusted Population

Province/Area	Population(K)	
Alberta	1627	
British Columbia	2184	
Manitoba	988	
New Brunswick	635	
Newfoundland	522	
NW Territories	35	
Nova Scotia	789	
Ontario 1	8880	(1)
Ontario 2	1540	(2)
Prince Edward IS	112	
Quebec 1	4822	(3)
Quebec 2	1206	(4)
Saskatchewen	926	
Yukon	18	

(1) 7703 x .8 + 302* x 9

(2) 7703 x .2

(3) 6028 x .8

(4) 6028 x .2

* 302 K = population of Ottawa; the factor of 9 provides the inflation mentioned in section 2.3.4 for capitals

Table 2.3-4

Brazil-Adjusted Population

State	Population (x 1000)
Acre	160
Alagoas	1271
Amapa	69
Amazonas	721
Bahia	5991
Ceara'	3338
Distrito Federal	1410*
Espirito Sauto	1189
Guias	3307
Guanabara	1955
Maranhao	2492
Mato Grosso	910
Minas Gerais	9799
Pura	1551
Paralba	2018
Purana	4278
Pernambuco	4137
Piaui	1263
Rio de Janeiro	3403
Rio Graude de Worte	1157
Rio Graude de Sul	5449
Rondonia	71
Roraima	29
Santa Catarina	2147
Sao Paulo	12975
Sergipe	760

*141K = population of Federal District; population in the Table is inflated as mentioned in section 2.3.4.

2.4 SPACE AND TERRESTRIAL SUPPLY FORECAST

2.4.1 Overview

A main subtask of Task 1 was to estimate the extent of both space and terrestrial plant in place for the time period of interest. This effort was largely conducted by Satellite Systems Engineering, Inc. (SSE).

The main objectives of this subtask were threefold:

1. To assess the demand for positions on the orbital arc in the late 1990's. This serves as the basis for evaluating the motivation behind a better utilization of the arc (through the introduction of multiple frequency reuses and scanning spot beam coverage).

2. To offer a snapshot of what kinds of commercial satellite services are likely to be offered in the late 1990's without the existence of a larger space platform, thus giving some indication of the satellite operator's perception of demand; and

3. To give a preliminary estimate of the extent of displacement if a large space station became operable during this timeframe.

The space segment estimates include number of satellites, frequency bands utilized by each, capacities, and orbital location.

An example model of satellite supply based on current and planned U.S. domestic satellite systems is shown in Tables 2.4-1 and 2.4-2. The tables list the name of the system, the frequency bands used, the number of satellites in orbit and the

Table 2.4-1

U.S. Domestic FSS Systems Satellite Supply

Satellite Systems	Frequency Band	Number of Satellites in Orbit Per Year 1985	1990	1995	2000
Advanced Bus. Communication	Ku	0	2	2	2
Alascom	C	1	2	2	2
American Satellite	C,Ku	1	3	3	0
	C,Ku,Ka	0	1	1	3
Cablesat General	C	1	2	2	2
Comstar	C	2	0	0	0
	Ku	0	3	3	3
Digital Telesat	C	0	1	1	1
	Ku	0	1	2	2
Equatorial	C	0	2	2	2
Fed. Express	Ku	0	2	2	2
Fordsat	C,Ku	0	3	3	3
Galaxy	C	3	4	4	4
	Ku	0	3	3	3
G-Star	Ku	2	3	3	3
Martin Marietta	Ku	0	2	2	2
National Exchange	C	0	2	2	2
	Ku	0	4	4	4
Rainbow	Ku	0	4	4	4
RCA Satcom	C	4	7	7	7
	Ku	2	3	3	3
SBS	Ku	4	1	1	1
	Ku	0	5	5	5
Spacenet	C,Ku	2	3	3	3
Telstar	C	3	4	4	4
USSSI	Ku	2	4	4	4
Westar	C	1	0	0	0
	C	4	7	7	7
	Ku	0	3	3	3
	TOTALS	32	81	82	81

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Table 2.4-2

U.S. Domestic FSS Systems Transponder Supply

Satellite Systems	Frequency Band	Number of 36 MHz Transponders	Number of Available Transponders By Year 1985	1990	1995	2000
Advanced Bus. Communic.	Ku	24	0	48	48	48
Alascom	C	24	24	48	48	48
American	C,Ku	36	36	108	108	108
Satellite	C,Ku,Ka	48	0	48	48	144
Cablesat General	C	24	24	48	48	48
Comstar	C	24	48	0	0	0
	Ku	24	0	72	72	72
Digital Telesat	C	24	0	24	24	24
	Ku	24	0	24	48	48
Equatorial	C	24	0	48	48	48
Fed. Express	Ku	48	0	96	96	96
Fordsat	C,Ku	48	0	144	144	144
Galaxy	C	24	72	96	96	96
	Ku	24	0	72	72	72
G-Star	Ku	24	48	72	72	72
Martin Marietta	Ku	24	0	48	48	48
Natl. Exchange	C	24	0	48	48	48
	Ku	24	0	96	96	96
Rainbow	Ku	24	0	96	96	96
RCA Satcom	C	24	96	168	168	168
	Ku	24	48	72	72	72
SBS	Ku	12	48	12	12	12
	Ku	24	0	120	120	120
Spacenet	C,Ku	36	72	108	108	108
Telstar	C	24	72	96	96	96
USSSI	Ku	24	48	96	96	96
Westar	C	12	12	0	0	0
	C	24	96	168	168	168
	Ku	24	0	72	72	72
		TOTALS	744	2148	2172	2268

number of available transponders for 5-year intervals up to the year 2000. The determination of equivalent transponders is based on a frequency allotment of 500 MHz bandwidth to an orbital location in C-band or Ku-band. Dual frequency reuse for CONUS coverage results in a maximum of 24 equivalent transponders for a C-band or Ku-band satellite and 48 equivalent transponders for a hybrid satellite. Spot beam coverage is not considered. These tables assume one-for-one replacement after the end of the expected design life, with no new systems being added.

The question of orbital locations is largely dependent on the results of Space WARC '85 and how soon the FCC will phase in 2° spacing. Working Group A-2 of the FCC Advisory Committee preparing for the Space WARC has projected that the saturation point of the U.S. portion of the C-band and Ku-band arc is between 48 and 65 satellites, depending on how quickly improved antennas are introduced on the ground. This estimate assumes that three satellite slots would be kept vacant as "guard band" slots to allow for possible adjustments in some orbit locations due to inhomogeneities between certain satellite systems or types of satellite services. There is obviously a major discrepancy between the number of satellites being proposed and the capacity of the orbital arc.

It is difficult to predict the types of traffic carried on the satellites during this time period, since satellite systems are usually designed before any customer has been signed.

The terrestrial segment estimates include numbers of earth stations serving the space segment, range of sizes and types of earth stations, and frequency bands utilized.

Information was obtained from FCC applications and statistics, direct contacts with the major terrestrial transmission system owners, and a literature search. There is a large body of material in the CCIR and CCITT area on this topic, with special reference to the introduction of the Integrated Services Digital Network (ISDN).

The quantity, range of sizes and types, and frequency bands utilized by the earth stations during this period are all directly related to the estimate of space segments in place. SSE keeps an updated data base of all FCC licensed earth stations by size and location, as well as an educated "guesstimate" of the approximate size and locations of all unlicensed earth stations (ie, the nearly 200,000 "backyard TVROs"). This data base was expanded to include the inputs from FCC applications for future satellite systems, interviews with industry analysts, and an extensive literature search.

2.4.2 Estimate of Satellite Transponder Supply

The supply estimates in this section were prepared by Satellite Systems Engineering, Inc. (SSE).

The following types of satellites were considered: U.S. Fixed Satellite Service (FSS), Direct Broadcast Satellites (DBS) and Mobile Satellite, Non-U.S. Region 2 FSS, Atlantic Ocean Region (A.O.R.) and Pacific Ocean Region (P.O.R.) FSS.

The SSE transponder supply model is based on the actual and planned supply of satellites. For example, in the United States, there are currently 23 fixed communications satellites in orbit. Many more are planned, and filings to the FCC indicate planned launch dates.

The SSE model provides the number of satellites and transponders in orbit now, and low, high and best estimates for corresponding numbers of satellites in orbit in 1990 and 1995.

For fixed service satellites, a 36-MHz transponder is used as a reference transponder. For DBS and mobile service satellites, the number of active channels planned is used.

The low estimates are based on satellites actually operational in space, satellites under construction, or authorized satellites. The high estimates are based on all known planned satellites. In general, the amount of planned systems will reflect a perceived demand that may not be realized in the short term. It appears from available FCC data on transponder loading that the market for communications satellites in the U.S. is over-saturated, in the sense that more transponders are available in orbit than are being used (even taking into account sparing philosophies).

The best guess estimates have been guided by these considerations. An attempt has been made to take into account the shift to higher frequencies with frequency reuse and the resulting changes effected in numbers of transponders by successive generations of satellites. An optimistic long-term demand is projected for U.S. DBS and mobile satellites, although financial and regulatory difficulties may be severe. The forecast is optimistic about the development of satellite communications over the Atlantic Ocean; however, it is more reserved about the Pacific and Latin American markets.

A summary of the U.S. domestic satellite supply is given in Table 2.4-3 and a summary of the non-U.S. domestic supply is given in Table 2.4-4.

The supply projections are taken from known planned satellite systems worldwide. Since it is highly unlikely that all planned systems will be built, a probability factor was applied to each system reflecting various considerations, including financial, market base, regulatory, and/or institutional factors.

Table 2.4-3

Forecast Of U.S. Domestic Satellite Transponder Supply

		1990	1995	2000
FSS*	LOW	636	804	****
	BEST	1048	1430	1951*****
	HIGH	2364	2280	****
DBS**	LOW	0	0	0
	BEST	10	42	42
	HIGH	222	222	222
MOBILE/***	LOW	0	0	0
RADIO-	BEST	3	6	6
NAVIGATION	HIGH	19	19	21

*	In equivalent 36 MHz transponders
**	In broadcast quality channels
***	In 4 MHz transponders
****	Not estimated
*****	Assumes constant growth from 1995

The key findings reached from the supply analysis are as follows:

- o U.S. Domestic FSS Supply roughly tracks demand.
- o Non-U.S. Supply is considerably more than demand.
- o DBS Supply roughly tracks demand.
- o Mobile Supply insufficient to handle demand in U.S. (as currently applied for); supply tracks with demand in Canada.
- o Maritime Supply exceeds demand.

Additional detail on the estimate of U.S. domestic satellite transponder supply is given in Table 2.4-5, and detail on the non-U.S. domestic supply is given in Table 2.4-6. The projected launch dates and configurations of Region 2 Commercial Communications Satellites over the period of 1984 to 2010 are shown in Figure 2.4-1.

Table 2.4-4

Forecast Of Non-U.S. Domestic Satellite Transponder Supply
(Includes Canada, Latin American, Caribbean,
Atlantic Ocean Region and Pacific Ocean Region)

		1990	1995	2000
FSS*	LOW	210	276	-
	BEST	384	574	574
	HIGH	1100	1650	-
DBS*	LOW	0	0	0
	BEST	0	12	12
	HIGH	6	24	24
Mobile***	LOW	0	0	0
	BEST	1	1	1
	HIGH	1	1	1
Maritime	LOW	1	2	2
	BEST	3	3	3
	HIGH	5	4	4

* In equivalent 36 MHz transponders
** In broadcast quality channels
*** In 4 MHz transponders
**** In equivalent 2nd generation Inmarsat transponders

2.4.3 Terrestrial Terminal Supply

The forecast of terrestrial terminal supply for satellite communications is divided into: a) FSS and DBS Service (for U.S. and non-U.S. segments) and b) Mobile Services. Additional detail on the quantities, characteristics; and distribution of the current population of earth stations in the United States is given in Appendix E-2.

Table 2.4-5

Estimate Of U.S. Domestic Satellite Supply And Transponders

System	Current # Sat./Tr. in orbit 1984	Freq.	Est. # Sat./Tr. in orbit 1990 low	high	best	Est. # Sat./Tr. in orbit 1995 low	high	best
U.S. FSS								
AURORA	1/24	C	1/24	3/72	2/48	1/24	3/72	2/48
AMERICAN	0/0	C,Ku,Ka	2/72	4/168	3/108	2/96	4/192	3/144
CABLESAT	0/0	C	0/0	2/48	0/0	0/0	2/48	0/0
COLUMBIA	0/0	C	0/0	2/48	0/0	0/0	2/48	0/0
COMSTAR	4/96	C	0/0	4/96	0/0	0/0	0/0	0/0
COMSTAR	0/0	Ku	0/0	3/72	1/24	0/0	3/72	2/48
DCBS	0/0	Ku,Ka	0/0	1/48	0/0	0/0	1/48	0/0
DIGISAT	0/0	C,Ku	0/0	3/72	0/0	0/0	3/72	1/24
EQUASTAR	0/0	C	0/0	2/48	1/24	0/0	2/48	1/24
FEDNET	0/0	Ku	0/0	2/96	0/0	0/0	2/96	2/96
FORDSAT	0/0	C,Ku	0/0	3/144	1/48	0/0	3/144	1/48
GALAXY	2/48	C	3/72	4/96	3/72	3/72	4/96	4/96
GALAXY	0/0	Ku	0/0	3/72	1/24	1/24	3/72	2/48
GALAXY	0/0	Ka	0/0	2/96	0/0	1/48	2/96	1/48
GSTAR	0/0	Ku	2/48	3/72	2/48	2/48	3/72	3/72
MARTIN	0/0	Ku	0/0	2/48	1/24	0/0	2/48	1/24
SATCOM	5/120	C	6/144	9/216	7/170	6/144	9/216	7/170
SATCOM	0/0	Ku	0/0	3/72	2/48	0/0	3/72	3/72
SBS	4/48	Ku	4/60	6/132	5/108	4/96	5/120	5/120
SPACENET	1/36	C,Ku	2/72	4/144	3/108	3/108	4/144	3/108
SPOTNET	0/0	C,Ku	0/0	7/168	0/0	0/0	7/168	0/0
TELSTAR	2/48	C	2/48	4/96	3/72	2/48	4/96	3/72
WESTAR	4/88	C	4/96	7/168	4/96	4/96	7/168	5/120
WESTAR	0/0	Ku	0/0	3/72	1/24	0/0	3/72	2/48
TOTALS:	23/508		26/636	86/2364	40/1048	29/804	77/2280	51/1430
U.S. DBS								
DBSC	0/0	DBS	0/0	2/20	1/10	0/0	2/20	1/10
DVSS	0/0	DBS	0/0	2/8	0/0	0/0	2/8	0/0
RCA	0/0	DBS	0/0	2/32	0/0	0/0	2/32	1/16
STC	0/0	DBS	0/0	2/6	0/0	0/0	2/6	0/0
USSB	0/0	DBS	0/0	2/12	0/0	0/0	2/12	0/0
HUGHES	0/0	DBS	0/0	2/32	0/0	0/0	2/32	1/16
NCN	0/0	DBS	0/0	2/12	0/0	0/0	2/12	0/0
SDT	0/0	DBS	0/0	2/32	0/0	0/0	2/32	0/0
SSS	0/0	DBS	0/0	2/12	0/0	0/0	2/12	0/0
NEX	0/0	DBS	0/0	2/32	0/0	0/0	2/32	0/0
ACC	0/0	DBS	0/0	2/12	0/0	0/0	2/12	0/0
TOTALS:	0/0		0/0	24/222	1/10	0/0	24/222	3/42
U.S. MOBILE/RADIONAVIGATION								
MOBILSAT**	0/0	UHF,L,Ku	0/0	2/6	0/0	0/0	2/6	0/0
SKYLINK *	0/0	UHF	0/0	3/3	0/0	0/0	3/3	0/0
OMNINET **	0/0	UHF,L,Ku	0/0	2/6	0/0	0/0	2/6	1/3
GEOSTAR *	0/0	L	0/0	4/4	0/0	0/0	4/4	2/2
TOTALS:	0/0		0/0	11/19	0/0	0/0	11/19	3/5

* 5 MHz/satellite at UHF; 10 MHz/satellite at L-band

** 5 MHz/satellite at UHF

Table 2.4-6

Estimate Of Non-U.S. Satellite Supply And Transponders

System	Current # Sat./Tr. in orbit 1984	Freq.	Est. # Sat./Tr. in orbit 1990			Est. # Sat./Tr. in orbit 1995		
			low	high	best	low	high	best
NON-U.S. REGION 2 FSS								
ANIK	2/48	C	2/48	2/48	2/48	2/48	2/48	2/48
ANIK	2/48	Ku	2/48	3/72	2/48	2/48	3/72	3/72
ARGENTINA	0/0	C	0/0	2/24	0/0	0/0	2/48	1/24
ASETA	0/0	C	0/0	2/24	0/0	0/0	2/24	1/12
MORELOS	0/0	C, Ku	0/0	2/72	1/36	0/0	2/72	2/72
PANAMSAT	0/0	C, Ku	0/0	1/48	0/0	0/0	1/48	0/0
SATCOL	0/0	C	0/0	2/48	0/0	0/0	2/48	1/24
SBTS	0/0	C	0/0	2/48	1/24	0/0	2/48	2/48
TOTALS:	4/96		4/96	16/384	6/156	4/96	16/408	12/300
INTERNATIONAL A.O.R. FSS								
CYGNUS	0/0	Ku	0/0	2/48	0/0	0/0	2/48	0/0
INT. IV*	3/26	C	0/0	0/0	0/0	0/0	0/0	0/0
INT. V*	4/144	C, Ku	3/72	5/180	3/72	0/0	0/0	0/0
INT. VI*	0/0	C, Ku	0/0	2/96	2/96	2/96	5/480	3/144
INT. VII*	0/0	C, Ku, Ka	0/0	0/0	0/0	0/0	4/288	0/0
INT. Y/Z*	0/0	Ku	0/0	3/72	1/24	0/0	5/120	2/48
ISI	0/0	Ku	0/0	2/96	0/0	0/0	2/96	0/0
ORION	0/0	Ku	0/0	2/44	0/0	0/0	2/44	1/22
UNISAT	0/0	C	1/6	2/12	0/0	0/0	0/0	0/0
TOTALS:	7/170		4/78	18/548	6/192	2/96	20/1076	6/214
INTERNATIONAL P.O.R. FSS								
INT. IV*	1/20	C	0/0	0/0	0/0	0/0	0/0	0/0
INT. V*	0/0	C, Ku	1/36	3/108	1/36	1/36	1/36	0/0
INT. VI*	0/0	C, Ku	0/0	1/48	0/0	1/48	2/96	1/48
PACIFIC	0/0	C	0/0	1/12	0/0	0/0	2/24	1/12
TOTALS:	1/20		1/36	5/168	1/36	2/84	5/166	2/60
NON-U.S. DBS								
CAN-DBS	0/0	DBS	0/0	1/6	0/0	0/0	2/12	1/6
S.AM.-DBS	0/0	DBS	0/0	0/0	0/0	0/0	2/12	1/6
TOTALS:	0/0		0/0	1/6	0/0	0/0	4/24	2/12
NON-US MOBILE/MARITIME								
INMARSAT **								
-MARECS	1/1	C, L	1/1	1/1	1/1	0/0	0/0	0/0
-MCS	4/4	C, L	4/4	4/4	4/4	0/0	0/0	0/0
-2ND GEN	0/0	C, L	0/0	4/4	2/2	2/2	4/4	3/3
M-SAT ***	0/0	UHF	0/0	1/1	1/1	0/0	1/1	1/1
TOTALS:	5/5		5/5	10/10	8/8	2/2	5/5	4/4

* Satellite/Transponder Supply numbers refer only to operational satellites.

** MARECS and MCS - 30 channels/satellite
2nd year - 150 channels/satellite

*** MSAT - 5 MHz/satellite

Figure 2.4-1

Projected Region 2 Commercial Communications Satellite In Orbit 1984-2010

e=expected end of life, based on design life   SOURCE: SATELLITE SYSTEMS DIGEST, Summer 1984 edition
p=planned launch date
o=currently in orbit   C=C-Band Ku=Ku-Band Ka=Ka-Band L=L-Band S=S-Band P=Probability of Implementation (SSE estimate - percentage)
C-12= 12 C-Band Transponders DBS= Direct Broadcast Satellite Band

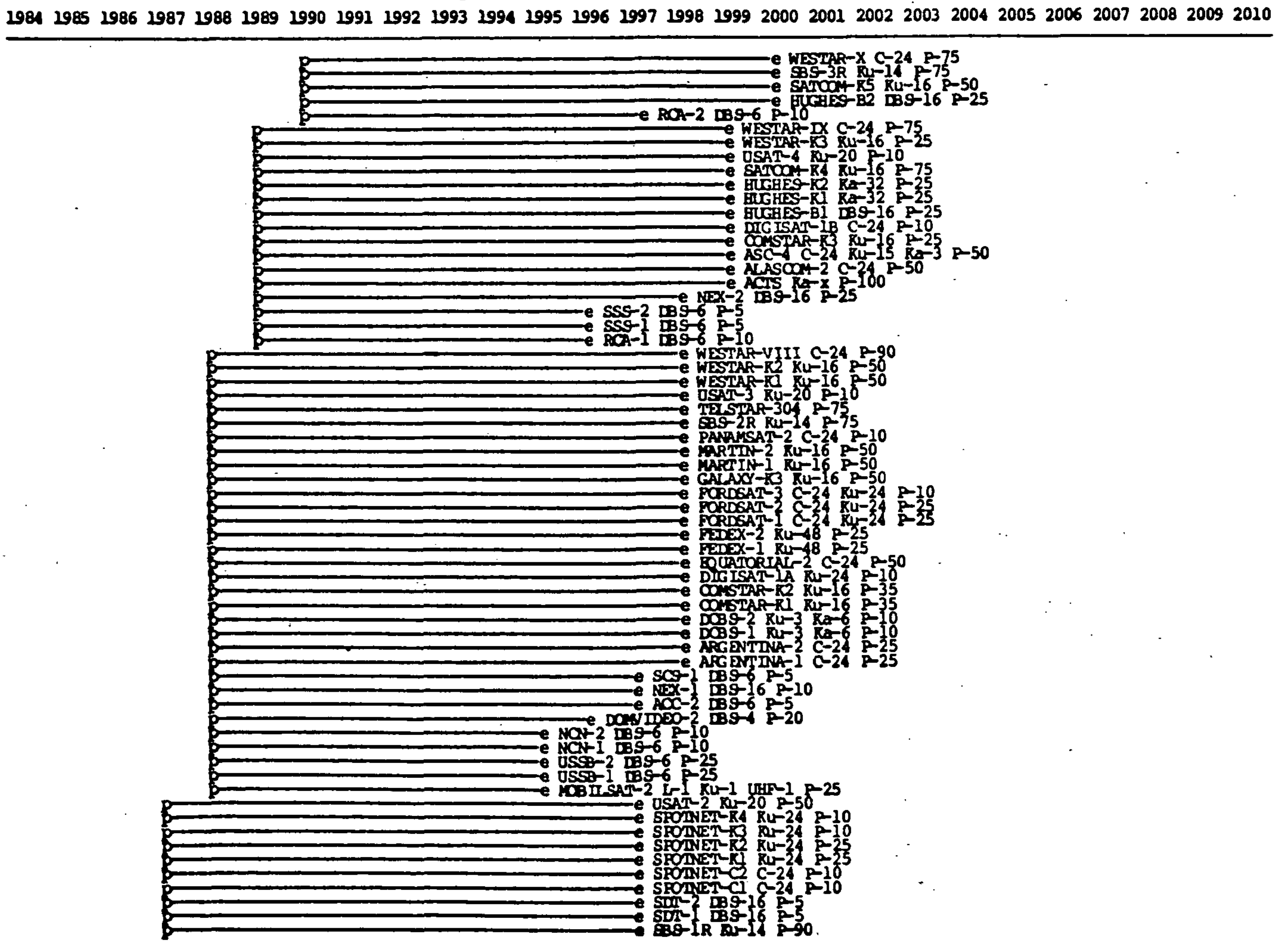

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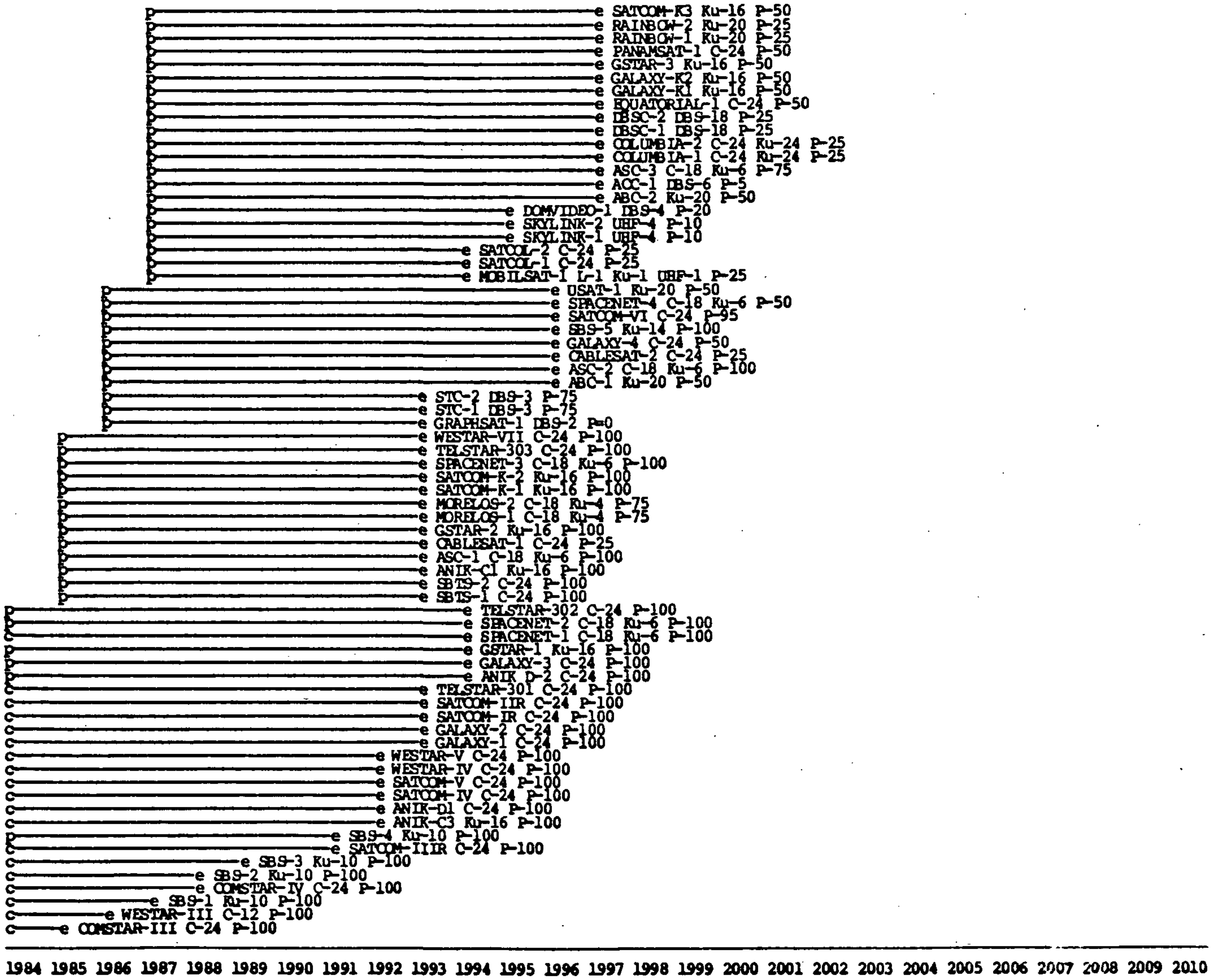
Figure 2.4-1 (Continued)



2.4.3.1 Terminals in Support of FSS and DBS Service

United States Located. A forecast of the earth station population within the United States for FSS and DBS service is given in Table 2.4-7.

Table 2.4-7

Earth Station Population Within The U.S.
(FSS And DBS Service)

	Licensed	Unlicensed	Total
Receive Only			
TVRO	5,707	506,793	512,500
Audio/Data RO	710	5,890	6,600
Transmit/Receive			
Carrier (i.e., shared use)	575		575
Dedicated (on Premise)	615		615
Other			
	98		98
Totals	7,705	512,683*	520,388

* It is to be noted that about 500,000 of the Receive Only TVRO terminals are unlicensed backyard installation and that this value is a very approximate estimate.

Data on the licensed earth stations comes from the Facilities and Services Division of the FCC's Common Carrier Bureau, July 1984. Data on the unlicensed earth stations comes from a variety of sources, including in-house data at SSE, contracts with satellite system operators and resellers, trade associations, industry publications and consultants, and users. The number of unlicensed TVRO's are approximate at best as this industry is very loosely structured and growing fast. All transmitting earth stations are licensed. 90% of all T/R's operating in Alaska are owned by Alascom and are shared usage carriers. Very few T/R's in either Alaska or Hawaii are for private, dedicated use.

The quantity of terminals projected for the future will be very dependent upon the growth of competitive fiber optic cable systems.

In the past few years fiber optic technology has experienced several major breakthroughs in capability, practicality of implementation, and costs. Over a dozen national and regional fiber networks are currently being implemented in the U.S. and it is possible that 80,000 route miles will be installed and operational by the late 1980's. This represents about 30% of the current long-haul plant in place.

Key parameters of current fiber optic network planning includes:

- o <u>3-5 Nationwide Networks</u>
  - -- AT&T, MCI, Sprint, etc.
  - -- 565 MB/s/fiber pairs
  - -- 5-20 fiber pairs/cable
  - -- 7,000 - 20,000 route miles for each network
- o <u>Many Regional Networks</u>

-- Lightnet	- East
-- Microtel	- East
-- Electra	- Central
-- Litel	- Central
-- LDX	- Central
-- Fibertrak	- West
-- United Telecom	- Central/West

Non-U.S. Located. A forecast of the FSS and DBS earth station population within Canada is given in Table 2.4-8. The large T/R corresponds to antenna dish sizes in excess of 10 meters; the medium T/R are less than 10 meters; the Receive Only (RO) are greater than 2 meters; and the DBS are less than 2 meters.

Table 2.4-8

FSS And DBS Terminals Within Canada

	1985	1990	2000
Large T/R	20	30	50
Medium T/R	100	200	1000
RO	10,000	25,000	25,000

A forecast of the FSS and DBS Terminals within Latin America, South America, and the Caribbean is given in Table 2.4-9. The large T/R stations represent the Intelsat gateway stations, and the medium T/R stations represent domestic and intra-regional stations.

Table 2.4-9

Terminals Within Latin America, South America, And The Caribbean
(FSS And DBS)

	1985	1990	2000
Large T/R	45	50	75
Medium T/R	70	200	1000
RO	50	2000 - 5000	50,000
DBS	0	0	100,000

2.4.3.2 Terminals in Support of Mobile Service

The forecast of earth terminals in support of U.S. and non-U.S. mobile services is given in Table 2.4-10.

Table 2.4-10

Terminals Used For Mobile Services

	Year 1990		Year 2000	
	U.S.	Canada	U.S.	Canada
Voice Users	45,000	2,000	180,000	20,000
Data Users	180,000	6,000	1,440,000	60,000
TOTAL	225,000	8,000	1,620,000	80,000

For the United States, it is expected that by 1990 there will be one mobile satellite system in place, with a total of 2 "transponders" of 15 MHz each (probably at L-band with spatial diversity and dual polarization). It is projected that the system will be used at 50% capacity, with a typical growth curve. One channel will serve 30 voice users, using loading statistics as stated by Omninet and Mobilsat. One channel will serve 120 data users, assuming BPSK Aloha modulation of 240 b/s messages. Current market estimates suggest the system will be equally shared by voice and data. The 15 MHz bandwidth will serve:

1500 channels x 30 voice users/ channel = 45,000 voice users

and

1500 channels x 120 data users/channel = 180,000 data users.

By the year 2000, it is expected that two mobile satellite systems will be in place, with a total of 8 "transponders" of 15 MHz each (some combination of L-band and UHF-band, with multiple spatial diversity and dual polarization). It is forecast that the year 2000 system will be used at 50% capacity. Thus, there will be a total of 60 MHz of capacity in use.

Using the previously described methodology, it is expected that 60 MHz would serve 180,000 voice users and 720,000 data users. However, it is predicted that QPSK will be commonly used for data by 1995 - 2000 (the voice bandwidth of 5 KHz is already at the edge of the state-of-the-art, and hence further bandwidth efficiency is not expected), thus doubling the number of expected data users. Thus, the 60 MHz bandwidth will serve 180,000 voice users and 1.44 million data users.

The Canadian estimate for year 1990 and year 2000 is based on the Phase B market survey done for Telesat Canada.

Table 2.4-10

Terminals Used For Mobile Services

	Year 1990		Year 2000	
	U.S.	Canada	U.S.	Canada
Voice Users	45,000	2,000	180,000	20,000
Data Users	180,000	6,000	1,440,000	60,000
TOTAL	225,000	8,000	1,620,000	80,000

2.5 CONSTRAINTS, SELECTION CRITERIA, AND OTHER CONSIDERATIONS

2.5.1 Study and Task Constraints

Several guidelines and constraints were imposed by the SOW and several others were added by Ford Aerospace during the study in order to limit the scope of this study. These limitation included:

General Guidelines: The study was to use payload configurations which were based on utilization of 1998 operational technology. No in-orbit payload assembly was to be required and a minimum system lifetime of ten years was to be feasible. In addition, a conformance to anticipated regulatory requirements was to be accommodated.

Other general guidelines included the accommodation of communications payloads only, and a rigid spacecraft antenna configuration was to be incorporated for the baseline FSS and DBS configurations. The system must be economically feasible, must be based on demonstrated needs, and must accommodate user/operator requirements.

Launch Concepts: The payload configurations and characteristics were to be subject to constraints imposed by various spacecraft/transportation system/space operations capabilities. These constraints on the payload are in terms of permissable weight/power volume/lifetime envelopes. Two sets of envelopes were to be considered initially:

Launch Concept 1: Up to a maximum single shuttle launch of combined spacecraft and upper stage with a spacecraft weight of up to 12,000 pounds.

Launch Concept 2: Allows a separate spacecraft (without upper stage) of size and weight up to a full shuttle launch capability (65,000 pounds).

Communications Service Baseline Requirements: The baseline service aggregation scenario requirements were to provide: 1) up to CONUS coverage b) Domestic FSS and DBS services (only) and c) Transmission at C/Ku/Ka frequency bands.

Variation to Service Aggregation Scenarios: The service coverage area was to be extended to include up to the entire western Hemisphere. Additional services including mobile and data collection were to be considered as well as additional frequency bands. An intersatellite link capability to international satellites or other non U.S. satellite or platforms was to be considered.

2.5.2 Service Aggregation Scenario Selection Criteria

Several interactive concepts are involved in the development of aggregation criteria. The first and simplest is the inclusion of multiple, distinct payloads-such as fixed communications, DBS, or CPS services - on a single satellite. A second level is aggregation of multiple users within a single payload. Also, the selection of aggregation criteria must go hand-in-hand with payload criteria ; the two sets of criteria cannot be developed independently. As an example, an aggregation scenario that would result in a payload set whose mass or power is excessive should be identified early to preclude wasted effort in the subsequent payload concept and definition tasks. Regulatory and institutional constraints can also interact with the ability to aggregate users within a payload, or even payloads on a platform. An established satellite user would have to see significant economic benefit before relinquishing his "very own" system.

The suggested evaluation criteria given in Appendix A to the RFP for this study included:

a. Potential communication capacity from an orbital slot.
b. Impacts on both space and terrestrial plant-in-place.
c. Communications service reliability/availability.

Criterion b has been discussed above vis-a-vis space impacts. Terrestrial plant-in-place impacts include such factors as ensuring that an existing carrier's terrestrial facilities - if its space plant were to shift to the platform - are still usable or easily modifiable with minimum downtime.

There is an interaction between criteria a and c. Most users would be reluctant to place all their traffic on a single satellite, even if sufficient capacity could be provided in a single orbital slot for that user. Thus, one could end up considering different mixes of payloads/users in different slots. Sparing considerations complicate the problem but must be taken into account. In spite of the aforementioned problems, the pressures on orbital slot availability, may very well drive the FCC to give preference to filings that conserve this resource or directly regulate the use of the orbital slot.

There are other criteria that could be considered in addition to those covered above. For example, in evaluating the inclusion of a payload serving a particular market segment, the economic benefit of a satellite-based system, relative to other alternatives, would provide a measure of the likelihood such a system would be viable. As an example, it would be very difficult for a satellite-based mobile system to compete with a cellular terrestrial system in a metropolitan area because of the latter's high degree of frequency reuse in a small area. On the other hand, a mobile user should not be expected to provide two different systems. Hence, compatibility issues must be considered.

As a result of the Task 1 efforts it was determined that the following selection criteria be used in the evaluation of the various service Aggregation Scenarios:

a. Optimum Communication Capacity From An Orbital Position.
b. Impact On Terrestrial And Space Plant-in-Place.
c. Communications Service Reliability/Availability
    - Risk Associated With "All Eggs In One Basket".
    - Numerical Reliability
    - Frequency Selection For Availability.
d. Institutional Issues
    - Antitrust Issues
    - Regulatory Issues (FCC, CCIR, CCITT)
    - Insurance Issues
    - Ownership And Financing
e. Multipayload Schedule Risk
f. Privacy Issues
g. Restriction On Re-Allocation Of Existing Service
h. Orbit Servicing Outages.

2.5.3 Payload Concept Evaluation Criteria

The key evaluation criteria for payload concepts are as follows:

a. Frequency spectrum utilization
    - Bandwidth
    - Re-use
    - Modulation efficiency
b. Inter-system interference
c. Communications service reliability, availability.
d. Growth potential/flexibility
e. Complexity (Risk)
f. Percent payload capacity utilization.

2.5.4 Other Consideration

In addition to the technical and performance constraints to be imposed on the Scenario development are various other parameters to be considered. The three factors examined in this study are: a) institutional barriers b) regulatory considerations and c) insurance issues.

2.5.4.1 Institutional Barriers

If the technical problems in developing, launching, and operating a geostationary communications platform can be solved and if the "economies of scale" materialize, the platform may make economic sense. However, there still remains the problems of institutional barriers.

The Communications Common Carriers have been restrained by antitrust laws. This was viewed as a problem even in assembling the "Carrier Working Group" for the LeRC 30/20 GHz Program. However, these carriers have a long history of working together on cooperative projects. The submarine cables, which have been in operation for almost 100 years, are usually owned by one carrier, but others have been able to use part of the capability. Intelsat was formed in 1963 to own the space segment of the satellites carrying international traffic. This international consortium has been remarkably successful in providing global communications services.

The carriers owning domestic and regional communications satellites have been able to lease spare capacity to one another. The Anik A satellites leased transponders to U.S. carriers before the U.S. domsats were launched. Currently, Anik C-2 has been tilted so that its antenna footprints fall on the U.S. rather than Canada, and high power Ku-band transponders are being leased to U.S.C.I. for television distribution in the Eastern U.S. The Comstar satellites were bought by Comsat and leased to AT&T, who in turn subleased channels to GTE. The Galaxy satellites are unique in that their owner, Hughes Communications, Inc., did not decide to be a common carrier, but leased the transponders to carriers. This has become known as a "condominium" satellite, since the transponders were all sold to individual owners.

The platform could follow any of these commercial models:

- a. The platform could be owned by a single organization, and spare channels could be leased to other carriers.
- b. The platform could be owned by a consortium formed for that purpose, and the consortium members could have access to the channels.
- c. The platform could be developed by a single organization, and communications channels could be sold to carriers.

An alternate system could have the platform owned by a government entity. This could presumably be the system chosen by a government with a PTT (postal, telephone, and telegraph) organization.

Purposes and Priorities of the Payloads: The purposes and the priorities of the payloads on the Geostationary Communications platform affect the institutional barriers. For example, these barriers can be quite different if the platform is owned by an international consortium such as Intelsat which operates on a world wide basis, or by a U.S. Commercial corporation operating domestically.

The following potential categories of payloads are possible.

- a. Satellite Communications
    - -- Commercial, domestic
    - -- Commercial, international
    - -- Governmental, domestic
    - -- Governmental, international
- b. Meteorological observation and dissemination'
- c. Earth resources observation and dissemination
- d. Military reconnaissance
- e. Scientific observations
- f. Engineering tests of components and system.

Platform Ownership Options: The communications satellite platform could have a number of different ownership options. these are listed below, with examples:

a. A U.S. common carrier (e.g., AT&T, GTE, ITT, WU, RCA Americom, SBS, etc.)
b. A consortium of U.S. carriers.
c. A U.S. designated monopoly corporation (a "carriers" carrier")
d. A U.S. government agency, e.g., NASA
e. A regional multinational consortium, e.g., Eutelsat
f. An international consortium e.g., Intelsat, Inmarsat.

Platform Ownership Responsibility: The responsibilities of ownership include obtaining or providing for :

a. Regulatory approvals,
b. Financing
c. Contracting for the spacecraft manufacture, payload integration, testing, and delivery to the launch site.
d. Launch Services.
e. Insurance
f. Tracking, telemetry, and command for a master Earth Station, including the orbit positioning and deployment, attitude control, station keeping, environmental control, configuration management, and radio-frequency interference control.
g. Payload management, switching control, terrestrial network management.

"Condominium" Payload Owners' Responsibilities: While the platform owner's responsibilities involve monitoring and control of the spacecraft as a whole, the individual payload owners can be responsible for:

a. The configuration of communications circuits, switching within the payload subsystems, and control of the individual antenna beam "footprints."
b. The switching of spare components within the payloads, and possibly, the replacement and repair of failed components or subsystems.
c. An oversight of the platform management which affects the operations and priorities of the individual payloads.

<u>Representative Scenarios</u>: Several representative scenarios of platform development are described, in order to review the institutional barriers which must be overcome.

Scenario #1: A U.S. domestic platform owned by an individual common carrier: Suppose that the number of communications satellites over North America grew so rapidly that the orbit capacity was filled in all practical frequency bands allocated for communications satellites. In order to increase the orbital capacity, one of the U.S. carriers assigned an orbital slot by the FCC proposed to build a large platform, and serve as the "landlord," subletting space and utilities (power, environmental control, attitude control, switching circuits, etc.) to other ("condominium") carriers interested in providing their own payloads for this platform.

The platform owner would have to obtain the regulatory approvals. The original application to the FCC would have to be amended to permit this use of his construction permit. Presumably, the amended platform would accommodate multiple frequency transmitters and receivers, multiple "spot" beam antennas, and could present problems in harmful radio-frequency interference to other authorized users of the radio spectrum. These concerns would have to be addressed, and the communications subsystem designed to obviate any such harmful interference. The FCC would have to circulate his amendment to all interested parties, review the responses, possibly hold evidentiary hearings, and then decide whether or not to permit his Application to be amended.

In the event that any of the interested parties was unsatisfied with the FCC results, he could resort to the Judicial Branch of the government to seek legal redress.

Assuming these barriers were overcome, the FCC would submit the amended application to the International Telecommunication Union, to insure that no other Administrations would suffer harmful interference from the operation of the platform in its assigned orbital position.

In order to permit multiple carriers to cooperate in designing and integrating communications payloads onto a platform, the Dept. of Justice would have to waive the anti-trust laws which are designed to prevent collusion between carriers on pricing services. Arguments showing this cooperation was in the public interest would be required to pursue such a waiver. If the current laws do not permit such cooperation, then the appropriate Congressional Committees could consider changes in the law to make this possible.

The FCC has limited the rate of return on domestic communications carriers to a fixed percentage of the invested capital. this limitation could restrict the potential profits of the platform owner, and make it difficult to raise the finances. While the recent trends have been for less regulation, these trends may not continue indefinitely.

The platform owner would have to obtain financing for development and construction. Because of the long lead times involved, several years would pass before any income would be realized from the platform's operation. The expenditures would start slowly, and build up steadily as the construction took place. Progress payments would be required for the launch vehicle, and the owner could incur costs on the order of a billion dollars or more at the time of the launch.

Since few corporations can generate this much cash from operating expenses, outside sources of financing will be required. The "condominium" owners could be a source of these funds, if they will pay in advance for space on the platform. Alternatively, the money could be borrowed or raised from private or public subscriptions. The public subscriptions come under the jurisdiction of the Securities and Exchange Commission.

Currently, communications satellites qualify for investment tax credits. These "ITC's" could enable a corporation to deduct some of the investment in the platform from operating profits in other activities. This assumes that the current laws on ITC's and depreciation allowances on high-technology enterprises will continue, and will apply to the platform as well as other communications satellites. The Internal Revenue Service must approve the use of the ITC's for the platform owners.

Insurance must be obtained for the platform, and the large expenses involved may strain the capacity of the underwriters. If the perceived risks in the platform exceed those of conventional satellites, the higher premiums may handicap the profit potential of the platform.

The launch services may not present institutional barriers, since the platform will presumably be launched on the space Shuttle. However, the size of the platform will require more extensive integration facilities at Cape Canaveral than are needed for smaller communications satellites.

After the platform is successfully launched, checked-out, and is operational, the multiple carriers on-board can effect a degree of interconnection which is rare in terrestrial circuits. Properly designed, the platform can permit interconnection via an on-board switching system of any uplink with any downlink. This can permit any earth station communicating with the platform to reach any other earth station, irrespective of the frequency bands. While this versatility can result in better utilization of all participating earth stations, the coordination in tariff charges and state and federal regulation of these tariffs can present new problems.

Assuming that these barriers can be overcome, the platform could offer a high degree of utilization of the geostationary orbit "slot", due to the interconnectability and multiple frequency re-use in "spot" beam antennas.

Scenario #2: An international consortium becomes the platform owner, and leases out communications subsystems to members of the consortium. If Intelsat became the owner, the institutional barriers are less formidable, because many of them have already been overcome. If a new international consortium were set up in competition with Intelsat, then the administrations involved would have to agree to permit competition with Intelsat's current monopoly.

In this scenario, suppose that a rival international consortium were set up to serve the heavy traffic areas of the Atlantic Basin in competition with Intelsat. The U.S. could use two approaches in permitting free entry into international satellite communications. One is to license the domestic applications first, and then deal with the other administrations; the other is to reverse this sequence.

Within the next several years, the question of whether or not to permit competition with Intelsat's current monopoly will be addressed by the Executive Branch (the Senior Interagency Group on International Communications Policy), by the FCC (either in licensing procedures or in a broad rule making inquiry), or by the Legislative Branch (in oversight hearings by relevant congressional committees). Congress might find it necessary to amend the Communications Satellite Act of 1962.

Assuming that competition to Intelsat is permitted, then the platform can communicate with earth stations in a number of Administrations. Each participating Administration could permit earth stations communicating on several frequency bands with a platform positioned over the Atlantic Ocean. Because of the use of "spot" beams antennas, the power flux densities ("p.f.d.'s") could be higher than that available from Intelsat satellites, and smaller earth station antennas could be used. Because of the direct communications between international corporations, or video distribution networks, and the elimination of terrestrial links and related expenses, the communications circuits would presumally be cheaper than those involving the local PTT's and Intelsat.

The institutional barriers which must be overcome to permit this scenario include the waiving of restrictions on competition to Intelsat, the permits to construct earth stations by all participating administrations, the coordination and assignment of an orbital slot by the ITU, and the permits to use high power flux densities within the antenna beam "footprints."

The financial barriers are similar to those described previously, but in this case the funds might be provided by the sponsoring administrations, or by private ventures from each corporation in proportion to the communications capability subscriptions. The managing entity could be a new consortium, or an existing satellite operator might be engaged to perform this service.

2.5.4.2 Regulatory Considerations

The following government organizations or corporate entities many present regulatory barriers in establishing a platform communications system.

FCC: Grants construction permits (licenses) and assigns orbital slots for domestic applicants, coordinates these slot assignments with the ITU, coordinates interference complaints by users of the radio spectrum, and regulates tariffs.

NTIA: Coordinates telecommunications policy in the Executive Branch of the government.

State Public Service Commissions: Regulates inter-state tariffs.

Dept. of Justice: Enforces the laws governing communications common carriers.

Congress: Makes the laws governing the carriers.

Courts (Judicial Branch of the Government): Adjudicates disputes between interested parties.

Dept. of State: Coordinates international agreements with other Administrations.

ITU (International Telecommunications Union): An agency of the United Nations which coordinates frequency assignments, orbital positions, and harmful interference between competing users of the radio-frequency spectrum.

UN: Parent organization of the ITU; makes policy related to international broadcasting.

Foreign Governments: Make treaties concerned with international communications.

Foreign Government PTT's (Postal, Telephone & Telegraph): State monopolies controlling the earth stations and communications interconnections on their territory.

IRS (Internal Revenue Service): Regulates the tax credits and depreciation schedules affecting communications satellite systems.

SEC (Securities Exchange Commission): Regulates stock offerings and private placements (which might be used to finance the platform).

Investment Bankers, and venture capitalists; Financing.

Insurance Companies: Underwrite risks on construction and delivery, launch and commissioning, plus the orbital operations or the platform.

NASA: Spacecraft integration at the launch site; launch services.

Master Control Earth Station: Tracking. telemetry, and control of the platform in orbit.

It is expected that key regulatory action would be required for the following:

a. Domestic Communications (orbital slots, frequency assignments, power levels, modulation techniques): FCC for commercial applications, IRAC for government applications.
b. Heavily trafficked frequency bands may require a long-term effort with the FCC to clear a platform orbital slot, or the use of a slot assigned to a satellite owner (or owners) with waivers to operate a platform.

c. Formation of consortia of U.S. common carriers will require anti-trust laws to be waived by the Dept of Justice.
d. Geostationary slots for both domestic and international communications must be assigned by the ITU.
e. Broadcasting across national borders requires approval by the administrations involved, and may involve the U.N.

2.5.4.3 Insurance Issues

The insurance of communications satellites is a relatively new business. It began with coverage of the launch phase of the Intelsat I (Early Bird) in 1965. The first coverage of the operating phase in orbit was with Western Union's Westar I in 1974. The insurance of property damage and malfunctions is now considered in four phases:

a. Manufacturing
b. Prelaunch, from the time the satellite leaves the factory until intentional ignition of the launch vehicle
c. Launch, ending with positioning in the geostationary orbit and (sometimes) checkout on orbit
d. Operation, with periodic renewals throughout the lifetime of the satellite

The industry has grown to the point that the total sums insured in 1983 are approximately $1.5 billion. However, the maximum capability on a single launch is limited to slightly over $200 million. Because a geostationary communications platform's cost will exceed this limit, the industry capacity must grow to support higher levels.

A second type of insurance involves liability claims. Even though some spectacular unplanned reentries have occurred, such as the 80-ton Skylab's crash over Western Australia in July of

1979, only minor damage has resulted. The total industry capability of third party liability is now on the order of $1 billion.

The geostationary platform poses some unique risks in comparison with individual satellites. The most obvious is "putting all your eggs in one basket." A catastrophic event such as a micrometeoroid impact could totally destroy a platform. A more likely event such as the loss of the attitude control subsystem could also render the platform useless. However, with the large weight and space and more redundant subsystems, a means of regaining control can be incorporated into the platform. The insurers must review the reliability assessments of the platform and compare them with individual satellites in order to determine the premiums that should be charged.

Another risk peculiar to the platform is the potential for radio-frequency interference (RFI) between diverse payloads. The juxtaposition of high-power transmitters and sensitive receivers has caused unanticipated problems on satellites carrying multiple payloads. For example, the high powered transmitters on Fleetsatcom produced intermodulation products (IMP) from nonlinear components which jammed the receivers. This satellite required extensive redesign and suffered schedule delays and cost overruns. The insurers must follow the designs and tests during the platform development to determine if this risk is acceptable. Alternately, the insurance policies could be written to preclude claims resulting from RFI between separate payloads.

The insurance of a large and expensive communications platform could present problems with the space insurance community in their present state of affairs. The total exposure on a single satellite launch has increased from a value of

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approximately $10 million in the late 60's, to a value slightly over $100 million currently. This trend is illustrated in Figure 2.5-1.

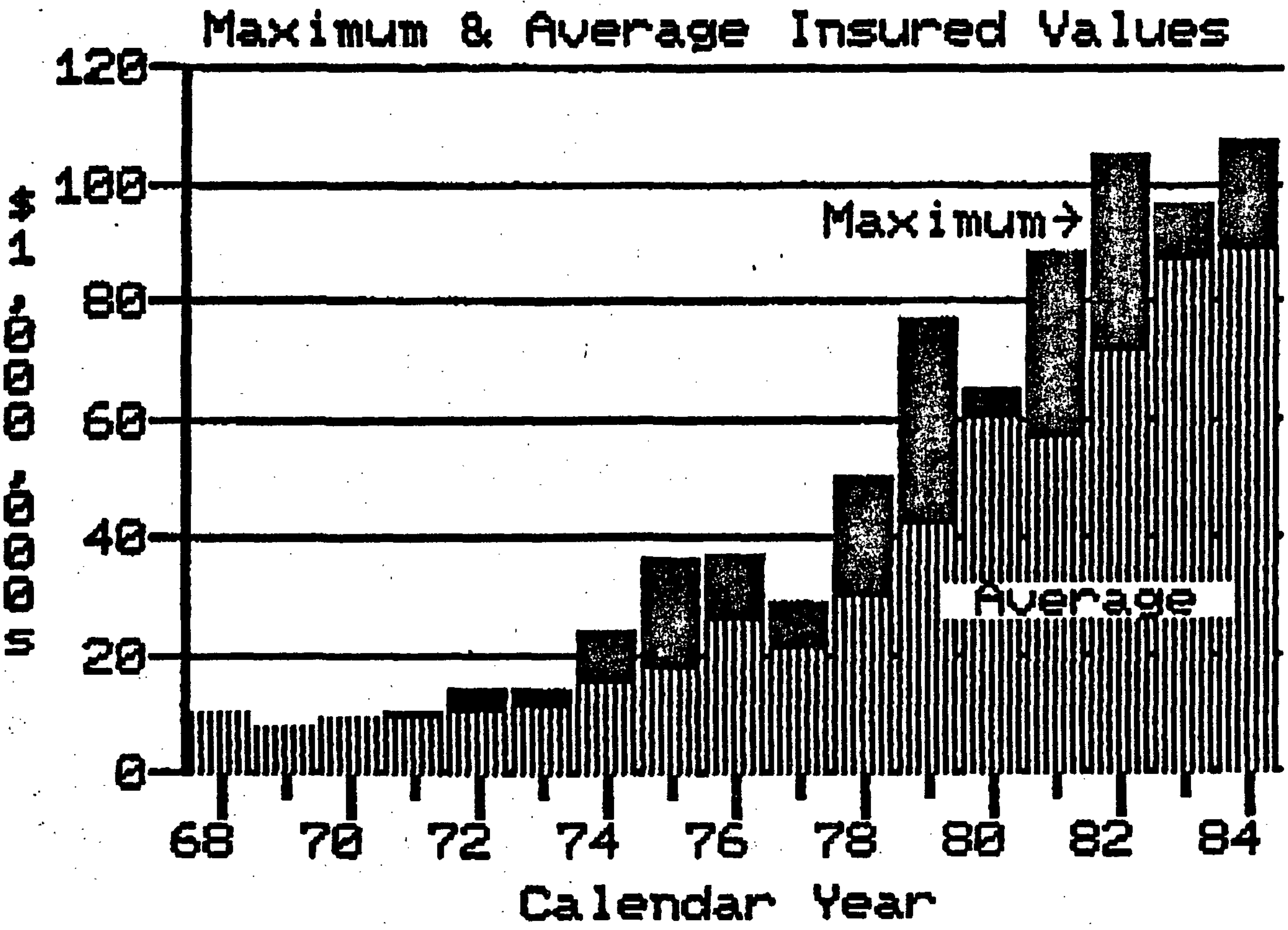

Figure 2.5-1. Insurance on Individual Satellites

On multiple satellite launches from a single launch vehicle, this exposure can be multiplied by a factor of two or three. The insurance underwriters became painfully aware of these risks during the 11th Shuttle Mission (Feb. '84) in which the failure of the PAM-D Perigee Kick Motors resulted in losses of $180 million for WESTAR VI and PALAPA B2. While these losses may be lessened by recovery and re-sale of these errant satellites, the loss was a bitter one for the underwriters. The subsequent loss of approximately $80 million launch of INTELSAT V F9 on the previously reliable Atlas/Centaur Launch Vehicle exacerbated the problem.

Ultimately, the space insurance business must be profitable in order for it to continue. Figure 2.5-2 shows the losses exceeding the premiums in '79, and rising sharply with the three losses mentioned above in'84. At the present time the total cumulative losses are approximately double the cumulative premiums which have be collected.

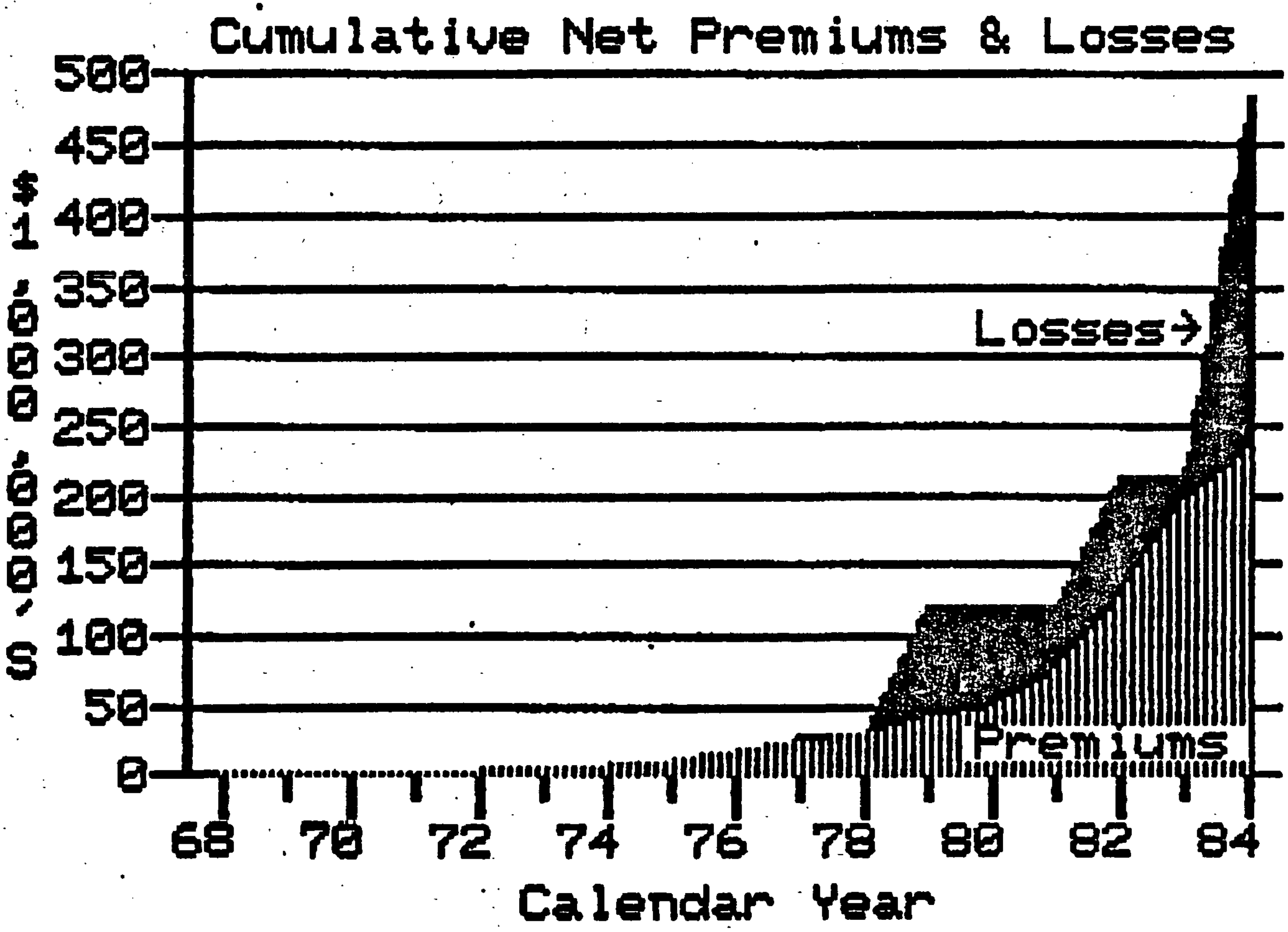

Figure 2.5-2. Cummulative Satellite Insurance

C-2

The insurance premium rates will have to increase to permit underwriters to become financially healthy again. The launch and commissioning rates have been between approximately 6% and 10% depending on the perceived reliability of the launch vehicle used. The rates quoted since the disasters of '84 have been roughly doubled. If the launch reliability improves, and the higher premiums contribute to the financial health of the underwriters, then their capacity can grow to the point that they could support a platform launch.

The platform may cost a billion dollars or more. This large expense will probably require outside financing, and the financiers will insist on insurance to limit their exposure. The successful launch and testing of an experimental version of the platform would help reduce the perceived risk on the first platform launch.

If the premium costs are much higher than that for individual communications satellites, the introduction of platforms may be delayed. Alternatively, the insurance could be written with deductibles; either the loss of one platform in a series of platform launches, or other limitation on the underwriters' payments in case of loss. In the case of a platform launched by government organization such as NASA, the practice has been to self-insure. This could be another reason that the initial platform would be experimental.

SECTION INDEX

3.0 AGGREGATION SCENARIO DEVELOPMENT (TASK 2)

3.1 OVERVIEW

The purpose of Task 2 of this study was to develop a minimum of six communications service aggregation scenarios describing potential groupings of voice, video and data services which maximize the communications service capacity of a single location in geostationary orbit.

Using the criteria developed in Task 1 and approved by NASA, a total of 8 service aggregation concepts were synthesized and tested against the criteria. The scenarios described potential groupings of voice, video, and data services that maximize the communication service capacity of a single location in geostationary orbit. Information was obtained on the following parameters:

- Traffic considerations
  - Capacity for each service by frequency
  - Re-use estimates based on beam size
  - Service area covered by service and frequency

- Platform attributes
  - Estimates of RF power required
  - Estimates of dc power required
  - Estimates of weight by service
  - Development risk assessment

- Required orbit locations by service

- Ground system attributes
  - Approximate number of earth stations by service
  - Approximate sizes of earth stations by service
  - Geographic location of earth stations
  - Effect on anticipated plant-in-place

The ranked scenarios and their descriptions were presented to NASA and five of the scenarios were selected for further development in this study (see section 3.4)

3.1.1 Rationale used in Scenario Development

The different services that potentially could be provided by satellite from the geostationary orbit are fixed (FSS), broadcast (BSS), maritime, aeronautical, land mobile, radio navigation, meteorological, military, data collection, voice broadcast, citizen band repeaters, etc. The satellite providing these services can operate in any one or a combination of three modes:

- o Global coverage
- o Regional, zone coverage
- o Domestic coverage

Each of the services (FSS, DBS, etc.) uses preassigned radio frequency (RF) bands allocated by the concerned regulatory agencies. The agencies coordinate with the International Telecommunications Union (ITU) for inter-region allocations. Although planned geosynchronous satellite services are varied, it is evident that fixed satellite services communications satellites outnumber all others. Frequency allocations for FSS, by international agreement, consist of:

	Frequency (MHz)		Available RF
Band	Uplink	Downlink	Bandwidth (MHz)
C	5925-6425	3700-4200	500
Ku	14000-14,500	11700-12,200	500
Ka	27500-29,500	17700-19,700	2000
Ka	29500-30,000	19700-20,200	500

Thus far, the C band has been the most widely utilized, to such extent that at certain locations (especially from 70° to

143° west longitude) it is thought of as a nearly depleted commodity. To that effect, during the 1979 World Administrative Radio Conference (WARC-79) and under much pressure from developing countries and Western European nations, it was resolved that "A World Administrative Radio Conference shall be convened not later than 1984 to guarantee in practice, for all countries, equitable access to the geostationary satellite orbit and the frequency bands allocated to space services."

Though the Ku-band and particularly the Ka-band are utilized less than the C-Band, it is likely they will be equivalently treated within any international and domestic planning procedure. However, their global, regional, and domestic allocation, repartition, and methods of utilization will offer more flexibility than those at the C-band because they are less thoroughly established from the network design and operation viewpoints. For instance, while 1° circular or even smaller spot beams will be desirable for some services in the U.S. at the Ku and Ka-bands, the same size spot beam will be unlikely at C-band. An already existing operational structure at C-band will prevail beyond the late 1990's whereby the usage of the band is locked to CONUS or 50 states plus Puerto Rico and Virgin Islands coverages. By the same token it would be hard to imagine at C-band the realization of a data transmission network (low speed/medium speed) with roof-mounted small dishes, whereas 1.5 meter or even smaller diameter dishes at the Ku band could be ideally suited for such a service.

The Ku-band was looked upon as a solution to the congestion existing in the C-band arc/spectrum. The Ku-band alleviates the congestion problem because it provides more available spectrum and therefore more capability than the C-band alone. However, also to be considered is that the capacity of the C and Ku-bands can be colocated or combined on one payload in orbit, thus optimizing usage of the orbit arc/spectrum. Additionally, the two bands can be interconnected to create specialized networks, not to mention the economies of scale that can be achieved for transponder costs. This can be extended to include the Ka band, which is quite attractive for very large capacity voice and data transmission (multicarrier FDM/FM and TDMA).

It is interesting to notice that whereas up to a few years ago the capacity provided for CONUS coverage from one orbital location was twelve 36 MHz C-band transponders, the aggregation of C/Ku/Ka-bands and the use of dual polarization make it possible to have as many as 168 (24 C + 24 Ku + 120 Ka) equivalent 36 MHz transponders from the same orbital location with no other reuse scenario.

The North American arc, which is facing C-band congestion problems, will get some relief from an orbital spacing reduction to 2° from the current 4°. However, the North American arc, which presently extends from 70° to 143°, (U.S. orbital arcs extend from 70° to 102° and from 118° to 143° with the Canadian arc extending from 102° to 118°), is in jeopardy of being reduced. Mexico has already received locations in the Canadian arc at 113.5° and 116.5° and Brazil has received locations at 65° and 70° at the end of the North American arc. In addition, Columbia has been allocated two orbital locations at 75.0° and 75.4° for it's planned domestic satellite system. It is anticipated that parts of it will be sought by other Region 2 countries. This is especially true of spots within the orbital arc from about 60° to 90°, which will be contested by the U.S. on one hand and Central American and Caribbean countries on the other. On the other hand, recent FCC filings have indicated that the sought-after orbital positions requested for U.S. coverage extend as far down as 55° west longitude.

Taking into consideration present orbit/spectrum constraints, available satellite and launch technology capabilities (physical dimensions, weight, and power), a growing requirement for the need for transponders, and the economies of scale derived by a larger number of transponders on a given spacecraft, leads to a future generation of increased capability communications satellites (platforms) that will weigh about 5000 lb (2265 kg) in geosynchronous orbit at beginning of life. Such a platform could be stretched up to a weight of 13,000 to 14,000 lb, still making use of single STS launch). More missions could be accommodated and a payload of about 200 equivalent 36 MHz C/Ku/Ka-bands communications transponders achieved. If the same economies of scale are applicable as shown in Table 3.1-1, reduced cost per transponder per year should be achieved. The cost per transponder per year has dropped from about $10 million in 1964 for Early Bird to about $370,000 today and is projected to drop to about $190,000 by 1987. The data in Table 3.1-1 has been compiled by Ford Aerospace research.

Table 3.1-1

History of Cost per Transponder Year

Procurement Year	Satellite	Number of Transponders Transponders/Band	Cost*/ Transponder/ Year$M (1982)
1972	Westar	12 C-band	0.65
1974	Satcom	24 C-band	0.50
1981	Galaxy	24 C-band	0.37
1981	Satcom	24 C-band	0.26
1982	Spacenet	36 Hybrid	0.28
1987	FASSC	54 Hybrid	0.19

*Launch plus satellite

The same analysis can be applied to other services and in particular to BSS, where the initial STC program direct broadcast satellite was planned as a three channel system, to where subsequent DBS systems will be considerably larger, perhaps reaching a capacity of up to 32 high-power RF channels per orbital slot as allocated by RARC-83.

With the basic services of voice, video, and data to be provided as before but where changes are bound to happen due to growing requirements, larger throughputs, use of new RF bands, planning and optimization of the orbit/spectrum, and the increasing cost effectiveness of transponders, a number of service aggregation scenarios can be postulated. Among these are:

- FSS only at C/Ku/Ka bands
- DBS only at Ku band
- FSS and DBS at C/Ku/Ka bands
- DBS and FSS (TV distribution only) at C/Ku bands
- FSS and mobile at L/C/Ku/Ka bands
- FSS (data transmission only) at Ku/Ka bands

A short description of each of these possible scenarios follows:

- FSS using up to 7000 MHz of bandwidth that will fulfill long distance and regional telephony requirements as well as data and video transmission requirements throughout the U.S. and/or between the U.S. and Western Europe on one hand, and the U.S. and countries of the Americas on the other.

- DBS for Region 2 using the 12.2 to 12.7 GHz RF band with direct and indirect circular polarization. An overall of 256 x 24 MHz RF channels are available for the U.S. from 8 orbital positions (8 x 32 channels) at 61.5°, 101°, 110°, 119°, 147°, 157°, 166°, and 175° of west longitude. 192 RF channels are available for Canada from 70.5°, 72.5°, 82°, 91°, 129°, and 138° west longitude. Both Brazil and Mexico have also expressed multichannel requirements from each of 4 orbital positions. Other Region 2 DBS aggregation possibilities are 115° west longitude for the Andean countries group, and at 103/04° west longitude for Colombia and Venezuela.

- o Mixed FSS and DBS missions using C/Ku/Ka bands serving the U.S., Western Europe, and Japan. Platforms would be located at pre-established DBS orbital positions and provide voice and data service transmissions as well, conforming to designated and established limits of power flux density.

- o Considerable TV programming as well (SMATV) transmission is presently taking place in the U.S. at the C-band with new service deployment planned at the Ku-band. These transmission media will prevail throughout the 1990s. A mix of FSS (TV transmission and distribution only) with downlinks between 3700-4200 MHz and 11700-12200 MHz and BSS services with downlinks between 12200-12700 MHz from pre-established DBS orbital positions could be envisaged.

- o Mixed FSS at C/Ku/Ka bands and mobile land services at VHF and L bands can be envisaged for the U.S. and/or between the U.S., the Americas, and Western Europe.

- o Data transmission requirements to be handled at Ku and Ka bands, thus allowing a capacity in excess of 6 Gb/s for a mix of high, medium, and low transmission bit rate services throughout the U.S., and between the U.S., other countries of the Americas, and Western Europe. This should be particularly attractive for low capacity users with roof-mounted small diameter antennas.

3.1.2 Adaptation of Traffic Models

For each service aggregation scenario, the basic traffic data bases developed in Task 1 were adapted to fit the particular scenario.

The adaptation required also depended on the traffic type being considered:

a. Trunking Services -A given earth station may serve several SMSAs. The NASA-provided traffic models were to the SMSA level. The SMSA-SMSA traffic was mapped to earth station-earth station traffic. This mapping depended, in turn, on the earth stations selected

b. CPS Services - In this case the traffic need not be mapped to earth stations because a large metropolitan area would have hundreds of such stations in close proximity, and it is not necessary to have traffic data at this level of detail for payload design. SMSA-SMSA data (including "artificial" SMSAs) was adequate in this situation. Space plant in place, such as SBS, can affect the potential platform traffic.

c. International - This traffic is routed to a very small number of gateway locations. The Intelsat traffic data base is by country only and is not broken down to individual earth stations. As long as the beam pattern covers the appropriate gateway terminals, then country-country data is adequate. Intelsat plant in place would need to be considered, although current Intelsat planning certainly envisions their carrying all international satellite traffic.

d. Point-to-Multipoint and Multipoint-to-Point - These types of traffic, such as DBS or data collection, will involve broad coverage areas. In these cases traffic estimates indicated that only one to four beams were necessary even if it is scanned.

e. Other - Adaptations of traffic data were evaluated on a case-by-case basis.

For those cases in which a data base was adapted to a scenario, a Ford Aerospace computer program was utilized. One of the capabilities of this program is to sequentially read in point-to-point traffic demands and match those demands with an earth station file. The program implicitly assumes all traffic endpoints are in the earth station file. A simple change to the program would allow traffic to be dropped if one or both endpoints are not in the data base.

3.1.3 Terrestrial System Characteristics

The selection of earth station location and size can have a strong interaction with traffic considerations. The main area where the geographic distribution of earth stations is important is in trunking traffic.

This is not to say some modeling of earth station population in nontrunking applications is inappropriate. For example, in developing a traffic data base for a mobile system, one approach would be to estimate the number of terminals by regions, such as offshore or rural/hinterland areas, and assume calling rates and holding times to derive erlangs of traffic, which in turn can be converted to circuits based on a blocking criterion. Traffic data would be on a region-region basis; terminal population estimates are only used as an intermediate step in the process.

3.1.4 Orbit Allocations

Initially, domestic service was provided by satellite carriers between a few general-purpose earth stations located near major metropolitan areas. The FCC generally has not until recently required showings of competitive feasibility or economic viability by new applicants in the interest that the public could benefit from diverse approaches offered by multiple entrants. However, the FCC has found it necessary to govern the assignment of the limited number of available orbital locations. The objective appears to be to accommodate as many applications as possible with a minimum of regulatory intrusion and administrative proceedings. The specific orbital location assigned by the FCC to each satellite takes into account not only the requirement of the payload application, but also the requirements of other satellites. Such assignments are usually made on a temporary basis and are subject to change by Commission order. The FCC retains this flexibility in order to accommodate the changing requirements of existing carriers as well as new domestic and foreign applications. Although the FCC has not imposed specific technical operating standards beyond those required by the ITU's International Radio Regulations, it has adopted orbital spacing criteria to conserve orbital arc. These criteria limit payload concept development and design latitude. The Commission had until April of 1983 an established a policy of 4^{o} orbital spacing at 6/4 GHz and 3^{o} at 14/12 GHz. The stated policy now is to move toward 2^{o} spacing in a phased plan. In July of 1985 in issuing licenses to a series of new applicants, the FCC also re-allocated the orbital locations of existing satellites requiring some to be moved $1 - 2^{o}$.

It is essential that the means of regulation, innovations, and strategies be examined so as to optimize usage of orbit and spectrum. This optimization is accomplished as follows:

a. Use of Ku and Ka bands to allow more spectrum and therefore greater capacity than at C-band alone. Use of the three bands that might complement each other in terms of services will implement the fixed satellite service. The related technologies are available; yet one can argue that the higher band components are more expensive than those at C-band, at least until such time that the demand for Ku and Ka-band components has caught up with that at C-band.

b. Achieve greater capacity at each orbital slot by:

1. Utilizing each band twice through dual polarization. The usage of only half of the band from a slot is a waste of the capacity available at that slot.

2. Using hybrid satellites or allowing for colocated C/Ku/Ka band satellites (coincidental orbital slots).

3. Cross-strapping the C/Ku/Ka bands to allow for network connectivity that will make available more growth capability for network users.

c. Utilize frequency reuse whenever enough spatial isolation exists. If the geographical separation between coverage areas is sufficiently large and the spacecraft antenna gain patterns have sufficiently fast roll-off characteristics, satellites using the same frequencies can be colocated in the geosynchronous orbit.

d. Closer orbital spacing (2^{o}) to allow more satellites in orbit. The concern over the scarcity of orbital slots has motivated the FCC into reducing the orbital spacing of U.S. communications satellites to 2^{o} for both C and Ku-bands from their present 4^{o} at C-band and 3^{o} at the Ku-band in order to create enough orbital slots to satisfy the requirement of new entrants. Currently there are only two Ka-band applicants and an orbital spacing of less than 2^{o} should be achievable. However, no formal spacing policy at Ka-band has yet been stated by the FCC.

This quest for minimum satellite orbital spacing in turn has necessitated an assessment of the maximum acceptable adjacent satellite interference levels, since as these permissible levels between two networks serving the same area increase, the orbital separation between the satellites of these networks can be reduced. To that effect, the International Radio Consultative Committee (CCIR) Reports 453-2, 455-2, and Recommendation 353-2 have concluded that greater percentages of the total noise budget can be allocated to interference from other satellite systems.

Key factors determining the relationship between the nominal angle of separation between adjacent satellites in the same bands and carrier-to-interference ratio (C/I) are the radiation pattern of earth station antennas and the resulting antenna sidelobe discrimination. Use should therefore be made of earth station antennas with improved sidelobe characteristics.

Similarly, spacecraft antennas with shaped beams should be used, so that they conform to the coverage area in order to achive high discrimination outside the coverage area.

Although the earth station antenna sidelobe pattern gain limit is established by G = 32 - 25 log theta, it should be recognized that the actual average antenna sidelobe discrimination is considerably larger, thus implying a lower interference.

e. Structuring and regulating the usage of the bands according to voice, video, data services, their capacities and the type of networks. For instance, the transmission of very high data bit rates would take place at the Ka-band whereas low data bit rates transmission would take place at the Ku-band with roof-mounted earth stations.

3.2 DESCRIPTION OF EIGHT CANDIDATE SCENARIOS

The results of the aggregation scenario development led to the following eight candidates:

Scenario I	- High capacity C and Ku-band FSS and Ka-band CPS
Scenario II	- Medium capacity CONUS FSS and medium power DBS
Scenario III	- Medium capacity CONUS Mobile Satellite Service (MSS)

Scenario IV - High capacity medium and high power DBS

Scenario V - High capacity CONUS FSS and Mobile (MSS)

Scenario VI-A - High capacity half CONUS FSS, Region 2 International, ISL to central/west CONUS and "European Platform", and Western Altantic Maritime

Scenario VI-B - High capacity half-CONUS FSS, Region 2 International, ISL to central/east CONUS and "East Asian Platform", and Eastern Pacific Maritime

Scenario VII - High capacity intra and inter Region II, plus ISL's for European and Asian international traffic, plus Region II DBS

These eight candidate scenarios are defined in Tables 3.2-1 to 3.2-8. The information contained in these tables was the first estimates of the scenario for ballpark sizing and characterization. During the subsequent concept development and definition, many of the scenarios as well as their characterization were modified to make them more suitable scenarios either technically or economically.

Table 3.2-1

Candidate Scenario I

ITEM	FREQUENCY BAND C	 Ku (FSS)	 Ka (FSS)	 Ka (CPS)	 Ku (DBS)	 UHF/L
CAPACITY	APPROX 5X REUSE APPROX 1.25° BW	APPROX 12X REUSE APPROX 0.45° BW		6 SCANNING BEAMS 0.3° BW		
SERVICE AREA COVERED	CONUS	CONUS		CONUS		
RF POWER (WATTS)				7.5-75		
PAYLOAD POWER (WATTS)				1000		
RISK FACTOR	MEDIUM	MEDIUM		HIGH		
APPROXIMATE WEIGHT (LBS)				850		
ORBIT LOCATION ACCEPTABLE (DEGREE WEST LONGITUDE)	70-143	70-143		100±10°		
APPROXIMATE NUMBER OF EARTH STATIONS						
SIZE OF EARTH STATIONS	3M RX ONLY 5-10M TX/RX	2M RX ONLY 3-7M TX/RX		3-5M TX/RX 5-7M TX/RX		
GEOGRAPHIC LOCATION OF EARTH STATIONS	CONUS	CONUS		CONUS		
IMPACT ON GROUND. PLANT-IN PLACE	MEDIUM	LOW		NEW SERVICE		
OTHERS	NETWORK TO Ku-BAND AND Ka-BAND	NETWORK TO C-BAND AND Ka-BAND		NETWORK TO C-BAND AND Ka-BAND		

Table 3.2-2

Candidate Scenario II

ITEM	FREQUENCY BAND					
	C	Ku (FSS)	Ka (FSS)	Ka (CPS)	Ku (DBS)	UHF/L
CAPACITY	24 X 36 MHz	24 X 54 MHz	16 BEAMS	6 BEAMS	16 CHANNELS (100W)	
SERVICE AREA COVERED	CONUS 2 BEAM	CONUS 1-CONUS BEAM, 2-REGIONAL BEAMS	16 LARGEST SMSA's	CONUS	4 CONUS 6 CH. X 2 BEAM	
RF POWER (WATTS)	6.5	50	7.5 TO 75	7.5-75	100	
PAYLOAD POWER (WATTS)	550	3000	1600	1000	4000	
RISK FACTOR	LOW	LOW	MEDIUM	HIGH	LOW	
APPROXIMATE WEIGHT (LBS)	240	700	700	650	450	
ORBIT LOCATION ACCEPTABLE (DEGREE WEST LONGITUDE)	70-143°	70-143°	101±10°	100±10°	61.5,101,110, 119,147,157,166 & 175°	
APPROXIMATE NUMBER OF EARTH STATIONS	50		54 EARTH STATIONS, 9 USERS/BEAM	6000	1-5 MILLION	
SIZE OF EARTH STATIONS	9M RX ONLY 5-10M TX/RX	2M RX ONLY 3-7M TX/RX	5-7M TX/RX	3-5M TX/RX 5-7M TX/RX	1-2M RX ONLY 5-10M TX/RX	
GEOGRAPHIC LOCATION OF EARTH STATIONS	CONUS	CONUS	16 LARGEST SMSA AREAS	CONUS	CONUS	
IMPACT ON GROUND, PLANT-IN-PLACE	LOW	LOW	NEW SERVICE	NEW SERVICE	LOW	
OTHERS						

Table 3.2-3

Candidate Scenario III

ITEM	FREQUENCY BAND					
	C	Ku (FSS)	Ka (FSS)	Ka (CPS)	Ku (DBS)	UHF/L
CAPACITY						APPROXIMATELY 100 BEAMS
SERVICE AREA COVERED						CONUS
RF POWER (WATTS)						30
PAYLOAD POWER (WATTS)						8500
RISK FACTOR						MODERATE-HIGH
APPROXIMATE WEIGHT (LBS)						4439
ORBIT LOCATION ACCEPTABLE (DEGREE WEST LONGITUDE)						100±10°
APPROXIMATE NUMBER OF EARTH STATIONS						270.000
SIZE OF EARTH STATIONS						SMALL NEAR OMNI
GEOGRAPHIC LOCATION OF EARTH STATIONS						CONUS
IMPACT ON GROUND, PLANT-IN-PLACE						LOW
OTHERS						

Table 3.2-4

Candidate Scenario IV

ITEM	FREQUENCY BAND					
	C	Ku (FSS)	Ka (FSS)	Ka (CPS)	Ku (DBS)	UHF/L
CAPACITY		48 x 24 MHz 50W			64 x 24 MHz	
SERVICE AREA COVERED		1 BEAM CONUS 2 BEAM 1/2 CONUS			2 BEAM FULL CONUS UP, 4 BEAMS 1/2 CONUS DOWN	
RF POWER (WATTS)		50			200	
PAYLOAD POWER (WATTS)		5500			26.000	
RISK FACTOR		LOW			LOW	
APPROXIMATE WEIGHT (LBS)		1300			1600	
ORBIT LOCATION ACCEPTABLE (DEGREE WEST LONGITUDE)		70-143			101.110.119.147	
APPROXIMATE NUMBER OF EARTH STATIONS		TBD			2-10 MILLION	
SIZE OF EARTH STATIONS		2M RX ONLY 3-7M TX/RX			0.6-1.0M RX ONLY 7M TX/RX UPLINK	
GEOGRAPHIC LOCATION OF EARTH STATIONS		CONUS			CONUS	
IMPACT ON GROUND, PLANT-IN-PLACE		LOW			NEW SERVICE	
OTHERS		STATIC SWITCHING TO ALLOW INTER-CONNECT TO AND FROM Ku (DBS)			STATIC SWITCHING TO ALLOW INTER-CONNECT TO AND FROM Ku (FSS)	

Table 3.2-5

Candidate Scenario V

ITEM	FREQUENCY BAND					
	C	Ku (FSS)	Ka (FSS)	Ka (CPS)	Ku (DBS)	UHF/L
CAPACITY	APPROX 5X REUSE APPROX 1.25° BW	APPROX 12X REUSE APPROX 0.45° BW	18 BEAMS 0.3° BW	6 BEAMS 0.3° BW	64 X 24 MHz	APPROX 100 BEAMS
SERVICE AREA COVERED	CONUS		18 LARGEST SMSA'S	CONUS	2 BEAMS FULL CONUS UP, 4 BEAMS 1/2 CONUS DOWN	CONUS
RF POWER (WATTS)			7.5 TO 75	7.5 TO 75	200	30
PAYLOAD POWER (WATTS)			1600	1000	26.000	8500
RISK FACTOR	MED	MED	MED	HIGH	LOW	MOD-HIGH
APPROXIMATE WEIGHT (LBS)			700	850	1600	4433
ORBIT LOCATION ACCEPTABLE (DEGREE WEST LONGITUDE)	70-143	70-143	101±10°	101±10°	101.110.119	100±10°
APPROXIMATE NUMBER OF EARTH STATIONS			54 EARTH STATIONS, 3 USERS/BEAM	8000	2-10 MILLION	270.000
SIZE OF EARTH STATIONS	3M RX ONLY 5-10M TX/RX	2M RX ONLY 3-7M TX/RX	5-7M TX/RX	3-5M TX/RX 5-7M TX/RX	0.6-1.0M RX ONLY 7M TX/RX	SMALL NEAR OMNI
GEOGRAPHIC LOCATION OF EARTH STATIONS	CONUS	CONUS	18 LARGEST SMSA AREA	CONUS	CONUS	CONUS
IMPACT ON GROUND, PLANT-IN-PLACE	MEDIUM	LOW	NEW SERVICE	NEW SERVICE		LOW
OTHERS	NETWORK TO Ku-BAND AND Ka-BAND			NETWORK TO C-BAND AND Ka-BAND		

Table 3.2-6

Candidate Scenario VI-A

ITEM	FREQUENCY BAND					
	C	Ku (FSS)	Ka (FSS)	Ka (CPS)	Ku (DBS)	UHF/L
CAPACITY	0.3° BW	SOME 24 MHz VID CH. 0.3° BW	0.3° BW x BEAMS	3 OR 4 BEAMS	2 EA 2-4 Gb/s	MARITIME
SERVICE AREA COVERED	PRIMARILY AOR INTELSAT & EASTERN 1/2 CONUS TRUNKING OR DOMESTIC LATIN AMERICA	PRIMARILY AOR INTELSAT & EASTERN 1/2 CONUS TRUNKING OR DOMESTIC LATIN AMERICA	PRIMARILY EASTERN CONUS TRUNKING	PRIMARILY EASTERN AND CENTRAL CONUS	1) TO VI-B 2) TO EUROPEAN PLATFORM	AOR REGION
RF POWER (WATTS)			7.5 TO 75	7.5 TO 75	25	
PAYLOAD POWER (WATTS)					350	
RISK FACTOR	MODERATE	MODERATE	MODERATE	MODERATE-HIGH	HIGH	MODERATE
APPROXIMATE WEIGHT (LBS)						
ORBIT LOCATION ACCEPTABLE (DEGREE WEST LONGITUDE)	APPROX 70	70-85°	70-85°	70-85°	≈160	0-85°
APPROXIMATE NUMBER OF EARTH STATIONS			3-4 USERS/BEAM	APPROX 3-4000		
SIZE OF EARTH STATIONS	5-10M TX/RX	3-7M TX/RX	5-7M TX/RX	3-7M TX/RX	APPROX 4M S/C ANTENNA	SMALL
GEOGRAPHIC LOCATION OF EARTH STATIONS	N. AMER/CANADA/ S. AMER/AFRICA/ EUROPE & NUMEROUS ISLANDS	N. AMER/CANADA/ S. AMER/AFRICA/ EUROPE & NUMEROUS ISLANDS	CENTRAL & EASTERN CONUS & SELECTED HIGH DENSITY ROUTES	CENTRAL & EASTERN CONUS & SELECTED HIGH DENSITY ROUTES		AOR REGION
IMPACT ON GROUND. PLANT-IN-PLACE	*MODERATE*	*LOW*	*NEW SERVICE*	*NEW SERVICE*	*LOW TO GND HIGH* TO CURRENT INTELSAT S/C	*LOW-MODERATE*
OTHERS	INSTITUTIONAL BARRIERS HIGH BBP TO ACCEPT C&Ku NETWORKING TO ISL	INSTITUTIONAL BARRIERS HIGH BBP TO ACCEPT C&Ku NETWORKING TO ISL	BBP TO ACCEPT C&Ku NETWORKING TO ISL	BBP TO ACCEPT C&Ku NETWORKING TO ISL	INSTITUTIONAL BARRIERS HIGH BBP TO ACCEPT C&Ku NETWORKING TO ISL	INSTITUTIONAL BARRIERS HIGH BBP TO ACCEPT C&Ku NETWORKING TO ISL

Table 3.2-7

Candidate Scenario VI-B

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ITEM	FREQUENCY BAND					
	C	Ku (FSS)	Ka (FSS)	Ka (CPS)	Ku (DBS)	UHF/L
CAPACITY	0.3° BW	SOME 24 MHz VID CH. 0.3° BW	0.3° BW x BEAMS	3 OR 4 BEAMS	2 EA 2-4 Gb/s	MARITIME
SERVICE AREA COVERED	PRIMARILY POR INTELSAT & WESTERN 1/2 CONUS & ALASKA & HAWAII	PRIMARILY POR INTELSAT & EASTERN 1/2 CONUS & ALASKA & HAWAII	PRIMARILY WESTERN CONUS TRUNKING	PRIMARILY PACIFIC & MTN CONUS PLUS SELECTED HIGH DENSITY ROUTES	1) TO VI-A 2) TO EAST ASIAN PLATFORM	CENTRAL & EASTERN POR REGION
RF POWER (WATTS)			7.5 TO 75	7.5 TO 75	25	
PAYLOAD POWER (WATTS)						
RISK FACTOR	MODERATE	MODERATE	MODERATE	MODERATE-HIGH	HIGH	MODERATE
APPROXIMATE WEIGHT (LBS)						
ORBIT LOCATION ACCEPTABLE (DEGREE WEST LONGITUDE)	APPROX 110-140°	APPROX 110-140°	APPROX 110-140°	APPROX 110-140°	≈160	110-175°
APPROXIMATE NUMBER OF EARTH STATIONS			3-4 USERS/BEAM	APPROX 3-4000		
SIZE OF EARTH STATIONS	5-10M TX/RX	3-7M TX/RX	5-7M TX/RX	3-7M TX/RX	N/A. APPROX 4M S/C ANTENNA	SMALL
GEOGRAPHIC LOCATION OF EARTH STATIONS	U.S.A./CANADA/ CENTRAL AMER/ MEXICO & S. AMERICA	U.S.A./CANADA/ CENTRAL AMER/ MEXICO & S. AMERICA	PACIFIC & MOUNTAIN CONUS & SELECTED HIGH DENSITY ROUTES	PACIFIC & MOUNTAIN CONUS & SELECTED HIGH DENSITY ROUTES		CENTRAL & EASTERN POR REGION
IMPACT ON GROUND. PLANT-IN-PLACE	MODERATE	LOW	NEW SERVICE	NEW SERVICE	LOW TO GND HIGH TO CURRENT INTELSAT S/C	LOW-MODERATE
OTHERS	INSTITUTIONAL BARRIERS HIGH BBP TO ACCEPT C&Ku NETWORKING TO ISL	INSTITUTIONAL BARRIERS HIGH BBP TO ACCEPT C&Ku NETWORKING TO ISL	BBP TO ACCEPT C&Ku NETWORKING TO ISL	BBP TO ACCEPT C&Ku NETWORKING TO ISL	INSTITUTIONAL BARRIERS HIGH BBP TO ACCEPT C&Ku NETWORKING TO ISL	INSTITUTIONAL BARRIERS HIGH BBP TO ACCEPT C&Ku NETWORKING TO ISL

Table 3.2-8

Candidate Scenario VII

ITEM	FREQUENCY BAND					
	C	Ku (FSS)	Ka (FSS)	Ka (CPS)	Ku (DBS)	UHF/L
CAPACITY	0.9° BW	0.3° BW	0.3° BW ___ BEAMS	0.3° BW 6 BEAMS	64 CH - CONUS 92 CH - LAT AMER	2 ILSs 2-4 Gb/s
SERVICE AREA COVERED	SOUTH OF BORDER & INTRA REGION 2	CANADA & US (AL. & HA.)	REGION 2 TRUNKING	CONUS	REGION 2	19 INTELSAT AOR 2) INTELSAT POR
RF POWER (WATTS)			7.5 TO 75	7.5 TO 75	64-100 92-50	25
PAYLOAD POWER (WATTS)				1000	16,500	950
RISK FACTOR	MODERATE-HIGH	MODERATE	MODERATE-HIGH	HIGH	MODERATE	HIGH
APPROXIMATE WEIGHT (LBS)				850		
ORBIT LOCATION ACCEPTABLE (DEGREE WEST LONGITUDE)	70-110	85-110	70-110	70-110	101 OR 110 FOR CONUS	±160° FROM SATELLITE
APPROXIMATE NUMBER OF EARTH STATIONS				8000	RX ONLY 2-10 MILLION	N/A
SIZE OF EARTH STATIONS	5-10M TX/RX	3-7M TX/RX	5-7M TX/RX	3-7M TX/RX	0.6-1.0M RX 5-7M TX/RX	4M S/C ANTENNA
GEOGRAPHIC LOCATION OF EARTH STATIONS	REGION 2	CANADA, US AL. & HAWAII	REGION 2	CONUS		N/A
IMPACT ON GROUND, PLANT-IN-PLACE			NEW SERVICE	NEW SERVICE		MODERATE ON GND HIGH ON INTELSAT SPACE SEGMENT
OTHERS	INSTITUTIONAL BARRIERS HIGH SSP TO NETWORK C, Ku, Ka & ISL SERVICES	INSTITUTIONAL BARRIERS MOD. SSP TO NETWORK C, Ku, Ka & ISL SERVICES	INSTITUTIONAL BARRIERS HIGH SSP TO NETWORK C, Ku, Ka & ISL SERVICES	SSP TO NETWORK C, Ku, Ka & ISL SERVICES	INSTITUTIONAL BARRIERS HIGH	INSTITUTIONAL BARRIERS HIGH SSP TO NETWORK C, Ku, Ka & ISL SERVICES

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3.3 REQUIREMENTS COMPLIANCE MATRIX AND RANKING

3.3.1 Criteria for Evaluation

A summary of the criteria for evaluation and ranking of aggregation scenario is given in Table 3.3-1. These criteria are derived from section 2.5.2 plus additions that evolved during task 2.

Table 3.3-1

Criteria for Evaluation and Ranking of Aggregation Scenarios

- Optimum communications capacity from an orbital position
- Address high growth markets
- Impact on terrestrial and space plant-in place
- Technical feasibility of service grouping
- Service CONUS FSS first then add international and Region 2 international and domestic.
- Communications service reliability/availability
  - Risk "all the eggs in one basket"
  - Numerical reliability
  - Frequency selection for availability
- Institutional issues
  - Antitrust issues
  - Regulatory issues (FCC, ITU, etc)
  - Insurance issues
  - Ownership and financing
- Multipayload schedule risk
- Privacy issues
- National security and pride
- Restriction on re-allocation of existing service
- Orbit servicing outages during GEO servicing

3.3.2 Launch Concept Compliance

The matrix shown in Table 3.3-2 provides a summary of scenario compliance with "baseline" or "variation" requirements and with the ability to be accomodated via launch concept #1 or launch concept #2.

Table 3.3-2

Scenario Compliance with Requirements and Launch Concept

SCENARIO / CONCEPT CRITERIA	I	II	III	IV	V	VI A	VI B	VII
"BASELINE" REQUIREMENT	X	X		X	X			
"VARIATION" REQUIREMENT			X			X	X	X
LAUNCH CONCEPT 1	X	X	X	X				
LAUNCH CONCEPT 2					X	X	X	X

3.3.3 Evaluation Ranking

A ranking of the ability of each of the scenarios to accomodate the various evaluation criteria is given in Table 3.3-3. A score of 1 represents the highest ranking to be achieved and a score of 8 is the lowest.

With no weighting functions to be applied among each of the criteria, and with equal incremental values applied to rankings within each criteria, the following ranking was obtained:

Table 3.3-3

Aggregation Scenario Ranking

SCENARIO / EVALUATION ITEM	I	II	III	IV	V	VI-A	VI-B	VII
1. OPTIMUM CAPACITY	6	5	8	7	4	2	3	1
2. IMPACT ON TERRESTRIAL PLACE	4	3	1	2	5	8	7	6
3. IMPACT ON SPACE PLANT IN PLACE	4	2	3	1	5	7	6	8
4. SERVICE RELIABILITY/AVAILABILITY	3	2	4	1	8	7	6	5
5. INSTITUTIONAL ISSUES	3	1	4	2	5	7	6	8
6. SCHEDULE RISK	3	2	4	1	6	8	7	5

Table 3.3-3

Aggregation Scenario Ranking (Continued)

EVALUATION ITEM \ SCENARIO	I	II	III	IV	V	VI-A	VI-B	VII
7. PRIVACY ISSUES	3	4	2	1	5	7	6	8
8. NATIONAL SECURITY AND PRIDE	3	1	4	2	5	7	6	8
9. RE-ALLOCATION OF EXISTING SERVICE	4	2	3	1	5	8	7	6
10. ORBIT SERVICING OUTAGES	3	4	2	1	5	7	6	8
11. HIGH DEMAND/ GROWTH	5	4	1	3	2	6	7	8
12. TECHNICAL FEASABILITY	3	2	4	1	5	7	6	8
13. CONUS FIRST	3	1	4	2	5	6	7	8
OVERALL	4	2	3	1	5	7	6	8

Highest	Scenario IV
	Scenario II
	Scenario III
	Scenario I
	Sceanrio V
	Seario VI-B
	Scenario VI-A
Lowest	Scenario VII

3.4 CONCLUSIONS

Eight scenarios were developed and ranked as an output of Task 2. A presentation of results was made to NASA-Lewis on 7 February 1985.

NASA selected Scenario II, IV, V and VI-A for development in Task 3. It was also decided to drop the mobile satellite service payload from Scenario V because it was a one of a kind payload that had significant impact on the configuration of the payloads. As the development of Scenario VI-A proceeded it became clear that the concept of an east and west half-CONUS coverage satellite did not make sense because the ISL between them would have become a high volume (approx. 9-10 Gb/s) link and this did not seem reasonable. Thus the concept was changed to full CONUS coverage and the split of the international and regional and domestic coverages changed. After the Task 3 review, and seeing the VI-A development NASA added the development of the VI-B Scenario to complete the Region 2 coverage requirements.

During the development of Scenario V, it became evident that the 15 foot reflectors, selected to be compatable with rigid reflectors in shuttle, provided a reasonable amount of re-use at C and Ku-band to be consistant with a 1/3 to 2/3 split in analog to digital traffic consistant with projections beyond the year 2000. This payload then became the basic CONUS coverage package for subsequent Scenarios.

A summary of the characteristics of the selected payloads is provided in Figure 3.4-1.

Figure 3.4-1. Summary of Scenario Configurations

	DIRECT BROADCAST	COMMUNICATIONS			OTHER SERVICES
		C-BAND	Ku-BAND	Ka-FIXED Ka-SCAN	
II	MED # CHAN MED POWER	CONUS	CONUS	CONUS	
IV	HIGH # CHAN HIGH POWER		CONUS		
V		CONUS	CONUS	CONUS	
TRANSITION TO LARGE PLATFORMS					
VI-A		CONUS & INT'L	CONUS	CONUS	MARITIME PAYLOAD WESTERN ATLANTIC INTERSATELLITE LINKS INTELSAT AOR
VI-B		REGION 2 NON-CONUS	CONUS & REGION 2	CONUS	MARITIME PAYLOAD EASTERN PACIFIC INTERSATELLITE LINKS INTELSAT POR

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4.0 PAYLOAD CONCEPT DEVELOPMENT (TASK 3)

4.1 OVERVIEW

The purpose of the payload concept development under Task 3 of the study was to define the selected Communication Service Aggregation Scenarios that were determined as an output of Task 2. The initial four concepts were Scenarios II, IV, V, and VI-A. Subsequent to the Task 3 Review, Scenario VI-B was added.

The key inputs to this effort from Task 1 results include:

a. System constraints and regulatory issues.
b. Space/ground plant-in-place data base.
c. Communication technology forecast data base.
d. Payload service technology forecast data base.
e. Payload concept criteria.

These inputs were synthesized under Task 2 into the NASA approved aggregation scenarios.

The process of developing payload concepts and their communications architectures involves essentially the following factors:

a. Quantify aggregation scenarios in terms of data bandwidth requirements.
b. Devise payload concepts to satisfy above requirements, subject to payload concept criteria already developed.
c. Optimize payload concept through system-wide trades of payload configurations and forecast technology advances of major component hardware/software/firmware.

The design process was iterated so that payload concepts and their attendant communications architectures were judged feasible. Table 4.1-1 describes some of the techniques employed in designing the payload concepts. Actual traffic loading to the payloads was performed. If payload designs do not consider traffic distributions, then poor utilization (fill factors) may result in the actual system.

Table 4.1-1

Payload Design Objectives

Minimize Cost per Revenue-Producing Circuit*
By Appplication Of:

- FREQUENCY REUSE
- TRAFFIC BALANCING
- MAXIMIZATION OF STATIC-SWITCHED FILL FACTORS
  - CONNECTIVITY
  - BEAM OVERFLOW
- ON-BOARD PROCESSING
- EQUIPMENT QUANTITIES TAILORED TO TRAFFIC

* A revenue-producing circuit is the actual traffic carried.

Communication payload concepts are described in terms of:

- Antenna Coverage
- Frequency Plan
- Modulation and Coding Scheme
- Access Methods
- Connectivity and Processing

The corresponding terrestrial system characteristics are presented as station system parameters and hardware, software, and operational considerations. Finally, the advantages of each payload concept are presented along with an evaluation and ranking.

4.2 APPROACH

4.2.1 Background

Since the advent of the early communications satellites, both space segment and ground segment have evolved to higher levels of performance, reliability, and lower cost. Some of the most important aspects of economic/technological developments, in their impact on payload concept, concern spectrum utilization, system related technologies, TDRSS, spacecraft/earth station technology and STS and launch technology.

Information regarding the various parameters used to describe a payload concept (listed in Section 4.1) is provided in the following subsections.

4.2.1.1 Antenna Coverage

Antenna coverage plays an important role in payload concept development. Early satellites provided global coverage using a single polarization. However, as traffic grew, some form of frequency reuse became necessary. Frequency reuse can be achieved by using multiple-beam antennas and/or dual polarization. Key considerations in concept development here are some major tradeoffs in terms of EIRP, adjacent beam interference, polarization isolation, and antenna complexity. For example, of the three major types of multiple beam antennas in terms of today's technology, reflector types are most commonly used (Intelsat IV, IV-A, Anik, Westar and RCA/Satcom) because they are relatively simple, lightweight, and easy to produce at low cost. The large feed structures of the reflector type, however, often impose a blockage constraint in the system design. An array-type antenna (DSCS II and Intelsat V), which consists of electrically steered, uniformly spaced radiators, combines output at each array element to form multiple beams through a separate beam-forming and steering network. Lens

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antennas can also be used to create multiple beams by focusing the energy from a primary array of feed horns through a microwave lens.

Figures 4.2-1 through 4.2-3 show the possible coverage from three western hemisphere synchronous satellite positions -- 60°W, 90°W and 120°W longitude, respectively. Clearly, the satellite position and coverage will be determined by the needs of the customers serviced. The large areas of South America are spatially remote from CONUS and can efficiently be serviced from the same orbital slot with compatible systems. It

Figure 4.2-1 Satellite Coverage from 60° W

Figure 4.2-2 Satellite Coverage from 90° W

is possible that services would be a mixture of 1990's state-of-the-art technology for CONUS coverage and less sophisticated systems for Central and South America.

Inter-satellite links can be used to link satellites in different orbital slots and to extend the range of east-west communications. Such links would most likely be at EHF frequencies (60 GHz) or light-wave as they would not pass through and be attenuated by the atmosphere.

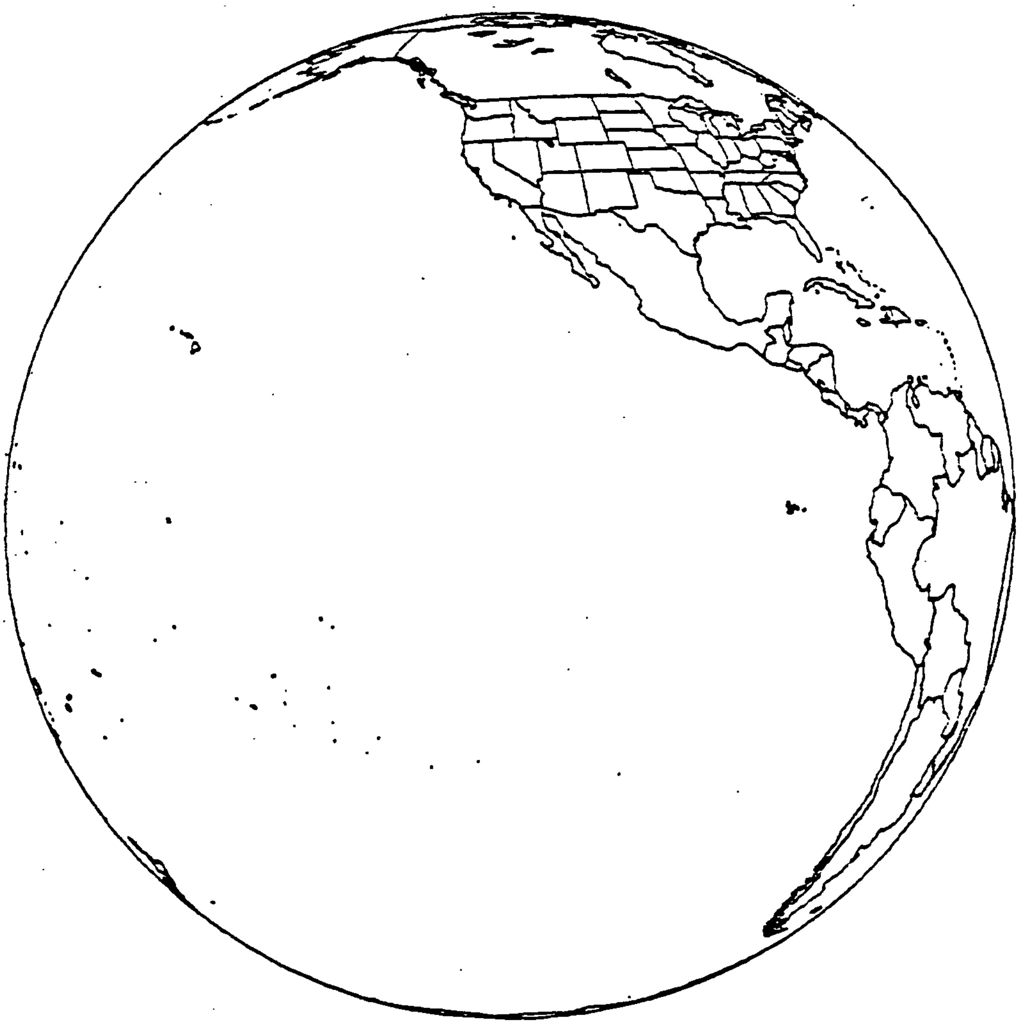


Figure 4.2-3 Satellite Coverage from 120° W

4.2.1.2 Frequency Plan

The frequencies presently allocated to non-military satellite communications in North America are the C band and the K band. The C band is the 6/4 GHz; the K band is further divided into the Ku band (14/12 GHz) and the Ka band (30/20 GHz).

The C band shares spectrum with terrestrial microwave systems. Advantages of the C band are that the signals are relatively free from atmospheric effects, the electronics are presently less costly, and the technology is further developed. The disadvantage, in addition to band congestion is that the power density is limited by FCC regulations to avoid interference with terrestrial microwave systems. This usually necessitates larger, more expensive antennas. The advantages of the K-band are that the satellites can be spaced more closely in orbit and the downlink power density can be higher, as there is no concern for interference with terrestrial microwave systems at present. This implies a smaller and less costly earth station antenna. The disadvantages include the fact that the signal is subject to atmospheric interference, and rain loss in excess of 10 dB is a major design concern.

Selection of an appropriate frequency plan depends on many factors, such as antenna coverage, traffic, orbital allocation, and interference issues. For example, the Ka-band fixed spot beams developed in this study varied from one 500 MHz channel up to five, depending on the traffic level in each beam. By adapting the frequency plan to projected traffic levels, considerable savings in cost, mass, and power were achieved.

4.2.1.3 Access Method

Another vital component in the payload concept development is the access method. Various multiple access techniques have been developed to allow simultaneous use of a given transponder by many earth stations. The sharing of payload capacity by many geographically dispersed users can be achieved by frequency division multiple access (FDMA), time (TDMA), space (SDMA), code (CDMA), and a number of hybrid combinations and variations, as highlighted in Figure 4.2-4.

Because of its proven technology, simplicity, low cost, and easy implementation to various networks, FDMA was the primary mode of multiple access in systems until the early 1970's. In FDMA, the bandwidth is divided into a number of non-overlapping frequency bands. Assigned bands are separated by guard bands to

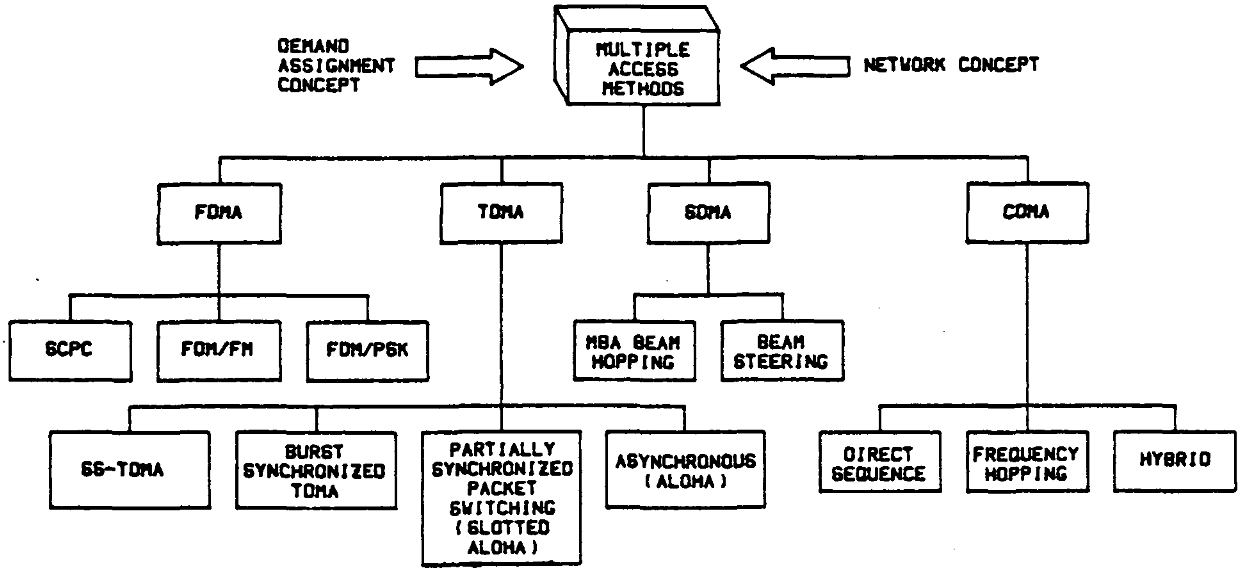


Figure 4.2-4 Various Techniques Achieve Multiple Access

reduce interference, and the payload transponder's power is divided among the accessing carriers. A common transmission method of FDMA is the multichannel-per-carrier FDM/FM/FDMA, which usually requires transponder power backoff or special bandwidth spacing considerations, both to alleviate AM/AM and AM/PM caused impairments. As such, FDMA has the general disadvantages of being less capacity efficient, compared with a single-access mode of operation. A later technique, SCPC/FDMA, using a single-channel-per-carrier concept, can provide some efficiency improvement in this regard, especially when it is used with demand assigned and signal activated schemes to take advantage of the usually low duty cycle and statistical randomness of user traffic (e.g., SPADE/Intelsat). SCPC/FDMA is particularly useful for small users in regional or domestic systems, but is not feasible for heavily aggregated high trunk traffic.

Since its initial development in the 1960's, significant advances have been made in TDMA. In TDMA, a given transmission time frame is divided into a number of generally non-overlapping time slots. Assigned channel slots are separated by guard time to reduce adjacent channel inter-symbol interferences, and the payload transponder's power is devoted to a single channel on a duty cycle basis. TDMA, in theory, yields the highest channel capacity because the only inefficiency arises from the guard times between adjacent channel slots, these times can be very small with improvements in synchronization/timing and network control techniques.

Some of the well known advantages of TDMA are:

- It is possible to make full use of transponder power. Experiments have shown that digital speech interpolation augmented TDMA can provide 6 dB improvement in transmission capacity.
- Simplifies frequency planning and ground station RF/IF hardware (e.g., number of up/down converters required) at the expense of digital hardware/firmware, which is increasingly less expensive.
- Can directly carry digital formats, and can be used for voice, data and video transmissions.
- Provides greater compatibility with terrestrial digital voice and data networks.
- Offers greater flexibility in accommodating future system growth.

A major disadvantage is that TDMA is not as efficient with thin route users. This disadvantage may disappear in the long term if acquisition cost of required EIRP and G/T can be significantly reduced from a total system point of view.

Another form of TDMA popular with transactional and computer data communications is the packet-switched transmission (e.g., Aloha and many variations thereof). Packet switching does not necessarily improve bandwidth efficiency over the traditional TDMA. However, it provides many simplifications of network access and network control that have traditionally been a major cost component of a TDMA system.

Space division multiple access (SDMA) is actually another form of TDMA, where the access is controlled by the payload antenna visibility. Rapid beam forming and steering synthesis, in conjunction with the multiple beam antenna (MBA), is a requisite technology.

The code division multiple access (CDMA) uses either pseudorandom noise-like code (PN) or a pseudorandom frequency hopping (FH) pattern to represent a single bit, or a group of information code bit(s). Combinations of PN and FH are also used.

As a means of multiple access, CDMA has not been extensively used. If the RF bandwidth is available, CDMA appears to be an excellent means of achieving low power density transmissions (e.g., TDRSS). With recent and projected advances (technology and cost) in fast frequency synthesizers, surface acoustic devices and correlation receiver hardware, CDMA may be viable for multichannel direct broadcast applications.

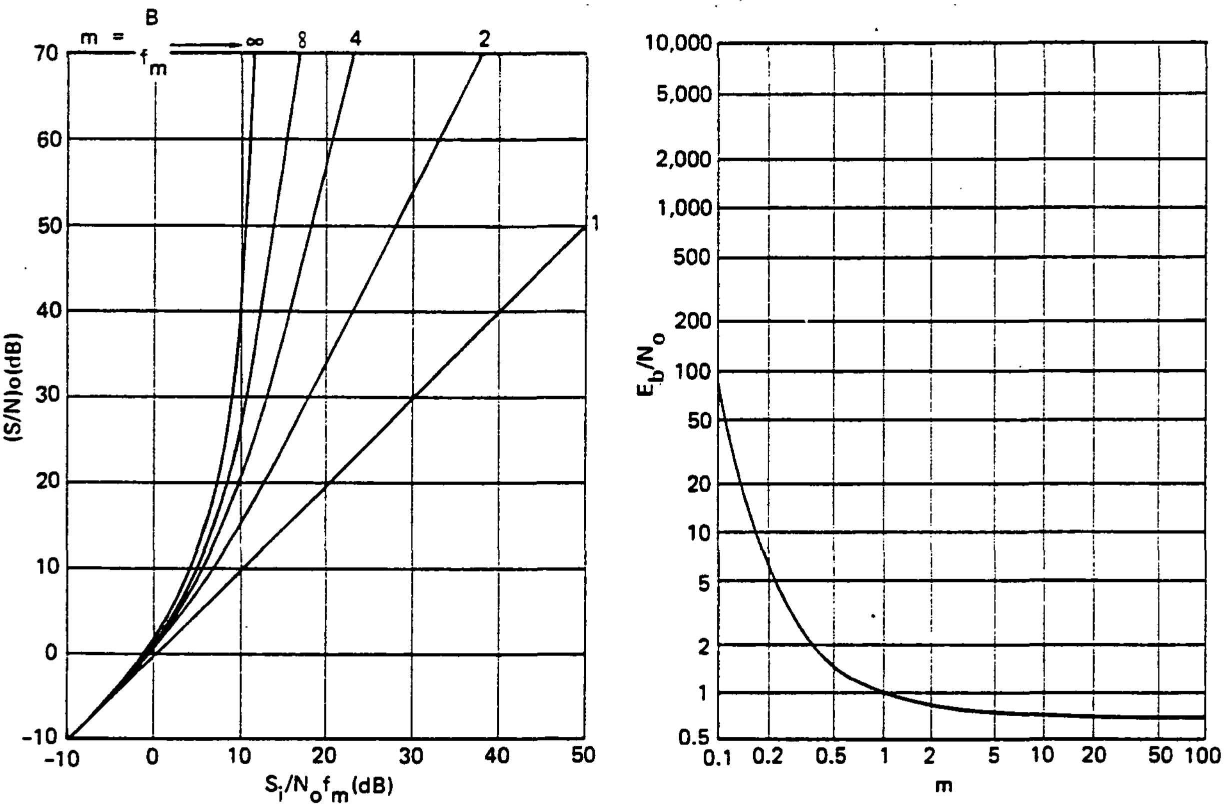
4.2.1.4 Modulation Scheme

The assignment of modulation scheme(s) and access method(s) is an integral process of the payload concept development. Although the performance measures applied to analog modulation systems (e.g., SNR) do not coincide precisely with those applied to digital modulation systems (e.g., BER), they both are a function of the bandwidth expansion factor m, which is defined as the ratio of RF spectrum required to the total intelligence bandwidth that is transmitted by the information source. The upper performance bounds for both analog and digital modulation have long been established by applying the bandwidth expansion factor m to the classic Shannon's equation. Figure 4.2-5 illustrates these theoretical performance bounds. Keeping a proper perspective of these theoretical bounds is quite helpful in dealing with projected technologies 15 years from the current state-of-the-art. Nevertheless, modern digital modulation techniques can be used as the starting point for modulation concept development. These techniques include PSK, FSK, ASK, MSK, APK, and many variations thereof. Figure 4.2-6 illustrates several basic modulation techniques.

Many factors should be considered in determining the modulation schemes. It is important to note that the determination is based, not just on the modem's projected performance and cost in the 1998 era, but also on the overall hardware/software environment projected in the same timeframe from a total payload system point of view.

Among the major factors one should consider in determining the modulation scheme are:

- Data rate to be applied.
- Data detection performance (Eb/No required for threshold BER and WER).
- Bandwidth efficiency (BT product required) if the payload concept is more bandwidth limited from a total space/ground system point of view.
- Feasibility of error correction/detection coding at required data rate if the payload concept is more power limited.
- Ease of modem implementation.
- Impact to overall system concept.



A. Analog Modulation

B. Digital Modulation

Figure 4.2-5 Upper Performance Boundaries

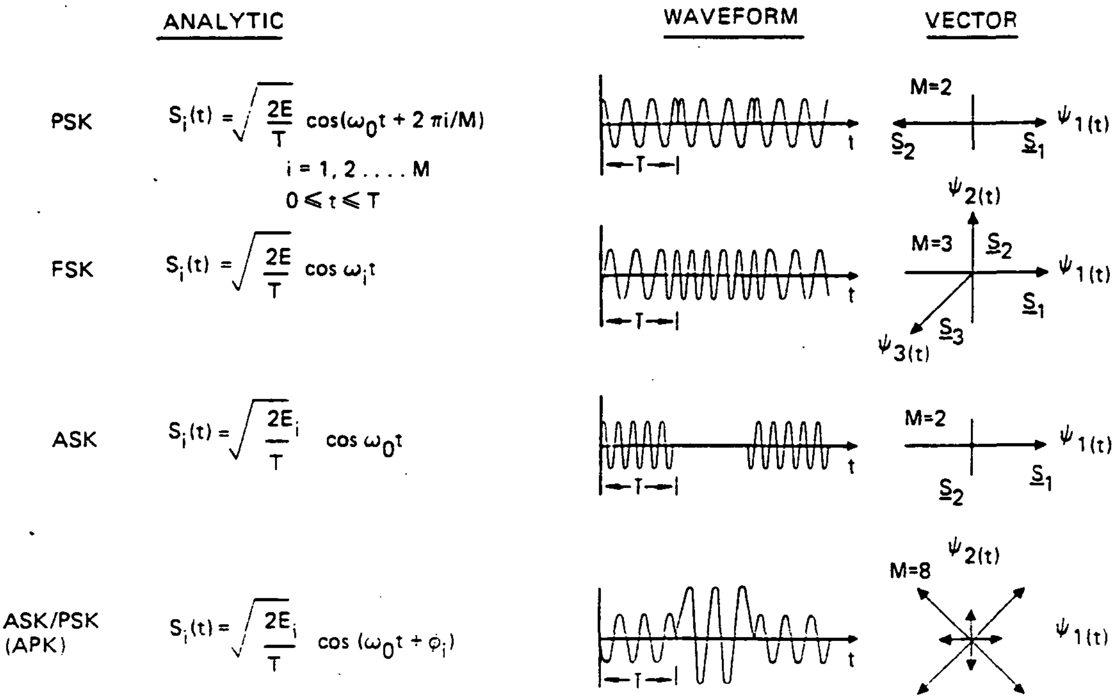


Figure 4.2-6 Basic Digital Modulations

4.2.1.5 Application of Coding

The merits/demerits of incorporating coding as a system parameter is a factor in the payload concept development. It also matters if decoding is performed on board the payload, or at earth stations, or both.

Forward error control, generally known as FEC, together with feedback error control, generally denoted as ARQ, are the two broad categories of error control mechanism employing channel encoding for communication systems.

In FEC, the receiver design, along with the signal design, channel encoding, power, and noise, determines the error rate. In ARQ, where a feedback channel is used, the final performance measure is usually the effective throughput rate and the undetected bit error rate. For extremely low error rate applications, a hybrid approach of FEC and ARQ may be used.

Both the FEC and the ARQ approaches are based on a variety of channel encoding techniques collectively known as coding. For FEC applications, the emphasis usually resides on the error correction capability of the coding. For ARQ applications, the error detection capability of the coding is emphasized.

Figure 4.2-7 illustrates the hierarchy of such error control mechanisms showing the three basic approaches (FEC, ARQ and Hybrid) using coding techniques as building blocks. Relative merits and demerits of these three approaches are highlighted in Table 4.2-1.

The coding techniques themselves embody essentially three different code groups: block code, convolutional code, and synchronization code, which is used mainly for code sync.

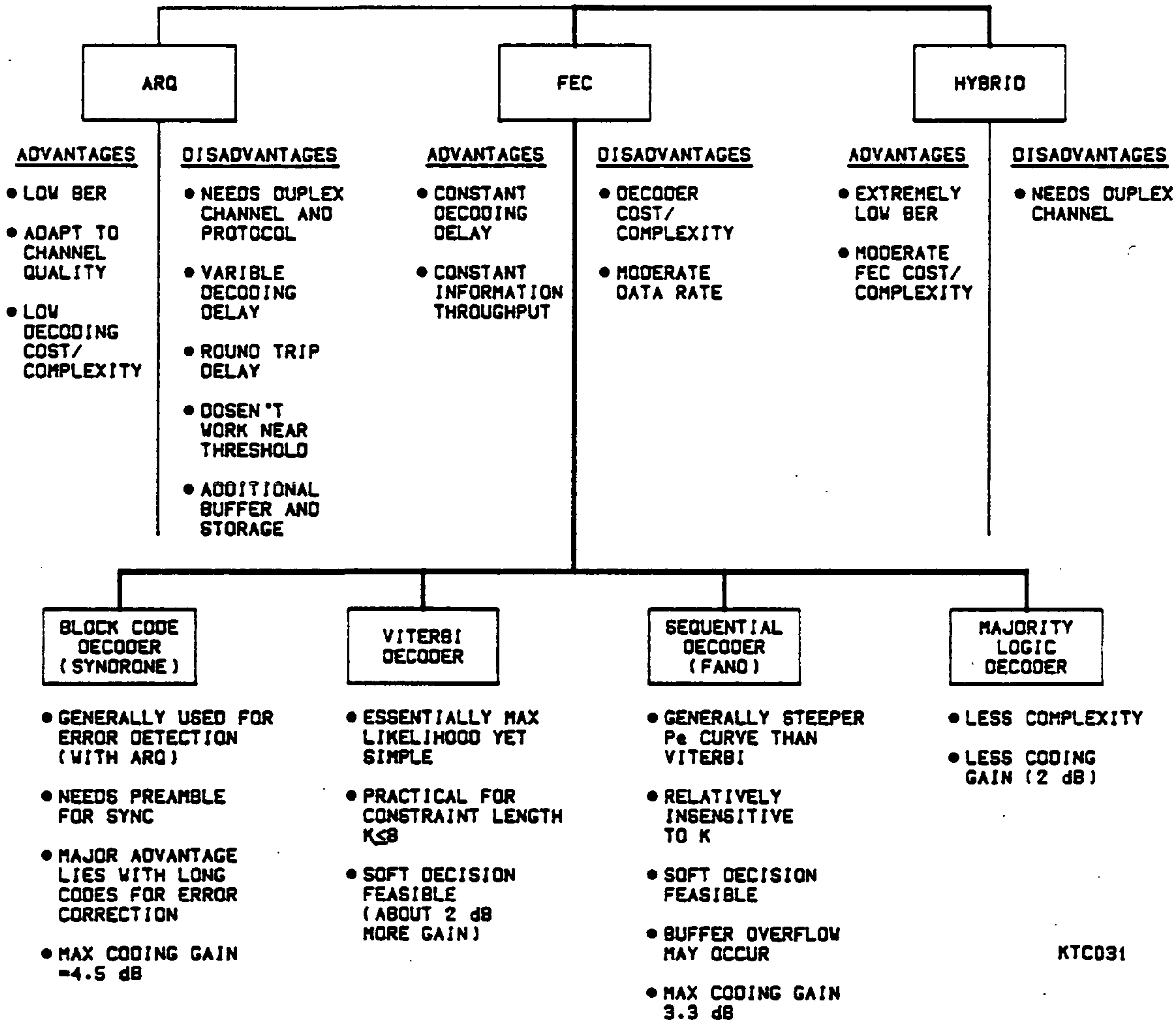


Figure 4.2-7 FEC Tradeoffs

Table 4.2-1

Error Control Techniques

Technique	Advantage	Disadvantage
FEC	Constant decoding delay Constant information throughput Needs no feedback channel Achieve low UBER	Decoder cost/complexity Moderate data rate
ARQ	Adapt to channel quality Low decoding/complexity	Needs feedback channel and protocol Variable decoding delay. Round trip delay burden. Fails when system margin not maintained
Hybrid	Achieve extremely low UBER (eg, 10^{-15} or 1.0E-15) Moderate FEC cost/complexity	Needs feedback channel

The basic idea of coding is to introduce structured redundancy into the information sequence in such a way that the capacity exists for combating errors introduced into a communication channel.

After Shannon's theory in 1948, a systematic approach to block coding based on a formal mathematical algebraic structure between the parity symbols and the information symbols was developed. This approach exploits the algebraic structure of the code for decoding such that an increase in the code length does not require a corresponding exponential increase in the complexity (A rough equivalent to the development of the Fast Fourier Transform (FFT) for the discrete Fourier transform). Many useful codes were developed as a result. These include the Golay, Hamming, Reed-Muller, Fire, BCH, Reed-Soloman and concatenated codes. Of these, the BCH code appears to be the best code for AWGN (Additive White Gaussian Noise) channels.

In addition to the systematic algebraic approach of the block code, a second approach has been developed based on the less structured probabilistic consideration of channel noise effect. This approach results in the concepts of recurrent or convolutional code and its attendant decoding schemes. The convolutional codes are considered the most effective coding developed for an AWGN channel.

For error detection, block code is preferred over the convolutional code because blocking or segmentation is necessary to facilitate retransmission of erred data detected. A decoder for error detection can be easily implemented with any parity check block code.

For error correction, convolutional codes appear to outperform block codes for the same implementation complexity. Furthermore, convolutional codes have the following characteristics:

- o Code sync is much simpler. The block code needs to resolve n-fold ambiguity while a rate 1/2 convolutional code needs only to resolve 2-fold ambiguity (4-fold for a rate 3/4 code).
- o Channel quality information can be easily used in Viterbi or sequential decoding algorithms. That is, bit quantization (soft decision) of demodulator output can be applied to the decoder instead of the demodulator decision itself (3-bit or 8 level soft decision gives approximately 2 dB more gain in Eb/No).
- o With soft decision, decode can monitor channel quality in real time.

Where coding gain is deemed feasible as a system parameter, a 3 dB coding gain can be used to offset any one of the following:

- Cut transmitter power by half
- Reduce antenna diameter by 30% at transmitter or at receiver
- Increase receiver noise figure by 3 dB
- Increase the data rate by 100%, bandwidth permitting
- Increase the communication link or orbital distance by 40%
- Tolerate 3 dB more of implementation losses
- Increase communication availability by an appropriate amount depending on rain statistics of sites

Of course, the main purpose of coding gain remains the reduction of the equivalent bit detection threshold for a given BER.

Like any other communications resource, coding gain is not without its limit. Coding gain is upper bounded by the Shannon capacity theorem. For a PSK channel (with respect to an Eb/No = 9.6 dB at BER = 10^{-5}), this theoretical bound is about 9.4 dB for a rate 1/2 code.

Since the state of the art achieves a coding gain of about 5 dB at this time, future improvement of 4 dB or so can be expected. It should also be noted that for algebraic block codes the existence of any code is further bounded by the so called Elias bound. Figure 4.2-8 summarizes various current coding performances as compared to the Shannon bound.

4.2.1.6 Connectivity Arrangements and Processing.

The use of onboard processing covers a wide range of functions that can enhance the performance of the total communications system. There are three major areas of interest:

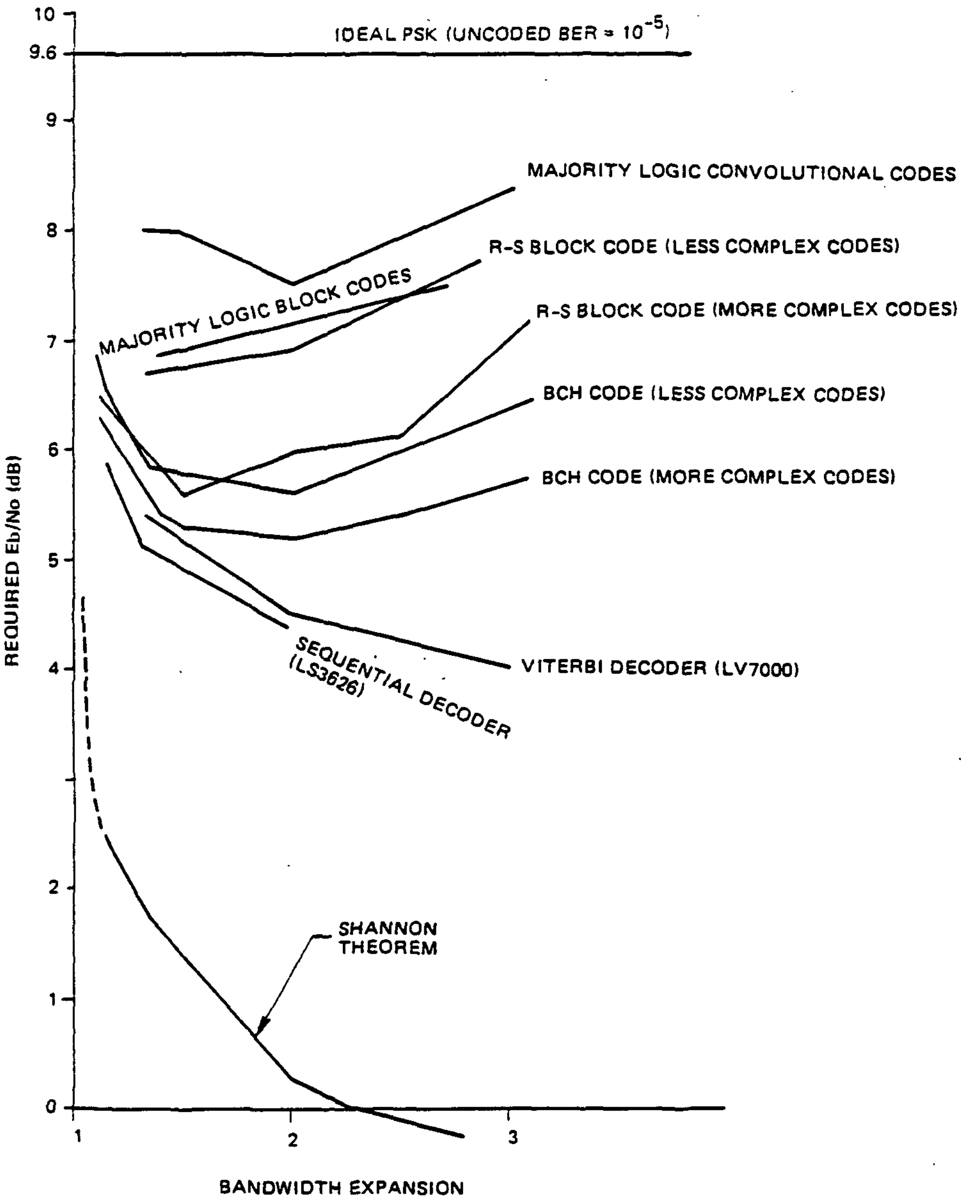


Figure 4.2-8. Performance Envelopes of Decoders

- o Switching/routing
- o Signal Processing
- o Control

4.2.1.6.1 Switching/Routing.

There are several options in providing connectivity for a given payload. The appropriate choice depends on several factors, such as traffic distribution, the number of beams, and the functions the traffic type must support. Figure 4.2-9 summarizes these options by means of simplified block diagrams.

1. No Switching - This configuration is typical of a standard domestic satellite with CONUS coverage. Generally, the ouput frequency of the receiver corresponds to the downlink RF frequency.

2. RF Switching - If frequency reuse and multiple beams are implemented, static switching may be employed at the RF (usually the downlink frequency) level. Switching is normally only done within the same frequency channel (e.g., 40 or 80 MHz).

3. Interband Switching - An example of this type of switching is C/Ku band interconnection used on the Intelsat V and is similar to 2 above except upconverters are required on the Ku downlink.

4. SS-TDMA - The static switch of 2 is replaced by a microwave switch matrix (MSM) which is dynamically reconfigurable in real time; uplink access must be TDMA.

5. IF Switching - The constraint in 2 and 3 that switching can only be done within a frequency channel can lead to reduced fill factors. The use of IF switching allows greater flexibility, but at the cost of up and down converters.

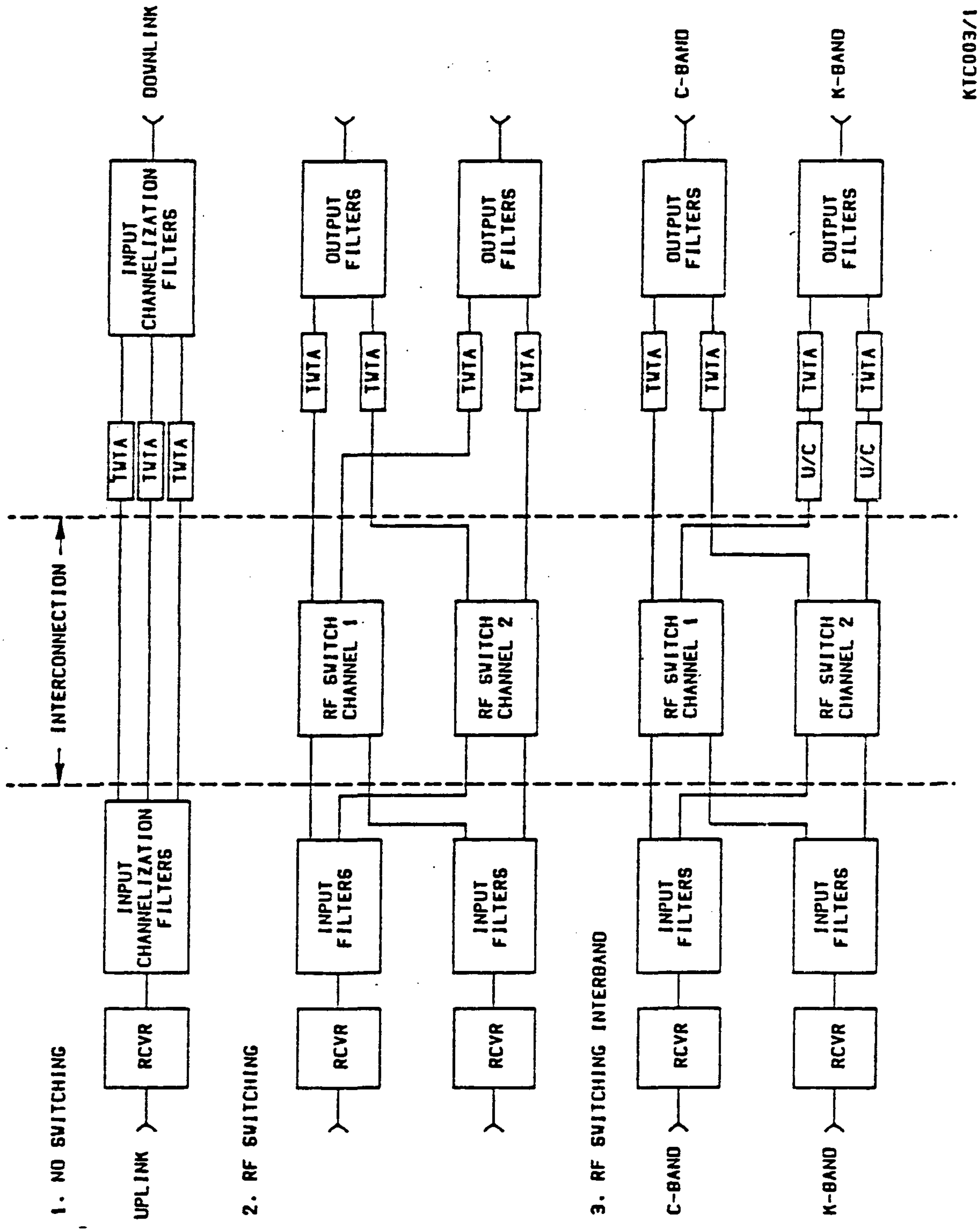


Figure 4.2-9. Interconnection Options
(Sheet 1 of 2)

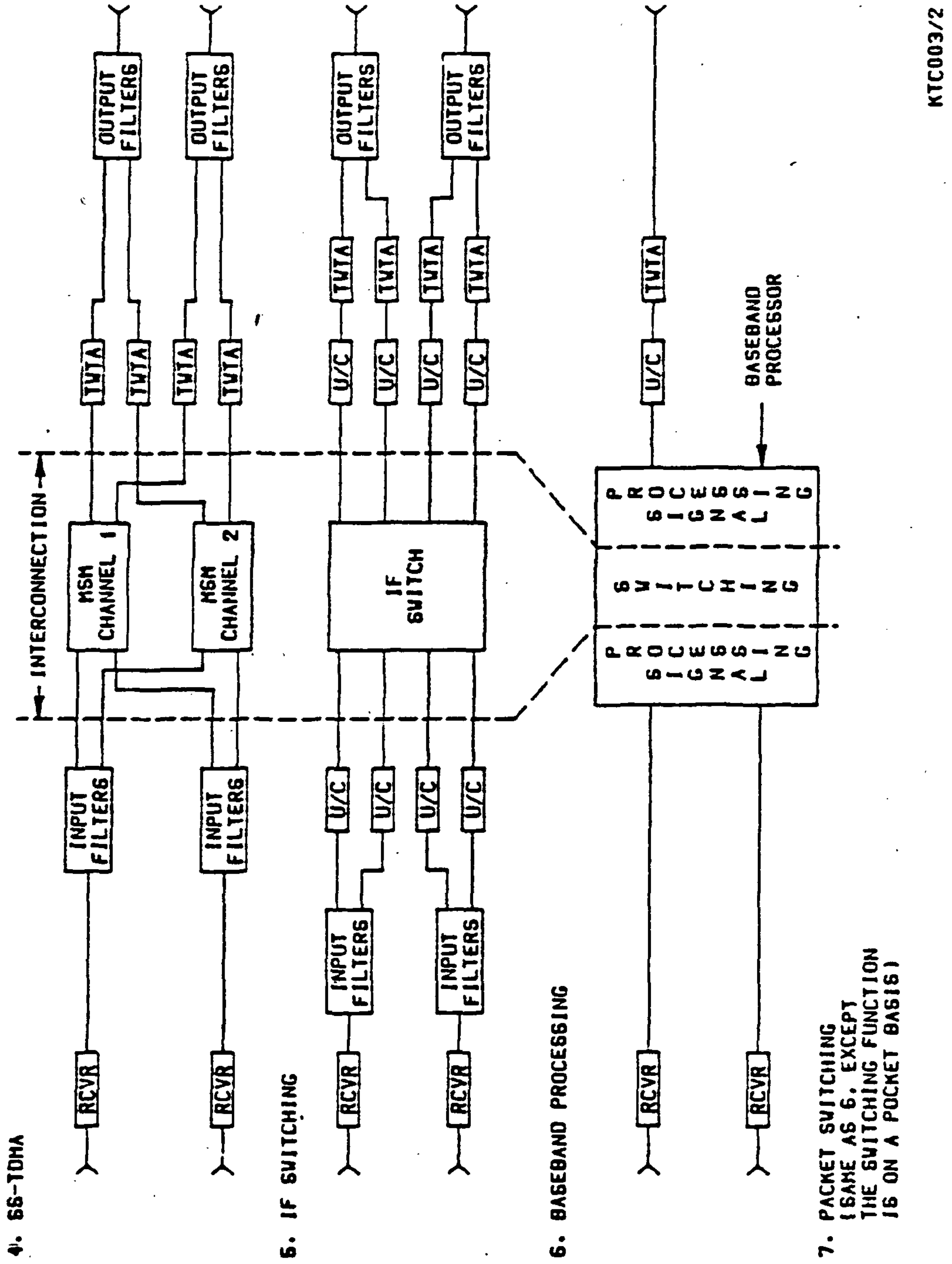


Figure 4.2-9. Interconnection Options
(Sheet 2 of 2)

6. <u>Baseband Processing</u> - The uplink signal is demodulated and demultiplexed to an appropriate level, and switching can then be performed. Other signal processing, such as decoding of digital bit streams, may also be done as required. Demultiplexing can be to the circuit, T1, or higher levels. After switching, the reverse functions are performed prior to downlinking.

7. <u>Packet Switching</u> - A variant of 6 would be to provide a packet switch on board the spacecraft. Although satellite packet systems, such as Aloha, exist today, the satellite does not perform any routing. Use of a true packet switch in the spacecraft would provide many advantages over the Aloha system and would be required in a multibeam case.

4.2.1.6.2 Signal Processing

Signal processing includes several potential functions. Figure 4.2-10 provides a generic view of signal processing. The exact functions used depends on the modulation/access schemes on the uplink and downlink. For example, suppose an architecture called for FDMA with digital modulation (QPSK or other) within each access on the uplink and TDM on the downlink. This approach could reduce earth station complexity and costs, since burst arrival synchronization is not needed. The various accesses would be frequency division demultiplexed, demodulated, and if required for switching, further demultiplxed on a time division basis. Then the functions of time division multiplexing and digital modulation would be required to obtain the output of the baseband processor. The selection of an appropriate sequence for a given payload will depend on such factors as earth station capabilities and traffic requirements

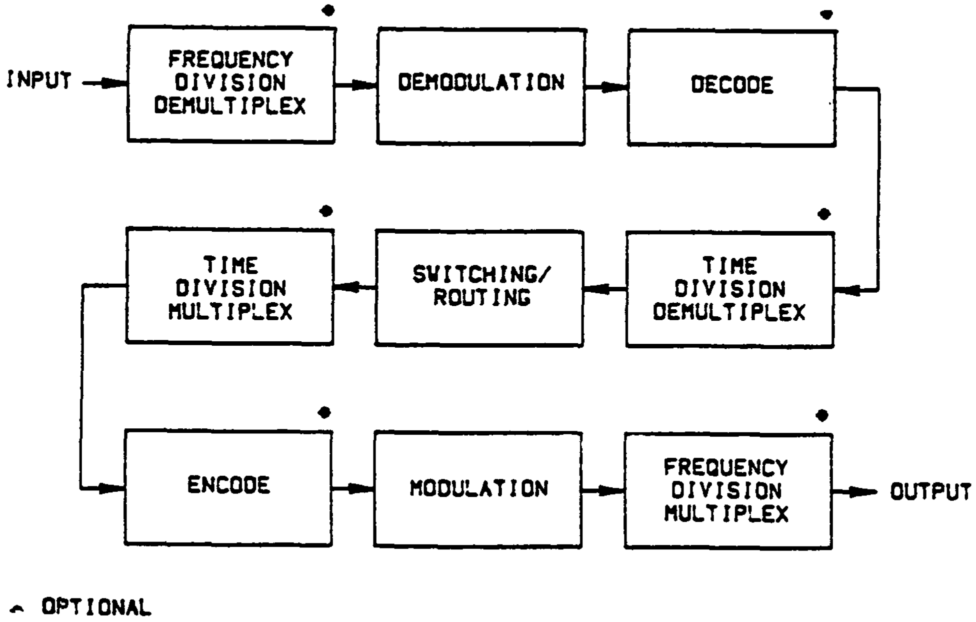


Figure 4.2-10 A Generic Baseband Processor

4.1.6.3 Control

A communications control capability must be provided, particularly for the switching/routing function. Reconfiguration of the system can take place on either a preplanned or a real-time basis. An example of the former would be changing RF connectivity between beams with static switches. This type of switching would only be done occasionally if significant changes in traffic patterns were to occur.

A CPS system, however, requires real-time switching at the circuit level. In the ACTS system, a central or master controlstation on the ground is required for network control. With 1998 technology, it may be possible to provide a large portion of the communications control capability in the satellite, as is being done in Milstar. This approach would reduce orderwire traffic and speed the setup of calls.

Other control functions would include SS-TDMA switch operation, beam pointing control, crosslink acquisition, and link control (adaptive techniques for rain fading).

Two important considerations in a control architecture are reliability and hardening. Single event upsets ("bit flips")are tolerable in signal processing or switching circuitry, but not in the control area. Various approaches - including use of a hardened technology such as CMOS/SOS, redundant (voting) systems, or error correction, can be used to solve this problem.

4.2.1.7 Ground Asset Feasibility

In order to establish a complete communication system architecture and to ensure system realizability and compatibility, the supporting terrestrial communications assets are hypothesized for each service aggregation scenario. The terrestrial segment under consideration includes the platform communications control facilities, the projected user terminals, and their ancillary interfaces to existing terrestrial communications networks.

From a platform communications control viewpoint, the extent of communication service control to be performed by a terrestrial control center, including demand assignment, resource allocation, and message routing/sorting, can be evaluated. Such scenarios presuppose continued advances in VLSI circuitry to permit colocation of digital baseband processing and switching equipment on a geosynchronnous platform. This equipment, used in conjunction with the multiple spatial reuse of spectrum offered by large spot beam antennas, has the potential of reducing the complexity of existing terrestrial master control stations while greatly increasing the degree of throughput.

4.2.2 Space/Ground System Trades and Concept Ranking

The payload concept development is not complete without an assessment of the system reliability/availability from a total space/ground system point of view.

The space/ground system reliability/availability refers to satellite (including satellite bus) availability and link availability. The satellite availability is the probability that a particular satellite will be available for use at a given time. This availability is a combination of satellite reliability, satellite replenishment, and in-orbit service strategy forecasted for 1998. Some of the significant variables whose values must be estimated in predicting the availability include:

- Number of satellites to be deployed
- Mean time to failure
- Cost of satellite and cost of delivery
- Cost of in-orbit services and cost of positioning spares
- Turnaround times to replace failed satellite and to service
- Event threshold that will trigger a decision to replenish or service
- Probability of further deterioration of payload during replenishment or service

The link availability is the probability that a link of specified capacity and quality connecting system users is operating at any time. Significant variables concerning link availability are:

- Satellite availability
- Earth terminal availability
- Satellite visibility
- Signal level variations
- Satellite conjunction

Each of these factors affects the link availability.

4.2.3 Traffic Loading Analyses

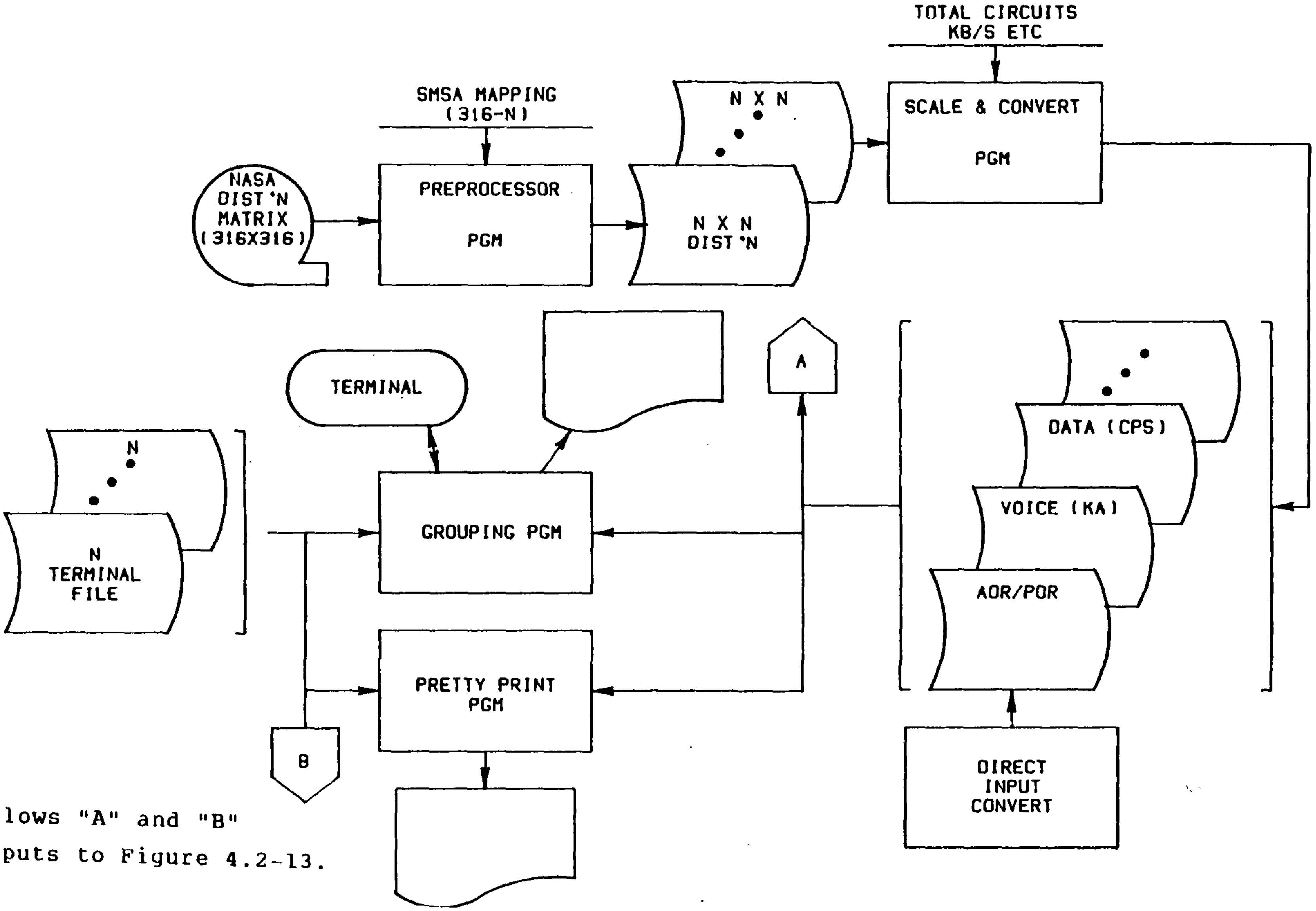
The payload concepts developed in Task 3 utilized several computer programs to manipulate various traffic data bases and to load the traffic to a given payload. Also, several concepts have been used to optimize payload designs relative to the assumed traffic forecasts.

4.2.3.1 Computer Programs

4.2.3.1.1 Traffic Data Base Programs

Two programs were developed to process the 316 x 316 SMSA traffic distribution tape provided by NASA at the beginning of the study. These are the "Preprocessor" and "Scale and Convert" programs depicted in Figure 4.2-11.

It was deemed that working with the full 316 x 316 matrix would result in a very large amount of time in just bookkeeping such factors as SMSA-to-beam relationships as design iterations proceeded. The Preprocessor provides the capability to shrink the original matrix to a smaller one by mapping each of the SMSA's to one of N regions, or "pseudo-terminals". No attempt was made to model <u>all</u> of the terminals on the system. The two basic mappings employed were to 20 x 20 and 84 x 84 matrices. The former was used for the 20 Ka-band fixed spot beams, and the latter was used for all other designs. The 84 regions, which



Note:

Data flows "A" and "B"
are inputs to Figure 4.2-13.

Figure 4.2-11 Preliminary Traffic Processing are sufficient for determining beam coverages, were based on [Ref. 12]. Figure 4.2-12 illustrates the regions (there are more than 84 regions, but some contained no SMSA's and hence no traffic). Appendix A contains listings for the two mappings, as well as printouts of the 20 x 20 and 84 x 84 matrices.

The original tape gave the distribution only, with the total of all entries equal an arbitrary value of 10^7. The output of the Preprocessor is similarly normalized. The Scale and Convert program accepts a single number which represents the total traffic of a given type--voice, data, etc., and converts an NxN distribution matrix to one whose total entries sum to the given number (with some roundoff), and with the same distribution. The total traffic numbers are described in Section 2.2.2.2. The output is also in binary form for more efficient storage and I/O in subsequent programs; the original tape was in "print" format.

Input of other traffic data bases, such as Intelsat, Canada, and Brazil, were manual, and existing programs were used to convert this input to the common binary format.

Two other programs shown in Figure 4.2-11 had been previously developed. The "Grouping" program allows one to group terminals arbitrarily, and provides a group-to-group traffic matrix. This aids the process of designing beam coverages from a traffic balancing aspect (see Section 4.2.3.2.4). Other uses, such as estimating ISL capacity requirements, can be performed with this program. Examples of the output are given in Appendix B. The "Pretty Print" program provides a listing of any desired traffic matrix; examples are given in various appendices (e.g., Appendix A).

One additional program, not shown in Figure 4.2-11, was developed to eliminate all traffic in the original NASA tape between SMSA's closer than 400 miles. Distances were based on

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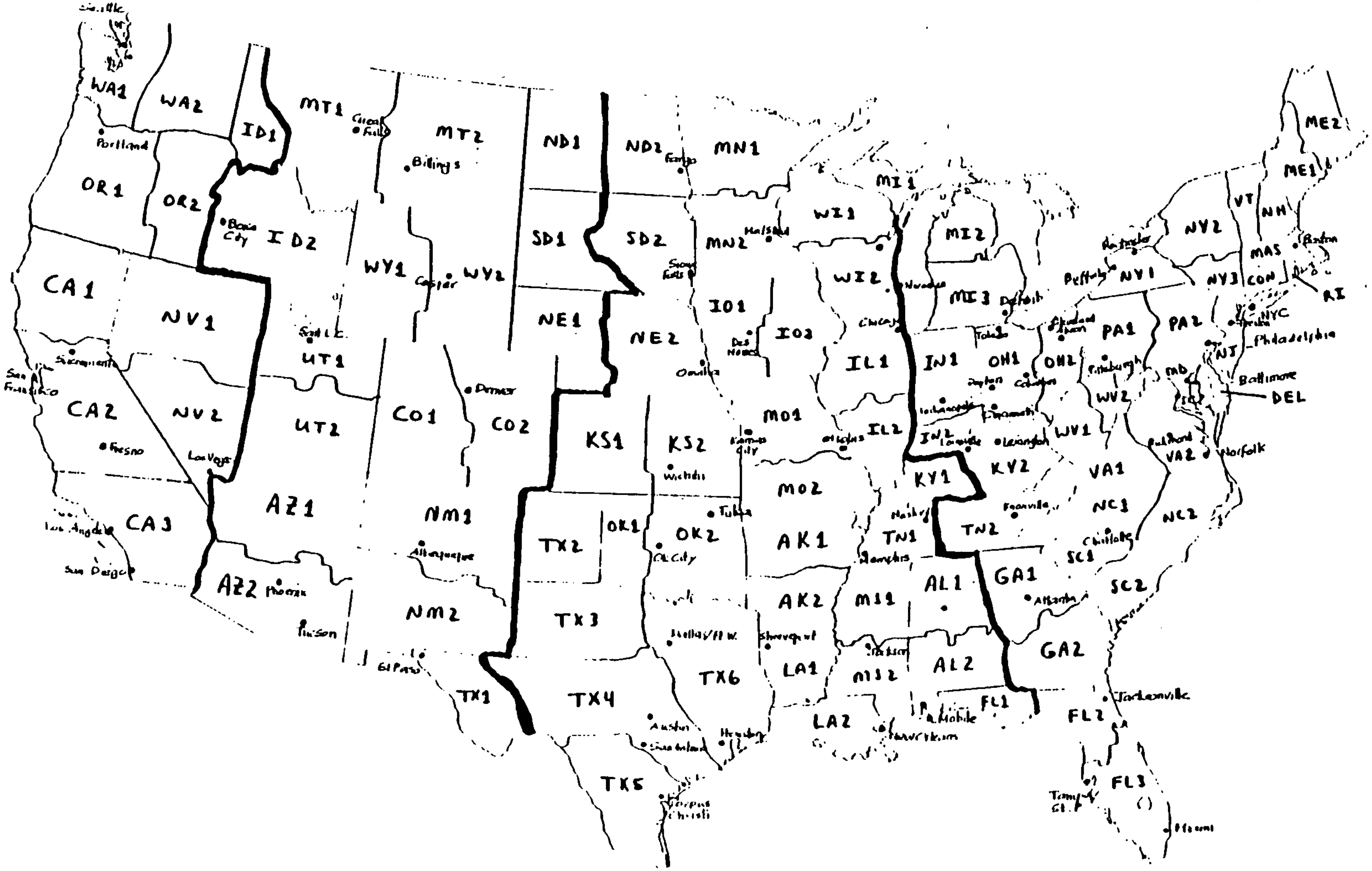

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Figure 4.2-12 State Subdivisions

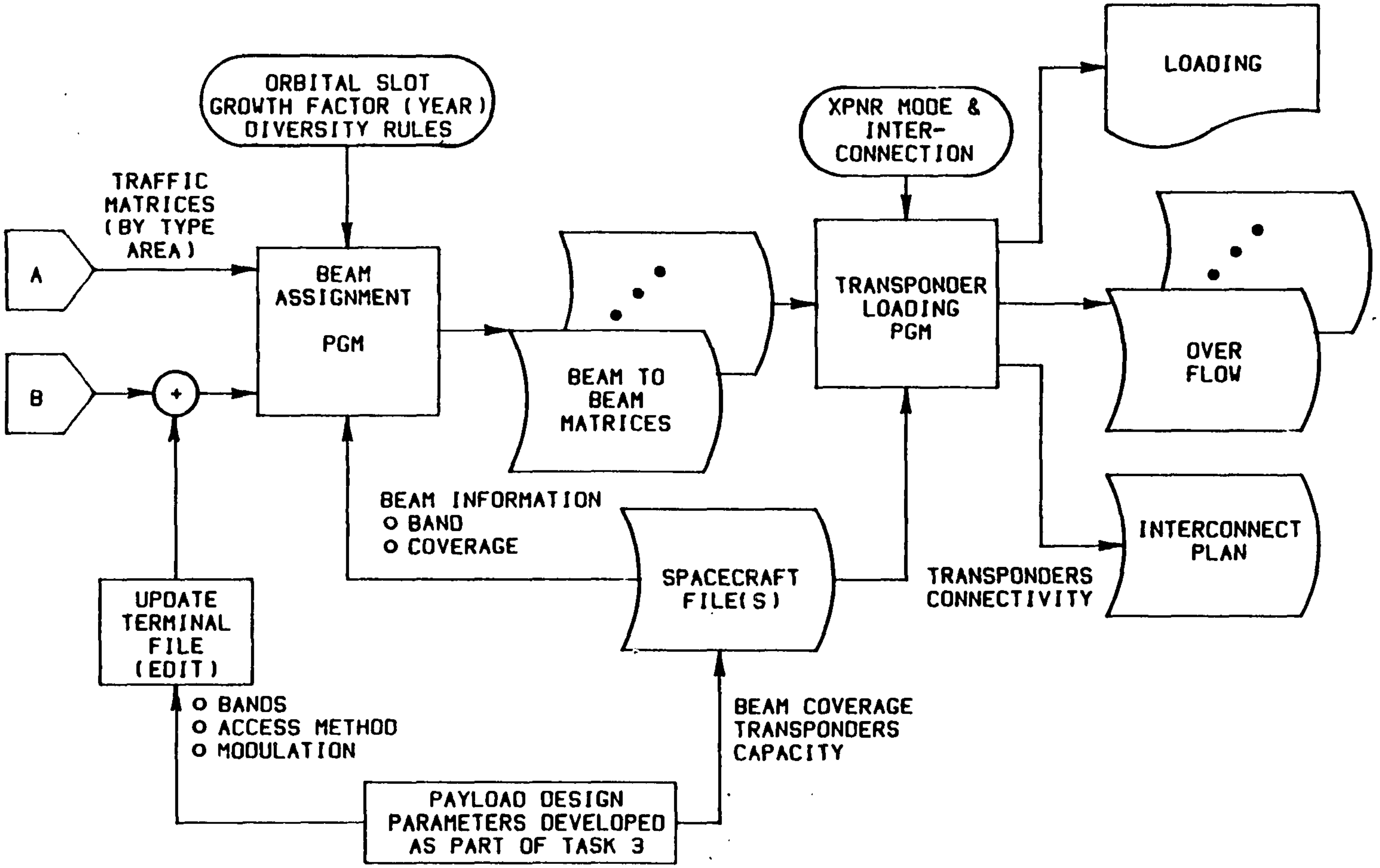


Figure 4.2-13 Satellite Integration Planning System (SNIPS)

V&H coordinates of each SMSA provided with the original NASA tape.

4.2.3.1.2 Traffic Loading Programs

Ford Aerospace developed a set of traffic loading programs several years ago to analyze payload designs for Intelsat and other spacecraft. It has been our experience in designing complex payloads that analysis of the numerous tradeoffs involved can be significantly enhanced by the use of automated tools; otherwise, only a very limited set of options can be investigated. Frequently, preferred designs only become apparent after many iterations of the design process.

Figure 4.2-13 illustrates the system called SNIPS -- Satellite/ Network Integration Planning System; some data inputs are carried over from Figure 4.2-11. SNIPS is designed primarily to evaluate a complex payload consisting of many transponders, multiple beams with frequency reuse, and a large traffic data base with many earth stations. It is precisely this type of payload that would be time-consuming to analyze manually. On the other hand, evaluation of a "simple" payload, such as DBS, is best performed manually.

Traffic data bases are described in the previous section. The earth station data base is a file of earth stations that will be operating with the payload being evaluated. The capabilities of each earth station are also contained in the data base. Briefly, the information required is the frequency bands (antennas), capacity, access type, modulation type, and any other capability, such as 24 kb/s voice encoding, which affects usage of satellite capacity. A spacecraft payload data base is required. Table 4.2-2 lists the elements contained in this file. Some other inputs, not shown in Figure 4.2-13, are also used. For example, the total traffic in the data base can be split between multiple orbital slots on a table-driven basis.

Table 4.2-2

Spacecraft Payload Data Base

Data Base Elements:

- Transponders
  - Frequency band and channel
  - Bandwidth
  - Beam
  - EIRP and G/T
  - Signal processing
- Interconnection and Switching
  - Permissible interconnections
  - SS/TDMA
  - Circuit
- Beams
  - Frequency band
  - Earth stations covered
  - Scanning spot beams

The heart of the system consists of two computer programs. The first program translates point-to-point traffic to a set of beam-to-beam traffic matrices by type: modulation, frequency band, etc. These matrices are built up by matching each point-to-point demand with the earth station capabilities and their beam location, as defined in the spacecraft data base, multipling by the slot diversity factor for the particular orbital slot under study, and accumulating the result in the appropriate beam-to-beam entry. This program is a simple, sequential process which automates a very large and tedious task. It is interactive, and multiple sets of beam-to-beam matrices can be generated and stored at one time.

The second program, also interactive, utilizes a combination of user input from the terminal and an optimization routine. The information the user must supply is how each transponder is operated (e.g., FDMA, TDMA) and the interconnection or switching of transponders, including SS-TDMA. A maximal flow algorithm is used to find the optimum loading using the set of beam-to-beam matrices discussed above. Outputs at the terminal are available which guide the user in determining a better transponder usage and interconnect plan. These outputs include such items as transponders with low fill, or unsatisfied demands. This iterative process continues until no better plan can be found. The final output gives the complete loading and can be used to evaluate the efficacy of a particular payload complement. Based on this evaluation, the earth station or spacecraft data bases can be altered and the process repeated.

A second version of the transponder loading program had to be developed for this study to analyze some of the very large payloads considered. Storage limitations on the PDP-11/70 prevented using the existing version of the program for these payloads. The new version did not utilize the maximal flow algorithm because the flow network set up by the program is the major driver regarding storage. The capabilities of the maximal flow algorithm are most useful when the beam design consists of several nested coverages, where the combinatorial aspects of beam overflows (see Section 4.2.3.2.6) become quite complicated. The payloads to which the new version was applied had only limited nesting and overflow, so there was not much loss in the ability of the program to find near-optimal loadings.

Other factors were handled by appropriate data base definitions. For example, U.S./Europe traffic routed to the ISL in Scenario VI-A used a "psuedo-beam" representing the ISL, with all European terminals located in the pseudo-beam.

4.2.3.2 Traffic and Payload Design Optimization

In this section, various concepts used in the design of the payloads are discussed. These concepts were primarily applied to the C- and Ku-band payloads, which were assumed to serve analog traffic; utilization becomes a critical issue when static switching of transponders must be employed. Some concepts were applied to other payloads, such as scan area coverages, as well.

4.2.3.2.1 Single Satellite Traffic Loading

Given the total traffic data base and its distribution, one must decide how traffic will be loaded to a single satellite. Figure 4.2-14 illustrates two possible approaches. In Approach 1, the total traffic is offered to the "first" satellite.

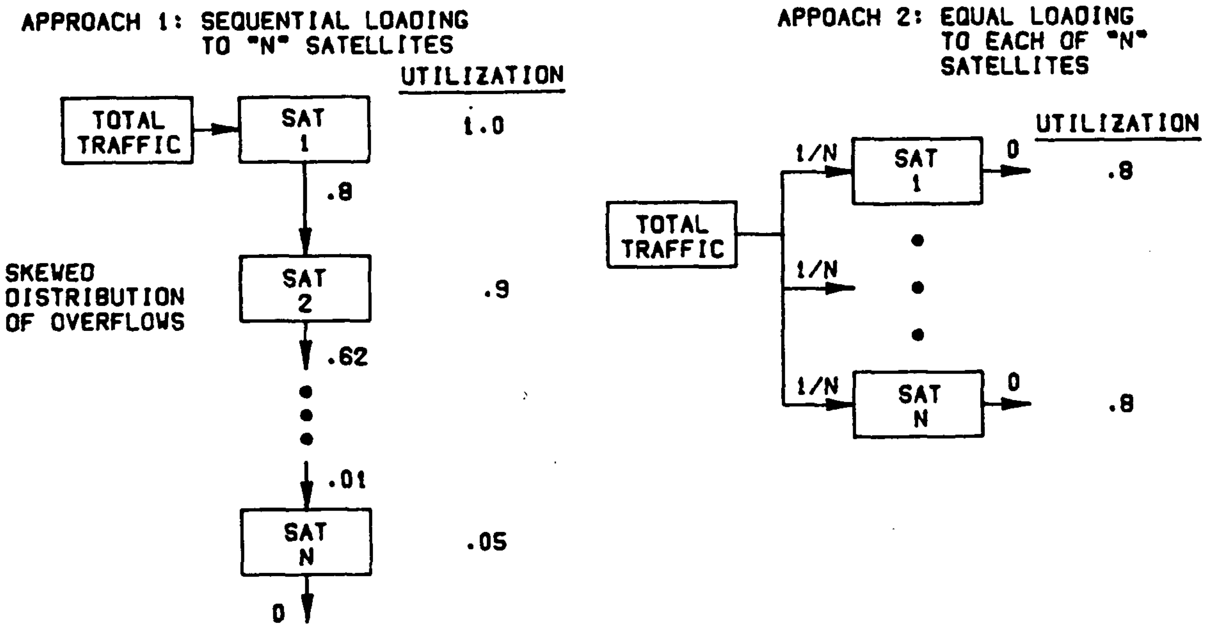


Figure 4.2-14 Loading to a Satellite Constellation

Since this satellite can carry only a fraction of the total traffic, it is likely that a utilization, or fill factor, of nearly 1.0 would be achieved. The remaining, or overflow-traffic, is now offered to the second satellite in the constellation, and so on until all traffic is loaded. The problem with this approach is that each overflow has a skewed distribution relative to the previous one. That is, the first satellite may carry all of the Seattle-Denver traffic, and the last satellite is only carrying New York-Chicago traffic.

Approach 2 divides the traffic into N equal partitions, each with the same distribution, where N is the number of satellites required to serve the total traffic. N is chosen as the smallest value which causes no overflows.

An argument can be made that if the total traffic were to be split among various major carriers or other users, the distributions would be similar - AT&T's distribution is probably very close to that of GTE Sprint or MCI. Approach 2 obviously fits this concept better than Approach 1. Another reason Approach 2 was adopted was that only a single loading is required, although iteration is required to find the appropriate value of N. Approach 1 would have required N different loadings, along with multiple traffic data bases. A different interconnect plan would have to be developed for each of the N loadings.

4.2.3.2.2 Traffic/Payload Assignments

Various types of U.S. domestic traffic were defined in [Ref. 8]. Table 4.2-3 indicates how each traffic type was assigned.

Table 4.2-3

Traffic/Payload Assignments

Traffic Type	Payload
Trunking	
Digital Voice + Video Conferencing Channels	Fixed Ka + Scan Ka Trunking
Data	Ku FSS(1)
Analog Voice	Ku FSS with overflow to C
CPS	
Voice + Data + Video Conferencing	Scan Ka CPS channels
Broadcast Video (3)	
Scenario II	Ku FSS and C
Scenarios V, VI-A, VI-B	C(2)

(1) In Scenarios V, VI-A, and VI-B, a small amount of thin route data, assumed to be low rate (9.6 Kb/s) was overflowed to C-band, analog modulation.

(2) Ku beam coverages in these scenarios precluded application to broadcast video.

(3) See Table XIX of [Ref. 8].

4.2.3.2.3 Effective Reuse

Satellite operators and manufacturers frequently make claims regarding the number of circuits which a particular spacecraft can carry. This value is arrived at by multiplying the number of transponders times the maximum capacity of each. As one increases the number of beams from a simple CONUS coverage, where traffic distribution characteristics are not a factor, to obtain greater reuse, utilization decreases. The effect is generally of an inverse-square form, as a function of the number of beams, because the point-to-point traffic is distributed over a 2-dimensional matrix. Figure 4.2-15 illustrates the effect.

Use of SS/TDMA can alleviate much of the problem, but other means must be employed for analog modulation. Subsequent sections will give simple examples to illustrate the concepts.

EFFECTIVE REUSE

"SATELLITE XYZ, THROUGH 100 TIMES REUSE OF BANDWIDTH, CAN CARRY OVER SEVEN MILLION SIMULTANEOUS VOICE CIRCUITS."

QUESTION: AT WHAT UTILIZATION WHEN LOADED WITH A REALISTIC TRAFFIC DISTRIBUTION?

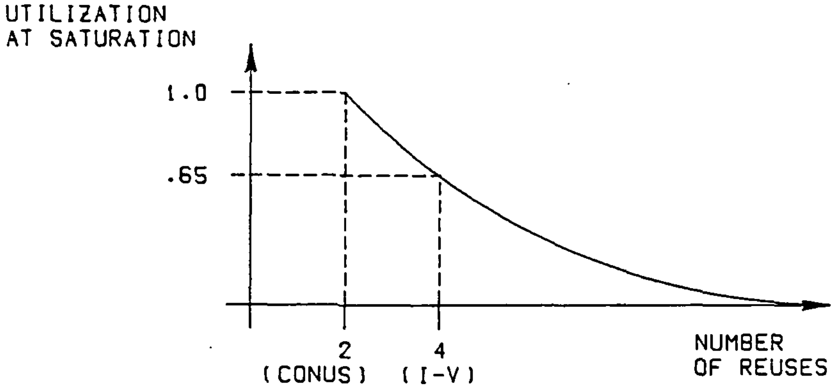


Figure 4.12-15 Effective Re=use

(1) The Ka-band fixed spots were assumed as given in Volume II of Western Union Report.

(2) In CONUS, or other broad coverage beams, such as the Ku coverage for Brazil in Scenario VI-B, the distribution of traffic is irrelevant.

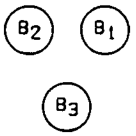
4.2.3.2.4 Traffic Balancing

An important concept in designing beam coverages is to provide equal loads in each beam (or, as equal as possible, given beam separation constraints). If this is not done, then as traffic with a fixed distribution is loaded, one beam will saturate at a point where other beams are not fully loaded. These beams will thus have unused equipment. The more unbalanced the traffic in various beams, the worse this problem becomes.

Figure 4.2-16 provides a simple example. Each of three transponders are routed through an SS/TDMA switch. Even though

ASSUMPTIONS: 3 BEAMS, 1 CHANNEL PER BEAM, 1000 CKTS/CHANNEL
SS/TDMA SWITCHING

TRAFFIC:	B_1	B_2	B_3	BEAM TOTAL
B_1	100	800	600	1500
B_2	800	0	0	800
B_3	600	0	100	700
				3000



FREQUENCY PLAN &
SATURATION LOADING

	F_1
B_1	1000
B_2	533
B_3	467

UTILIZATION (AT SATURATION) $= \frac{2000}{3000} = .67$

"EFFECTIVE" REUSE IS 2X, NOT 3X

Figure 4.2-16 Traffic Balancing and Utilization the total traffic can, in theory, be carried, the distribution is such that Beam 1 saturates at a level of 2/3 of the traffic. The 100 circuits from Beam 3 to itself could also be loaded, but then the distribution of the traffic carried would be different than the distribution of the total (see Section 4.2.3.2.1).

Note that traffic balancing applies to an SS/TDMA architecture, because it concerns the total traffic generated by a beam, and not connectivity between beams, where other problems, subsequently discussed, can arise.

There were two areas where balancing did not apply in the payload concepts:

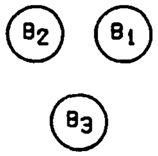
4.2.3.2.5 Connectivity

When static switching is used to interconnect channels of a given frequency, a common approach to switching on-board, e.g., Intelsat-V and most channels in Intelsat-VI, then it is possible that capacity exists in the beams, but they cannot be interconnected because of the switching arrangement described above. Figure 4.2-17 illustrates the situation. There is a demand for 1000 circuits (each direction) between Beams 2 and 3, but it is not possible to interconnect the unused transponder in each of these beams. The interconnection can be changed to accommodate the Beam 2 - Beam 3 traffic, but one of the other required connectivities will be lost.

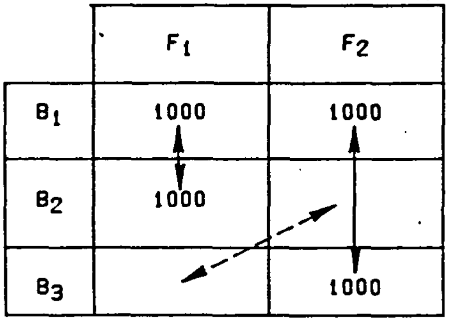
This problem usually only occurs when one is trying to squeeze the last few requirements into the loading, so does not cause a severe problem. Typically, it may reduce the loading by about 5%.

ASSUMPTIONS: 3 BEAMS, 2 CHANNELS PER BEAM, 1000 CKTS/CHANNEL.
STATIC SWITCHING (3 X 3 PER CHANNEL)

TRAFFIC:	B_1	B_2	B_3	BEAM TOTAL
B_1	0	1000	1000	2000
B_2	1000	0	1000	2000
B_3	1000	1000	0	2000
				6000



FREQUENCY PLAN



	F_1	F_2
B_1	1000	1000
B_2	1000	
B_3		1000

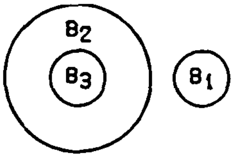
$$\text{UTILIZATION} = \frac{4000}{6000} = .67$$

Figure 4.2-17 Connectivity and Utilization

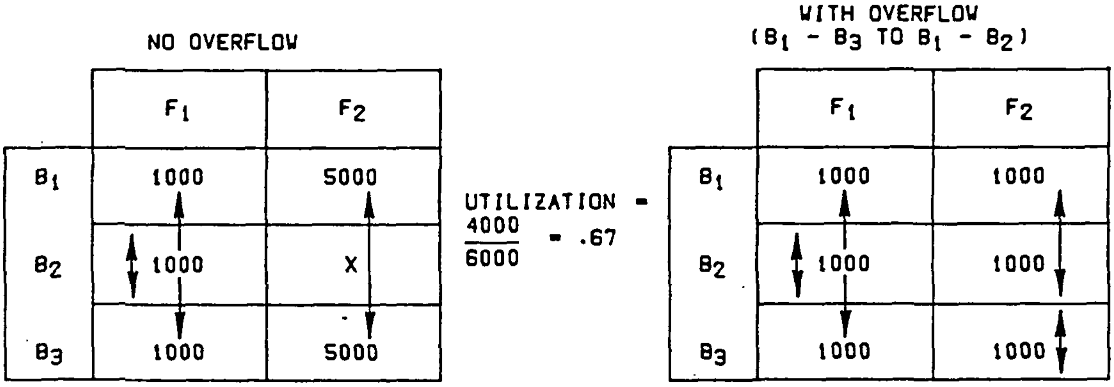
4.2.3.2.6 Beam Overflows

A very useful technique, when one has nested beam coverages, is to allow overflows from the smaller beams to those that "cover" them. Figure 4.2-18 shows how this can be done. Of the 1500 circuits (each way) between Beams 1 and 3, 1000 can be loaded in F1 transponders. The remaining 500 are then combined with the 500 circuits between Beams 1 and 2, and loaded in F2 transponders. Those terminals in Beam 3, whose traffic is overflowed, must operate at Beam 2 frequencies and/or polarization.

o ASSUMPTIONS: 3 BEAMS, 2 CHANNEL PER BEAM, 1000 CKTS/CHANNEL.
STATIC SWITCHING (3 X 3 PER CHANNEL)



TRAFFIC:	B_1	B_2	B_3	BEAM TOTAL
B_1	0	500	1500	2000
B_2	500	1000	0	1500
B_3	1500	0	1000	2500 6000



UTILIZATION $= \frac{4000}{6000} = .67$

UTILIZATION $= \frac{6000}{6000} = 1.0$

Figure 4.2.18 Beam Overflows and Utilization

4.2.3.2.7 Modularity of Capacity

When a static switching connection is made between two beams, then the entire capacity of the transponders is devoted to carrying traffic between the two beams. An extreme example ofthe problem occurs in Scenario VI-A in the "South of the Border" coverages. Some of the beam- to-beam requirements are as low as 19 circuits. With assumed transponder capacities of 2800 circuits, a fill factor of less than 1% would result.

One way to alleviate the problem is to split a 36 MHz bandwidth into two or more sub-bands, each with their own switching. Another approach is to perform A/D and D/A conversion on board, and utilize SS/TDMA or BBP to route a digitized signal, thus providing the advantages of this architectuare to analog users. Both of these approaches have been used in our payload concepts where appropriate.

4.3 SCENARIO II PAYLOAD CONCEPT DEVELOPMENT

4.3.1 General Description

Scenario II consists of medium capacity CONUS (including Alaska, Hawaii, and Puerto Rico) FSS and medium power DBS payloads. As shown in Figure 4.3-1, the FSS payload provides Ka-band (fixed and scanned) Ku-band and C-band coverages. The DBS payload provides CONUS coverage with two beams, allowing programming for two different time zones. Figure 4.3-2 summarizes the Scenario II payload.

4.3.2 Institutional and Regulatory Issues for Scenario II

The purposes and priorities are FSS and DBS communications within the CONUS. The FSS (point-to-point) communications face intense competition for the long-distance traffic, which was only recently the exclusive province of AT&T Long Lines. This competition is not only from terrestrial circuits. There is intense competition for orbital positions in applications before the FCC. By the time that the platform is ready to apply to the FCC for constructon permits, the available orbital slots in the C and Ku (FSS) Bands will undoubtedly be assigned. The Ka (FSS) Bands may also be assigned.

The DBS applications have undergone a change from the initial concepts of high-powered (200 w.) spacecraft transmitters with quarter-CONUS beams to 100 w. transmitters with half-CONUS beams. This change has permitted the incorporation of more transponders, and the plans to use large spacecraft has increased the number of transponders (channels) to 16 per satellite. Since each orbital slot can support only 32 of these channels, only two of these satellites can be co-located at each orbital slot. This approach lowers the orbital capacity for DBS satellites over the CONUS, and will probably increase the competition for DBS assignments. However, the DBS economic

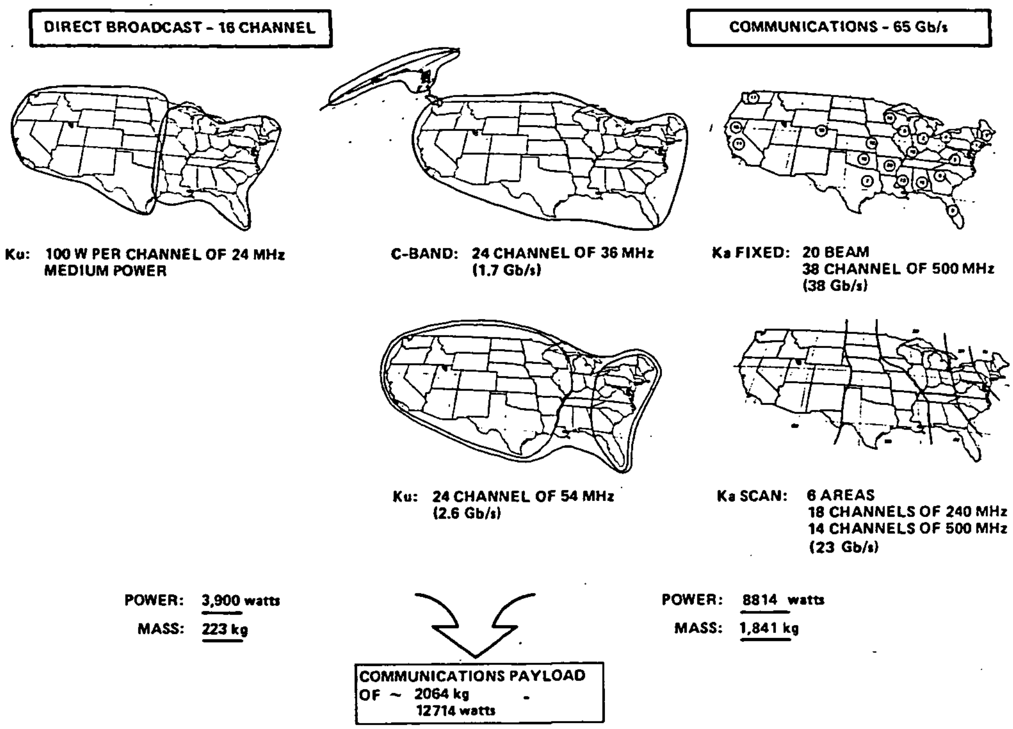


Figure 4.3-1 Scenario II - Services Allocation

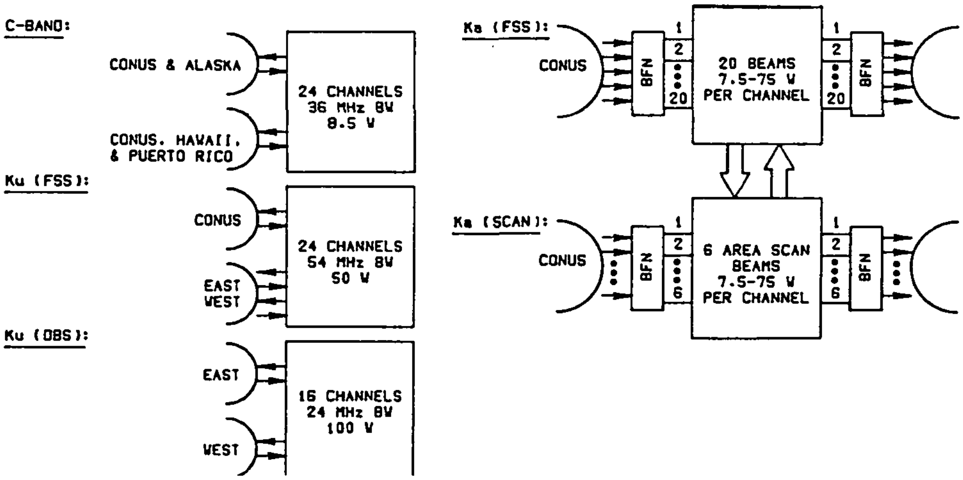


Figure 4.3-2 Scenario II Overview

returns remain to be demonstrated. Recent abandonment or postponement on DBS plans by a number of entrants has cast doubts on the DBS future, and may lessen competition in this field.

In order to obtain a suitable orbital position, a current licensee, or a number of current licensees, of these slot assignments will have to agree to use their geostationary orbit slot or slots for a platform. An alternative is to persuade the FCC to identify an orbital slot for future platform use, and to make no permanent assignments for this slot. If the case for the platform could be made strong enough, the FCC could refuse to renew the current slot assignments and re-assign a slot to the platform.

The likelihood of the FCC maintaining a spare slot for the platform, or withdrawing "squatter's rights" from a current holder of an orbital slot for reassignment to the platform, appear to be remote. This possibility could change if the orbit became so crowded that the platform provided the only viable solution. However, the current slump in the demand for satellite capacity, and the possibility of additional spectrum allocations for satellite communications, indicate that other solutions will be available. Hence, the most likely prospect is for one or more of the carriers holding suitable orbital slots, combining into a Consortium to build and operate the platform. A financially strong domestic carrier, who holds suitable orbital slot assignments, could take the lead and incorporate the payloads of other carriers into the platform.

The dominant carrier would be expected to take the lead in the following activities:

1. Obtaining the financing.
2. Obtaining the regulatory approvals from the FCC. Dealing with the concerns of other satellite carriers who may oppose the platform concept. Coordinating with other users of the radio-frequency spectrum who may suffer or cause harmful interference.
3. Enlisting the participation and support of other carriers who are interested in owning a payload on the platform, and in taking the lead in clearing away any anti-trust laws which may preclude such cooperation by carriers.
4. Procuring the spacecraft.
5. Integrating the payloads.
6. Arranging for launch services.
7. Obtaining launch, commissioning, and on-orbit life insurance.
8. Arranging for tracking, telemetry, and command services.
9. Operating a master control center.
11. Arranging for terrestrial networking
11. Marketing the communications services in cooperation with the condominium payload owners.

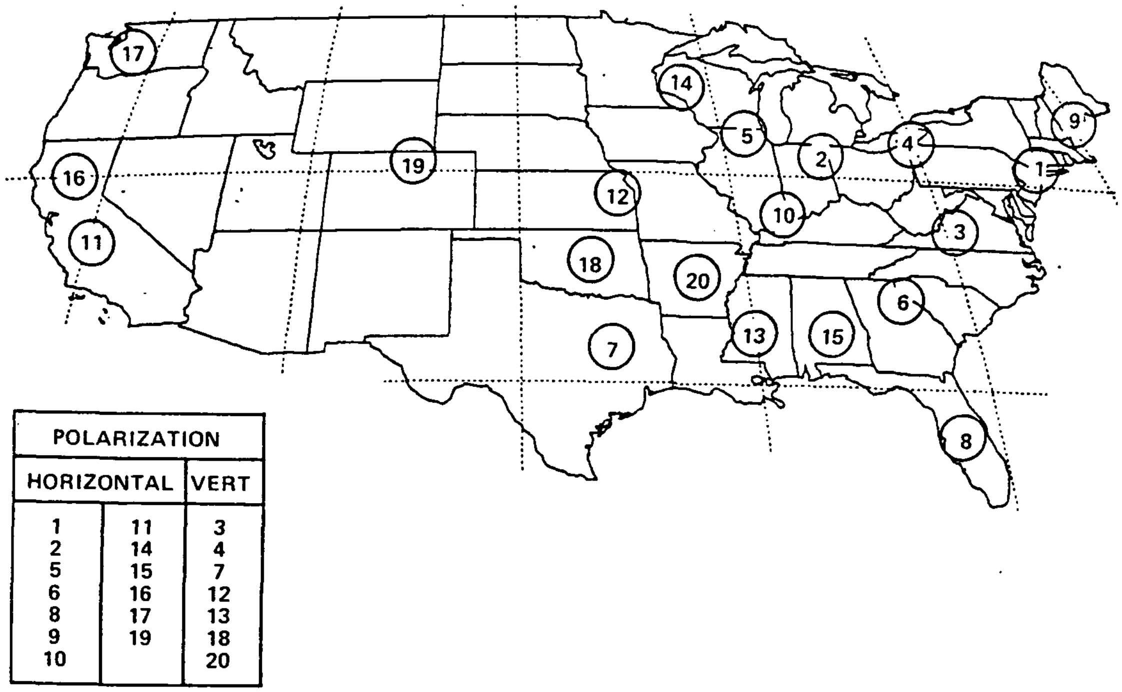
The dominant carrier would need extensive financial resources ("deep pockets") to carry out the activities listed above. The carrier may also require a partnership with a satellite manufacturer who has the capability and interest in building communications satellite platforms. Such a manufacturer would have to have successfully built communications satellites in the past, but not be committed to the "status quo" series of individual communication satellites.

4.3.3 Summary Antenna Coverages

4.3.3.1 Ka-Band Fixed Spot Beams

The Ka-band fixed beams consist of 20 spot beams, as shown in Figure 4.3-3. These locations are the same ones used in the "20 Earth Station Model" described in Volume II of the Western Union Report.

The assignments of various beams to either horizontal or vertical polarization, shown in Figure 4.3-3, is influenced by the scan area design discussed subsequently. Any fixed beam which lies within a scan area of a given polarization must, of course, be of the opposite polarization. Although one could use frequency separation between the fixed and scanned beams, doing



POLARIZATION		
HORIZONTAL		VERT
1	11	3
2	14	4
5	15	7
6	16	12
8	17	13
9	19	18
10		20

Figure 4.3-3 W.U. 20 Node - Ka Band FSS Scenario II

so would reduce the effective reuse of the Ka-band spectrum and hence reduce the total capacity of the design. (The issue of depolarization is discussed in Section 7.7.)

4.3.3.2 Ka-Band Scan Beams

The Ka-band scan areas are depicted in Figure 4.3-4. A total of 6 areas were defined, but somewhat differently than previous concepts. The usual approach has been to set up alternating bands of opposite polarization. The approach adopted here is almost the same, except scan areas 3 and 4 constitute a "split" band.

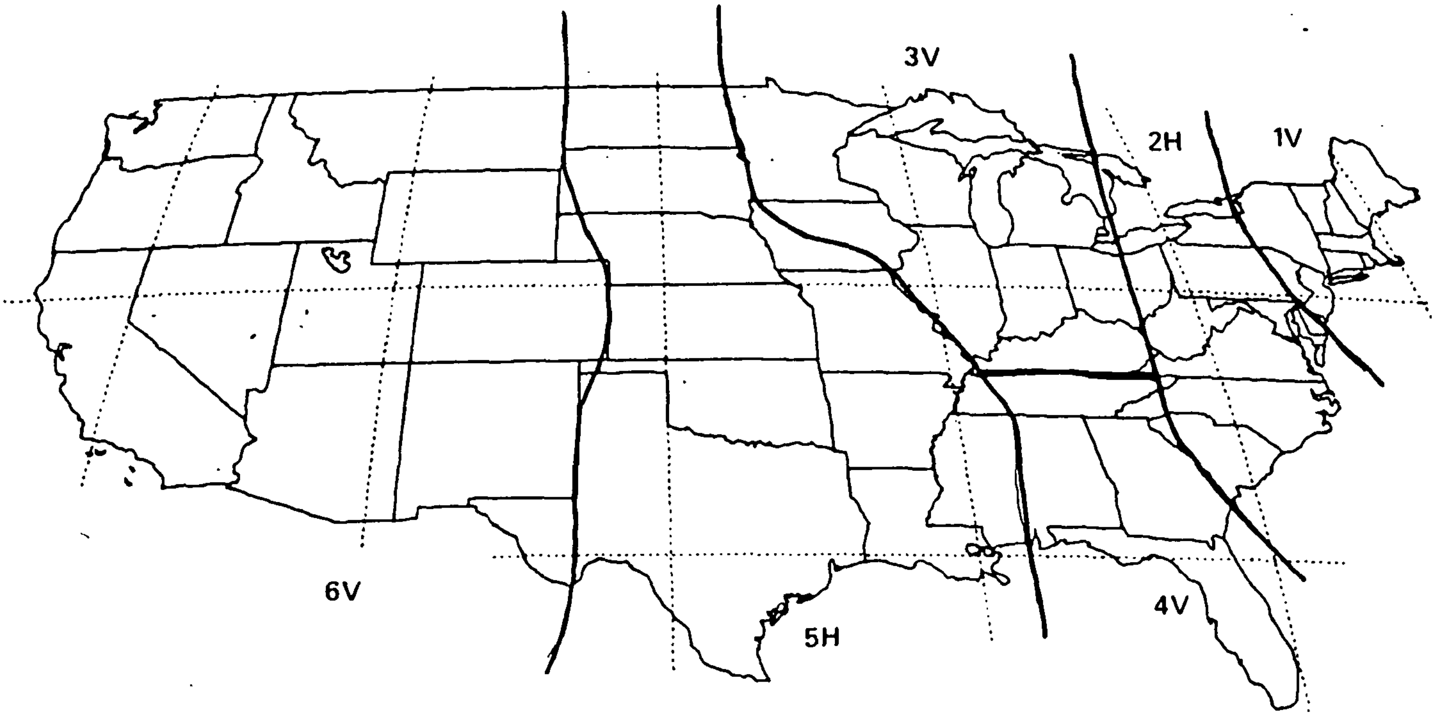


Figure 4.3-4 Ka-Band 6 Sector Scan Areas

There were two major reasons which led to this configuration:

1) Fixed Beam constraints
2) Traffic balancing

The 20 fixed beam locations were assumed to be given. The setting of CPS scan area boundaries is severely constrained by these fixed beams, as shown in Figure 4.3-5. Normally, one can achieve a minimum spatial separation between two beams of identical polarization of about two beam widths (between centers). As Figure 4.3-5 illustrates, however, when overlaying a broader coverage, the minimum separation is forced to three beam widths because of the overlay boundaries which must be set between the fixed beams.

- TRAFFIC BALANCING IS DESIRED OBJECTIVE
- SEVERE BOUNDARY CONSTRAINTS IMPOSED BY FIXED BEAM LOCATIONS

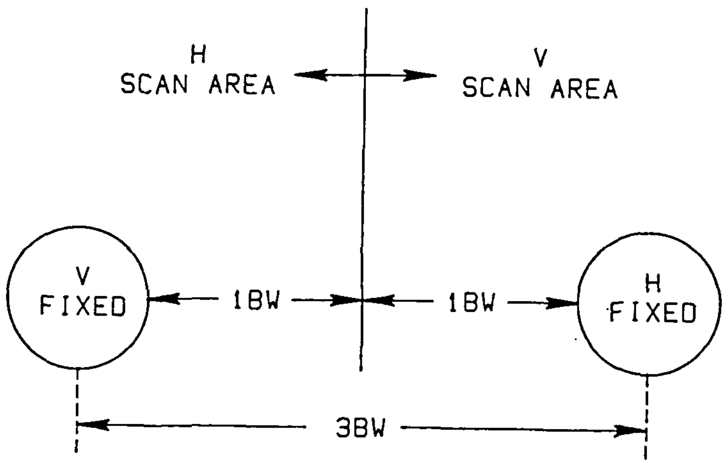


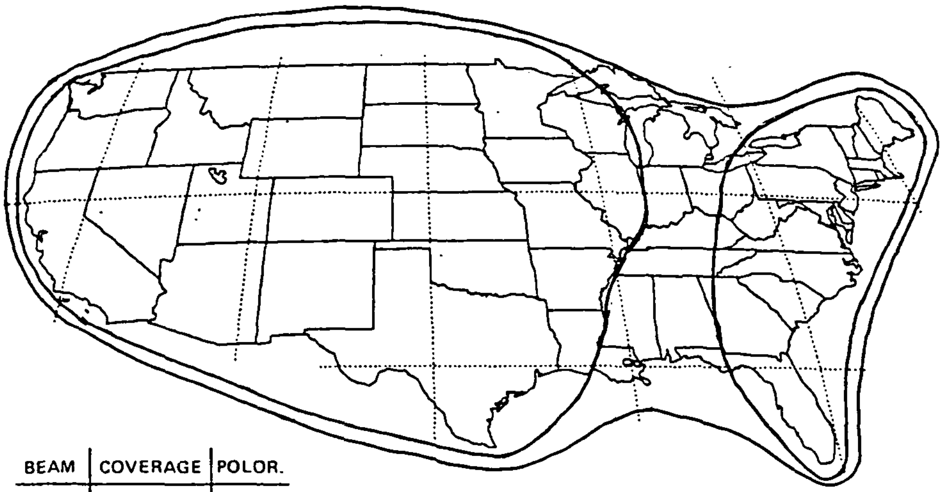
Figure 4.3-5 CPS Scan Area Design

These fixed beam constraints make it quite difficult to draw the scan area boundaries to optimize coverage from a traffic balancing point of view, a concept discussed in Section 4.2.3.2.4. The total CPS traffic generated within the combined areas 3 and 4 is almost twice that of the next largest scan area, yet the fixed beam locations, and the 3-beam width problem discussed above do not allow setting the scan area boundaries in that region in any other way.

By splitting this critical area in two, and employing frequency reuse in each half, at the <u>same</u> polarization, a significant improvement in traffic balancing is obtained. The impact of this is that algorithms which generate the scan beam dwells must ensure that the beams of scan areas 3 and 4 never simultaneously dwell along the boundary between the two areas. Since the traffic levels in Kentucky and Tennessee are relatively low, this is not a particularly stringent constraint.

4.3.3.3 <u>Ku-Band FSS Beams</u>

The Ku-band FSS coverage is shown in Figure 4.3-6. There are three beams. The East and West beams are designed to provide a



BEAM	COVERAGE	POLOR.
1	CONUS	H
2	WEST	V
3	EAST	V

Figure 4.3-6 Ku-Band FSS - Scenario II

traffic balance. Since traffic can be overflowed to the Ku CONUS beam (see Section 4.2.3.2.6 for a description of the concept of beam overflows), then balancing is not critical.

4.3.3.4 C-Band Beams

The C-band coverage is a standard CONUS, including Alaska, Hawaii, and Puerto Rico, design with polarization (2x) reuse, as depicted in Figure 4.3-7.

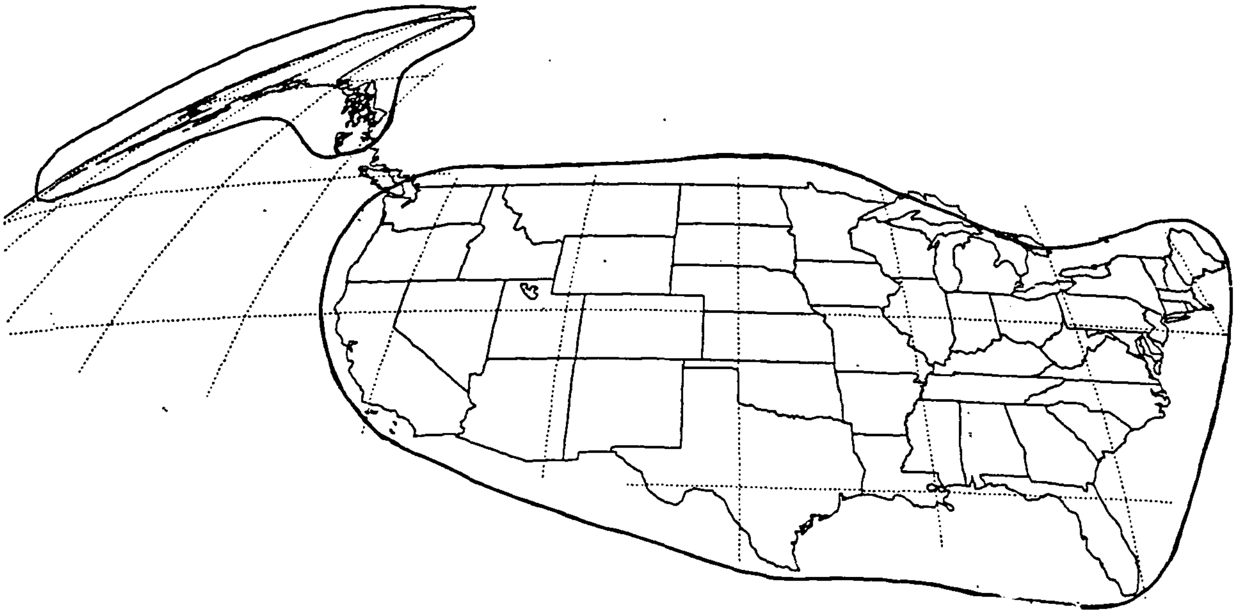


Figure 4.3-7 C-Band FSS -Scenario II

4.3.3.5 Ku-Band DBS Beams

Finally, the DBS coverage consists of two beams, and is identical to the coverages defined for the STC satellite. The issue of traffic balancing does not apply here because the distribution of "Receive Only" terminals is tranparent to the satellite, which is operating in a broadcast mode. Figure 4.3-8 shows the coverages.

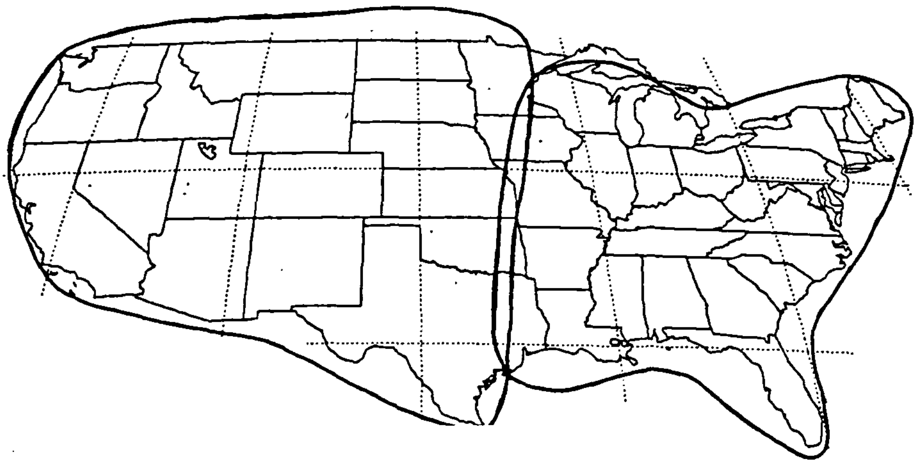


Figure 4.3-8 Ku-Band DBS - Scenario II

Detailed beam contours, based on the reflectors and feed arrays developed in Task 4, are contained in 5.2.6.2.

4.3.4 Transponder Configurations

4.3.4.1 Ka-Band Trunking

The capacity required to meet trunking requirements must use both the fixed beams and some portion of the scan beam capacity. This is required if the design is to provide connectivity for all assigned trunking traffic. Figure 4.3-9 illustrates that a significant percentage of the trunking traffic lies outside the fixed Ka spot beams.

The original design developed in Task 3 routed the fixed-to-scan traffic through the SS/TDMA switches associated with the fixed beams to the baseband processor for routing to the scan beams (and the inverse routing). This design resulted in a major impact on the size of the BBP (based on 2 bits per Hertz), and hence an alternate scheme was subsequently developed, as shown in Figure 4.3-10.

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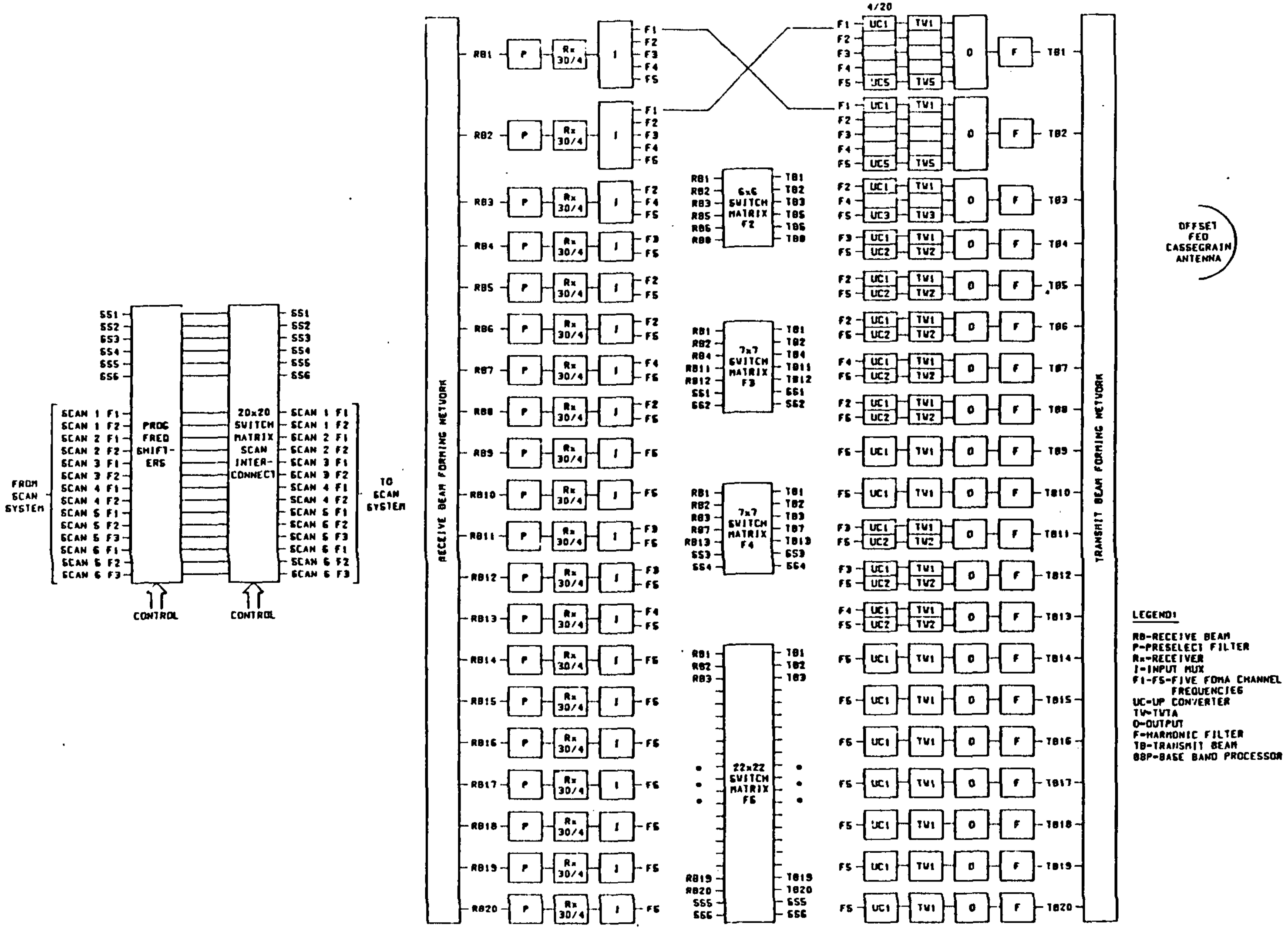

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Figure 4.3-10 Scenario II - Ka (FSS)

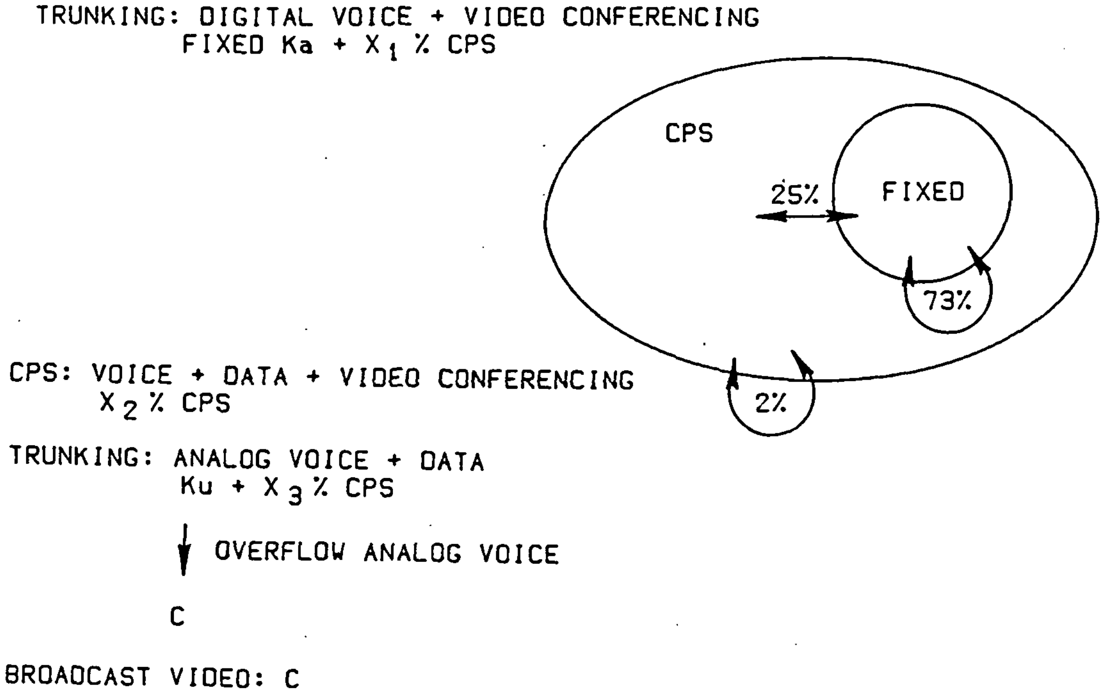


Figure 4.3-9 Ka Band Traffic Distribution

In this approach, certain transponders associated with the scan beams are designed for trunking, and are routed to a scan beam SS/TDMA switch; programmable frequency shifters are required with this switch because a given scan beam transponder may, at different times in the data frame, have to be routed to different fixed beam switch matrices. Each fixed beam matrix operates in a single Ka-band 500 MHz channel. This arrangement is functionally equivalent to the use of a BBP for a <u>trunking application</u> since one does not require circuit level demand assignment as in CPS. There is a slight loss, due to guard times, relative to a BBP approach.

There are other aspects to the design which bear mentioning. Most fixed beams do not use the full bandwidth available. This is because of widely varying traffic levels generated by each beam if one maintains the distribution of the traffic loaded to a single satellite the same as the total traffic distribution(see Section 4.2). Thus, only thirty-eight 500 MHz transponders are needed, as compared to a theoretical maximum of 100; a significant mass and power saving is the obvious result.

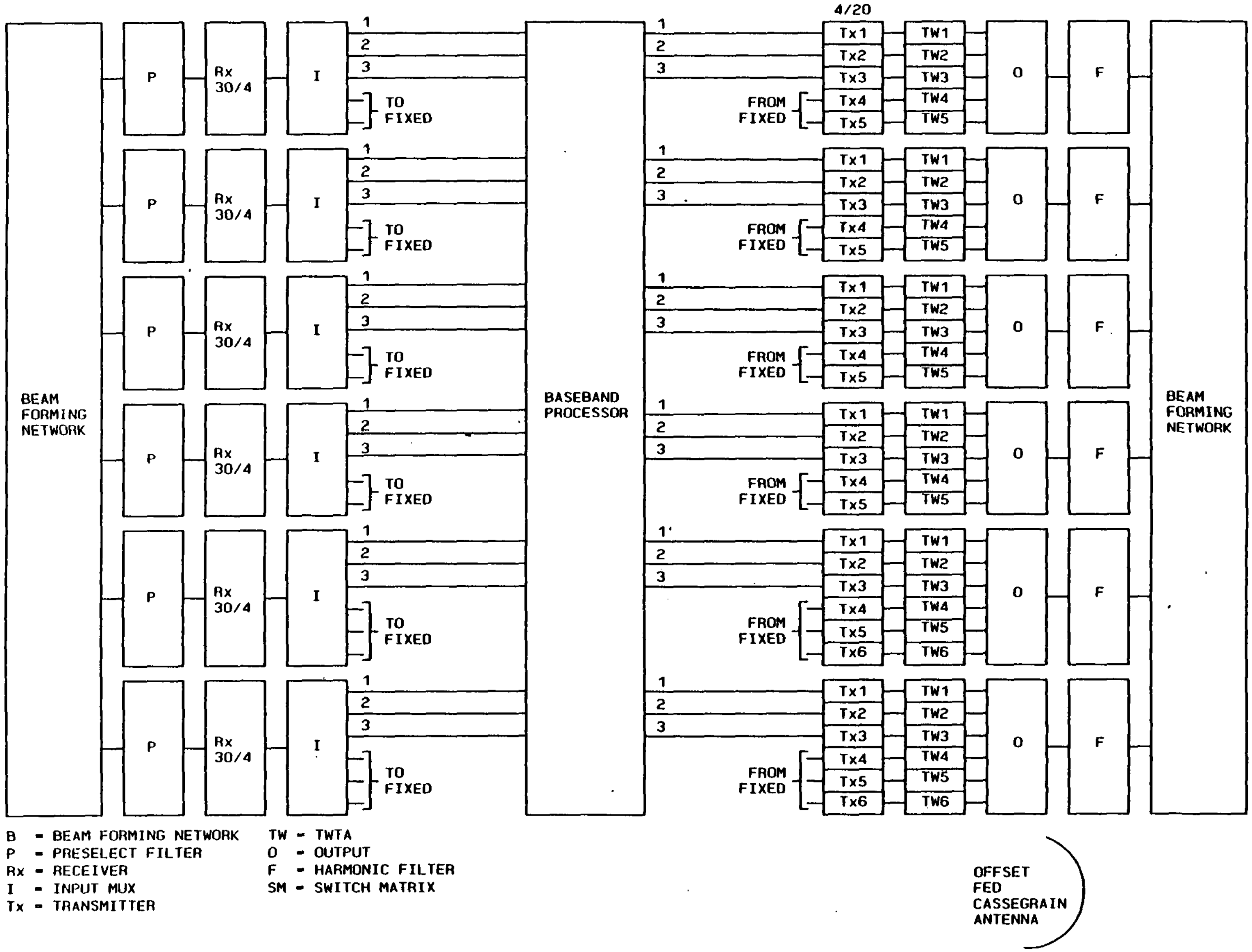
Because the distribution is not uniform, then we can also adapt the size of the SS/TDMA switches to the traffic. For example, Fixed Beams 1 and 2 have sufficient traffic between them to justify a "hard-wired" connection (see frequency F1 in Figure 4.3-10). The six beams served by the F2 switch have enough traffic between them to justify a switch dedicated to only that traffic. Frequency F5 and its switch provide total connectivity between all beams.

4.3.4.2 Ka-Band CPS

The overall Ka-band CPS configuration is shown in Figure 4.3-11. Each scan beam provides three 240 MHz channels which are routed to/from the BBP, with a fourth channel as a spare (not shown).

The BBP configuration for a single scan beam is detailed in Figure 4.3-12. It is assumed that, for CPS operation, the data rate in each 240 MHz channel is 480 Mb/s - based on 2 bits per Hertz. One channel is divided into four subchannels of 120 Mb/s, two of which can be further divided into four 30 Mb/s subchannels on an optional basis. The other two subchannels can operate at either 120 or 60 Mb/s. Also, FEC (forward error correction) can be selectively provided on the 120/4-30 channels when required.

A second channel is a dual rate channel which can operate at either 480 or 240 Mb/s. The third channel is fixed at 480 Mb/s. All downlink channels operate at 480 Mb/s, with selective FEC.



Ford Aerospace & Communications Corporation

Figure 4.3-11 Ka-band (Scan) Payload

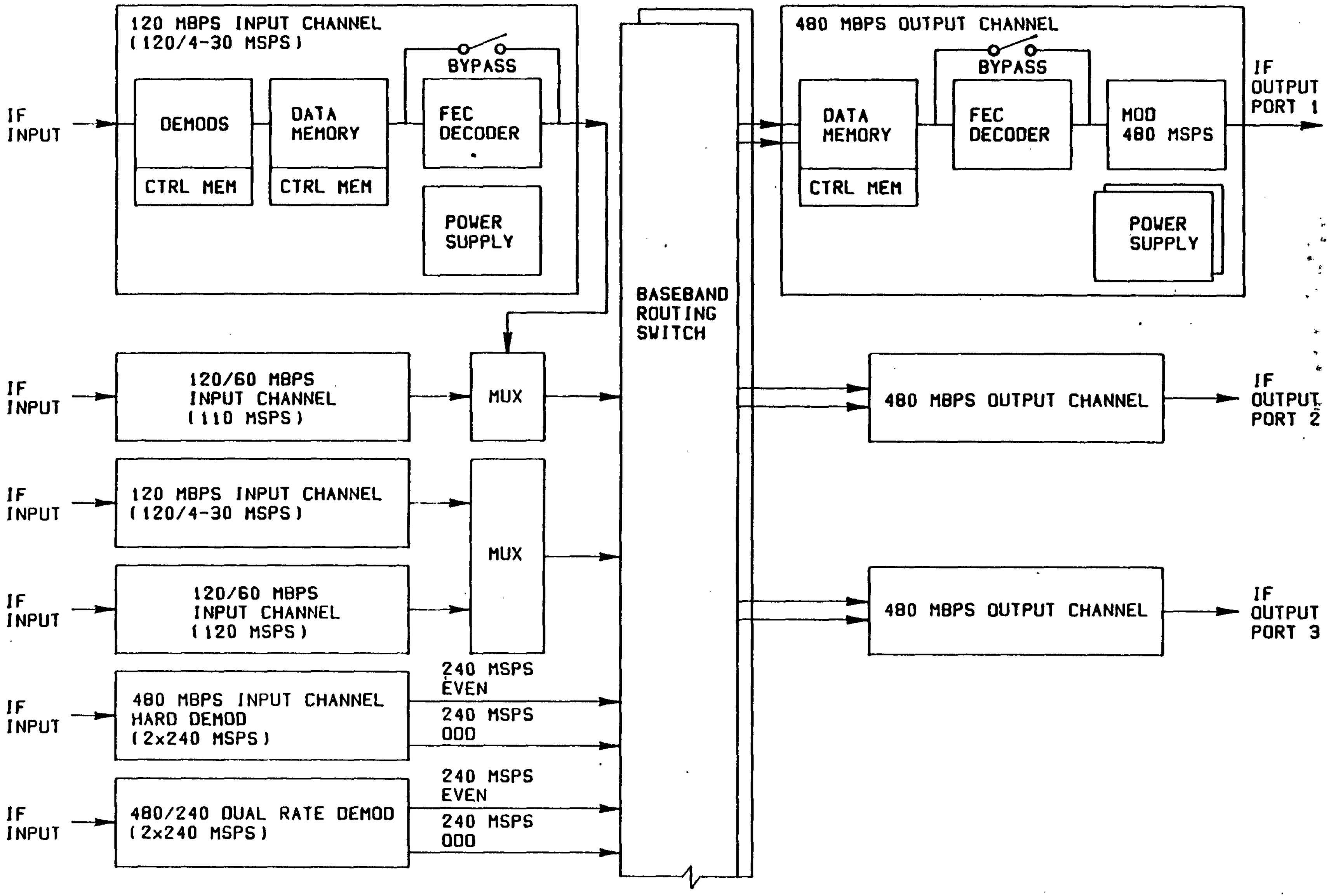


Figure 4.3-12 Typical Baseband Processor I/O Channel per Scan Beam

The dual rate channels and FEC are intended to provide additional link margin to counter rain attenuation effects. The lower data rates or FEC are employed only on those dwells experiencing excessive fading. The scan area with the most CPS traffic is number three, with 1339 Mb/s (Appendix G.2). Since a total capacity of 1440 Mb/s is available, there is a 8% margin (more in other beams) to accommodate reduced throughput due to fading. Rain distribution statistics indicate that only a very small percentage of the traffic would be affected at any one time.

4.3.4.3 Ku-Band (FSS) Configuration

The Ku-band (FSS) configuration consists of eight 54 MHz transponders in each of the three beams; a 3 x 3 switch provides connectivity for each channel. At least one of these switches must be able to operate in an SS/TDMA mode to handle trunking data which has been allocated to this payload. (See Table 4.2-3.) The overall block diagram is depicted in Figure 4.3-13.

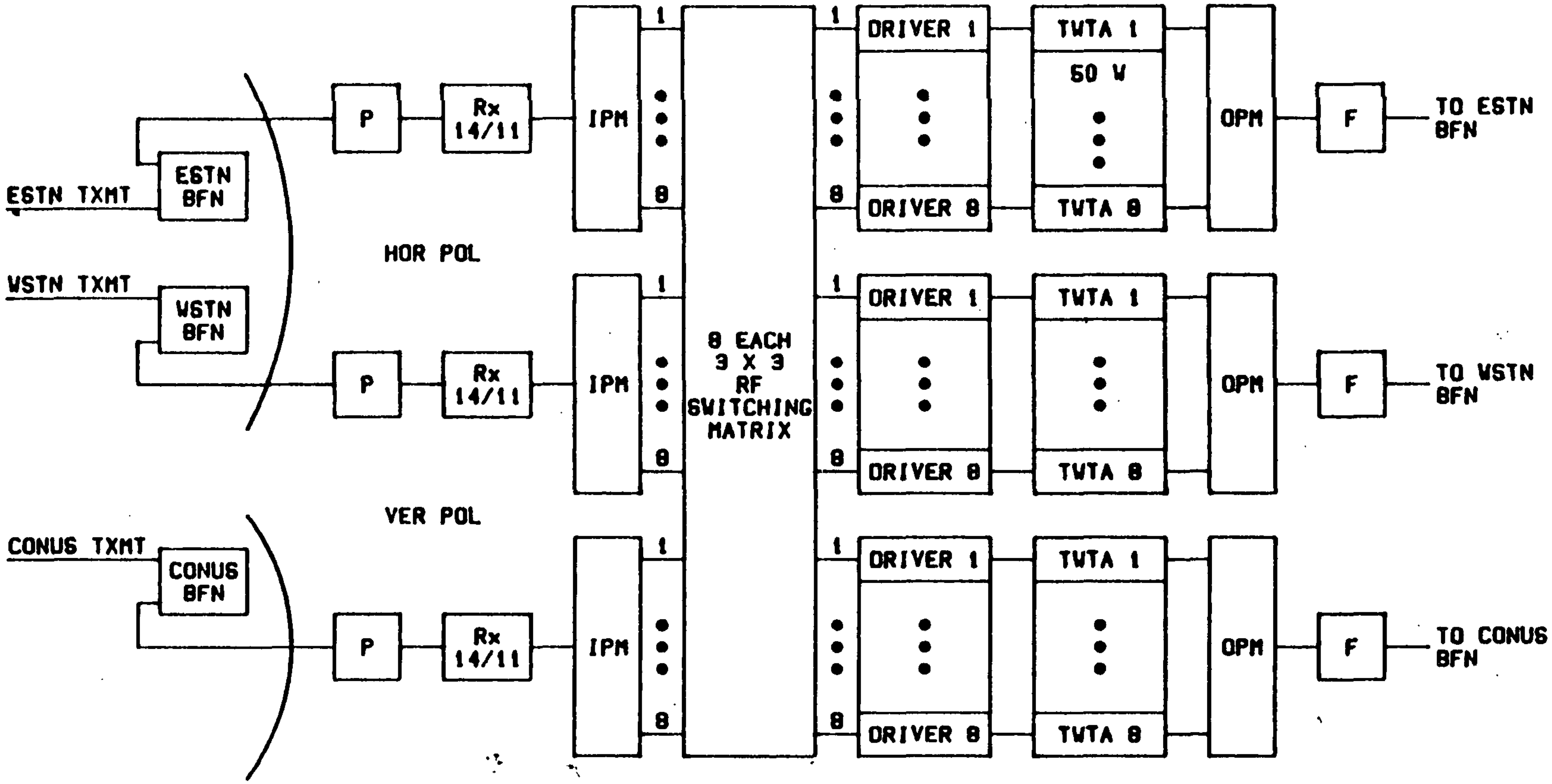
4.3.4.4 C-Band Configuration

Figure 4.3-14 indicates the C-band design, which is a fairly standard twenty-four channel CONUS configuration. Coverage for Alaska is provided by the vertically polarized beam, and Hawaii and Puerto Rico are serviced by the horizontal beam.

No switching is required since CONUS beams provide total connectivity.

4.3.4.5 Ku-Band (DBS) Configuration

The DBS payload provides eight 24 MHz channels to each of the two beams. These channels are separated by frequency because the two beams overlap slightly. The switching arrangement is



P: PRESELECT FILTER
BFN: BEAM FORMING NETWORK
IPM: INPUT MULTIPLEXER
OPM: OUTPUT MULTIPLEXER
F: HARMONIC FILTER
TXMT: TRANSMITTER

Figure 4.3-13 Scenario II - Ku (FSS) Configuration

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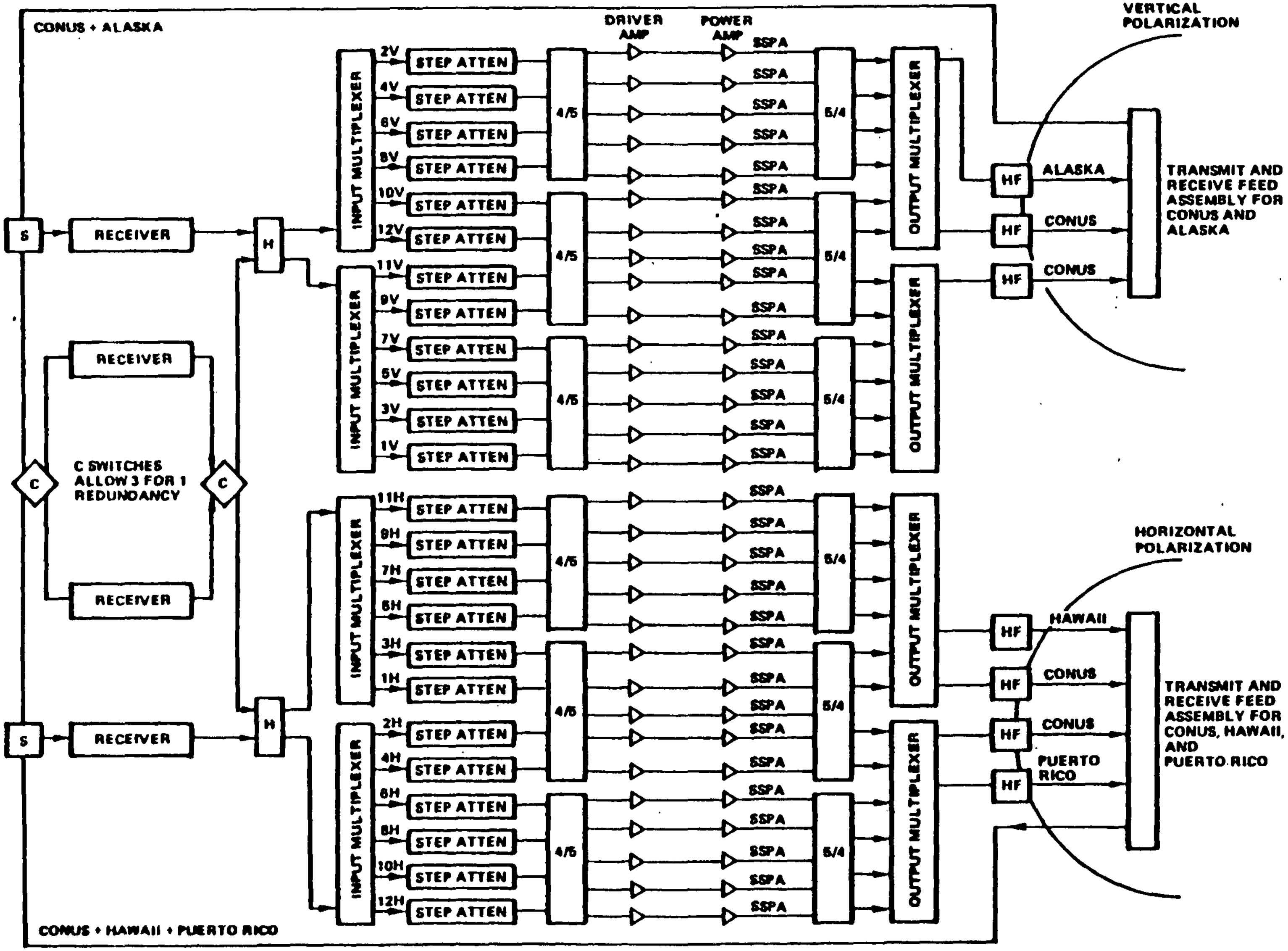


Figure 4.3-14 Scenario II - C-Band FSS Configuration

such that one uplink channel can be routed to either one or two downlinks. This provides the user the flexibility of transmitting different programs to each area at the same time, or a single program to both areas. Figure 4.3-15 provides the block diagram for the DBS payload.

4.3.4.6 Frequency Plan and Modulation/Access

Table 4.3-1 provides a description of the Scenario II payloads regarding frequency usage and the modulation/access methods assumed to be used.

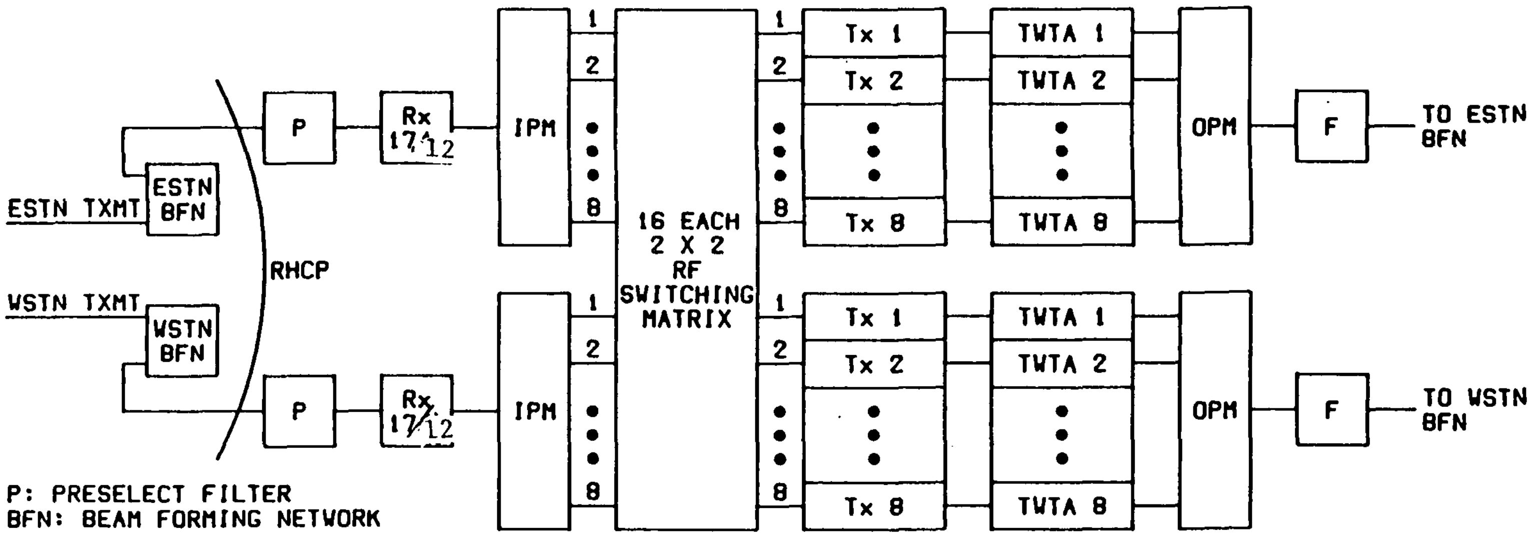
4.3.5 Traffic Loading

The total traffic loaded to a single Scenario II satellite is given in Table 4.3-2. The various payload's loading is that at saturation, and hence correspond to different numbers of satellites.

A more detailed loading analysis, to the transponder level, is given in Appendix G.

The maximum throughput, by application, for Scenario II is given in Table 4.8-4. Based on the above loadings and the theoretical capacity, utilizations are as follows:

Ka-Trunking	.76
Ka-CPS	.76
Ku-FSS	.62
C	.92
Weighted Average	.76



P: PRESELECT FILTER
BFN: BEAM FORMING NETWORK
IPM: INPUT MULTIPLEXER
OPM: OUTPUT MULTIPLEXER
F: HARMONIC FILTER
Rx: RECEIVER
Tx: TRANSMITTER

Figure 4.3-15 Scenario II - Ku (DBS)

Table 4.3-1

Scenario II Frequency Plan and Modulation/Access

Application	Frequency (GHz)	Xpdr Band-width (MHz)	No. of Xpdr	Modulation/ Access	Notes
Ka-Trunking (Fixed + Scan)	17.7-20.2 27.5-30.0	500	38 Fixed 14 Scan	SS/TDMA/ 8 Phase PSK	(1)
Ka-CPS	(Same as above)	240	18	SS/TDMA/ QPSK	(2)
Ku-Voice	11.7-12.2	54	24	FDMA/CSSB	
Ku-Data	14-14.5			SS/TDMA/ 8-PSK	
Ku-Video				FM-TV	
C-Voice	3.7-4.2 5.925-6.425	36	24	FDMA/CSSB	
C-Video				FM-TV	
Ku-DBS	12.2-12.7 17.3-17.8	24	16	FM-TV	

(1) See Figure 4.3-10 for frequency/ beam usage.

(2) Each of three channels in a beam is configured differently. (See Figure 4.3-12.)

(3) See Table 4.2-3 for traffic/payload assignments.

Table 4.3-2

Scenario II Traffic Loading Summary

Application	Traffic Carried	Corresponding(1) # Satellites
Ka-Trunking	1356 K HVC(2) + 2660 video conf.(3)	6.7
Ka-CPS	6565 MB/S	7
Ku	107K HVC + 200 MB/S data + 15 Broadcast video(4)	27
C	120K HVC + 10 Broadcast Video(4)	27

(1) Assume 0/40 digital - analog split - see section 4.8.6.

(2) HVC = "Half Voice Circuit".

(3) 2.1 MB/s per channel - See Table 2.2.7-3.

(4) See Table XIX of [Ref. 8].

Appropriate conversions, i.e., one half voice circuit equals 24 Kb/s, were made to obtain a common unit of comparison. The Ku computation of utilization, as an example, is

$$\frac{107K \times 24\ K + 200M + 15 \times 72\ M/2.5}{5184M} = .62,$$

where $K=10^3$ and $M = 10^6$

4.3.6 Terrestrial System Characteristics

The size of earth station antennas is given for each frequency band/application in the scenario descriptions of section 3.2. Modulation and access requirements are listed in Table 4.3-1; EIRP and G/T characteristics are presented in Section 5. The remainder of this section discusses any other special considerations.

Those stations operating in an SS/TDMA mode must be able to acquire proper synchronization and timing; this includes all Ka-Band stations, and those with Ku-Band data. Ka-Band trunking stations require 960 MB/S modems, and CPS stations must interface with the orderwire system for control of demand assignment.

4.4 SCENARIO IV PAYLOAD CONCEPT DEVELOPMENT

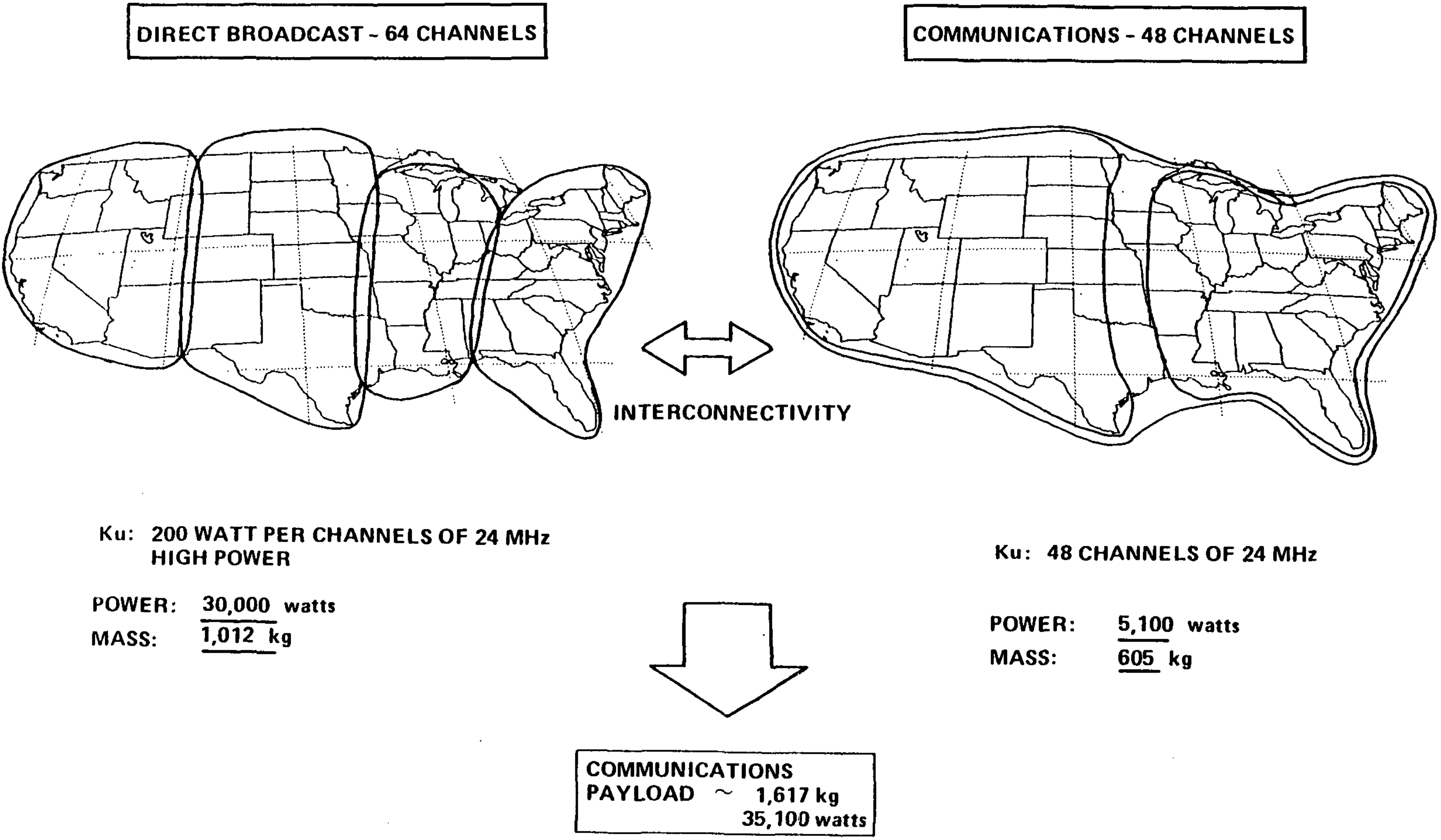
4.4.1 General Description

Scenario IV is a medium and high power broadcast satellite. The high power channels are in the Ku DBS band, and the medium power channels are in the Ku FSS band, as shown in Figure 4.4-1. Considerable flexibility is provided to the user to select combinations of uplinking and downlinking programs to the various beams. Figure 4.4-2 summarizes the Scenario IV payload.

4.4.2 Institutional and Regulatory Issues

Scenario IV presents fewer institutional and regulatory barriers than Scenario II because the frequency bands are limited to the Ku FSS and DBS bands. The coverage is restricted to the CONUS. The intense competition for orbital slots at C-Band is avoided, and the difficulties involved in obtaining a construction permit for a communications satellite using 4 frequency bands from a single orbital slot is obviated. However, the power flux density in the Ku-Band DBS is 6 dB greater than would be present on Scenario II, and this may present additional problems on the shared use of this Band.

The 64 channels of direct broadcast television is four times more channels than proposed on Scenario II. The presence of this many channels will challenge the alternative television distribution systems (terrestrial broadcasting and cable television) more directly. Competition for the programming sources (television networks, producing studios) will become more intense. Regulatory agencies (the FCC's Broadcasting Bureau) will become more involved. The legislative and judicial branches of the government dealing with copywrite laws will be drawn into the arguments of how the program originators and owners should be compensated for direct to home satellite broadcasting.



DIRECT BROADCAST - 64 CHANNELS

COMMUNICATIONS - 48 CHANNELS

INTERCONNECTIVITY

Ku: 200 WATT PER CHANNELS OF 24 MHz
HIGH POWER

POWER: 30,000 watts
MASS: 1,012 kg

Ku: 48 CHANNELS OF 24 MHz

POWER: 5,100 watts
MASS: 605 kg

COMMUNICATIONS
PAYLOAD ~ 1,617 kg
35,100 watts

Figure 4.4-1 Scenario IV - Services Allocation

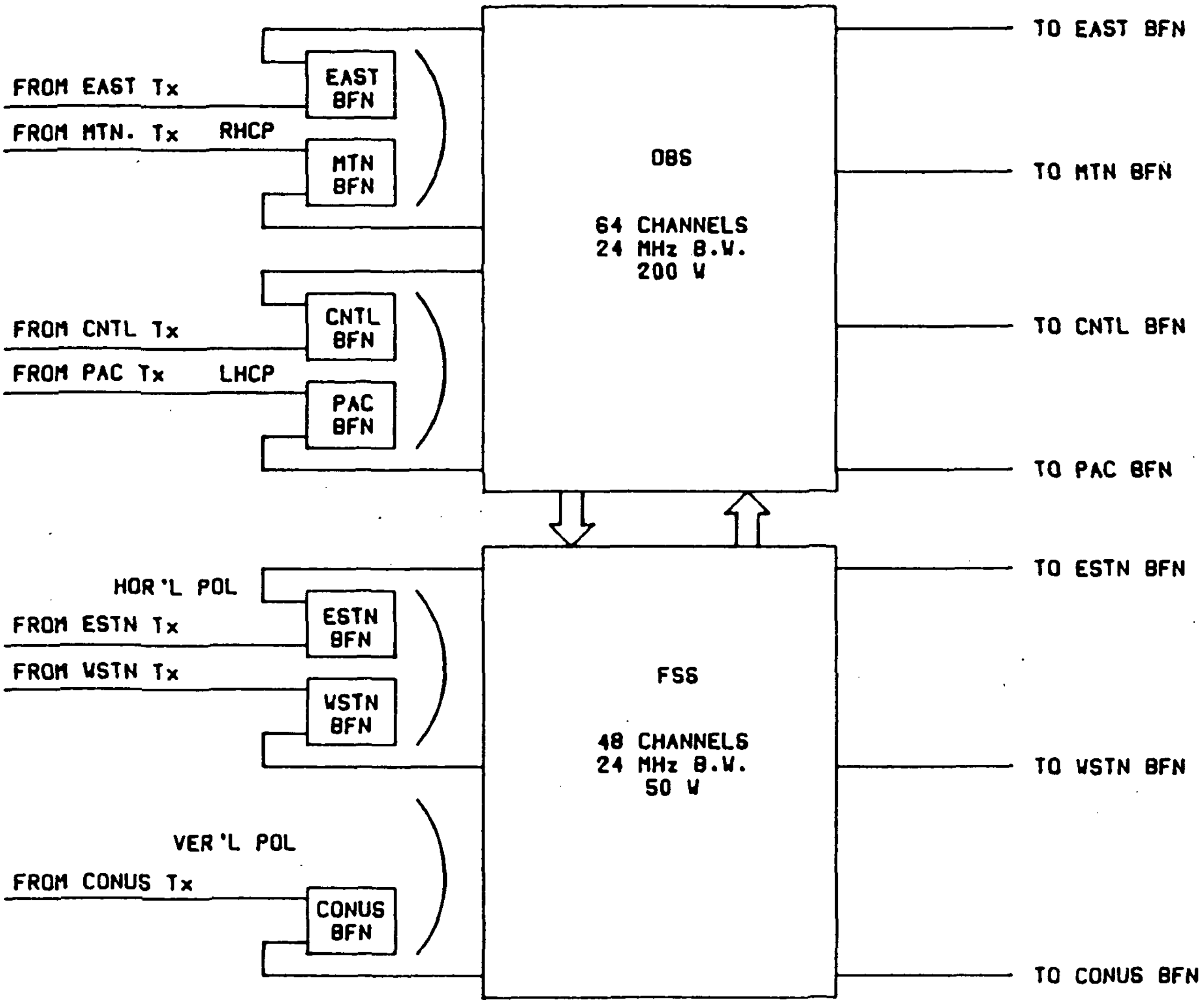


Figure 4.4-2 Scenario IV Payload Overview

The interconnectivity between the FSS and DBS transmitters would further blur the fuzzy distinctions which now exist between the two communications services. The power-flux-density differences of 9 dB may result in two types of TV R/O receiver terminals on the ground. Widespread deployment of these terminals may require the adoption of standards for these receivers by the manufacturers.

In this scenario, a consortium would probably be led by a broadcaster, a television network, or a movie studio rather than a communications common carrier. Again, a satellite manufacturer might be included as a partner because of the interest in a new line (and concept) of communications satellites.

A consortium would be expected to perform all the functions listed previously for Scenario II, but the institutional barriers would more likely be those addressed by the FCC's Broadcasting rather than Common Carrier Bureau.

Additional barriers which confront DBS plans include the local zoning regulation which may keep TV R/O dishes out of suburban and urban areas. DBS activities in Chicago were restricted by local zoning ordinances supported by the local cable TV operators. The FCC has advised local zoning boards that federal laws could take precedence over local ones, but as yet has issued no orders to this effect.

The question of scrambling (encoding) video signals will affect the future of DBS. Bills have been introduced in Congress which would prevent cable programmers from scrambling their signals for the next two years. The eventual effect of scrambling on the DBS business is uncertain, and may depend on the cost and availability of the decoders.

4.4.3 Summary Antenna Coverages

4.4.3.1 Ku-Band FSS Beams

There are three beams available at the Ku FSS band as shown in Figure 4.4-3. The CONUS coverage beam can be used to provide programming, using a single channel, where time zone issues are not critical, and also to address the Central Time Zone programs. In the latter case, these programs would be received throughout CONUS. The East Beam can provide Eastern Time Zone coverage, and the West Beam covers both Pacific and Mountain Zones. These beams provide some overlap into the East and West portions of the Central Time Zone respectively.

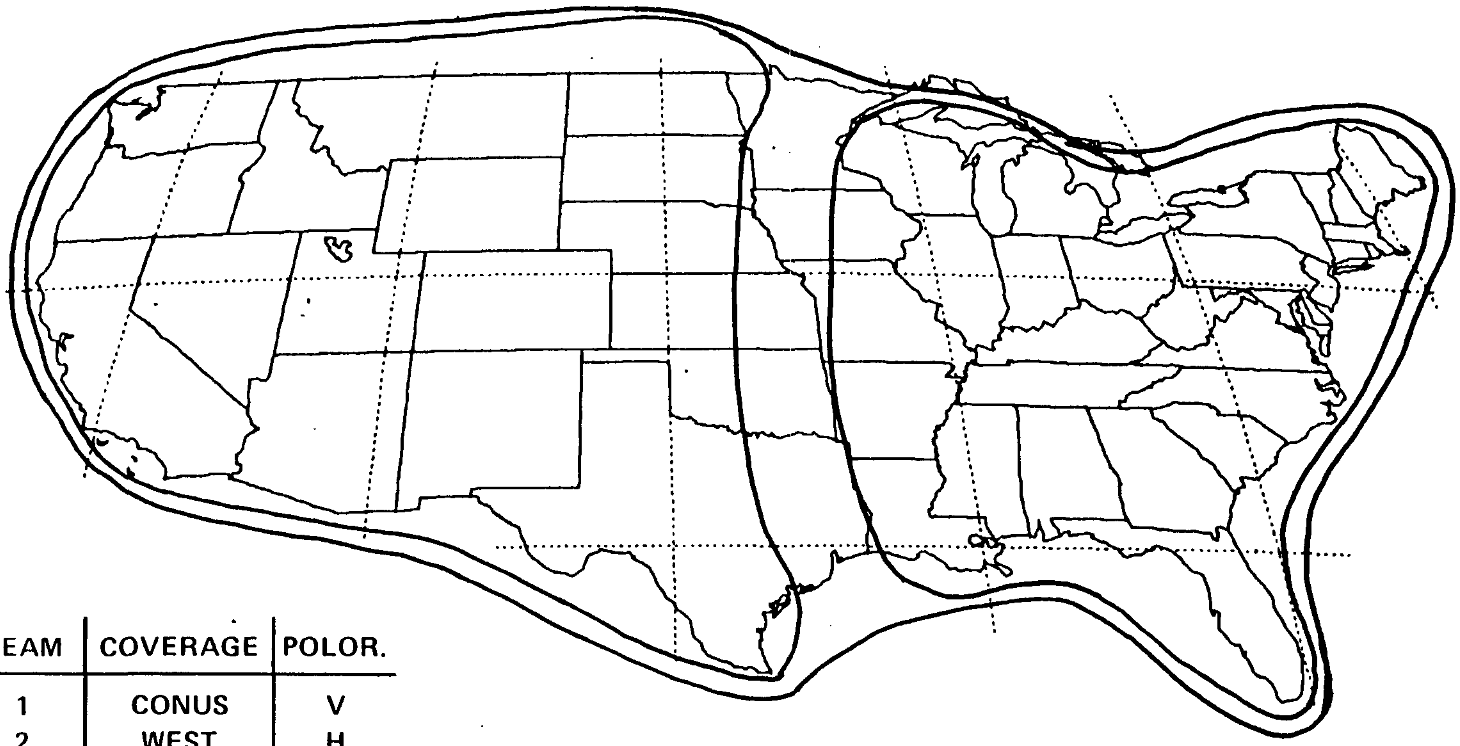
The basic configuration here is similar to the Scenario II Ku FSS coverages, except the East and West beams are not skewed to the East, because we are using this band for broadcast rather than point-to-point traffic.

4.4.3.2 Ku-Band DBS Beams

The Ku-Band DBS beams are shown in Figure 4.4-4; each beam covers, approximately, one time zone. Beam coverages were set at about the same size to maintain nearly constant flux densities in each zone.

4.4.4 Transponder Configuration

Figure 4.4-5 provides a composite block diagram for Scenario IV. Each of the seven beams (FSS and DBS) contains sixteen 24 MHz channels. The DBS downlinks utilize 200 watts RF, while the FSS downlinks are 50W. Also, the beam sizes, or coverage area, of the DBS package are smaller, providing an even higher EIRP for DBS.



BEAM	COVERAGE	POLOR.
1	CONUS	V
2	WEST	H
3	EAST	H

Figure 4.4-3 Scenario IV - Ku-Band FSS Coverage

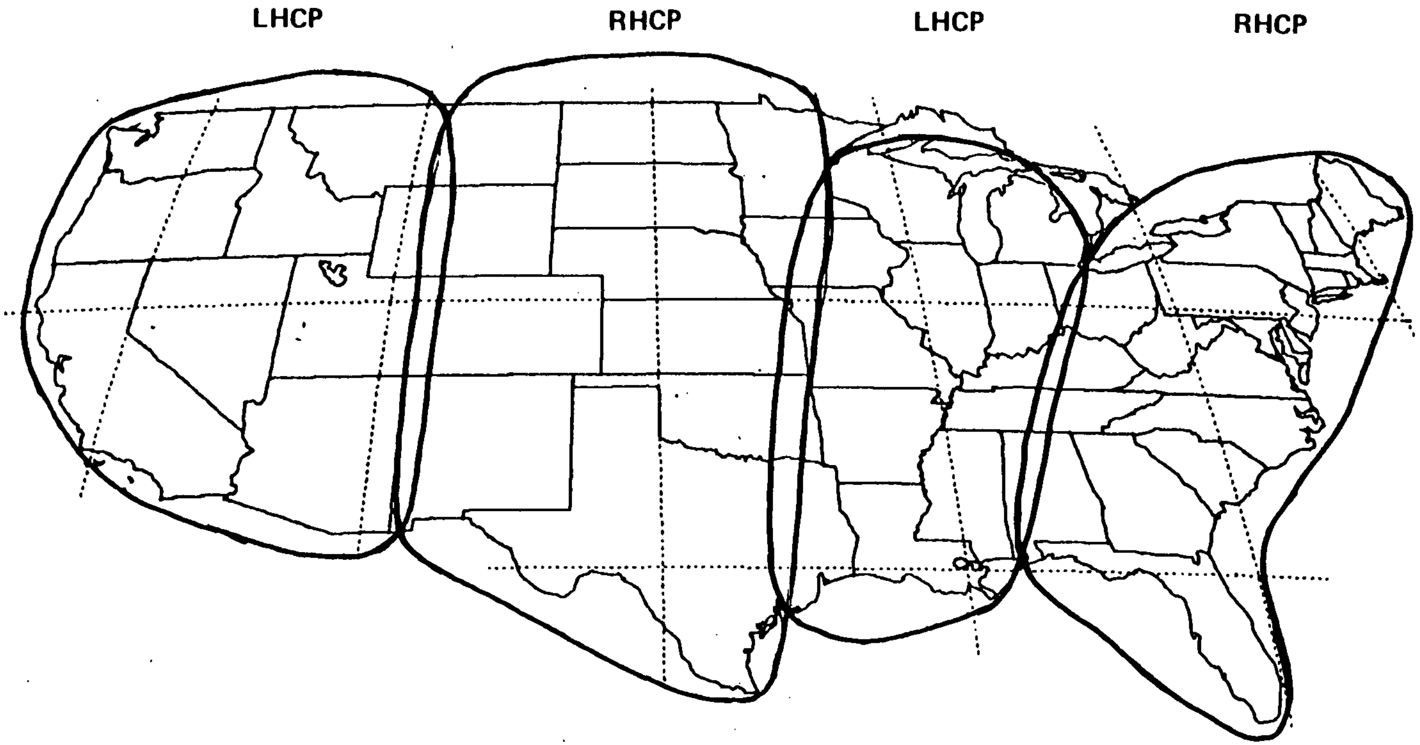


Figure 4.4-4 Scenario IV - Ku-Band DBS Coverage

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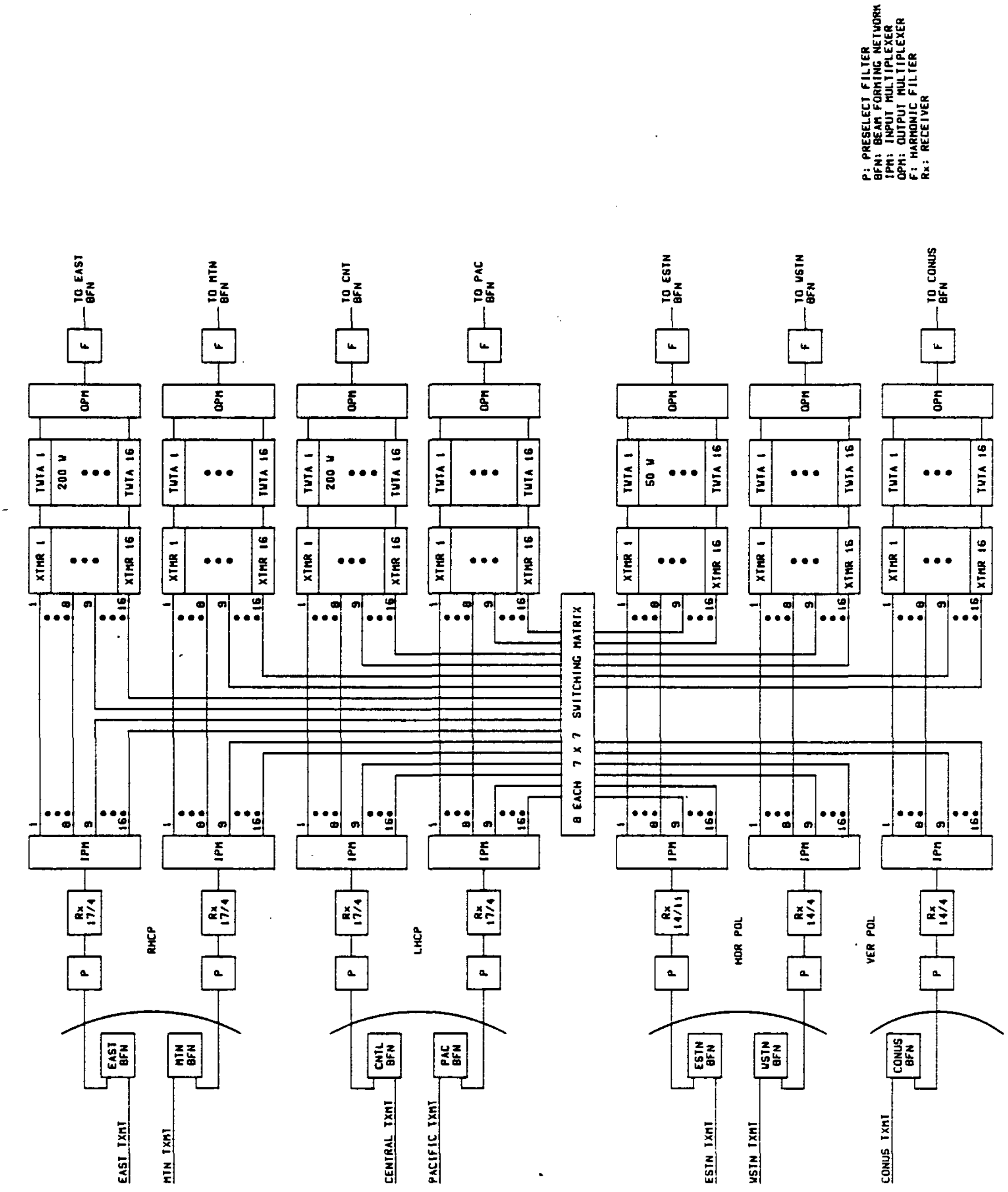

Figure 4.4-5 Scenario IV - Composite Block Diagram

A major feature of this scenario is that a great deal of flexibility is provided to the user for various networking options. This includes normal time zone differences for programming as well as special situations such as NFL football broadcasts.

Switching is provided for half the channels in each beam by eight 7x7 switching matrices; the receivers convert the 14 or 17 GHz uplinks to a common 4 GHz IF frequency for interconnecton. Also, the switching configuration is different than a typical satellite RF static switch in that it allows "1:N" routing. Any one of the switched uplink channels can be routed to as many as seven downlink channels.

Half the channels in each beam are not switched, and would be used primarily for local programming.

Table 4.4-1 presents a summary of the frequency plan and modulation/access methods.

Table 4.4-1

Frequency Plan and Modulation/Access

Application	Frequencies (GHz)	Transponder Bandwidth (MHz)	No. Transponder	Modulation/ Access
Ku-FSS	11.7-12.2 14-14.5	24	48	FM-TV
Ku-DBS	12.2-12.7 17.3-17.8	24	64	FM-TV

(1) Currently, only one TV channel can be carried in a 24 MHz transponder. Future developments may allow two channels - for CATV, Education, etc. [Ref. 8].

4.4.5 Traffic Loading

Traffic issues are not applicable to this Scenario which involves direct broadcast only.

4.4.6 Terrestrial System Characteristics

The major distinguishing factor in Scenario IV is, of course, the very large number of receive only earth stations. A small number of transmit stations would be required for uplinking the broadcasts. The size of the Tx/Rx and Rx only stations is given in Section 3.2

4.5 SCENARIO V PAYLOAD CONCEPT DEVELOPMENT

4.5.1 General Description

Scenario V is, in many ways, similar to Scenario II, except that there is no Ku (DBS) payload, and the frequency reuse of Ku (FSS) and C-Band has been significantly increased. Originally, Scenario V also included a land mobile payload; this was deleted subsequent to the Task 3 review. Figure 4.5-1 shows the various coverages. The Ka-band spot and scan beams are identical to Scenario II. An overview of the payload is given in Figure 4.5-2.

4.5.2 Institutional and Regulatory Issues

Scenario V faces the problems of obtaining an orbital slot permitting the use of the three FSS Bands over the CONUS. As in Scenario II, these problems appear so formidable that the solution may require the participation of licensees holding suitable slots. Instead of C-Band coverage of the CONUS with a single beam as in Scenario II, Scenario V uses dual polarization and four spot beams, two of which overlap in the Northeast. Similarly, the Ku-Band FSS uses dual polarization and 9 spot beams, two of which overlap in the Northeast. The Ka-Band FSS uses 20 small spot beams, plus six separate areas covered by a scanning spot beam.

This frequency re-use is good for spectrum utilization, but requires a coordination of dual polarizations in regional areas which is not currently done, and will need the cooperation of the current communications satellite owners and users, as well as the earth station manufacturers to be accomplished. Obtaining this cooperation and coordination is a formidable task, and one which could render much of the existing equipment obsolete. This might require expensive installations of new, compatible equipment.

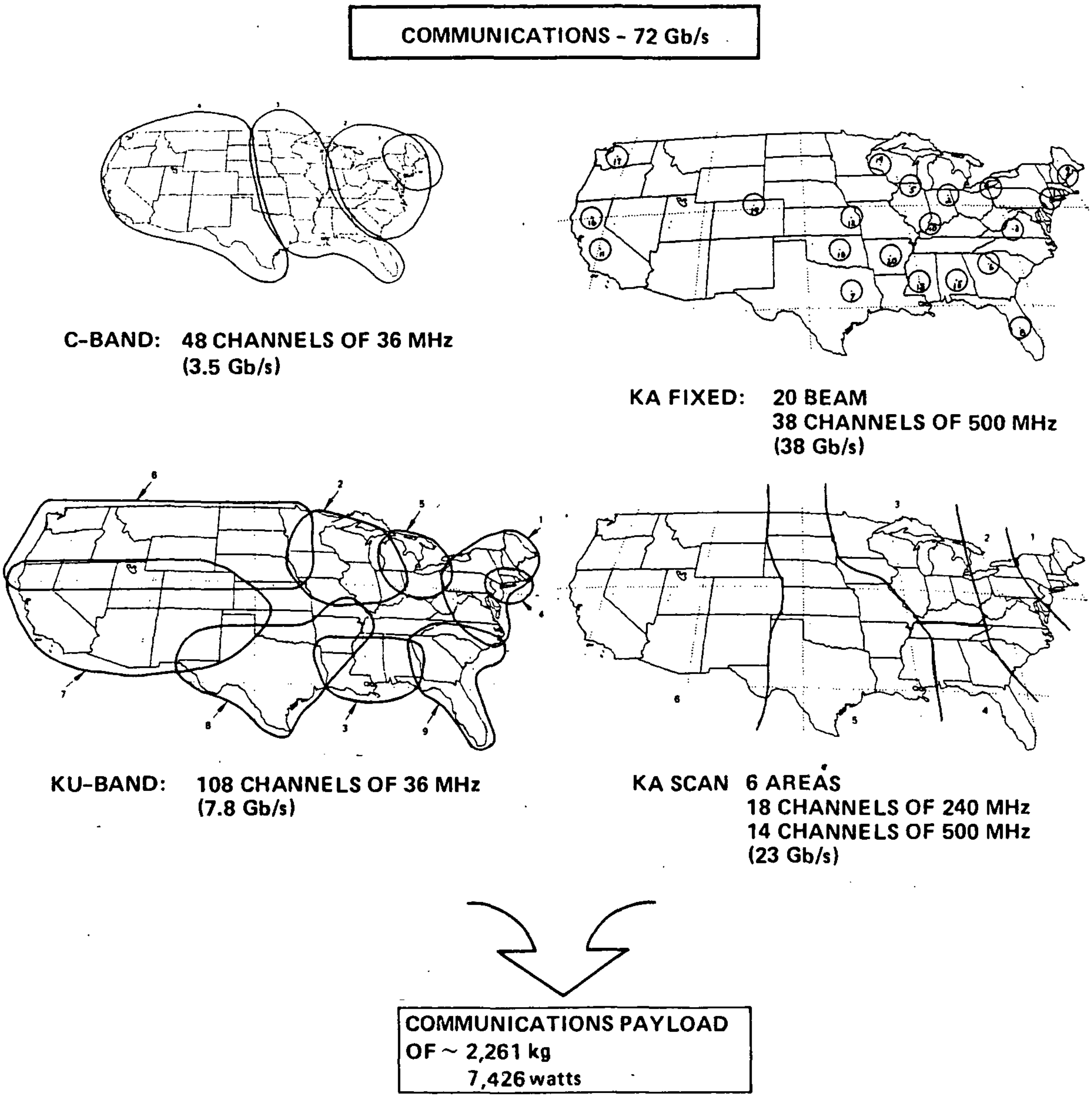

Figure 4.5-1 Scenario V - Services Allocation

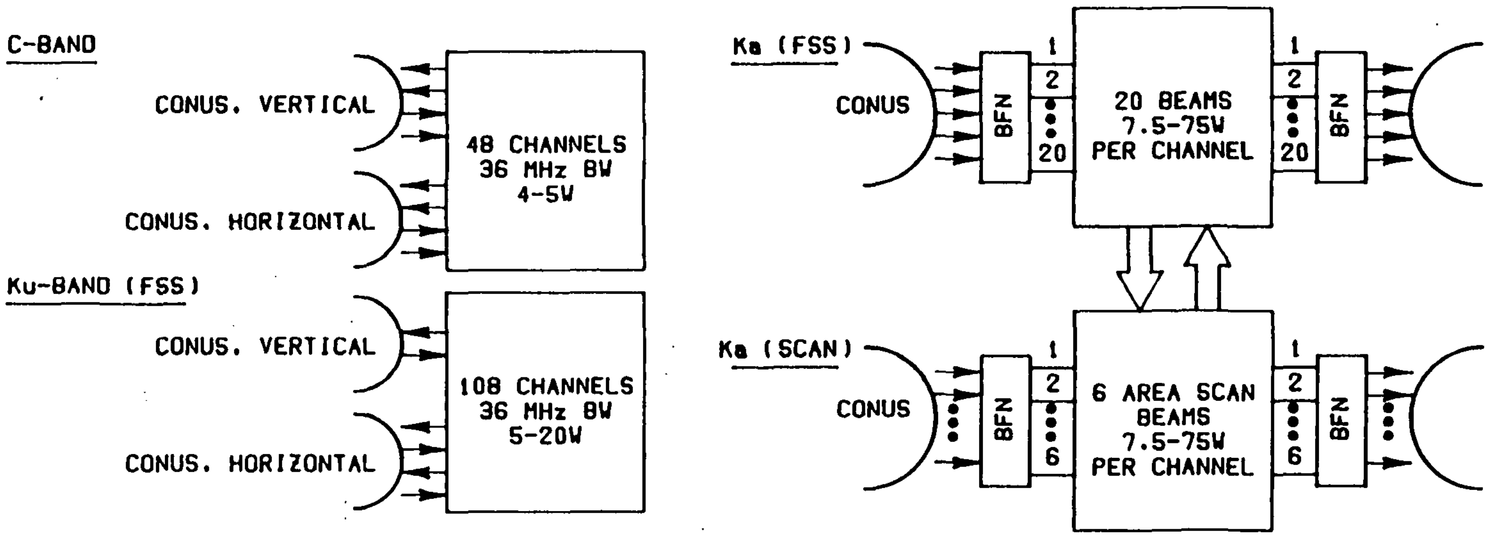

Figure 4.5-2 Scenario V - Composite Block Diagram

4.5.3 Summary Antenna Coverages

4.5.3.1 Ka-Band Fixed Spot Beams

(Refer to Section 4.3.3.1)

4.5.3.2 Ka-Band Scan Beams

(Refer to Section 4.3.3.2)

4.5.3.3 Ku-Band FSS Beams

The beam coverages shown in Figure 4.5-3 for Scenario V Ku-Band are designed to maximize the effective frequency reuse, given a 15' reflector limit and the assumed traffic distribution. The 15' limit is based on the shuttle bay diameter, and the use of the rigid reflector to minimize costs. These coverages are the result of several iterations; there are probably further improvements that could be made, but the overall utilization - see section 4.8.5 - is quite good.

The coverages may, at first glance, seem to be unusual, but the concepts presented in Section 4.2.3.2 were used extensively. Although New York has the highest concentration of traffic, the Midwest (Chicago-Detroit) area proved to be more difficult to design beam coverages for. This was true in the Ka-Band scan areas, previously discussed in Section 4.3.3.2, as well. In New York, one has a "cushion" to the East (in the Atlantic Ocean), which allows one to obtain two times reuse in that area. (See Beam 4H in Figure 4.5-3.) The Midwest also has a very high traffic level, but it is not possible to provide the additional full reuse because adjacent areas on both sides must be covered, and beam width and beam separation factors constrain the design.

There are a few low traffic areas which are not covered at all. This traffic was overflowed to C-Band. An alternative

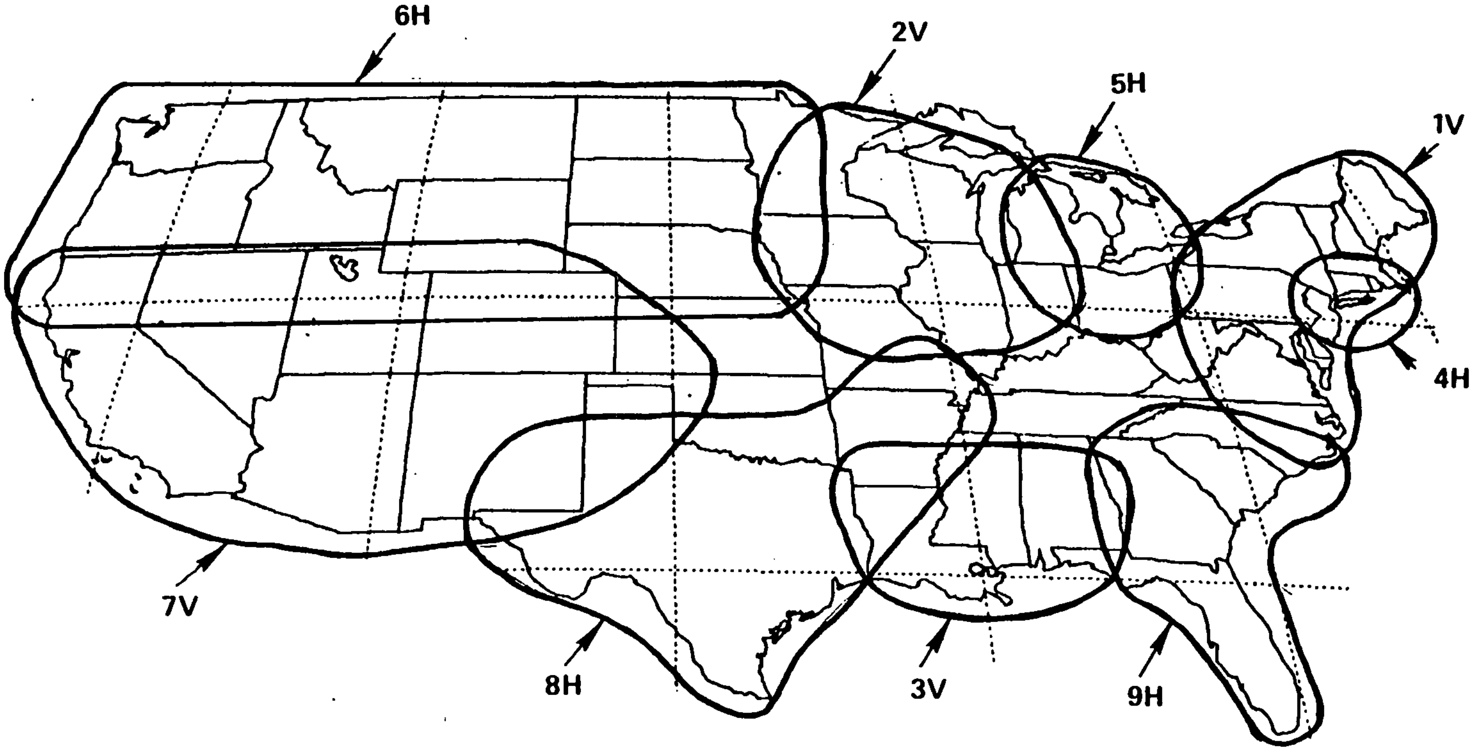

Figure 4.5-3 Scenario V - Ku-Band FSS Coverage

design, which was not investigated, would be to provide limited C/Ku connectivity, thus allowing traffic between Kentucky and New York, for example, to use C-Band in Kentucky and Ku-Band in New York.

It should also be noted that the Scenario V concept, as finally developed, obtained 9 times reuse, instead of the 12 times estimated in Task 2 - see Section 3.2. The latter value was obtained by deviding the 6° width (satellite field of view) of CONUS by .45°. However, because of the lower traffic density in the Western U.S., the reuses would be wasted; thus, beams 6H and 7V are approximately 3° in width. A higher reuse was obtained in the Eastern U.S. by splitting beams on a North/South basis as well as East/West.

4.5.3.4 C-Band Beams

A total of four beams are provided at C-Band in Scenario V. As in the Ku-Band designs, the maximum reuse possible, relative to beam separation and traffic considerations, was the goal. A fifth reuse would have been possible for the West Coast - the initial design included such a beam but traffic levels do not justify the equipment. Figure 4.5-4 shows the coverages.

4.5.4. Transponder Configuration

4.5.4.1 Ka-Band Trunking

(Refer to Section 4.3.4.1)

4.5.4.2 Ka-Band Scan

(Refer to Section 4.3.4.2)

4.5.4.3 Ku-Band

It was not possible to maintain the same Ku Bandwidths used in

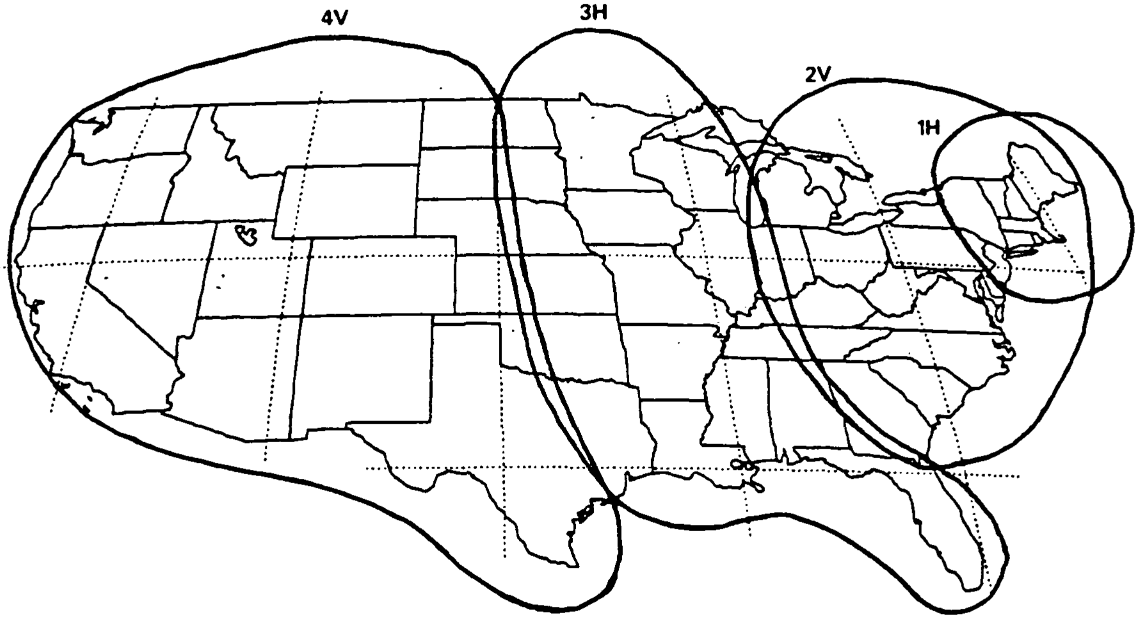

Figure 4.5-4 Scenario V - C-Band FSS Coverage

Scenario II (54 MHz). A maximum of 8 channels would be available, but there are 9 beams in Scenario V. Because of the assumption that analog modulation is used (except for a small amount of trunking data), static switching would result in lack of complete connectivity. The configuration selected has ten 36 MHz, two 18 MHz, and three 12 MHz channels, each channel interconnected with a 9x9 switch. The five narrow band channels were provided to help solve the modularity problem discussed in Section 4.2.3.2.7. Also, one of the 36 MHz channels must have an SS/TDMA capability to provide connectivity for data. Figure 4.5-5 shows the configuration.

4.5.4.4 C-Band

Figure 4.5-6 illustrates the C-Band transponder configuration. Each channel may be interconnected among the four beams by means of 4x4 switches.

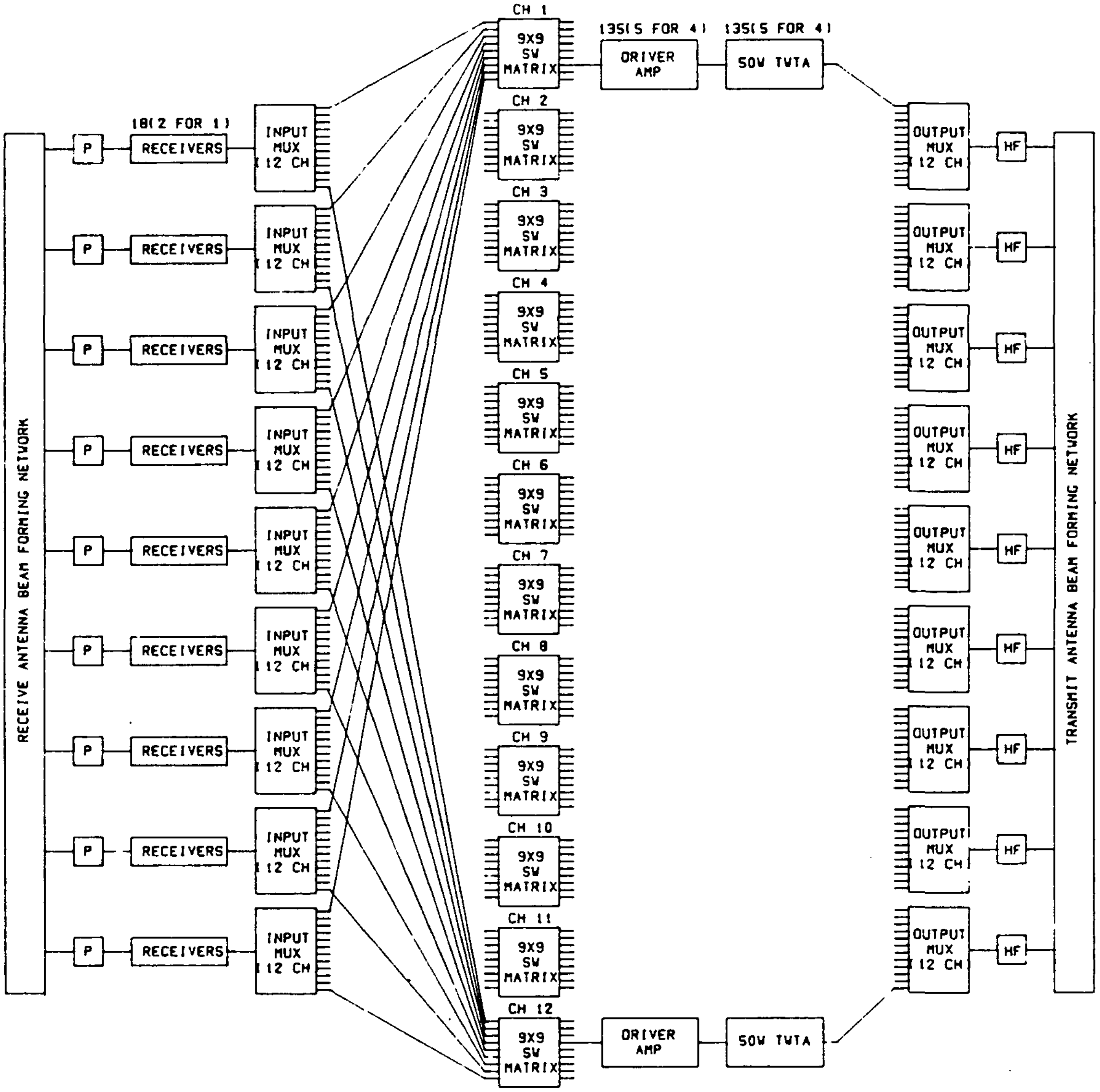

Figure 4.5-5 Scenario V Ku-Band FSS Block Diagram

4.5.4.5 Frequency Plan and Modulation/Access

Table 4.5-1 provides a description of the Scenario V payloads regarding frequency usage and the modulation/access methods assumed to be used.

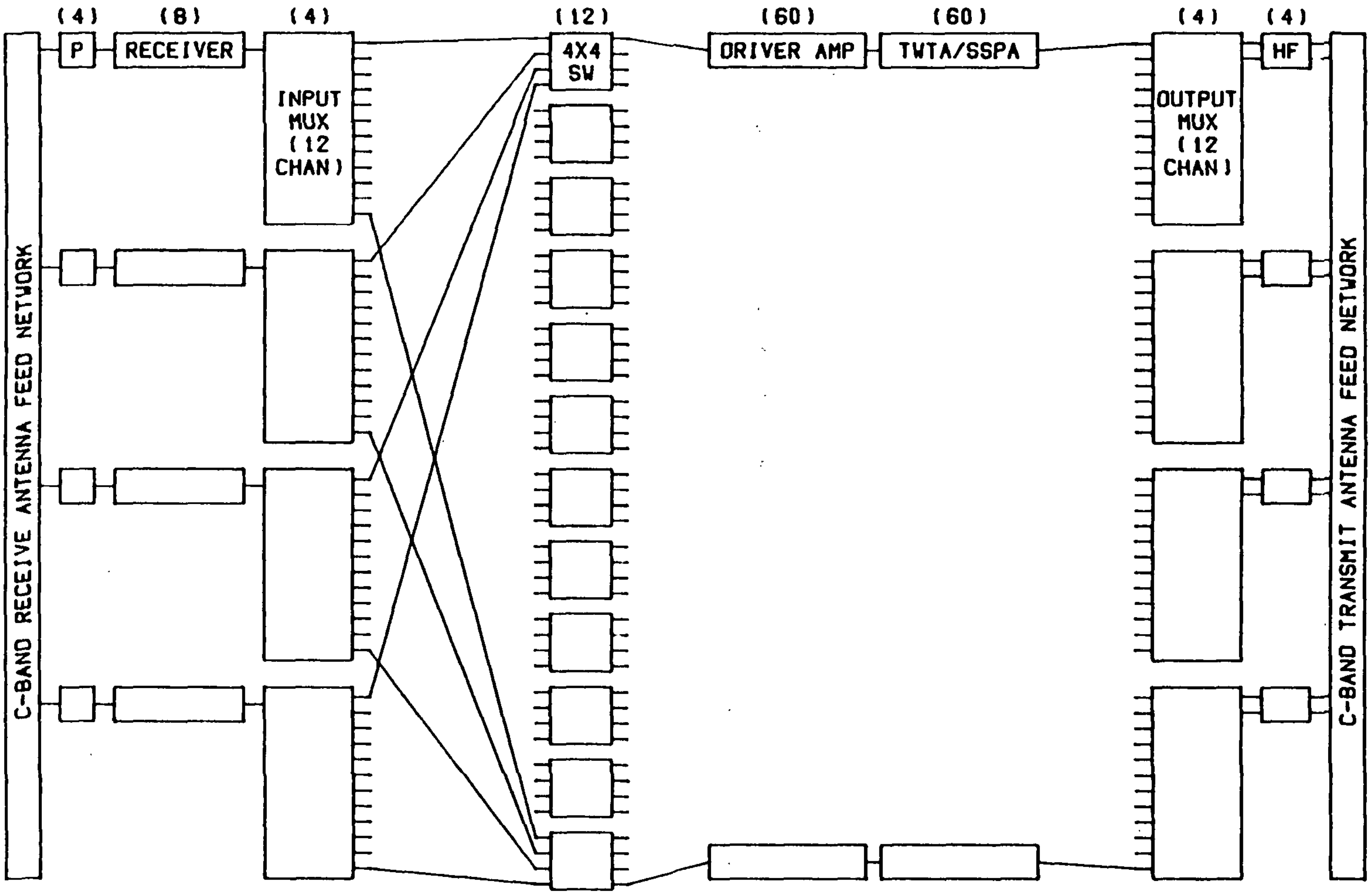

Figure 4.5-6 Scenario V C-Band FSS Block Diagram

Table 4.5-1

Scenario V Frequency Plan and Modulation/Access

Application	Frequencies (GHz)	Transponder Bandwidth(MHz)	No. Transponder	Modulation/ Access
Ka-Trunking (fixed+scan)	17.7-20.2 27.5-30.0	500	38 fixed 14 scan	SS/TDMA/ 8-PSK
Ka-Scan	17.7-20.2 27.5-30.0	240	18	SS/TDMA/ 8-PSK
Ku-Voice Ku-Data	11.7-12.2 14-14.5	36, 18, 12	90,18,27	FDMA/CSSB SS/TDMA/8-PSK
C-Voice	3.7-4.2 5.925-6.425	36	48	FDMA/CSSB
C-Video				FM-TV

4.5.5 Traffic Loading

The total traffic loaded to a single Scenario V satellite is given in Table 4.5-2, under the assumption that no broadcast video channels are loaded, i.e., Scenario IV satellites carry all such traffic.

Table 4.5-2

Scenario V Traffic Loading Summary

Application	Traffic Carried	Corresponding(1) # Satellites
Ka-Trunking	1356 K HVC(2) + 2660 video Conf.(3)	6.7
Ka-Scan	6565 Mb/s	7
Ku	519 K HVC + 519 Mb/s data	8.8
C	178K HVC	8.8

(1) Assumes 60/40 digital-analog split - see section 4.8.6
(2) HVC = "Half Voice Circuit"
(3) 2.1 Mb/s per channel - See Table 2.2.7-3

Table 4.5-3 contains the loading under the assumption that broadcast video is carried on the Scenario V satellites.

Table 4.5.3

Scenario V Traffic Loading Summary
(With Broadcast Video)

Appliication	Traffic Carried	Corresponding(1) # Satellites
Ka-Trunking	1356K HVC (2)+ 2660 video conf. (3)	6.7
Ka-Scan	6565 Mb/s	7
Ku	441K HVC + 400 Mb/s data	11.4
C	95K HVC + 45 Broadcast Video	11.4

(1) Assumes 60/40 digital - analog split - see section 4.8.6
(2) HVC: "Half Voice Circuit"
(3) 2.1 Mb/s per channel - see Table 2.2.7-3
(4) See Table XIX of [Ref. 8].

Appendix G contains detailed loadings for the Ka-band payloads, and Appendix I contains details for the C/Ku payloads.

As in Section 4.3.5, the following utilizations can be derived for Scenario V (no video):

Ka-Trunking	.76
Ka-Scan	.76
Ku-FSS	.83
C	.62
Weighted Average	.77

For Scenario V (with video), the results are:

Ka-Trunking	.76
Ka-Scan	.76
Ku-FSS	.71
C	.52
Weighted Average	.73

4.5.6 Terrestrial System Characteristics

(Refer to Section 4.3.6)

4.6 SCENARIO VI-A PAYLOAD CONCEPT DEVELOPMENT

4.6.1 General Description

Scenario VI-A consists of the Scenario V payloads, plus a) C-Band coverage of Intelsat gateway stations in Central and South America and the Caribbean, b) two intersatellite links and c) a C/L-Band maritime payload. Figure 4.6-1 summarizes the coverages provided by Scenario VI-A and Figure 4.6-2 indicates the payload equipment.

The original concept, presented in Section 3.2, was to have a complementary pair of satellites (Scenarios VI-A and VI-B), with Scenario VI-A primarily serving the Eastern U.S. and Atlantic Ocean Region (AOR), while VI-B served the Western U.S. and Pacific Ocean Region (POR). This approach was later modified for several reasons.

1) Lower U.S. capacity from given orbital arc.
2) High ISL traffic to connect Eastern and Western U.S.
3) Conflicting design requirements for INTELSAT and non-U.S. domestic coverage (described in Section 4.6.3.5).

The current approach to Scenarios VI-A/VI-B is shown in Figure 4.6-3. Scenario VI-A provides coverage for all Region 2 international and regional traffic, except Canada which is covered by VI-B; U.S. traffic could use either VI-A or VI-B, but for simplicity it was assumed all of this traffic was on VI-A. The routing of the traffic, within each satellite, is shown in Figure 4.6-3. For example, circuits from Canada to Brazil are

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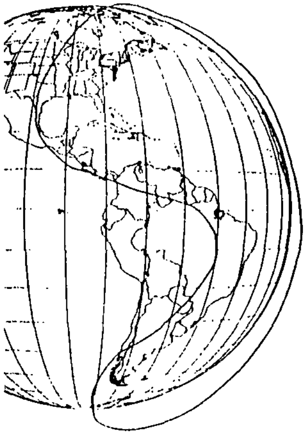
INTER SATELLITE LINKS

- TO/FROM EUROPEAN PLATFORM
- TO/FROM WESTERN PLATFORM

POWER: 160 watts
MASS: 110 kg

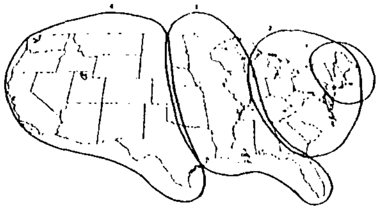
MARITIME PAYLOAD



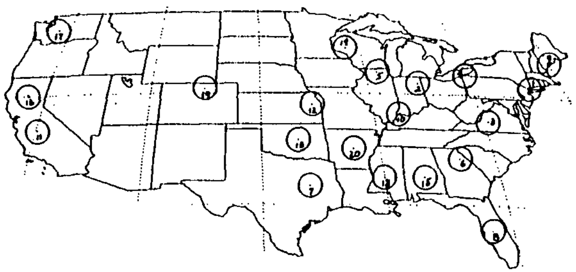
C/L - BAND: 125 VOICE CIRCUITS

POWER: 650 watts
MASS: 80 kg

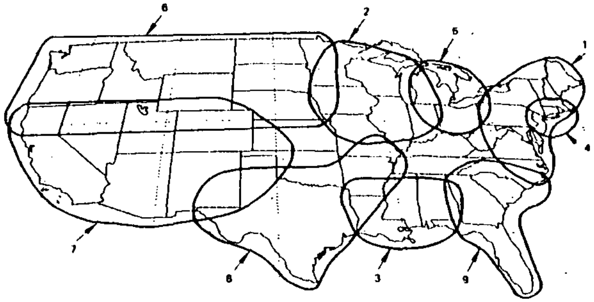
COMMUNICATIONS - 80 Gb/s



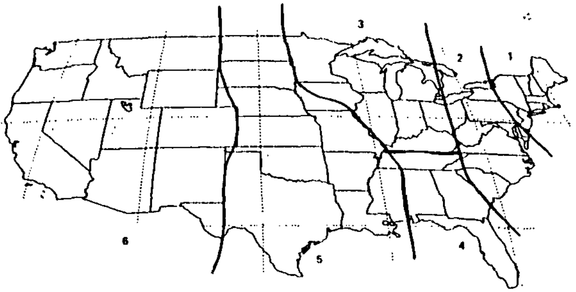
C-BAND: 48 CHAN OF 36 MHz
(3.5 Gb/s)



Ka FIXED: 20 BEAM
38 CHAN OF 500 MHz
(38 Gb/s)



Ku-BAND: 108 CHAN OF 36 MHz
(7.8 Gb/s)



Ka-SCAN 6 AREAS
18 CHAN of 240 MHz
14 CHANNELS of 500 MHz
(23 Gb/s)

C-BAND: 108 CHAN OF 36 MHz
(7.8 Gb/s)

POWER: 9,600 watts
MASS: 3,010 kg

COMMUNICATIONS PAYLOAD
OF ~ 3,200 kg
10,400 watts

Figure 4.6-1 Scenario VI-A - Services Allocation

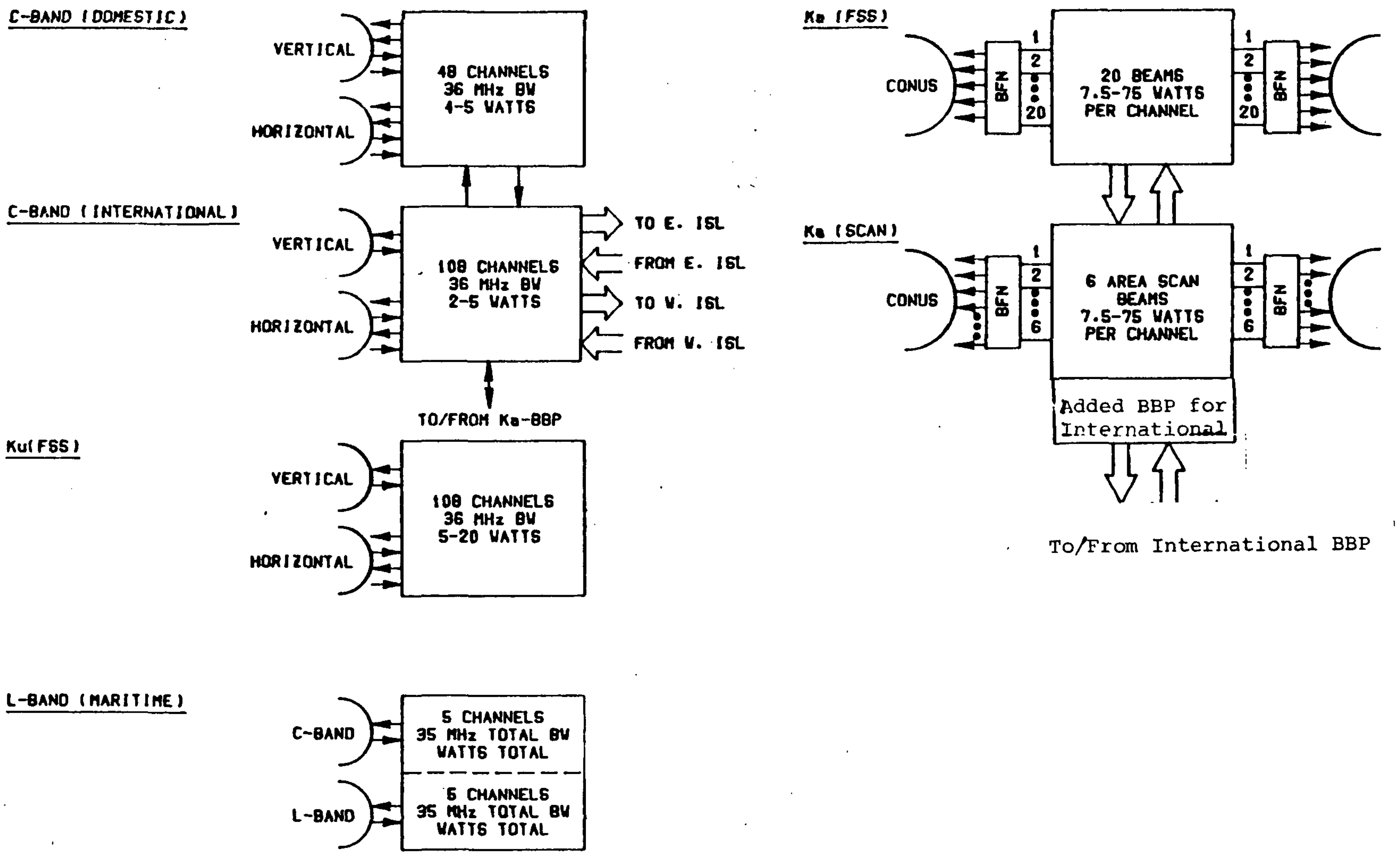


Figure 4.6-2 Scenario VI-A Payload Overview

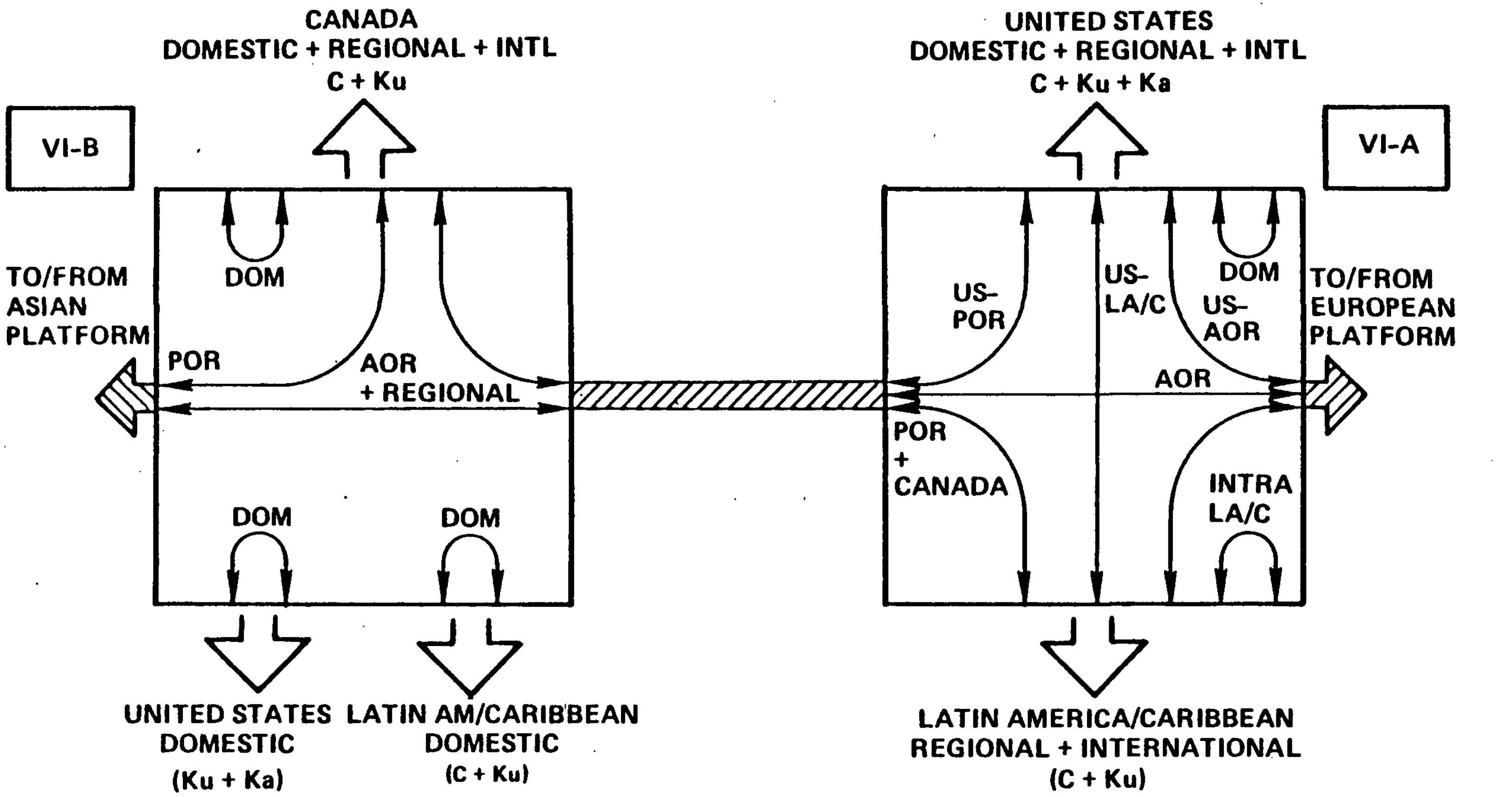


Figure 4.6-3 Scenario VI-A And B Traffic Flow

uplinked on Scenario VI-B, crosslinked to Scenario VI-A, and then downlinked to one of Brazil's gateways. Access for international/regional traffic in the U.S. and Canada need not be via gateway earth stations - it is combined with the domestic point-to-point coverage.

4.6.2 Institutional and Regulatory Issues

Scenario VI-A provides FSS CONUS coverage at C, Ku, and Ka Bands, FSS C-Band Coverage to Latin America, Maritime Mobile Satellite Coverage at C and L Bands, and Intersatellite Links to a European Platform.

The CONUS coverage FSS at C, Ku, and Ka Bands face the same barriers as discussed in the previous Scenarios. The international communications introduce a new set of institutional and regulatory barriers.

The Latin American C-Band coverage constitutes a regional satellite system. A number of regional satellite systems are in operation, including Indonesia's PALAPA (which serve some neighboring countries), the European Telecommunications Satellite Organization's (Eutelsat's) ECS 1 & 2 (which provides a wide range of business communications services in Europe), France's Telecom 1A (which provides service to France and French territories in the Western Hemisphere, and the Arab Nation's Arabsat (which will provide voice, data, and video transmission to Arabian countries). Video signals from U.S. "cable birds" are received widely in Caribbean and Latin American countries. The Soviet Union's Intersputnik is a satellite network interconnecting the Communist Bloc Nations.

Intelsat (a consortium of 109 member nations operating a global satellite system) has claimed it would be economically harmed by competition, especially over the heavily-trafficked

Atlantic Ocean. In spite of Intelsat's protests, the current U.S. Administration has favored competition over monopolies, and will probably permit increased competition in international satellite communication. The initial competition will probably be in video transmission, and in private line service to small terminals on customer premises. This business should grow rapidly because it can be offered cheaper than the relatively high tariffs on Intelsat circuits. (these high tariffs result mainly from the charges of the Intelsat "signatories," who hold monopolies in the "Gateway terminals" used in the Intelsat networks. The Intelsat space segment charges are usually only 10% of the total bill).

With the U.S. determination that separate satellite systems are in the national interest, the success of the Latin American regional satellite system requires the cooperation and participation of the Latin nations involved. This participation will probably be forthcoming, because these nations are interested in better communications systems which can be provided better by multiple small terminals on customer premises, rather than reliance on the Intelsat "Gateway terminal" approach.

In any case, a new set of regulatory and institution barriers are involved in international communications. The participants include INTELSAT and the rival satellite systems, the international cable companies and the Intelsat Signatories (who are usually the government-controlled Postal, Telephone, and Telegraph "PTT's" in most countries). The Department of State and its counterparts abroad are also involved. FCC authorizations are needed for the ground terminals to be located in the U.S., and the satellite, if it is to be a U.S. registered satellite. Authorizations are needed from the PTT's for the foreign-based ground terminals. The International Telecommunications Union is involved in the assignment of the orbital slots. Obviously, coordination with other administrations might be affected.

These considerations also apply to the inter-satellite link between the U.S. platform and foreign satellites. The development and incorporation of these intersatellite links between regional satellites presents additional competition to Intelsat and the international cable companies, and they can be expected to oppose them. However, the ITU has allocated a number of frequency bands (generally in the millimeter wave region of the spectrum which does not penetrate the atmosphere) to the intersatellite service. Intelsat can be expected to oppose the routing of traffic via intersatellite links between regional satellites, if that traffic could otherwise be routed via Intelsat satellites.

The Maritime Payload uses the C&L Bands allocated to the Maritime Mobil Satellite Service, but the footprint is restricted to the Atlantic Ocean and adjoining seas. The power-flux-density appears higher than available from the current Inmarsat satellites, and thus can reach smaller, and less-expensive terminals. If this payload is incorporated into the Inmarsat System, the institutional barriers are minor. If this service is proposed as a rival to Inmarsat, then Inmarsat and the shipping interests who have a vested interest in the current system can be expected to oppose this competition.

4.6.3 Summary Antenna Coverages

4.6.3.1 Ka-Band Fixed Spot Beams

(Refer to Section 4.3.3.1)

4.6.3.2 Ka-Band Scan Beams

(Refer to section 4.3.3.2)

4.6.3.3 Ku-Band FSS Beams

(Refer to section 4.5.3.3)

4.6.3.4 C-Band (U.S.) Beams

(Refer to Section 4.5.3.4)

4.6.3.5 C-Band (Regional/International) Beams

A total of nine beams is provided in this payload which cover all of the Intelsat gateway stations for Central America, South America, and the Caribbean. Figure 4.6-4 shows the coverages. The polarizations have been chosen to maximize isolation with respect to the U.S. C-band beams.

The major reason for placing all of the regional/international capacity for these areas on one satellite (Scenario VI-A) and all the domestic coverage on another (Scenario VI-B) is that a problem, which is essentially the same as the Ka scan area boundaries vs Ka fixed spot beam issues discussed in section 4.3.3.2, exists here also. The "spot" beams correspond to the coverage of gateway stations, and the "scan areas" are the broader coverage required for full domestic service. The alternative solution would have been to go to very small beam sizes at C-Band, with the resultant very large antenna. Even with the small beams, it was apparent that design of coverages to meet both requirements would have been difficult, if not impossible.

4.6.3.6 C/L Band Maritime Beams

Figure 4.6-5 illustrates maritime coverage for the Westen Atlantic provided by a Scenario VI-A spacecraft at 85°W longitude. To maximize the coverage, the Scenario VI-A should be positioned well to the East.

Figure 4.6-4 Scenario VI-A - C-Band International FSS Coverage

4.6.4 Transponder Configuration

4.6.4.1 Ka-Band Trunking

(Refer to Section 4.3.4.1)

4.6.4.2 Ka-Band Scan

(Refer to Section 4.3.4.2)

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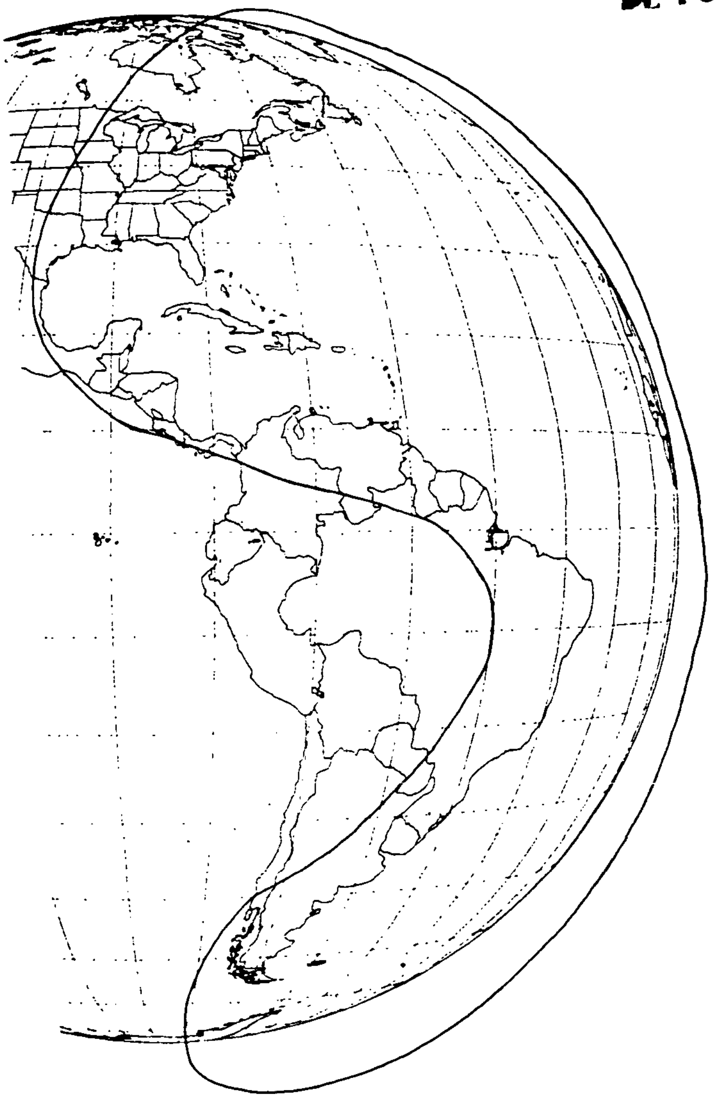


Figure 4.6-5 Scenario VI-A - C/L-Band Maritime Coverage

4.6.4.3 Ku-Band (FSS) Configuration

(Refer to Section 4.5.4.3

4.6.4.4 C-Band (U.S.) Configuration

(Refer to section 4.5.4.4)

4.6.4.5 C-Band (Regional/International) Configuration

The distinguishing feature of the Regional/International payload is the inclusion of baseband processing, in particular A/D and D/A conversion. It is assumed that the modulation used by the countries involved is analog, although the larger users might have some digital circuits on INTELSAT. There are two primary reasons why conversion to digital is included:

(1) Circuits are routed to/from ISLs or the U.S. Ka-band BBP, which are assumed to be digital.

(2) The problem of low utilization caused by modular capacity (see Section 4.2.3.2.7) is particularly severe in this application.

To expand on the latter area, the traffic involved is very low, especially between the nine beams; several matrix entries are as low as 19 HVC, and the average over all 81 possible entries is only 155 (see Appendix J-2).

In Scenario V, two Ku-Band channels were split into either two or three subchannels. Although the same approach could have been used here, A/D + D/A conversion was required anyway due to reason (1) above, so this approach was adopted to provide subchannelization to counteract low fills.

It should be emphasized that the A/D and D/A conversions are not equivalent to a transmultiplexer, because the digital signals generated could not be processed through a D channel bank or other TDM equipment to recover the individual circuits. Rather, the digital signal is used only for on-board switching/ routing. In Figure 4.6-6, FDM accesses of different bandwidths are illustrated; each access is converted to a digital stream of the appropriate rate (sampling rate times bits per sample). Once the digital signal is obtained, it can be buffered; on-board control would then perform framing and synchronization and empty the buffer at high burst rates through the baseband processor switch.

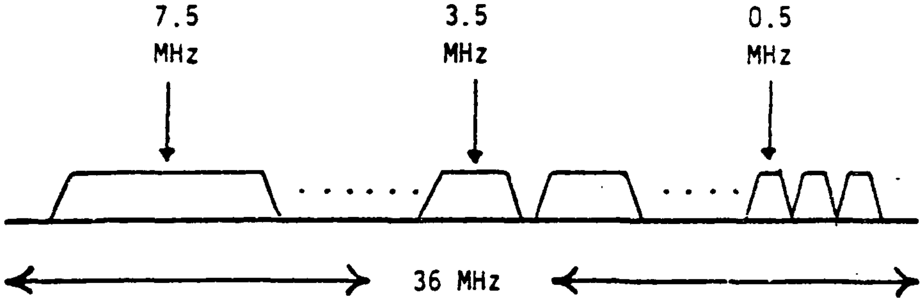


Figure 4.6-6 Representative FDM Subchannelization

The overall routing between CONUS (BBP), ISLs, and the LAM/C processor is shown in Figure 4.6-7. This digital routing switch provides all of the required connectivities shown in Figure 4.6-3.

4.6.4.6 C/L-Band Maritime Configuration

This payload is representative of an INMARSAT second generation (125 channel) capability. Figure 4.6-8 illustrates the basic configuration.

4.6.4.7 Inter-Satellite Links

The ISL assumed for Scenario VI-A is a 60 GHz system, as shown in Figure 4.6-9. It was assumed that a single channel could carry two 750 Mb/s streams.

4.6.4.8 Frequency Plan and Modulation/Access

Table 4.6-1 shows the frequencies and modulation/access methods only for those payloads unique to Scenario VI-A. The remainder of the Scenario VI-A payloads are identical to Scenario V, Table 4.5-1.

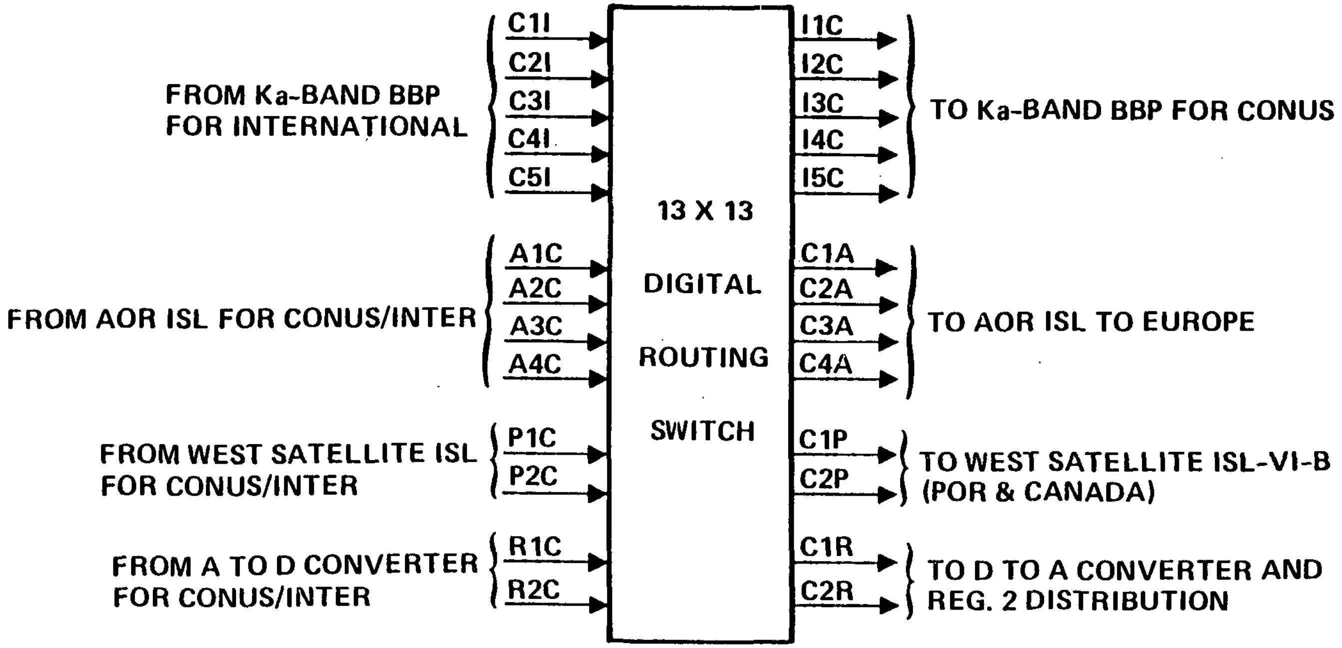
Table 4.6-1

Scenario VI-A Frequency Plan and Modulation/Access

Application	Frequencies (GHz)	Transponder Bandwidth(MHz)	No. Xpdrs	Modulation/ Access
C-International	3.7-4.2 5.925-6.425	36	108	FDMA/FDM/FM
C/L Maritime	1.530-1.546 6.425-6.441	16 (Forward)	1	
	1.6265-1.6475 3.6-3.621	21(Return)	1	SCPC
ISL	59.0-64.0	1500	3	TDM/QPSK

4.6.5 Traffic Loading

The single satellite loading for Scenario VI-A is presented in Table 4.6-2.



*EACH DATA INPUT/OUTPUT LINE CARRIES 750 Mb/s

Figure 4.6-7 International Routing Switch

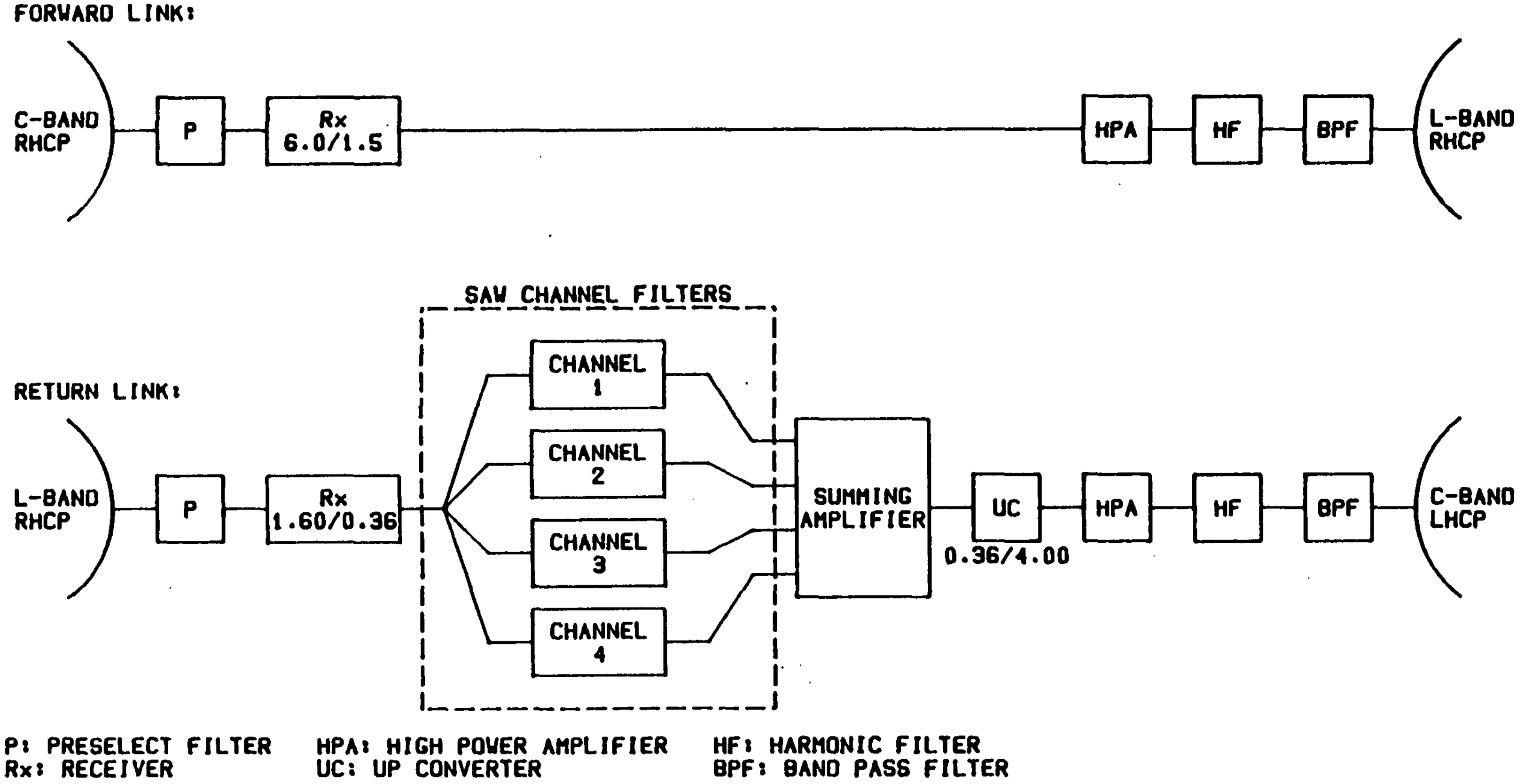


Figure 4.6-8 Scenario VI-A C/L-Band Block Diagram

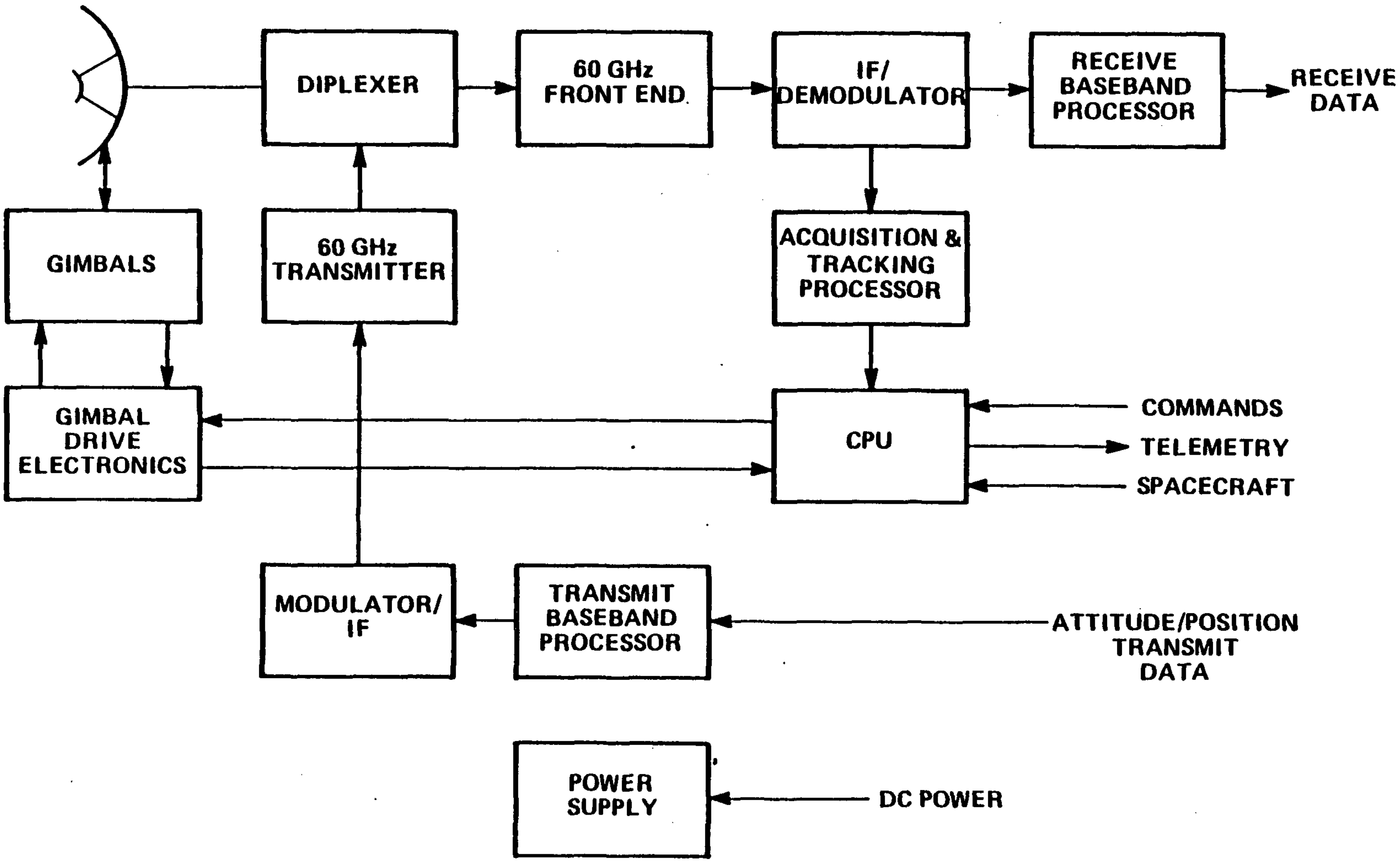


Figure 4.6-9 Scenario VI-A ISL Block Diagram

Table 4.6-2

Scenario VI-A Traffic Loading Summary

Application	Traffic Carried	Corresponding(1) # Satellites
Ka-Trunking	1356K HVC(2) + 2660 video conf.(3)	6.7
Ka-Scan	6565 Mb/s	7
Ku	519K HVC + 519 Mb/s data	8.8
C(U.S.)	178K HVC	8.8
C(LAM/C)	60K HVC + 41 (36 MHz) channels video	1
ISL	158K HVC	1

(1) Assumes 60/40 digital - analog split - see section 4.8.6
(2) HVC = "Half Voice Circuit"
(3) 2.1 Mb/s per channel - See Table 2.2.7-3

Appendix J provides detailed loadings for the VI-A specific payloads; the remainder are covered in Appendices G and I.

Utilizations are as follows:

Ka-Trunk	.76
Ka-Scan	.76
Ku	.83
C(U.S.)	.62
C(LAM/C)	.61
ISL	.84
Weighted Average	.76

4.6.6 Terrestrial System Characteristics

See Section 4.5.6 for the earth station descriptions regarding the Scenario V payloads which are included as part of VI-A.

The gateway stations used in Latin American/Caribbean (LAM/C) are assumed to be INTELSAT Standard "A" stations. The maritime mobile stations are standard INMARSAT-type terminals.

4.7 SCENARIO VI-B PAYLOAD CONCEPT DEVELOPMENT

4.7.1 General Description

Scenario VI-B consists of the Scenario V payload, less the C-Band for U.S. coverage. In addition, it provides all domestic service for Canada, Mexico, and Latin America, including Brazil. Both Canada and Brazil use a combination of C-and Ku-band to provide the necessary reuse to meet projected traffic. Also, Mexico has been assigned two 36 MHz Ku-band channels from the Scenario V beam 8H (see Figure 4.5-3), which had two unused channels. This capacity is not necessary to meet year 2008 demand, but the Morales Satellite does provide some Ku capacity. The addition of this coverage complicates the antenna design, and may not be worth the extra expense for only two channels. Figure 4.7-1 shows the services allocation and Figure 4.7-2 summarizes the Scenario VI-B payload.

4.7.2 Institutional and Regulatory Issues

(Refer to Section 4.6.2)

4.7.3 Summary Antenna Coverages

4.7.3.1 Ka-Band Fixed Spot Beams

(Refer to Section 4.3.3.1)

4.7.3.2 Ka-Band Scan Beams

(Refer to Section 4.3.3.2)

4.7.3.3 Ku-Band (U.S.) Beams

(Refer to section 4.5.3.3)

INTER SATELLITE LINKS

- TO/FROM ASIAN PLATFORM
- TO/FROM EASTERN PLATFORM

POWER: 130 WATTS

MASS: 106 g

MARITIME PAYLOAD

C/L-BAND: 125 VOICE CIRCUITS

POWER: 650 watts

MASS: 44 kg

C-BAND: 108 CHAN OF 36 MHz
(7.8 Gb/s)

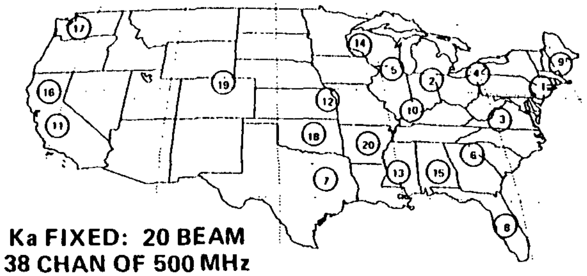
Ku-BAND: 38 CHAN OF 36 MHz
(2.7 Gb/s)

POWER: 10,400 watts

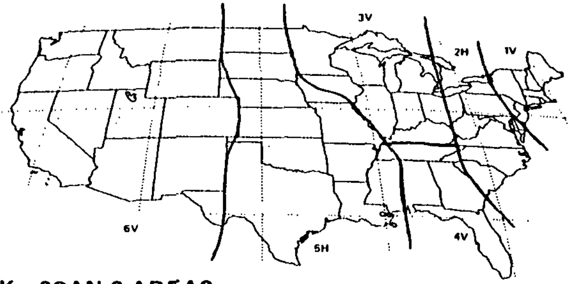
MASS: 2,775 kg

**COMMUNICATIONS PAYLOAD
OF 2,925 kg and 11,200 watts**

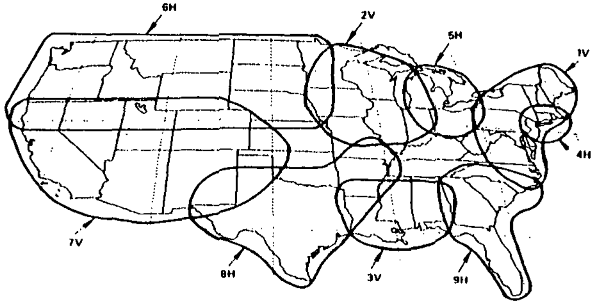
COMMUNICATIONS – 80 Gb/s



Ka FIXED: 20 BEAM
38 CHAN OF 500 MHz
(38 Gb/s)



Ka-SCAN 6 AREAS
18 CHAN OF 240 MHz
14 CHAN OF 500 MHz
(23 Gb/s)



Ku-BAND: 108 CHAN OF 36 MHz
(7.8 Gb/s)

Figure 4.7-1 Scenario VI-B - Services Allocation

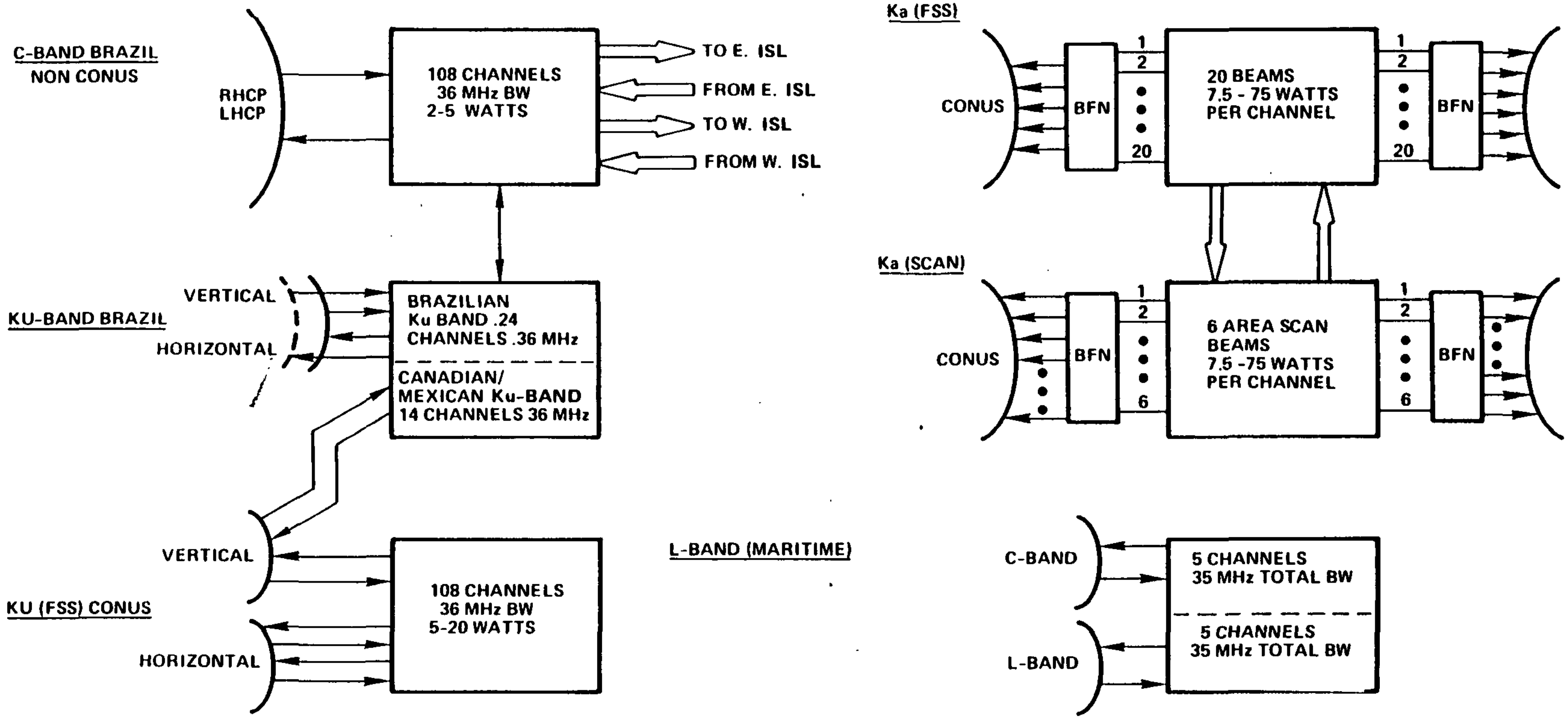


Figure 4.7-2 Scenario VI-B Payload Overview

4.7.3.4 Ku-Band (Non U.S.) Beams

Figure 4.7-3 shows three separate Ku-Band coverages. A single spot beam is provided in the Toronto/Montreal area, and assumes terrestrial back haul. The concentration of traffic in this area is very high, and obtainning sufficient reuse at C-Band only would have been difficult and also required smaller beamwidths (larger antennas). This spot beam is horizontally polarized to match the Scenario V Ku Beams 4 and 5 (see Figure 4.5-3) and utilizes spatial separation to obtain frequency reuse.

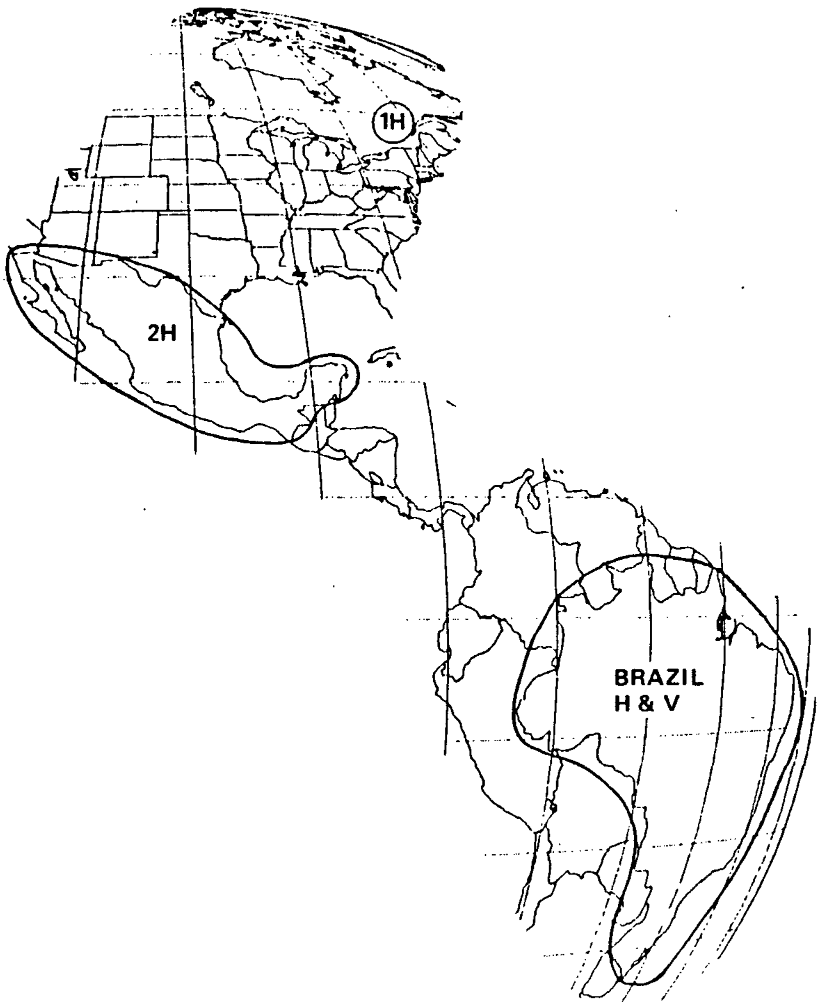


Figure 4.7-3 Scenario VI-B - Ku-Band Non-CONUS Coverage

The Mexico beam is also horizontally polarized, and shares the spectrum with Scenario V beam 8 (two channels). As noted in Section 4.7.1, this coverage could be eliminated.

Finally, Brazil has complete Ku-band coverage with two times (polarization) reuse. The demand level, and assumed transponder capacities, dictated over 3 times reuse, with much of the traffic concentrated in the Rio De Janeiro - Sao Paulo area. As in Canada, obtaining the necessary reuse at C-Band only in this area would have been difficult without going to very large antennas.

4.7.3.5 C-Band (Non-U.S.) Beams

It was previously mentioned in Section 4.7.1, that U.S. C-band coverage was dropped from Scenario VI-B. This was due to provision of C-band coverage for both Canada and Mexico. Canada is covered by three beams, with an intentional overlap of the Central and Eastern Beams in the Toronto area - See Figure 4.7-4.

Mexico has two beams, with an overlap in the central portion of the country (Mexico City, Guadalajara). A Central America/Caribbean beam is provided, although no traffic forecasts exist for those areas.

Beam 7 of Figure 4.7-4 provides all necessary coverage for Venezuela, Columbia, Ecuador, and Peru, with capacity available for the Northwest portion of Brazil. Beam 8 provides coverage

4.7.3.6 C/L-Band Maritime Beams

Figure 4.7-5 shows coverage of the Pacific for the Scenario VI-B platform.

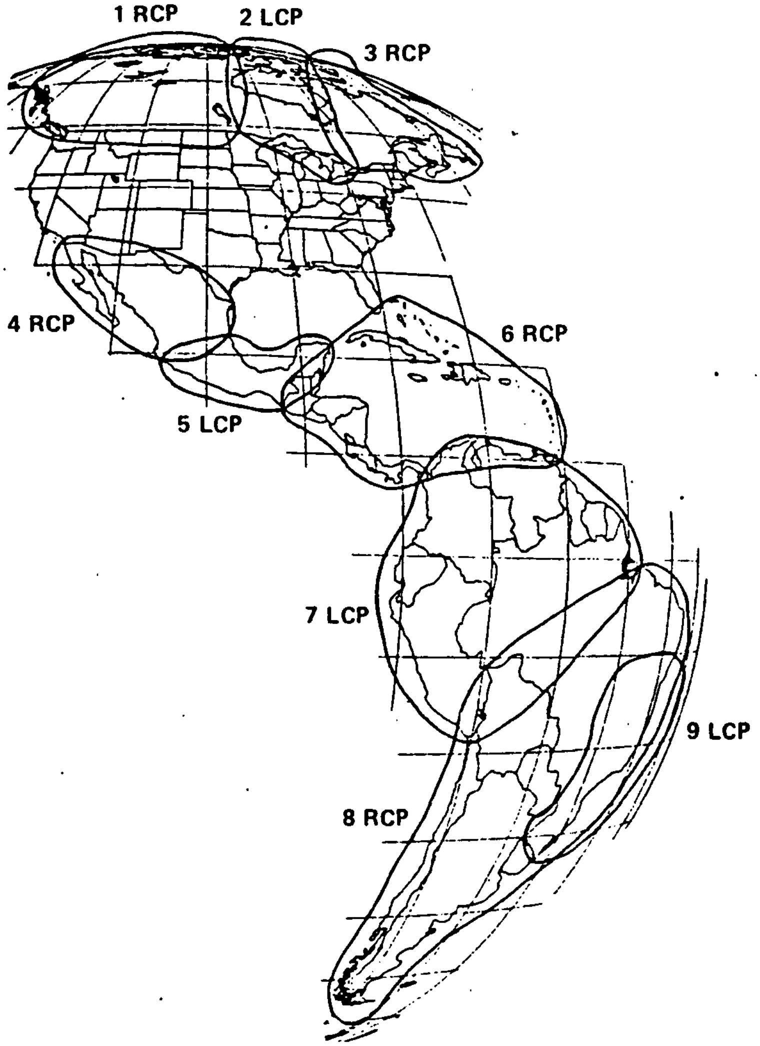


Figure 4.7-4 Scenario VI-B - C-Band Non-CONUS Coverage

4.7.4 Transponder Configuration

4.7.4.1 Ka-Band Trunking

(Refer to Section 4.3.4.1)

4.7.4.2 Ka-Band Scan

(Refer to Section 4.3.4.2)

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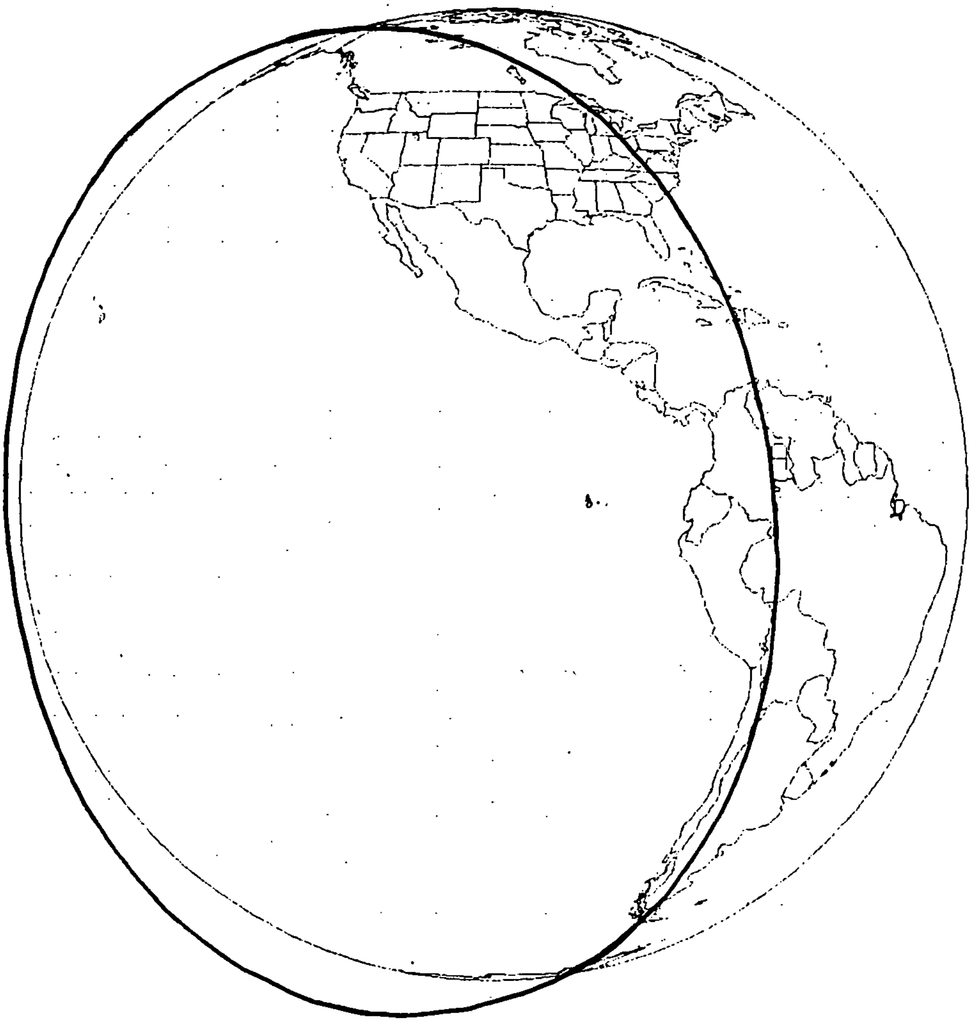


Figure 4.7-5 Scenario VI-B - C/L-Band Maritime Coverage

4.7.4.3 Ku-Band (U.S.)

(Refer to Section 4.5.4.3)

4.7.4.4 Canadian Domestic, Regional, and International Configuration

Nine channels in each of the four beams (including the Ku-band spot) are interconnected via 4x4 switches. Three channels are processed for routing to the ISLs (see Figure 4.6-3 for the Scenario VI-B routing scheme). As with the U.S. in Scenario VI-A, it is possible for an earth station in Canada to have access to both domestic and international/regional routing, i.e., no gateways are required. Figure 4.7-6 illustrates the payload; it should also be mentioned that the BBP in VI-B provides connectivity between the two ISLs.

4.7.4.5 Mexico/Caribbean Configuration

As shown in Figure 4.7-7, one half of the channels in each C-Band beam are connected via 3x3 switches; the other half are directly connected, as are the two Ku-Band channels. As previously mentioned, these channels could be deleted because of the additional antenna complexity.

4.7.4.6 South American Configuration

Figure 4.7-8 illustrates the South American Domestic configuration. The majority of the capacity of this payload is to satisfy Brazil's traffic; a total of only 12 of the 60 channels are used for the other countries. As with the Mexico/ Caribbean design, only half of the channels are inter- connected; C to Ku-Band cross strapping is provided in the six channels.

4.7.4.7 C/L-Band Maritime Configuration

(Refer to Section 4.6.4.6)

4.7.4.8 Inter-Satellite Links

(Refer to Section 4.6.4.7)

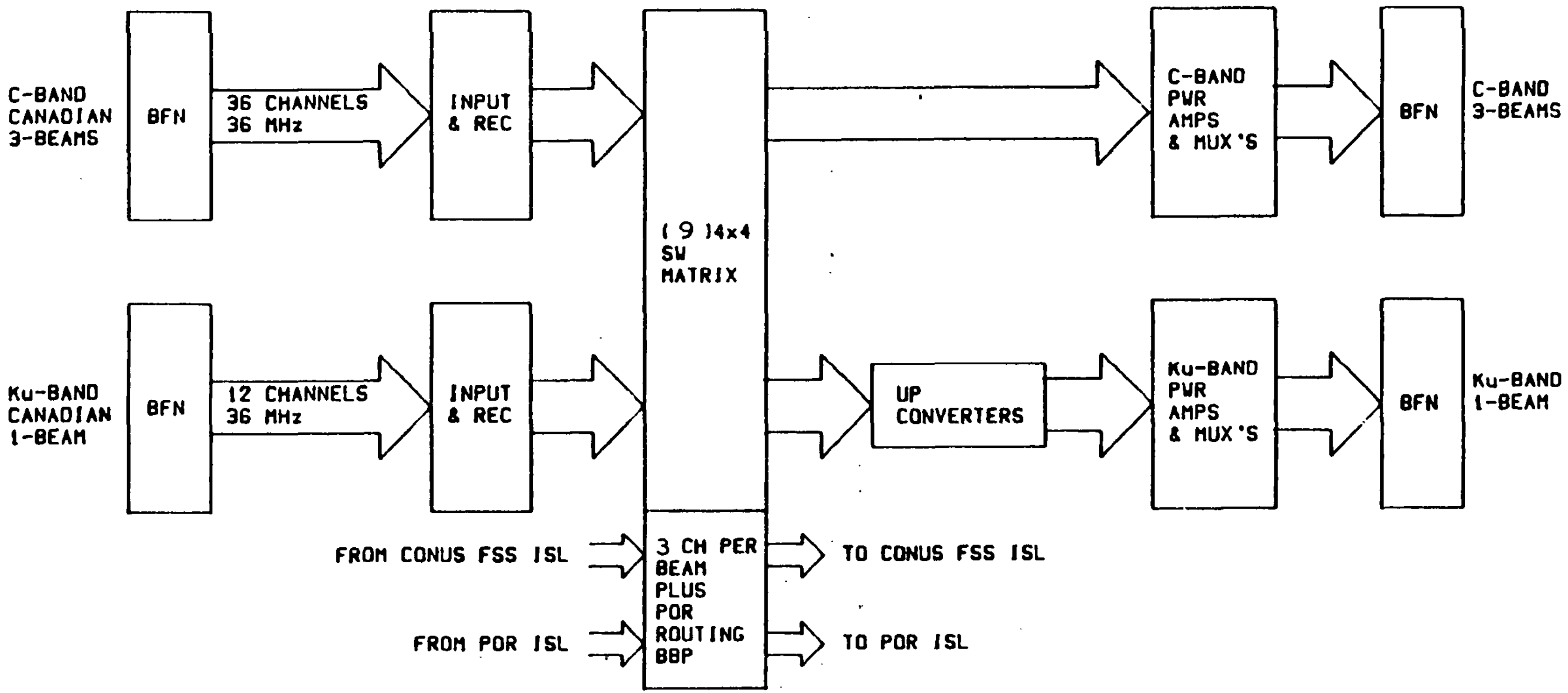


Figure 4.7-6 Canadian Payload Block Diagram

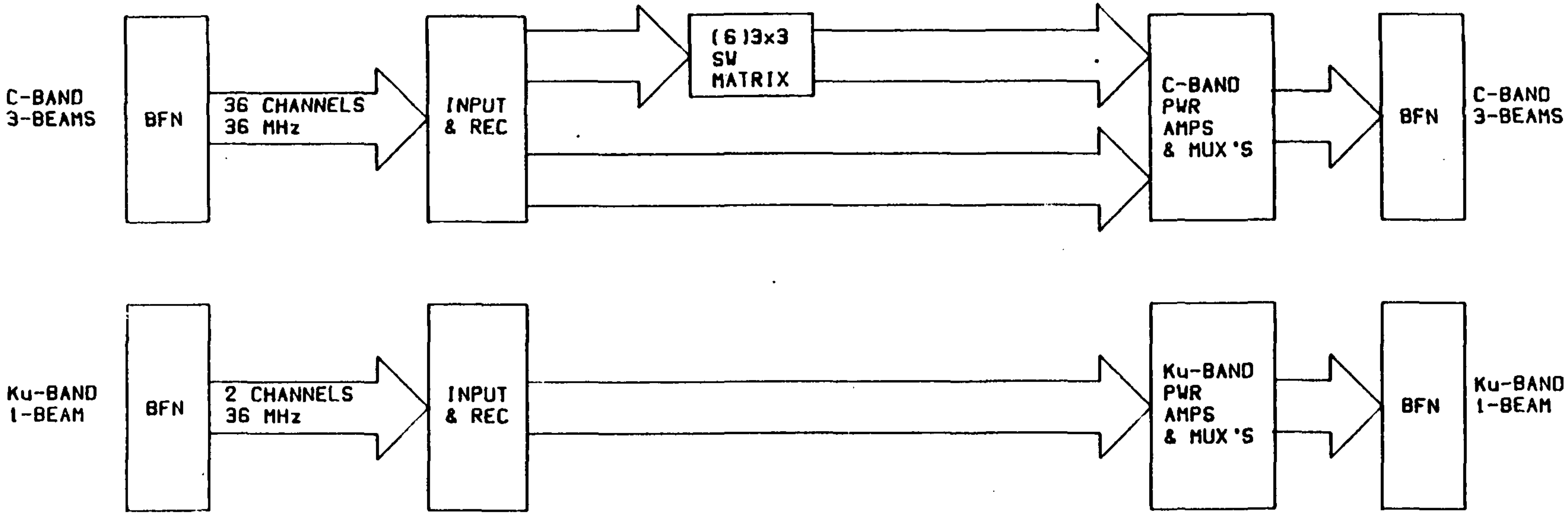


Figure 4.7-7 Mexican/Caribbean Payload Block Diagram

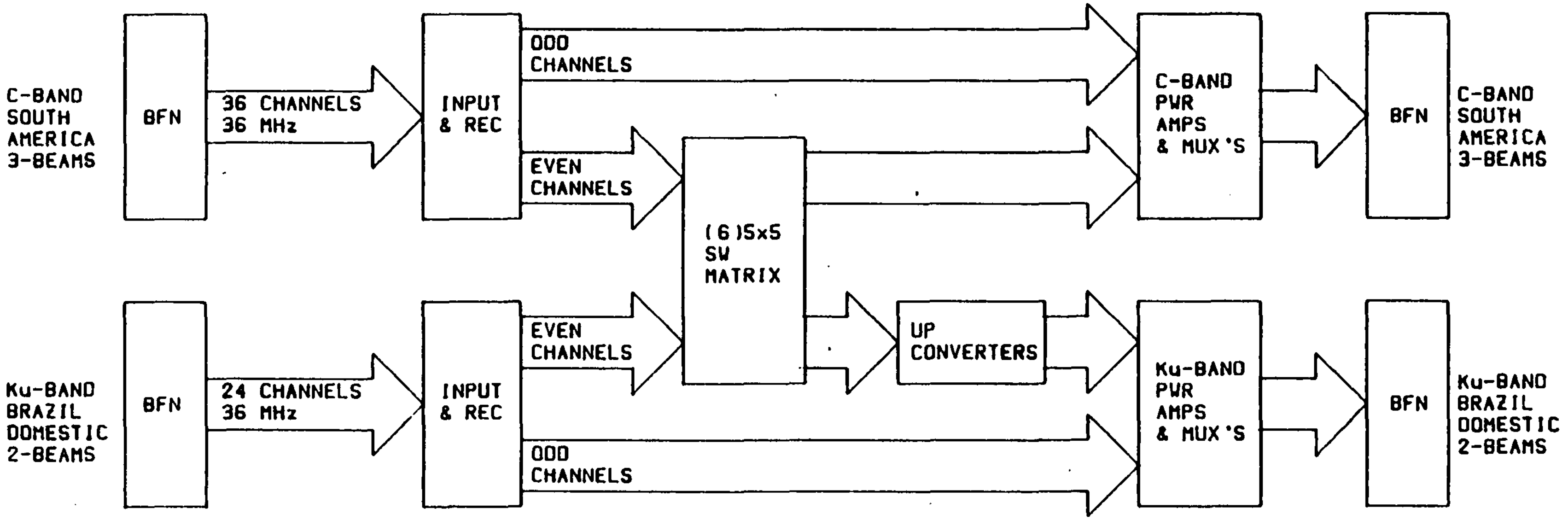


Figure 4.7-8 South American Domestic Payload Block Diagram

4.7.4.9 Frequency Plan and Modulation/Access

The frequency plan and modulation/access is the same as that shown previously in Tables 4.5-1 and 4.6-1, with the exception that the Canadian channels are assumed to be SS/TDMA/8-PSK, and the Mexico and South American channels are SCPC.

4.7.5 Traffic Loading

Table 4.7-1 contains the single satellite loading for Scenario VI-B.

Table 4.7.1

Scenario VI-B Traffic Loading Summary

Application	Corresponding(1) Traffic Carried	# Satellites
Ka-Trunking	1356K HVC (2) + 2660 video conf.(3)	6.7
Ka-Scan	6565 Mb/s	7
Ku (U.S.)	519K HVC 519 Mb/s data	8.8
Ku (Non U.S.)	64K HVC	1
C (Non U.S.)	178K HVC	1
ISL	87K HVC	1

(1) Assumes 60/40 digital - analog split - See Section 4.8.6.
(2) HVC = "Half Voice Circuit"
(3) 2.1 Mb/s per channel See Table 2.2.7-3.

Appendix K contains loading details for the VI-B specific payloads; the remainder are covered in Appendices G and I.

Utilizations are as follows:

Ka-Trunking	.76
Ka-Scan	.76
Ku (U.S.)	.83
Ku (Non-U.S.)	.81
C (Non-U.S.)	.75
ISL	.70
Weighted Average	.77

4.7.6 Terrestrial System Characteristics

See Section 4.5.6 for the earth station descriptions regarding the Scenario V payload which are included as part of VI-B.

4.8 CONCLUSIONS AND RANKING OF SCENARIOS

4.8.1 Conclusions

The basic conclusion reached as a result of Task 3 studies is that payload concepts, which are optimized relative to traffic distributon characteristics with high utilization and frequency reuse, can provide very large capacities from a single orbital slot.

Regarding U.S. domestic FSS demand, the designs developed provide more digital capacity than analog (see Section 4.8.6). This is primarily due to the assumed use of digital modulation at Ka-band, where there is more bandwidth available.

It has also been demonstrated that the aggregation of payloads is possible. Such aggregation includes frequency reuse at C and Ku-band for non-U.S. applications, in conjunction with high reuse in those bands within the U.S.

A ten satellite network, consisting of a combination of payload concepts developed, can meet virtually all Region 2, Year 2008, requirements. The satellite breakdown and traffic allocation is shown in Table 4.8-1.

Section 4.8.8 provides a quantitative ranking of the scenarios. A summary of the ranking with the major qualitative factors for each scenario is shown in Table 4.8-1A.

4.8.2 Bandwidth and Reuse

Table 4.8-2 provides the total bandwidth available at the various bands for each scenario. Effective bandwidth was used (e.g., 12 transponders at 36 MHz = .43 GHz, instead of .5 GHz).

Table 4.8-1

Summary of Platform Constellation

Payload	Number of Satellites	Traffic Served
IV	3	U.S. Broadcast Video
V	3	U.S. Domestic FSS
VI-A	2	U.S. Domesitc FSS + AOR International ISL) + Intra-Regional (except Canada)
VI-B	2	U.S. Domestic FSS + Non-U.S. Domestic + Canada (International/Regional) + POR International (ISL)

Notes:

(1) Sparing for U.S. Domestic, included in forecasts. (See Section 2.2.1.2.)

(2) In order for seven V/VI Satellites to serve U.S. Domestic FSS, digital penetration must be approximately 70%. (See Section 4.8.6.)

4.8.3 Efficiency

In order to evaluate the capacity of a given payload relative to the traffic, one must make assumptions regarding the modulation and link performance to arrive at the maximum capacity of a transponder operating in that mode. Table 4.8-3 summarizes the assumptions regarding these capacities.

4.8.4 Throughput

Tables 4.8-2 and 4.8-3 were combined, along with Tables 4.3-1, 4.5-1, 4.6-1, and Section 4.7.4.9, which delineate the modulation used for each payload, to give the communications throughput for each payload in a single platform of each scenario type (Maritime and DBS not included). Half voice

Table 4.8-1A

Overall Ranking of Scenarios

1. Scenario V - High Capacity CONUS
   - Optimized to CONUS distribution
   - All rigid reflectors
   - Seven satellite constellation satisfies demand through 2008
   - Limited barriers

2. Scenario IV - High Capacity DBS
   - Single location for multiple users
   - Minimizes ground assets
   - FSS payload tailored to DBS
   - On-board networking

3. Scenario II - Medium Capacity CONUS
   - Replacement of mid-90's payloads
   - High capacity digital Ka-band
   - Poor analog balance for CONUS (92% digital)
   - No major barriers (orbital location restricted)

4+ Scenario VI-A - International Traffic
   - Highest throughout Scenario
   - Lowest utilization/capacity
   - Major institutional barriers
   - Suitable for integration with Scenario V and VI-B

4- Scenario VI-B - Non-CONUS Domestic
   - Efficient use of orbital arc
   - Extremely difficult institutional barriers
   - Suitable for integration with Scenario V and VI-A

Table 4.8-2

Effective Bandwidth (GHz)

Communication Band	Scenario II	IV	V	VI-A	VI-B
Ka	30.3	--	30.3	30.3	30.3
Ku (FSS)	1.3	1.2	3.9	3.9	5.2
Ku (DBS)	.4	1.5	--	--	--
C	.9	--	1.7	5.6	3.
L	--	--	--	.035	.035
ISL	--	--	--	4.5	3.0

Table 4.8-3

Summary of Modulation Capacity Assumptions

Modulation Technique	Capacity (36 MHz)
8 PSK	72 Mb/s
CSSB	6000 HVC
FDM/FM	2800 HVC
SCPC	1800 HVC
Video-FM	2.5 Channels
SQPSK (ISL)	1.5 Gb/s*

* per ISL channel

circuits were converted to digital bit rates based on an assumed 24 Kb/s per circuit. Because the capacity assumptions of Table 4.8-3 have been included, the resulting values do not match previous ones (Figures 4.3-1, 4.5-1, 4,6-1, and 4.7-1) which were on an assumed 2 bits/Hz basis. Table 4.8-4 provides the results, as well as a total throughput figure for each scenario.

Table 4.8-4

Maximum Throughput (Gb/s) By Scenario

	Scenario			
Application	II	V	VI-A	VI-B
Ka-Trunking	49.9	49.9	49.9	49.9
Ka-CPS	8.6	8.6	8.6	8.6
Ku-FSS	5.2	15.6	15.6	17.5
C	3.5	6.9	14.2	5.7
ISL	--	--	4.5	3.0
Total	67	81	93	85

4.8.5 Utilization

The concept of utilization of communications capacity of a satellite is somewhat nebulous. The maximum theoretical throughput depends not only on the number of transponders and their bandwidth, but also on the modulation/access method used. Further, one can have a mixture even within the same transponder; e.g., two digital voice circuits encoded at 32 Kb/s are equivalent to one circuit at 64 Kb/s. Depending on whether throughput is measured as a bit rate or in terms of half voice circuits, different values of throughput are obtained.

Based on the discussion above, determination of absolute utilizations is probably not possible. However, one can apply a consistent definition of utilization to different payloads, and obtain a relative measure of utilization. This is the approach used in Sections 4.3.5, 4.5.5, 4.6.5, and 4.7.5. The basic approach used was to convert all traffic types to a data rate, using 24 Kb/s per HVC, 2.1 Mb/s per video conferencing channel, and 29 Mb/s per broadcast channel. C and Ku capa- cities were calculated based on 6000 HVC per 36 MHz trans- ponder. Table 4.8-5 summarizes the results (exclusive of Scenario IV)).

The overall utilizations for each scenario are very close. This is due to two major factors:

1. The same Ka-band design was used for all scenarios, and the capacity at Ka-band is a significant proportion of the total.
2. Because we are dealing with traffic between many terminals, some version of the law of large numbers seems to apply.

Higher fills in the Ka-Trunking were not attained because of the modularity factor (see Section 4.2.3.2.7), and the use of scan beams to carry some trunking traffic. For example, two 500 MHz transponders were assigned to Scan Beam #1 for trunking, each with an assumed capacity of 40000 HVC, even though only 39,194 circuits were assigned to that beam (see Appendix G). All but 8000 of these circuits were in fact overflowed from either Fixed Beams 1 or 9, implying a constraint on the scan cycle that 75% of the dwell must be on these two positions. By providing an additional channel, then the time required is only one-half, or about 38%. The scan cycle must be able to accommodate both trunking and CPS requirements.

The C-band (U.S) utilization for Scenarios V, VI-A and VI-B could have been improved with further design iteration. The overflow from the Ku beams to the C-beams was not as balanced as anticipated (see Appendix I).

Table 4.8-5

Summary of Utilization

Application	Scenario II	Scenario V	Scenario VI-A	Scenario VI-B
Ka Trunking	.76	.76	.76	.76
Ka-CPS	.76	.76	.76	.76
Ku (U.S-FSS)	.62	.83	.83	.83
Ku (Non-U.S.)	-	-	-	.81
C (U.S.)	.92	.62	.62	-
C (International)	-	-	.61	-
C (Non-U.S.)	-	-	-	.75
ISL		-	.84	.70
Weighted Average	.760	.765	.756	.774

4.8.6 Digital/Analog Tradeoffs

The traffic loading results given in Sections 4.3.5 and 4.5.5, regarding U.S. domestic FSS requirements, were in a sense for the digital/analog ratio (60/40) assumed in Section 2.2.7. In order to provide a parametric view of the two designs (II and V) regarding the digital/analog question, Figures 4.8-1 and 4.8-2 were developed. It is emphasized that these two figures are for the payload concept for the two scenarios, including the assumed modulation associated with the individual payloads.

The graphs presented in these two figures show the percent of total digital traffic (solid lines) served by N satellites, or percent of total analog traffic (dashed lines) served by N satellites, as a function of the digital penetration. Points on the curves whose value is less than 1.0 do not have adequate capacity to serve all the demand; those over 1.0 have excess (unused) capacity.

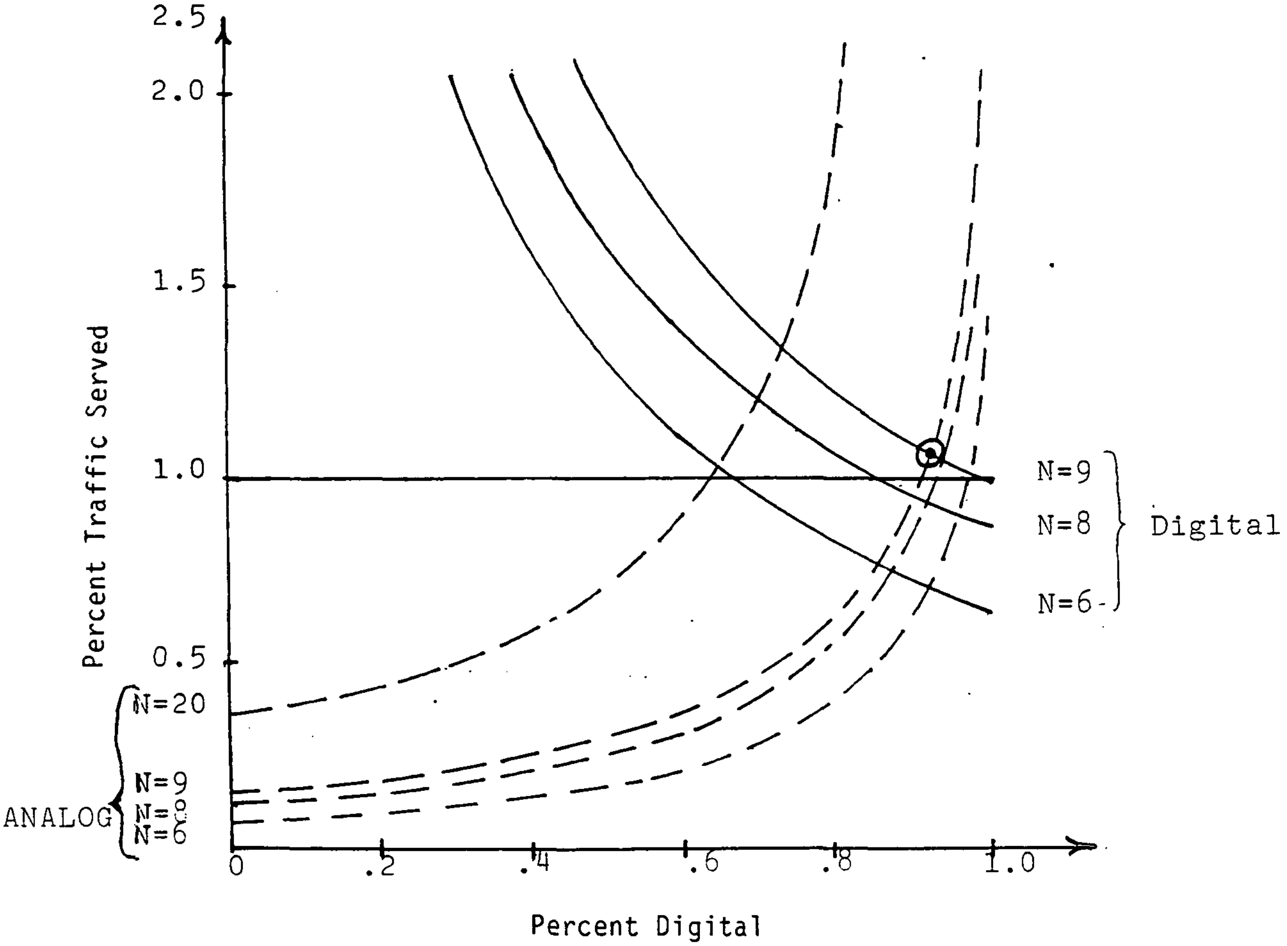


Figure 4.8-1 Scenario II Digital/Analog Tradeoff

The curves can be used in various ways. For example, if we assume a 60/40 split in the digital/analog ratio, then six satellites will satisfy the digital demand (with excess capacity), but will serve only 22% of analog traffic in Scenario II, and 69% of analog traffic in Scenario V.

Regarding Scenario II, both digital and analog requirements can be fully met with 9 satellites, but the digital level must be in the range .87-.95. Scenario V can meet the requirements

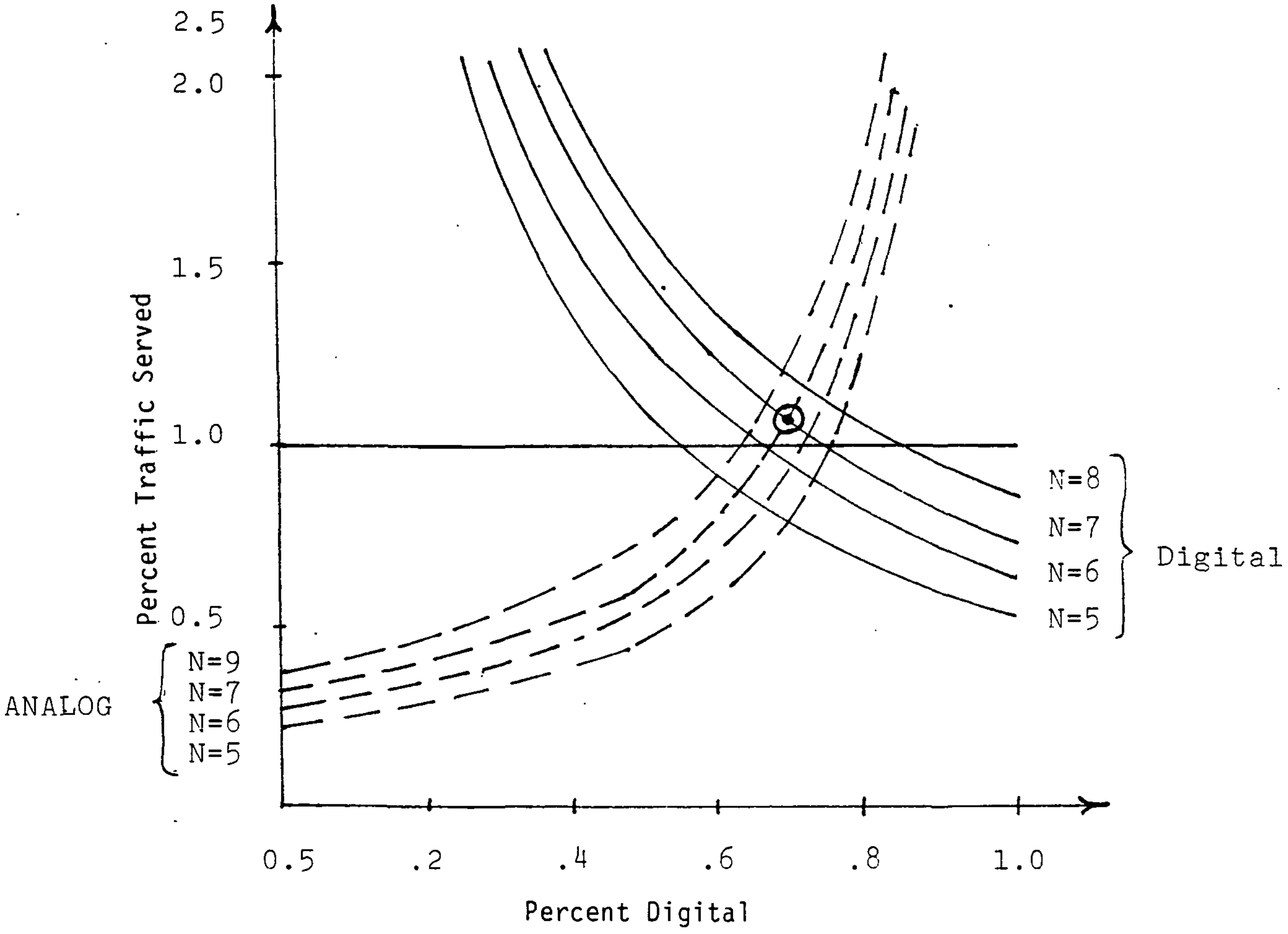


Figure 4.8-2 Scenario V Digital/Analog Tradeoff

with only 7 satellites, with digital levels of .68-.74 (see circled point in each figure).

4.8.7 Qualitative Issues

4.8.7.1 Interference

There are several potential issues in the area of interference between payloads which would require detailed analysis. An obvious problem area is an overlap in frequencies, shown in

Table 4.3-1, between the Ku-DBS uplink and the Ka downlink. The frequencies given in the table are obtained from ITU Radio Regulations, as well as FCC filings. The 100 MHz overlap is not a problem when payloads are in different satellites. Even though one frequency is an uplink and the other is a downlink, one cannot transmit and receive at the same frequency on the same satellite. Hence, the Scenario II frequency plan would require some modification; e.g., increasing the Ka-band to 17.8-20.3 (frequencies for satellite fixed service are allocated from 17.7-21.2).

The large bandwidth available at Ka-band (2.5 GHz) could produce spurious harmonics at L-band (1.5 GHz) and at the IF frequency (4 GHz) used in many of the payloads. The adjacent frequency bands at Ku FSS and DBS are another possible source of spurious signals. Also, L-band has historically had problems due to passive intermods (structural effects).

4.8.7.2 Reliability/Availability

A major issue with any large platform with multiple payloads is to provide very high reliability, especially in the bus-e.g., power and attitude control system. From the individual payload point of view, spare capacity has been provided through the traffic forecasts (see Section 2.2.1.2) for U.S. domestic requirements.

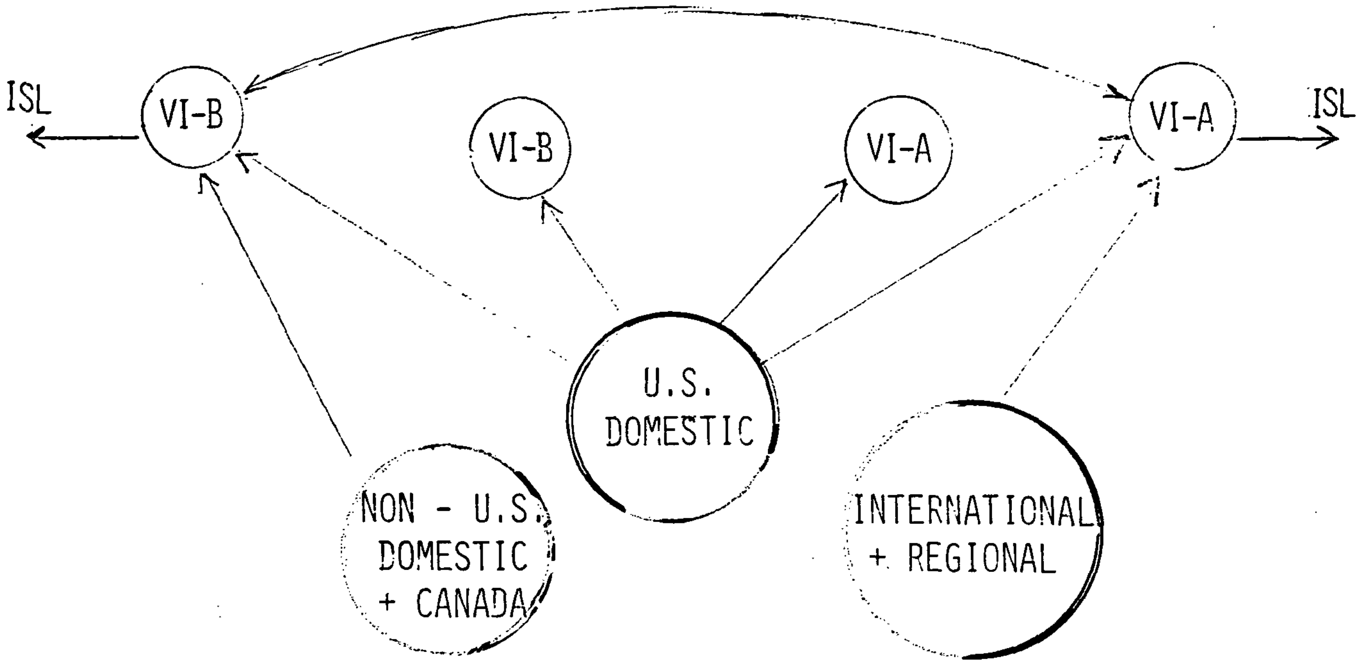
The reliability issue for Scenario VI-A and VI-B must be addressed separately because the payloads which have been added, over and above the Scenario V U.S. domestic capability, can service all projected traffic with a single satellite. The approach proposed in Table 4.8-1 is to provide two each of the VI-A and VI-B. This is not, from an overall point of view, supplying 2:1 redundancy, because the U.S. domestic portion of VI-A and B, which is a large part of tahe total capacity, is being spared at much less than 2:1. The same argument can be made regarding allocation of bus costs to the U.S. domestic and other payloads.

Figure 4.8-3 shows two possible approaches for sparing VI-A and VI-B. In Approach A, a single VI-A or B provides all service (except U.S. domestic requirements). There are two drawbacks to this approach. First, a complete loss of an active satellite would result in several hours outage while either the "spare" is moved, or many customers repointed their antennas. Also, moving the spare to preclude non-U.S. users from repointing, will cause U.S. domestic users to repoint. A second problem is that the larger Intelsat users today try to diversify their circuits over more than one satellite. In Approach B, if the satellite linked to the European or Asian platforms has, as a minimum, its ISL's operating, then a 50/50 split can be achieved wherein loss of either of the VI-A's (or VI-B's) maintains connectivity for 50% of the circuits for those countries requiring such diversity and willing to pay for the extra earth station. Even if the satellite linked to Europe or Asia has a total, catastrophic failure, connectivity can be reestablished (for those who have diversified) by merely reacquiring the ISL on the remaining VI-A or VI-B.

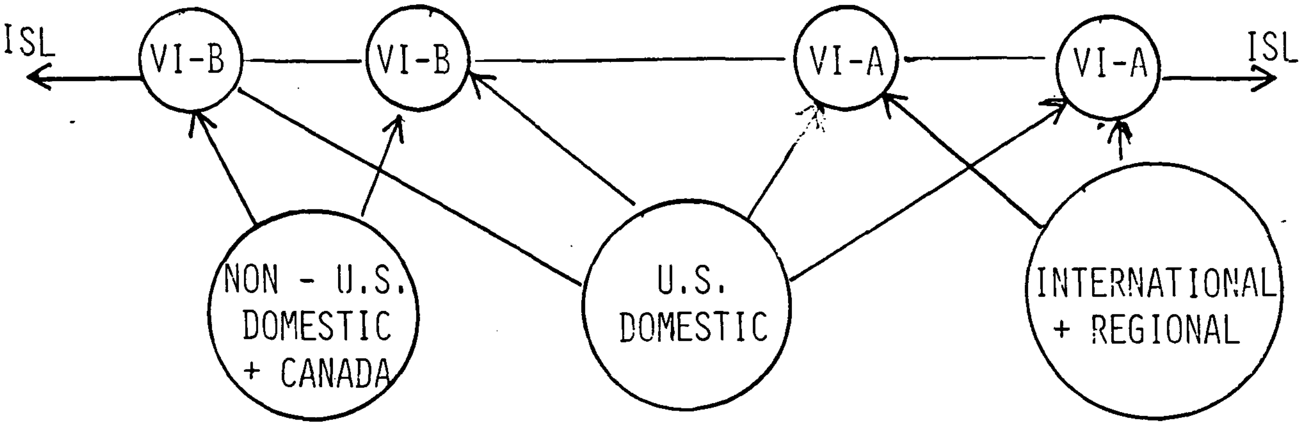
If ISL capacities could be significantly increased by use of optical links, then an alternate routing capability would exist; i.e., if the AOR link failed. The circuits could be rerouted via VI-B, the Asian Platform, and finally to the European Platform.

4.8.7.3 Growth Potential/Flexibility

The growth potential of the payload concepts developed in Task 3 is provided, basically, by addition of satellites as needed; the traffic loadings performed were to saturation of a single satellite. In a real system, of course, a satellite would not instantaneously saturate when launched. A schedule of one



APPROACH A



APPROACH B

Figure 4.8-3 Alternative Approaches To VI-A and B Sparing launch per year, or slightly longer, would meet the projected growth, 1998 to 2008, for the heaviest demand - U.S. domestic.

Certain payloads have the flexibility to operate in different modulation/access schemes; others are not as flexible. For example, the C/Ku transponders have many options regarding how they are used, but the Ka transponders must use SS/TDMA, would allow analog transmission, but with only five (maximum) FDM channels and 26 beams (including scan beams), providing connectivity would be impossible. Smaller bandwidth channels could be used, but at the cost of many more physical transponders.

The Scenario VI-A coverages of LAM/C have considerable spare capacity, thus allowing for flexibility. The Scenario VI-B domestic coverages do not have nearly as much spare capacity, although Approach B, described in Figure 4.8-3, wherein both Scenario VI-B satellites are active, would provide additional flexibility. In this case a higher outage would occur in the event of complete failure of one of the Scenario VI-B satellites.

4.8.7.4 Complexity

The payloads defined in Task 3 are, in large part, scaled from existing technology. For example, the Scenario V Ku-band beam forming network (9 beams) is not significantly more complicated than an Intelsat-VI BFN (6 beams), although the fairly close tolerances on beam separation used in Scenario V do complicate the design and manufacture processes.

The highest risk area is considered to be the on-board processing; i.e., base band processor, SS/TDMA, scan beams, and the control of these entities. Although the NASA ACTS satellite will demonstrate feasibility of these systems, the payloads using on-board processing designed in this study yield an order of magnitude increase in size and complexity.

4.8.8 Ranking

Table 4.8-6 summarizes the overall ranking of each scenario for the various payload concept evaluation criteria. The overall ranking was obtained by simply adding the rankings in each category, rather than using weighting factors. The same approach was used in the ranking by aggregation criteria in Section 3.

Table 4.8-6

Ranking of Payload Scenarios

Payload Concept Criteria	Scenario II	IV	V	VI-A	VI-B
Bandwidth-Reuse	4	5	3	1	2
Modulation Efficiency	4	5	1	2	3
Interference	2	1	3	4	5
Reliability/ Availability	2	1	3	4	5
Growth	2	1	1	1	2
Complexity	2	1	3	5	4
Utilization	4	3	2	5	1
Total	20	17	16	22	22
Ranking	3	2	1	4+	4-

There is one entry in Table 4.8-6 which was included to provide a consistent comparison, the utilization for Scenario IV. One can argue that 100% utilization is probably not possible; e.g., if a single uplink is switched to more than one downlink beam area, then some uplink capacity will be unused. The value chosen here was simply the average of the utilization of the other four scenarios.

SECTION INDEX

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5.0 PAYLOAD DEFINITION (TASK 4)

5.1 OVERVIEW

Based on the NASA selected system concepts and the modifications made to the original scenario aggregations, the five selected scenarios were then developed in this Task 4 to define the space segment hardware to the component level. In this section each of the payloads will be categorized to Launch Concept 1 or 2.

5.1.1 Scope of Task 4 - Payload Definition

The purpose of Task 4 of this study is to define payload system configurations and corresponding technical characteristics for the payload concepts and architectures developed in Task 3 subject to NASA-furnished constraints imposed by spacecraft/transportation system capabilities.

Two launch concepts were considered:

- o Launch Concept #1 - Up to a maximum single shuttle launch of combined spacecraft and upper stage with a spacecraft weight of up to 12,000 pounds (5443 kg.).

- o Launch Concept #2 - Allows a separate spacecraft (without upper stage) of size and weight up to a full shuttle launch capability of 65,000 pounds (29,484 kg).

The report section includes descriptions of the five selected scenario payload configurations, their corresponding technical characteristics, and the requirements that they impose on the spacecraft, transportation, and space operation systems. Detailed descriptions of transponder and antenna elements, as well as baseband processor where applicable, are included together with weight, power, and volume characteristics.

The impact of emerging (low risk) and projected 1994 (high risk) technology on the payload characteristics is identified.

5.1.2 Weight and Power for All Scenarios

Table 5.1-1 provides a summary of the weight and power for Scenarios II, IV and V, and Table 5.1-2 is the same for Scenarios VI-A and VI-B. Included in the estimates are the coax, waveguide, and harness interconnects, plus an estimate for integration hardware to put the components together and provide necessary brackets for support and mounting. Not included are any structure or satellite mounting hardware such as between the feed and reflector. Both tables are based on projected (high risk) technology. It is anticipated that Table 5.1-1 payload could fit launch concept 1 and Table 5.1-2 payloads would fall into launch Concept 2. Table 5.1-2 payloads would also require some LEO assembly due to the number of reflectors.

Table 5.1-1

Characteristics of Scenario Payloads Using Projected Technology
(Integration Hardware Included)

	Scenario II		Scenario IV		Scenario V	
PAYLOAD	Wt(kg)	Pwr(W)	Wt(kg)	Pwr(W)	Wt (kg)	Pwr(W)
C-Band FSS	89	659	-	-	246	708
Ku-Band FSS	261	2522	605	5075	523	785
Ku-Band DBS	223	3876	1012	29960	-	-
Ka-Band	1492	5933	-	-	1492	5933
TOTAL SCENARIO	2065	12990	1617	35035	2261	7426

Table 5.1-2

Characteristics of Scenario Payloads Using Projected Technology

(Integration Hardware Included)

PAYLOAD	Scenario VI-A Wt(kg)	Scenario VI-A Pwr(W)	Scenario VI-B Wt (kg)	Scenario VI-B Pwr(W)
C-Band FSS(Domestic)	246	708	-	-
C-Band FSS(Int'l)	750	2166	-	-
C-Band FSS(Non-CONUS)	-	-	574	1903
Ku-Band FSS(CONUS)	523	785	523	785
Ku-Band FSS(Non-CONUS)	-	-	186	1796
Ka-Band FSS(CONUS)	1492	5933	1492	5933
Maritime	79	649	44	649
Inter Satellite Links	111	160	107	131
TOTAL SCENARIO	3201	10401	2926	11197

5.1.3 Weight and Power of Payloads used in Scenarios

Table 5.1-3 provides a summary of the weight and power required by each of the 16 different payload elements used in the five Scenarios based on projected (high risk) technology. Table 5.1-4 is the same breakdown using emerging (low risk) technology. Use of the low risk technology would make Scenario V and possibly Scenario II exceed the single shuttle to GEO capability without fuel servicing or augmented perigee boost.

Table 5.1-3

Weight and Power of Payload Elements Using High Risk Technology

Payload Element	Used in Scenarios	Weight(kg)	Power(Watts)
C-Band FSS(2 x reuse)	II	89	659
C-Band FSS(4 x reuse)	V, VI-A	246	708
C/L Band Maritime	VI-A	79	649
C/L Band Maritime	VI-B	63	649
C-Band Intn'l(9 x reuse)	VI-A	750	2166
C-Band Non-CONUS(9 x reuse)	VI-B	574	1903
Ku-Band FSS(3 x reuse)	II	261	2522
Ku-Band FSS(3 x reuse)	IV	605	5075
Ku-Band FSS(9 x reuse)	V, VI-A, VI-B	523	785
Ku-Band Non-CONUS	VI-B	186	1796
Ku-Band DBS(no reuse)	II	223	3876
Ku-Band DBS(4 x reuse)	IV	1012	29960
Ka-Band FSS(CONUS)	II, V, VI-A, VI-B	1492	5933
60 GHz Inter-Sat	VI-A	111	160
60 GHz Inter-Sat	VI-B	107	131

Table 5.1-4

Weight and Power of Payload Elements Using Low Risk Technology

Payload Element	Used in Scenarios	Weight(kg)	Power(Watts)
C-Band FSS	II	121	922
C-Band FSS	V, VI-A	327	1001
C/L Band Maritime	VI-A	105	855
C/L Band Maritime	VI-B	63	855
C-Band International	VI-A	987	3140
C-Band Non-U.S.	VI-B	745	2704
Ku-Band FSS	II	315	3444
Ku-Band FSS	IV	751	7052
Ku-Band FSS	V, VI-A, VI-B	812	1164
Ku-Band Non U.S.	VI-B	301	2751
Ku-Band DBS	II	278	4554
Ku-Band DBS	IV	1227	34060
Ka-Band FSS	II, V, VI-A, VI-B	2007	6849
Ka-Band Scan	II, V, VI, VI-B	2007	6849
60 GHz Inter-Sat	VI-A	147	285
60 GHz Inter-Sat	VI-B	140	224

5.1.4 Approach to Payload Definition Development

To accomplish the payload definition Ford Aerospace utilized the approach of "top-down system engineering" methodology complemented with multilevel tradeoff analysis and iterations. This encompassed the following key activities:

- Analyze payload requirement to identify key issues and design drivers.
- Allocate functions to ensure compliance with system constraints envelope and requirements.
- Establish performance budgets/trades to optimize utilization of plant in place and technology forecasted in 1998.
- Generate baseline payload definitions to assess alternative approaches/options as appropriate.

The "top-down system engineering" ensures that payload concept definitions are logically synthesized. Multilevel trade analyses, with iterations as required, ensures that impartial consideration of all NASA concepts and assets applicable to this study as well as new technology forecasted are integrated into the overall system design. This results in an end payload definition for each concept that is cost effective, capable of growth, and resilient to various operational and failure modes.

For each payload concept, a payload configuration is derived in terms of antenna placement and deployment and other electrical, mechanical, and structural characteristics; transponder characteristics; and onboard processing characteristics. The configurations were developed as a total system, with due consideration to the bus interface characteristics and other constraints.

Antenna. The design of a satellite antenna system has undergone drastic changes since the advent of communication satellites. Such designs will continue to change with new requirements for advanced antenna systems, including those associated with the advent of digital signal processing and new devices such as MMICs and solid-state power amplifiers.

The major challenges in antenna design and development are: (1) greater antenna aperture size, (2) wider frequency bandwidth capability, (3) faster pattern reconfiguration, and (4) greater pattern control. A large antenna aperture of several hundred wavelengths size allows high concentration of limited radiated power onto small regions of the earth to provide a highly shaped beam. This also enables the formation of several simultaneous beams for frequency reuse and reduces potential interference between beams and satellites. A highly shaped beam increases EIRP, thus reducing the amount of power required from a space-borne TWT or SSPA, and reduces the required earth terminal antenna size. A multiple-beam antenna (MBA) system greatly increases the communication system capacity. Better pattern control reduces sidelobes and thus improves the signal-to-noise ratio (SNR) in a given MBA system, and also allows a greater number of satellites to be placed in synchronous orbit. Wider frequency bandwidth also increases system capacity. Pattern reconfigurability permits implementation of TDMA systems and pattern nulling.

A large antenna aperture poses problems in pattern control, feed and beam-forming network design, test and evaluation, and space-craft integration. Scan aberrations are increased as the scanning beams scan a greater number of beamwidths away from the antenna axis. A large antenna aperture also increases integration problems on a space-limited spacecraft and requires a greater number of feeds, which implies more power divider network components and further challenging design problems such as beam-forming network layout, size, and weight. Such increased complexity also results in requirements for added testing during breadboard development and space-qualification phases.

The ultimate capacity of a communication satellite is limited by the available frequency bandwidth. The demand for wideband data and video teleconferencing will saturate the existing lower frequency band capacity. Higher frequency bands such as Ka-band or higher will be needed. As the operating frequency increases, the size of feed elements and beam-forming network components decreases and the number of components and their total loss will increase accordingly. Faster pattern reconfiguration and pattern control increases the complexity in the design of switching and control components - variable power dividers and variable phase shifters. The advances in digital data processing and new devices, such as SSPA and MMIC, will revolutionize the design concepts and implementation of future advanced satellite antenna systems such as those considered in this study.

The problems addressed above involve three major design areas for a satellite antenna system:

a. Optical Design - may involve a specially shaped reflector/lens, phased array or combination, or a microstrip antenna.

b. Feed Array - may involve possibly hundreds or thousands of individual elements to properly illuminate the optical aperture for multiple or scanning beams.

c. Beam-Forming Network - involves microwave distribution and control devices designed to excite individual elements of the feed array, as well as frequency-selective surfaces (FSS) used as spatial filters for multifrequency bands. SSPA or MMIC will be used to compensate for BFN losses and provide the required EIRP in an active antenna system.

The optical problem involves the design of an optical system, such as reflector, lens, phased array, or microstrip antenna, to allow positioning of a narrow fixed or scanning beam anywhere within a field of view. One of the current MBA concepts requires the formation of 10 to 100 pencil beams, each fully reusing a common frequency band and all emanating from a single large antenna aperture. Another application requires 16 simultaneous beams to be electronically steered over a ±30° field of view.

The shape of each beam must be varied to provide the gain required to accommodate system specifications.

The key to the successful design of such systems is the choice of a good optical system. A reflector antenna system has been the first choice because of its simplicity and design maturity. A lens antenna system is generally heavy for low-frequency-band operation. Higher frequency operation might make a lens system attractive for a future satellite antenna system. A phased array, or microstrip antenna, requires a complex BFN. Its use will be highly dependent on low-cost design, development, and fabrication techniques, and/or the design maturity of SSPA or MMIC. The use of larger aperture reflectors larger than the 15 ft diameter of the STS will lead to unfurlable reflectors and interface problems with the large, low-frequency, flexible body interaction with the control system.

The feed array problem involves the types of feed elements, feed configuration, and interface with BFN. The feed elements may be large multimode horns, arrays of small horns, or other structures, properly combined in clusters to produce the desired beams, but flexible enough to allow close spacing and finite control of adjacent beams.

The BFN problem involves design of a microwave network with minimum loss and adequate flexibility to excite the individual feed elements with proper amplitudes and phases to form the desired shaped beams or multiple beams, and to reconfigure beams or switch beams as required. With advances in electronic technology and signal processing, analog information such as amplitude and phase may be converted into digital form and computer-controlled by an on-board microprocessor. Such digital beam-forming networks with SSPA or MMIC components will definitely add a new dimension and pose new design problems in future satellite antenna systems.

Each problem individually influences the design of a satellite antenna system. System optimization is required to select the best combination of solutions to achieve not only the desired performance but also low cost and low risk for the whole system. Table 5.1-5 summarizes this discussion and presents the required technology development and risks at each phase.

Table 5.1-5.

Evolution of Satellite Antenna System Technology

	Antenna Concept	Key Components	Required Technology Development	Risks
1960s	Simple beam	Antenna, connectors	Light weight space-qualified material	Reliability
1960-70s	Shaped beam	Reflector	"	Reliability
1970-80s	Reconfigure-able over space	VPD/VPS, reflector, lens, BFN components	Frequency reuse, wider bandwidth	Reliability
1980-90s	Reconfigure-able over channels	Gridded reflector, shaped reflector, dual reflector, high frequency BFN components, FSS	Computer aided design, high frequency VPD/VPS, switches, SSPA, reflector tolerance	Reliability
1980s +	Reconfigure-able over time	MMIC, BFN controller, large aperture optics	MMIC High speed computation, wide angle scanning optics, optics tolerance, high frequency wideband or multiband BFN components	Feasibility, cost,& reliability

RF Transponder. The RF transponders for the payload concepts are defined and developed in block diagram form. For each payload, alternative RF transponder configurations were identified to serve as the basis for trade studies. These configurations utilize the forecasted 1998 RF transponder technology. Where applicable, provisions for in-orbit deployment, repair or testing at Space Station were considered. This in-orbit servicing capability will be considered in arriving at the chosen payload implementations.

Trade studies of the alternative configurations were made, based on their flexibility, growth potential, reliability, technical/economic risks, size, weight, and power. The selected configuration for each payload concept then then further developed in block diagram form. These configurations were then expanded in sufficient detail to identify the number of transponders, their frequency plan, interconnectivity, and redundancy implementation to achieve the desired reliability.

The block diagrams were developed to the component level (receivers, filters, switches, filters, amplifiers, etc.) to aid in assessing the required volume, weight, and power requirements.

On-board Processing. In the definition of payload concepts/ architectures for a given service aggregation scenario, performance requirements for on-board processing were developed. By matching the onboard processing technology data base to the performance requirements developed in Task 3, the hardware necessary to support a given architecture was estimated.

Trade studies of the alternative configurations were made based on their flexibility, growth potential, reliability. technical/ economic risks, size, weight, and power. The selected configuration for each payload concept was then further developed in block diagram form. These configurations were then developed in sufficient detail to identify the number of input and output channels, their frequency plan, interconnectivity, and redundancy implementation to achieve the desired reliability. Estimates of processor weight, power and volume were based on data from 30/20 GHz Communications System Baseband Processor Subsystem, Phase I Final Report (Ref. 45).

Interface to Bus. The primary purpose of these sections are to collect and synthesize the interface requirements for the various aggregated payload concepts into a consistent use of requirements to be made available to a geosynchronous platform bus study and/ or potential bus manufacturer. The concept of a large, geosynchronous telecommunications facility preserves the classical payload-to-bus interfaces (mechanical, electrical, thermal, telemetry/command, and attitude control). The level of interface documentation required is determined by the particular payload-to-bus integration scheme implemented. These schemes range from the "palletized" payload concept, complete with antenna support structure, requiring a simple bus interface and relatively little interface information, to the more complex "component" payload concept where individual elements require integration to the bus and unit level interface information must be supplied. The type of interface information required for each integration scheme is listed in Table 5.1-6. From an overall program management standpoint, palletized payloads appear to be more nearly optimum. This concept establishes clear, well defined areas of responsibility and performance, simplifies the integration and test of the payload, and possibly simplifies in-orbit servicing and replacement. The controls interface is influenced significantly by the antenna system selected and the control of large flexible structures.

Table 5.1-6

Bus Interface Parameters

For Each Payload Scenario:

Service: (C, Ku, Ka, DBS, etc.)

Payload Description: (Type, Number, etc.)

Mass: (kg)

Power Required: (kW)

Eclipse Capability: (100%, 50%, 0%)

Pointing Requirement: (°)

Antenna Description: (Type, Size, Physical Constraint, and Number)

Temperature Requirement (°C)

Lifetime: (years)

Boxes (Count and Dimensions)

5.2 SCENARIO II DEFINITION

5.2.1 Introduction

Scenario II can be described as a transition satellite containing conventional, current, two times re-use C-band and three times re-use Ku-band payloads. In addition, it provides a high capacity Ka-band fixed and scanning beam payload and an introductory level Ku-band DBS payload. The services provided are listed below:

1) 24 channels, 36 MHz, standard C-band FSS payload, 2 x re-use
2) 24 channels, 54 MHz, standard Ku-band FSS payload, 3 x re-use
3) 20 beams, 38 channels, 500 MHz, Ka-band FSS trunking payload, 7.6 x re-use
4) 6 area scan beam, 18 channels - 240 MHz, and 14 channels - 500 MHz, Ka-band CPS/thin route trunking, 5.76 x re-use.
5) 16 channels, 24 MHz, Ku-band, DBS payload, 2 beams, 8 channels each.

The satellite is primarily intended as a Fixed Satellite Service (FSS) satellite although it also contains a Direct Broadcast Service (DBS) payload. This combination of payloads puts severe limitations on its orbital positioning since currently only 101^{o} and 110^{o}W longitude are compatible locations for all the payloads.

An overview block diagram of the payload elements is shown in Figure 5.2.1-1. Table 5.2.1-1 lists the major scenario bus interface requirements and Tables 5.2.1-2 and 5.2.1-3 present the major antenna and transponder characteristics respectively. The two Ka-band antennae require individual gimbal systems for steering the two sub-reflectors to achieve $\pm 0.02^{o}$ pointing of the RF boresight. The other antennae will be rigidly mounted to the spacecraft body and body steered via the bus control system.

Figure 5.2.1-1 Scenario II - Overview

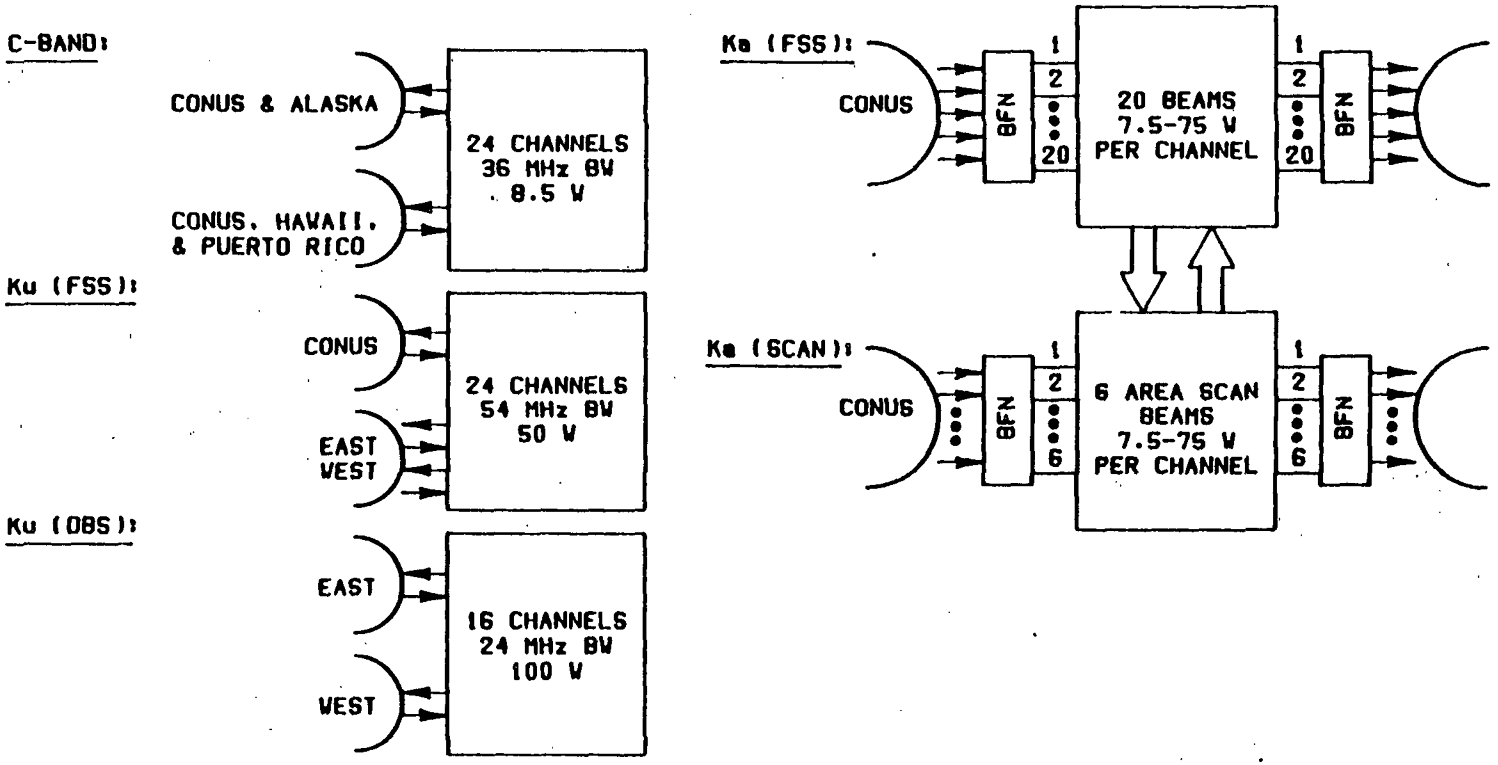

Table 5.2.1-1

Scenario II - Payload Summary

o	Mass	2065 kg
o	Power Required	
	Sunlight	13,000 watts
	Eclipse	75% min.; 100% desired
o	Pointing Requirement	± 0.05° absolute (ie:RF boresight)
o	Temperature Requirements	
	Antenna	-90°C to 110°C
	Transponder	-10°C to + 50°C, (TWTA's + 60°C)
o	Thermal Dissipation	appx. 5 kW TWT's; 500 W EPC's & 1 kW feeds
o	Lifetime	10 yr. without servicing

Table 5.2.1-2

Scenario II Antenna Configuration

Antenna System	Freq (GHz)	Reflector	Polarization	Feed
o C-Band FSS	6/4	Dual Gridded reflector 1.4x1.8m	Linear	2x7-feed arrays
o Ku-Band FSS	14/11	Dual gridded Reflector 8'(2.44m)	Linear	2x80-feed Arrays
o Ku-Band DBS	17/12	One solid 8' (2.44m)reflector for Tx.,one solid 6'(1.8m) reflector for Rx.	CP	2x55-feed Arrays (requires septum polarizer)
o Ka-Band FSS	30/20	One solid 13' (4m.)reflector for Tx one solid 9'(2.7m) reflector for Rx.(dual shaped reflector each with sub-reflector)	Linear	Tx: 500 feeds, 830 switches 140 OMJ's; same for Rx.

Table 5.2.1-3

Transponder Summary Scenario II

Payload	U/L,D/L Freq.GHz	Number Channels	Channel BW (MHz.)	RCVR Type, (Number)	HPA Type (Number)	HPA Power,W
C-Band FSS	6/4	24	36	6/4(4)	SSPA(30)	8.5
Ku-Band FSS	14/11	24	54	14/11(6)	TWTA(30)	50
Ku-Band DBS	17/12	16	24	17/12(4)	TWTA(20)	100
Ka-Band FSS	30/20	38	500	30/4(40)	TWTA(49)	75
Ka-Band Scan	30/20	32	240/500	30/4(12)	TWTA(40)	75

Due to the use of TWTA's for the Ku-band FSS and DBS payloads, a 10 year life is all that can be envisioned at this time. The replacement of TWTA's at GEO, or return of the payload from GEO for servicing and replacement of TWTA's, is not anticipated for the early year 2000 time period. It is estimated that the identified redundancy is compatible with a 10 year life application.

If lower risk technology is utilized it is possible that fuel servicing at GEO or perigee augmentation at LEO could be utilized to maintain the Launch Concept 1 status of the payload.

Table 5.2.1-4 presents a summary of the high and low risk weight and power for the individual payload elements in Scenario II.

Table 5.2.1-4

Scenario II - Weight and Power

	WEIGHT(KG)		POWER(W)	
	Low Risk	High Risk	Low Risk	High Risk
C-Band FSS				
Transponder	102.3	72.2	922	659
Antenna	19.1	16.7	-	-
Sub Total	121.4	88.9	922	659
Ku-Band FSS				
Transponder	280.5	231.7	3444	2522
Antenna	34.1	28.8	-	-
Sub Total	314.6	260.5	3444	2522
Ku-Band DBS				
Transponder	246.3	195.5	4554	3876
Antenna	31.5	27	-	-
Sub-Total	277.8	222.5	4554	3876
Ka-Band FSS & Scan				
FSS Transponder	751.4	516.3	3305	3043
SCAN Transponder	636.0	447.6	2180	1936
Baseband Proc.	355.0	297.4	1360	952
Antenna	264.5	230.4	4	2
Sub-Total	2006.9	1491.7	6849	5933
SCENARIO II TOTAL	2720.7	2063.6	15769	12990

In Appendix G-4, Tables 1 thru 14, show that all of the payload elements have viable links with the various types of anticipated modulation and access types. While some of the margins are low, the links represent the worst case conditions, and if this scenario were to be studied further for full system definition, link margins could be improved for actual implementation. A typical link for the C-band FSS Companded Single Side Band carrying 6000 half-voice circuits is shown in Table 5.2.1-5.

5.2.2 C-Band FSS Payload

5.2.2.1 Overview of C-Band FSS

This payload is patterned after current day C-band, 24 channel payloads used by ATT, RCA, Galaxy, etc. This would be a replacement for continuation of service. It provides a 2 times re-use factor via horizontal and vertical, linear polarization isolation. The coverage is full CONUS with some selected coverage for Alaska, Hawaii and Puerto Rico. The payload features dual-gridded reflectors to obtain the polarization purity required. The reflectors are a stacked assembly with slightly offset focal points for physical separation of the feed assemblies. The transponder is a straight forward design and no on-board processing is provided. Figure 5.2.2-1 is a block diagram of the C-band FSS payload for Scenario II showing the breakdown to the component level.

Table 5.2.2-1 shows the estimated weight, power, and volume for low risk (emerging) technology and high risk (projected) technology for the transponder and antenna. Also included in the estimates are the coax, waveguide, and harness interconnects, plus an estimate for integration hardware to put the components together and provide necessary brackets for support and mounting. This does not include any structure or satellite mounting hardware such as between the feed and reflector.

Table 5.2.1-5

Scenario II - C-Band (FSS) - Link Budget

MODULATION: CSSB, Suppressed Carrier (6000 HVC/36 MHz)

Mid-band Downlink Freq. = 3.95 GHz
Mid-band Uplink Freq. = 6.15 GHz
Uplink Free Space Loss = 200.0 dB
No. of Channels, N = 6000

Saturated EIRP = 36.0 dBW
SFD =-84.0 dBW/m^2
Satellite Gain =161.1 dB
Satellite G/T = -2.1 dB/K

Transmitter Power	10.0 dBW	10.00 Watts
Transmit Line Loss	1.3 dB	Allocation
Transmitting Antenna Gain	25.0 dBi	Gridded Reflector
Output Backoff	5.0 dB	
Net EIRP	28.7 dBW	
Total Load	22.6 dBm0	-15.2 + 10 Log N
Reference Power EIRP, Pr	6.1 dBW	Net EIRP - Total Load
Free Space Loss	196.1 dB	38700 km; 30° Elev
Pointing Loss	0.5 dB	Allocation
Atmospheric Degradation	0.0 dB	
Net Path Loss	196.6 dB	
Power Flux Density	-134.0 dBW/m^2	(Clear Sky)
Receiving Antenna Gain	50.1 dBi	10 m dish, 60% eff.
Receive Line Loss	0.1 dB	Allocation
System Noise Temperature	19.4 dB-K	
Receive G/T	30.7 dB/K	(Clear Sky)
Boltzmann's Constant	-228.6 dBW/Hz-K	
Downlink Pr/No	68.8 dB-Hz	
Uplink Pr/No	71.6 dB-Hz	Worst-case
Downlink Interference Pr/Io	68.8 dB-Hz	
Uplink Interference Pr/Io	68.9 dB-Hz	
Intermodulation Pr/IMo	68.9 dB-Hz	14.7 dB = P1/P3
Terrestrial Pr/Io	86.7 dB-Hz	
Cross-polarization Pr/Io	79.6 dB-Hz	
Overall Pr/No	62.2 dB-Hz	
Required Pr/No	61.9 dB-Hz	
Pr/No Margin	0.3 dB-Hz	

Figure 5.2.2-1 Scenario II - C-Band 6/4 GHz Communication Subsystem

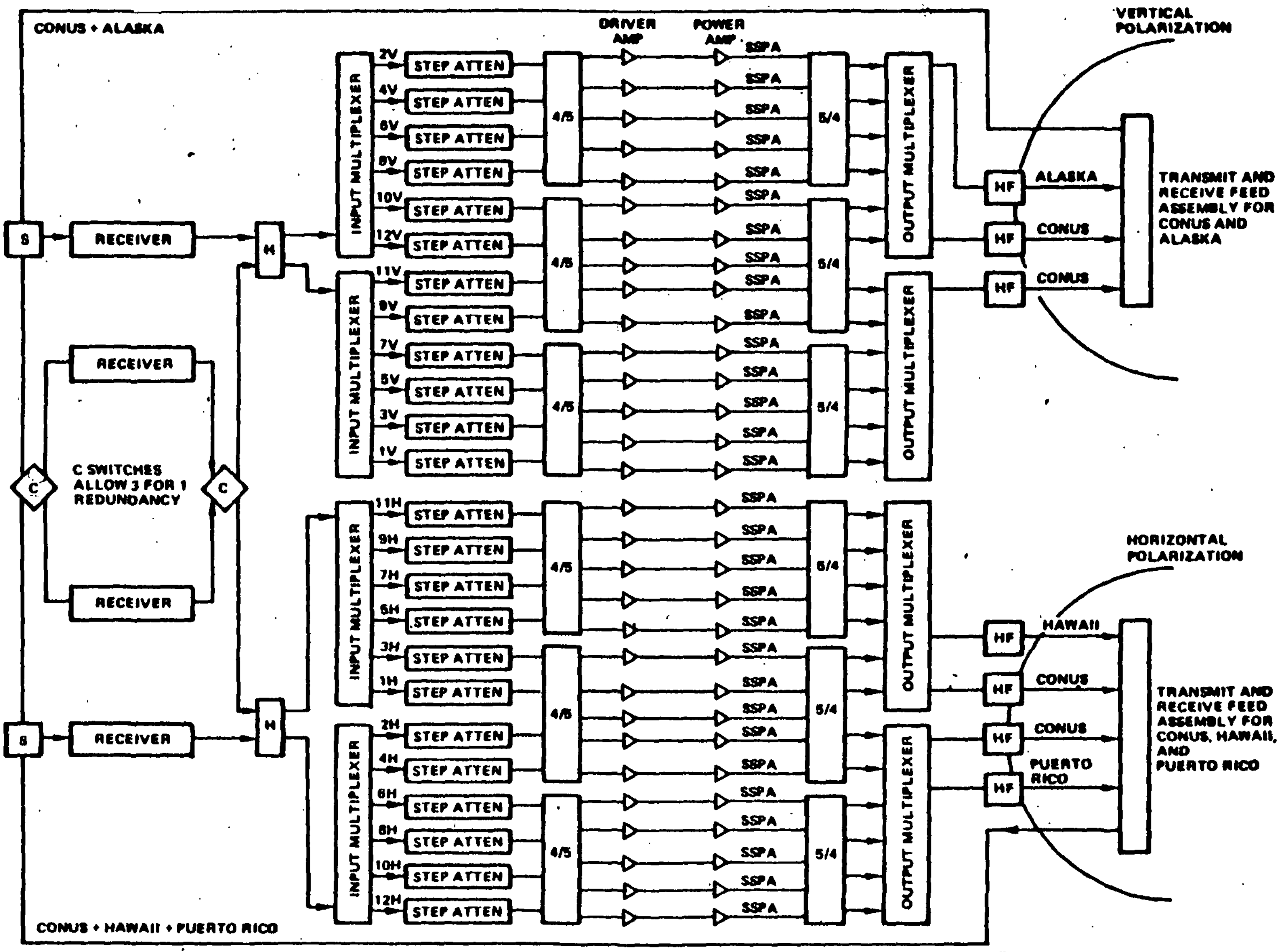

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Table 5.2.2-1

Scenario II - Payload Summary

C-Band FSS

	ITEM	P/L QTY REQ'D	REQ. QTY REQ'D	LOW RISK TECHNOLOGY						HIGH RISK TECHNOLOGY						COMMENTS
				UNIT			PAYLOAD			UNIT			PAYLOAD			
				WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	
1	C-BAND RECEIVER, 6/4 GHz	2	4	1.6	7.5	175	6.4	15	700	0.7	4.8	50	2.8	9.6	200	
2	INPUT MULTIPLEXER, 6 CHANNEL, 36 MHz	4	4	2.1	-	432	8.4	-	1728	1.7	-	250	6.8	-	1000	
3	REDUNDANCY SWITCH MATRIX (RING) 5/4	6	6	1.4	-	160	8.4	-	960	0.7	-	25	4.2		150	
4	Comm Control & Interface	1	2	1	8	200	2	8	400	0.8	6	150	1.6	6.0	300	
5	SSPA, 4 GHz, 8.5 WATT with 2 VGA's	24	30	0.8	34.0	48	24	816	1440	0.4	24.3	20	12.0	583.2	600	
6	REDUNDANCY SWITCH MATRIX (RING) 5/4	6	6	1.4	-	160	8.4	-	9600	0.7	-	25	4.2	-	150	
7	OUTPUT MULTIPLEXER 6 CHANNEL	4	4	2.1	-	1800	8.4	-	7200	1.4	-	1200	5.6	-	4800	
8	HARMONIC FILTER	7	7	0.3	-	40	2.1	-	280	0.3	-	40	2.1	-	280	
9	PRESELECT FILTER WITH ISOLATOR	2	2	0.5	-	64	1	-	128	0.5	-	64	1.0	-	128	
10	SPOT SWITCHES COAX	2	2	0.08	-	6	0.16	-	12	0.08	-	6	0.16	-	12	
11	TRANSFER SWITCH, COAX	2	2	0.14	-	12	0.28	-	24	0.14	-	12	0.28		24	
12	3 dB HYBRID	2	2	0.05	-	2	0.10	-	4	0.05	-	2	0.1	-	4	
13	COAX, SET	1	1	6.0	-	-	6.0	-	-	6.0	-	-	6.0	-	-	
14	WAVEGUIDE, SET	1	1	3.0	-	-	3.0	-	-	3.0	-	-	3.0	-	-	
15	HARNESS	1	1	10.0	-	-	10.0	-	-	10.0	-	-	10.0	-	-	
16	INTERATION HARDWARE, SET	1	1	5%			4.4	-	-	5%	-	-	3.0	-	-	
17	Margin Req'd			10%	10%	5%	9.3	83	1124	15%	10%	5%	9.4	60	382	
18																
19	Total Trasnponder						102.3	922	23,600				72.2	659	8030	
20																
21	Antenna Reflector(Dual Gridded)	1	1	11	-	-	11	-	-	9.2	-	-	9.2	-	-	
22	Antenna Feed Vertical	1	1	3.6	-	6400	3.6	-	6400	3.0	-	6000	3.0	-	6000	
23	Antenna Feed Horizontal	1	1	3.6	-	6400	3.6	-	6400	3.0	-	6000	3.0	-	6000	
24	Margin Req'd			5%	-	10%	0.9	-	1280	10%	-	10%	1.5	-	1200	
25																
26	Total Antenna						19.1	-	14080				16.7	-	13,200	
27																
28	TOTAL PAYLOAD						121.4	922	37680				88.9		21230	
29																
30																

C-4

5.2.2.2 Antenna

The C-Band FSS antenna subsystem provides transmission at 4 GHz and reception at 6 GHz of dually linear-polarized communications signals. The antenna coverage regions include CONUS, Alaska, Hawaii, and Puerto Rico as depicted in Figure 5.2.2-2. The odd/even mode of operation is employed in the transmit system to alleviate the difficulty in the design of a multiplexer. Table 5.2.2-2 presents the antenna subsystem requirements.

Table 5.2.2-2

C-Band FSS Antenna Subsystem Requirements

Parameters	Requirements	
Frequency	Transmit:	4 GHz band
	Receive:	6 GHz band
Polarization	Dual Linear	
Coverage Area	Combination of CONUS, Alaska, Hawaii, and Puerto Rico	
Co-Polarization Isolation	None	
Cross-Polarization Isolation	30 dB	

The antenna will consist of two gridded, offset-fed reflectors and two multi-horn feed array systems, one for vertical and another for horizontal polarization, as depicted in Figure 5.2.2-3. Each reflector/array system operates in both the transmit and receive bands. The block diagram of the

Figure 5.2.2-2 C-Band FSS Antenna Coverage

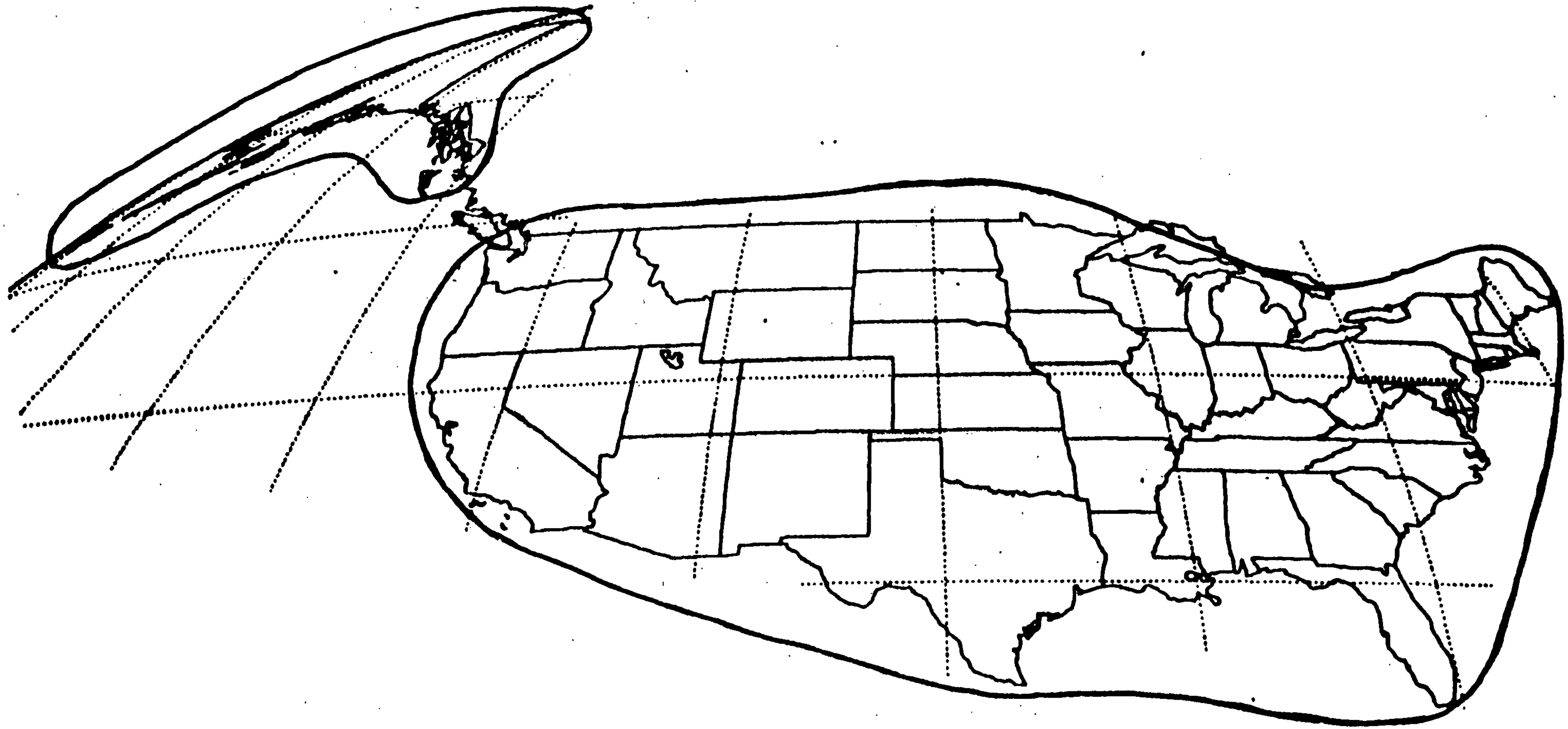

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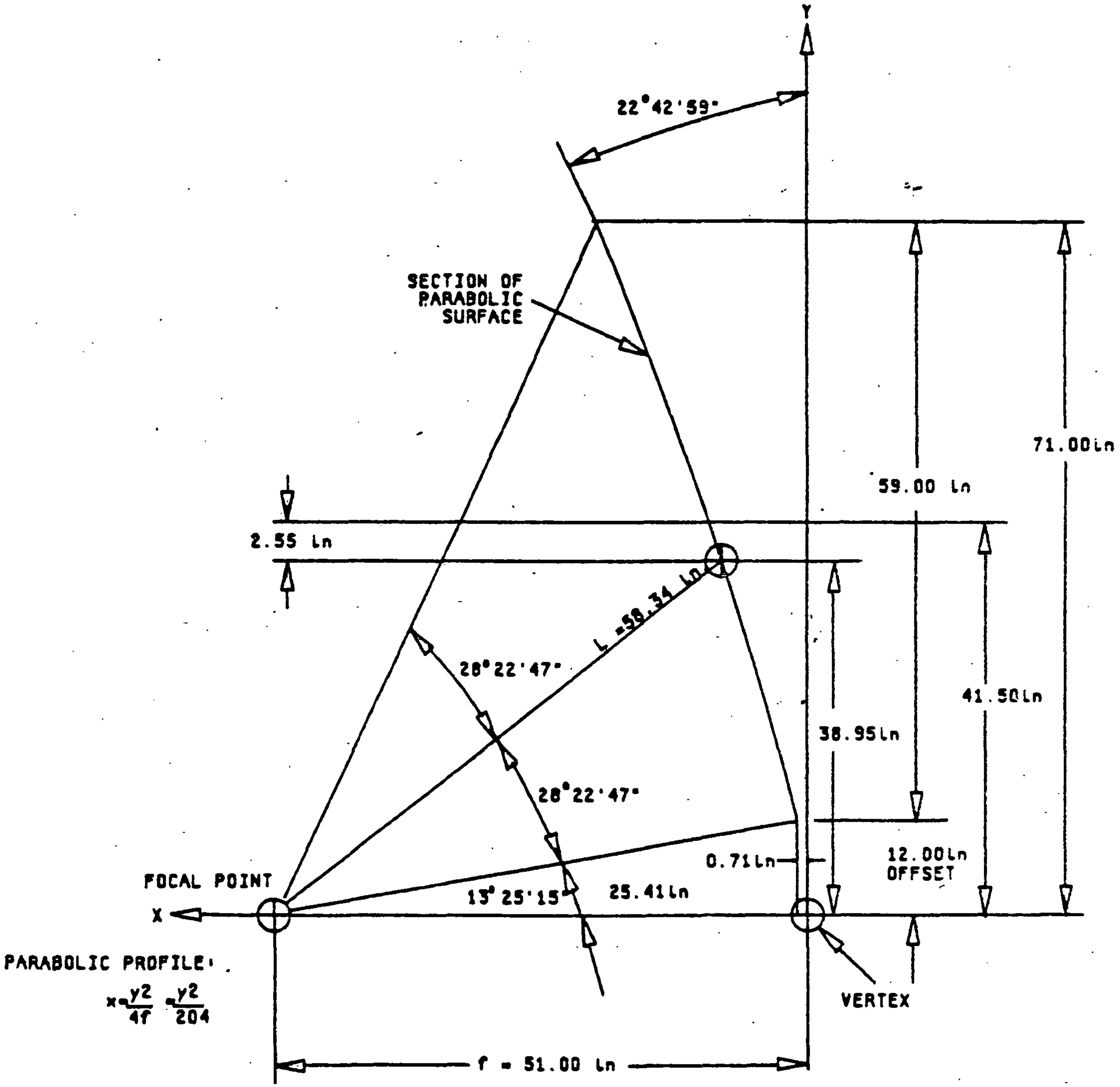
Figure 5.2.2-3 Geometry for C-Band Reflector with 12-inch Offset



communications antenna subsystems are shown in Figures 5.2.2-4 and 5.2.2-5. The gridded reflector is used to lower the reflected cross-polarized energy generated by the offset reflector surface and the feed array. Such a system can provide at least 30 dB cross-polarization isolation.

The predicted antenna radiation patterns are shown from Figures 5.2.2-6 to 5.2.2-12. The calculated edge-of-coverage gains are summarized in Table 5.2.2.3 .

Table 5.2.2-3

C-Band FSS Predicted Performance

Polarization	Function	Coverage Region	Predicted Gain (dB)	Estimated Percent of Required Area covered by Predicted Gain (%)
	Transmit	CONUS	27.0	99.5
			26.8	99.9
			26.5	100.0
Vertical	Transmit	Alaska	27.0	100
	Transmit	CONUS+Alaska	25.0	100
	Receive	CONUS+Alaska	25.0	100
	Transmit	CONUS	27.2	100
	Transmit	Hawaii	31.8	100
	Transmit	Puerto Rico	29.7	100
Horizontal	Transmit	CONUS+Hawaii	25.1	100
	Transmit	CONUS+Puerto Rico	25.1	100
	Receive	CONUS + Hawaii + Puerto Rico	25.1	100

Figure 5.2.2-4 Horizontal Transmit Polarization Feed System

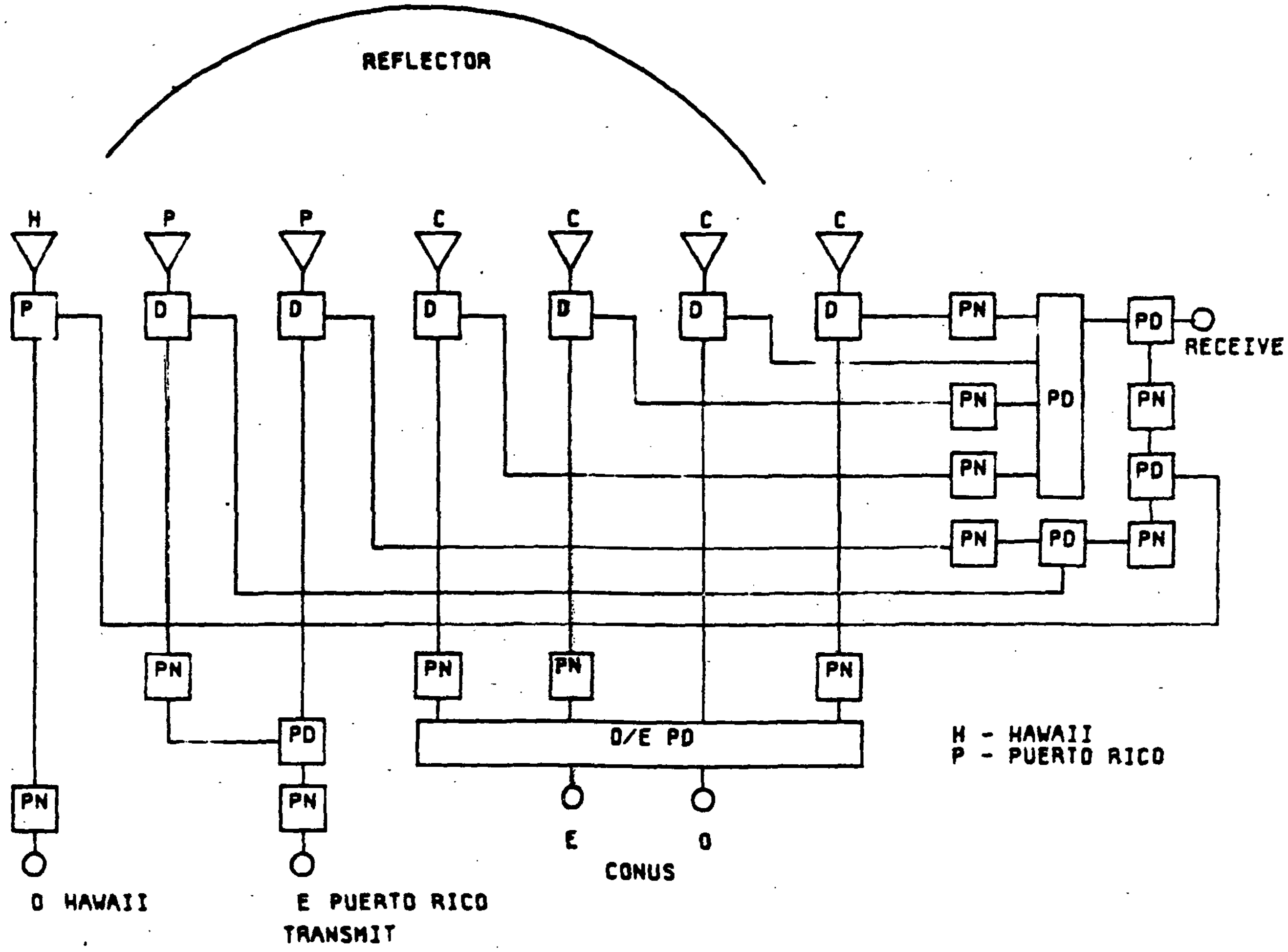


Figure 5.2.2-5 VerticalTransmit Polarization Feed System

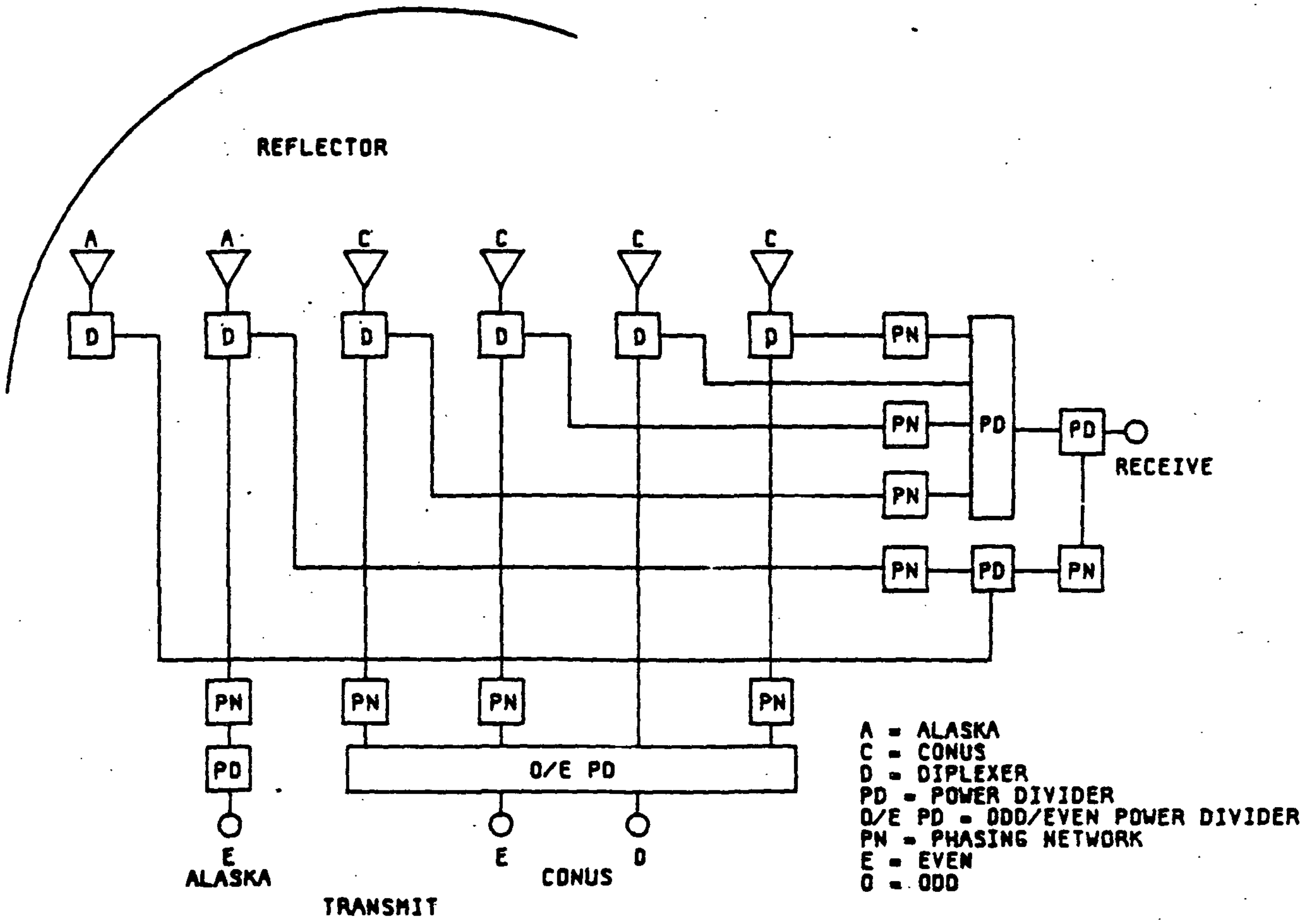


Figure 5.2.2-6 Calculated Transmit Innermost Vertical Polarization Contour - CONUS and Alaska

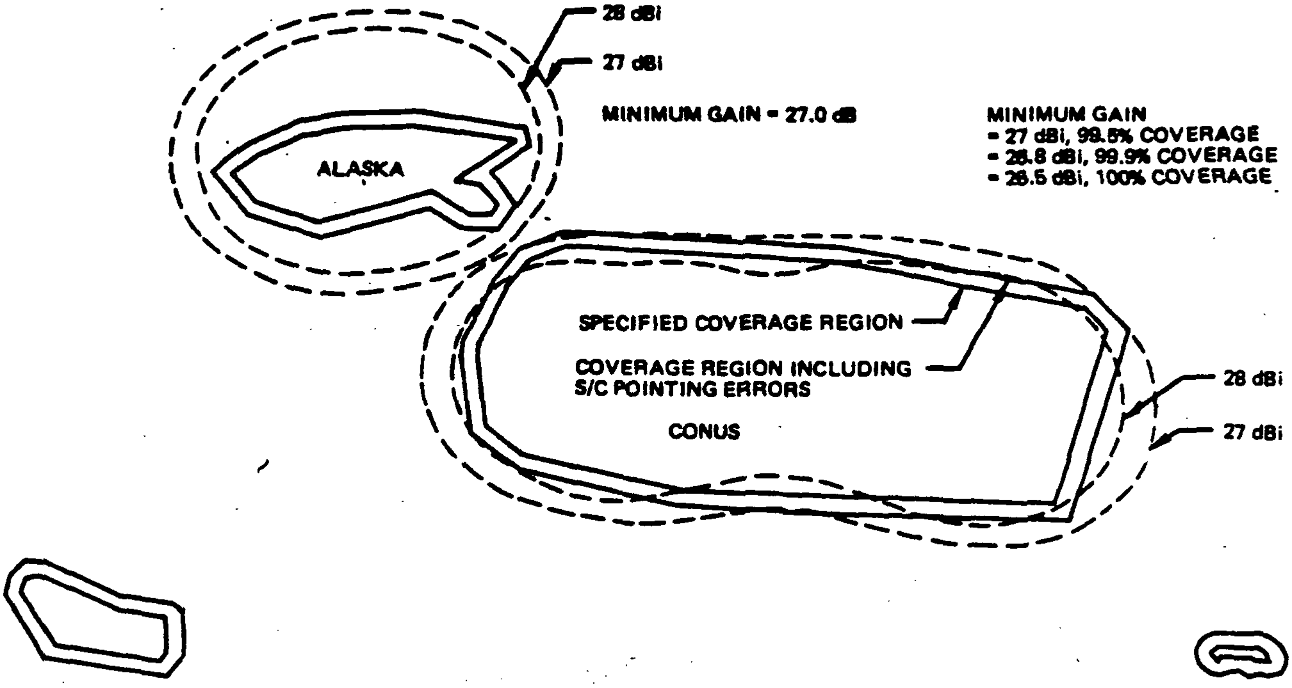


Figure 5.2.2-7 Calculated Innermost Transmit Vertical Polarization Contour - CONUS and Alaska Combined

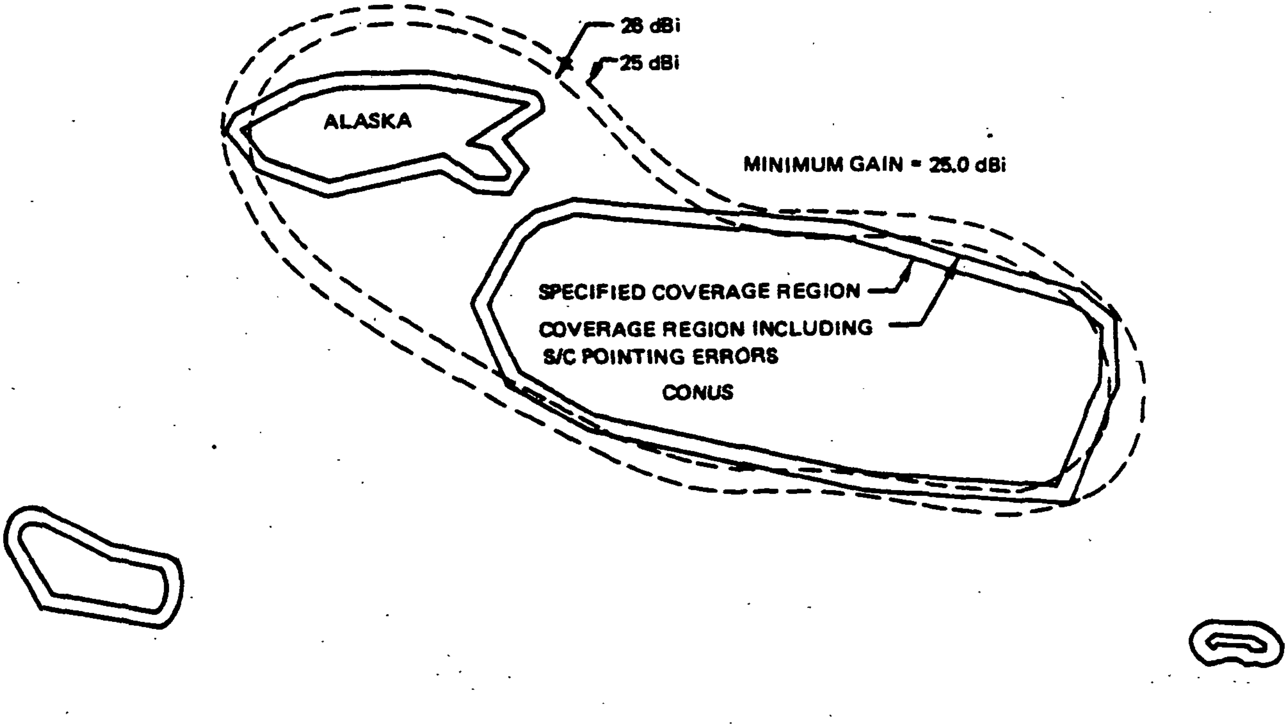


Figure 5.2.2-8 Calculated Innermost Receive Vertical Polarization Contours

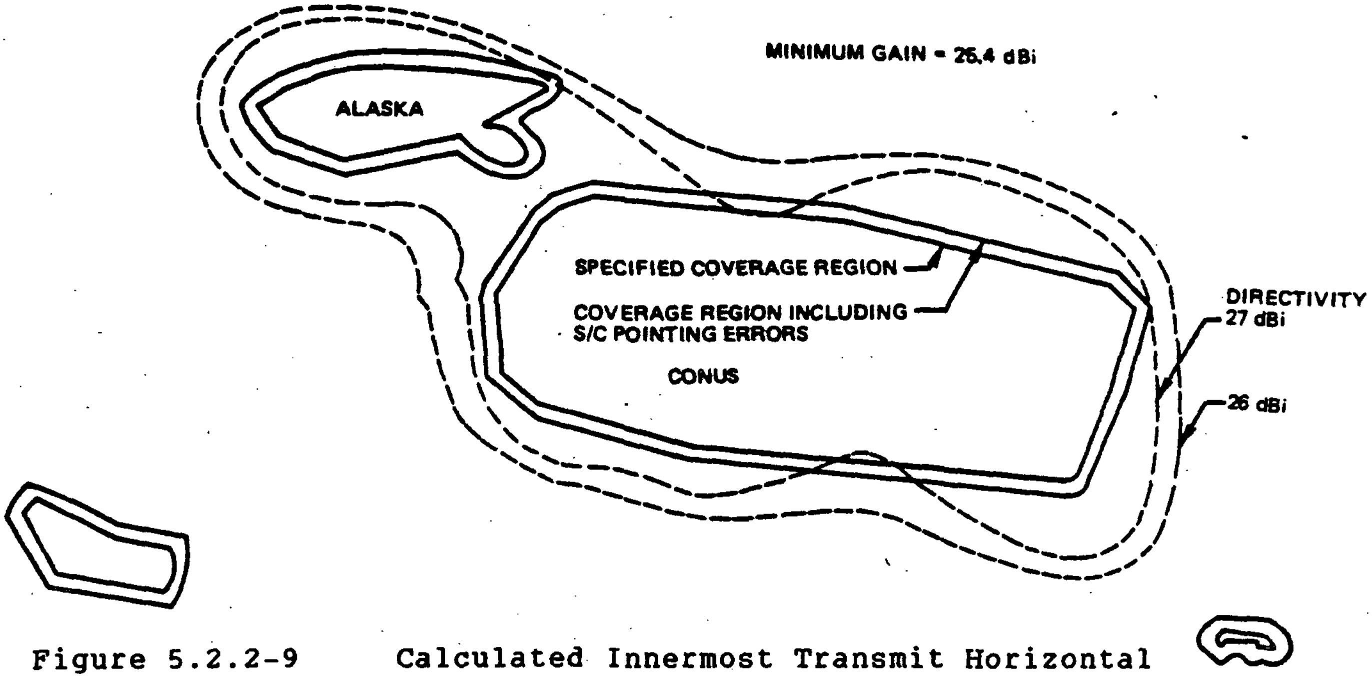


Figure 5.2.2-9 Calculated Innermost Transmit Horizontal Polarization Contours - CONUS and Puerto Rico

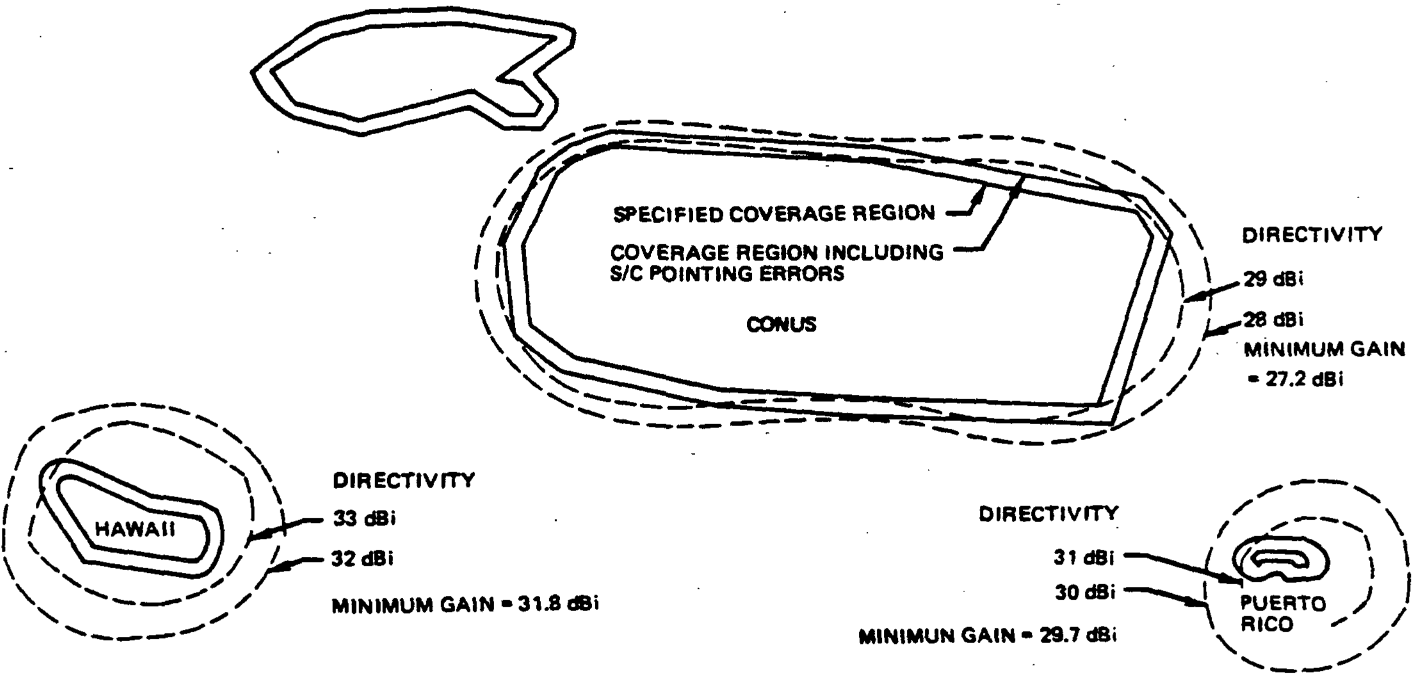


Figure 5.2.2-10 Calculated Innermost Transmit Horizontal Polarization Contours - CONUS and Puerto Rico

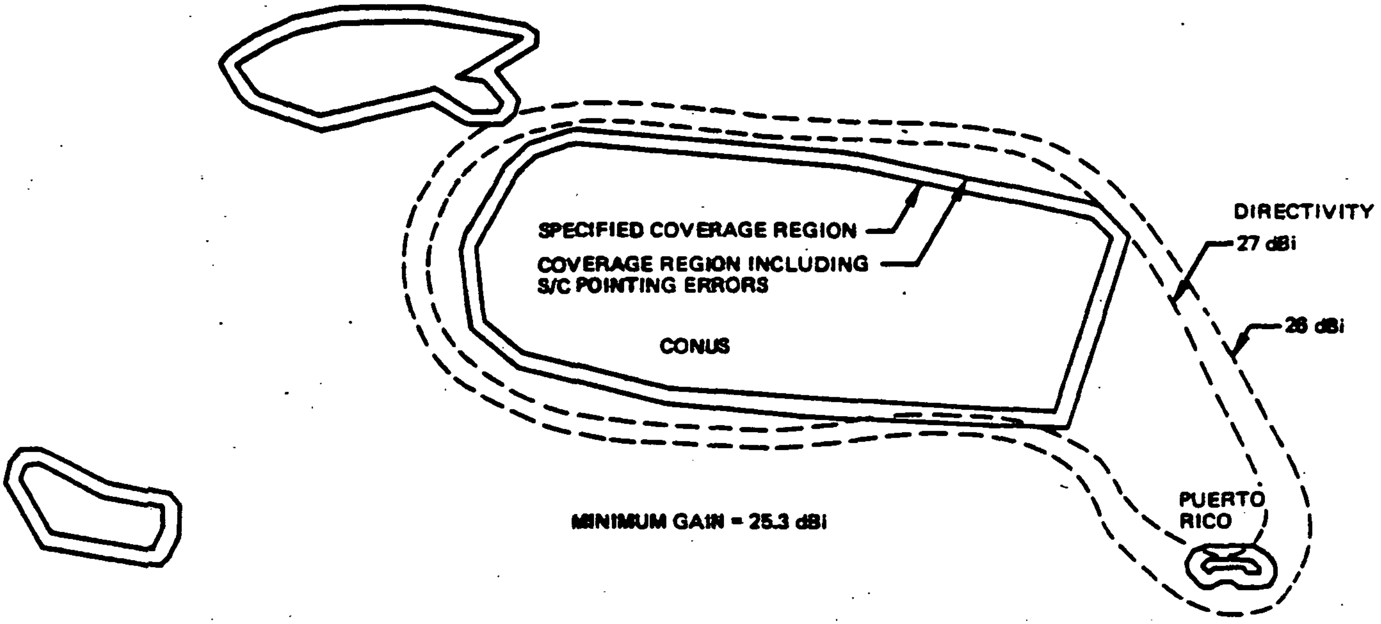


Figure 5.2.2-11 Calculated Innermost Transmit Horizontal Polarization Contours - CONUS and Hawaii

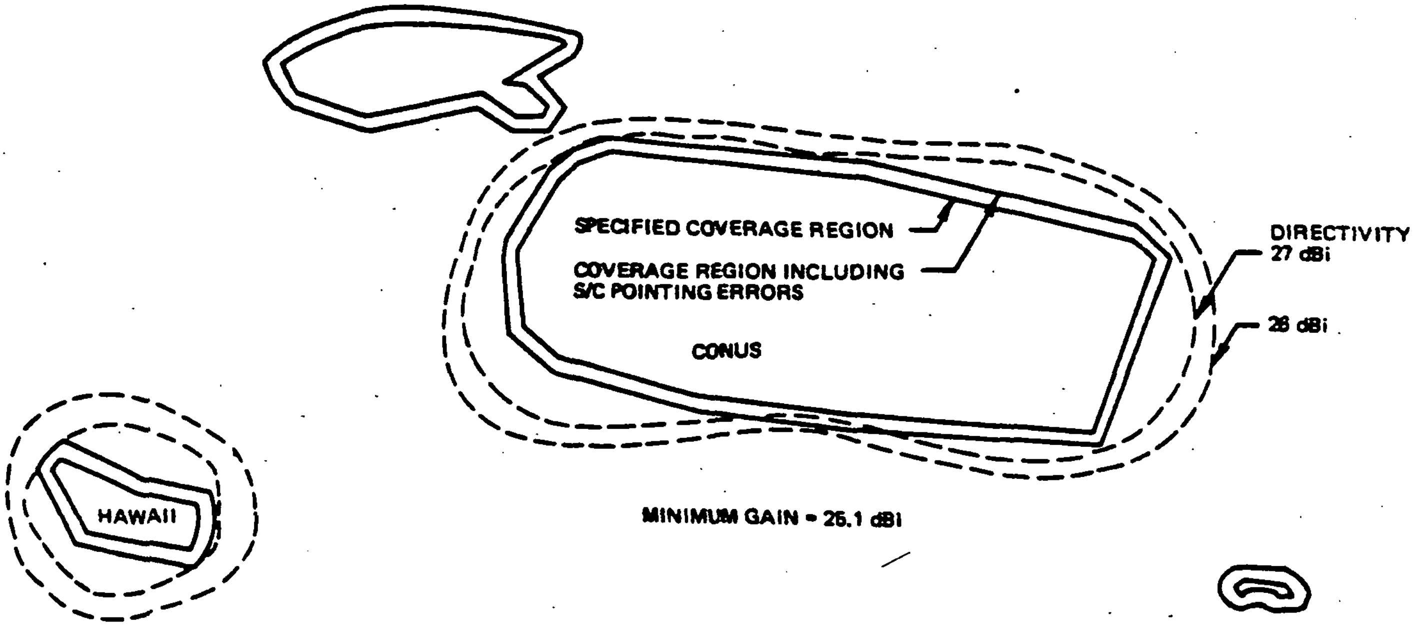
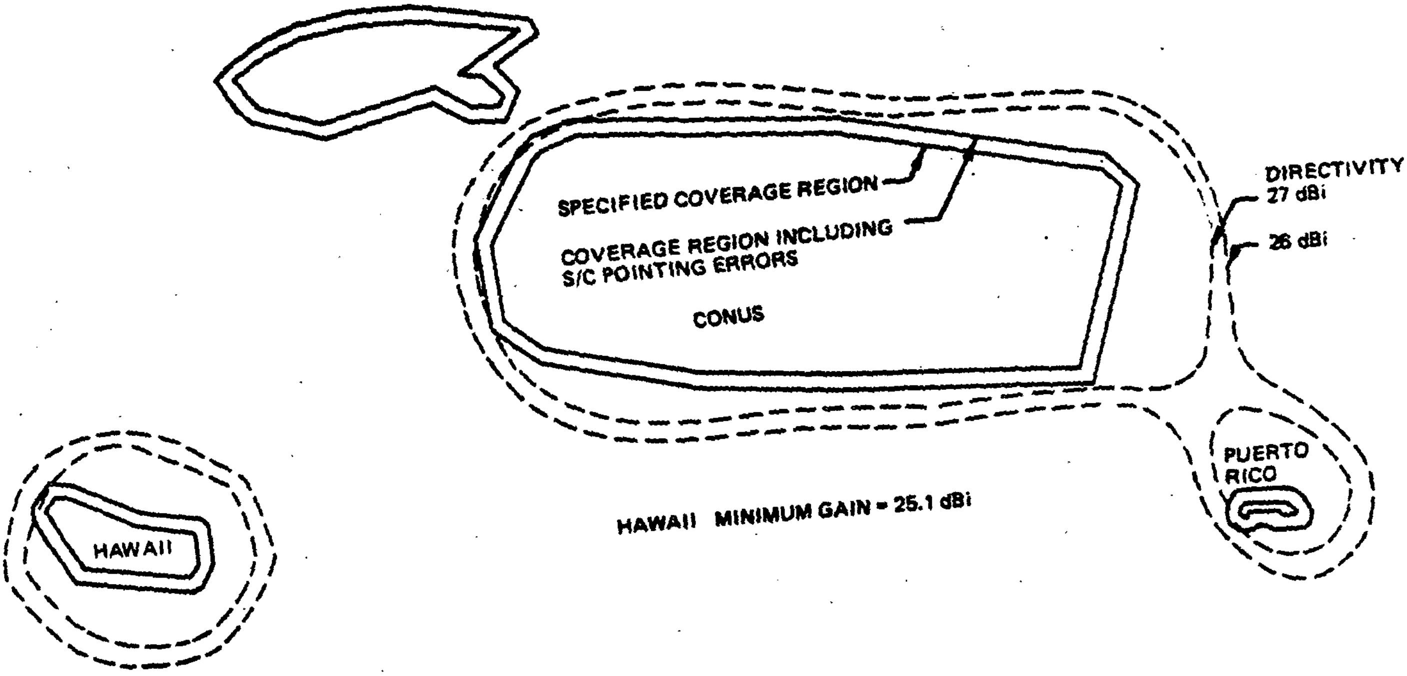


Figure 5.2.2-12 Calculated Innermost Receive Horizontal Polarization Contours



The critical technology items of an antenna subsystem are isolation, pointing accuracy, variable power divider (VPD) / Phase shifter (VPS), feed array, and reflector. No technology development is required in the C-band FSS antenna subsystem except the reflector. The weight of the reflector could be reduced about 20% in 1994 due to the more advanced materials that are being developed for the reflector surface. The assessment of these critical items are presented in Table 5.2.2-4.

Table 5.2.2-4

Assessment of Critical Technology Items

ITEM		LOW RISK	HIGH RISK
Isolation	Co-pol	NA	NA
Isolation	Cross-pol	30 dB	33 dB
Pointing Accuracy		None	None
Reflector		Weight:11kg	Weight: 9kg
Feed Array		Weight:7.2 kg Graphite Epoxy	Weight: 6.0 kg
VPD/VPS		NA	NA

5.2.2.3 C-Band Transponder, Fixed Satellite Service

The C-Band transponder subsystem consists of two independent, 12 channel transponders, and hence provides a total channel capacity of 24 channels, each of 36 MHz bandwidth. Both transponders utilize the same 500 MHz FSS band, having an uplink at 6 GHz and a downlink at 4 GHz. The transponders receive their inputs from the verticallypolarized (Alaska/CONUS coverage) and horizontally polarized (Hawaii/Pureto Rico/CONUS coverage) antenna feed assemblies. Each of the two 6 GHz inputs is filtered by an input preselector and then amplified and downconverted to 4GHz by the receiver. The 500 MHz IF band is subdivided by an input multiplexer into twelve, 36 MHz channels. The channels are individually amplified by SSPAs which contain one or more variable gain amplifiers. The latter permit automatic accommodation of varying uplink levels, using an AGC loop, and SSPA back off via ground control. The signals in the two sets of twelve individual channels are combined in two twelve channel output multiplexers and filtered by harmonic/band pass filters prior to transmission from the vertically and horizontally polarized transmit antennas. The transponder subsystem features four for two receiver redundancy and five for four SSPA redundancy. Component descriptions for low risk and high risk technology are contained in the following sections.

5.2.2.3.1 6/4 GHz Receiver

Using low risk technology this receiver provides for low noise amplification at 6 GHz. It down converts 6 GHz to 4 GHz with a Schottky diode mixer. The mixer is followed by bandpass filtering and amplification at 4 GHz. The local oscillator is a temperature controlled crystal oscillator followed by a multiplier chain.

<u>Electrical Performance</u>

Noise Figure	3.0 dB
Gain	70 dB
Output Power @c/3IM=-40dBc	+13 dBm
Frequency stability	+1/-2 ppm
DC power	7.5 watts

Mechanically, the receiver contains four subassembly trays a front end, a driver, a local oscillator and a DC/DC converter.

The trays are assembled in a vertical stack. RF signal connections between the front end, driver and local oscillator trays are made with short loops of semirigid coaxial cable. A selectable coaxial attenuator is included in the RF signal path at the input to the driver to allow for adjustment of the overall gain. Regulated DC voltages are supplied to the front end, driver and local oscillator trays through a DC harness running vertically along the side of the stack.

The microwave tray is an aluminum chassis that contains substrate assemblies that are bonded into the chassis, and substrate/carrier assemblies that are bolted in the chassis. The substrate assemblies consist of MIC isolators, filters and temperature compensation. The substrate/carrier assemblies are MIC amplifiers. These amplifiers are constructed using hermetically packaged semiconductors, chip resistors, and chip capacitors on thin film alumina substrates. The bias circuits are constructed using thick film alumina substrates, hermetically packaged semiconductors, chip resistors and chip capacitors.

Mechanical Parameters

Mass	1.6 kg
Volume	175 cu in.

Using high risk technology, the 6 GHz preamp will be updated with the latest low noise GaAs FET. This will improve noise figure from 3.0 dB to 1.5 dB. The mixer should be integrated with the bandpass filtering. The will enhance the mixer performance by improving gain flatness over temperature and reducing test time. The 4 GHz amplifiers should be replaced by monolithic gain blocks. These gain blocks are common to this receiver and many other applications. This would reduce test time and improve overall receiver performance. The crystal oscilator chain could be replaced by a dielectric resonator oscilator. The DRO will reduce complexity and cost. The current receiver uses an analog circuit to temperature compensate the receiver gain. Future receivers should use a digital system to improve gain stability. The preamp, mixer/filter, DRO, and digital temperature compensation require development that is geared toward space qualification. The 4GHz gain block would be developed in the commerical market and could be space qualified. Power consumption will be reduced 4.8 watts primarily by the use of the DRO.

The use of monolithic gain blocks and dielectric oscilators will reduce the size of the receiver. The number of subassemblies can be reduced from 4 to 3. These would be a DC/DC converter, front end/local oscilator, and driver.

Mechanical Parameters

Mass	0.7 kg
Volume	50 cu in.

5.2.2.3.2. 4 GHz Input Multiplexers

Using low risk technology, dual mode TE113 dielectric quasi elliptic filters and equalizers will be used. The electrical and mechanical design for the 24 and 36 MHz channels will be similar to that qualified and flown on the Arabsat program. Circulator coupling and hybrid splitting of adjacent channels will be used as is standard on today's communications satellites. Depending on the specifications, self-equalized filters may be required. The dielectric resonators will be housed in aluminum cylindrical cavities with two orthogonal modes used per resonator to minimize size and weight.

The 240 and 500 MHz wide channels would be realized in more conventional standard rectangular or possibly TE_{11} dual mode cylindrical cavities. Depending on the specifications, these cavities could be aluminum. Again depending on the specifications, a coaxial resonator filter made of aluminum may well meet the requirements. A 14 section coaxial cavity coupled filter is used as the 241 MHz input channel filter on the Intelsat V program. This approach is light weight and very compact.

Using high risk technology, dielectric resonators currently exist for realizing the 24 and 36 MHz wide 4 GHz input filters as explained above, however, much work remains to be done in providing lighter weight packaging. There are several promising approaches that need investigation to determine if low electrical losses can still be achieved with very small packages. These approaches would involve integrated construction with isolators and filter resonators in the same plane to permit stacking and easy interfacing with MIC and monolithic amplifiers. Amplifier coupling could be used at the input of each filter to minimize the need for isolator coupling. Chip amplifiers would certainly weigh less than a ferrite circulator.

In addition, it is anticipated that low loss temperature-stable resonator materials with dielectric constants of 80 will be available in the next few years. Currently, available materials are approximately in the 30 range. The higher dielectric constant will permit the realization of smaller and more compact filter packages both at 4 and 11 GHz.

These packages could easily be integrated with monolithic amplifiers and mixers to achieve high performance and very compact receivers. Unique construction techniques and filter types need to be developed to take advantage of these emerging technologies in microwave monolithic circuits and materials.

No significant improvement in the coaxial cavity filters is anticipated by 1994, if the specifications permit the use of these filters. Since they are coaxial their loss and insertion loss variation are higher than waveguide filters. Hence, they are not suitable for all input multiplexer application.

5.2.2.3.3 4 GHz SSPA, 8.5 Watt

Using low risk technology the 8.5 watt, 4 GHz solid state power amplifier would use Gallium Arsenide FETs as the active devices. The output stage combines the output of three 3-watt FETs and is driven by one 3 watt FET of the same type. This 3 Watt device has matching circuits incorporated within the device package to match the FET chip to 50 ohms, thereby minimizing amplifier tune and test time and maximizing the performance by accomplishing the matching as closely as possible to the chip. The three-way divider/combiner circuit uses a 4.77 dB interdigitated (Lange) coupler and a 3 dB interdigitated coupler. Four stages of low power gain precede the power stages. Two of these low level stages use dual-gate FETs to provide a variable gain which is set by the voltage on the second gate. The RF circuitry is etched in thin film metalization on alumina substrates which are bonded to moly or Kovar carriers. The amplifier uses a modular construction. Four separate modules are individually tuned and tested and then integrated. Four interstage isolators are included to minimize interaction between the modules when they are integrated. The isolators are the drop-in microstrip type to minimize size and weight, except for the output isolator which is stripline for lowest loss.

Using high risk technology, rapid advances in gallium arsenide technology and monolithic microwave integrated circuits (MMICs) should make possible substantial improvements in size and performance by 1994. Because of thermal considerations and the need to maximize the efficiency, it is not expected that the output stage will be in monolithic form. It is anticipated, however, that 8.5 watts output power will be available from a single device package with probably two FET chips, and with matching circuitry and combining circuitry integrated within the single package. This will reduce the size by eliminating the need for the large three-way divider/combiners. MMIC technology should make it possible to integrate several stages of low power-amplification on a single chip. Similarly the VGA should be realizable on a single chip. Thus, a 1994 8.5 watt amplifier could consist of two low power gain chips, a driver amplifier in one device package, and the output stage in a second package, leading to a significant reduction in size and weight.

5.2.2.3.4 4 GHz Output Multiplexers

Using low risk technology, the up to 12 channel 4 GHz multiplexers would be built using the graphite epoxy (GFRP) technology developed for the multiplexers on the Intelsat V program. The GFRP material is light weight, strong, and as temperature stable as the much heavier steel alloy, invar. Dual mode cylindrical cavities would be used in order to reduce the number of required cavities for an n pole filter to n/2. A common GFRP waveguide would be used to combine the outputs of the filters to form the multiplexers. This design approach has been qualified and flown on the Intelsat-V, Insat and Arabsat programs.

Properties of dielectric materials for microwave applications are constantly improving. Using high risk technology, the electrical loses at 4 GHz will be equivalent to, or better than, waveguide filters. Dielectric resonator filters have been used for input filters on the Arabsat program and by 1994 will be used in 4 GHz output filters at power levels up to 10 watts. These filters will use dual mode dielectric resonators to reduce the number of cavities. The cavity walls will be made of aluminum to save weight, and their outputs will be combined on a common waveguide or coaxial manifold depending on the system interface requirements.

There is important work that should be done on the physical mounting of the resonators so that they are rugged enough to survive launch without degrading the electrical performance. In addition, methods of keeping the resonators cool under high power conditions must be studied. The work should result in a mass and size 3 times smaller than available today.

5.2.2.3.5 Preselect and Harmonic Filters

Using low risk technology, standard Tchebyscheff TR_{01} rectangular aluminum waveguide filters are used for preselect filters. This technology has been used for decades and the design approach and implementation are routine. Standard waffle iron filters have been used for decades as harmonic filters. Recently, new advanced designs have been developed that are smaller and lighter. These designs have been qualified and flown on the Intelsat V program. These new designs have successfully passed multipaction testing at power levels of 1000 watts.

Since there is generally only one preselect or harmonic filter per antenna feed, efforts to significantly reduce the size and weight have very little impact on satellite mass and layout. Preselect filters and harmonic filters are usually implemented in aluminum waveguide and so do not weigh much more and are no larger than a short piece of waveguide.

In addition, these filters are often installed as a part of the waveguide run from the antenna feeds to the input or output of the transponder and so take up no additional space. Therefore, no improvement in preselect or harmonic filter technology is anticipated or required for future applications.

5.2.3 Ka-Band FSS Payload

5.2.3.1 Overview of a Ka-Band FSS Payload

The payload is to handle the 20 largest traffic center trunking nodes between themselves and via interconnect to the second tier switch and the baseload processor to the rest of CONUS traffic. The selected 20 nodes were based on the Western Union Study, as discussed in Section 4. The twenty beam locations were converted to latitude and longitude in Appendix G-1.1 for antenna design purposes. The system was allowed to use the entire 2.5 GHz of bandwidth; however, as can be seen in the block diagram, Figure 5.2.3-1, only two locations required the entire bandwidth and many required less than 20% of the bandwidth for equivalent percentage of actual traffic applied based on the CONUS distribution model. The payload uses all digital traffic at very high data rates, 960 Mb/s, and very high speed on-board SS-TDMA. The system uses an 8 PSK modulation to achieve a 2 bit per Hertz, highly efficient modulation scheme. The antenna system requires two reflectors and two sub-reflectors, with the sub-reflectors gimballed for independent pointing control of the 0.3° beamwidth beams for receive and transmit.

Table 5.2.3-1 shows the estimated weight, power and volume for low risk (emerging) technology and high risk (projected) technology for the transponder and antenna. Also included in the estimates are the coax, waveguide, and harness interconnects, plus an estimate for integration hardware to put the components together and provide necessary brackets for support and mounting. This does not include any structure or satellite mounting hardware rack between the feed and reflector.

5.2.3.2 Ka-Band FSS Antenna Subsystem

The Ka-band FSS antenna subsystem provides transmission at 20 GHz and reception at 30 GHz of dually linear-polarized

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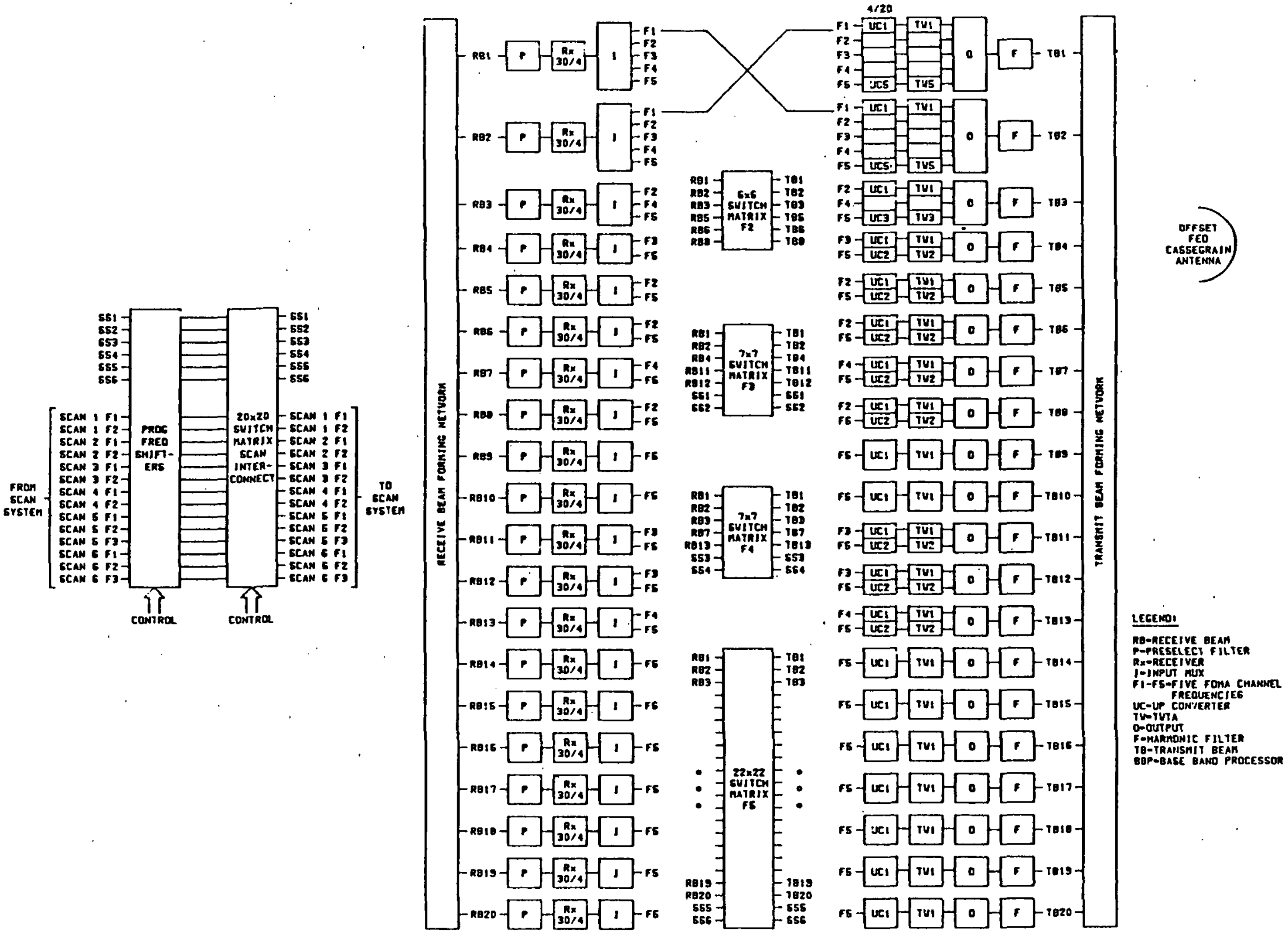

Figure 5.2.3-1 Ka-Band FSS Payload

Table 5.2.3-1

Ka-BAND FSS

Ka-Band FSS Summary

Scenario II, V, VI - A & B Payload Summary

	ITEM	P/L QTY REQ'D	REQ. QTY REQ'D	LOW RISK TECHNOLOGY						HIGH RISK TECHNOLOGY						COMMENTS
				UNIT			PAYLOAD			UNIT			PAYLOAD			
				WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	
1	30/4 GHz RECEIVER	20	40	1.6	8.0	175	64	160	700	0.6	5.5	50	24	110	2000	
2	INPUT MUX, 5 CHANNEL	2	2	1.75	-	360	3.5	-	720	0.75	-	180	1.5	-	360	
3	INPUT MUX, 3 CHANNEL	1	1	1.05	-	216	1.05	-	216	0.45	-	108	0.45	-	108	
4	INPUT MUX, 2 CHANNEL	8	8	0.70	-	144	5.60	-	1152	0.3	-	72	2.4	-	576	
5	INPUT MUX, 1 CHANNEL	9	9	0.35	-	72	3.15	-	648	0.15	-	36	1.35	-	324	
6	BEAM SWITCHING MATRIX, 6x6	1	1	.74	3.6	50	.74	3.6	50	0.3	2.4	18	0.3	2.4	18	
7	BEAM SWITCHING MATRIX, 7x7	2	2	1.0	4.9	70	2	9.8	140	0.4	3.3	45	0.8	6.6	90	
8	BEAM SWITCHING MATRIX, 22x22 DYNAMIC	1	1	10.0	48.4	675	10.0	48.4	675	4	32.3	225	4.0	32.3	225	
9	CHANNEL 1 UPCONVERTER 4/20GHz	2	3	1.4	7.0	140	4.2	14	420	0.7	4	45	2.1	8	135	
10	CHANNEL 2 UPCONVERTER "	6	7	1.4	7.0	140	9.8	42	980	0.7	4	45	4.9	24	315	
11	CHANNEL 3 UPCONVERTER "	5	7	1.4	7.0	140	9.8	35.0	980	0.7	4	45	4.9	20	315	
12	CHANNEL 4 UPCONVERTER 4/20GHz	5	7	1.4	7.0	140	9.8	35.0	980	0.7	4	45	4.9	20	315	
13	CHANNEL 5 UPCONVERTER 4/20GHz	20	25	1.4	7.0	140	35	140	3500	0.7	4	45	17.5	80	1125	
14	5/4 SWITCH MATRICES, REDUNDANCY(RING) COAX	7	7	1.4	-	160	9.8	-	1120	0.7	-	25	4.9	-	175	
15	7/5 SWITCH MATRICES, REDUNDANCY(RING) COAX	2	2	1.8	-	200	3.6	-	400	0.9	-	35	1.8	-	70	
16	5/4 SWITCH MATRIX, REDUNDANCY(RING) W/G	7	7	1.6	-	40	11.2	-	280	1.2	-	40	8.4	-	280	
17	7/5 SWITCH MATRIX, REDUNDANCY(RING) W/G	2	2	2.0	-	50	4.0	-	100	1.6	-	50	3.2	-	100	
18	OMUX, 5 CHANNEL	2	2	1.5	-	288	3.0	-	576	1.5	-	210	3.0	-	420	
19	OMUX, 3 CHANNEL	1	1	0.9	-	162	0.9	-	162	0.9	-	126	0.9	-	126	
20	OMUX, 2 CHANNEL	8	8	0.6	-	108	4.8	-	864	0.6	-	84	4.8	-	672	
21	OMUX, 1 CHANNEL	9	9	0.3	-	54	2.7		486	0.3	-	42	2.7	-	378	
22	HARMONIC FILTERS	20	20	0.15	-	4	3.0	-	80	0.15	-	4	3.0	-	80	
23	PRESELECT FILTERS	20	20	0.07	-	3	1.4	-	60	0.07	-	3	1.4	-	60	
24	SPDT SWITCHES, W/G 30 GHz	20	20	0.12	-	3	2.4	-	60	0.12	-	3	2.4	-	60	
25	TRANSFER SWITCHES W/G 30 GHz	10	10	0.15	-	3	1.5	-	30	0.15	-	3	1.5	-	30	
26	SPDT SWITCHES, COAX 4 GHz	20	20	0.08	-	6	1.6	-	120	0.08	-	6	1.6	-	120	
27	TRANSFER SWITCHES, COAX 4 GHz	10	10	0.14	-	12	1.4		120	0.14	-	12	1.4	-	120	
28	COAX SET	1	1	6.0	-	-	6.0	-	-	6	-	-	6	-	-	
29	WAVEGUIDE, SET	1	1	9.0	-	-	9.0	-	-	9	-	-	9	-	-	
30	HARNESS	1	1	15.0	-	-	15.0	-	-	15	-	-	15	-	-	
31	TWTA's 20 GHz, Avg 30W (49% Tx 93% EPC)	38	49	8.3	65.8	200	406.7	2501	9800	5.8	64.5	180	284.2	2451	8820	
32	COMM CONTROL & INTERFACE	1	2	2	16	400	4	16	800	1.6	12	300	3.2	12	600	
33	INTEGRATION HARDWARE	1	1	5%	-	-	32.5	-	-	5%	-	-	21.4	-	-	
34	MARGIN REQ'd.			10%	10%	10%	68.3	300	2622	15%	10%	10%	67.4	277	1802	
35																
36	TOTAL TRANSPONDER						751.4	3305	28841				516.3	3043	19819	

communication signals. The antenna will produce 20 simultaneous fixed beams directed at twenty specified cities in CONUS, as shown in Figure 5.2.3-2. The interbeam isolation shall be 30 dB or better. Table 5.2.3-2 summarizes the antenna subsystem requirements.

Table 5.2.3-2

Ka-Band FSS Antenna Subsystem Requirements

Parameters	Requirements	
Frequency	Downlink	17.7-20.2 GHz
Number of Beams	20	
Polarization	Dual Linear	
C/I	30 dB	
Pointing Accuracy	Pitch & Roll Yaw	0.02° 0.4 °

The antenna will consist of two dual offset shaped reflectors, one 4 meter for downlink and one 3 meter for uplink, as depicted in Figure 5.2.3-3 and 5.2.3-4. The reflector surface is shaped to produce a 0.3° half-power beamwidth with less than 1 dB scan loss over the view of CONUS. A seven (or up to thirteen) element cluster of waveguide horns will be used to produce a low sidelobe radiation pattern for each beam. Figure 5.2.3-5 shows a typical fixed beam antenna pattern. The cross polarization is below 40 dB and therefore is not included. The predicted antenna performance is summarized in Table 5.2.3-3.

Figure 5.2.3-2   Satellite Position 101.0 West (100W,37N1) K - Fixed

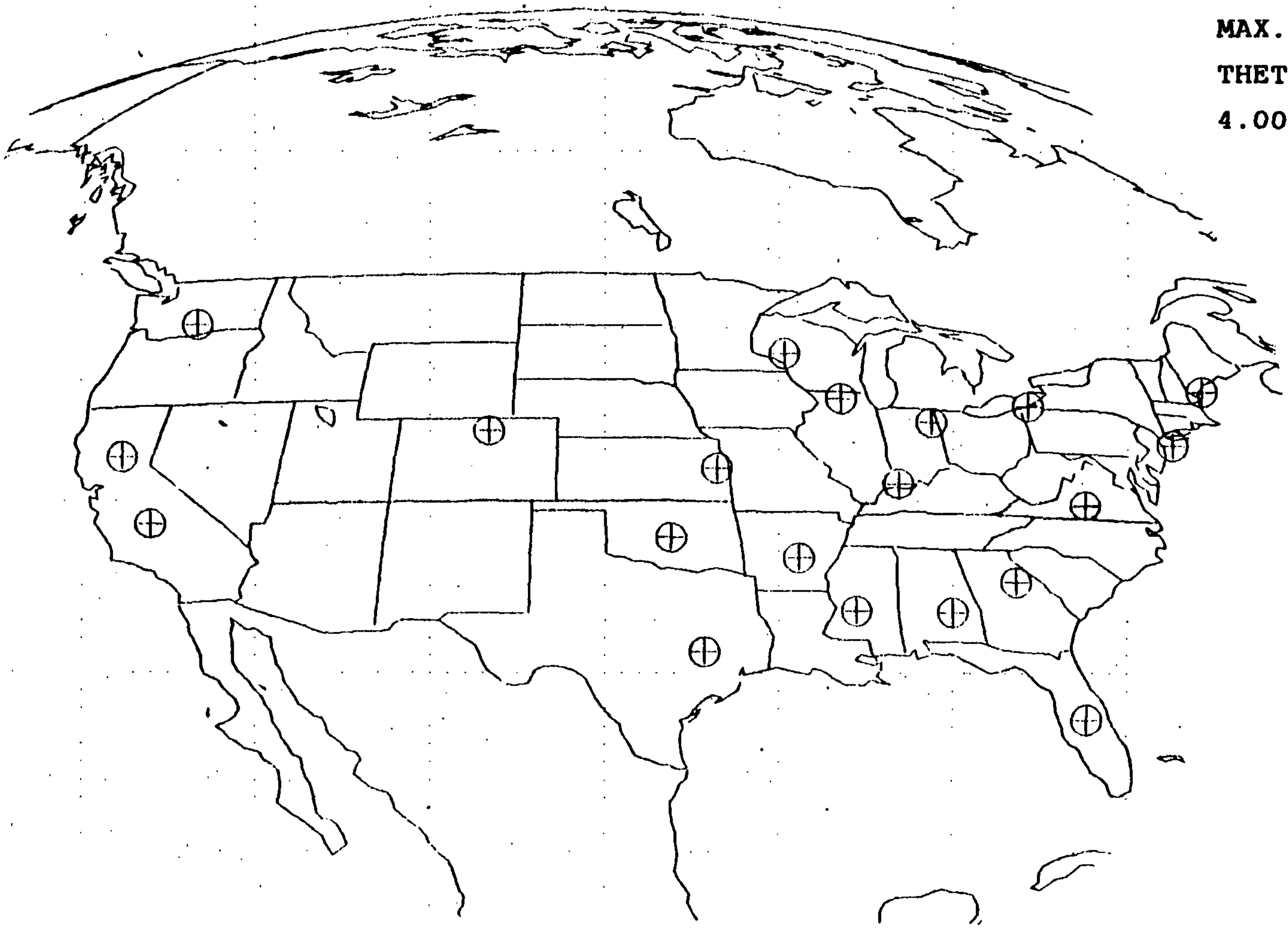

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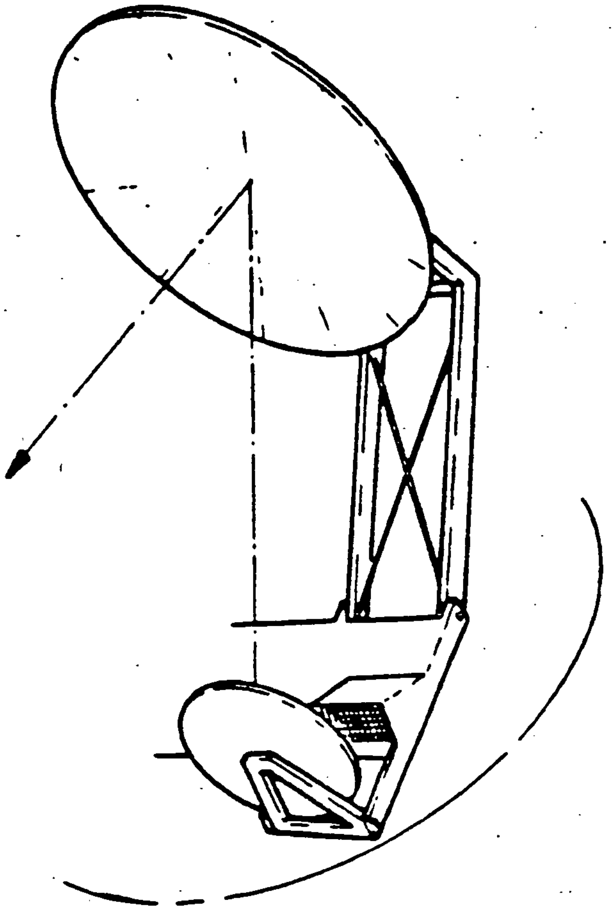
Figure 5.2.3-3 Downlink MBA Configuration

Figure 5.2.3-4 Uplink MBA Configuration



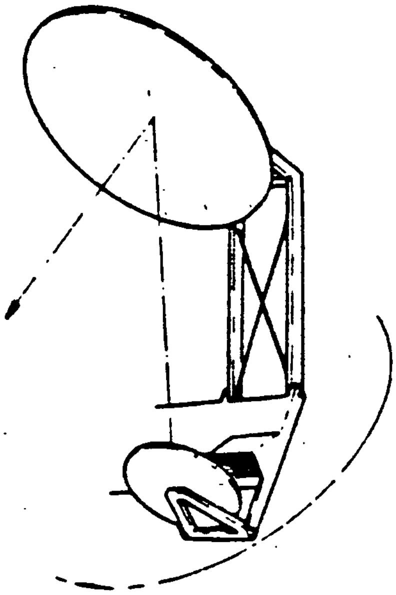


Figure 5.2.3-5 Measured El Pattern Horizontal Polarization

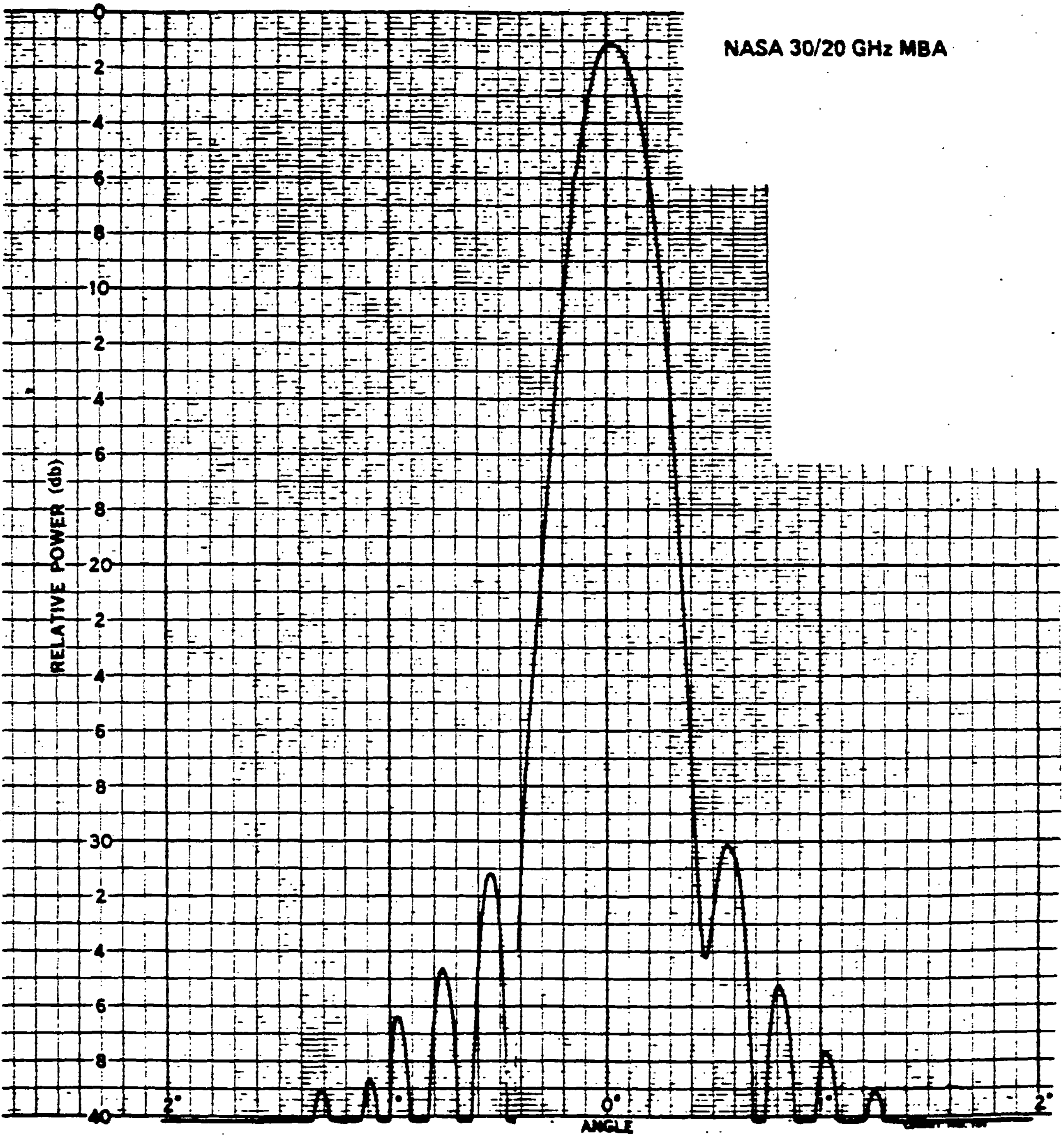


Table 5.2.3-3

Predicted Ka-Band FSS Antenna Subsystem Performance

Peak Gain	53 dBi
Sidelobe Isolation	30 dB
Cross-Pol Isolation	30 dB

The same antenna may be used for the Ka-band scan antenna subsystem. The critical technology items will be addressed in that subsection.

5.2.3.3 Ka-Band Transponder, Fixed Satellite Service

The Ka-Band FSS Transponder Subsystem consists of two 5 channel transponders, one 3 channel transponder, eight 2 channel transponders, and 9 single channel transponders, each channel having a 500 MHz bandwidth. Channel switching between beams and cross links to the scan beams are accomplished at the 4 GHz intermediate frequency.

The twenty outputs of the receiver beam forming network are fed to dedicated receivers via preselector filters. The receivers amplify and downconvert the received signals to the 4 GHz IF band. The IF bands of all but the single channels transponder are subdivided in two, three or five channels by the input multiplexers, which also provide the required narrow band receive filtering responses. The input multiplexers are followed by five switch matrices which allow connections between a) the two F1 channels, b) the six F2 channels, c) the five F3 channels, d) the five F4 channels, and e) the twenty F5 channels. In addition, the F3, F4 and F5 switch matrices (7x7, 7x7 and 2x22, respectively) have two extra input and output ports to permit interconnection between the Ka-Band, FSS transponders and the Ka-Band, scan beam transponders. The 38 FSS outputs of the switch matrices are amplified in variable gain amplifiers, then upconverted to 20 GHz. The upconverter output amplifier has the capability of driving the highest power TWTA (TWTA RF output ranges from 5 watts to 75 watts) to saturation.

The outputs of the TWTAs in the single channel transponders are narrow band filtered, and the outputs of the remaining TWTAs are recombined in output multiplexers, which also provide the required narrow band transmit filtering response. The downlink signals are further filtered by passband and harmonic filters prior to transmission from the beam forming network and offset fed Cassegrain transmit antenna.

The transponder subsystem features four for two redundancy for the receivers, and five for four redundancy for the 38 upconverters and TWTAs. Component descriptions for low risk and high risk technology are contained in the following sections.

5.2.3.3.1 30/4 GHz Receiver

Using low risk technology, this receiver provides for a low noise mixer that down converts 30 GHz to 4 GHz with a Schottky diode mixer. The mixer is followed by bandpass filtering and amplification at 4 GHz. The local oscillator is a temperature controlled crystal oscillator followed by a multiplier chain.

Electrical Performance

Noise Figure	8.5 dB
Gain	70 dB
Output power @ c/3IM = 40dBc	+13 dBm
Frequency stability	+1/-2 ppm
DC power	8.0 watts

Mechanically the receiver contains four subassembly trays: a front end, a driver, a local oscillator and a DC/DC converter.

The trays are assembled in a vertical stack. RF signal connections between the front end, driver, and local oscillator trays are made with short loops of semirigid coaxial cable. A selectable coaxial attenuator is included in the RF signal path at the input to the driver to allow for adjustment of the overall gain. Regulated DC voltages are supplied to the front end, driver, and local oscillator trays through a DC harness running vertically along the side of the stack.

The microwave tray is an aluminum chassis that contains substrate assemblies that are bonded into the chassis and substrate/carrier assemblies that are bolted in the chassis. The substrate assemblies consist of MIC isolators, filters and temperature compensation. The substrate/carrier assemblies are MIC amplifiers. The amplifiers are constructed using hermetically packaged semiconductors, chip resistors, and chip capacitors on thin film alumina substrates. The bias circuits are constructed using thick film alumina substrates, hermetically packaged semiconductors, chip resistors and chip capacitors.

Mechanical Parameters

Mass	1.6 kg
Volume	175 cu in

Using high risk technology, the 30 GHz/4 GHz receiver will be preceeded by a low noise GaAs FET amplifier. This will improve the noise figure from 8.5 dB to 4.0 dB. The mixer should be integrated with the bandpass filtering. This will enhance the mixer performance by improving gain flatness over temperature and reducing test time. The 4 GHz amplifier should be replaced by monolithic gain blocks. These gain blocks are common to this receiver and many other applications. This would reduce test time and improve overall receiver performance. The crystal oscillator chain could be replaced by a dielectric resonator oscillator. The DRO will reduce complexity and cost. The current receiver uses an analog circuit to temperature compensate the receiver gain. Future receivers should use a digital system to improve gain stability. The preamp, mixer/filter, DRO and digital temperature compensation require development that is geared toward space qualification. The 4 GHz gain block would be developed in the commercial market and could be space qualified. Power consumption will be reduced 5.5 watts, primarily by the use of the DRO.

The use of monolithic gain blocks and dielectric oscillators will reduce the size of the receiver. The number of subassemblies can be reduced from 4 to 3. These would be a DC/DC converter, front end/local oscilator, and driver.

Mechanical Parameters

Mass	0.6K kg
Volume	50 cu in

5.2.3.3.2 4 GHz Input Multiplexer

See 5.2.2.3.2.

5.2.3.3.3 Dynamic IF Switch Matrix

Using emerging technology, the switch matrix provides 2.5 GHz band width in the frequency band from 3.5 GHz to 6.0 GHz with a switching speed of less than 5 ns. The basic architecture contains a coupler cross-bar switch matrix.

This architecture has the following advantages:

- Planar structure with possible monolithic MIC in the future.
- Modular approach with simple manufacturing.

- Enhanced reliability due to:
  - --Minimum active devices per crosspoint.
  - --Failure of a device results in, at the most, the loss of only one crosspoint.
  - --Redundancy is simpler to implement.
- Good input/output match.

The switch amplifier module is a two-stage amplifier using dual gate FET's in chip form. Matching circuits are implemented using thin film MIC technology. Because of its modular form, any size matrix from 2 x 2 to 22 x 22 can be constructed with the same basic building blocks.

Electrical Parameters

Size	20 x 20
Switching Speed	5 ns
I.F.Frequency	3.5 to 6.0 GHz
Loss	20 dB
Gain Flatness	1.0 dB/GHz
DC Power	48 watts

The major emphasis in the mechanical package design is to minimize size, reduce assembly time, and ease tuning and testing. The package consists of two chassis mounted one on top of the other. The chassis contain two submatrices: a 22 x 12 and a 22 x 10, which form the final 20 x 20 basic matrix, plus two additional input rows, and two output columns needed for redundancy (final size 22 x 22).

Each set of two crosspoints within the matrix consists of a thin-film switch amplifier module and a thick film switch-driver module. The input couplers and the switch-driver module are installed on one side of the chassis. The switch-amplifier modules and the output coupler substrates are installed on the opposite side.

Mechanical Parameters	
Volume	675 cu in
Mass	10 kg

Using high risk technology, the dynamic microwave switch matrix design must be based on an extension of existing technologies. The dual gate GaAs FET is the primary candidate for a switch at frequencies higher than 1 GHz and at rates faster than 1 ns. The gallium arsenide monolithic circuit technology in use today in gigabit logic, monolithic microwave amplifiers, and monolithic microwave mixers will be the basis for designing a microwave switch matrix. An ideal building block would be a 10 x 10 port monolithic GaAs IC. This 10 x 10 GaAs IC would be the basic building block for switch matrices of larger or smaller sizes.

Electrical Parameters	
Size	20 x 20
Switching Speed	5 ns
I.F. Frequency	2 GHz to 20 GHz
Bandwidth	1 GHz
Loss	0 dB
Gain Flatness	1.0 dB
DC Power	32 watts

The major factor in determining the mechanical design is the location and type of RF connectors and interconnection between the 10 x 10 monolithic GaAs IC. The IC would be about 0.3 x 0.3 inches.

Mechanical Parameters	
Volume	225 cu in
Mass	4 kg

5.2.3.3.4 4/20 GHz Upconvertor

Using low risk technology, the upconverter provides for amplification at 4 GHz. It up converts 4 GHz to 20 GHz with a Schottky diode mixer. The mixer is followed by bandpass filtering. The local oscillator is a temperature controlled crystal oscillator followed by a multiplier chain. The 4 GHz amplification is done with dual gate FET's that also provide variable or stepped gain control.

Electrical Performance

Gain	15 dB
Output Power @ c/3IM = -40dBc	-10 dBm
Frequency stability	+1/-2 ppm
DC Power	6.5 watts

Mechanically the upconverter contains three subassembly trays: a front end, a local oscillator and a DC/DC converter.

The trays are assembled in a vertical stack. RF signal connections between the front end and local oscillator trays are made with a short loop of coax cable. Regulated DC voltages are supplied to the front end and local oscillator trays through a DC harness run vertically along the side of the stack.

The microwave tray is an aluminum chassis that contains substrate assemblies that are bonded into the chassis, and substrate/carrier assemblies that are bolted in the chassis. The substrate assemblies consist of MIC isolators, filters and temperature compensation. The substrate/carrier assemblies are MIC amplifiers. These amplifiers are constructed using hermetically packaged semiconductors, chip resistors, and chip capacitors on thin film alumina substrates. The bias circuits are constructed using thick film alumina substrates hermetically packaged semiconductors, chip resistors and chip capacitors.

Mechanical Parameters

Mass	1.4 kg
Volume	140 cu in

Using high risk technology, the 4 GHz amplifier will be updated with the latest dual gate GasFet's. The mixer should be integrated with bandpass filtering. This will enhance the mixer performance by improving gain flatness over temperature and reducing test time. The crystal oscillator will be replaced by a dielectric resonator oscillator. The DRO will reduce complexity and cost. The current upconverter uses an analog circuit to temperature compensate upconverter gain. Future upconverters should use a digital system to improve gain stability. The amplifier, DRO, and digital temperature compensation require development that is geared toward space qualification. The power consumption will be reduced to 4.0 watts primarily by the use of the DRO.

The use of the dielectric oscilators will reduce the size of the upconverter. The number of subassemblies can be reduced from 3 to 2. These would be a DC/DC converter and front end/local oscillator.

Mechanical Parameters

Mass	0.7 kg
Volume	45 cu in

5.2.3.3.5 20 GHz-75 Watt TWTA

The TWTA technology for this application is at the forefront of TWT technology today. Current TWT's achieve efficiencies on the order of 40% and power supplies are the same as the Ku-Band; i.e., approximately 90%. Higher TWT efficiencies will be realized with helix velocity taper and collector optimization. Also, the use of linearizers as part of TWTA packages will provide additional improvement in TWT efficiency, and this will yield TWT efficiencies in the 45% range. High risk technology utilizing multi-stage, advanced carbon, coated dispenser, or mixed metal cathodes, all requiring improved thermal interface due to the high power density for these small sizes, could utilize diamond helix support structures to yield efficiencies greater than 50%. NASA or government funding in this area would be required to flight qualify these items.

Power supplies, on the other hand, are not likely to improve much because the magnetic implementation currently limits the size and weight. Evolutionary changes to supplies with higher switching rates will yield converter efficiencies in the 92%-93% range. However, for these high power tubes (200 watts), in large quantities on the spacecraft, with spacecraft power requirements of 15-40 kW, an AC coupled main power distribution system could yield EPC efficiencies on the order of 95-96% by elimination of the chopper. This would yield a higher overall efficiency for the spacecraft also, but would require development of the AC distribution system for the bus.

5.2.3.3.6 20 GHz Output Multiplexers

Using low risk technology, these filters will be constructed using invar dual mode cylindrical cavity TE 111 filters coupled together on a common waveguide manifold even though the power level is 75 watts. The exotic high power techniques used on 50 to 200 watt 11 GHz filters are not required on these 20 GHz filters because of the wider bandwidth. The wide bandwidth results in much lower electrical losses and reduces heat dissipation.

Using high risk technology, the standard waveguide filters will still be required in 1994. Some improvement in mass should result from improvements in temperature control and heat sinking through heat pipes and other means. The improvement could be as much as 25%. Use of lighter weight materials in the mechanical design will also contribute to the mass reduction.

Some effort should be devoted to applying quasi-optical dielectric filter techniques to the 30 GHz range. It may be possible to develop filter realizations with very low losses using reflow or other material that have proven successful for filters at 60 GHz and higher frequencies.

5.2.3.3.7 Preselect and Harmonic Filters

See 5.2.2.3.5.

5.2.3.3.8 Programmable Frequency Shifters

The high risk technology application of the frequency shifters allows deletion of approximately a 2/3 portion of the BBP capacity. The frequency shifters only weigh 10 kg. The concept here is that the second tier switch becomes the equivalent of a T1 type of routing; i.e., 1.5 Mbps in doing this and using the scanning beam antenna provides the total connectivity to CONUS coverage. The use of DRO's for the oscillators, GaAs, MMIC for the switches, and VLSI for the digital control logic will result in very lightweight, low power equipment to replace significant BBP capacity by eliminating the need for on-board demodulation, storage, routing and re-modulation. Currently there is nothing on the market that performs this function. However certain military applications do use frequency shifting schemes for coding. The number and IF frequency here are peculiar to the commerical space applications and would require NASA/government subsidy to develop the quantity and speeds required by this payload architecture.

5.2.4 <u>Ka-Band Scan Payload</u>

5.2.4.1 Overview of Ka-Band Scan Payload

The payload utilizes an agile beam antenna that scans the entire CONUS coverage area in six segments. The payload provides the interconnectivity between the fixed beam traffic discussed in the prior section and the remaining CONUS area not connected to the twenty node network. In addition, the payload provides direct to user CPS service at data rates lower than the trunking network, and can handle switching on-board down to the circuit level via the baseband processor. The payload is an all digital, high data rate, high speed, on-board SS-TDMA architecture. The downlink burst rate is 480 Mb/s and uplink rates of 240, 120, 60 and 30 Mb/s can be accommodated. The basic system is patterned after the experimental ACTS system with a capacity of 1.5 Gb/s per scan beam.

In order to reduce baseband processor capacity and save weight and power, the second tier switching using high speed programmable frequency shifters was implemented to handle the thin route trunking portion of the traffic. The fast switching, fast settling programmable oscillators are an area that would need further effort and tradeoff. The antenna reflector systems for this payload are common with the Ka-Band FSS payload while the feed network is different. The trunking network utilizes 500 MHz bandwidth channels while the CPS service utilizes 240 MHz channels.

The six sector scan coverage areas were developed in Section 4 to the SMSA level and the covered areas converted into latitude and longitude coordinates for development of the antenna. Appendix G-2.1 contains the coordinates for each coverage area.

Figure 5.2.4-1 presents the block diagram for the Ka-Band Scan payload. Table 5.2.4-1 gives the estimated weight, power, and volume for the low risk (emerging) technology and the high risk (projected) technology for the transponder and antenna. Also included in the estimates are the coax, waveguide, and harness interconnects, plus an estimate for integration hardware to put the components together and provide necessary brackets for

Figure 5.2.4-1 Scenario II (Scan)

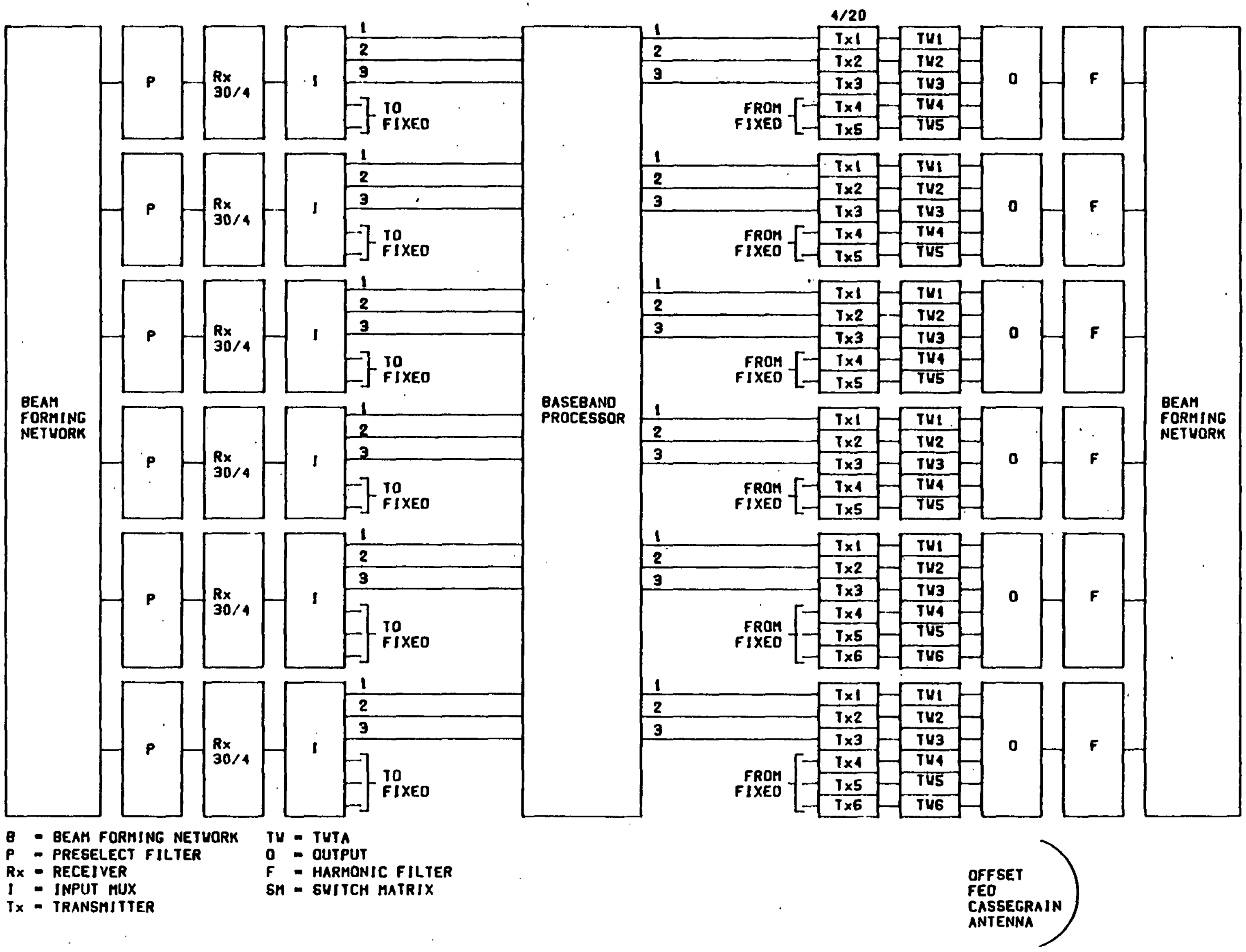


Table 5.2.4-1

Scenario II, V, VI - A & B - Payload Summary

Ka-Band Scan

	ITEM	P/L QTY REQ'D	REQ. QTY REQ'D	LOW RISK TECHNOLOGY						HIGH RISK TECHNOLOGY						COMMENTS
				UNIT			PAYLOAD			UNIT			PAYLOAD			
				WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	
1	30/4 GHz RECEIVER	6	12	1.6	8.0	175	19.2	48.0	2100	0.6	5.5	86	7.2	33	1032	
2	INPUT MULTIPLEXER, 5 CHANNEL	4	4	1.75	-	360	7	-	1440	0.75	-	180	3.0	-	720	
3	INPUT MULTIPLEXER, 6 CHANNEL	2	2	2.10	-	432	4.2	-	864	0.9	-	216	1.8	-	432	
4	BASEBAND PROCESSOR	1	1	294	1236	27380	294	1236	27380	236	865	23273	236	865	23273	
5	5/4 REDUNDANCY SWITCH MATRIX(RING) COAX	8	8	1.4	-	160	11.2	-	1280	0.7	-	25	5.6	-	200	
6	UPCONVERTERS(+VGAS)	32	40	1.4	7.0	140	56	224	560	0.7	4.0	45	28	128	1800	
7	TWTAs, 20 GHz, 18@15W+14@30W	32	40	8.3	33.6&65.8	200	332	1526	8000	5.8	32.9&64.5	180	232	1495	7200	
8	OUTPUT MULTIPLEXER, 5 CHANNEL	4	4	1.5	-	640	6.0	-	2560	1.5	-	210	6	-	840	
9	OUTPUT MULTIPLEXER 6 CHANNEL	6	6	1.8	-	768	10.8	-	4608	1.8	-	252	10.8	-	1512	
10	5/4 REDUNDANCY SWITCH MATRIX(RING) W/G	8	8	1.6	-	40	12.8	-	320	1.2	-	40	9.6	-	320	
11	HARMONIC FILTERS	32	32	.15	-	4	4.8	-	128	0.15	-	4	4.8	-	128	
12	PRESELECT FILTER	6	6	.07	-	3	0.48	-	18	0.07	-	3	0.48	-	18	
13	SPDT SWITCHES, 30 GHz, W/G	6	6	.12	-	3	0.72	-	18	0.12	-	3	0.72	-	18	
14	TRANSFER SWITCHES 30 GHz, W/G	3	3	.15	-	3	0.45	-	9	0.15	-	3	0.45	-	9	
15	TRANSFER SWITCHES, 4 GHz COAX	3	3	.14	-	12	0.42	-	36	0.14	-	12	0.42	-	36	
16	SPDT SWITCHES, 4 GHz, COAX	6	6	.08	-	6	0.48	-	36	0.08	-	6	0.48	-	36	
17	COAX, SET	1	1	5.3	-	-	5.3	-	-	5.3	-	-	5.3	-	-	
18	WAVEGUIDE, SET	1	1	8.0	-	-	8.0	-	-	8.0	-	-	8.0	-	-	
19	HARNESS	1	1	13.3	-	-	13.3	-	-	13.3	-	-	13.3	-	-	
20	COMM CONTROL & INTERFACE	1	2	2	16	400	4	16	800	1.6	12	300	3.2	12	600	
21	PROGRAMMABLE FREQUENCY SHIFTER	1	1	20	120	480	20	120	480	10	60	150	10	60	150	
22	DYMANIC 20 x 20 SWITCH MATRIX, 4 GHz	1	1	10	48.4	675	10	48.4	675	4	32.3	225	4	32.3	225	
23	INTEGRATION HARDWARE, SET	1	1	5%	-	-	41	-	-	5%	-	-	29.6	-	-	
24	MARGIN REQUIRED	-	-	15%	10%	10%	129	321.8	5131	20%	10%	15%	124.1	262.5	5782	
25																
26	TOTAL TRANSPONDER						991	3540	56443				745	2887.8	44331	
27																
28																
29	ANTENNA REFLECTORS(2 MAIN & 2 SUB)	1 set	1 set	62	-	-	62	-	-	50	-	-	50	-	-	
30	ANTENNA FEED NETWORK (1 RX + Tx)	1 set	1 set	167	-	118200	167	-	118200	150	-	118200	150	-	118200	
31	ANTENNA CONTROL ELECTRONICS & INTERFACE	1	2	0.5	4	75	1	4	150	0.2	2	40	0.4	2	80	
32	MARGIN REQUIRED			15%	10%	10%	34.5	0.4	11835	15%	10%	10%	30	0.2	11828	
33																
34	TOTAL ANTENNA						264.5	4.4	130185				230.4	2.2	130108	
35																
36	TOTAL PAYLOAD						1255.5	3544.4	186628				975.4	2890	174439	

support and mounting. Not included are any structure or satellite mounting hardware such as between the feed and reflector.

5.2.4.2 Ka-Band Scan Antenna Subsystem

The Ka-band scan antenna subsystem provides transmission at 20 GHz and reception at 30 GHz of dual linearly polarized communications signals. The antenna will produce six scanning spot beams. Each spot beam must scan a separate zone of CONUS as shown in Figure 5.2.4.-2. Table 5.2.4-2 presents the antenna subsystem requirements.

Table 5.2.4-2

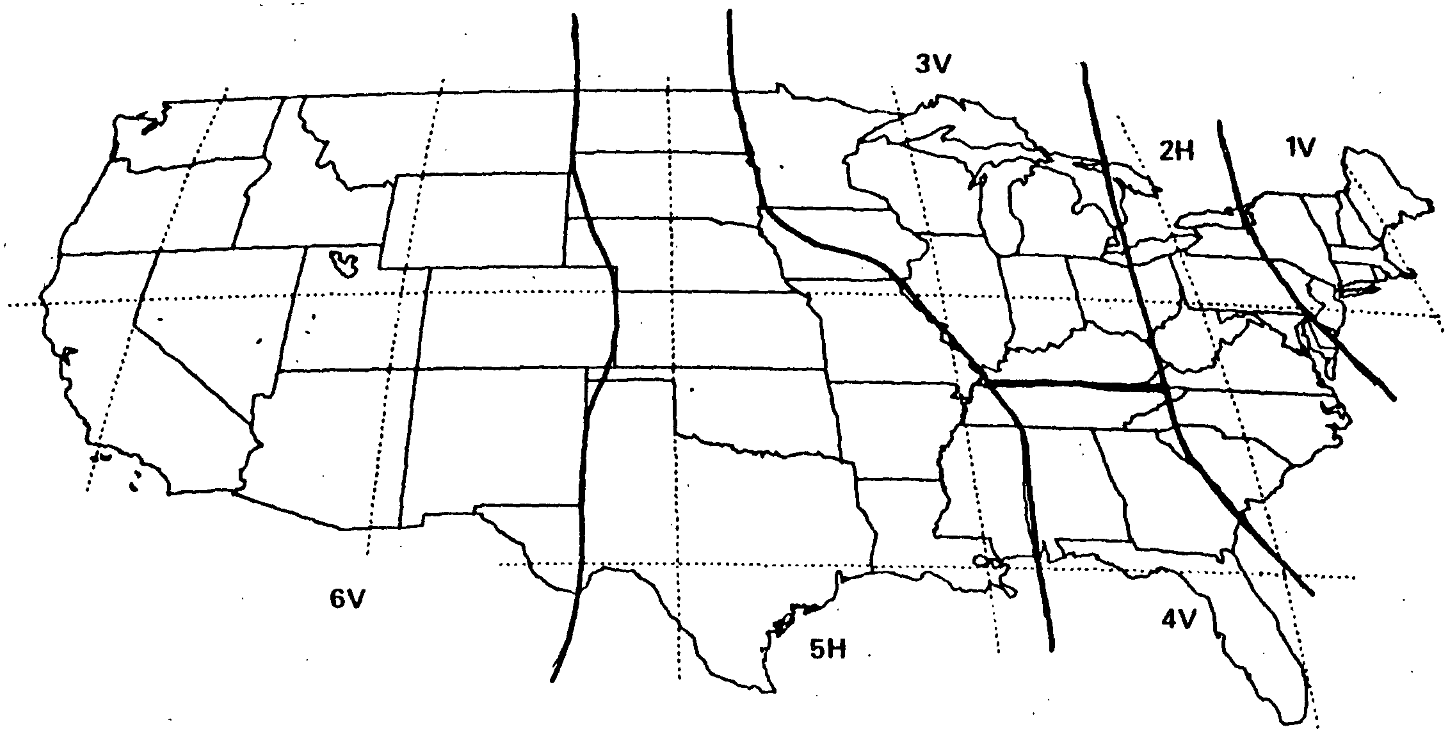
Ka-Band Scan Antenna Subsystems Requirements

PARAMETERS	REQUIREMENTS	
Frequency	Downlink 17.7 - 20.2 GHz Uplink 27.5 - 30.0 GHz	
Number of Beams	6 scanning beams	
Polarization	Dual Sensor	
C/I	30 dB	
Pointing Accuracy	Pitch Roll Yaw	0.02° 0.04°

The Ka-Band scan antenna and FSS antenna may share the same reflector aperture. It is assumed that the scan and FSS frequency bands are separated adequately so that they are able to be isolated by passive filtering in the satellite and ground terminals. In addition, it is planned to use different polarizations for the scan and FSS beams. Therefore, both beams can be operated simultaneously without causing mutual interference.

Figure 5.2.4-1 Ka-Band - 6 Sector Scan Areas

Scenario V



The feed array will consist of 500 elements of two-wavelength square waveguide horns providing coverage, as shown in Figure 5.2.4-3. Some of the horns are connected to an orthoganal linear polarized orthomode junction (OMJ), a dual port diplexer providing separate FSS, and scan beams ports. A seven-element cluster of waveguide horns was chosen to provide low sidelobes for each beam. Passive ferrite circulator switches and variable power dividers (VPDs) and variable phase shifters (VPSs) will be used. Each zone will use the required number of switches and 8 VPDs for the scanning beam. Figure 5.2.4-4 illustrates the switch/VPD network concept. In the figure, each element is labeled with a letter of the alphabet between A and H. Each seven feed cluster will than be connected with a group of different letters through the electronically controlled passive ferrite circular switches. The antenna performance is summarized in Table 5.2.4-3.

Table 5.2.4-3

Predicted Ka-Band FSS Antenna Subsystem Performance

Parameters	Predicted Performance
Peak Gain	50.8 dBi
C/I	30 dB

An alternate approach to the antenna subsystem is to incorporate a frequency-selective surface in the system as shown in Figure 5.2.4-5. The frequency selective surface is used as a spatial filter so that the same reflector aperture can be used for both the transmit and receive bands. Since the frequency ratio is 1.5:1, a single-layered frequency selective surface cannot provide the required sharp cutoff for this small ratio. A multi-layered frequency-selective surface is required. The impact of the multiple-reflected energy in a multiple beam antenna system has

Figure 5.2.4-3 Coverage from 599 Element Feed Array

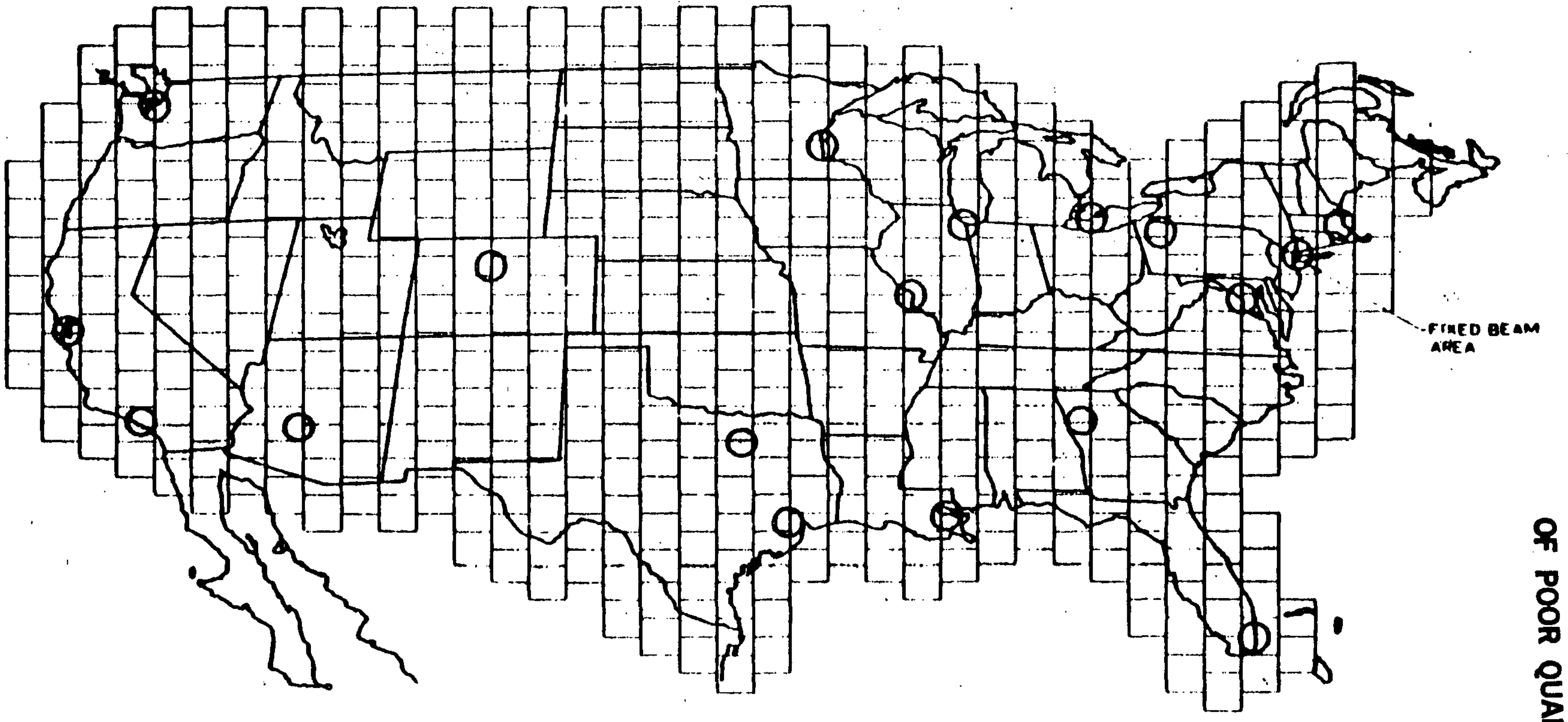


Figure 5.2.4-4 BFN with Combination of Switches and VPD's

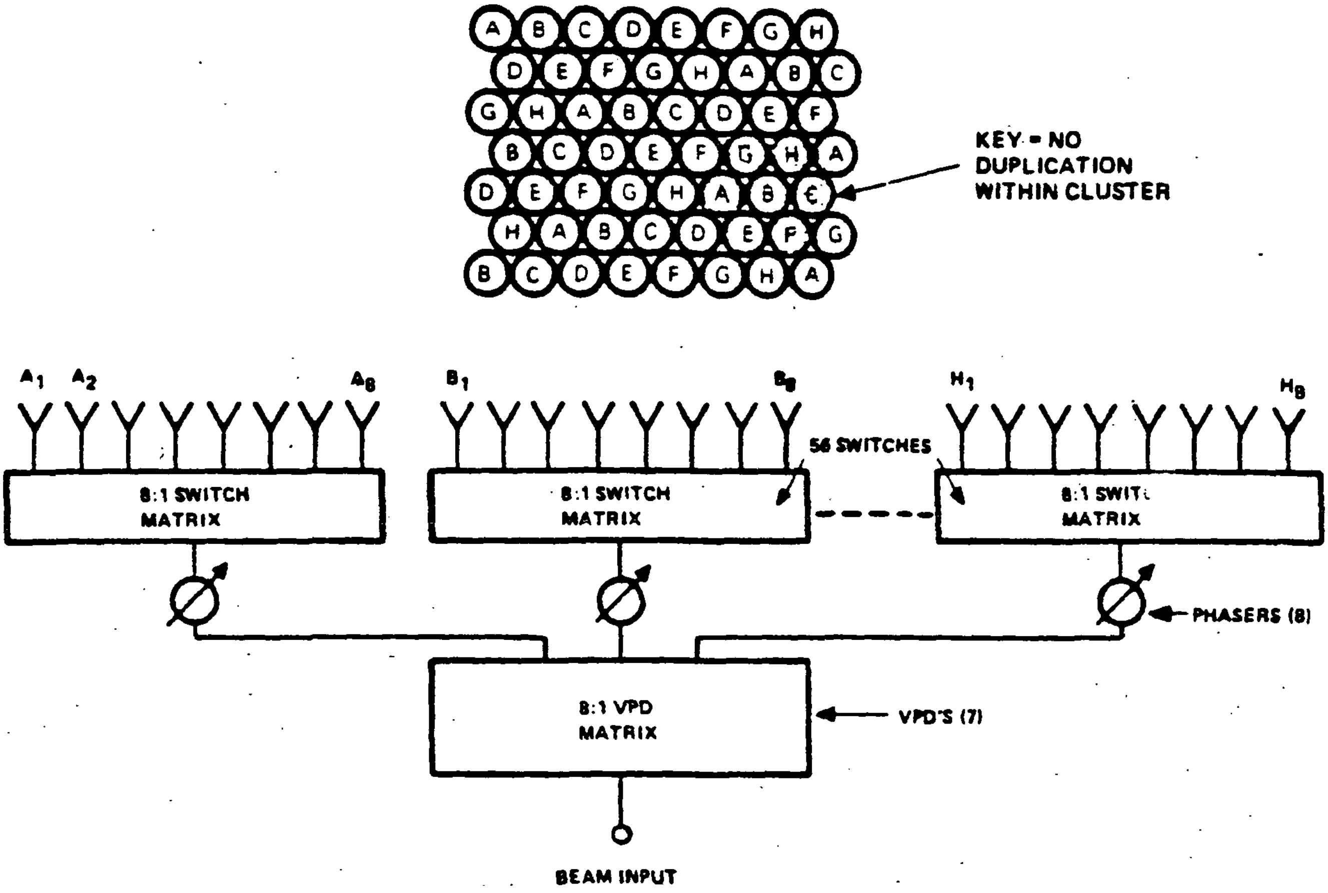
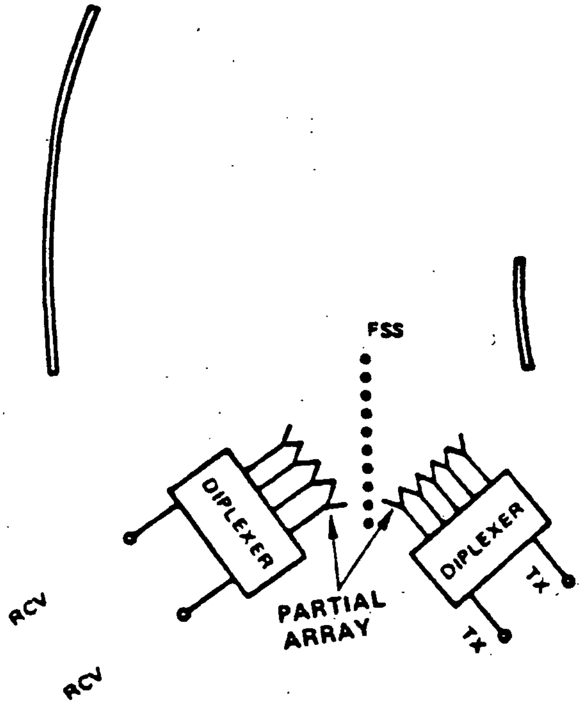


Figure 5.2-4-5 Frequency Selective Surface Implementation



to be evaluated to ensure the low cross-polarization required for a frequency reuse system. These requirements are most stringent, and the design itself represents the present state-of-art.

The use of an active beam forming network (BFN); i.e., hundreds of low power small solid-state monolithic amplifiers distributed in the BFN to replace the single high power TWT at each beam port, can be used to improve EIRP and system reliability. However, it requires two major technology accomplishments. One is the development of the amplifier module technology for the exit specification required for this function. The other is the study and development of a multiple beam antenna optics and microwave network configuration.

The present weight estimate for this system is about 264 kg. This weight might be reduced about 20% in 1994 due to the development of a lighter material for the reflector surface. The assessment of the technology-critical items are summarized in Table 5.2.4-4.

5.2.4.3 Ka-Band Scan Transponder Subsystem

The Ka-Band Scan Beam Transponder Subsytem consists of four five channel transponders, and two, six channel transponders. Channels 1,2 and 3 have a bandwidth of 240 MHz and channels 4,5 and 6 have bandwidth of 500 MHz. Channel switching between beams and crosslinks to the FSS transponders are accomplished dynamically by a baseband processor.

The six outputs of the receive beam forming network are fed to dedicated receivers via preselector filters. The receivers amplify and downconvert the received signals to the 4 GHz IF band. The IF bands of the five channel transponders are subdivided into three 240 MHz channels and two 500 MHz channels by the input multiplexers, which also provide the required narrow band receive filtering responses. The six channel transponders have an additional 500 MHz channel.

Table 5.2.4-4

The assessment of the level of risk of Critical Technology Items

ITEMS	LOW RISK	HIGH RISK
Isolation	30 dB	30 dB
Reflectors	62 kg	20% lighter
VPD/VPS	Achievable	Achievable
Frequency -selective surface	Needs development	Achievable
Active BFN	Needs Development	Slight Development

The input multiplexers are followed by a baseband processor which accepts the 4 GHz inputs from all the 240 MHz channels, downconverts them to baseband and dynamically switches and reroutes the individual baseband signals. These are then regrouped, modulated on FM Carriers and upconverted to the 4 GHz IF. The fourteen 500 MHz channel outputs from the input multiplexer are routed directly to the FSS Ka-Band transponder where they are frequency shifted to appropriate bands and switched to the desired fixed beams by a 20x20 solid state switch matrix. Fourteen 500 MHz channels from the FSS transponder fixed beams are also frequency shifted as necessary and switched to the desired scan beams by the same solid state switch matrix.

The eighteen 240 MHz channel, IF outputs from the baseband processor and the fourteen 500 MHz channel outputs from the FSS switch matrix are amplified in variable gain amplifiers, then upconverted to 20 GHz. The upconverter output amplifier has the capability of driving the highest power TWTA (TWTA RF output ranges from 5 watts to 75 watts) to saturation.

The outputs of the TWTAs are recombined in output multiplexers, which also provide the required narrow band transmit filtering resonses.

The downlink signals are further filtered by passband and harmonic filters prior to transmission from the beam forming network and offset fed cassegrain transmit antenna.

The transponder subsystem features four for two redundancy for the receivers and five for four redundancy for the upconverters and TWTAs.

Component description for low risk and high risk technology are contained in sections 5.2.3.3.1 through 5.2.3.3.8.

5.2.4.4 Baseband Processor

The baseband processor (BBP) subsystem planned for use in this payload is an advanced version of the Motorola effort that has been on going since 1980. The BBP, while using less capacity throughput than the full-up 30/20 GHz system, is operating at higher data rates and more input channels. Based on low risk technology, the BBP would still be a development risk due to the high data rates. The use of the VLSI work in the ECL (MOSAIC) and CMOS done to date could handle the processing needs once qualified and demonstrated on ACTS.

Functionally, the BBP, as part of the satellite transponder system, is required to process, route, and control message traffic amoung individual users. To this end, the BBP
(1) demodulates the channelized uplink TDMA transmissions,

(2) transfers the demodulated data on a store-and-forward basis wherein message segments are accumulated in the output registers according to their intended destinations, (3) remodulates the sorted data for downlink transmission (the downlink channelization approaches a pure TDM architecture), and (4) provides network timing and synchronization. Figure 5.2.4-6 is an overall concept of the BBP.

The BBP provides the capability to route traffic from any terminal to any other terminal. It further provides the capability to distribute CPS traffic on a one-to-several basis.

The BBP utilizes a combination of 4 dB of FEC coding gain and 6 dB improvement in signal-to-noise ratio through the decoding of the uplinks and encoding of the downlinks. FEC is applied adaptively only for those terminals degraded by rain. A maximum total of 125 Mbps of uplink traffic and 125 Mbps of downlink traffic can be processed as coded traffic. This FEC capacity is to be apportioned among the terminals as needed. The IF frequencies are nominally in the range of 3 to 4 GHz. The system throughput capacity is nominally 9 Gbps.

Figure 5.2.4-7 breaks down one of the scan beam input/output channel architecture. Each scan beam can handle 1.5 Gbps on three 480 Mbps downlink channels. The uplink channels have a maximum of 1.5 Gbps, and lesser rates reduce the overall system capacity.

For low risk technology, the ACTS BBP weight, power, and volume are the basis of the estimate. For the high risk technology, it is assumed that additional VLSI development and advances in speed/power would yield lighter weight, lower power and correspondingly lower volume. This is an area where the custom VLSI work would not likely be done without NASA/government subsidized effort.

Figure 5.2.4-6 Baseband Processor

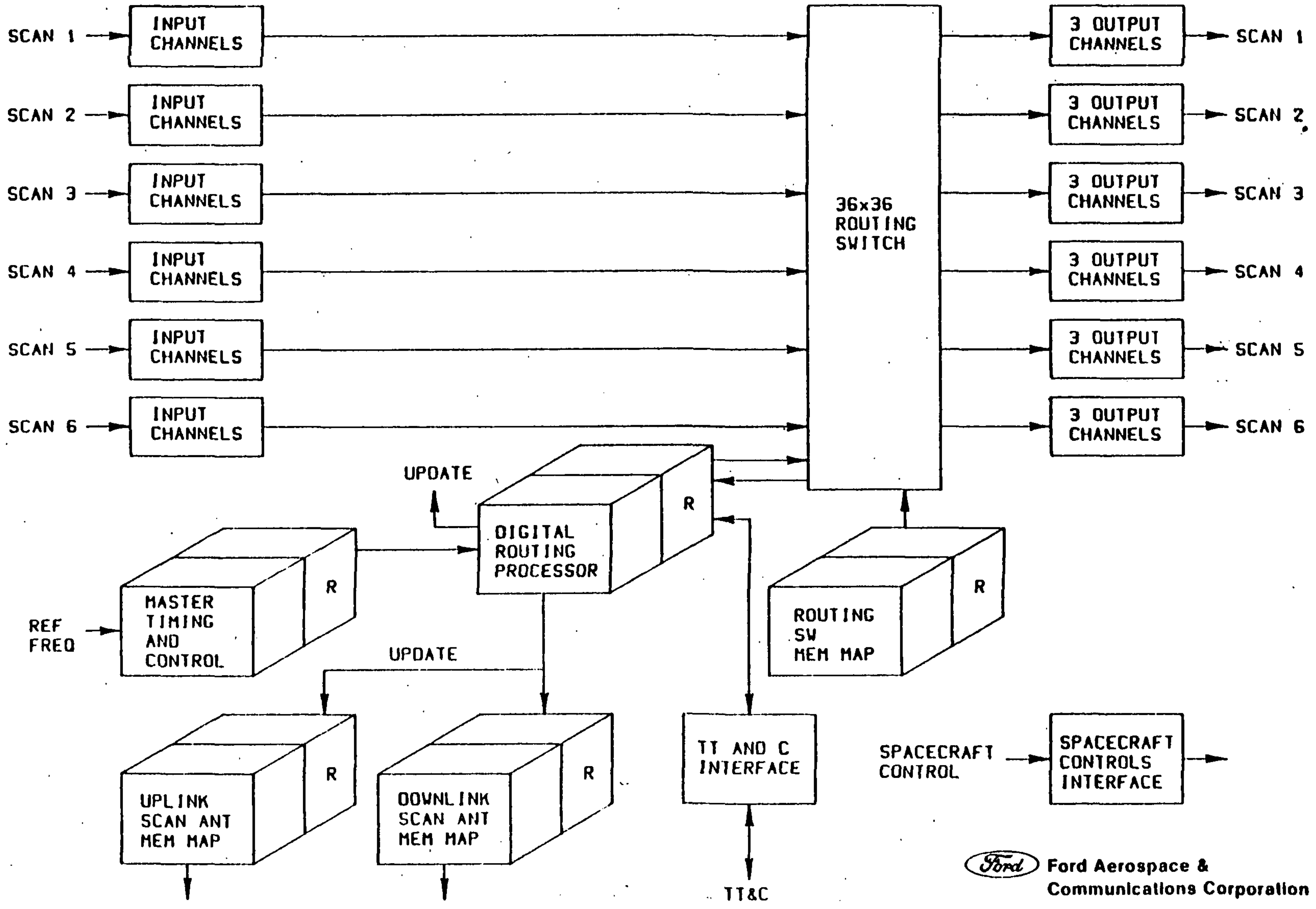
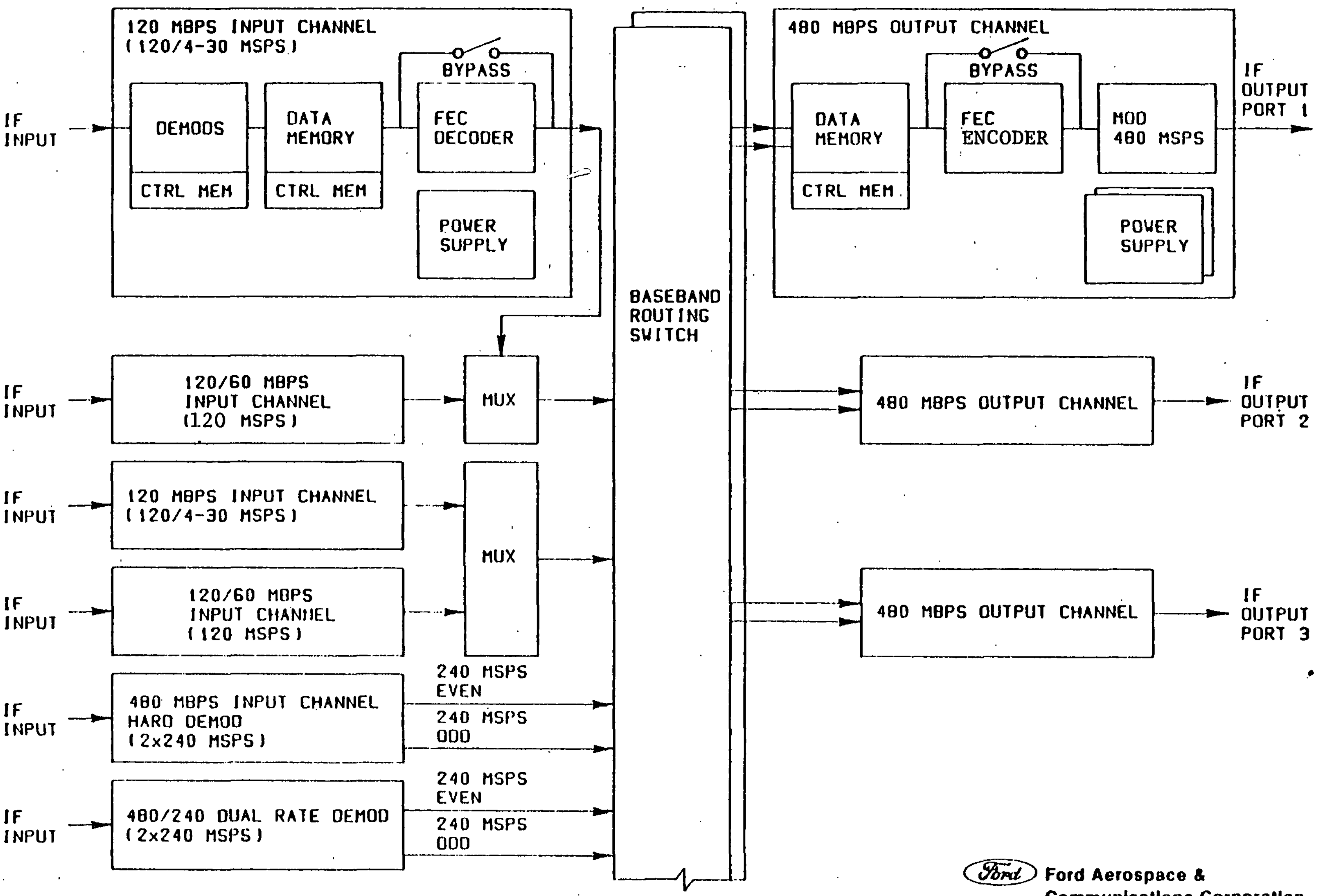


Figure 5.2.4-7 Typical Baseband Processor
I/O Channel per Scan Beam



Ford Aerospace &
Communications Corporation

5.2.5 Ku-Band FSS Payload

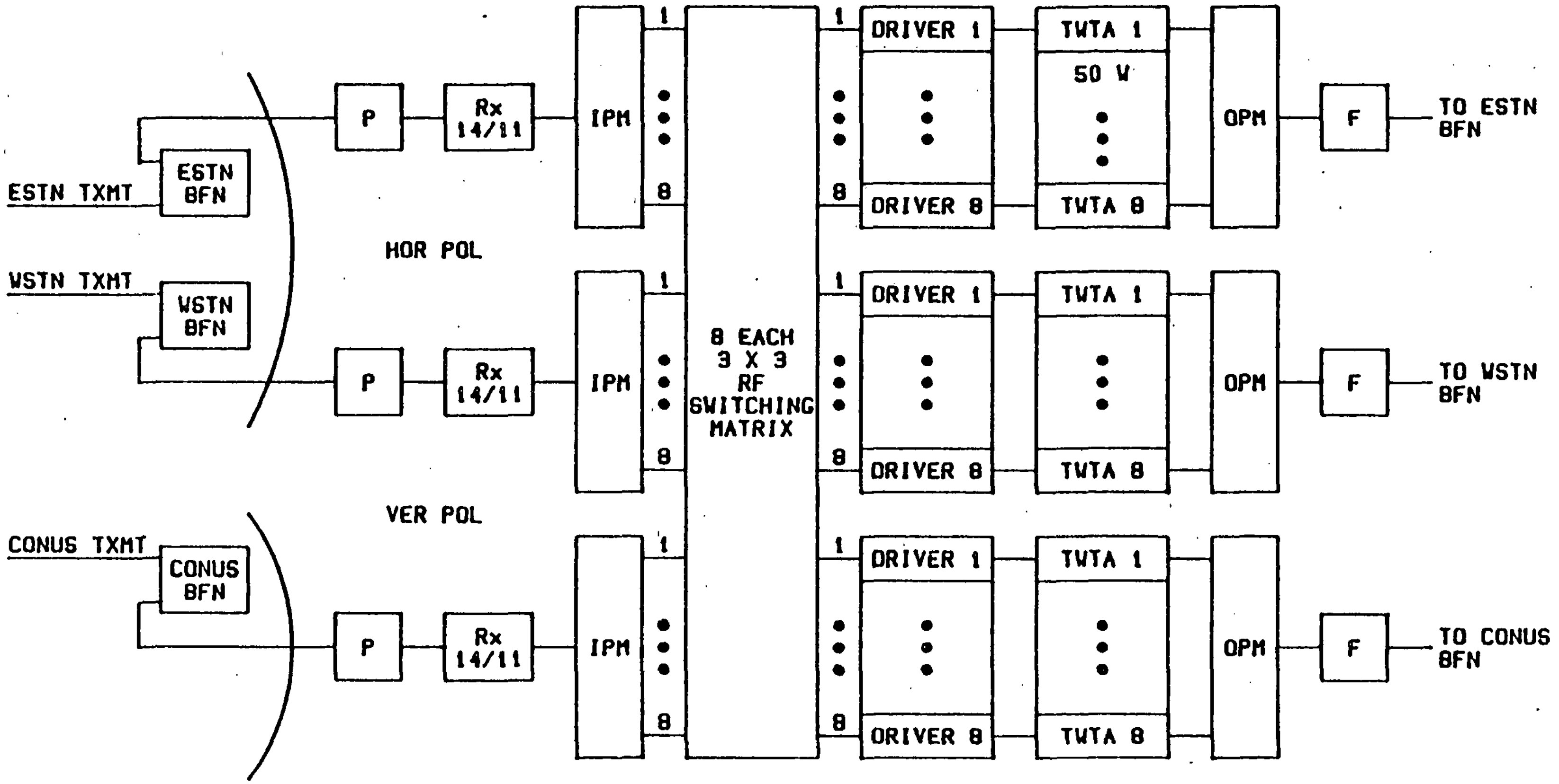
5.2.5.1 Overview of Ku-Band FSS Payload

The payload is similar to the current generation of Ku-Band payloads being launched from 1985 thru 1988. Thus this would be a one for one replacement. It utilizes an uplink of 14 GHz and a downlink of 11 GHz. It has 3 times re-use with one CONUS beam and an eastern and western coverage area beam, all interconnected via electronic switches. The payload features a dual gridded reflector to obtain the polarization purity required for re-use. The reflector assembly is stacked with a slight offset in focal point for physical separation of the feed assemblies. The transponder is of straight forward design and no on-board processing is provided. The block diagram shown in Figure 5.2.5-1 indicates TWTA's for the output amplifiers. However, an alternate using distributed lower power solid state amplifiers in the beam forming network would lead to improved reliability and eliminate the wear out mechanisms inherent in TWTA's. The coverage areas for the East and West beams were developed in Section 4 to the SMSA level and the convered areas converted into latitude and longitude coordinates for development of the antenna. Appendix G-3.1 contains a listing of the beam coverage areas for each beam. Table 5.2.5-1 shows the estimated weight, power and volume for low risk (emerging) technology and high risk (projected) technology for the transponder and antenna. Also included in the estimate are the coax, waveguide, and harness interconnects plus a estimate for integration hardware to put the components together and provide necessary brackets for support and mounting. This does not include any structure or satellite mounting hardware such as between the feeds and the reflectors.

5.2.5.2 Ku-Band FSS Antenna Subsystem

The Ku-Band FSS antenna subsystem provides transmission at 11 GHz and reception at 14 GHz of dual linearly polarized

Figure 5.2.5-1 Scenario II - Ku (FSS)



P: PRESELECT FILTER
BFN: BEAM FORMING NETWORK
IPM: INPUT MULTIPLEXER
OPM: OUTPUT MULTIPLEXER
F: HARMONIC FILTER
TXMT: TRANSMITTER

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Table 5.2.5--2

Scenario II - Payload Summary
Ku-Band FSS

	ITEM	P/L QTY REQ'D	REQ. QTY REQ'D	LOW RISK TECHNOLOGY						HIGH RISK TECHNOLOGY						COMMENTS
				UNIT			PAYLOAD			UNIT			PAYLOAD			
				WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	
1	14/11 GHz RECEIVER	3	6	1.8	9	175	10.8	27	1050	0.7	6.0	50	4.2	18	300	
2	INPUT MULTIPLEXER, 8 CHANNEL, 54 MHz	3	3	3.6	-	1536	10.8		4608	1.2	-	144	3.6	-	432	
3	SWITCH MATRIX, 3x3 CH SWITCHING	8	8	0.9	-	96	7.2		768	0.5	2.5	35	4	20	280	
4	DRIVER AMPLIFIER, VARIABLE GAIN, 11GHz	24	30	0.5	4	20	15	96	600	0.2	2.7	30	6	64.8	900	
5	TWTA/SSPA, 11 GHz, SOW	24	30	4.5	125	250	135	3000	7500	4.0	91	200	120	2184	6000	
6	OUTPUT MULTIPLEXER, 8 CHANNEL, 54 MHz	3	3	4.0	-	1024	12.0		3072	3	-	768	9	-	2304	
7	5/4 REDUNDANCY SWITCH MATRIX, COAX(RING)	6	6	1.4	-	160	8.4		960	0.7	-	25	4.2	-	150	
8	5/4 REDUNDANCY SWITCH MATRIX, W/E(RING)	6	6	2.0	-	200	12.0		1200	1.6	-	200	9.6	-	1200	
9	HARMONIC FILTER	24	24	0.1	-	13.5	2.4		324	0.1	-	135	2.4	-	324	
10	PRESELECT FILTER	3	3	0.1	-	13.5	0.3		40.5	0.1	-	13.5	0.3	-	40.5	
11	SPDT SWITCH, W/G, 14 GHz	3	3	0.15	-	16	0.45		48	0.15	-	16	0.45	-	48	
12	SPDT SWITCH, COAX, 11 GHz	3	3	0.08	-	36	0.24		18	0.08	-	36	0.24	-	108	
13	COAX, SET	1	1	4.0	-	-	4.0			4	-	-	4	-	-	
14	WAVEGUIDE, SET	1	1	12.0			12.0			12	-	-	12	-	-	
15	HARNESS	1	1	10.0			10.0			10	-	-	10	-	-	
16	COMM, CONTROL & INTERFACE	1	2	1	8	200	2	8	400	0.8	6	150	1.6	6	300	
17	TRANSFER SWITCH W/G	1	1	0.18	-	16	0.18	-	16	0.18	-	16	0.18	-	16	
18	TRANSFER SWITCH COAX	1	1	0.14	-	12	0.14	-	12	0.14	-	12	0.14	-	12	
19	INTEGRATION HARDWARE, SET	1	1	5%	-	-	12.1	-	-	5%	-	-	9.6	-	-	
20	MARGIN REQUIRED			10%	10%	10%	25.5	313	2062	15%	10%	10%	30.2	229	1242	
21																
22	TOTAL TRANSPONDER						280.5	3444	22679				231.7	2522	13657	
23																
24																
25	ANTENNA REFLECTOR(DUAL GRIDDED 2.5m)	1	1	18.6	-	-	18.6	-	-	15	-	-	15	-	-	
26	ANTENNA FEED VERTICAL	1	1	6.2	-	3600	6.2	-	3600	5.6	-	3300	5.6	-	3300	
27	ANTENNA FEED HORIZONTAL	1	1	6.2	-	3600	6.2	-	3600	5.6	-	3300	5.6	-	3300	
28	MARGIN REQUIRED			10%	-	10%	3.1	-	720	10%		10%	2.6	-	660	
29																
30	TOTAL ANTENNA						34.1		7920				28.8	-	7260	
31																
32																
33	TOTAL PAYLOAD						314.6	3444	30599				260.5	2522	20917	

communications signals. The antenna coverage regions include horizontal polarization for full CONUS and vertical polarization for east and west half CONUS as shown in Figure 5.2.5-2. The requirements of the antenna subsystem are summarized in Table 5.2.5-2

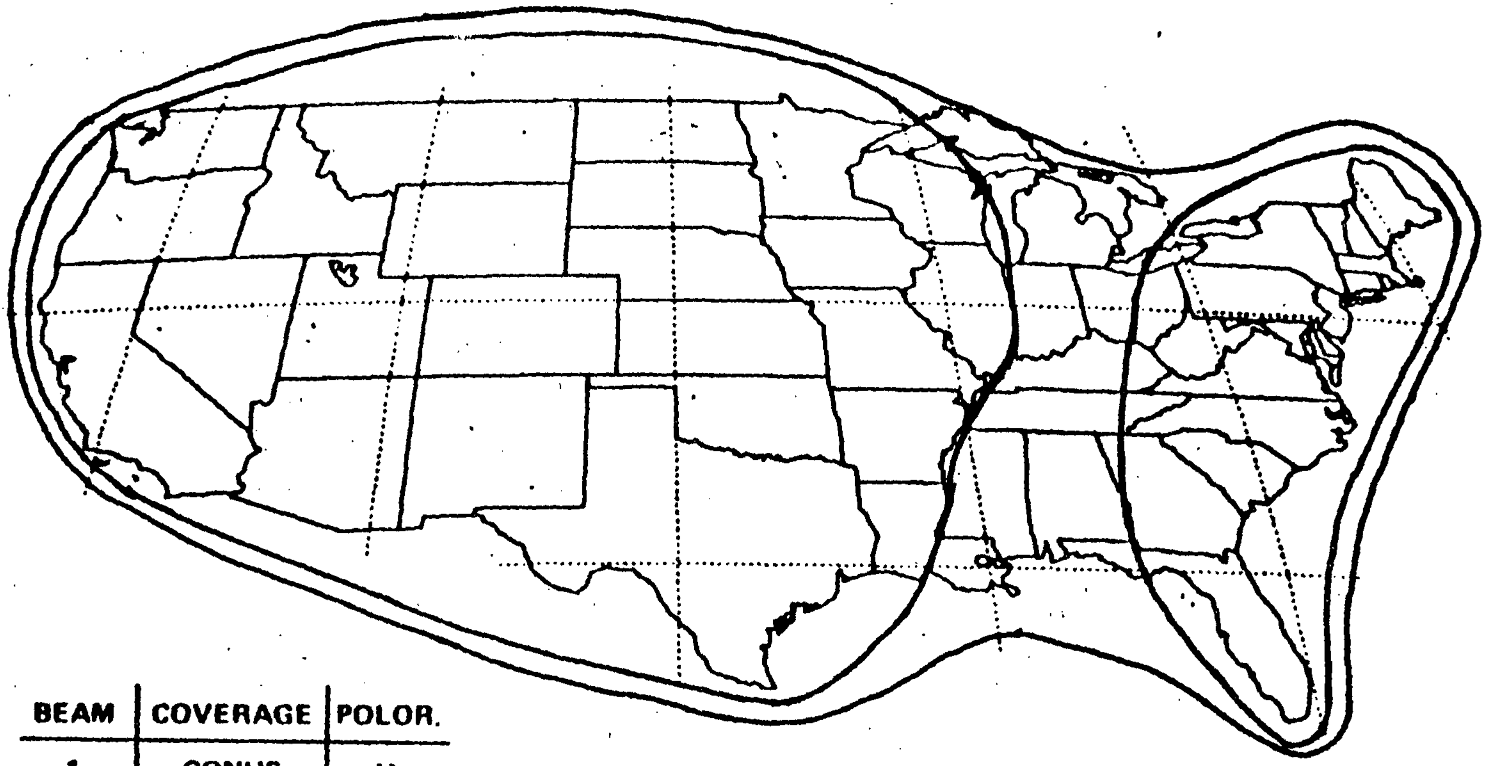
The antenna will consist of two overlapped, gridded reflectors and two multihorn feed array systems, as depicted in Figure 5.2.5-3. The grids of the reflector are selected to run either in the horizontal on vertical direction for horizontal or vertical polarization. They are used to help lower cross-polarization energy that is produced by the field curvature of the asymetric paraboloid, as well as the cross-polarization radiated from the feed array. The polarization isolation achieved is greater than 30 dB. In order to provide adequate reliable isolation between the east and west CONUS beams for frequency reuse, the size of the reflector should be at least 13'. Figures 5.3.5-4 to 5.2.5-6 present the antenna radiation patterns for full CONUS beam, and east and west CONUS beams. The predicted edge-of-coverage antenna gains are given in Table 5.2.5-3.

Table 5.2.5-2

Ku-Band FSS Antenna Subsystem Requirements

Parameters	Requirements
Frequency:	Transmit: 11 GHz Band Receive: 14 GHz band
Polarization	Full CONUS: Horizontal East/West Half CONUS: Vertical
Coverage Area	Full CONUS; East/West half CONUS
Isolation:	30 dB

Figure 5.2.5-2 Ku-Band FSS Coverage Requirement



BEAM	COVERAGE	POLOR.
1	CONUS	H
2	WEST	V
3	EAST	V

Figure 5.2.5-3 Ku-Band FSS Antenna Configuration

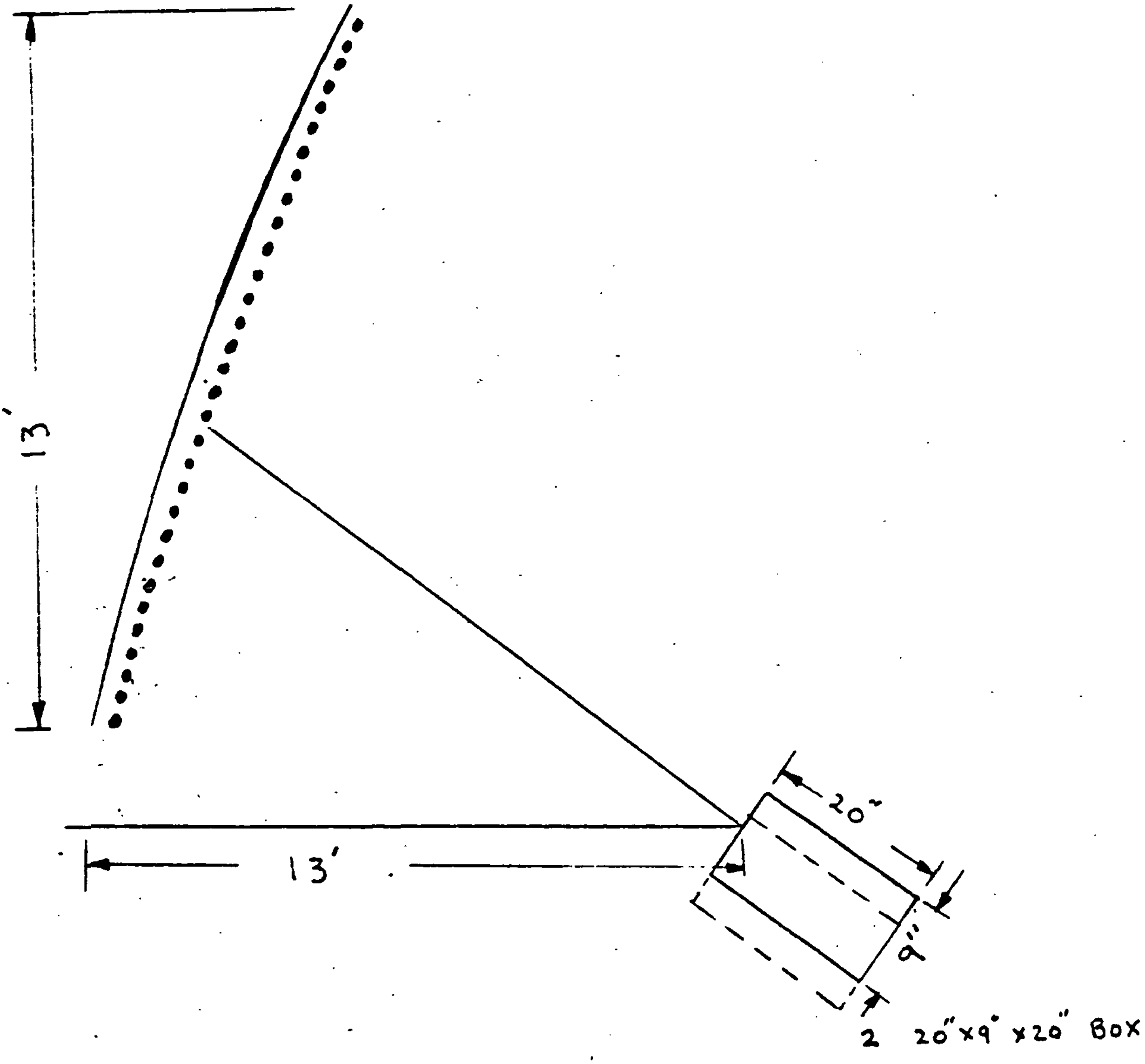
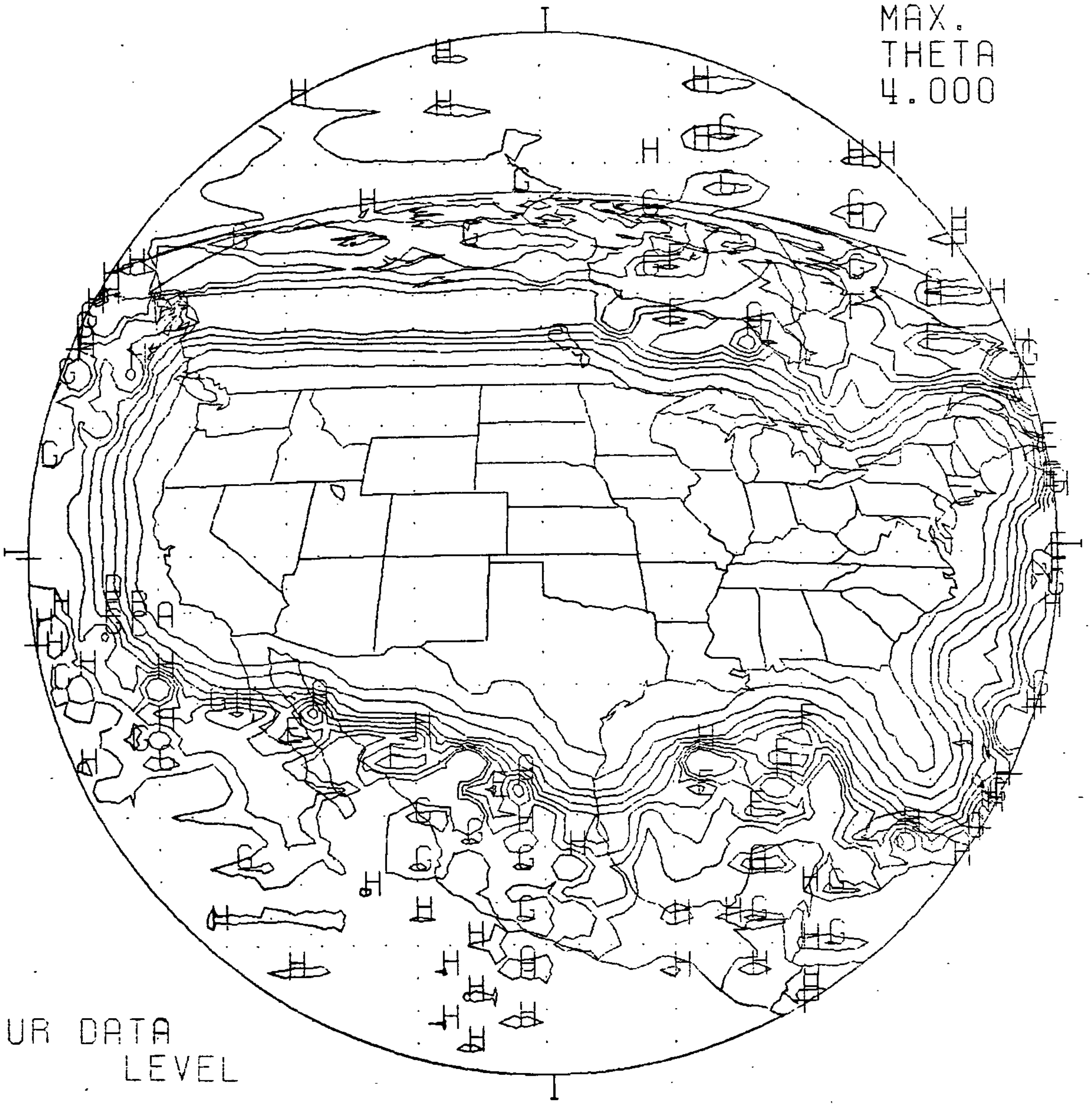


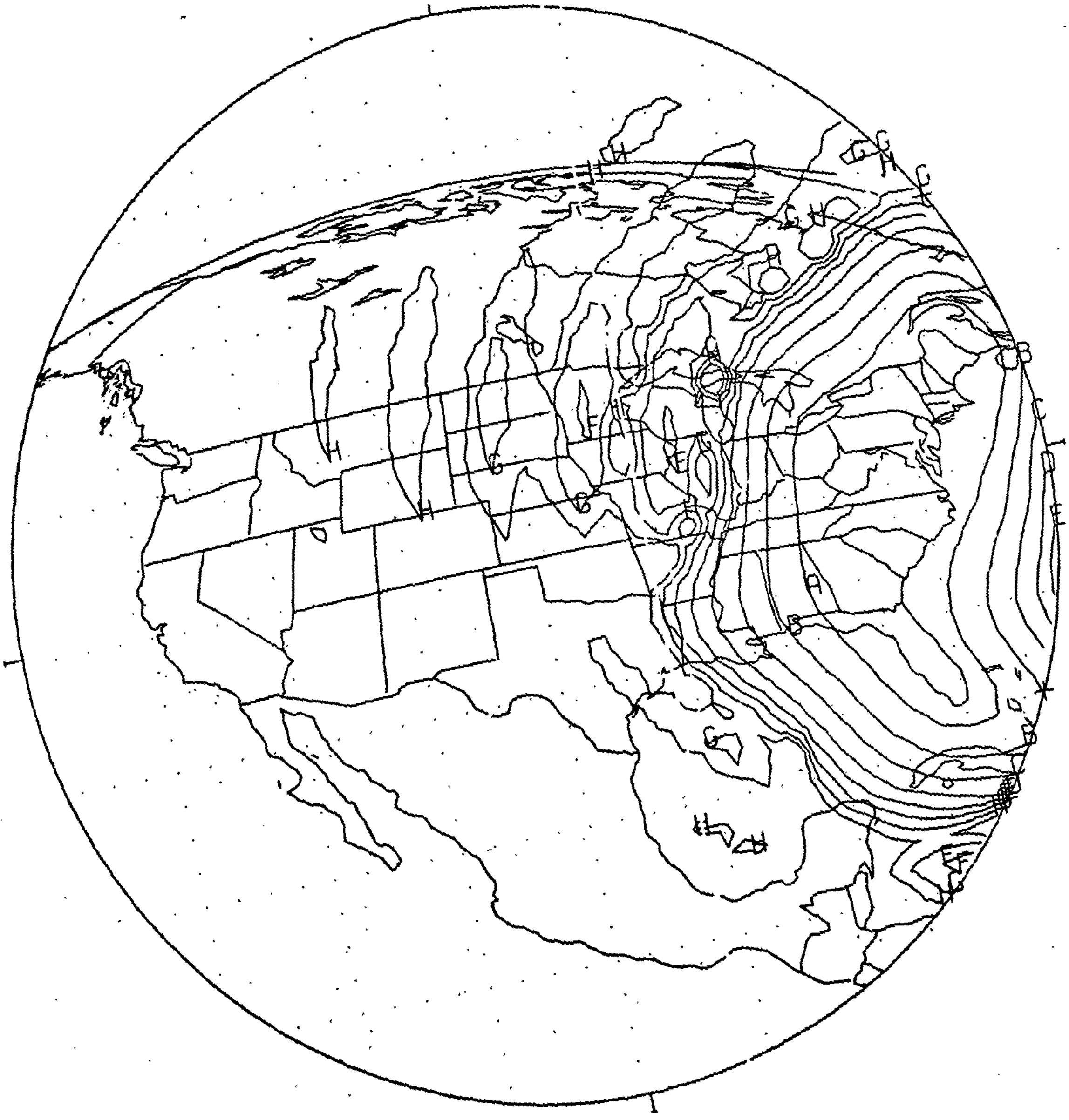
Figure 5.2.5-4 Ku-Band FSS CONUS Antenna Pattern



CONTOUR DATA

SYMBOL	LEVEL
A	-3.000(29 DBI)
B	-6.000
C	-10.000
D	-15.000
E	-20.000
F	-25.000
G	-30.000
H	-35.000

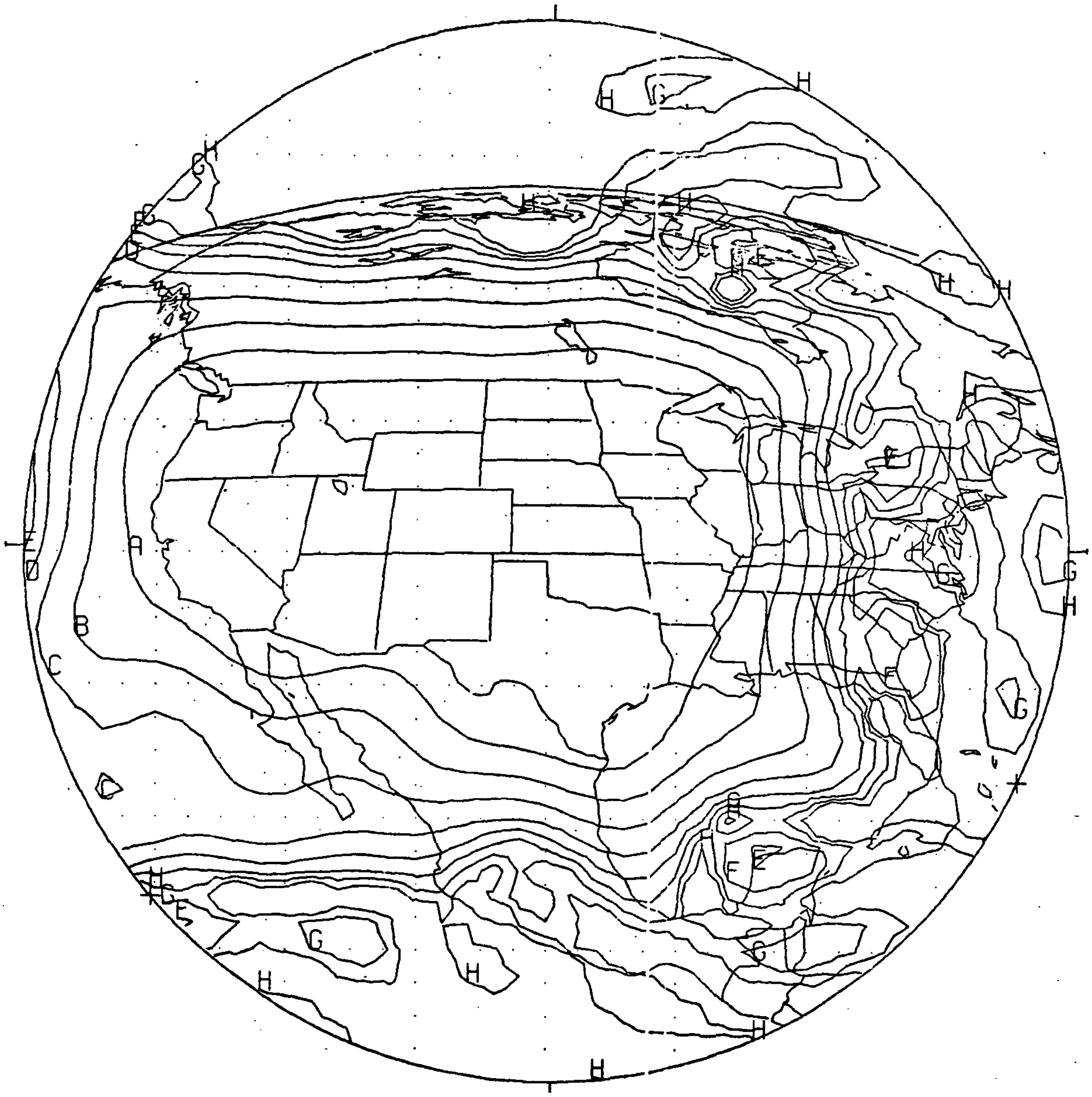
Figure 5.2.5-5 Ku-Band FSS Eastern Antenna Pattern



CONTOUR DATA

SYMBOL	LEVEL
A	-3.000 (35.2 dBi.)
B	-6.000
C	-10.000
D	-15.000
E	-20.000
F	-25.000
G	-30.000
H	-35.000

Figure 5.2.5-6 Ku-Band FSS Western Antenna Pattern



CONTOUR DATA

SYMBOL	LEVEL
A	-3.000 (29.7 dBi.)
B	-6.000
C	-10.000
D	-15.000
E	-20.000
F	-25.000
G	-30.000
H	-35.000

Table 5.2.5-3

Ku-Band FSS Predicted Antenna Gain

Coverage	Gain (dBi)
Full CONUS	29
East Half CONUS	35.2
West Half CONUS	29.7

Diurnal and seasonal solar variations can cause temperature extremes and gradients on the reflector surface, which in turn mechanically distort the reflector and degrade the electrical performance. Advanced Kevlar fiber composite materials are used for the structural elements of the reflector assembly to provide maximum thermal stability and structural strength with minimum weight. Each reflector is a Kevlar/epoxy laminate sandwich thin shell bonded to a backside on ring reinforced structure. The sandwich shell supports the gridded system of wire. The largest existing dual gridded reflector that has even been built is 6 ft. The proposed size, 13 ft of reflector aperture, thus presents a challenging mechanical and electrical design problem in order to provide the required mechanical stiffness and strength in the present state-of-art technology.

A shared feed approach is proposed in the feed array of the multiple-beam antenna system. Conventionally, the shaped beam for east CONUS coverage is formed by a feed array of group 1; for the west half CONUS coverage, a feed array of group 2. Group 1 and group 2 do not have any feed in common. A shared feed system is one that has feed horns shared by the two groups. The number of available feeds for each coverage is increased. The sidelobe levels are lower because of better beam shaping. However, the losses of the beam forming network are higher. This kind of beam forming network tends to be frequency sensitive.

Table 5.2.5-4 summarizes the assessment of the critical technology items for this subsystem.

Table 5.2.5-4

Assessment of the Level of Risk of Critical Technology Items

Items	Low Risk	High Risk
Cross-pol isolation	30 dB	33 dB
Co-pol isolation	25 dB	27 dB
Feed array (Shared feed)	Needs development	Achievable
Reflector	Needs development	Achievable
Weight(Reflector)	18.6 kg	20% less

5.2.5.3 Ku-Band FSS Transponder

The Ku-Band Transponder Subsystem consists of three crosslinked 8 channel transponders, each of the 24 channels having a bandwidth of 54 MHz. The three 8 channel transponders each utilize the same 500 MHz FSS band, having an uplink at 14 GHz and downlink at 11 GHz. The transponder subsystem has three inputs, one each from the Eastern and Western beam-forming networks (horizontally polarized), and one from the CONUS beam forming network (vertically polarized). Each of the three 14 GHz inputs is filtered by an input preselector, then amplified and down converted to 11 GHz by the receiver. The receiver output is fed to an input multiplexer which subdivides the 500 MHz IF band into eight 54 MHz channels.

The three input multiplexers are followed by eight, 3x3 switch matrices. The latter permit signals in any uplink channel received via the Eastern region, Western region or CONUS beam forming networks (BFN) to be re-transmitted via the appropriate BFN to either the same region or to one of the other two regions.

Each of the 24 channels is individually amplified by a driver amplifier, which contains one or more variable gain amplifiers. The latter permit automatic accommodation of varying uplink levels using an AGC loop, and also up to 16 dB of power amp back off via ground control. For the Ku-Band fixed satellite service, 50 watt TWTAs are necessary to ensure sufficient EIRP. The outputs of the TWTAs in each set of eight channels are combined in an output multiplexer, and filtered by a harmonic/bandpass filter prior to transmission from the appropriate antenna.

The transponder subsystem features 6 for 3 redundancy for the receivers and 5 for 4 redundancy for the TWTAs.

5.2.5.3.1 14/11 GHz Receiver

Using low risk technology this receiver provides for low noise amplification at 14 GHz. It down converts 14 GHz to 11 GHz with a Schottky diode mixer. The mixer is followed by bandpass filtering and amplification at 11 GHz. The local oscillator is a temperature controlled crystal oscillator followed by a multiplier chain.

Electrical Performance

Noise Figure	3.5 dB
Gain	70 dB
Output power @ c/3IM=-40dBc	13 dBm
Frequency stability	+1/-2 ppm
DC power	9.0 watts

Mechanically the receiver contains four subassembly trays: a front end, a driver,a local oscillator and a DC/DC converter.

The trays are assembled in a vertical stack. RF signal connections between the front end, driver, and local oscillator trays are made with short loops of semi-rigid coaxial cable.

A selectable coaxial attenuator is included in the RF signal path at the input to the driver to allow for adjustment of the overall gain. Regulated DC voltages are supplied to the front end, driver and local oscillator trays through a DC harness running vertically along the side of the stack.

The microwave tray is an aluminum chassis that contains substrate assemblies that are bonded into the chassis and substrate/carrier assembles that are bolted in the chassis. The substrate assemblies consist of MIC isolators, filters and temperature compensation. The substrate/carrier assemblies are MIC amplifiers. The amplifiers are constructed using hermetically packaged semiconductors, chip resistors, and chip capacitors on this film alumina substrates. The bias circuits are constructed using thick film alumina substrates, hermetically packaged semiconductors, chip resistors and chip capacitors.

Mechanical Parameters

Mass	1.8 kg
Volume	175 cu in

Using high risk technology, the 14 GHz preamp will be updated with the latest low noise GaAs FET. This will improve noise figure from 3.5 dB to 2.5 dB. The mixer should be integrated with the bandpass filtering. This will enhance the mixer performance by improving gain flatness over temperature and reducing test time. The 4 GHz amplifiers should be replaced by monolithic gain blocks. These gain blocks are common to this receiver and many other applications. This would reduce test time and improve overall receiver performance. The crystal oscillator chain could be replaced by a dielectric resonator oscillator. The DRO will reduce complexity and cost. The current receiver uses an analog circuit to temperature compensate the receiver gain. Future receivers should use a digital system to improve gain stability. The preamp, mixer/filter, DRO, and digital temperature compensation require development that is geared toward space qualification. The 11 GHz gain block would be developed in the commerical market and could be space qualified. Power consumption will be reduced to 6.0 watts primarily by the use of the DRO.

The use of monolithic gain blocks and dielectric oscilators will reduce the size of the receiver. The number of subassemblies can be reduced from 4 to 3. These would be a DC/DC convertor, front end/local oscillator, and driver.

Mechanical Parameters

Mass	0.7 kg
Volume	50 cu in

5.2.5.3.2 11 GHz Input Multiplexers

Using low risk technology TE113 dual mode invar quasi-elliptic or self-equalized filters would be used for the 24, 36, and 54 MHz wide input filters. They would be coupled together using coaxial circulators. The 500 MHz filters would be realized using less exotic filters in order to reduce complexity, size and mass. Standard rectangular waveguide or coaxial cavities might be used depending on the specifications. Since the 500 MHz channels have significantly lower loss, dielectric resonators could possibly be used to reduce the weight and size even further.

Using high risk technology, it is anticipated that by 1994 dielectrics will be available that give excellent performance at 11 GHz. Today there are materials available that give Qs exceeding 10,000. Development efforts need to be spent in establishing mechanical mounting configurations that will not significantly degrade the filter losses and still hold the resonator rigidly in place. Use of these filter will reduce the mass and size of the input multiplexers by a factor of three.

The impact on satellite size can be very significant if there are a large number of these filters required per system.

The development plans for 4 GHz dielectric resonator input multiplexers and their integration with monolithic circuits applies equally well to the 11 GHz designs. The problem at 11 GHz is more difficult and should be studied concurrently with the 4 GHz problem in an effort to ready this technology for applications in 1994.

In addition, methods of mounting dielectric resonators without degrading electrical performance are even more critical at 11 GHz than 4 GHz. Several approaches must be conceived and evaluated in order to have successful implementation available for 1994. The potential improvement is at last a times three reduction in size and mass.

5.2.5.3.3 RF Switch Matrix

See Section 5.2.3.3.3.

5.2.5.3.4 12 GHz Driver

Using low risk technology, the 12 GHz driver amplifier would use dual-gate FETs to provide variable gain amplification. The voltage applied to the second gate establishes the gain. Chip FET devices are used to eliminate package parasitics which at this frequency would degrade the performance and make it difficult to achieve the desired gain flatness over a range of gain settings. As a result of using unpackaged devices, the amplifier module must be hermetically sealed. The RF circuitry is etched in thin film metalization on alumina substrates which are bonded to moly or Kovar carriers. The amplifier module is integrated in the housing with drop-in microstrip isolators to assure good input and output VSWR's.

Using high risk technology, rapid advances in gallium arsenide technology and monolithic microwave integrated circuits should make it possible to realize several stages of low level, voltage-controllable gain on a single chip, leading to a significant reduction in size and weight. It is expected that achieving the required performance in a monolithic form will require significant development risk and cost.

5.2.5.3.5 11 GHz - 50 Watt TWTA

The TWTA technology for this application is reasonably mature. Current TWT's achieve efficiencies on the order of 45 to 50% and power supply efficiencies in the 88-90% range are common place. Higher TWT efficiencies will be realizied with helix velocity tapers and collector optimization. There is also a trend toward using linearizers with the TWTA package, which will provide additional improvement in TWT efficiency and phase shift. This will yield TWT's with approximately 50% efficiency. The above changes are evolutionary and low risk. High risk improvements could lead to efficiencies in the 65% range for the TWT utilizing advanced carbon cathodes, coated dispenser cathodes or mixed metal cathodes. This would also yield lifetimes greater than 10 years. To achieve the high efficiency, use of diamond rods to replace the BeO rods would be required. The processing of these TWT's requires development.

Power supplies on the other hand are not likely to improve much because the magnetics currently limit the size and weight. Evolutionary change to supplies with higher switching rates will yield converter efficiencies in the 92-93% range.

5.2.5.3.6 11 GHz Output Multiplexers

Using low-risk technology, the 11 GHz output multiplexers will consist of manifold coupled TE 113 cylindrical cavity quasi-elliptic filters using two orthogonal modes per cavity for two resonators. The filters will be constructed of invar for temperature stability using the mechanical design approach developed on the Intelsat V IBS program for the 10 and 20 watts units.

The 50 and 100 watt units will also be invar, but they will use the TE114 cylindrical mode in order to reduce the heat dissipated and the electronic loss, Adequate heat sinking will be provided to maintain operating temperatures below 100 degrees C. The basic techniques have been developed on internal development programs for high power direct broadcast applications.

Using high risk technology, dielectric resonators should be available for use at 11 GHz in applications of 10 and possibly 20 watts. The construction techniques will be similar to that used in 4 GHz output filters, with dual mode resonators inside aluminum housings. This work could result in a mass and size 1/3 that available today.

At power levels of 50 to 200 watts, standard waveguide filters will still have to be used in 1994. If the heat level and associated temperature can be accurately controlled, it may be possible to use lighter materials than invar to minimize frequency shift with temperature. Improvements in heat sinking through heat pipes and other means should reduce the mass by as much as 25%.

Techniques for minimizing temperature variations in these high power multiplexers should be studied over the next two years in order to establish the basic approaches that must be developed for application in 1994.

5.2.5.3.7 Pre-Select and Harmonic Filters

See 5.2.2.3.5.

5.2.6 Ku-Band DBS Payload

5.2.6.1 Overview of Ku-Band DBS Payload

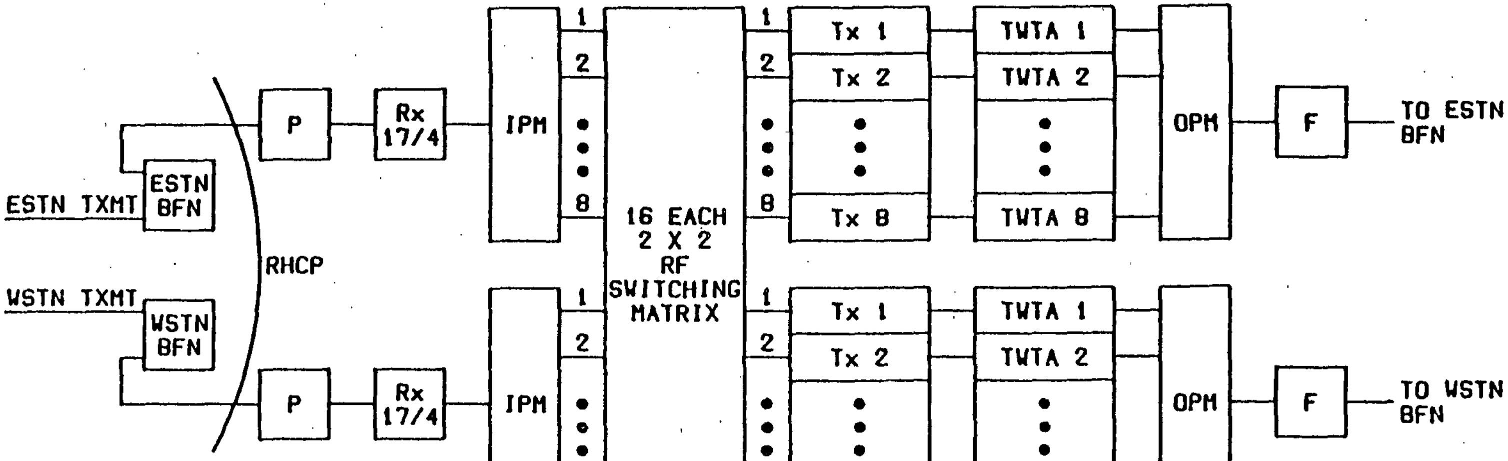
This payload is a medium power, 100 watt, Ku-band DBS payload similar to some recent filings with the FCC, The described payload could be a replacement for one of those payloads. It utilizes an uplink at 17 GHz and a downlink at 12 GHz. It has eight 24 MHz channels for each of the eastern and western beam coverage areas. It provides overlapping coverage since the eight channels in each beam are separated by frequency. The simplified block diagram is shown in Figure 5.2.6-1. TWTA's are used at the 100 watt level. However, an alternate approach using distributed lower power, solid state amplifiers, in the beam forming network would lead to improved reliability and eliminate the wear out mechanisms inherent in TWTA's.

Table 5.2.6-1 shows the estimated weight, power, and volume for low risk (emerging) technology and high risk (projected) technology for the transponder and antenna. Also included in the estimates are the coax, waveguide, and harness interconnects, plus an estimate for integration hardware to put the components together and provide necessary brackets for support and mounting. Not included are any structure or satellite mounting hardware, such as between the feed and reflector.

5.2.6.2 Ku-Band DBS Antenna Subsystem

The Ku-band DBS antenna subsystem provides transmission at 12 GHz and reception at 17 GHz of dually circular-polarized communication signals. The purpose of the communication antenna is to provide direct coverage to one of the two areas of CONUS as shown in Figure 5.2.6-2. Table 5.2.6-2 summarizes the antenna subsystem requirements.

Figure 5.2.6-1 Scenario II - Ku (DBS)



P: PRESELECT FILTER
BFN: BEAM FORMING NETWORK
IPM: INPUT MULTIPLEXER
OPM: OUTPUT MULTIPLEXER
F: HARMONIC FILTER
Rx: RECEIVER
Tx: TRANSMITTER

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Table 5.2.6-1

Scenario II - Payload Summary

Ku-Band DBS

	ITEM	P/L QTY REQ'D	REQ. QTY REQ'D	LOW RISK TECHNOLOGY						HIGH RISK TECHNOLOGY						COMMENTS
				UNIT			PAYLOAD			UNIT			PAYLOAD			
				WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	
1	17/4 GHz RECIEVER	2	4	1.8	9.0	175	7.2	18.0	700	0.9	6.0	50	3.6	12	200	
2	INPUT MULTIPLEXER, 8 CHANNEL, 24 MHz	2	2	3.6	-	1536	7.2		3072	2.4	-	1024	4.8	-	2048	
3	BEAM SWITCHING MATRIX, 2x2	8	8	0.2	-	12	1.6		96	0.2	-	12	1.6	-	96	
4	5/4 REDUNDANCY SWITCH MATRIX(RING) COAX	4	4	1.4	-	160	5.6		640	0.7	-	25	2.8	-	100	
5	DRIVER AMPLIFIER VARIABLE GAIN /RECEIVER	16	20	1.4	7.0	140	28	112	2800	0.7	4	45	14	64	900	
6	DBS TWTA, 100 W	16	20	6.0	250	300	120.0	4000	6000	5.2	215	250	104	3440	5000	
7	5/4 REDUNDANCY SWITCH MATRIX (RING) W/G	4	4	2.0	-	200	8.0		800	1.6	-	180	6.4	-	720	
8	OUTPUT MULTIPLEXER, 8 CHANNEL, 12 GHz	2	2	6.0	-	1024	12.0		2048	4.5	-	768	9.0	-	1536	
9	HARMONIC FILTER	16	16	0.1	-	13.5	1.6		216	0.1	-	13.5	1.6	-	216	
10	PRESELECT FILTER	2	2	0.1	-	11.2	0.2		22.4	0.1	-	11.2	0.2	-	22.4	
11	SPDT SWITCH W/G, 17 GHz	2	2	0.15	-	16	0.30		32.0	0.15	-	16	0.3	-	32	
12	TRANSFER SWITCH W/G 17 GHz	1	1	0.18	-	16	0.18		16	0.18	-	16	0.18	-	16	
13	TRANSFER SWITCH, COAX 12 GHz	1	1	0.14	-	12	0.14		12	0.14	-	12	0.14	-	12	
14	SPDT SWITCH, COAX, 12 GHz	2	2	0.08	-	6	0.16		12	0.08	-	6	0.16	-	12	
15	COAX, SET	1	1	3.0	-	-	3.0		-	3.0	-	-	3.0	-	-	
16	WAVEGUIDE, SET	1	1	8.0	-	-	8.0		-	8.0	-	-	8.0	-	-	
17	HARNESS	1	1	7.0	-	-	7.0		-	7.0	-	-	7.0	-	-	
18	COMM CONTROL & INTERFACE	1	2	1.5	10	250	3.0	10	500	1.2	8.0	190	2.4	8	380	
19	INTEGRATION HARDWARE	1	1	5%	-	-	10.7	-	-	5%	-	-	8.5	-		
20	MARGIN REQ'D	-	-	10%	10%	5%	22.4	414	848	10%	10%	5%	17.8	352	565	
21																
22	TOTAL TRANSPONDER						246.3	4554	17,815				195.5	3876	11,855	
23																
24	ANTENNA REFLECTORS	1 set	1 set	20	-	-	20	-	-	16	-	-	16	-	-	
25	ANTENNA FEEDS	1 set	1 set	10	-	4972	10	-	4972	8.5	-	4500	8.5	-	4500	
26	MARGIN REQ'D.			10%		10%	1.5	-	498	10%	-	10%	2.5	-	450	
27																
28	TOTAL ANTENNA						31.5	-	5470				27.0	-	4950	
29																
30	TOTAL PAYLOAD						277.8	4554	23285				222.5	3876	16805	

1 FOLDOUT FRAME

2 FOLDOUT FRAME

Figure 5.2.6-2 Ku-Band DBS Coverage Requirement

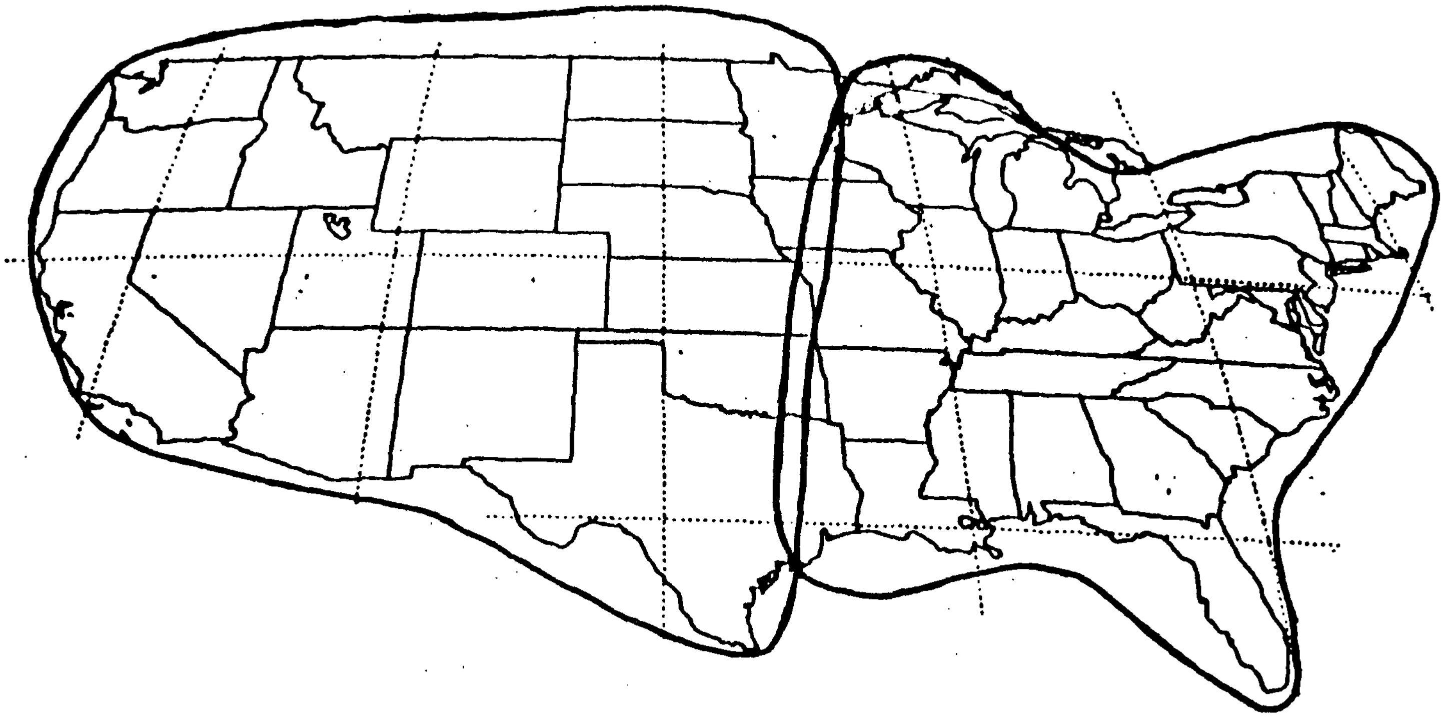


Table 5.2.6-2

Ku-Band DBS Antenna Subsystem Requirements

Parameter	Requirements
Frequency	Transmit: 12 GHz band Receive: 17 GHz band
Polarization	Dual circular polarization
Coverage Area	East/West Half CONUS
Isolation	27 dB

The antenna will consist of two solid, offset parabolic reflectors, one 2.5 meter for transmit and one 1.9 meter for receive, as depicted in Figure 5.2.6-3. Each reflector will be illuminated by an array of 55 individual feed horns which are excited from two input ports through a feed network consisting of a series of cascaded hybrid power dividers. A polarizer is employed at each horn to produce circular polarization. Figures 5.2.6-4 and 5.2.6-5 present the antenna radiation patterns. Table 5.2.6-3 shows the predicted antenna gain of the system.

Table 5.2.6-3

Ku-Band DBS Predicted Antenna Gain

Coverage	Gain (dBi)
East Half CONUS	31.4
West Half CONUS	29.8

All technologies required in this system are well developed. The level of risk of the technology is low. The estimated weight of the two reflectors is 20 kg. The reflector design is a graphite epoxy laminate sandwich shell bonded to a backside

Figure 5.2.6-3 Ku-Band DBS - Scenario II

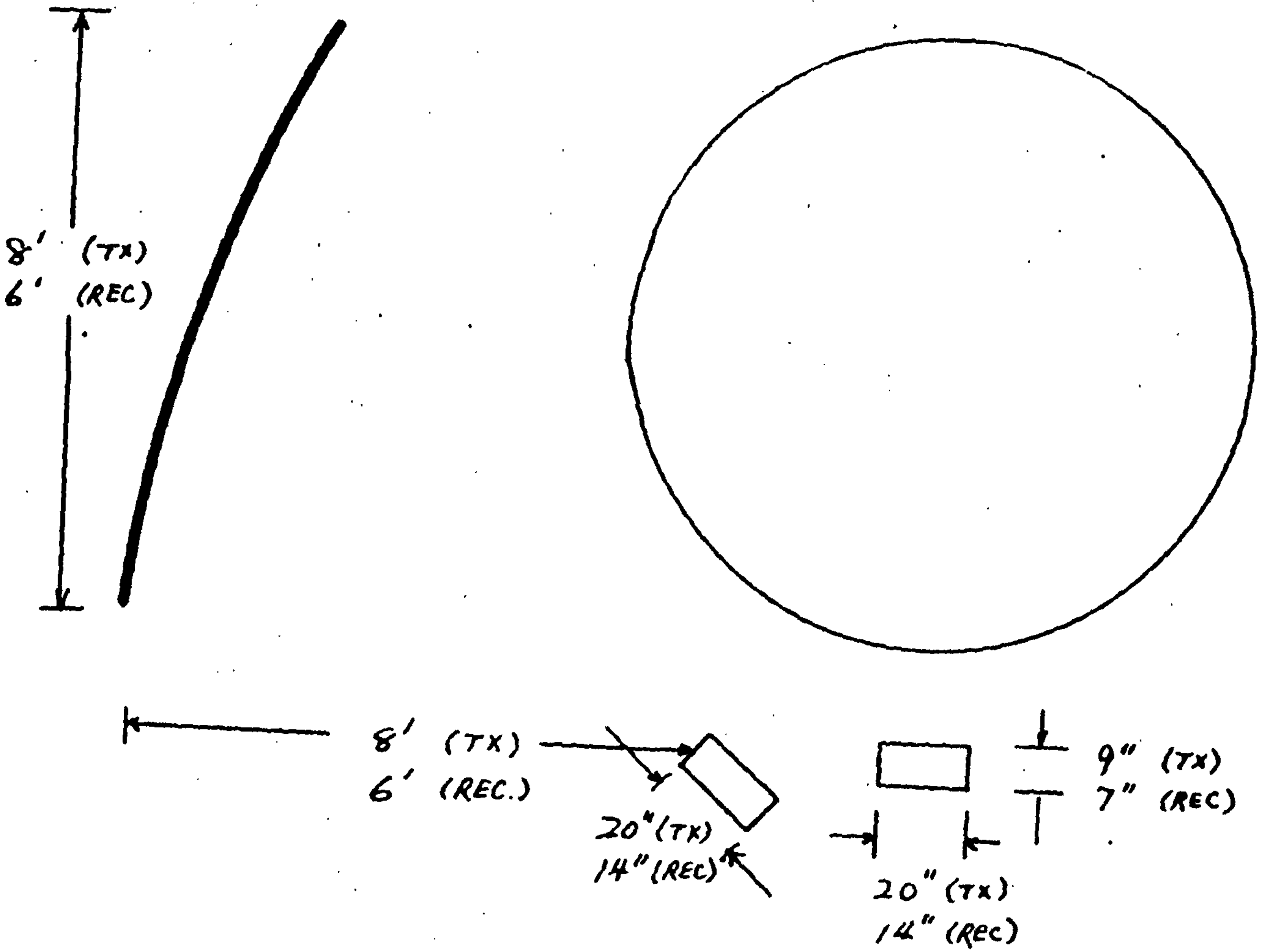
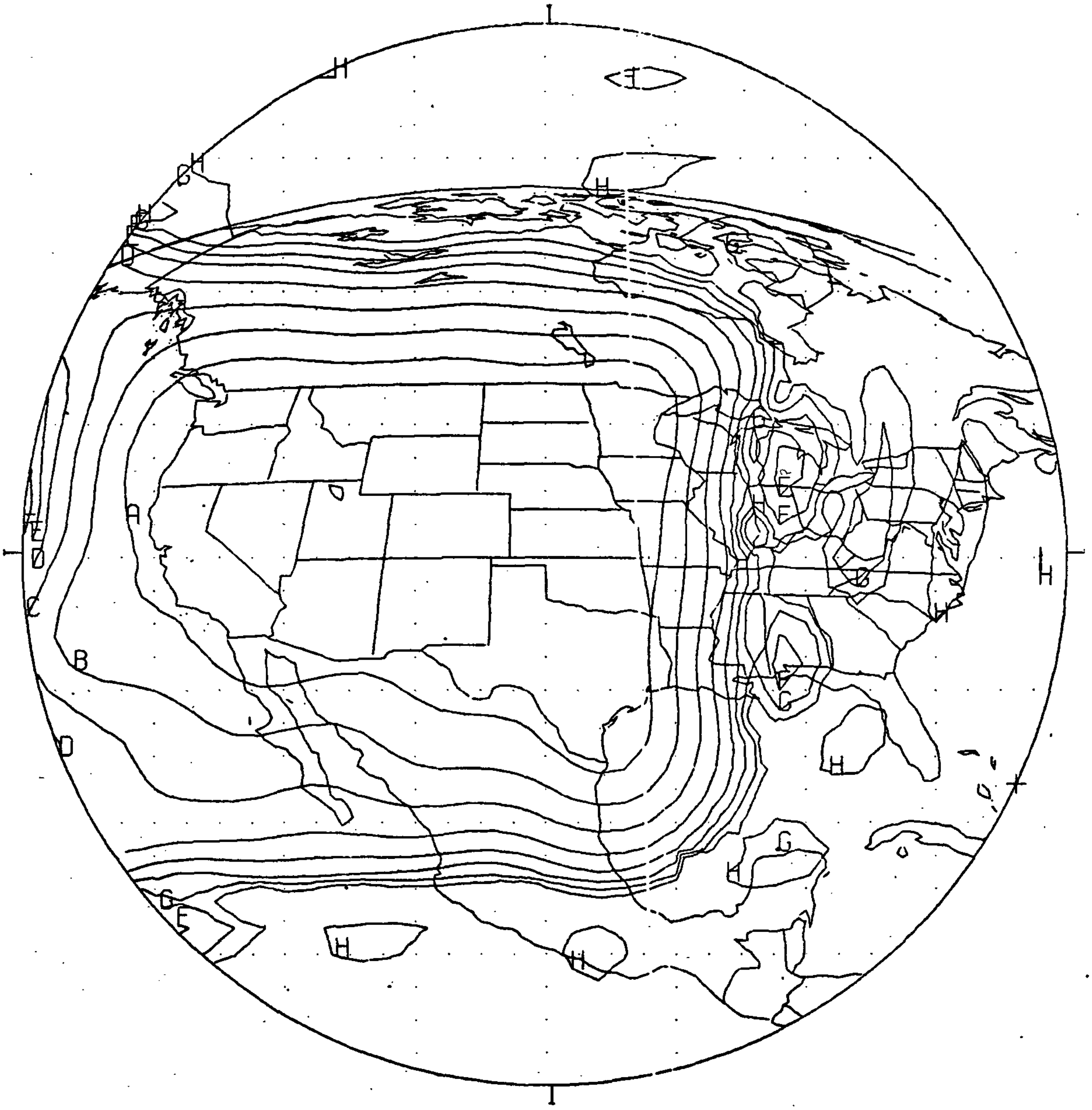


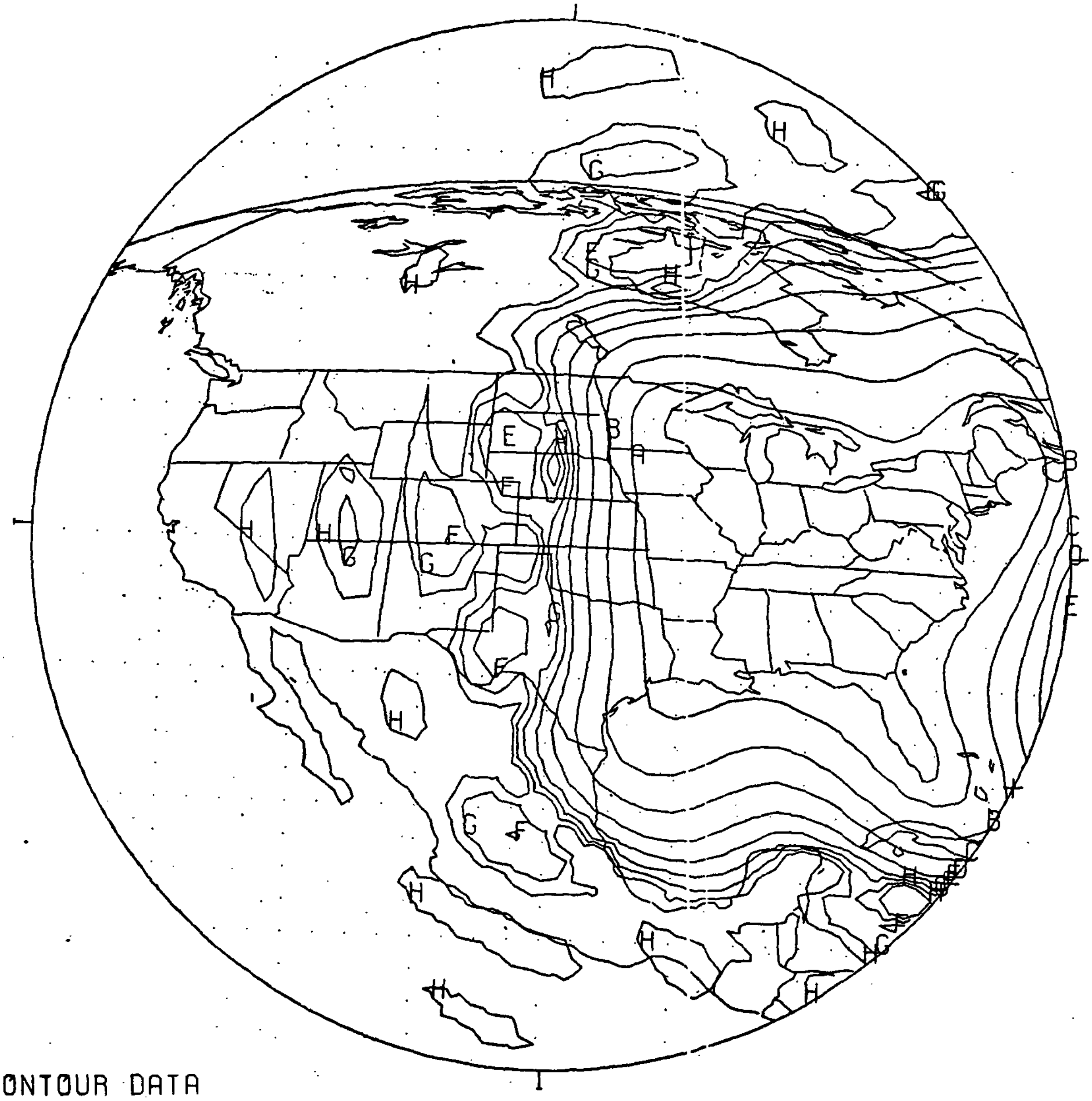
Figure 5.2.6-4 Ku-Band DBS Western Antenna Pattern



CONTOUR DATA

SYMBOL	LEVEL
A	-3.000 (29.8 dBi.)
B	-6.000
C	-10.000
D	-15.000
E	-20.000
F	-25.000
G	-30.000
H	-35.000

Figure 5.2.6-5 Ku-Band DBS Eastern Antenna Pattern



CONTOUR DATA

SYMBOL	LEVEL
A	-3.000 (31.4 dBi.)
B	-6.000
C	-10.000
D	-15.000
E	-20.000
F	-25.000
G	-30.000
H	-35.000

reinforcing rib structure. The weight could be reduced about 20% by 1994 due to the current development of a more advanced graphite material for the reflector surface.

5.2.6.3 Ku-Band Transponder Subsystem, Direct Broadcast Service

The DBS Transponder Subsystem consists of two crosslinked 8 channel transponders, each of the 16 channels having a bandwidth of 24 MHz. The two 8 channel transponders utilize the same 500 MHz FSS band, having an uplink at 17 GHz and downlink at 12 GHz, but occupy alternate channel slots. The two transponders receive their inputs from the eastern and western coverage beam forming networks of the RHCP antenna feed assemblies. Each of the two 17 GHz inputs are filtered by an input preselector, then amplified and downconverted to 4 GHz by the receiver. The receiver output is fed to an input multiplexer which subdivides the 500 MHz IF band into eight 24 MHz channels. Since one of the receiver local oscillators is offset by one channel spacing from the other, the IF channel frequencies are the same for both transponders. The three input multiplexer are followed by eight transfer switches. The latter permit any uplink channel received via either the eastern region or western region beam forming network (BFN) to be re-transmitted via the appropriate BFN to the same region or to the other region.

Each of the 16 channels is individually upconverted to 12 GHz and then amplified by a driver amplifier which contains one or more variable gain amplifiers. The latter permit automatic accommodation of varying uplink levels, using an AGC loop, and also up to 16 dB of power amp back-off via ground control. For the Ku-Band direct broadcast service, 100 watt TWTAs are necessary to ensure sufficient EIRP. The outputs of the TWTAs in each set of eight channels are combined in an output multiplexer, then filtered by a harmonic/band pass filter prior to transmission from the transmit antenna via the appropriate BFN.

The transponder subsystem features 2 for 1 redundancy for the receivers and 5 for 4 redundancy for the TWTAs.

5.2.6.3.1 17/4 GHz Receiver

Using low risk technology this receiver provides for low noise amplification at 17 GHz. It down converts 17 GHz to 4 GHz with a Schottky diode mixer. The mixer is followed by bandpass filtering and amplification at 4 GHz. The local oscillator is a temperature controlled crystal oscillator followed by a multiplier chain.

Electrical Performance

Noise figure	4.0 dB
Gain	70 dB
Output power @ c/3 IM = -40 dBc	+13 dBm
Frequency stability	+1/-2 ppm
DC power 9.0 watts	

Mechanicaly the receiver contains four subassembly trays: a front end, a driver, a local oscillator, and a DC/DC converter.

The trays are assembled in a vertical stack. RF signal connections between the front end, driver and local oscillator trays are made with short loops of semirigid coaxial cable. A selectable coaxial attenuator is included in the RF signal path at the input to the driver to allow for adjustment of the overall gain. Regulated DC voltages are supplied to the front end, driver and local oscillator trays through a DC harness running vertically along the side of the stack.

The microwave tray is an aluminum chassis that contains substrate assemblies that are bonded into the chassis and substrate/carrier assemblies that are bolted in the chassis. The substrate assemblies consist of MIC isolators, filters and temperature compensation. The substrate/carrier assemblies are MIC amplifiers. These amplifiers are constructed using hermetically packaged semiconductors, chip resistors, and chip capacitors on thin film alumina substrates. The bias circuits are constructed using thick film alumina substrates, hermetically packaged semiconductors, chip resistors and chip capacitors.

Mechanical Parameters

Mass	1.8 kg
Volume	175 cu in

Using high risk technology the 17 GHz preamp will be updated with the latest low noise GaAs FET. This will impove the noise figure from 4.0 dB to 2.5 dB. The mixer should be integrated with the bandpasss filtering. This will enhance the mixer performance by improving gain flatness over temperature and reducing test time. The 4 GHz amplifiers should be replaced by monolithic gain blocks. These gain blocks are common to this receiver and many other applications. This would reduce test time and improve overall receiver performance. The crystal oscillator chain could be replaced by a dielectric resonator oscillator. The DRO will reduce complexity and cost. The current receiver uses an analog circuit to temperature compensate the receiver gain. Future receivers should use a digital system to improve gain stability. The preamp, mixer/filter, DRO, and digital temperature compensation require development that is geared toward space qualification. The 4 GHz gain block would be developed in the commerical market and could be space qualified. Power consumption will be reduced to 6.0 watts primarily by the use of the DRO.

The use of monolithic gain blocks and dielectric oscillators will reduce the size of the receiver. The number of sub-assemblies can be reduce 4 to 3. These would be a DC/dc converter, front end/local oscillator, and driver.

Mechanical Parameters

Mass	0.9 kg
Volume	50 cu in

5.2.6.3.2 4 GHz Input Multiplexer

See 5.2.2.3.2.

5.2.6.3.3 R.F. Switch Matrix

See 5.2.3.3.3.

5.2.6.3.4 4 GHz/11, 12 GHz Upconverter

Using low risk technology, this upconverter provides for amplification at 4 GHz. It up converts 4 GHz to 11 or 12 GHz with a Schottky diode mixer. The mixer is followed by bandpass filtering. The local oscillator is a temperature controlled crystal oscillator followed by a multiplier chain. The 4 GHz amplification is done with dual gate FET's that also provide variable or stepped gain control.

Electrical Performance

Gain	15 dB
Output power @ c/3IM = -40dBc	-10 dBm
Frequency stability	+1/-2 ppm
DC power	7.0 watts

Mechanicaly the upconverter contains three subassembly trays: a front end, a local oscillator and a DC/DC converter.

The trays are assembled in a vertical stack. RF signal connections between the front end, and local oscillator trays are made with a short loop of coax cable. Regulated DC voltages are supplied to the front end, and local oscillator trays through a DC harness running vertically along the side of the stack.

The microwave tray is an aluminum chassis that contains: substrate assemblies that are bonded into the chassis and substrate/carrier assemblies that are bolted in the chassis. The substrate assemblies consist of MIC isolators, filters and temperature compensation. The substrate/carrier assemblies are MIC amplifiers. These amplifiers are constructed using hermetically packaged semiconductors, chip resistors, and chip capacitors on thin film alumina substrates. The bias circuits are constructed using thick film alumina substrates, hermeticaly packaged semiconductors, chip resistors and chip capacitors.

Mechanical Parameters

Mass	1.4 kg
Volume	140 cu in

Using high risk technology, the 4 GHz amplifier will be updated with the latest dual gate GaAs FET. The mixer should be integrated with bandpass filtering. This will enhance the mixer performance by improving gain flatness over temperature and reducing test time. The crystal oscillator will be replaced by a dielectric resonator oscillator. The DRO will reduce complexity and cost. The current upconverter uses an analog circuit to temperature compensate upconverter gain. Future upconverters should incorporate a digital system to improve gain stability. The amplifier, DRO, and digital temperature compensation require development that is geared toward space qualification. The power consumption will be reduced to 4.0 watts, primarily by the use of the DRO.

The use of the dielectric oscillators will reduce the size of the upconverter. The number of subassemblies can be reduce from

3 to 2. These would be a DC/DC converter and front end/local oscillator.

Mechanical Parameters

Mass	0.4 kg
Volume	45 cu in

5.2.6.3.5 12 GHz - 100/200 Watt TWTA

The TWTA technology for this application is reasonably mature. Current TWT's achieve efficiencies on the order of 45 to 50%, and power supplies in the 88-90% range are commonplace. Higher TWT efficiencies will be realizied with helix velocity tapers and collector optimization. There is also a trend toward using linearizers with the TWTA package, which will provide additional improvement is TWT efficiency and phase shift. This will yield TWT's with 50-55% efficiency. The above changes are evolutionary and low risk. High risk improvements could lead to efficiencies in the 65% range for the TWT utilizing advanced carbon cathodes, coated dispenser cathodes, or mixed metal cathodes. To achieve the high efficiency, use of diamond rods instead of the BeO rods would be required.

Power supplies on the other hand are not likely to improve much as the magnetics currently limit the size and weight. Evolutionary change to supplies with higher switching rates will yield converter efficiencies in the 92-93% range. However, for these high power TWTAs in large quantities on the satellite, (i.e., spacecraft of 15 - 40 kW), an AC coupled main power distribution system could yield EPC efficiencies on the order of 95-96% by elimination of the chopper. This would yield a higher overall efficiency for the spacecraft also, but would require development of the AC distribution system for the bus.

5.2.6.3.6 12 GHz Output Multiplexer

See 5.2.5.3.6.

5.2.6.3.7 Pre-Select and Harmonic Filters

See 5.2.2.3.5.

5.3 SCENARIO IV DEFINITION

5.3.1 Introduction

Scenario IV can be described as a high capacity, high power video distribution satellite containing a replacement for a current version Ku-Band FSS payload, and a new direct to home Ku-Band DBS payload. Each payload is broken down to 24 MHz bandwidth channels to allow interconnectivity between bands for on-board networking. The services provided are listed below:

- 48 Channels, medium power, Ku-band. FSS payload
  - 3 beams - 1 CONUS & 2 regional CONUS
  - 16 channels per beam
  - 3 x re-use.

- 64 channels, high power, Ku-band, DBS payload
  - 4 beam - time zone
  - 16 channels per beam
  - 4 x re-use

- Interconnectivity for half the channels from FSS to DBS

The on-board interconnectivity for half of the channels provides the networking necessary for a broadcast mode, one uplink to all downlinks, or one uplink to each downlink. This flexibility eliminates the ground cut ins and outs and also allows ground uplink sources to have only one antenna for both cable and direct to home distribution on only one satellite.

An overview block diagram of the payload elements is shown in Figure 5.3.1-1. Table 5.3.1-1 lists the major scenario bus interface requirements and Table 5.3.1-2 and 5.3.1-3 present the major antenna and transponder characterictics respectively. The antennas will be rigidly mounted to the body and body steered via the bus control system.

Figure 5.3.1-1 Scenario IV Overview

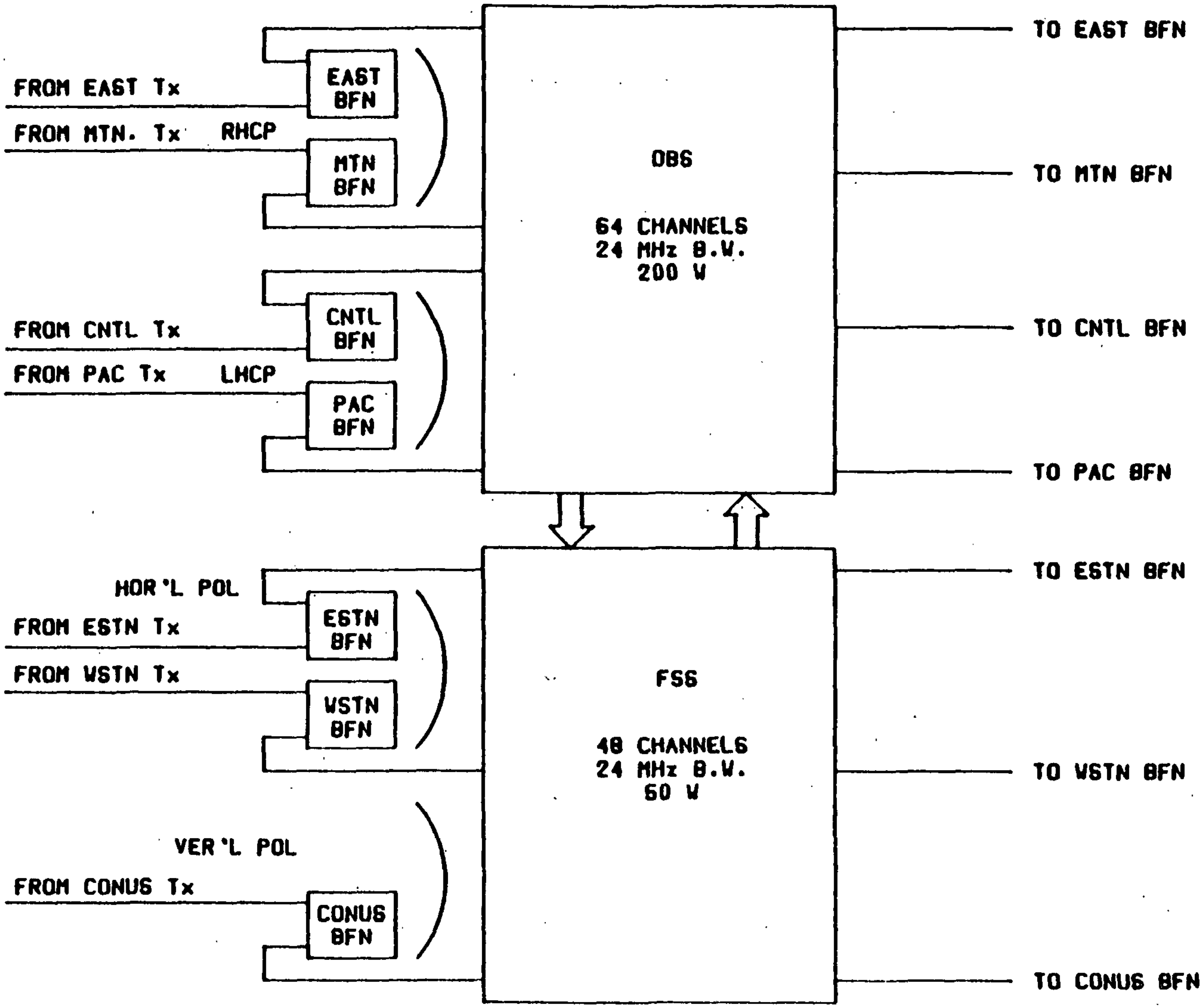


Table 5.3.1-1

Scenario IV - Payload Summary

o Mass	1616 kg
o Power Required	
Sunlight	35,035 watts
Eclipse	50% min; 75% desired
o Pointing Requirement	± 0.05° absolute (ie: RF boresight)
o Temperature Requirements	
Antenna	-90° to +110°C
Transponder	-10°C to +59°C, TWTA's +60°C
o Thermal Dissipation	1.5 kW in EPC's, 8 kW in TWT's & 4 kW in feeds & w/g losses
o Life Time	10 year without servicing

Table 5.3.1-2

Scenario IV Antenna Configuration

Antenna System	Freq (GHz)	Reflector	Polarization	Feed Arrays
Ku-Band DBS	17/12	one 8' (2.44m) solid reflector/ one 6' (1.8) solid reflector	CP	2x55 feeds plus 2x55 polarizers
Ku-Band FSS	14/11	13'(4m) dual gridded reflector	Linear	2x334 feeds.

Table 5.3.1-3

Transponder Summary Scenario IV

Payload	U/L,D/L Frez. GHz	Number Channels	Channel BW, R/F	RCVR Type (Number)	HPA Type Number	HPA Power,
Ku Band DBS	17/12	64	24	17/4	TWTA(80)	200
Ku Band FSS	14/11	48	24	14/4	TWTA(60)	50

Due to the use of TWTA's for the Ku-band FSS and DBS payloads, a 10 year life is all that can be envisioned at this time. Replacement of TWTA's at GEO or return of the payload from GEO for servicing and replacement of TWTA's is not anticipated for the early 2000 time period. It is estimated that the identified redundancy is compatable with a 10 year life application.

If lower risk technology is utilized, it is possible that fuel servicing at GEO or perigee augmentation at LEO could be utilized to maintain the Launch Concept 1 status of the payload.

Table 5.3.1-4 presents a summary of the high and low risk weight and power for the individual payload elements in Scenario IV.

In Appendix H, Tables 1 thru 4 show that all of the payload elements have viable links with the various types of anticipated modulation and access types. While some of the margins are low, the links represent the worst case condition, and if this scenario were to be studied further for full system definition, it is expected that the link margin could be improved for actual implementation.

Table 5.3.1-4

Scenario IV - Weight and Power

	WEIGHT(KG)		POWER(W)	
	Low Risk	High Risk	Low Risk	High Risk
Ku-Band FSS				
Transponder	624.3	496	7052	5075
Antenna	126.5	108.5	-	-
Sub Total	750.8	604.5	7052	5075
Ku-Band DBS				
Transponder	1194	984	34060	29960
Antenna	33	27.5	-	-
Sub Total	1227	1011.5	34060	29960
SCENARIO IV TOTAL	1977.8	1616	41112	35035

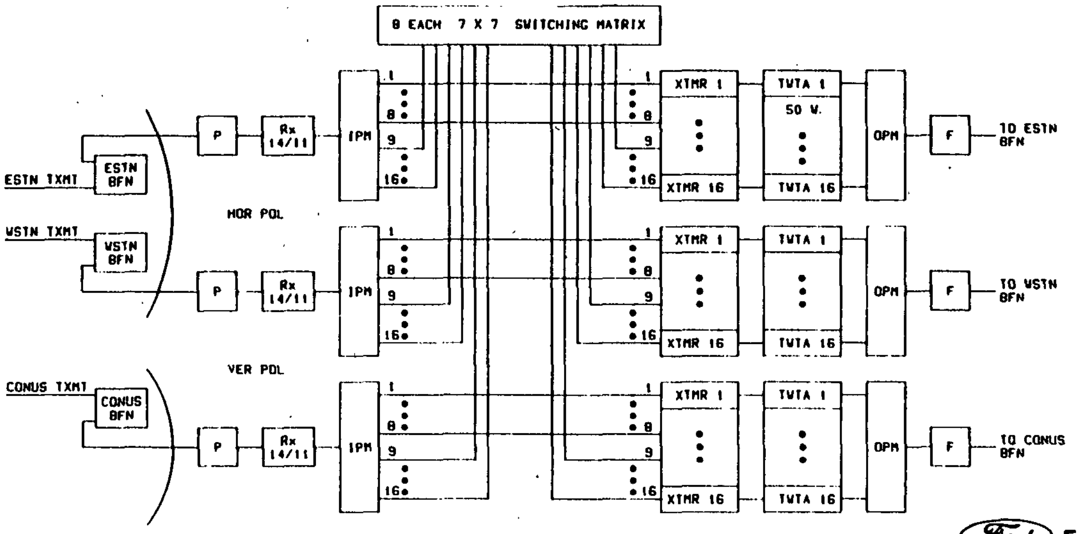
5.3.2 Ku-Band FSS Payload

5.3.2.1 Overview of Ku-Band FSS Payload

The payload, while similar to the FSS payload described in 5.2.5 is different in that it uses 24 MHz bandwidth channels rather than 54 or 36 MHz channels. This is to tailor this payload to the video distribution characteristics and be switchable to the DBS band for on-board networking. This payload still has a 3 times re-use with respect to CONUS coverage, with one full CONUS beam, and two regional, eastern and western coverage area, beams.

The payload features a dual gridded reflector to obtain the polarization purity required for re-use. The reflector assembly is stacked with a slight offset in focal point for physical separation of the feed assemblies. The transponder is straight forward design and no on-board processing is provided. The block diagram shown in Figure 5.3.2-1 indicates TWTA's for the output amplifiers. An alternate approach using multiple lower power solid state amplifiers in the beam forming network can be foreseen in the late 1990's time frame. This would lead to improved reliability and eliminate the wear out mechanisms inherent in TWTA's. Table 5.3.2-1 shows the estimated weight, power and volume for low risk (emerging) technology and high risk (projected) technology for the transponder and antenna. Also included in the estimate, are the coax, waveguide, and harness interconnects, plus an estimate for integration hardware to put the components together and provide necessary brackets for support and mounting. This does not include any structure or satellite mounting hardware, such as between the feeds and the reflectors.

Figure 5.3.2-1 Scenario IV - Ku-Band FSS



P: PRESELECT FILTER
BFN: BEAM FORMING NETWORK
IPM: INPUT MULTIPLEXER
OPM: OUTPUT MULTIPLEXER
F: HARMONIC FILTER
Rx: RECEIVER

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Table 5.3.2-1

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Scenario IV - Payload Summary

Ku-Band FSS

	ITEM	P/L QTY REQ'D	REQ. QTY REQ'D	LOW RISK TECHNOLOGY						HIGH RISK TECHNOLOGY						COMMENTS
				UNIT			PAYLOAD			UNIT			PAYLOAD			
				WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	
1	14/ 4 GHz RECEIVER	3	6	1.8	8	175	10.8	24	1050	0.9	6.0	50	5.4	18	300	
2	INPUT MULTIPLEXER,16 CHANNEL, 24 MHz	3	3	5.6	- -	1152	16.8		3456	4.5	-	576	13.5	-	1728	
3	BEAM SWITCH MATRIX, 7x7& BRDCST MX	8	8	1.0	4.9	70	8	39.2	560	0.4	3.3	45	3.2	26.4	360	
4	5/4 REDUNDANCY SWITCH MATRIX, COAX	12	12	1.4	-	160	16.8		1920	0.7	-	25	8.4	-	300	
5	UPCONVERTERS(+VGAS) 4/11 GHz	48	60	1.4	7.0	140	84	336	8400	0.7	4	45	42	192	2700	
6	TWTAs, 12 GHz, 50 WATTS	48	60	4.5	125	250	270	6000	15000	4	91	200	240	4368	12000	
7	5/4 REDUNDANCY SWITCH MATRIX, COAX(RING)	12	12	2.0	-	200	24.0	-	2400	1.6	-	200	19.2	-	2400	
8	OUTPUT MULTIPLEXER, 16 CNL,24MHz,11GHz	3	3	16.0		2048	48	-	6144	6.0	-	1536	18	-	4608	
9	HARMONIC FILTER	48	48	0.1		13.5	4.8		648	0.1	-	13.5	4.8	-	648	
10	PRESELECT FILTER	3	3	0.1		11.2	0.3		33.6	0.1	-	11.2	0.3	-	33.6	
11	SPDT SWITHC, W/G, 14 GHz	3	3	0.15		16	0.45		48	0.15	-	16	0.45	-	48	
12	TRANSFER SWITCH, W/G 17 GHz or 14 GHz	1	1	0.18	-	16	0.18		16	0.18	-	16	0.18	-	16	
13	TRANSFER SWITCH COAX, 4 GHz	1	1	0.14	-	12	0.14		12	0.14	-	12	0.14	-	12	
14	SPDT SWITCH, COAX, 4 GHz	3	3	0.08	-	6	0.24		18	0.08	-	6	0.24	-	18	
15	COAX SET	1	1	8.0	-		8.0			8	-	-	8	-	-	
16	WAVEGUIDE, SET	1	1	24.0			24.0			24	-	-	24	-	-	
17	HARNESS	1	1	20.0			20.0			20	-	-	20	-	-	
18	COMM, CONTROL & INTERFACE	1	2	2	12	200	4	12	600	1.5	10	250	3	10	500	
19	INTEGRATION HARDWARE SET	1	1	5%	-	-	27	-	-	5%	-	-	20.5	-	-	
20	MARGIN REQUIRED			10%	10%	5%	56.7	641	2015.3	15%	10%	10%	64.7	461	2567	
21																
22	TOTAL TRANSPONDER						624.3	7052	42321				496	5075	28239	
23																
24																
25	ANTENNA REFLECTOR(DUAL GRIDDED)4.0m)	1	1	50	-	-	50	-	-	40	-	-	40	-	-	
26	ANTENNA FEED VERTICAL	1	1	32.5	-	13440	32.5	-	13440	29.3	-	12100	29.3	-	12100	
27	ANTENNA FEED HORIZONTAL	1	1	32.5	-	13440	32.5	-	13440	29.3	-	12100	29.3	-	12100	
28	*MARGIN REQUIRED*			10%	-	10%	11.5	-	2688	10%	-	10%	9.9	-	2420	
29																
30	TOTAL ANTENNA						126.5	-	29,568				108.5	-	26620	
31																
32																
33	TOTAL PAYLOAD						750.8	7052	71889				604.5	5075	54859	

WDL 791 2/76

FOLDOUT FRAME

2 FOLDOUT FRAME

5.3.2.2 Ku-Band FSS Antenna Subsystem

The Ku-Band FSS antenna subsystem provides transmission at 11 GHz and reception at 14 GHz of dually linearly polarized communications signals. The antenna coverage regions include a horizontal polarization for full CONUS beam and a vertical polarization for east and west half CONUS beam as shown in Figure 5.3.2-2. The requirements of the antenna subsystem are summarized in Table 5.3.2-2

Table 5.3.2-2

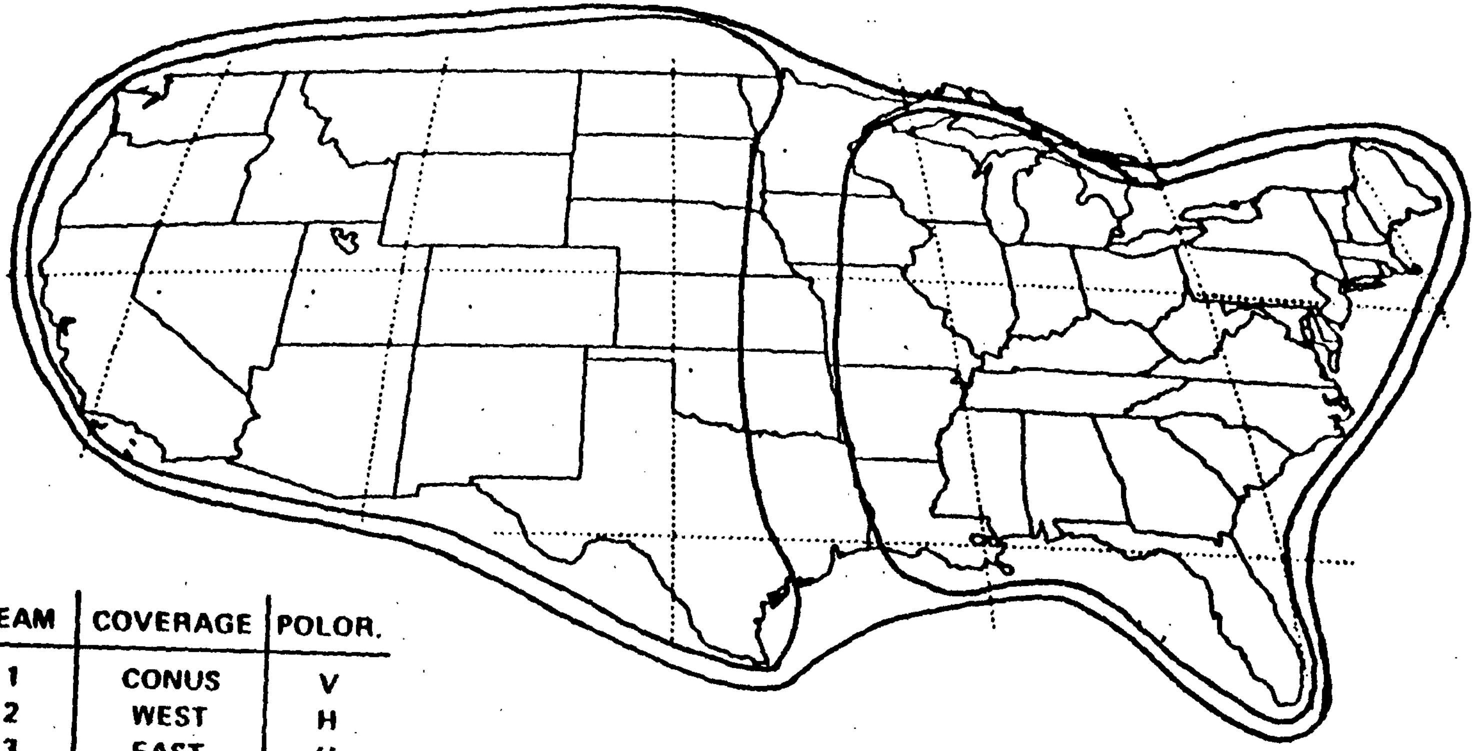
Ku-Band FSS Antenna Subsystem Requirements

Parameters	Requirements
Frequency:	Transmit: 11 GHz Band Receive: 14 GHz band
Polarization	Full CONUS: Vertical East/West Half CONUS: Horizontal
Coverage Area	Full CONUS; East/West half CONUS
Isolation:	30 dB

The antenna subsystem will consist of two overlapped, gridded reflectors and two multihorn feed array systems, as depicted in Figure 5.3.2-3. The grids of the reflector are selected to run either in the horizontal on vertical direction for horizatal or vertical polarization. They are used to help lower cross-polarization energy that is produced by the field curvature of an asymmetric paraboloid, as well as the cross-polarization radiated from the feed array. The polarization isolation achieved is greater than 30 dB. In order to provide adequate reliable isolation between the east and west CONUS beams for frequency reuse, the size of the reflector should be at least 13'. Figures 5.3.2-4 to 5.3.2-6 present the antenna radiation patterns for the

C-5

Figure 5.3.2-2 Ku-Band FSS Antenna Coverage Requirement



BEAM	COVERAGE	POLOR.
1	CONUS	V
2	WEST	H
3	EAST	H

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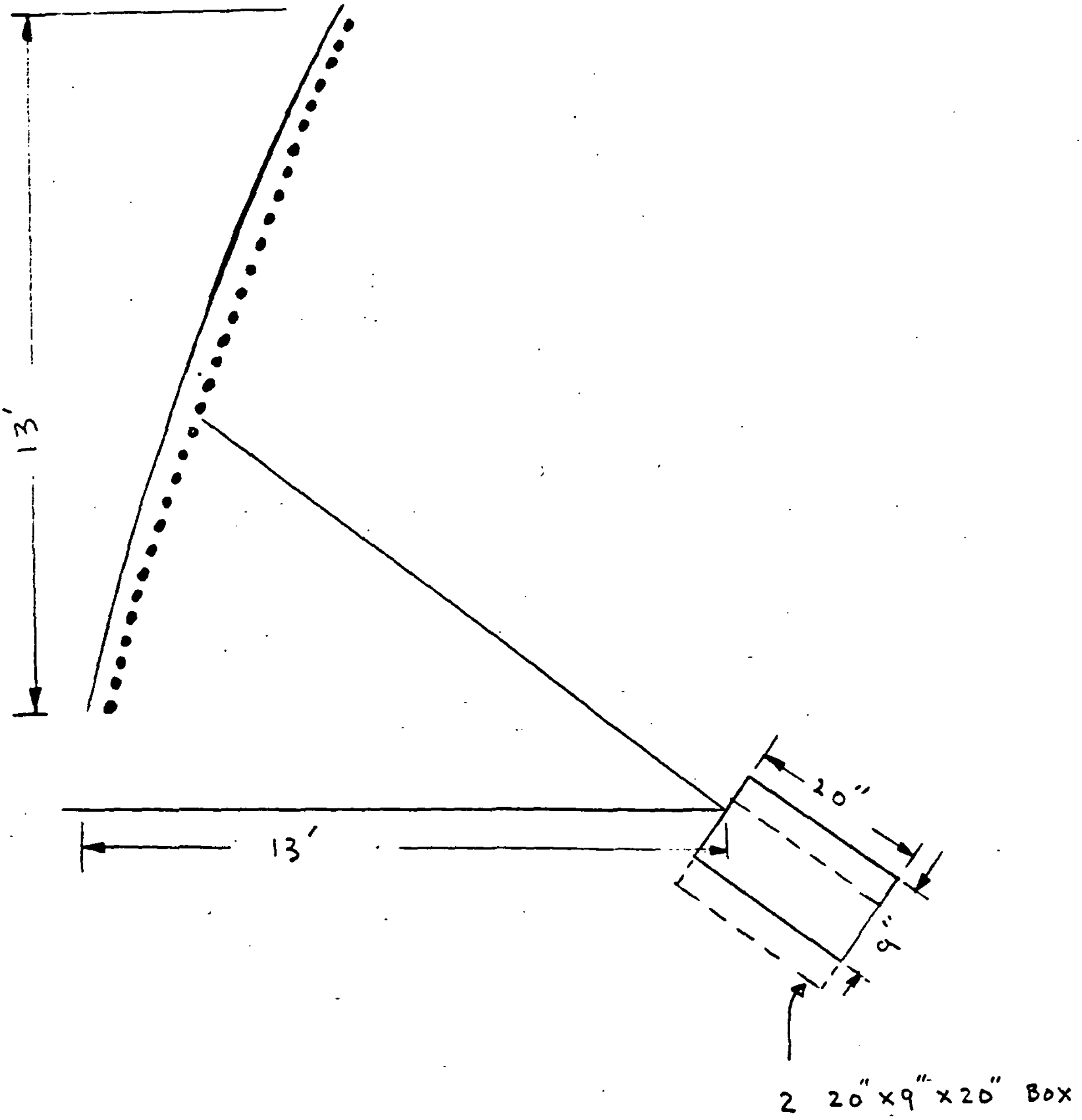
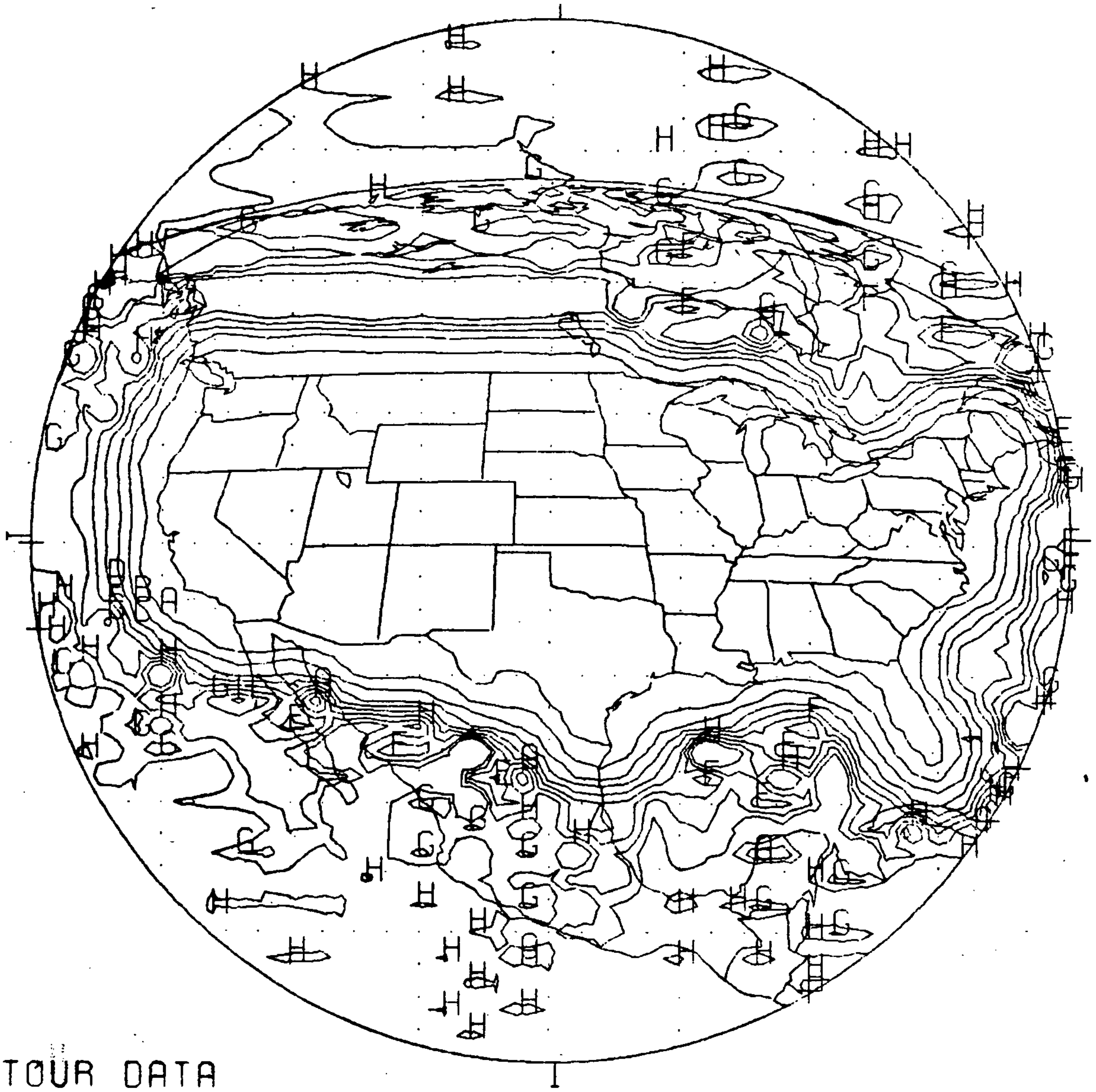


Figure 5.3.2-3 Ku-Band FSS Antenna Configuration

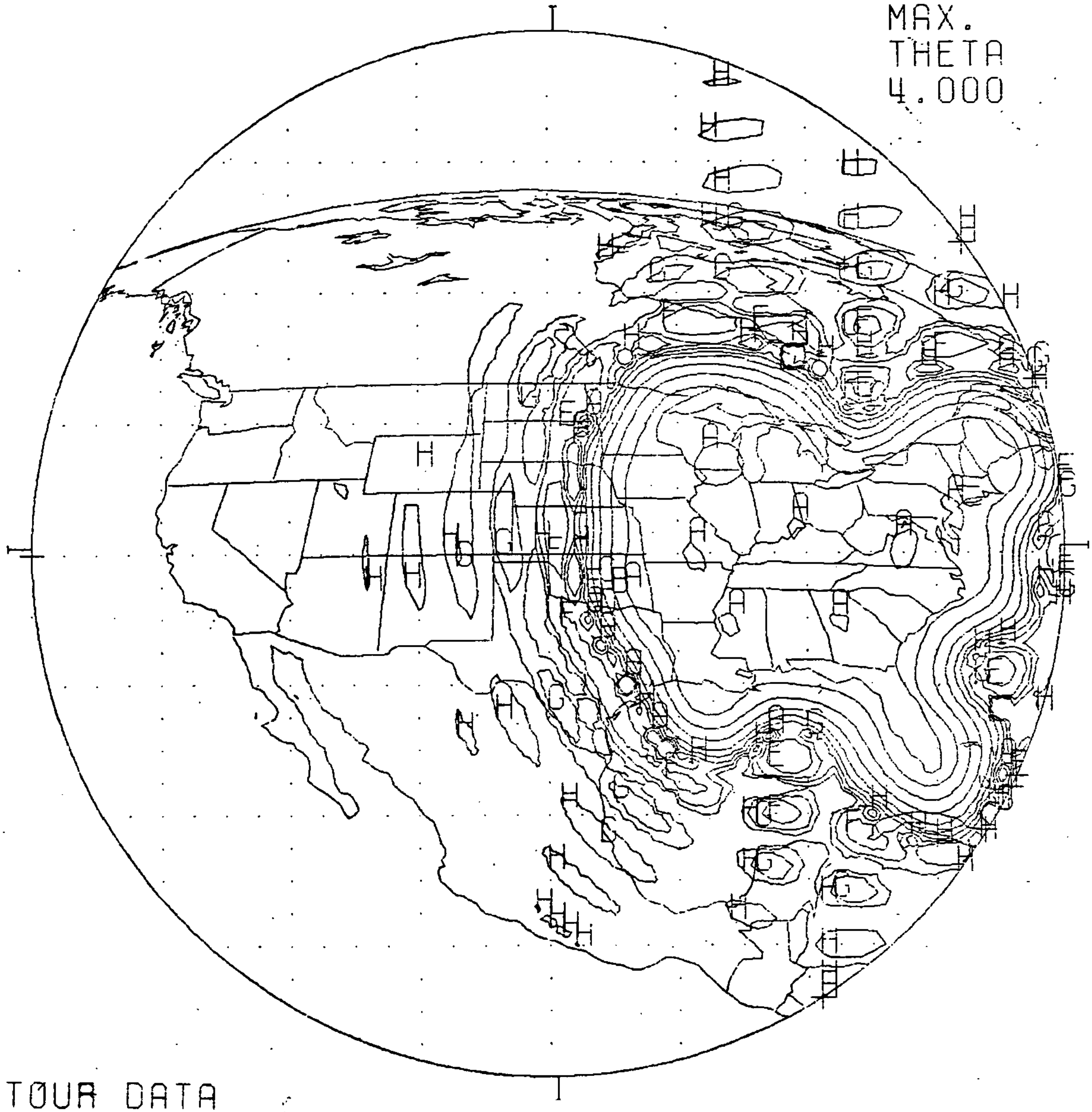
Figure 5.3.2-4 Ku-Band FSS CONUS Antenna Pattern



CONTOUR DATA

SYMBOL	LEVEL
A	-3.000(29 DBI)
B	-6.000
C	-10.000
D	-15.000
E	-20.000
F	-25.000
G	-30.000
H	-35.000

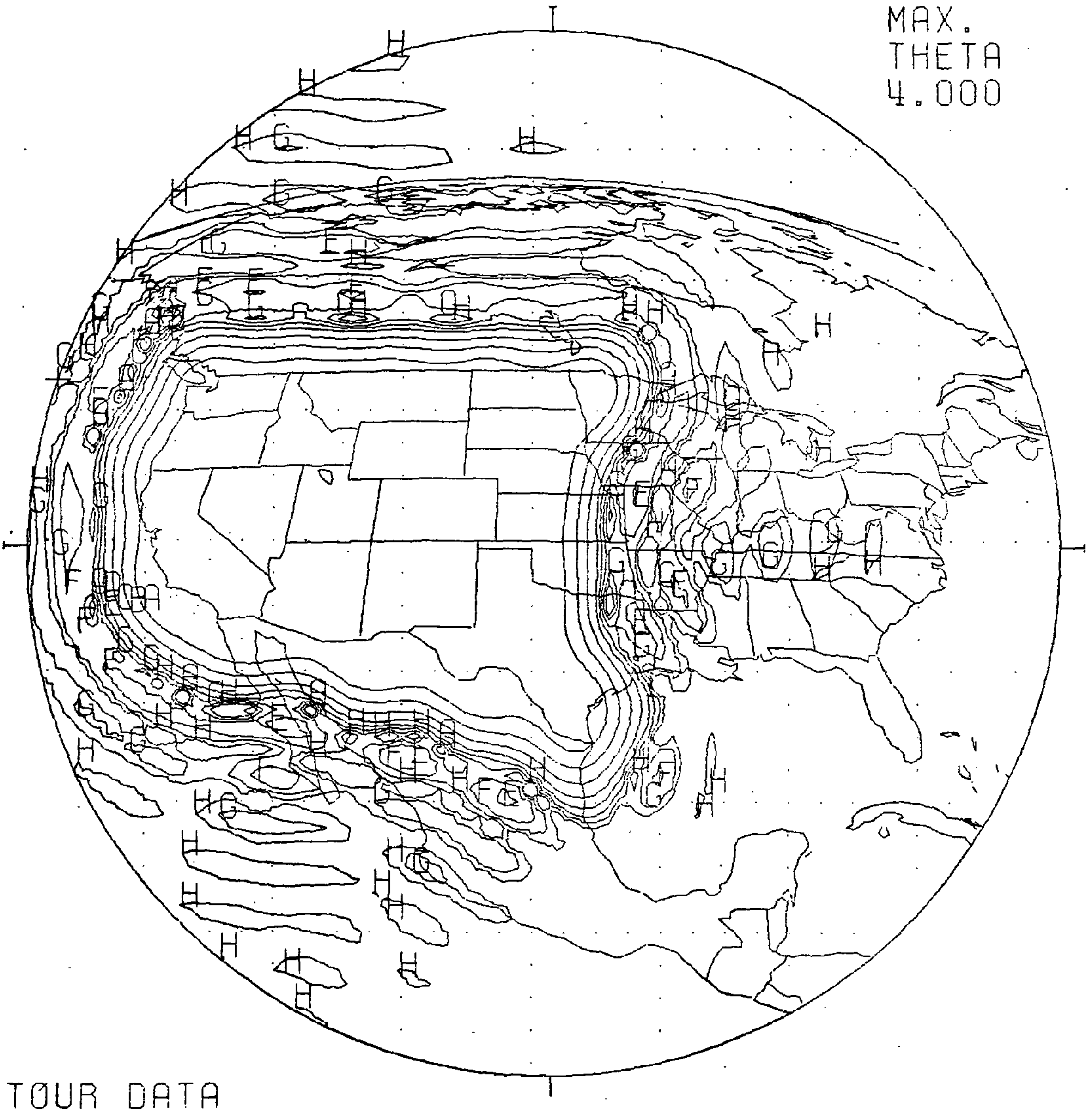
•Figure 5.3.2-5 Ku-Band FSS Eastern Antenna Pattern



CONTOUR DATA

SYMBOL	LEVEL
A	-3.000 (31.9 DBI)
B	-6.000
C	-10.000
D	-15.000
E	-20.000
F	-25.000
G	-30.000
H	-35.000

Figure 5.3.2-6 Ku-Band FSS Western Antenna Pattern



CONTOUR DATA

SYMBOL	LEVEL
A	-3.000 (30.7 DBI)
B	-6.000
C	-10.000
D	-15.000
E	-20.000
F	-25.000
G	-30.000
4	-35.000

full CONUS beam, and the east and west CONUS beams. The predicted edge-of-coverage antenna gains are given in Table 5.3.2-3.

Table 5.3.2-3

Ku-Band FSS Predicted Antenna Gain

Coverage	Gain (dBi)
Full CONUS	29
East Half CONUS	31.9
West Half CONUS	30.7

Diurnal and seasonal solar variations can cause temperature extremes and gradients on the reflector surface, which in turn mechanically distort the reflector, and degrade the electrical performance. Advanced Kevlar fiber composite materials are used for the structural elements of the reflector assembly to provide maximum thermal stability and structural strength with minimum weight. Each reflector is a Kevlar/epoxy laminate sandwich thin shell bonded to a backside on ring reinforcing structure. The sandwich shell supports the gridded system of wire. The largest existing dual gridded reflector that has ever been built is 6 feet. The proposed size, 13 feet of reflector aperture, presents many challenging mechanical, and hence electrical design problems, to provide the required mechanical stiffness and strength in the present state-of-art technology.

A shared feed approach is proposed in the feed array of the multiple-beam antenna system. Conventionally, the shaped beam for east CONUS coverage is formed by a feed array of group 1; for the west half CONUS coverage, a feed array of group 2. Group 1 and group 2 do not have any feed in common. A shared feed system has feed horns shared by the two groups. The number of available feeds for each coverage is increased. The sidelobe levels are lower because of better beam shaping. However, the losses of the beam forming network are higher. This kind of beam forming network tends to be frequency sensitive.

Table 5.3.2-4 summarizes the assessment of the critical technology items for this subsystem.

Table 5.3.2-4

Assessment of the Level of Risk of Critical Technology Items

Items	Low Risk	High Risk
Cross-pol Isolation	30 dB	33 dB
Co-pol Isolation	25 dB	27 dB
Feed Array (Shared Feed)	Needs Development	Achievable
Reflector	Needs Development	Achievable
Weight(Reflector)	18.6 kg	20% less

5.3.2.3 Ku-Band Transponder Subsystem Fixed Satellite Service

The Ku-Band Transponder subsystem consists of three 16 channel transponders, and hence has a total capacity of 48 channels, each having a bandwidth of 24 MHz. Channels nine to sixteen of each transponder are cross-linked at the 4 GHz IF to the same channels of the four DBS transponders. The three transponders utilize the same 500 MHz FSS band, having an uplink at 14 GHz and downlink at 11 GHz. The transponder subsystem receives two inputs from the horizontally polarized feed assembly (Eastern and Western coverages) and one from the vertically polarized feed assemly (CONUS coverage). Each of the three 14 GHz inputs is filtered by an input preselector, then amplified and down coverted to 4 GHz by the receiver. The receiver output is fed to an input multiplexer which subdivides the 500 MHz IF band into sixteen 24 MHz channels, while also providing the required narrow band receive filtering responses.

The three input multiplexers are followed by eight 7x7 switch matrices. The latter permit signals in any of the uplink channels 9 to 16 received via the Eastern region, Western region, or CONUS beam forming network (BFN), to be re-transmitted via any of the four DBS transponder output sections and associated BFNs (Eastern, Mountain, Central and Pacific regions). The switch matrix also contains hybrids which permit a broadcast mode of operation.

Each of the 48 channels is individually amplified by a driver amplifier, which contains one or more variable gain amplifiers. The latter permit automatic accommodation of varying uplink levels using an AGC loop, and also up to 16 dB of power amp back off via ground control. For the Ku Band fixed satellite service, 50 watt TWTAs are necessary to ensure sufficient EIRP. The outputs of the TWTAs in each set of sixteen channels are combined in an output multiplexer, and filtered by a harmonic/ bandpass filter prior to transmission from the appropriate antenna feed assembly. The transponder subsystem features 2 for 1 redundancy for the receivers and 5 for 4 redundancy for the TWTAs.

5.3.2.3.1 14 GHz/4 GHz Receiver

Using low risk technology, this receiver provides for low noise amplification at 14 GHz. It down converts 14 GHz to 4 GHz with a Schottky diode mixer. The mixer is followed by bandpass filtering and amplification at 4 GHz. The local oscillator is temperature controlled crystal oscillator followed by a multiplier chain.

<u>Electrical Performance</u>

Noise figure	3.5 dB
Gain	70 dB
Output power @ c/3IM=-40dBc	+13 dBm
Frequency stability	+1/-2 ppm
DC power	8.0 watts

Mechanically the receiver contains four subassembly trays: a front end, a driver, a local oscillator, and a DC/DC converter

The trays are assembled in a vertical stack. RF signal connections between the front end, driver, and local oscillator trays are made with short loops of semirigid coaxial cable. A selectable coaxial attenuator is included in the RF signal path at the input to the driver to allow for adjustment of the overall gain. Regulated DC voltages are supplied to the front end, driver, and local oscillator trays through a DC harness running vertically along the side of the stack.

The microwave tray is an aluminum chassis that contains substrate assemblies that are bonded into the chassis, and substrate/carrier assemblies that are bolted in the chassis. The substrate assemblies consist of MIC isolators, filters and temperature compensation. The substrate/carrier assemblies are MIC amplifiers. The amplifiers are constructed using hermetically packaged semiconductors, chip resistors, and chip capacitors on this film alumina substrates. The bias circuits are constructed using thick film alumina substrates, hermetically packaged semiconductors, chip resistors and chip capacitors.

Mechanical Parameters

Mass	1.8 kg
Volume	175 cu in

Using high risk technology, the 14 GHz preamp will be updated with the latest low noise GaAs FET. This will improve the noise figure from 3.5 dB to 2.0 dB. The mixer should be integrated with the bandpasss filtering. This will enhance the mixer performance by improving gain flatness over temperature and reducing test time. The 4 GHz amplifiers should be replaced by monolithic gain blocks. These gain blocks are common to this receiver and many other applications. This would reduce test time and improve overall receiver performance. The crystal oscillator chain could be replaced by a dielectric resonator oscillator (DRO). The DRO will reduce complexity and cost. The current receiver uses an analog circuit to temperature compensate the receiver gain. Future receivers should use a digital system to improve gain stability. The preamp, mixer/filter, DRO, and digital temperature compensation require development that is geared toward space qualification. The 4 GHz gain block would be developed in the commerical market and could be space qualified. Power consumption will be reduced to 6.0 watts, primarily by the use of the DRO.

The use of monolithic gain blocks and dielectric oscillators will reduce the size of the receiver. The number of subassemblies can be reduced from 4 to 3. These would be a DC/DC converter, front end/local oscillator, and driver.

Mechanical Parameters

Mass	0.9 kg
Volume	50 cu in

5.3.2.3.2 4 GHz Input Multiplexer

See 5.2.2.3.2.

5.3.2.3.3 R.F. Switch Matrix

See 5.2.3.3.3.

5.3.2.3.4 4/11 GHz Upconvertor

See 5.2.6.3.4.

5.3.2.3.5 11 GHz - 50 Watt TWTA

See 5.2.5.3.5.

5.3.2.3.6 11 GHz Output Multiplexer

See 5.2.5.3.6.

5.3.2.3.7 Pre-Select and Harmonic Filter

See 5.2.2.3.5.

5.3.3 Ku-Band DBS Payload

5.3.3.1 Overview of Ku-Band DBS Payload

This payload is a high power, 200 watt, Ku-band DBS payload. It utilizes an uplink of 17 GHz and a downlink at 12 GHz. It has sixteen 24 MHz channels for each of the four beam coverage areas. Isolation is provided by alternate use of RHCP and LHCP. The simplified block diagram is shown in Figure 5.3.3-1. TWTA's are used at the 200 watt level and it is not likely that at this power level solid state amplifiers are a viable alternate. The on-board interconnectivity for eight of the channels allows networking and eliminates some of the ground switch over problems. It also provides a broadcast mode of operation to all seven (4 DBS and 3 FSS) beams with one uplink.

Table 5.3.3-1 shows the estimated weight, power, and volume for low risk (emerging) technology and high risk (projected) technology for the transponder and antenna. Also included in the estimates are the coax, waveguide, and harness interconnects, plus an estimate for integration hardware to put the components together and provide necessary brackets for support and mounting. This does not include any structure or satellite mounting hardware, such as between the feed and reflector.

Figure 5.3.3-1   Scenario IV - Ku-Band DBS Payload

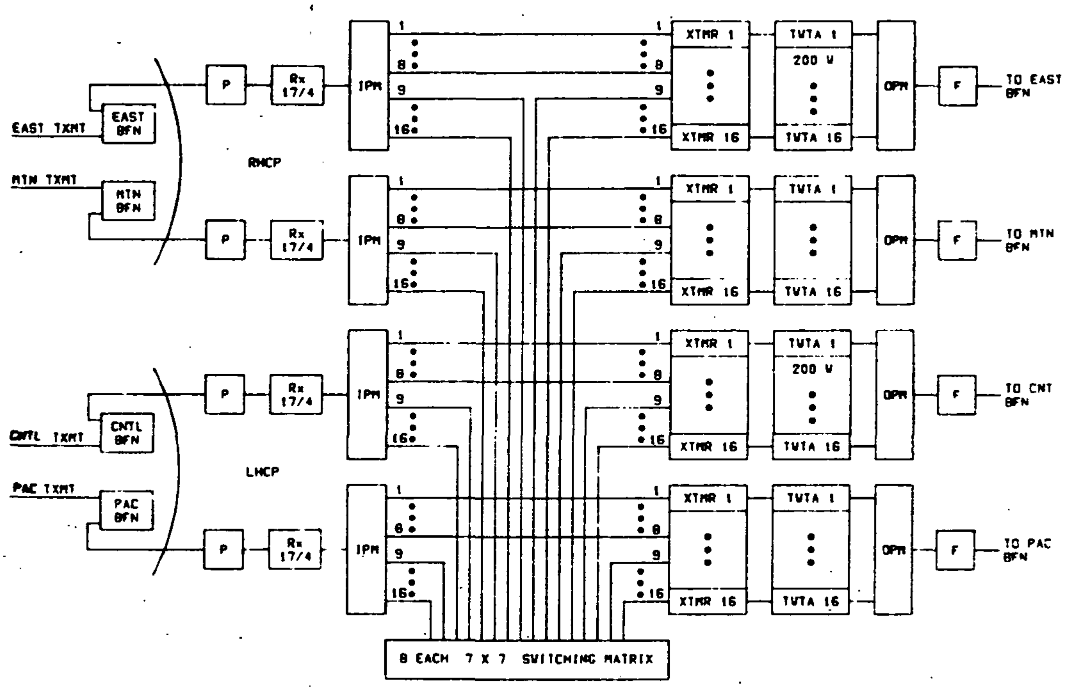


Table 5.3-3-1

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Scenario IV - Payload

Ku-Band DBS

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				LOW RISK TECHNOLOGY						HIGH RISK TECHNOLOGY						COMMENTS
	ITEM	P/L QTY REQ'D	REQ. QTY REQ'D	UNIT			PAYLOAD			UNIT			PAYLOAD			
				WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	
1	17/4 GHz RECEIVER	4	8	1.8	8.0	175	14.4	32	1400	0.7	5.5	50	5.6	22	400	
2	INPUT MULTIPLEXER, 16 CHANNEL, 4 GHz, 24 MHz	4	4	5.6	-	1152	22.4		4608	4.5	-	576	18	-	2304	
3	5/4 REDUNDANCY MATRIX, COAS (RING)	16	16	1.4		160	22.4		2560	0.7	-	25	11.2	-	400	
4	UPCONVERTERS (VGAS) 4/12 GHz	64	80	1.4	7.0	140	112	448	11200	0.7	4	45	56	256	3600	
5	5/4 REDUNDANCY SWITCH MATRIX, W/G(RING)	16	16	2.0	-	200	32	-	3200	1.6	-	200	25.6	-	3200	
6	TWTAs, 11 Ghz 200 W	64	80	8.6	476	400	688	30464	32000	7.2	421	350	576	26944	28000	
7	OUTPUT MULTIPLEXER, 16 CHANNEL, 24 MHz,12GHz	4	4	16.0		2048	64		8192	12	-	1536	48	-	6144	
8	HARMONIC FILTER	64	64	0.1		13.5	6.4		864	0.1	-	13.5	6.4	-	864	
9	PRESELECT FILTER	4	4	0.1		11.2	0.4		44.8	0.1	-	11.2	0.4	-	45	
10	SPDT SEITCH, W/G, 17 GHz	4	4	0.15	-	16	0.60		64	0.15	-	16	0.6	-	64	
11	TRANSFER SWITCH, W/G 17 GHz	2	2	0.18	-	16	0.36		32	0.18	-	16	0.36	-	32	
12	TRANSFER SWITCH, COAX 4 GHz	2	2	0.14	-	12	0.28		24	0.14	-	12	0.28	-	24	
13	SPDT SWITCH, COAX, 4 GHz	4	4	0.08	-	6	0.32		24	0.08	-	6	0.32	-	24	
14	COAX, SET	1	1	10.7	-		10.7			10.7	-	-	10.7	-	-	
15	WAVEGUIDE, SET	1	1	26.7	-		26.7			26.7	-	-	26.7	-	-	
16	HARNESS	1	1	26.7			26.7			26.7	-	-	26.7	-	-	
17	COMM, CONTROL AND INTERFACE	1	2	3	20	500	6	20	1000	2	15	400	2	15	800	
18	INTEGRATION HARDWARE	1	1	5%	-	-	51.7	-	-	5%	-	-	40.7	-	-	
19	MARGIN REQUIRED			10%	10%	5%	108.5	3096	3260	15%	10%	10%	128.3	2723	4590	
20																
21	TOTAL TRNASPONDER						1194	34060	68473				984	29960	50491	
22																
23																
24	TRANSMIT ANTENNA(2.5m)	1	1	12	-	-	12	-	-	9.6	-	-	9.6	-	-	
25	TRANSMIT FEED NETWORK	1	1	5	-	3600	5	-	3600	4.5	-	3300	4.5	-	3300	
26	RECEIVE ANTENNA(1.9m)	1	1	8	-	-	8	-	-	6.4	-	-	6.4	-	-	
27	RECEIVE FEED NETWORK	1	1	5	-	1372	5	-	1372	4.5	-	1235	4.5	-	1235	
28	MARGIN REQUIRED			10%	-	10%	3	-	497	10%	-	10%	2.5	-	454	
29																
30	TOTAL ANTENNA						33	—	5469				27.5	—	4989	
31																
32																
33	TOTAL PAYLOAD						1227	34,060	73942				1011.5	29960	55480	

5.3.3.2 Ku-Band DBS Antenna Subsystem

The Ku-band DBS antenna subsystem provides transmission at 12 GHz and reception at 17 GHz of dually circularly-polarized communication signals. The purpose of the communication antenna is to provide direct coverage to one of the four areas of CONUS (Eastern, Central Mountain, Pacific), as shown in Figure 5.3.3-2. Table 5.3.3-2 summarizes the antenna subsystem requirements.

Table 5.3.3-2

<u>Ku-Band DBS Antenna Subsystem Requirements</u>

Parameter	Requirements
Frequency	
Transmit:	12 GHz band
Receive:	17 GHz band
Polarization	Dual circular polarization
Coverage Area	Eastern Service Area
	Central Service Area
	Mountain Service Area
	Pacific Service Area
Cross-polarization Isolation	27 dB

The antenna will consist of two solid, offset parabolic reflectors, one 2.44 meter for transmit and one 1.8 meter for receive, as depicted in Figure 5.3.3-3. Each reflector will be illuminated by an array of 55 individual feed horns which are excited from two input ports through a feed network consisting of a series of cascaded hybrid power dividers. A polarizer is employed at each horn to produce circular polarization. Figures 5.3.3-4 thru 5.3.3-7 present the antenna radiation patterns, Table 5.3.3-3 shows the predicted antenna gains of the system.

Figure 5.3.3-2 Ku-Band DBS Antenna Coverage Requirement

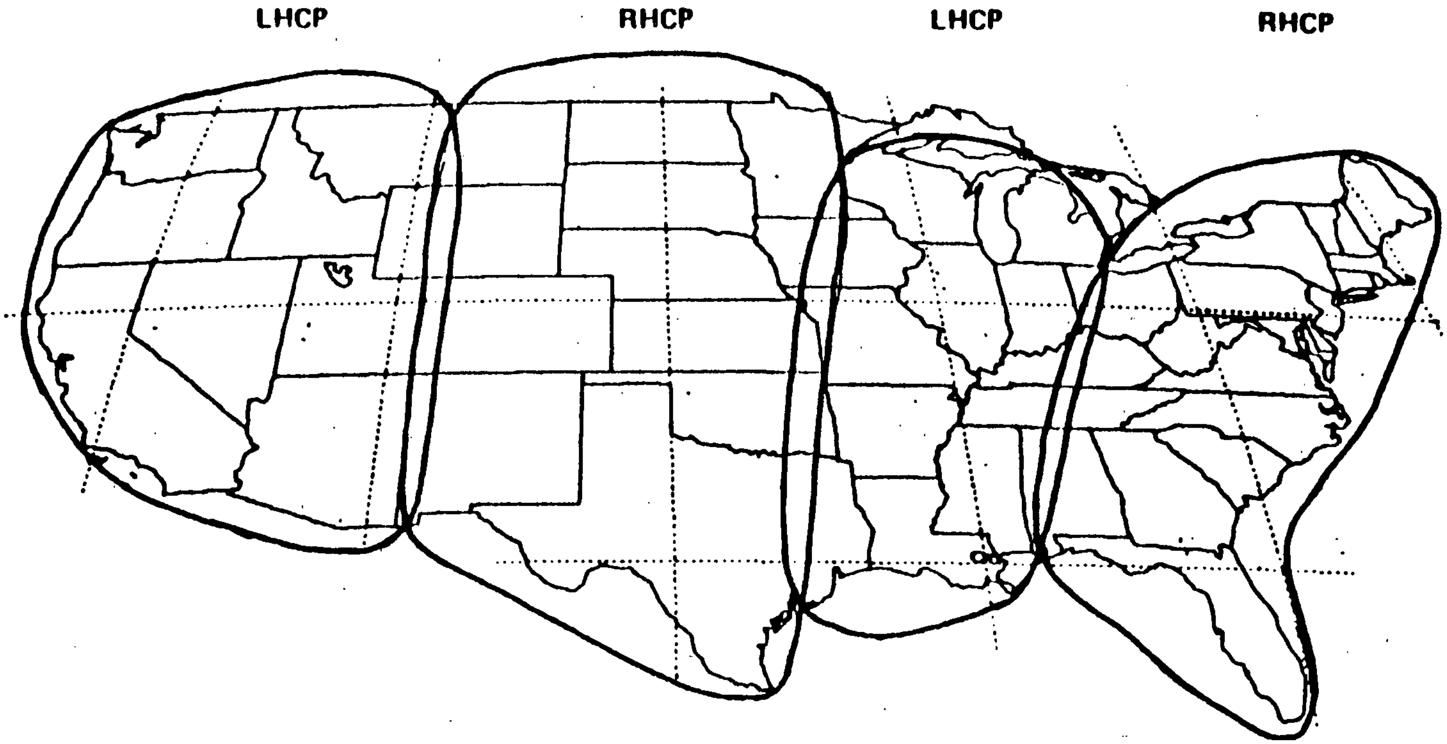

Figure 5.3.3-3 Ku-Band DBS - Scenario IV

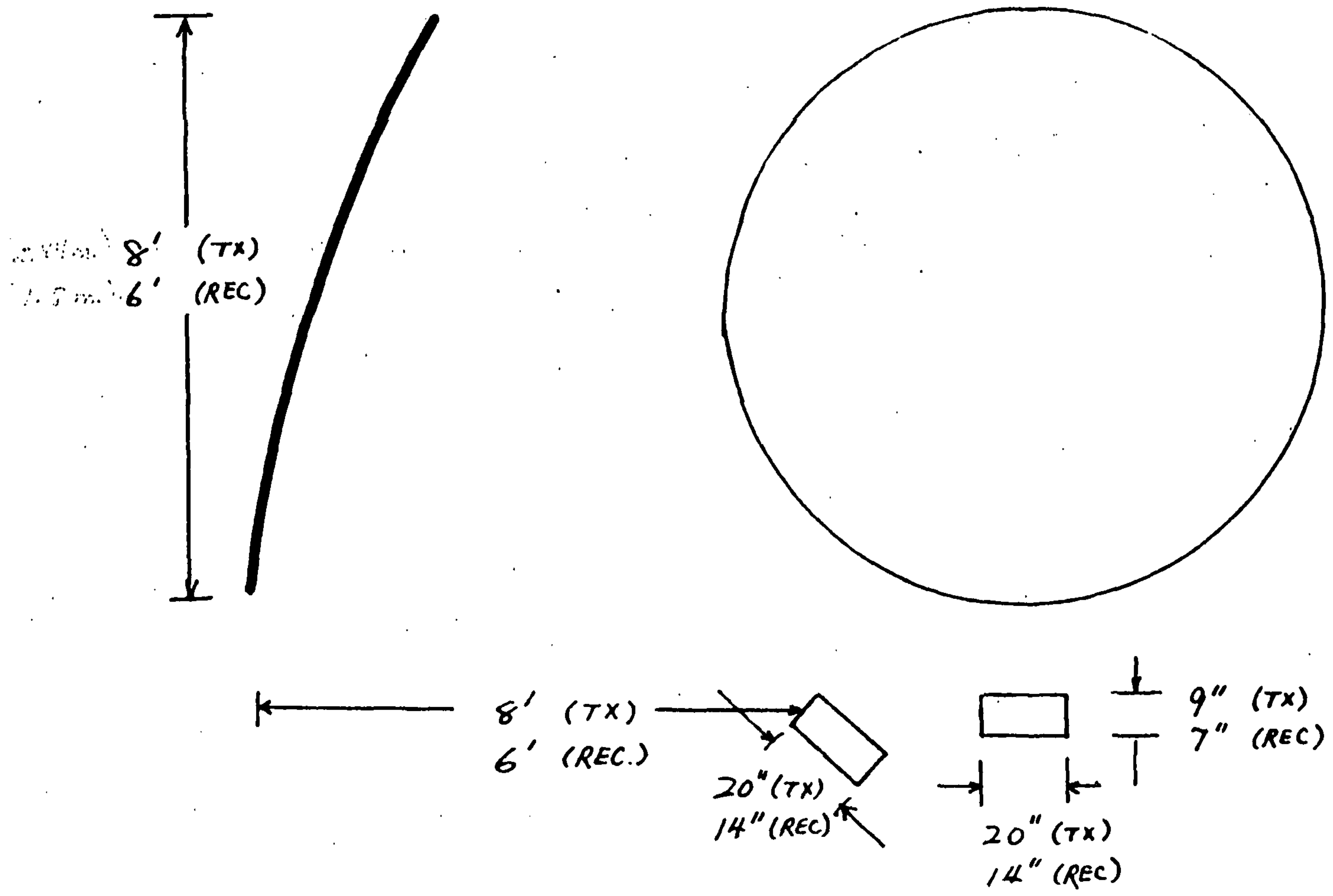

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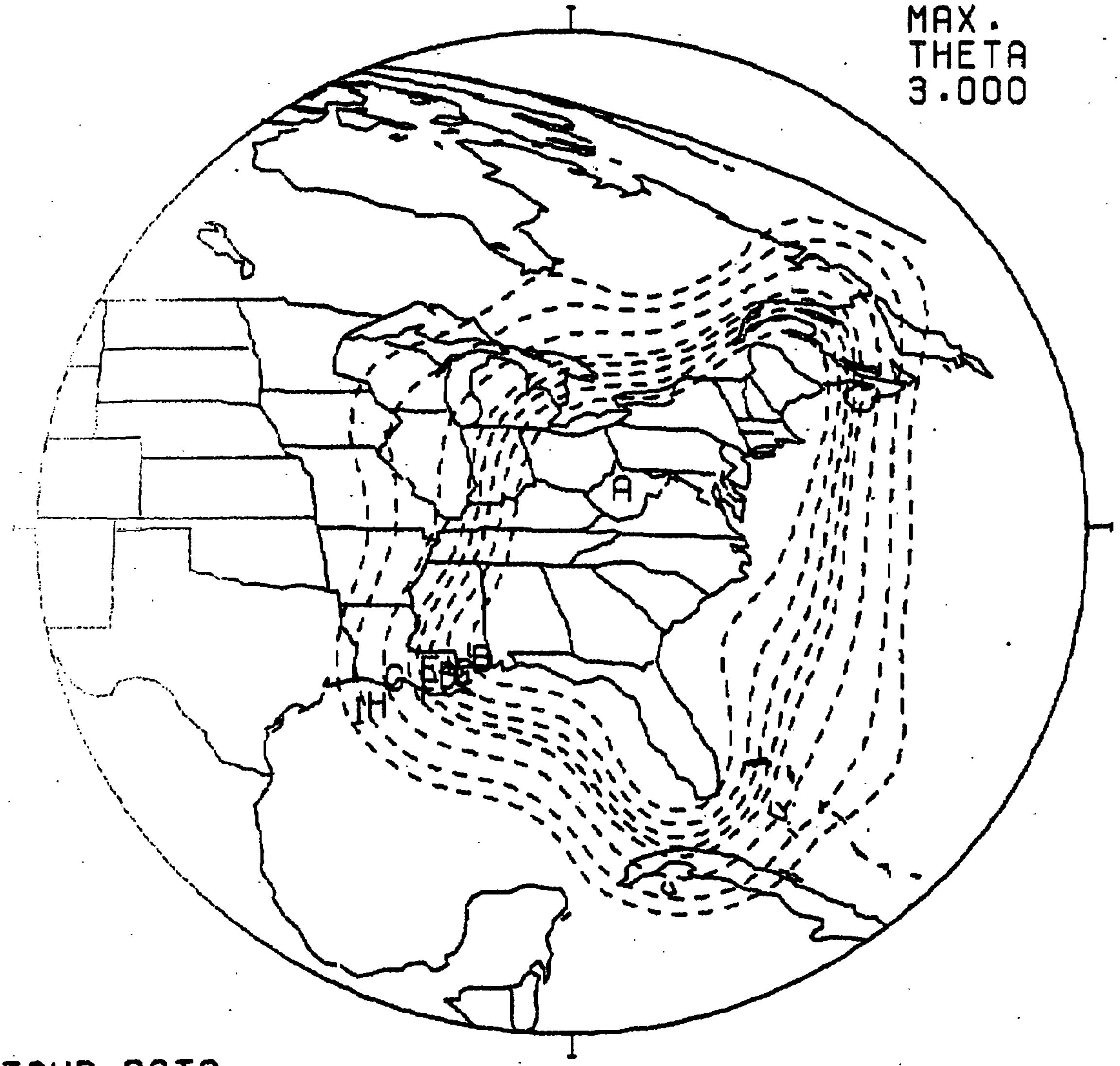
Figure 5.3.3-4 Ku-Band DBS Eastern Antenna Pattern



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G	-10.000
H	-15.000
I	-20.000

EAST BEAM 101 DEGREE

-39.124 WAS ADDED
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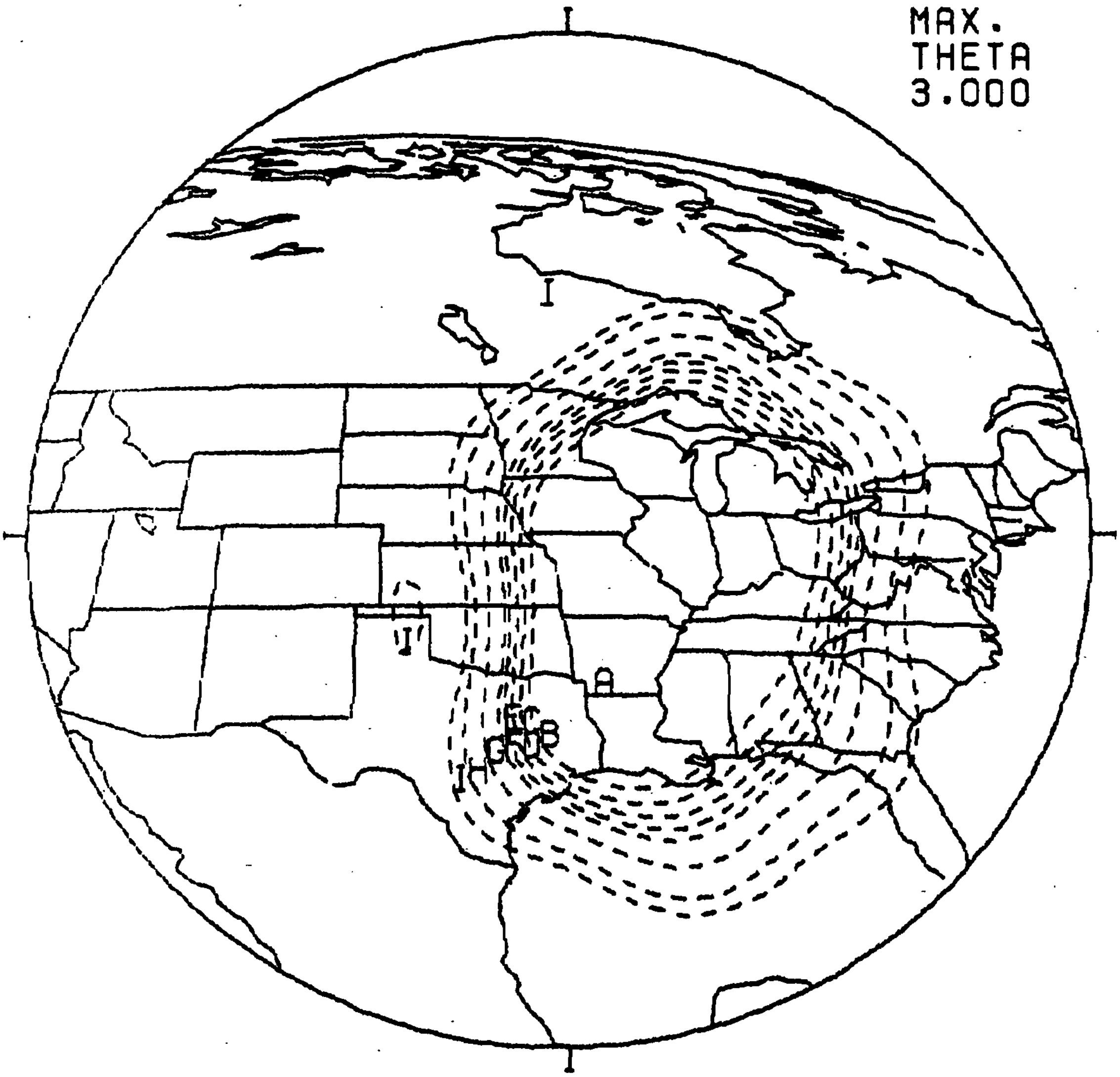
Figure 5.3.3-5 Ku-Band DBS Central Antenna Pattern



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E	-6.000
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G	-10.000
H	-15.000
I	-20.000

CENTRAL BEAM 101 DEGREE

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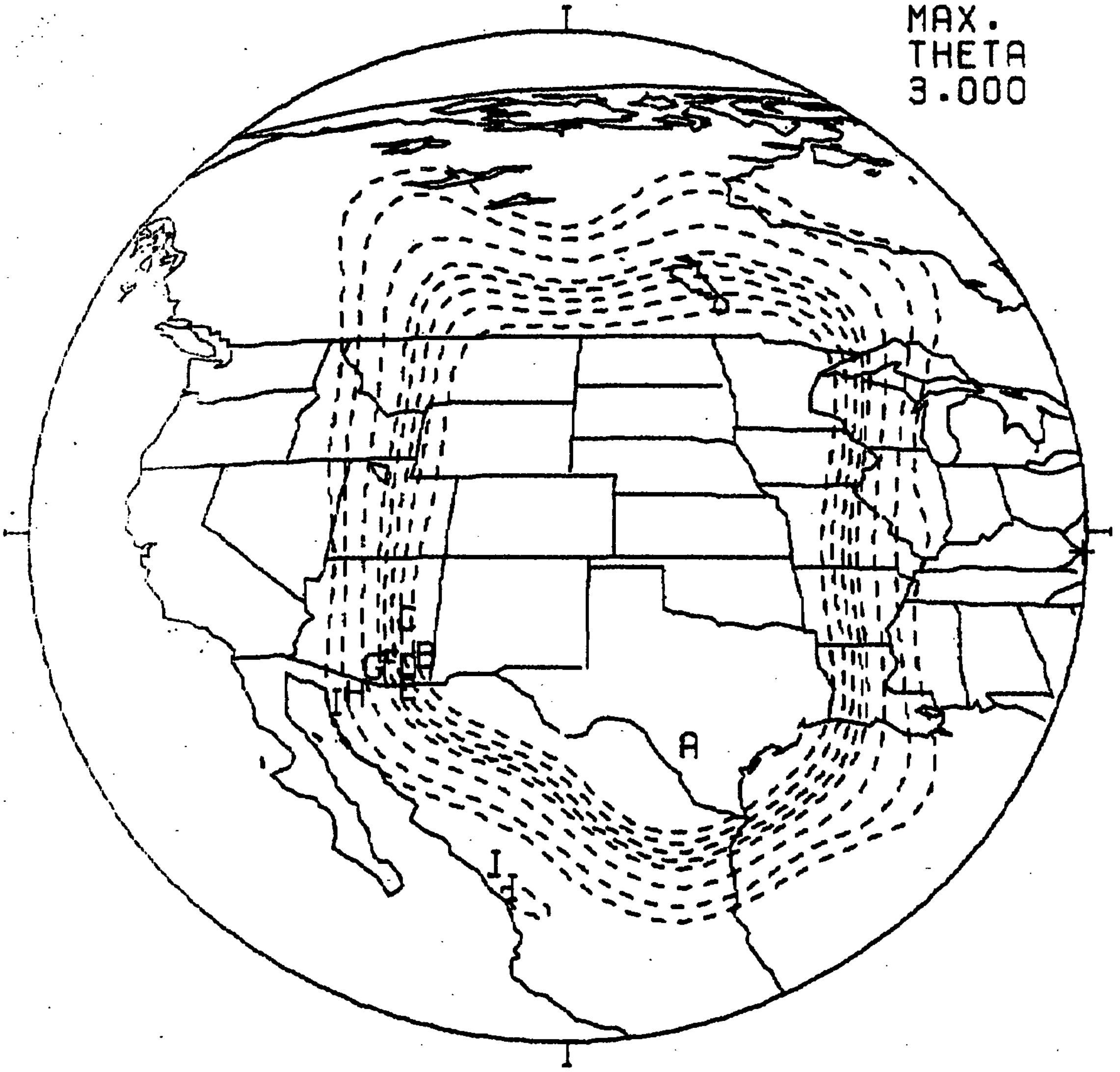
Figure 5.3.3-6 Ku-Band DBS Mountain Antenna Pattern



CONTOUR DATA

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C	-4.000
D	-5.000
E	-6.000
F	-7.000
G	-10.000
H	-15.000
I	-20.000

MOUNTAIN BEAM 101 DEGREE

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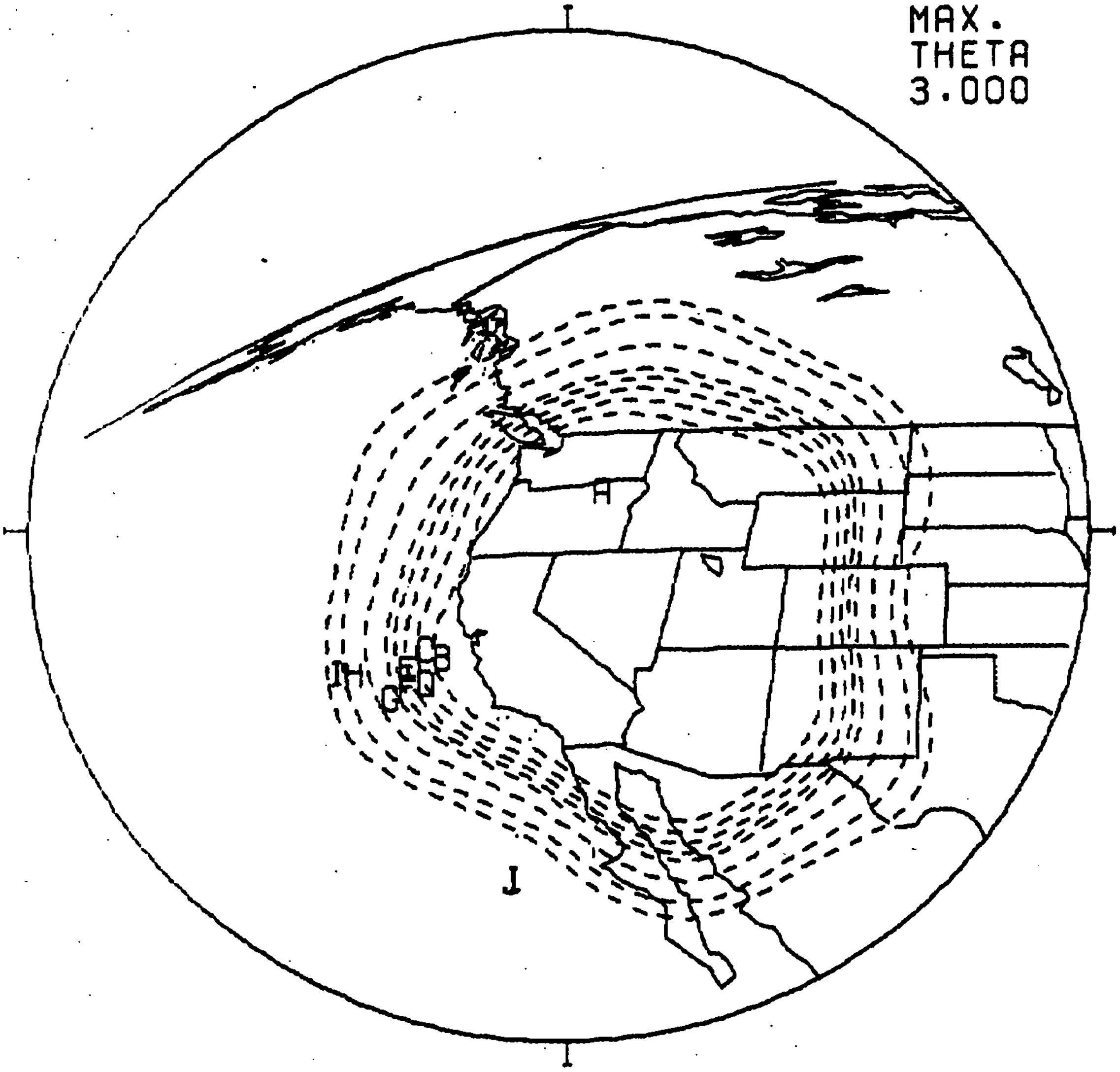
TO INPUT DATA

Figure 5.3.3-7 Ku-Band DBS Pacific Antenna Pattern



CONTOUR DATA

SYMBOL	LEVEL
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B	-3.000
C	-4.000
D	-5.000
E	-6.000
F	-7.000
G	-10.000
H	-15.000
I	-20.000

GHZ PACIFIC BEAM 101 DEGREE

-38.613 WAS ADDED
TO INPUT DATA

Table 5.3.3-3

Ku-Band DBS Predicted Antenna Gain

Coverage	Gain (dBi)
Eastern	33.2
Central	33.5
Mountain	32.8
Pacific	33

All technologies required in this system are well developed. The level of risk of the technology is low. The estimated weight of two reflectors is 20 kg. The reflector design is a graphite epoxy laminate sandwich shell bonded to a backside reinforcing rib structure. The weight could be reduced by about 20% by 1994 due to the current development of a more advanced graphite materials for the reflector surface.

5.3.3.3 Ku-Band Transponder, Direct Broadcast Service

The DBS Transponder Subsystem consists of four 16 channel transponders, and hence has a total capacity of 64 channels, each having a bandwidth of 24 MHz. Channels 9 to 16 of each transponder are cross-linked at the 4 GHz IF to the same channels of the three FSS transponders. The four transponders utilize the same 500 MHz DBS band, having an uplink at 17 GHz and downlink at 12 GHz. The transponder subsystem receives two inputs from the RHCP antenna feed assembly (Eastern and Mountain coverages) and two inputs from the LHCP antenna feed assembly (Central and Pacific coverages). Each of the four 17 GHz inputs is filtered by an input preselector, then amplified and downconverted to 4 GHz by the receiver. The receiver output is fed to an input multiplexer which subdivides the 500 MHz IF band into sixteen 24 MHz channels, while also providing the required narrow band receive filtering responses.

The three input multiplexers are followed by eight 7x7 switch matrices. The latter permits signals in any of the uplink channels 9 to 16 (received via the Eastern, Mountain, Central, or Pacific region beam forming networks(BFN)) to be re-transmitted via any of the three FSS transponder output sections or/and any of the four DBS output sections and associated BFNs. The switch matrix also contains hybrids which permit a broadcast mode of operation.

Each of the 64 channels is individually upconverted to 12 GHz and then amplified by a driver amplifier, which contains one or more variable gain amplifiers. The latter permit automatic accommodation of varying uplink levels, using an AGC loop, and also up to 16 dB of power-amp back-off via ground control. For the Ku-Band direct broadcast service, 200 watt TWTAs are necessary to ensure sufficient EIRP. The outputs of the TWTAs in each set of sixteen channels are combined in an output multiplexer, which also provides the required narrowband transmit filtering response. The downlink signals are further filtered by a harmonic/bandpass filter prior to transmission via the appropriate antenna feed assembly.

The transponder subsystem features 6 for 3 redundancy for the receivers, and 5 for 4 redundancy for the TWTAs.

5.3.3.3.1 17/4 GHz Receiver

See 5.2.6.3.1.

5.3.3.3.2 4 GHz Multiplexer

See 5.2.2.3.2.

5.3.3.3.3 4/12 GHz Upconverter

See 5.2.6.3.4.

5.3.3.3.4 12 GHz - 200 Watt TWTA

See 5.2.6.3.5.

5.3.3.3.5 12 GHz Output Multiplexer

See 5.2.5.3.6.

5.3.3.3.6 Pre-Select and Harmonic Filters

See 5.2.2.3.5.

5.4 SCENARIO V DEFINITION

5.4.1 Introduction

Scenario V can be described as a high capacity, CONUS, FSS satellite payload that is designed to meet the distributional characteristics of CONUS traffic, assuming approximately 60% of the traffic is digital. The scenario uses all three FSS bands, C, Ku, and Ka-band. It has static, reconfigurable switch networks at C and Ku-band, and dynamic switching and baseband processing at Ka-band. The services provided are listed below:

- 48 Channels, 36 MHz, C-band, FSS payload, 4 beams, 12 channels each, 4 x re-use.
- 108 channels 36 MHz, Ku-band, FSS payload, 9 beams, 12 channels each, 9 x re-use.
- 38 channels, 500 MHz, Ka-band, FSS payload, 20 beams, approximately 2 channels each, 7.6 x re-use.
- 18 channels of 240 MHz, and 14 channels of 500 MHz, Ka-band, CPS payload, 6 beams, CPS/thin route trunking, 4.6 x re-use.

The C and Ku-band payloads are designed for primarily high capacity analog voice trunking, while the Ka-band is an all digital SS TDMA system using high efficiency modulation techniques to achieve a 2 bits per hertz capacity. The satellite can utilize a wide variety of orbital locations. However, once the Ka-Band antenna spots are determined, only about $\pm 5^{\circ}$ of orbital movement can be accomodated. This may require 2 or 3 options on the design to allow use of orbital positions in the U.S. arc.

An overview block diagram of the payload elements is shown in Figure 5.4.1-1. Table 5.4.1-1 lists the major bus/payload interface requirements and Tables 5.4.1-2 and 5.4.1-3 present the major antenna and transponder characteristics respectively. The two Ka-Band antennae require individual gimbal systems for steering the two sub-reflectors to achieve ± 0.02° pointing of the RF boresight. The other antennae will be rigidly mounted to the body and body steered via the bus control system.

Table 5.4.1-1

Scenario V - Payload Summary

o Mass	2261 kg
o Power Required	
Sunlight	7500 watts
Eclipse	75% min; 100% desired
o Pointing Reqmt.	± 0.05° absolute (ie: RF boresight)
o Temp. Reqmts.	
Antenna	-90° to +110°C
Transponder	-10°C to +50°C, TWTA's +60°C
o Thermal Diss.	5 kW TWT, 500 W. EPC's, 1 kW Feeds & W/G
o Life Time	10 years without servicing

Due to the use of TWTA's for the Ka-band FSS payload, a 10 year life is all that can be envisaged at this time. Replacement of TWTA's at GEO is not anticipated for the early 2000 time period. It is estimated that the identified redundancy is compatible with a 10 year life application.

Figure 5.4.1-1 Scenario V - Overview

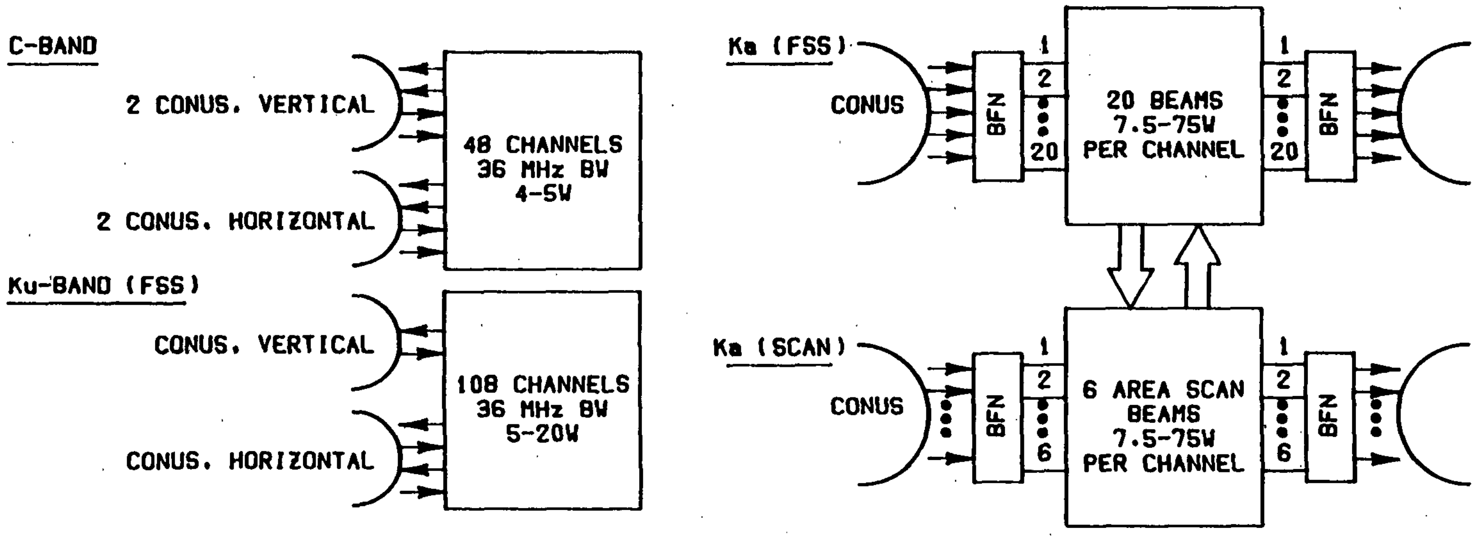


Table 5.4.1-2

Scenario V Antenna Configuration

Antenna System	Freq (GHz)	Reflector	Polarization	Feed Arrays
C-Band FSS	6/4	15'(4.6m) dual gridded reflector	Linear	2x26 feeds plus 2x26 diplexers
Ku-Band FSS	14/11	15'(4.6m) dual gridded reflector	Linear	2x450 feeds.
Ka-Band FSS	30/20	One solid 13' (4.0m) reflector for tx, one solid 9'(2.7m.) reflector for rec (dual shaped reflector, each with subreflector)	Linear	Tx:500 feeds, 830 switches, 140 orthomode junctions; same for receive

Table 5.4.1-3

Transponder Summary Scenario V

Payload	U/L,D/L Freq. GHz	Number Channels	Channel BW(MHz)	RCVR Type (Number)	HPA Type (Number)	HPA Power,W
C-Band FSS	6/4	48	36	6/4(8)	SSPA(60)	4
Ku-Band FSS	14/11	108	36	14/11(18)	SSPA(135)	2
Ka-Band FSS	30/20	38	500	30/4(40)	TWTA(49)	75
Ka-Band Scan	30/20	32	240/500	30/4(12)	TWTA(40)	75

If lower risk technology is utilized, it is possible that fuel servicing at GEO or perigee augmentation at LEO could be utilized to bring this payload within the limits of the Launch Concept 1.

Table 5.4.1-4 presents a summary of the high and low risk weight and power for the individual payload elements in Scenario V.

In Appendix I-3, Tables 1 through 6 show that all of the payload elements have viable links with the various types of anticipated modulation and access. While some of the margins are low, the links represent the worst case conditions. If this scenario were to be studied further for full system definition, it is expected that link margins could be improved for actual implementation.

5.4.2 C-Band FSS Payload

5.4.2.1 Overview of C-Band FSS Payload

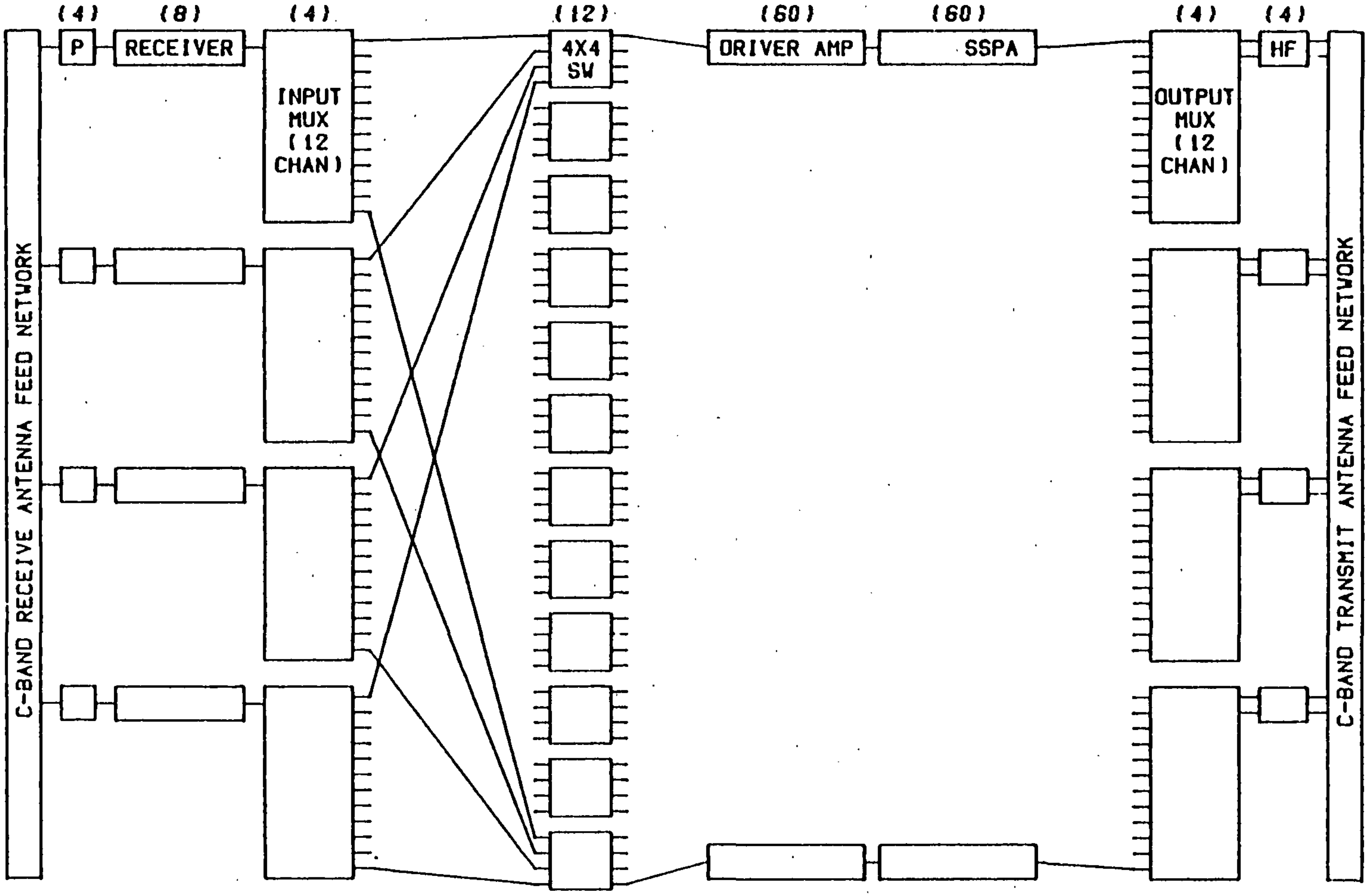
This payload doubles the capacity of the current day C-band payloads by using shaped beam technology. The system uses horizontal and vertical linear polarization isolation for 2 times reuse and spatial isolation of shaped beams to double the capacity with respect to CONUS coverage. The beam coverages use three beams to cover CONUS, and a fourth beam doubling the re-use in the northeast corner of CONUS. The payload features a dual gridded reflector assembly to obtain the polarization purity required for the re-use. Each of the transponder channels is of straight-forward design, and although electronic switches are used for routing, it is only for traffic pattern changes and only used on a limited basis. It does, however, also provide the flexibility to use the system as a SS-TDMA digital modulation if so desired. Figure 5.4.2-1 is a block diagram of the C-Band FSS payload for Scenario V showing the breakdown to the

Table 5.4.1-4

Scenario V - Weight and Power

	WEIGHT(KG)		POWER(W)	
	Low Risk	High Risk	Low Risk	High Risk
C-Band FSS				
Transponder	235	171.7	1001	708
Antenna	92.4	74.1	-	-
Sub Total	327.4	245.8	1001	708
Ku-Band FSS				
Transponder	625	362.4	1164	785
Antenna	187	160.6	-	-
Sub Total	812	523	1164	785
Ka-Band FSS & Scan				
FSS Transponder	751.4	516.3	3305	3043
SCAN Transponder	636.0	447.6	2180	1936
Baseband Proc.	355.0	297.4	1360	952
Antenna	264.5	230.4	4	2
Sub-Total	2006.9	1491.7	6849	5933
SCENARIO V TOTAL	3146.3	2260.5	9014	7426

Figure 5.4.2-1 C-Band FSS - Scenario V



component level. Table 5.4.2-1 shows the projected antenna gain and the power applifier power levels necessary to maintain the required 36 dBW EIRP consistent with the WARC required power flux density (PFD) of - 142.0 dBW/m^2 for Region 2. The nine beam coverage areas were developed in Section 4 to the SMSA level and the covered SMSA's converted into lattitude and longitude coordinates for development of the antenna. Appendix I-2.2 contains the coordinates for each beam coverage area.

Table 5.4.2-1

Power Requirements For C-Band FSS, Scenario V

(Single Carrier Operation)

EIRP= 36.0 dBW
PFD= -142.0 dBW/m^2

BEAM	G (dB)	P (dBW)	P (W)
1H	36.8	0.7	1.175
2V	34.5	3.0	1.995
3H	30.1	7.4	5.495
4V	28.9	8.6	7.244

Table 5.4.2-2 shows the estimated weight, power, and volume for low risk (emerging) technology and high risk (projected) technology for the transponder and antenna. Also included in the estimates are the coax, waveguide, and harness interconnects, plus an estimate for integration hardware to put the components together and provide necessary brackets for support and mounting. This does not include any structure or satellite mounting hardware, such as between the feed and reflector.

5.4.2.2 C-Band Antenna Subsystem

The C-Band FSS antenna subsystem provides transmission at 4 GHz and reception at 6 GHz of dual linear-polarized communications signals. The purpose of the communication antenna is to provide 4 beams to cover CONUS as shown in Figure 5.4.2-2. The orthogonal polarization is used for each

Table 5.4.2-2

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Scenario V & VI - Payload Summary
C-Band FSS

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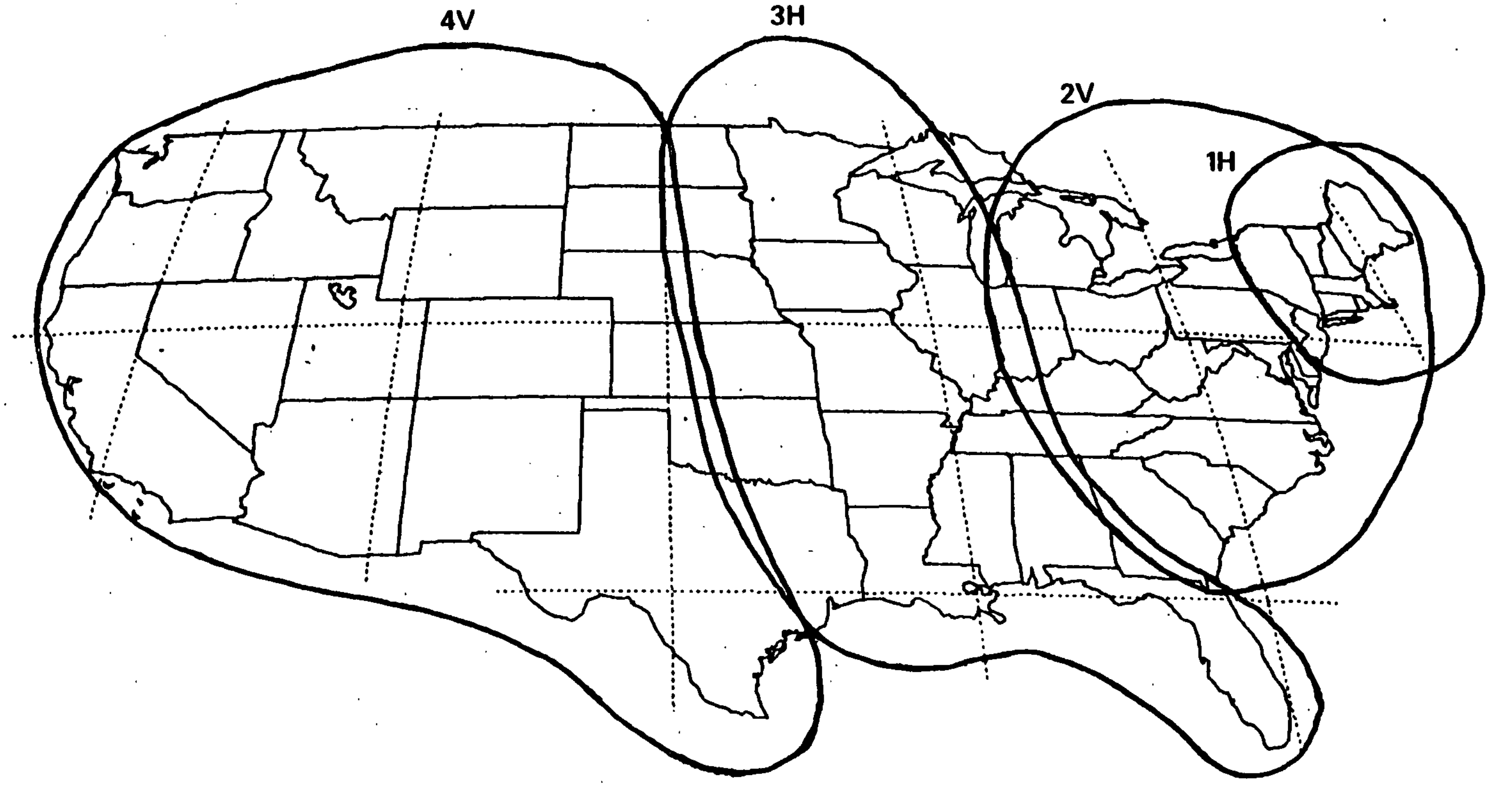
	ITEM	P/L QTY REQ'D	REQ. QTY REQ'D	LOW RISK TECHNOLOGY						HIGH RISK TECHNOLOGY						COMMENTS
				UNIT			PAYLOAD			UNIT			PAYLOAD			
				WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	
1	6/4 GHz RECEIVER	4	8	1.6	7.5	175	12.8	30	1400	0.7	4.8	50	5.6	19.2	400	
2	INPUT MULTIPLEXER, 12 CHANNEL, 36 MHz	4	4	4.2	-	864	16.8	-	3456	3.4	-	500	13.6	-	2000	
3	BEAM SWITCHING MATRIX 4 x 4	12	12	1.8	-	192	21.6	-	2304	1.0	1.0	10	12	12	120	
4	REDUNDANCY SWITCH MATRIX, 4GHz, COAX	12	12	1.4	-	160	16.8	-	1920	0.7	-	25	8.4	-	300	
5	COMM CONTROL & INTERFACE	1	2	2	16	400	4	16	800	1.6	12	300	3.2	12	600	
6	SSPA, 4 GHz 4.0 WATT(with 2 VGAS)=4.4	48	60	0.7	18	48	42	864	2880	0.4	12.5	20	24.0	600	1200	
7	5/4 REDUNDANCY SWITCH MATRIX, 4 GHz COAX	12	12	1.4	-	160	16.8	-	1920	0.7	-	25	8.4	-	300	
8	OUTPUT MULTIPLEXER, 12 CHANNEL, 36 MHz	4	4	4.2	-	3600	16.8	-	14400	2.8	-	2400	11.2	-	9600	
9	HARMONIC FILTER,	48	48	0.3	-	40	14.4	-	1920	0.3	-	40	14.4	-	1920	
10	PRESELECT FILTER + ISOLATOR	4	4	0.5	-	64	2	-	256	0.5	-	64	2.0	-	256	
11	SPDT SWITCH, 6 GHz,(COAX) + 4 GHz	8	8	0.1	-	6	0.8	-	48	0.1	-	6	0.8	-	48	
12	TRANSFER SWITCH, 6 GHz (COAX) 4 GHz	4	4	0.15	-	12	0.6	-	48	0.15	-	12	0.6	-	48	
13																
14																
15	COAX SET	1	1	12.0	-	-	12.0	-		12	-	-	12	-		
16	WAVEGUIDE, SET	1	1	6.0	-	-	6.0	-	-	6	-	-	6	-		
17	HARNESS	1	1	20.0			20.0	-	-	20	-	-	20	-		
18	INTEGRATION HARDWARE, SET	1	1	5%	-	-	10.2	-	-	5%	-	-	7.1	-		
19	MARGIN REQ'D			10%	10%	5%	21.4	91	1568	15%	10%	5%	22.4	64.3	840	
20																
21	TOTAL TRANSPONDER						235	1001	32920				171.7	707.5	17,632	
22																
23																
24	ANTENNA REFLECTORS(DUAL GRIDDED)	1	1	70	-	-	70	-	-	53	-	-	53	-	-	
25	ANTENNA FEED VERTICAL	1	1	9	-	8640	9	-	8640	7.2	-	8000	7.2	-	8000	
26	ANTENNA FEED HORIZONTAL	1	1	9	-	8640	9		8640	7.2	-	8000	7.2	-	8000	
27	MARGIN REQUIRED			5%	-	10%	4.4		1728	10%	-	10%	6.7	-	1600	
28																
29	TOTAL ANTENNA						92.4	-	19008				74.1	-	17,600	
30																
31	TOTAL PAYLOAD						327.4	1001	51928				245.8	707.5	35,232	

Figure 5.4.2-2 C-Band FSS Antenna Coverage Requirement



neighboring beams Table 5.4.2-3 presents the antenna subsystem requirements.

Table 5.4.2-3

C-Band FSS Antenna Subsystem Requirements

Parameters	Requirements
Frequency	Transmit: 4 GHz band Receive: 6 GHz band
Polarization	Dual Linear
Coverage area	4 Beams cover CONUS
Cross-pol Isolation	30 dB
Co-pol Isolation	27 dB

The antenna will consist of two overlapped, gridded reflectors and two multihorn feed array systems, as depicted in Figure 5.4.2-3. The grids of the reflector are selected to run either in the horizontal or vertical direction for horizontal or vertical polarization. They are used to help lower cross-polarization energy that is produced by the field curvature of an asymetric paraboloid, as well as the cross-polarization radiated from the feed array. The cross-polarization isolation achieved is greater than 30 dB. In order to provide adequate sidelobe isolation between beams for frequency reuse, the size of reflector should be 15'. Figures 5.4.2-4 to 5.4.2-7 present the antenna radiation pattern for each beam.

The predicted edge-of-coverage antenna gains are given in Table 5.4.2-4.

Figure 5.4.2-3 C-Band FSS Antenna Configuration

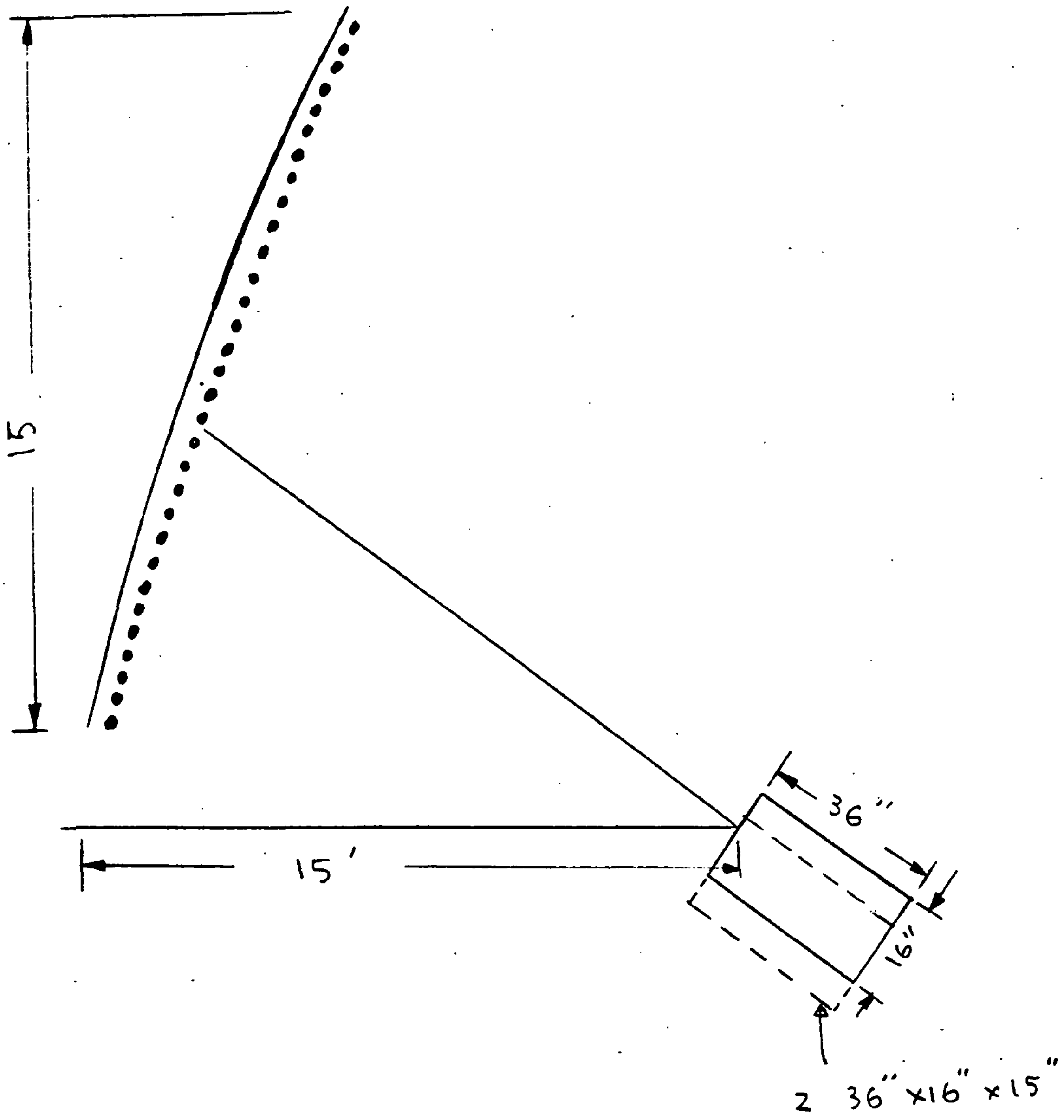


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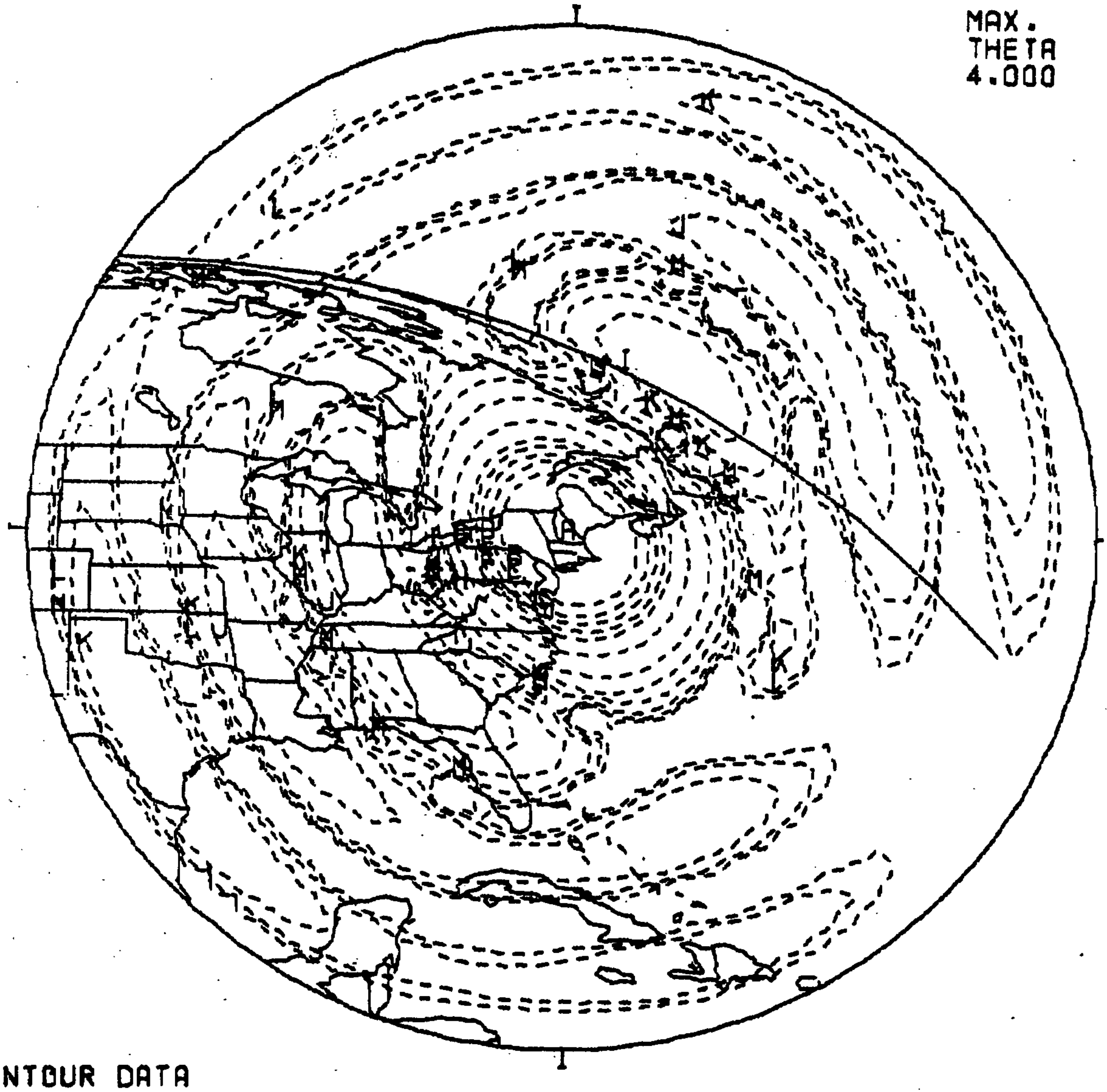
Figure 5.4.2-4 C-Band FSS Northeast Spot Antenna Pattern



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E	-6.000	
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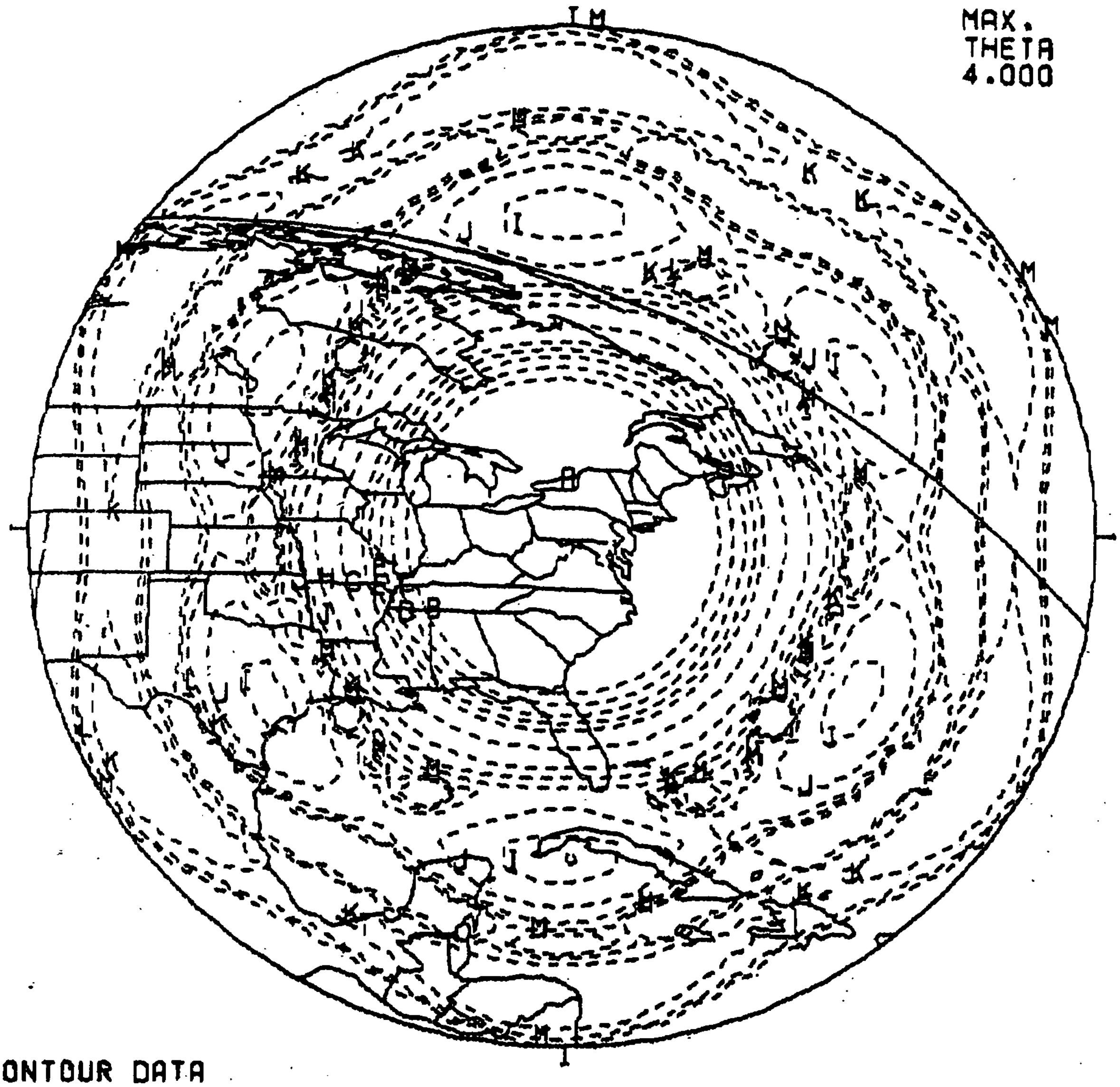
G	-10.000	
H	-15.000	
I	-20.000	
J	-25.000	
K	-30.000	
L	-33.000	
M	-35.000	

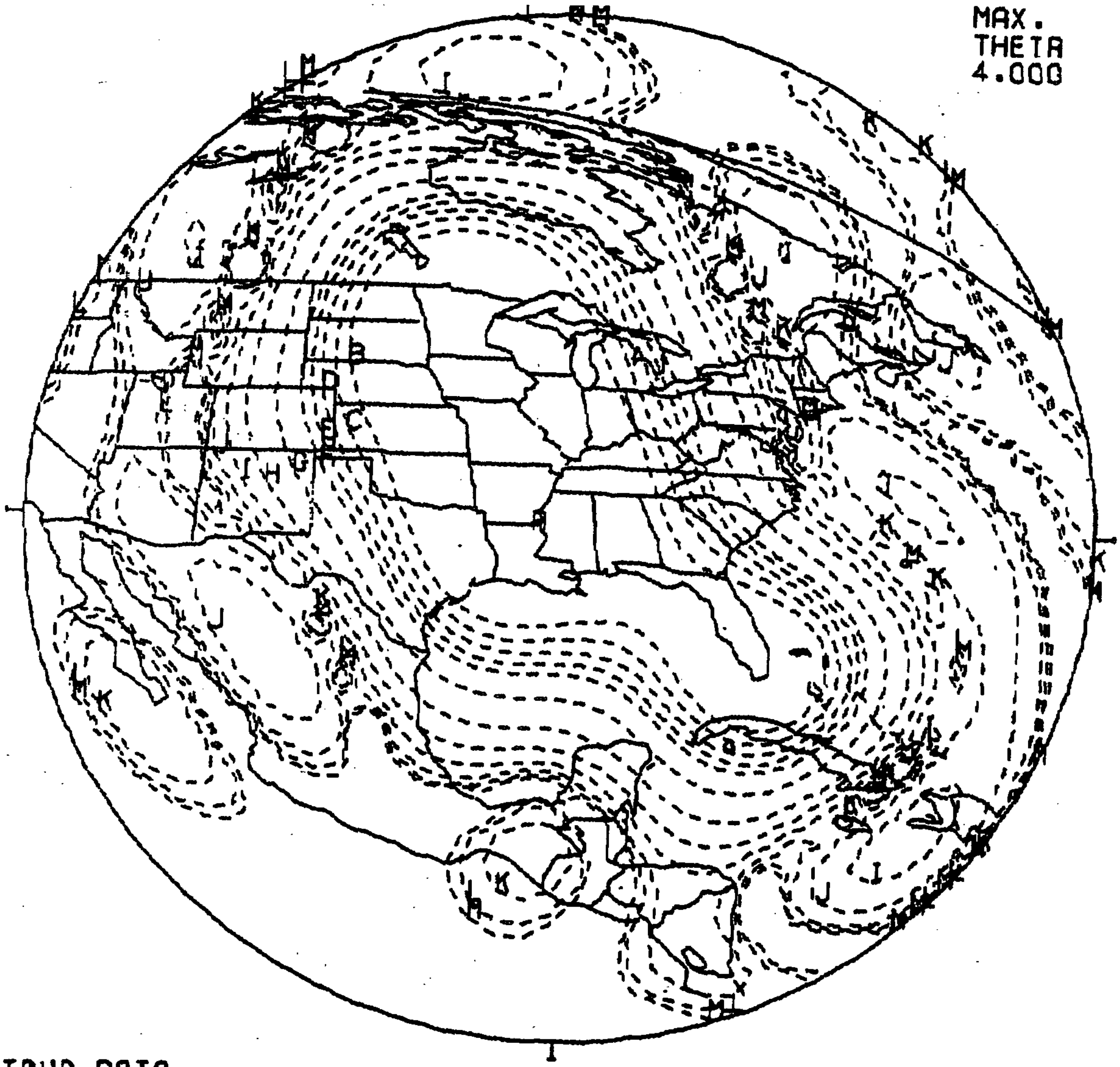
Figure 5.4.2-5 C-Band FSS Northeast Antenna Pattern



CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (34.5 dBi.)
C	-4.000
D	-5.000
E	-6.000
F	-7.000
G	-10.000
H	-15.000
I	-20.000
J	-25.000
K	-30.000
L	-33.000
M	-35.000

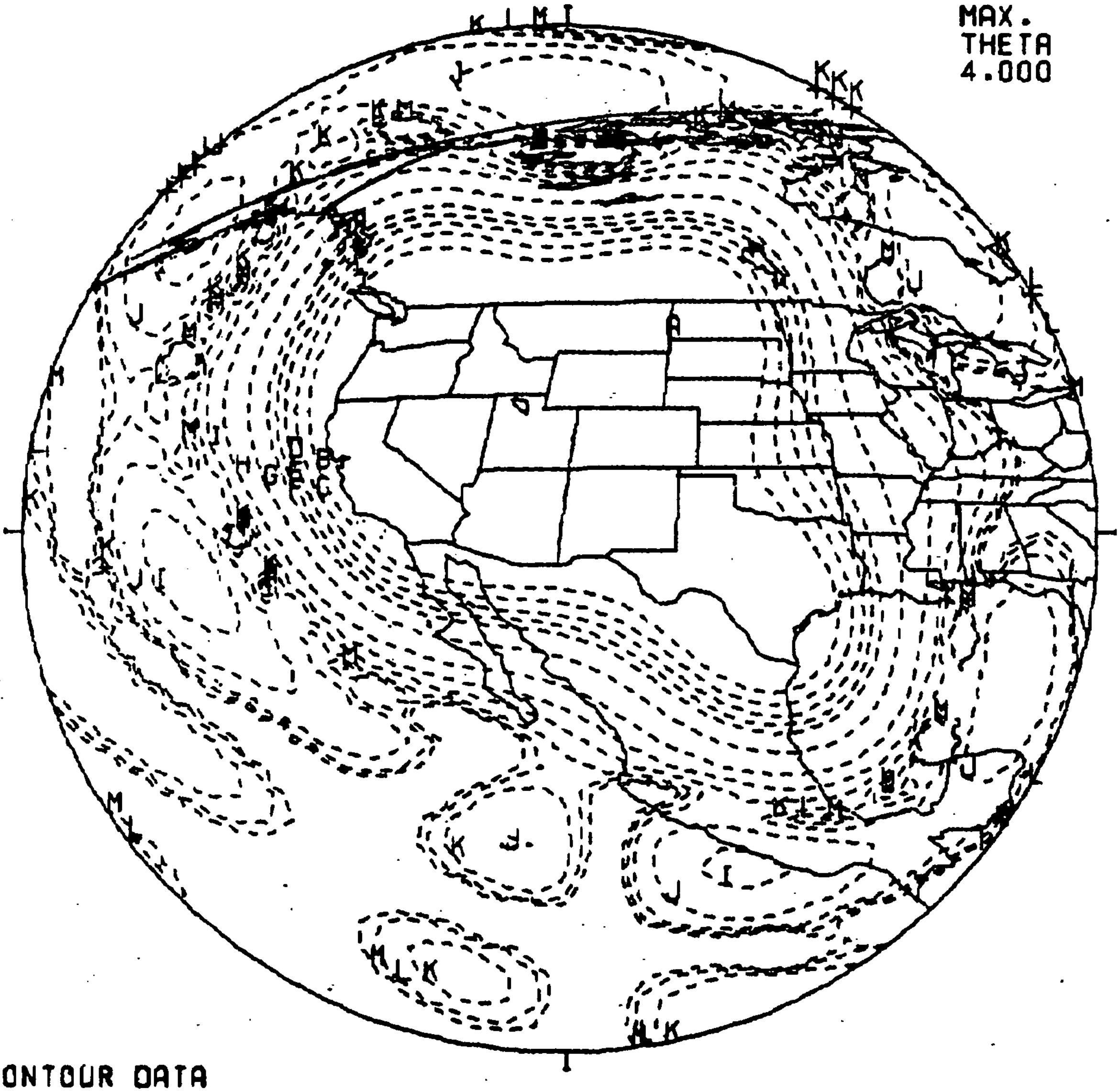
Figure 5.4.2-6 C-Band FSS Mideast Antenna Pattern



CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (30.1 dBi.)
C	-4.000
D	-5.000
E	-6.000
F	-7.000
G	-10.000
H	-15.000
I	-20.000
J	-25.000
K	-30.000
L	-33.000
M	-35.000

Figure 5.4.2-7 C-Band FSS Western Antenna Pattern



CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (28.9 dBi.)
C	-4.000
D	-5.000
E	-6.000
F	-7.000
G	-10.000
H	-15.000
I	-20.000
J	-25.000
K	-30.000
L	-33.000
M	-35.000

Table 5.4.2-4

C-Band FSS Predicted Antenna Gain

Coverage (Beam No.)	Gain (dBi)
1H	36.8
2V	34.5
3H	30.1
4V	28.9

Diurnal and seasonal solar variations can cause temperature extremes and gradients on the reflector surface, which, in turn, mechanically distort the reflector and degrade the electrical performance. Advanced Kevlar fiber composite materials are used for the structural elements of the reflector assembly to provide maximum thermal stability and structural strength with minimum weight. Each reflector is a Kevlar/epoxy laminate sandwich thin shell bonded in a backside or ring reinforcing structure. The sandwich shell supports the gridded system of wire. The largest existing dual gridded reflector that has even been built is 72". The proposed size, 15' of reflector aperture, presents challenging mechanical and electrical design problems to provide the required mechanical stiffness and strength using present state-of-art technology. In addition, a 15' reflector is the maximum size that can be accomodated in the space shuttle bay as an integral solid reflector. Therefore, in order to stow the reflector in the shuttle bay, it will have to be canted to achieve the elliptical shape. An unfurable reflector is not practical, even in 1994 technology, because of the thermal distortion, manufactoring tolerances, and the distortion of the straight grids on the reflector surface.

Table 5.4.2-5 summarizes the assessment of the critical technology items for this subsystem.

Table 5.4.2-5

Assessment Of The Level Of Risk Of Critical Technology Items

Item	Low Risk	High Risk
Cross-Pol Isolation	27 dB	30 dB
Reflector development	Need development	Slight
Weight (Reflector)	70 kg	20% less

5.4.2.3 C-Band Transponder Subsystem, Fixed Satellite Service

The C-Band transponder subsystem consists of four independent, 12 channel transponders, and hence has a total capacity of 48 channels, each having a bandwidth of 36 MHz. The four transponders utilize the same 500 MHz FSS band, having an uplink at 6 GHz and a downlink at 4 GHz.

Each of the four 6 GHz inputs from the antenna feed assembly is filtered by an input preselector and then amplified and downconverted to 4 GHz by the receiver. The 500 MHz IF band is subdivided by an input multiplexer into twelve 36 MHz channels. The filters of the input multiplexer also provide the required narrow band receive filtering responses.

Twelve 4x4 switch matrices enable signals in any uplink channel of one transponder to be connected to the same channel in any of the other three transponders.

The channels are individually amplified by up to 8.5 watt SSPAs, which contain one or more variable gain amplifiers. The latter permit automatic accommodation of varying uplink levels, using an AGC loop, and SSPA back off via ground control. The outputs of the SSPAs in each set of twelve channels are combined in a twelve channel output multiplexer which also provides the required narrow band transmit filtering responses. The downlink signals are further filtered by harmonic/bandpass filters prior to transmission from the transmit antenna feed assembly. The transponder subsystem features four for two receiver redundancy and five for four SSPA redundancy.

5.4.2.3.1 6/4 GHz Receiver

See 5.2.2.3.1.

5.4.2.3.2 4GHz Input Multiplexer

See 5.2.2.3.2.

5.4.2.3.3 RF Switch Matrix

See 5.2.3.3.3.

5.4.2.3.4 4GHz 8.5 watt SSPA

See 5.2.2.3.3.

5.4.2.3.5 4 GHz Output Multiplexer

See 5.2.2.3.4.

5.4.2.3.6 Pre-Select and Harmonic Filters

See 5.2.2.3.5.

5.4.3 Ka-Band FSS Payload

This payload is identical to the Ka-Band FSS payload described in Scenario II. See Section 5.2.3 for a detailed description.

5.4.4 Ka-Band Scan Payload

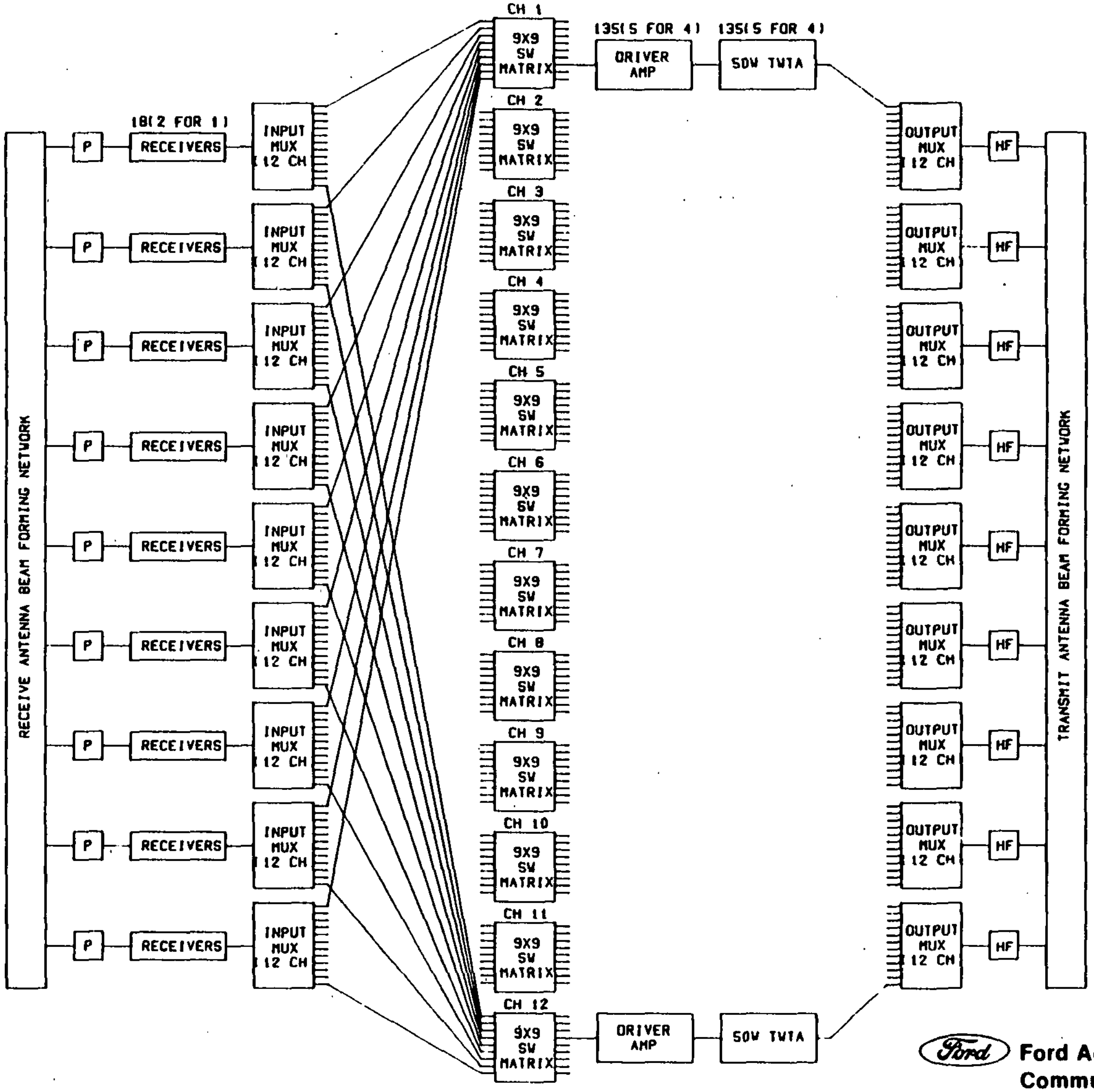
This payload is identical to the Ka-Band Scan payload described in Scenario II. See Section 5.2.4 for a detailed description.

5.4.5 Ku-Band FSS Payload

5.4.5.1 Overview of Ku-Band FSS Payload

This payload triples the capacity of the current day Ku-band payloads by using shaped beam technology. The system uses horizontal and vertical linear polarization isolation for 2 times reuse, and spatial isolation of shaped beams to achieve 9 times reuse with respect to CONUS coverage. The beam coverages use eight beams to cover CONUS and a ninth beam doubling the reuse in the New York/New Jersey area of CONUS. The payload features a dual gridded reflector assembly to obtain the polarization purity required for the reuse. Each of the transponder channels is of straight-forward design, and although electronic switches are used for routing, it is only for traffic pattern changes, and only used on a limited basis. It does, however, also provide the flexibility to use the system as a SS-TDMA digital modulation system if so desired. Figure 5.4.5-1 is a block diagram of the Ku-Band FSS payload for Scenario V showing the breakdown to the component level. Table 5.4.5-1 shows the projected antenna gain and the power applifier power levels necessary to maintain the required 39 dBW EIRP consistent with the WARC required power flux density (PFD) of - 138.0 dBw/m^2 for Region 2. The nine beam coverage areas were developed in Section 4 to the SMSA level and the covered SMSA's converted into lattitude and longitude coordinates for development of the antenna. Appendix I-1.2 contains the coordinates for each beam coverage area.

Figure 5.4.5-1 Ku-Band FSS. Scenario V



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Ford Aerospace &
Communications Corporation

Table 5.4.5-1

Power Requirements For Ku-Band FSS, Scenario V
(Single Carrier Operation)

EIRP= 39.0 dBW
PFD= -138.0 dBW/m^2

Beam	G, dB	P, dBW	P, W
1	39.9	0.6	1.148
2	40.1	0.4	1.096
3	40.9	-0.4	0.912
4	47.4	-6.9	0.204
5	39.7	0.8	1.202
6	33.4	7.1	5.129
7	35.8	4.7	2.951
8	36.5	4.0	2.512
9	39.0	1.5	1.413

Table 5.4.5-2 shows the estimated weight, power, and volume for low risk (emerging) technology and high risk (projected) technology for the transponder and antenna. Also included in the estimates are the coax, waveguide, and harness interconnects, plus an estimate for integration hardware to put the components together and provide necessary brackets for support and mounting. This does not include any structure or satellite mounting hardware, such as between the feed amd reflector.

5.4.5.2 Ku-Band FS Antenna Subsytem

The Ku-Band FSS antenna subsystem provides transmisssion at 11 GHz and reception at 14 GHz of dually linear-polarized communications signals. The purpose of the communication antenna is to provide a beams to cover CONUS as shown in Figure 5.4.5-2. The

Table 5.4.5-2

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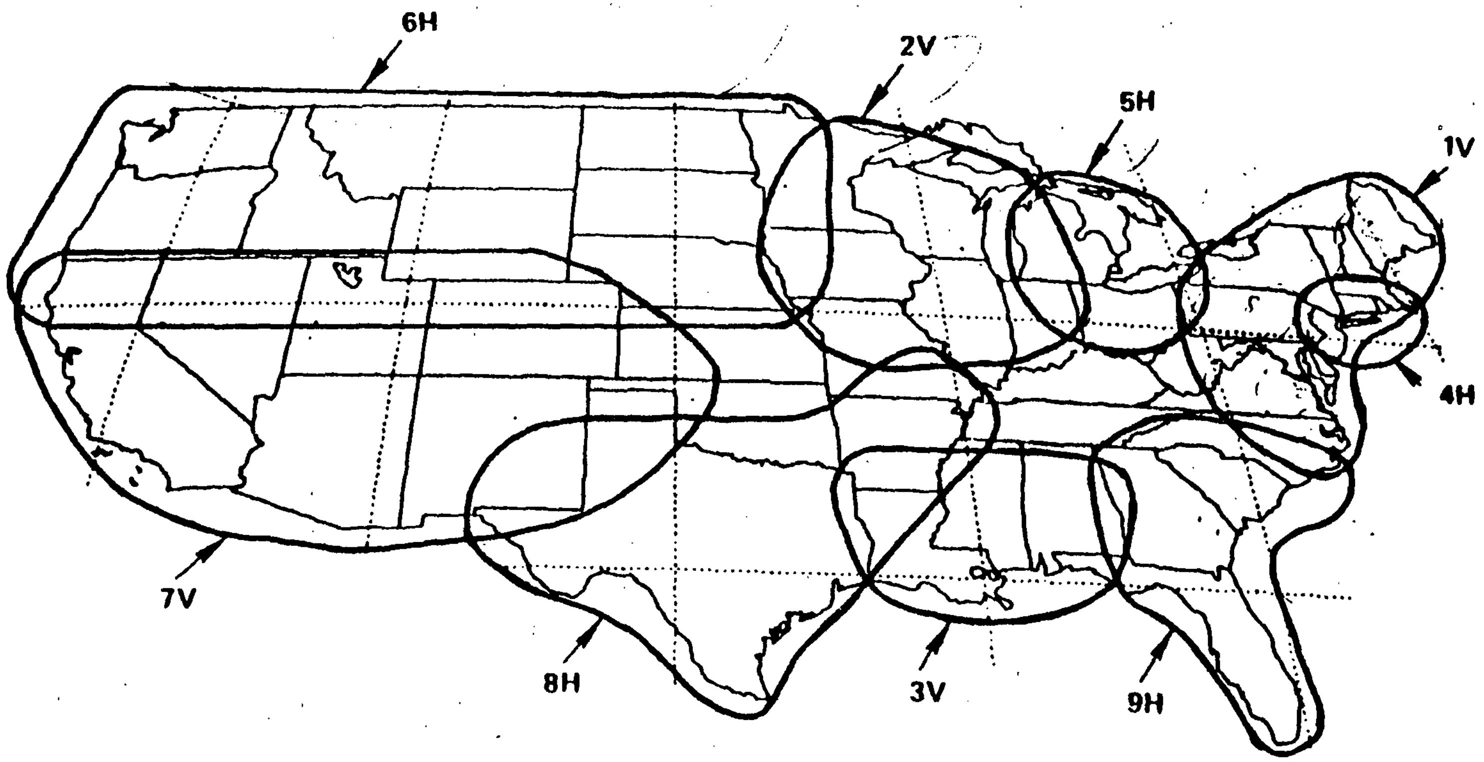
Scenario V, VI- A & B - Payload Summary

Ku-Band FSS

	ITEM	P/L QTY REQ'D	REQ. QTY REQ'D	LOW RISK TECHNOLOGY						HIGH RISK TECHNOLOGY						COMMENTS
				UNIT			PAYLOAD			UNIT			PAYLOAD			
				WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	
1	14/11 GHz RECEIVER	9	18	1.8	9	175	32.4	81	3150	0.9	6.0	50	16.2	54	900	
2	INPUTMULTIPLEXER, 12 CHANNEL, 11GHz 36 GHz	9	9	5.4	-	2304	48.6		20736	3.6	-	1536	32.4	-	13824	
3	BEAM SWITCH MATRIX 9x9	12	12	1.7	8.1	113	20.4	97.2	1356	0.7	5.4	40	8.4	64.8	480	
4	5/4 REDUNDANCY SWITCH MATRIX, 11GHz, COAX	27	27	1.4		160	37.8		4320	0.7	-	25	18.9	-	675	
5	COMM CONTROL & INTERFACE	1	2	2	16	400	4	16	800	1.6	12	300	3.2	12	600	
6	SSPA, 11GHz, 2 WATT(+2VGAS)	108	135	1.4	8	48	184	864	6480	0.5	5.4	40	67.5	583.2	5400	
7	5/4 REDUNDANCY SWITCH MATRIX, 11 GHz W/G(RING)	27	27	1.4	-	200	37.8		5400	1.0	-	200	27	-	5400	
8	OUTPUT MULTIPLEXER, 12CHANNEL, 36 MHz	9	9	6.0	-	1536	54.0		13824	2.0	-	512	18	-	4608	
9	HARMONIC FILTER	9	9	0.1	-	13.5	0.9		121.5	0.1	-	13.5	0.9	-	121.5	
10	PRESELECT FILTER	9	9	0.1	-	13.5	0.9		121.5	0.1	-	13.5	0.9	-	121.5	
11	SPDT SWITCH, W/G 14 GHz	9	9	0.15	-	16	1.35	-	144	0.15	-	16	1.35	-	144	
12	TRANSFER SWITCH, W/G, 14 GHz	4	4	0.18	-	16	0.72	-	64	0.18	-	16	0.72	-	64	
13	TRANSFER SWITCH, COAX	4	4	0.14	-	12	0.56	-	48	0.14	-	12	0.56	-	48	
14	SPDT SWITCH, COAX 11 GHz	9	9	0.08	-	6	0.72	-	54	0.08	-	6	0.72	-	54	
15	COAX, SET	1	1	18	-		18	-		18	-	-	18	-	-	
16	WAVEGUIDE, SET	1	1	54	-		54	-		54	-	-	54	-	-	
17	HARNESS	1	1	45	-		45	-		45	-	-	45	-	-	
18	INTEGRATION HARDWARE	1	1	5%	-		27.1	-		5%	-	-	15.7	-	-	
19	MARGIN REQ'D.			10%	10%	5%	56.8	106	2831	10%	10%	10%	32.9	71	3244	
20																
21	TOTAL TRANSPONDER						625	1164	59450				362.4	785	35684	
22																
23																
24	ANTENNA REFLECTOR (4.3M dual gridded)	1	1	70	-	-	70	-	-	56	-	-	56	-	-	
25	VERTICAL FEED NETWORK	1	1	50	-	17280	50	-	17280	45	-	15552	45	-	15552	
26	HORIZONTAL FEED NETWORK	1	1	50	-	17280	50	-	17280	45	-	15552	45	-	15552	
27	MARGIN REQ'D.			10%		10%	17	-	3456	10	-	10%	14.6	-	3110	
28																
29	TOTAL ANTENNA						187	-	38016				160.6	-	34214	
30																
31																
32	TOTAL PAYLOAD						812	1164	97466				523	785	69898	

Figure 5.4.5-2 Ku-Band FSS Antenna Coverage Requirement



combination of co-polarization and cross-polarization isolation among these beams provides the required interbeam isolation for this system. Table 5.4.5-3 summarizes the antenna subsystem requirements.

Table 5.4.5-3

Ku-Band FSS Antenna Subsystem Requirements

Parameters	Requirements
Frequency	Transmit: 11 GHz Band Receive: 14 GHz band
Polarization	Dual Linear
Coverage area	9 Beams cover CONUS
Cross-pol Isolation	30 dB
Co-pol Isolation	27 dB

The antenna will consist of two overlapped, gridded reflectors and two multibeam feed array systems as depicted in Figure 5.4.5-3. The grids of the reflector are selected to run either in the horizontal or vertical direction for horizontal or vertical polarization. They are used to help lower cross-polarization energy that is produced by the field curvature of the asymetric paraboloid, as well as the cross-polarization radiated from the feed array. The cross-polarization isolation achieved is greater than 30 dB. In order to provide adequate sidelobe isolation between the east and west half CONUS beams for frequency reuse, the size of reflector should be 15'. Figures 5.4.5-4 to 5.4.5-4 to 5.4.5-12 present the antenna radiation patterns for the nine beams.

Figure 5.4.5-3 Ku-Band FSS Antenna Configuration

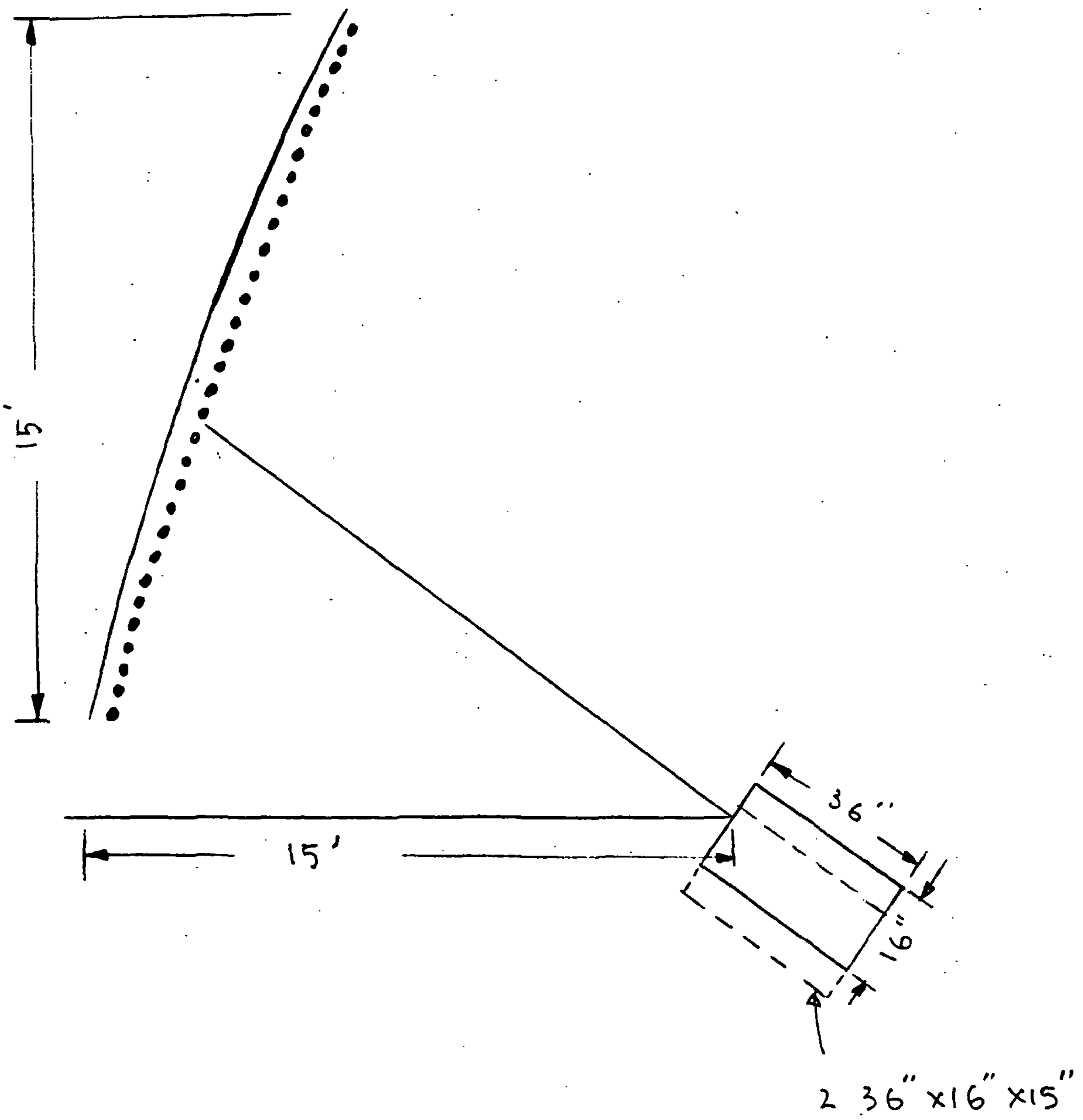
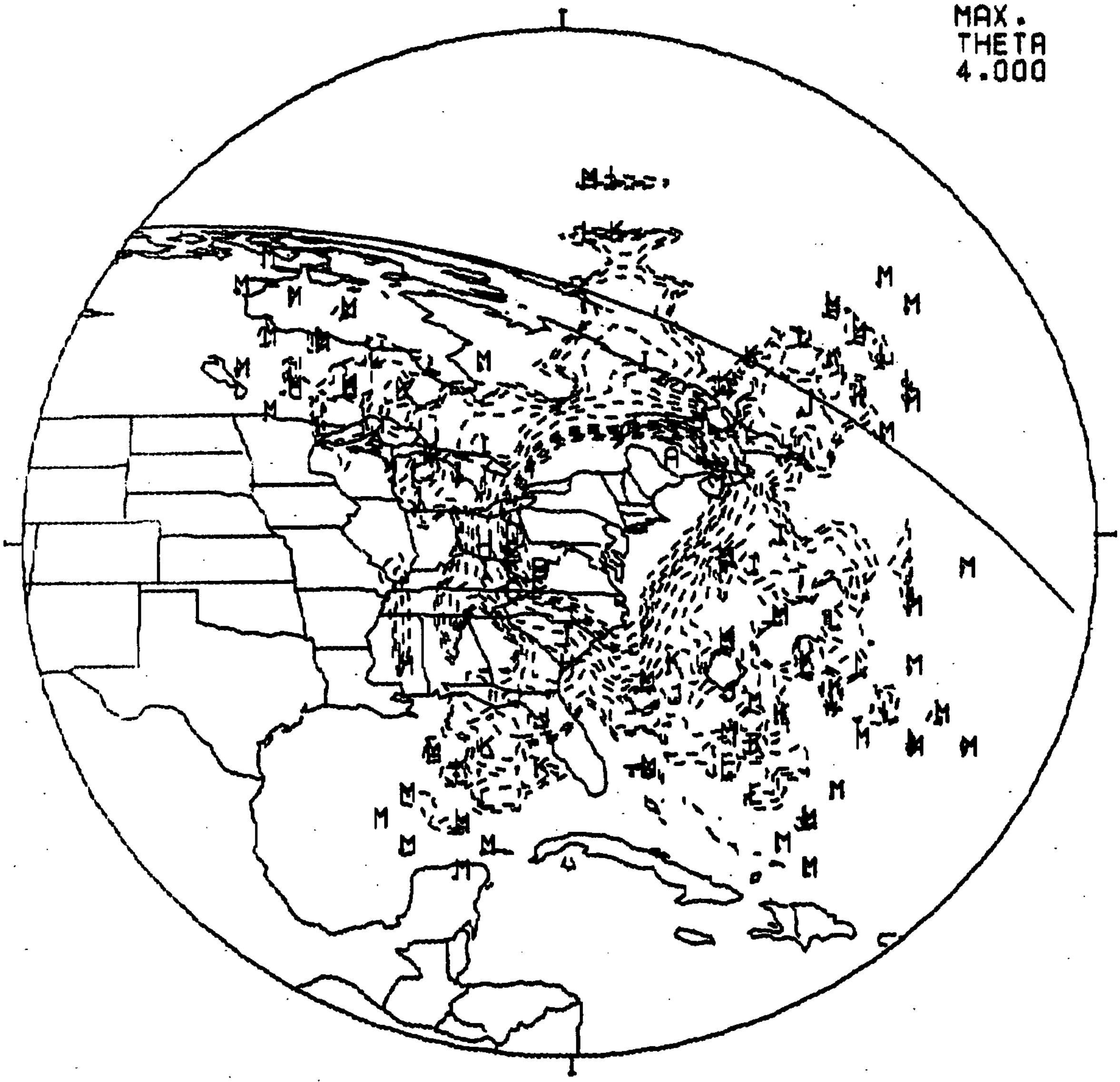


Figure 5.4.5-4 Ku-Band FSS Beam 1V Antenna Pattern

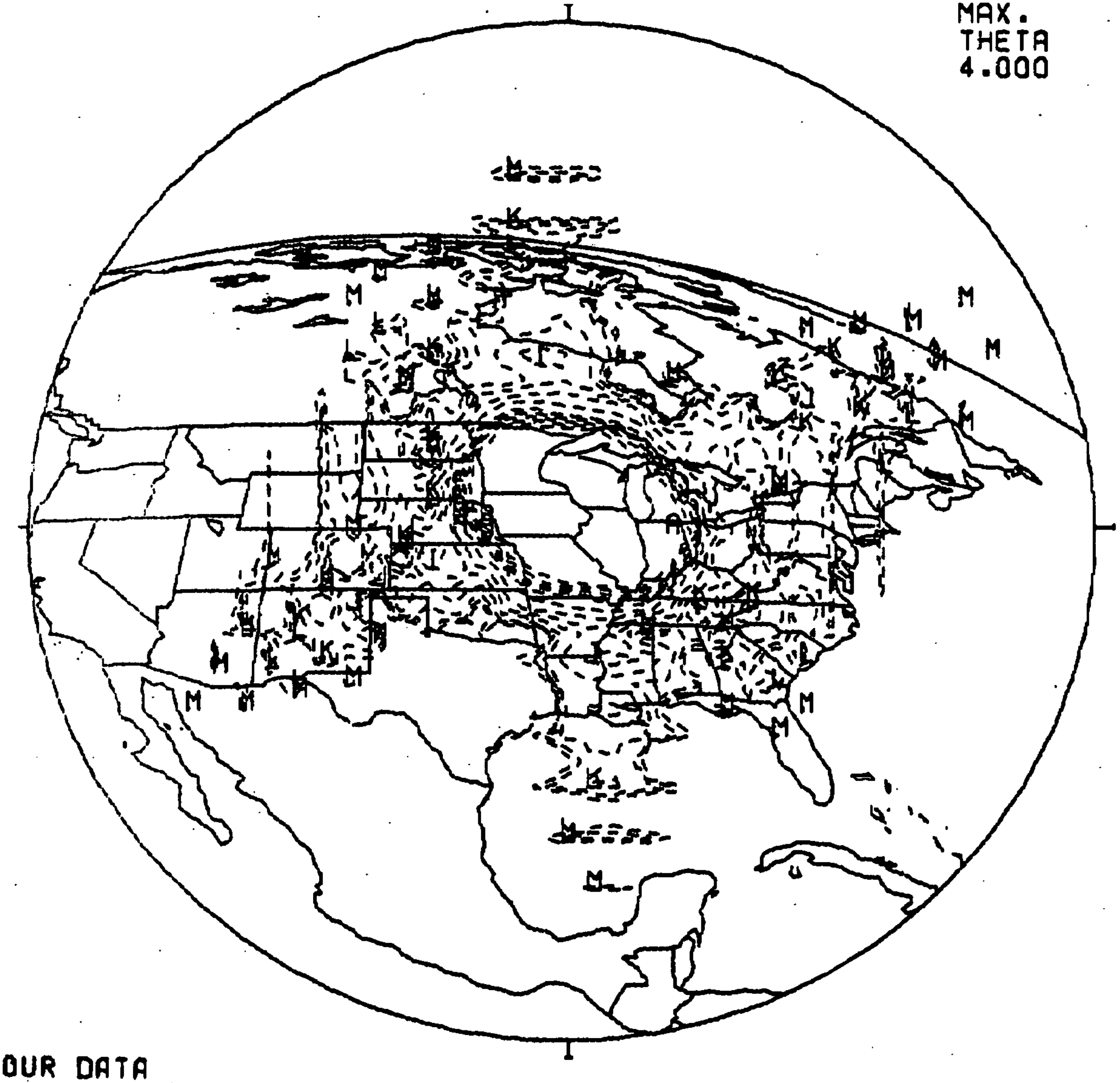


CONTOUR DATA

BEAM 1V

SYMBOL	LEVEL
A	0.000
B	-3.000 (39.9 dBi)
C	-4.000
D	-5.000
E	-6.000
F	-7.000
G	-10.000
H	-15.000
I	-20.000
J	-25.000
K	-30.000
L	-33.000
M	-35.000

Figure 5.4.5-5 Ku-Band FSS Beam 2V Antenna Pattern

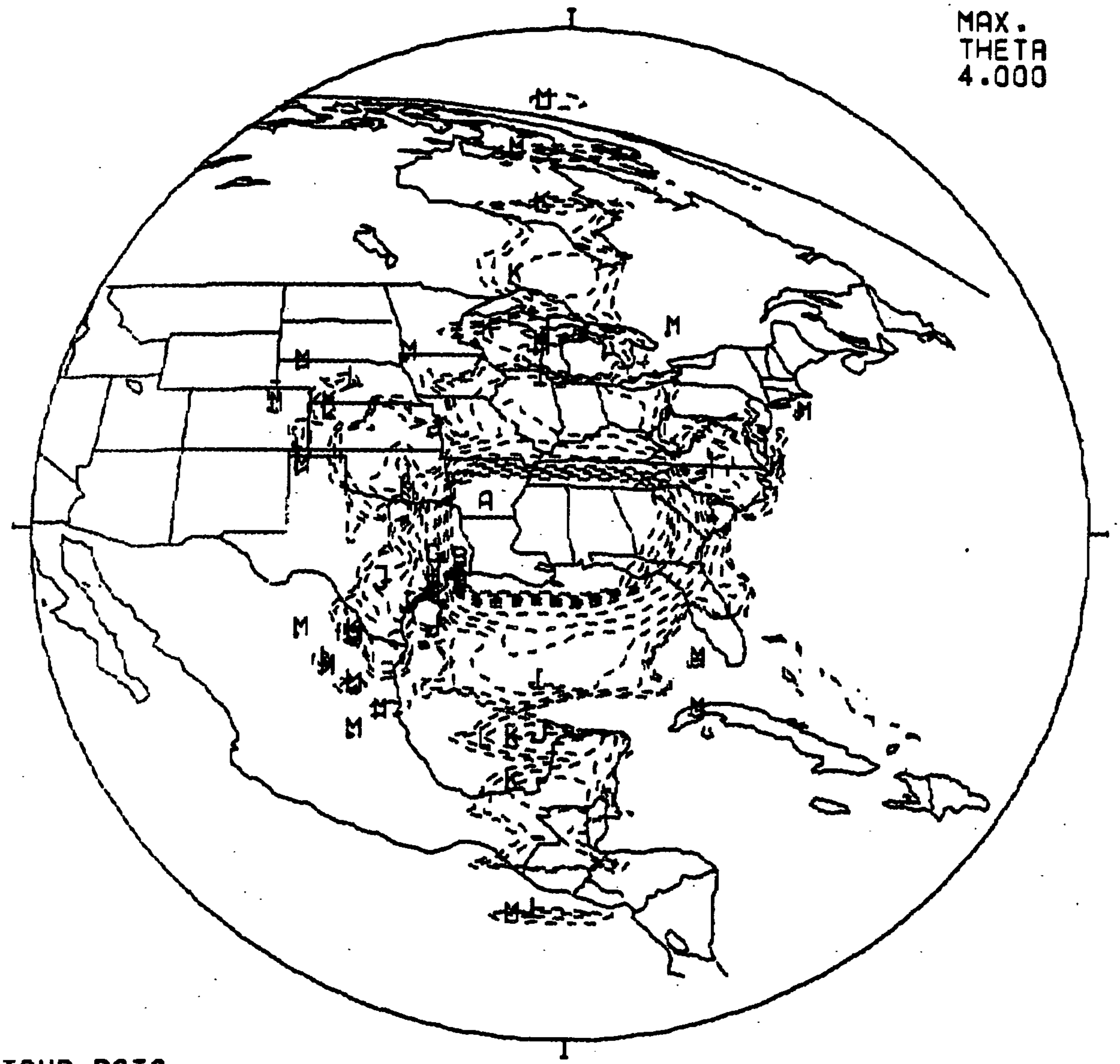


CONTOUR DATA

SYMBOL	LEVEL	
A	0.000	
B	-3.000	(40.1 dBi)
C	-4.000	
D	-5.000	
E	-6.000	
F	-7.000	
G	-10.000	
H	-15.000	
I	-20.000	
J	-25.000	
K	-30.000	
L	-33.000	
M	-35.000	

BEAM 2V

Figure 5.4.5-6 Ku-Band FSS Beam 3V Antenna Pattern

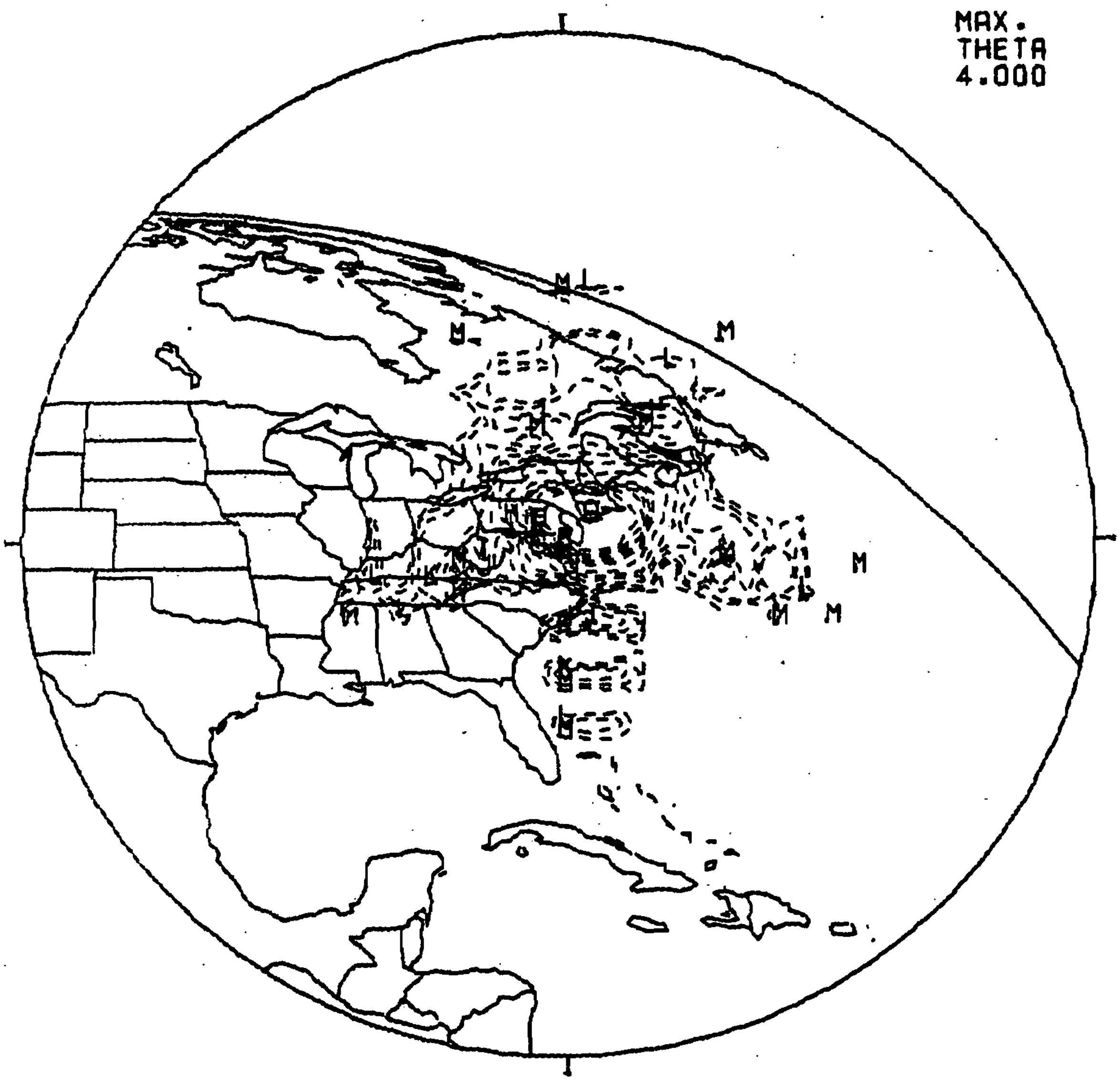


CONTOUR DATA

SYMBOL	LEVEL	
A	0.000	
B	-3.000	(40.9 dBi)
C	-4.000	
D	-5.000	
E	-6.000	
F	-7.000	
G	-10.000	
H	-15.000	
I	-20.000	
J	-25.000	
K	-30.000	
L	-33.000	
M	-35.000	

BEAM 3V

Figure 5.4.5-7 Ku-Band FSS Beam 4H Antenna Pattern

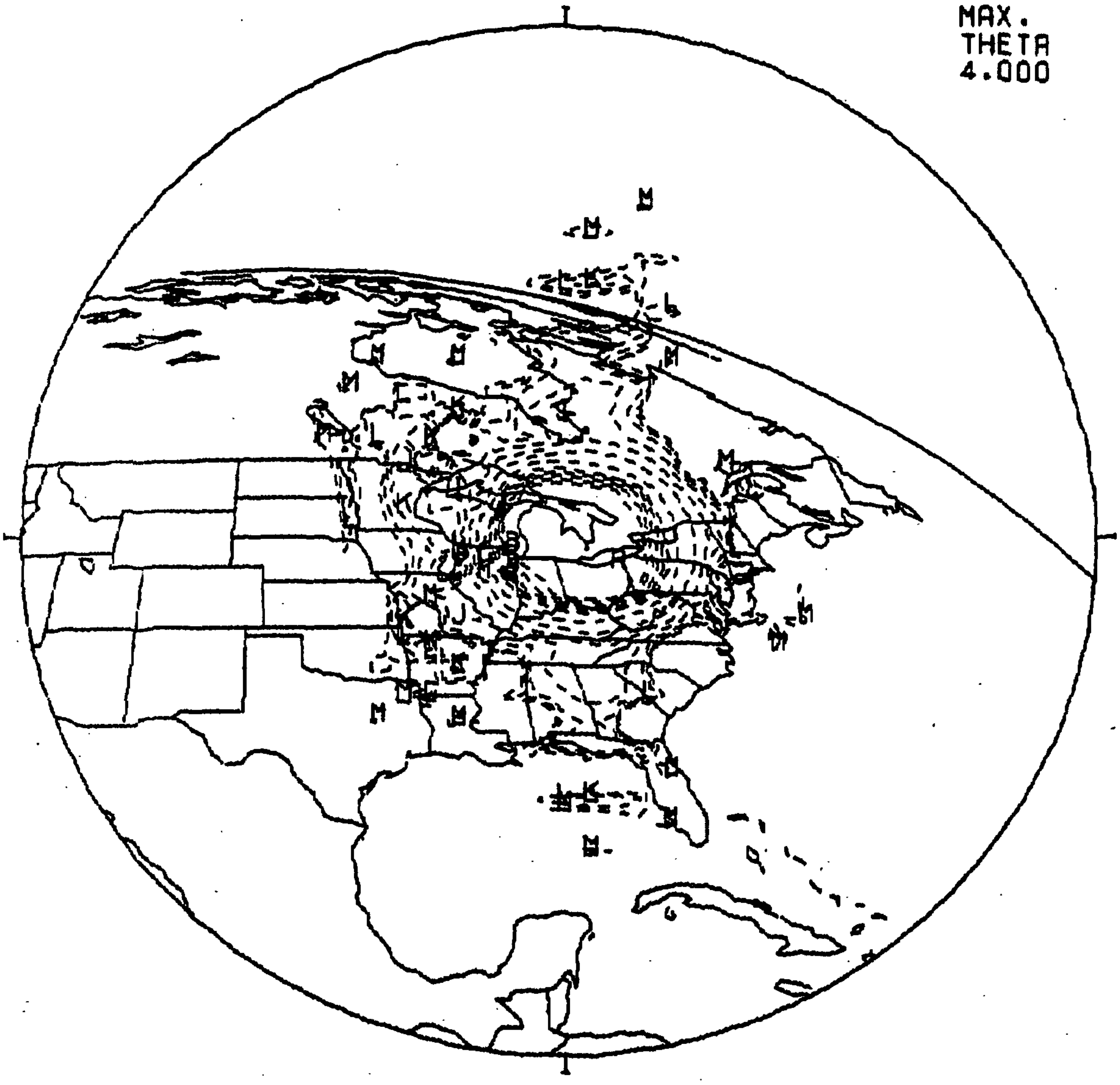


CONTOUR DATA

BEAM 4H

SYMBOL	LEVEL
A	0.000
B	-3.000 (47.4 dBi)
C	-4.000
D	-5.000
E	-6.000
F	-7.000
G	-10.000
H	-15.000
I	-20.000
J	-25.000
K	-30.000
L	-33.000
M	-35.000

Figure 5.4.5-8 Ku-Band FSS Beam 5H Antenna Pattern

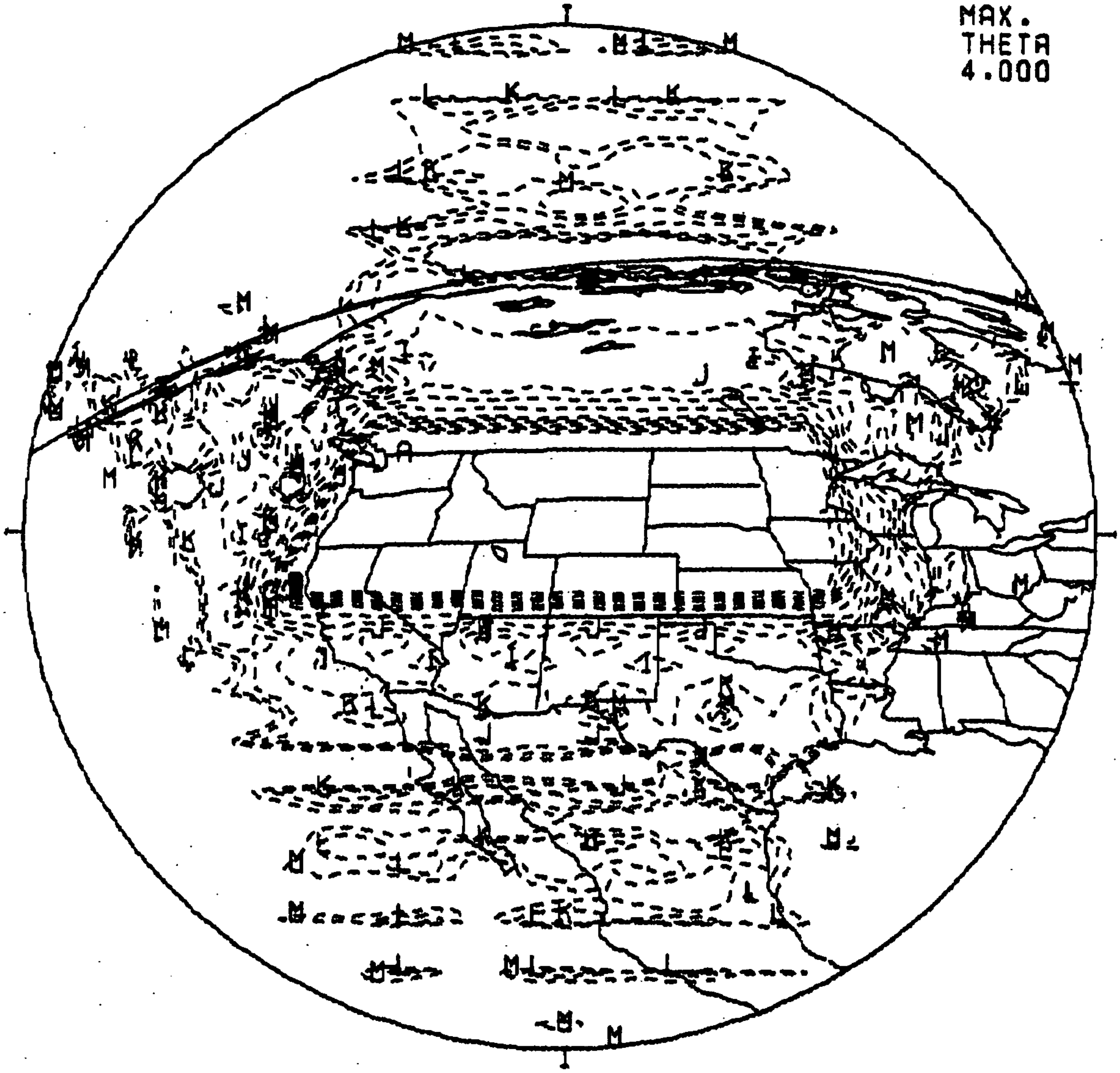


CONTOUR DATA

SYMBOL	LEVEL	
A	0.000	
B	-3.000	(39.7 dBi)
C	-4.000	
D	-5.000	
E	-6.000	
F	-7.000	
G	-10.000	
H	-15.000	
I	-20.000	
J	-25.000	
K	-30.000	
L	-33.000	
M	-35.000	

BEAM 5H

Figure 5.4.5-9 Ku-Band FSS Beam 6H Antenna Pattern

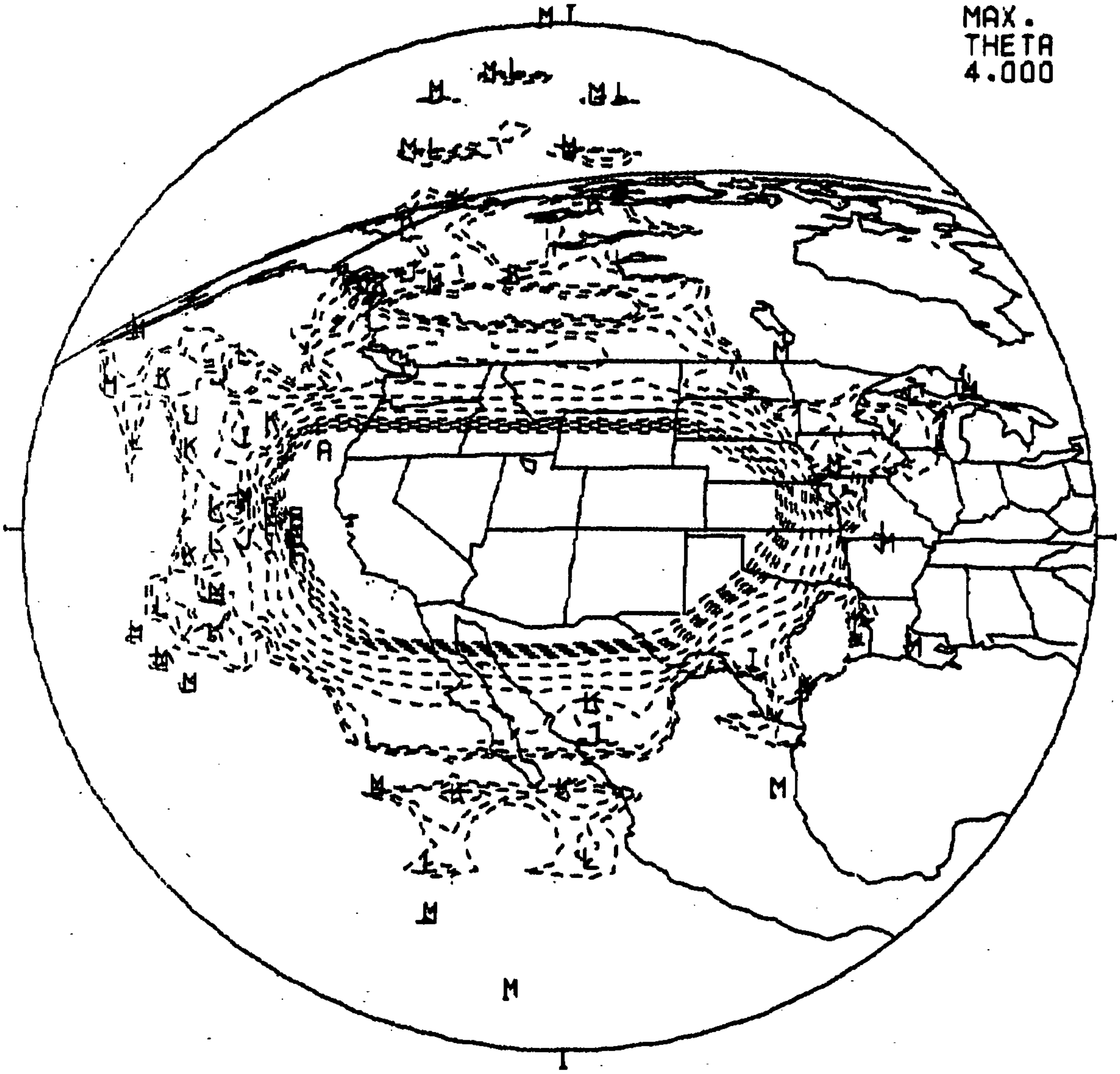


BEAM 6H

CONTOUR DATA

SYMBOL	LEVEL	
A	0.000	
B	-3.000	(33.4 dBi)
C	-4.000	
D	-5.000	
E	-6.000	
F	-7.000	
G	-10.000	
H	-15.000	
I	-20.000	
J	-25.000	
K	-30.000	
L	-33.000	
M	-35.000	

Figure 5.4.5-10 Ku-Band FSS Beam 7V Antenna Pattern

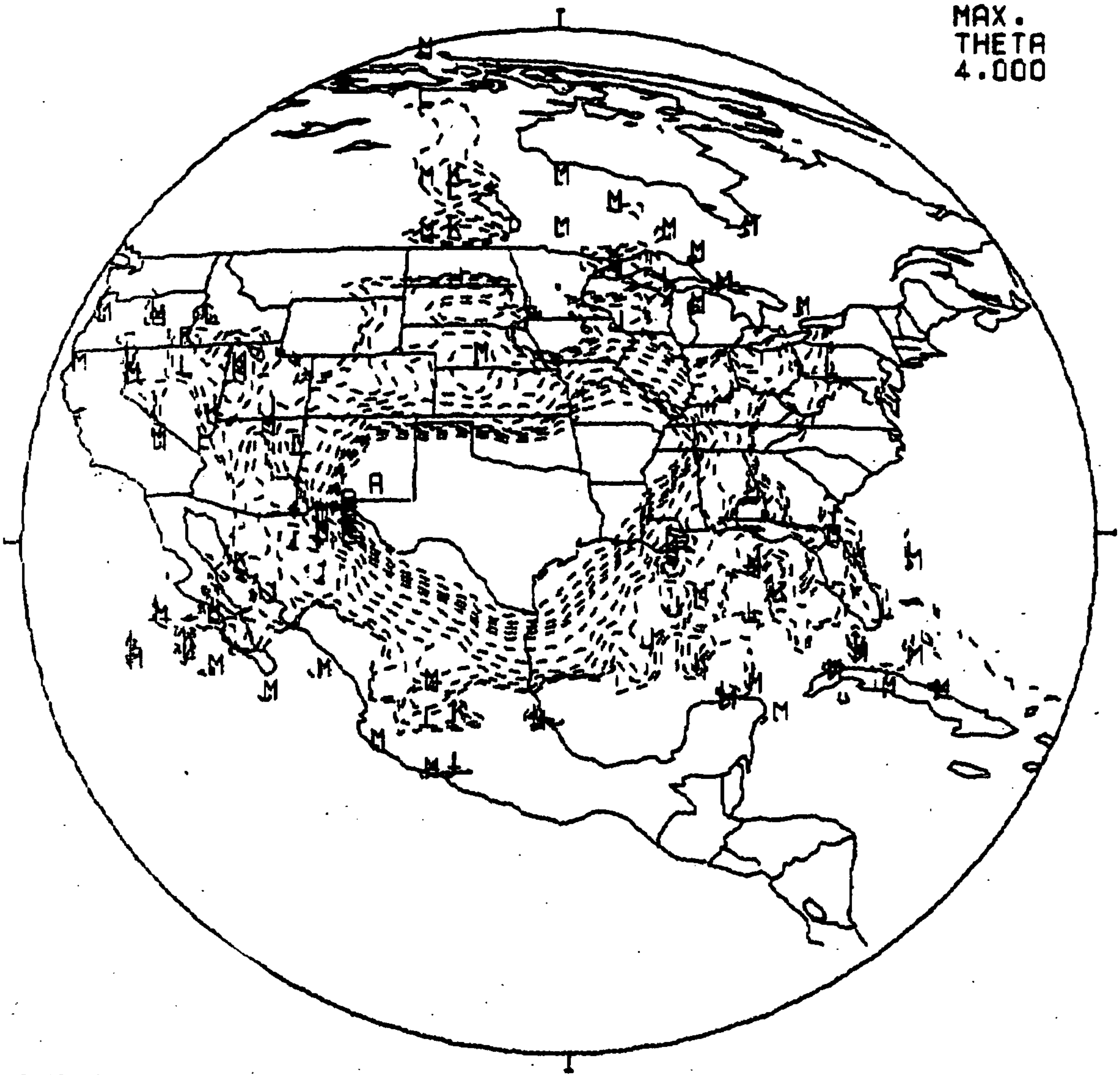


BEAM 7V

CONTOUR DATA

SYMBOL	LEVEL	
A	0.000	
B	-3.000	(35.8 dBi)
C	-4.000	
D	-5.000	
E	-6.000	
F	-7.000	
G	-10.000	
H	-15.000	
I	-20.000	
J	-25.000	
K	-30.000	
L	-33.000	
M	-35.000	

Figure 5.4.5-11 Ku-Band FSS Beam 8H Antenna Pattern

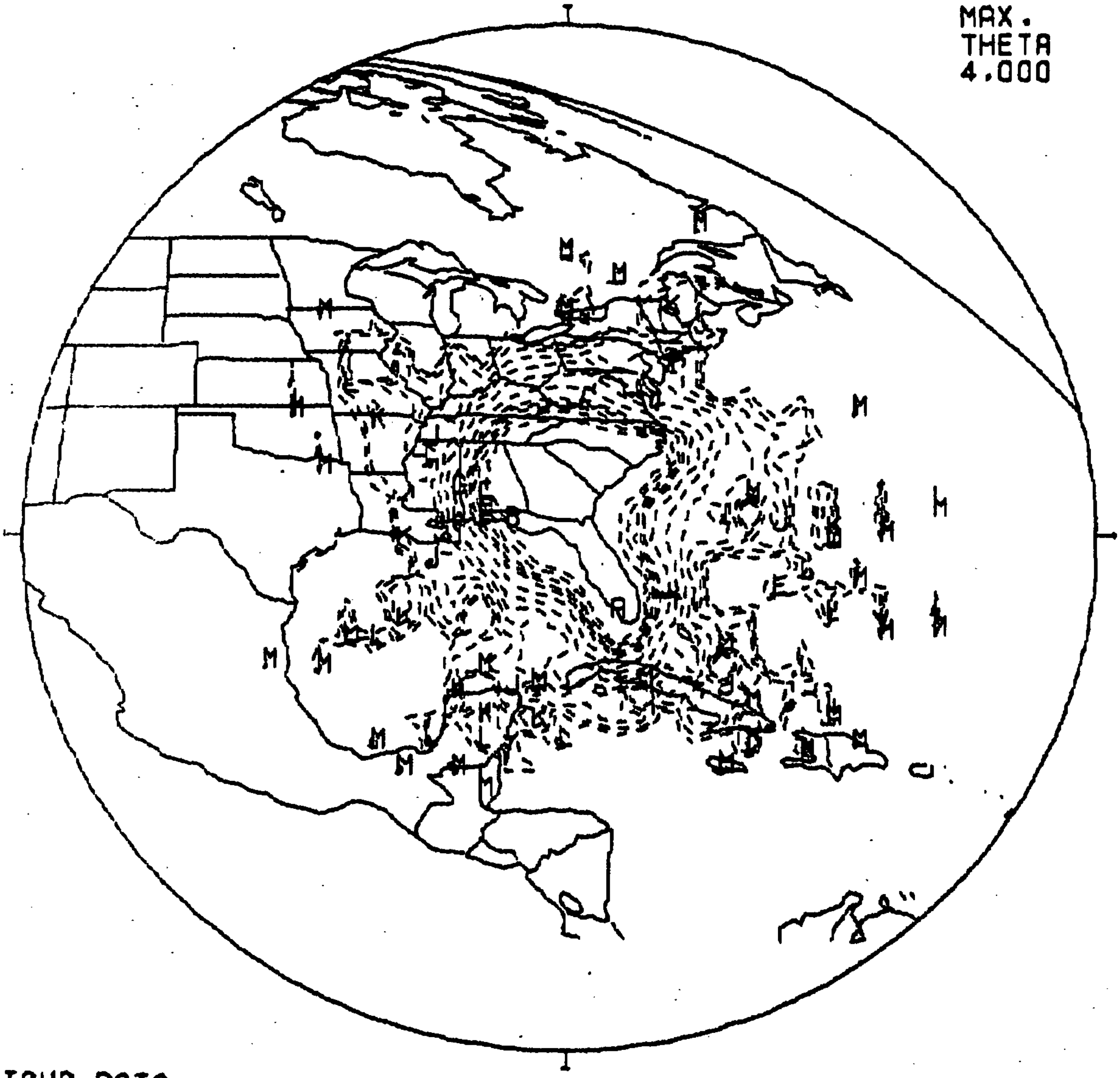


CONTOUR DATA

BEAM 8H

SYMBOL	LEVEL	
A	0.000	
B	-3.000	(36.5 dBi)
C	-4.000	
D	-5.000	
E	-6.000	
F	-7.000	
G	-10.000	
H	-15.000	
I	-20.000	
J	-25.000	
K	-30.000	
L	-33.000	
M	-35.000	

Figure 5.4.5-12 Ku-Band FSS Beam 9H Antenna Pattern



CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (39.0 dBi)
C	-4.000
D	-5.000
E	-6.000
F	-7.000
G	-10.000
H	-15.000
I	-20.000
J	-25.000
K	-30.000
L	-33.000
M	-35.000

BEAM 9H

The predicted edge-of-coverage antenna gains are given in Table 5.4.5-4.

Table 5.4.5-4

Ku-Band FSS Predicted Antenna Gain

Coverage Beam No.	GAin dBi
1	39.9
2	40.1
3	40.9
4	47.4
5	39.7
6	33.4
7	35.8
8	36.5
9	39

Diurnal and seasonal solar variations can cause temperature extremes and gradients on the reflector surface, which, in turn, mechanically distort the reflector and degrade the electrical performance. Advanced Kevlar fiber composite materials are used for the structural elements of the reflector assembly to provide maximum thermal stability and structural strength with minimum weight. Each reflector is a Kevlar/epoxy laminate sandwich thin shell bonded in a backside or ring reinforcing structure. The sandwich shell supports the gridded system of wire. The largest existing dual gridded reflector that has even been built is 72". The proposed size, 15' of reflector aperture, presents a challenging mechanical and electrical design problem to provide the required mechanical stiffness and strength using present state-of-art technology. In addition, a 15' reflector is the maximum size that can be accomodated in the space shuttle bay with an integral solid reflector. Therefore, in order to stow the reflector in the shuttle bay, the reflector will have to be canted to achieve the elliptical shape. An unfurlable reflector is not practical, even in 1994 technology, because of the thermal distortion, manufactoring tolerances, and the distortion of the straight grids on the reflector surface.

Table 5.4.5-5 summarizes the assessment of the critical technology items for this subsystem.

Table 5.4.5-5

Assessment Of The Level Of Risk Of Critical Technology Items

Item	Low Risk	High Risk
Cross-Pol isolation 30 dB		27 dB
Reflector	Needs development	Slight development
Weight (Reflector)	70 kg	20% less

5.4.5.3 Ku-Band Transponder Subsystem, Fixed Satellite Service

The Ku-Band Transponder Subsystem consists of nine, 12 channel transponders, and hence has a total capacity of 108 channels, each having a bandwidth of 36 MHz. The nine transponders utilize the same 500 MHz FSS band, having an uplink at 14 GHz and downlink at 11 GHz. Each of the nine 14 Ghz inputs from the receive antenna beam forming network is filtered by an input preselector, then amplified and down converted to 11 GHz by the receiver. The receiver output is fed to an input multiplexer which subdivides the 500 MHz IF band into twelve, 36 MHz channels, while also providing the required narrow band receive filtering responses.

The input multiplexers are followed by twelve, 9x9 switch matrices. The latter permit signals in any of the uplink channels of a given transponder to be re-transmitted via any of the other eight transponder output sections.

Each of the 108 channels is individually amplified by an SSPA, which contains one or more variable gain amplifiers. The latter permit automatic accomodation of varying uplink levels using an AGC loop, and also up to 16 dB of power amp back-off via ground control. For the Ku-band fixed satellite service, from 1 watt to 5 watts are necessary to ensure adaquate EIRP. If higher power EIRP is approved for Region 2, higher power SSPA's could provide up to 20 watts, raising the EIRP by 6 dB to 45 dBW

The outputs of the SSPAs in each set of twelve channels are combined in an output multiplexer, which also provides the required narrow band transmit filtering responses. The downlink signals are further filtered by a harmonic/bandpass filter prior to transmission from the antenna feed assembly. The transponder subsystem features 4 for 2 redundancy for the receivers, and 5 for 4 redundancy for the SSPAs.

5.4.5.3.1 14/11 GHz Receiver

See 5.2.5.3.1.

5.4.5.3.2 11 GHz Input Multiplexer

See 5.2.5.3.6.

5.4.5.3.3 RF Switch Matrix

See 5.2.3.3.3.

5.4.5.3.4 11 GHz Power Amplifiers

5.4.5.3.4.1 11 GHz SSPA, 5 Watt

The 5 Watt, 11 GHz solid state power amplifier of low risk technology uses gallium arsenide FETs as the active devices. The output stage combines the output of three 2 watt FETs and is driven by one 2 watt FET of the same type. This 2 watt device has matching circuits incorporated within the device package to match the FET chip to 50 ohms, thereby minimizing amplifier tune and test time and maximizing the performance by accomplishing the matching as closely as possible to the chip. The three-way divider/combiner circuit is of the Wilkinson type. Four stages of lower power gain precede the power stages. Two of these low level stages use dual-gate FETs to provide a variable gain which is set by the voltage on the second gate. The RF circuitry is etched in thin film metalization on alumina substrates which are bonded to moly or Kovar carriers. The amplifier uses a modular construction. Four separate modules are individually tuned, tested, and then integrated. Four interstate isolators are included to minimize interaction between the modules when they are integrated. The isolators are of the drop-in microstrip type to minimize size and weight, except for the output isolator which is stripline for lowest loss.

For high risk technology, rapid advances in gallium arsenide technology and monolithic microwave integrated circuits (MMICs) should make possible substantial improvements in size and performance by 1994. Because of thermal considerations and the need to maximize the efficiency, it is not expected that the output stages will be in monolithic form. It is anticipated, however, that 5 watts output power will be available from a single device package with probably two FET chips, and matching and combining circuitry integrated within the single package. This will reduce the size by eliminating the need for the large three-way divider/combiners. MMIC technology should make it possible to integrate several stages of low power amplification on a single chip. Similarly the VGA should be realizable on a single chip. Thus, a 1994 5 watt amplifier could consist of two low power gain chips, a driver amplifier in one device package, and the output stage in a second package, leading to a significant reduction in size and weight.

It is expected that commercial applications will lead the device manufacturers to develop the packaged 5 watt device. However, to obtain the required low power gain and variable gain in a monolithic form, some non-recurring investment by NASA or the user community will be required.

5.4.5.3.4.2 11 GHz SSPA 10 Watt

The 10 watt, 11 GHz solid state power amplifier of low risk technology uses gallium arsenide FETs as the active devices. The output stage combines the output of six 2-watt FETs. It consists of two 5 watt amplifiers with two-way divider/ combiners on the input and output. Each 5 watt amplifier consists of three devices, 3-way Wilkinson divider/combiners, and a driver stage. The 2 watt device has matching circuits incorporated within the device package to match the FET chip to 50 ohms, thereby minimizing amplifier tune and test time and maximizing the performance by accomplishing the matching as closely as possible to the chip.

Four stages of lower power gain precede the power stage. Two of these low level stages use dual-gate FETs to provide a variable gain which is set by the voltage on the second gate. The RF circuitry is etched in this film metalization on alumina substrates which are bonded to moly or Kovar carriers. The amplifiers use a modular construction. Four separate modules are individually tuned and tested and then integrated. Four interstage isolators are included to minimize interaction between the modules when they are integrated. The isolators are of the drop in microstrip type to minimize size and weight, except for the output isolator which is stripline for lowest loss.

For high risk technology, rapid advances in gallium arsenide technology and monolithic microwave integrated circuits (MMICs) should make possible substantial improvements in size and performance by 1994. Because of thermal considerations and the need to maximize the efficiency, it is not expected that the output stages will be in monolithic form. It is anticipated, however, that 5 watts of output power will be available from a single device package with probably two FET chips, and matching circuitry and combining circuitry integrated within the single package. 10 watts will then be achievable by combining two of these 5 watt devices by means of Wilkinson dividers. This will reduce the size signficantly by eliminating the need for the large three-way divider/combiners. MMIC technology should make it possible to integrate several stages of low power amplification on a single chip. Similarly, the VGA should be realizable on a single chip. Thus, a 1994 10-watt amplifier could consist of two low power gain chips, a driver amplifier in one device package, and an output stage consisting of two 5 watt devices, leading to a significant reduction in size and weight in comparison to the 1984 version.

We expect that commerical applications will lead the device manufacturers to develop the packaged 5-watt device. However, to obtain the required low power gain and variable gain in a monolithic form, and to integrate all the devices into a space qualified 10-watt SSPA, some non-recurring investment by NASA or the user community will be required.

5.4.5.3.4.3 11 GHz SSPA 10 Watt

The 20 watt, 11 GHz solid state power amplifier of low risk technology uses gallium arsenide FETs as the active devices.

The output stage combines the output of twelve 2-watt FETs. This can be accomplished in one of at least two ways. Two six-FET stages, such as used in the 10-watt amplifier, can be combined with two-way divider/combiners. This is relatively straight forward, but combining twelve devices in this way is bulky and inefficient. A better alternative is the use of a twelve-way radial combiner. Two stages of gain will be included in each of the twelve paths between the input divider and output combiner so that the input divider can be driven by a single device. The 2-watt devices have matching circuits incorporated within the device package to match the FET chip to 50 ohms, thereby minimizing amplifier tune and test time and maximizing the performance by accomplishing the matching as closely as possible to the chip.

Four stages of lower power gain precede the power stage. Two of these low level stages use dual-gate FETs to provide a variable gain which is set by the voltage on the second gate. The RF circuitry is etched in thin film metalization on alumina substrates which are bonded to moly or Kovar carriers. The amplifiers use a modular construction. Four separate modules are individually tuned and tested and then integrated. Four interstage isolators are included to minimize interaction between the modules when they are integrated. The isolators are the drop in microstrip type to minimize size and weight, except for the output isolator which is stripline for lowest loss.

For high risk technology, rapid advances in gallium arsenide technology and monolithic microwave integrated circuits (MMICs) should make possible substantial improvements in size and performance by 1994. Because of thermal considerations and the need to maximize the efficiency, it is not expected that the output stages will be in monolithic form. It is anticipated, however, that 5 watts of output power will be available from a single device package with probably two FET chips, and matching circuitry and combining circuitry integrated within the single package. 20 watts will then be achievable by combining four of these 5-watt devices by means of Wilkinson dividers. This will reduce the size significantly in comparison with the 12-way divider/combiner and 12 gain stages. MMIC technology should make it possible to integrate several stages of low power amplification on a single chip. Similarly the VGA should be realizable on a single chip. Thus, a 1994 20-watt amplifier could consist of two low power gain chips, two driver stages each using one packaged device, and an output stage consisting of four 5-watt devices, leading to a significant reduction in size and weight in comparison to the 1984 version.

It is expected that commercial applications will lead the device manufacturers to develop the packaged 5-watt device. However, to obtain the required low power gain and variable gain in a monolithic form and to integrate all the devices into a space qualified 20-watt SSPA, some non-recurring investment by NASA or the user community will be required.

5.4.5.3.5 11 GHz Output Multiplexers

See 5.2.5.3.6.

5.4.5.3.6 Pre-Select and Harmonic Filters

See 5.2.2.3.5.

5.5 SCENARIO VI-A DEFINITION

5.5.1 Introduction

Scenario VI-A is the first of a complementary pair of satellites designed to handle all of the WARC Region 2 Intelsat traffic, intra Region 2 as well as AOR and POR traffic, and provide all domestic coverages for non-CONUS region 2 traffic. This satellite is the easterly located satellite and handles the primary processing of all of the Intelsat traffic except Canada. The satellite also provides the high capacity CONUS FSS payloads described in Scenario V. The Intelsat traffic is routed via the baseband processor to an eastern or western ISL link. The services provided are listed below:

- 48 Channels, 36 MHz, C-band CONUS FSS payload, 4 beams, 12 channels each, 4 x re-use.
- 108 channels 36 MHz, Ku-band, CONUS FSS payload, 9 beams, 12 channels each, 9 x re-use.
- 108 channels 36 MHz, C-band, International FSS payload, 9 beams, 12 channels each, 9 x re-use.
- 38 channels, 500 MHz, Ka-band, CONUS FSS payload, 20 beams, approximately 2 channels each, 7.6 x re-use.
- 18 channels, 240 MHz, and 14 channels, 500 MHz, Ka-band, CONUS FSS payload, 6 beams, CPS/thin route trunking, 4.6 x re-use.
- C/L-band, Maritime payload, L to C-band - ship to shore; C to L-band - shore to ship.
- Intersatellite link (ISL), 3 links 2 to the east and 1 to the west, each 1.5 Gbps capacity.

The C/L-band Maritime payload is the same as the second generation Marisat that can handle 125 voice circuits. The location of this scenario satellite is assumed to be 85°W for antenna coverage. A location further east of 85° W would be acceptable down to about 70°W.

An overview block diagram of the payload elements is shown in Figure 5.5.1-1. Table 5.5.1-1 lists the major bus/payload interface requirements, and Tables 5.5.1-2 and 5.5.1-3 present the major antenna and transponder characteristics respectively. The two Ka-Band antennae require individual gimbal systems for

Table 5.5.1-1

<u>Scenario VI-A - Payload Interface Requirements</u>

o Mass	3200 kg
o Power Required	
Sunlight	10,400 watts
Eclipse	75% min; 100% desired
o Pointing Requirement	± 0.05° absolute (ie: RF boresight)
o Temperature Requirements	
Antenna	-90° to +110°C
Transponder	-10°C to +59°C, TWTA's +60°C
o Thermal Dissipation	1.5 kW in EPC's, 8 kW in TWT's & 4 kW in feeds, & W/G losses
o Lifetime	10 years without servicing

Figure 5.5.1-1 Scenario VI-A Overview

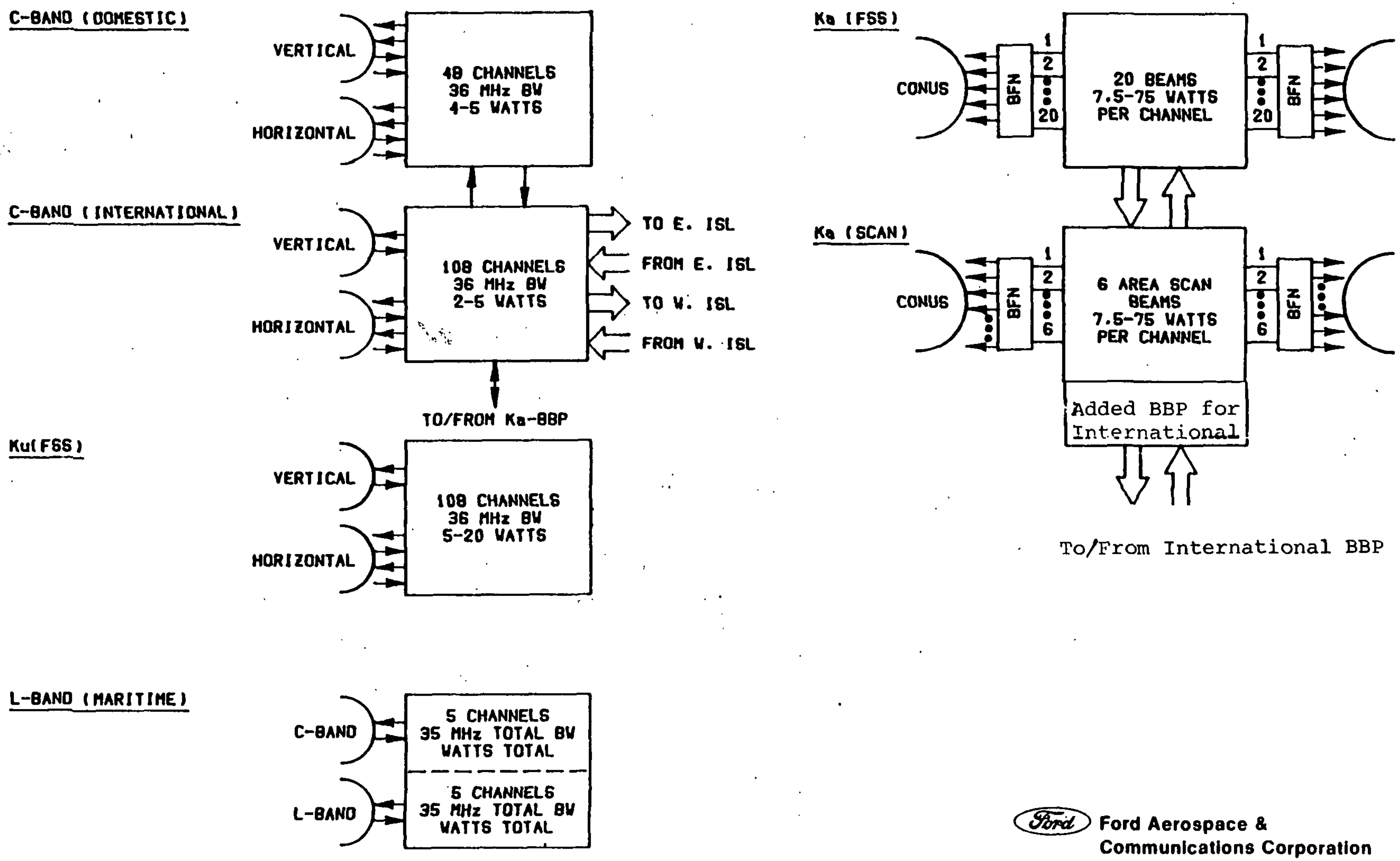


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Table 5.5.1-2

Scenario VI-A Antenna Configuration

Antenna System	Freq (GHz)	Reflector	Polarization	Feed Arrays
C-Band FSS	4/6	15' (4.6m) dual gridded reflector	Linear	2x26 feeds plus 2x26 diplexers
Ku-Band FSS	11/14	15'(4.6m)) dual gridded reflector	Linear	2x450 feeds.
Ka-Band FSS	20/30	One solid 13' (4.0m) reflector for tx, one solid 9' (2.7m) reflector for rec (dual shaped reflector each with subreflector)	Linear	Tx:500 feeds, 830 sws, 140 omj's; same for receive
C-Band Int'l.	4/6	One 5m dual gridded and 4m dual gridded	Linear	2x92 feeds plus 2x92 diplexers
C/L-Band Maritime	1.5-1.7 3.6-3.65 6.425-6.441	One (3m) solid; One (1.2m) solid One (.76m) solid reflectors	CP	twelve 9.5" feed arrays; twelve 4.2" feed arrays; twelve 2.4" feed arraya
GEO-GEO	60 GHz	One gimballed 3m reflector for each ISL. One east & one west	CP	Center fed cassegrain

Table 5.5.1-3

Transponder Summary Scenario VI-A

Payload	U/L,D/L Freq. GHz	Number Channels	Channel BW, RF	RCVR Type (Number)	HPA Type Number	HPA Power, W
C Band FSS(CONUS)	6/4	48	36	6/4(8)	SSPA(60)	4
Ku Band FSS (CONUS)	14/11	108	36	14/11(18)	SSPA(135)	2
C-Band FSS (INTL)	6/4	108	36	6/4(18)	SSPA(135)	4.5
Ka-band FSS	30/20	38	500	30/4(40)	TWTA(49)	75
Ka-band Scan	30/20	32	240/500	30/4(12)	TWTA(40)	75
C/L-band Maritime	6/1.5 1.6/3.6	1 2	Total 35 Total 35	6/1.5(2) 1/6/0.35 (2)	SSPA(6) SSPA(2)	70 8.5
ISL	60/60	3	1.5 GHz	60/8(4)	Impatt(6) diode	5

steering the two sub-reflectors to achieve ± 0.02° pointing of the RF boresight, as well as the two ISL reflectors. The other antennae will be rigidly mounted to the body and body steered via the bus control system.

Due to the use of TWTA's for the Ka-band FSS payload, a 10-year life is all that can be envisaged at this time because replacement of TWTA's at GEO, or return of the payload from GEO for servicing and replacement of TWTA's, is not anticipated for the early 2000 time period. It is estimated that the identified redundancy is compatible with a 10-year life application.

This scenario, as opposed to the prior scenarios, requires in-orbit assembly and a modular approach to spacecraft assembly. This may allow replacement of the Ka-band transponder package to extend the life to fifteen or twenty years with GEO servicing. If the spacecraft were designed to allow replacement of the transponder package, it would probably require an added weight penalty for the modularity. This scenario is clearly a launch concept 2 scenario, and thus opens the possibility of the modular approach.

Table 5.5.1-4 presents a summary of the high and low risk weight and power for the individual payload elements in Scenario VI-A.

In Appendix J, Tables 1 thru 8 show that all of the payload elements have viable links with the various types of anticipated modulation and access types. While some of the margins are low, the links represent the worst case condition. If this scenario were to be studied further for full system definition, link margins could be improved for actual implementation.

Table 5.5.1-4

Scenario VI-A Weight and Power

	WEIGHT(KG)		POWER(W)	
	Low Risk	High Risk	Low Risk	High Risk
C-Band FSS (Domestic)				
Transponder	235	171.7	1001	708
Antenna	92.4	74.1	-	-
Sub Total	327.4	245.8	1001	708
Ku-Band FSS				
Transponder	625	362.4	1164	785
Antenna	187	160.6	-	-
Sub Total	812	523	1164	785
Ka-Band FSS & Scan				
FSS Transponder	751.4	516.3	3305	3043
SCAN Transponder	636.0	447.6	2180	1936
Baseband Proc.	355.0	297.4	1360	952
Antenna	264.5	230.4	4	2
Sub-Total	2006.9	1491.7	6849	5933
C-Band FSS(International)				
Transponder	449.5	301.9	2319	1592
Itnl. Baseband Prcr.	231	193.3	649	454
Adl. CONUS Bsbd Prcr.	34.5	28.8	172	120
Antenna	271.7	225.5	-	-
Sub Total	986.7	749.5	3140	2166
Maritime				
Transponder	58.2	39.9	855	649
Antenna	47	39.2	-	-
Sub-Total	105.2	79.1	855	649
ISL's	146.9	110.6	285	160
SCENARIO VI-A TOTAL	4385.1	3199.7	13294	10401

5.5.2 C-Band FSS Payload

The payload is identical to the C-Band FSS payload described in Scenario V. See Section 5.4.2 for detailed description.

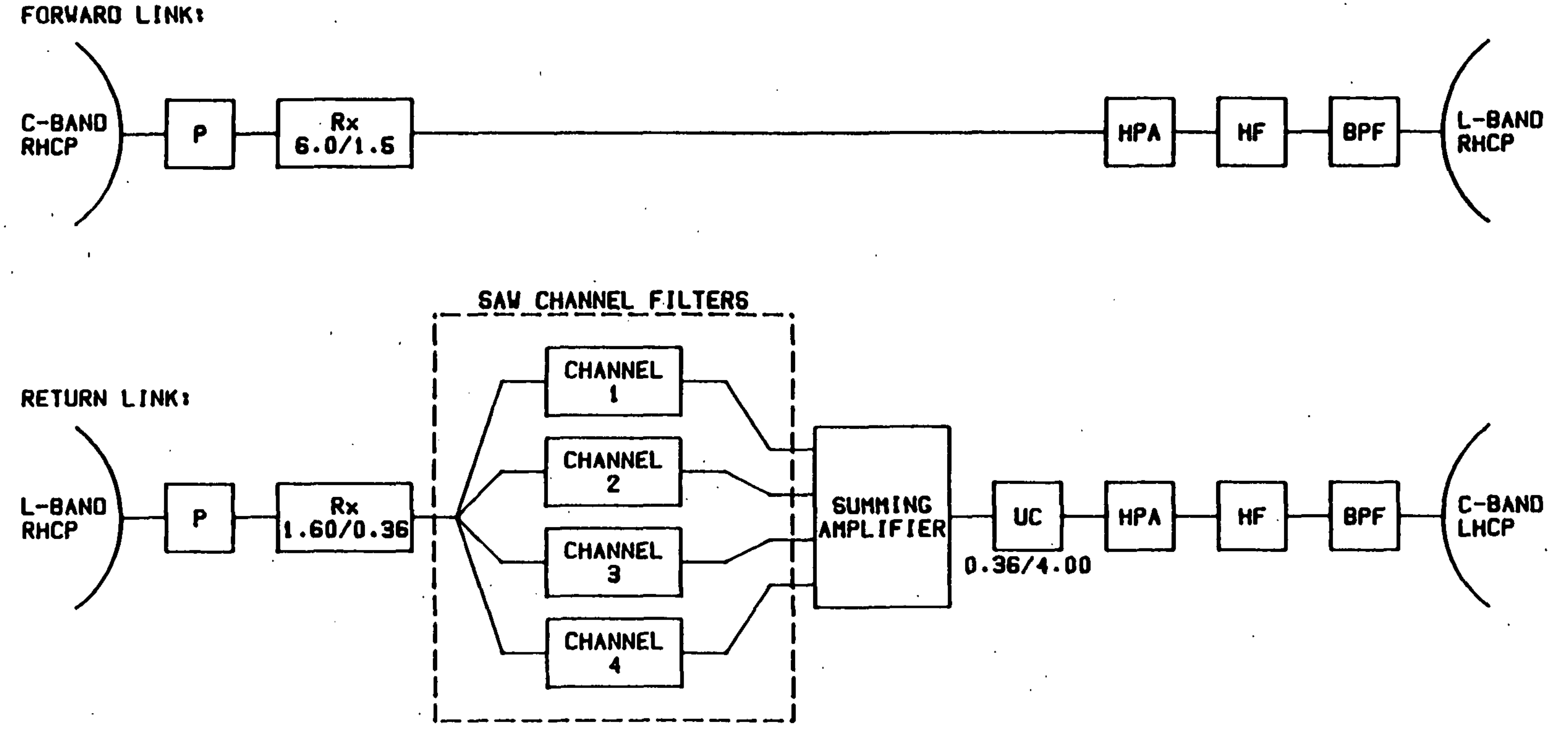
5.5.3 C/L Band Maritime Payload - Western Atlantic

5.5.3.1 Overview of C/L-Band Maritime Payload

This payload is the same as the second generation Inmarsat transponders capable of handling 125 voice circuits. This payload provides one-quarter of the worldwide coverage, with the western satellite Scenario VI-B providing eastern Pacific coverage, a European platform providing eastern Atlantic, and an Asian platform providing western Pacific coverage. The less than global coverage beam from each satellite will increase the antenna gain slightly and result in improved performance. Also, splitting the ocean regions in half will double the available circuits for the ocean area. Figure 5.5.3-1 is a block diagram of the Maritime payload for Scenario VI-A showing the breakdown to the component level.

Table 5.5.3-1 shows the estimated weight, power, and volume for low risk (emerging) technology and high risk (projected) tech- nology for the transponder and antenna. Also included in the estimates are the coax, waveguide, and harness interconnects, plus an estimate for integration hardware to put the components together and provide necessary brackets for support and mount- ing. This does not include any structure or satellite mounting hardware, such as between the feed and reflector.

Figure 5.5.3-1 Scenario VI-A - Maritime - C/L



P: PRESELECT FILTER
Rx: RECEIVER
HPA: HIGH POWER AMPLIFIER
UC: UP CONVERTER
HF: HARMONIC FILTER
BPF: BAND PASS FILTER

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Table 5.5.3-1

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WESTERN ATLANTIC MARITIME C/L-BAND

Scenario VI-A Payload Summary

	ITEM	P/L QTY REQ'D	REQ. QTY REQ'D	LOW RISK TECHNOLOGY						HIGH RISK TECHNOLOGY						COMMENTS
				UNIT			PAYLOAD			UNIT			PAYLOAD			
				WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	
1	6.0/1.5 GHz RECEIVER	1	2	1.6	8.0	175	3.2	8	350	0.5	5.5	50	1	5.5	100	
2	L Band HIGH POWER AMPLIFIERS(100W)	1	2	13	700	1300	26.0	700	2600	10	540	1000	20	540	2000	
3	BP/HARMONIC FILTER, 1.5 GHz	1	1	0.5	-	120	0.5	-	120	0.5	-	120	0.5	-	120	
4	CHANNEL FILTER, 1.5 GHz	1	1	0.3	-	50	0.3		50	0.2	-	40	0.2	-	40	
5	PRESELECT FILTER, 6GHz	1	1	0.3	-	50	0.3		50	0.3	-	50	0.3	-	50	
6	COAX SET & WAVEGUIDE	1	1	1.6	-	-	1.6		-	1.6	-	-	1.6	-	-	
7	HARNESS	1	1	6.0	-	-	6.0		-	6.0	-	-	6	-	-	
8																
9	SPDT SWITCH 6GHz CPAX 1.5 GHz COAX	4	4	0.08	-	6	0.3		24	0.08	-	6	0.3	-	24	
10	1.6/0.36 GHz RECEIVER, DUAL CONVERSION	1	2	2.6	16.0	275	5.2	16	550	0.8	12	60	1.6	12	120	
11	(W 4 SAW FILTER, SUMMMING-AMP AND 0.36/4 UPCONVERTER)															
12	C-Band HIGH POWER AMPLIFIER(9W)	1	2	2.0	50	240	4.0	50	480	0.6	30	80	1.2	30	160	
13	PRESELECT FILTER 0.36 GHz	1	1	0.4	-	48	0.8		48	0.4	-	48	0.4	-	48	
14	SPDT SWITCH COAX 0.36 GHz, 4 GHz	4	4	0.08	-	6	0.3		24	0.08	-	6	0.3	-	24	
15	BP/HARMONIC FILTER, 4 GHz, W/G	1	1	0.3	-	48	0.3		48	0.3	-	48	0.3	-	48	
16	CHANNEL FILTER, 4 GHz CAVITY, DIEL	1	1	0.4	-	140	0.4		140	0.3	-	50	0.3	-	50	
17	L BAND LINEARRERIZER	1	2	0.6	3.0	24	1.2	3	48	0.3	2.5	12	0.6	2.5	24	
18	INTEGRATION HARDWARE SET	1	1	5%	-	-	2.5	-	-	5%	-	-	1.7	-	-	
19	MARGIN REQUIRED			10%	10%	5%	5.3	78	227	10%	10%	10%	3.6	59	281	
20																
21	TOTAL TRANSPONDER						58.2	855	4759				39.9	649	3089	
22																
23																
24	L-BAND ANTENNA Tx/Rx 3m	1	1	22.7	-	-	22.7	-	-	18.2	-	-	18.2	-	-	
25	L-BAND FEED	1	1	8	-	72000	8	-	72000	7.2	-	64800	7.2	-	64800	
26	C-BAND ANTENNA Tx Im.	1	1	4.5	-	-	4.5	-	-	3.6	-	-	3.6	-	-	
27	C-BAND Tx FEED	1	1	4	-	7500	4	-	7500	3.6	-	6750	3.6	-	6750	
28	C-BAND ANTENNA Rx x0.75m	1	1	1.5	-	-	1.5	-	-	1.2	-	-	1.2	-	-	
29	C-BAND Rx FEED	1	1	2.0	-	2880	2.0	-	2880	1.8	-	2592	1.8	-	2592	
30	MARGIN REQUIRED			10%	-	10%	4.3	-	8238	10%	-	10%	3.6	-	7414	
31																
32	TOTAL ANTENNA						47		90618				39.2	-	81556	
33																
34																
35	TOTAL PAYLOAD						105.2	855	95377				79.1	649	84645	

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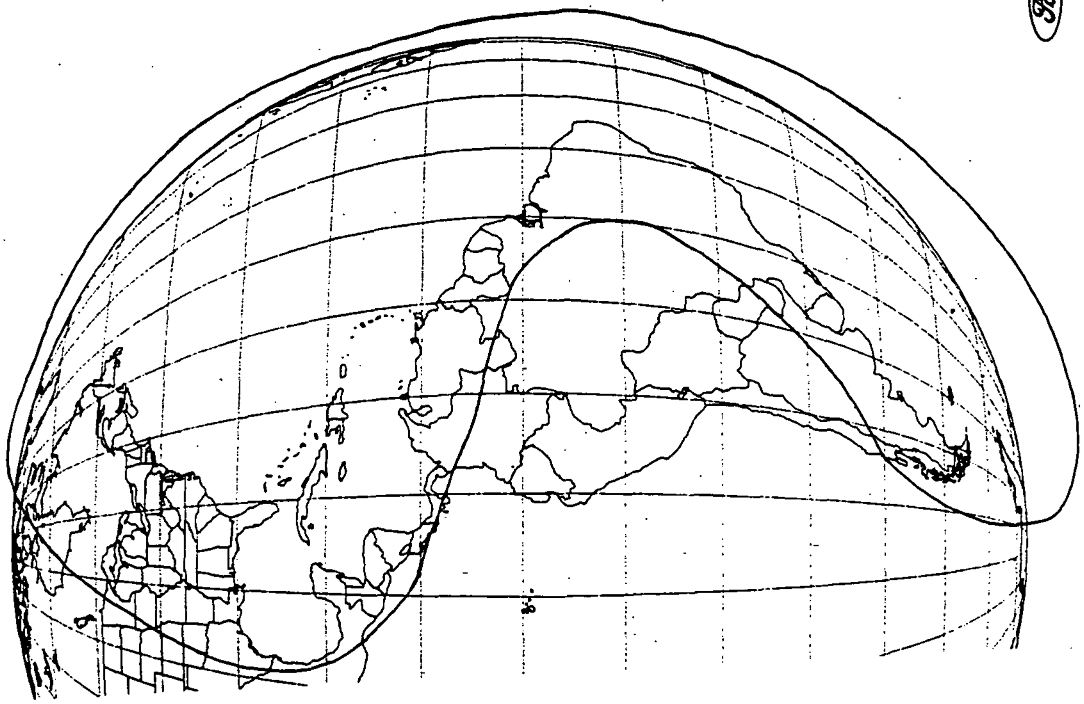

Figure 5.5.3-2 Western Atlantic Maritime Coverage Area

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5.5.3.2 C/L-Band Maritime Antenna Subsystem

The C/L Band Maritime Antenna Subsystem provides communications at 1.5-1.7 GHz, 3.6-3.65 GHz, and 6.425-6.441 GHz bands. The polarization is circular. The purpose of the antenna is to provide a beam to cover the West Atlantic Region, as shown in Figure 5.5.3-2.

The antenna will consist of 3 solid reflectors: a 3 meter reflector for 1.6 GHz band; a 1.2 meter reflector for 3.6 GHz band; and a 0.76 meter reflector for 6.4 GHz band, as shown in *Figure* 5.5.3-3. *Each reflector will be illuminated by 12 feeds.* A polarizer is employed at each feed to produce circular polarization. Figure 5.5.3-4 shows the beam layout to cover the West Atlantic region. Figure 5.5.3-5 presents the antenna radiation patterns. The edge-of-coverage gain is 18.5 dbi.

All technologies required in this system are well developed. The level of risk of the technology items is low.

5.5.3.3 Maritime Transponder Subsystem

The Maritime transponder subsystem consists of two independent transponders. The forward link is provided by a single channel transponder with an uplink at C-Band and downlink at L-Band and a channel bandwidth of 35 MHz. The 6.0 GHz input from the RHCP antenna is filtered by the input preselector, then amplified and downconverted to 1.5 GHz by the receiver. The receiver output is narrow band filtered and then amplified by the L-Band high power amplifier. Further filtering is provided by narrow-band bandpass and harmonic rejection filters prior to downlink transmission via the L-Band, RHCP antenna.

The return link is provided by a four channel, dual-conversion transponder, having an L-Band uplink and C-Band downlink and a total channel bandwidth of 35 MHz. The 1.6 GHz input from the

Figure 5.5.3-3 Scenario VI-A - Maritime - C/L Antenna Reflector

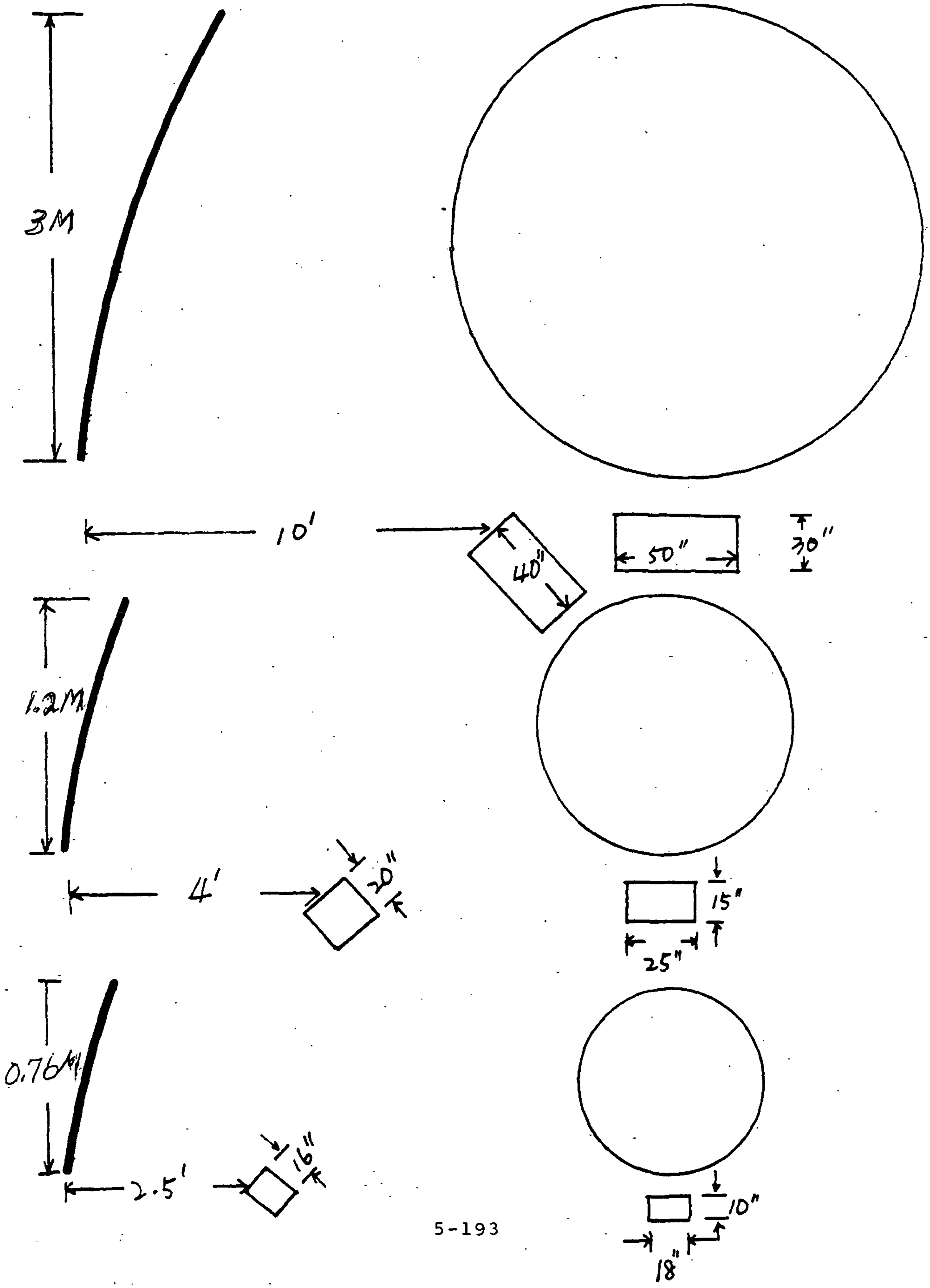

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Figure 5.5.3-4 Maritime Beam Layout

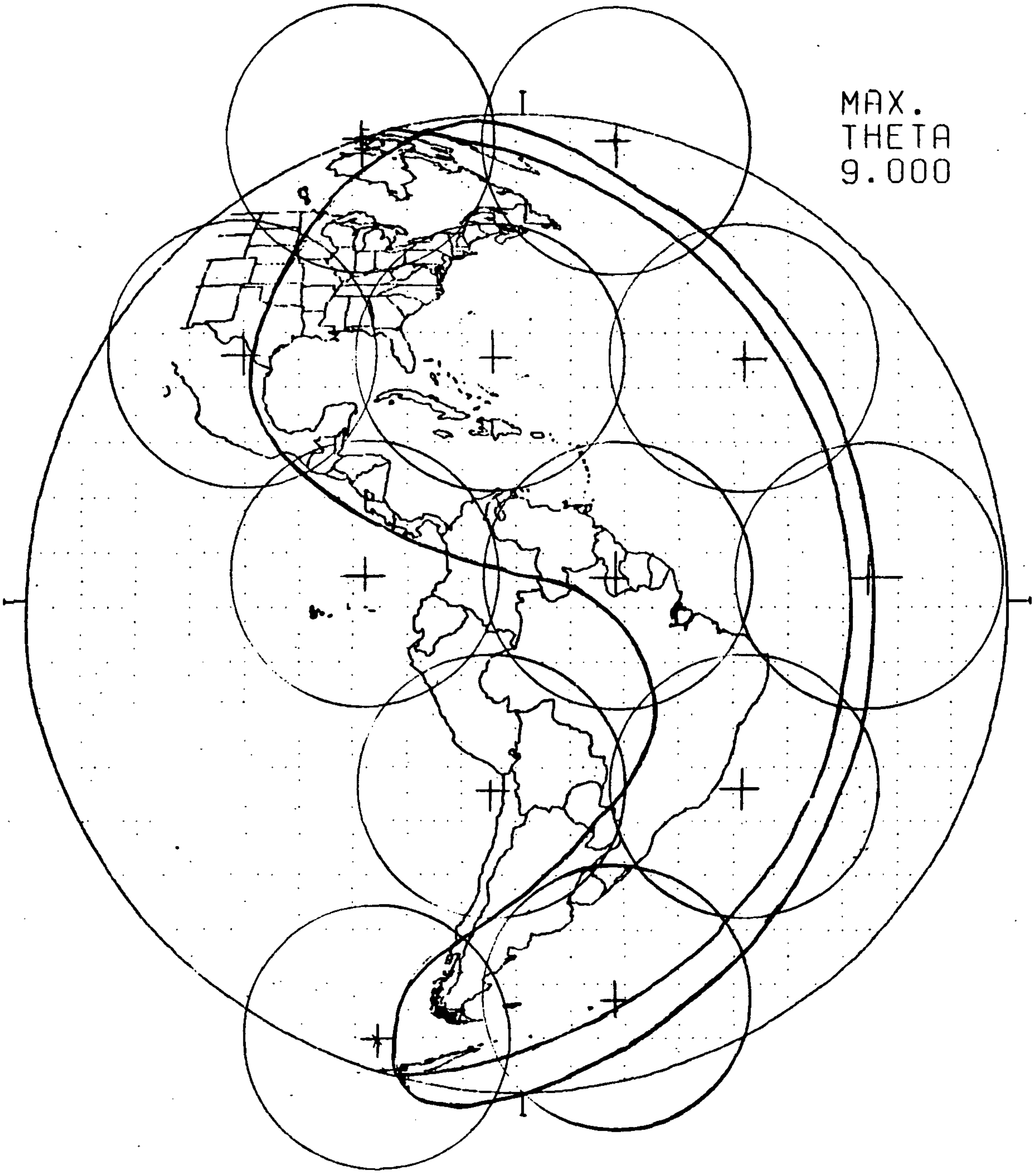
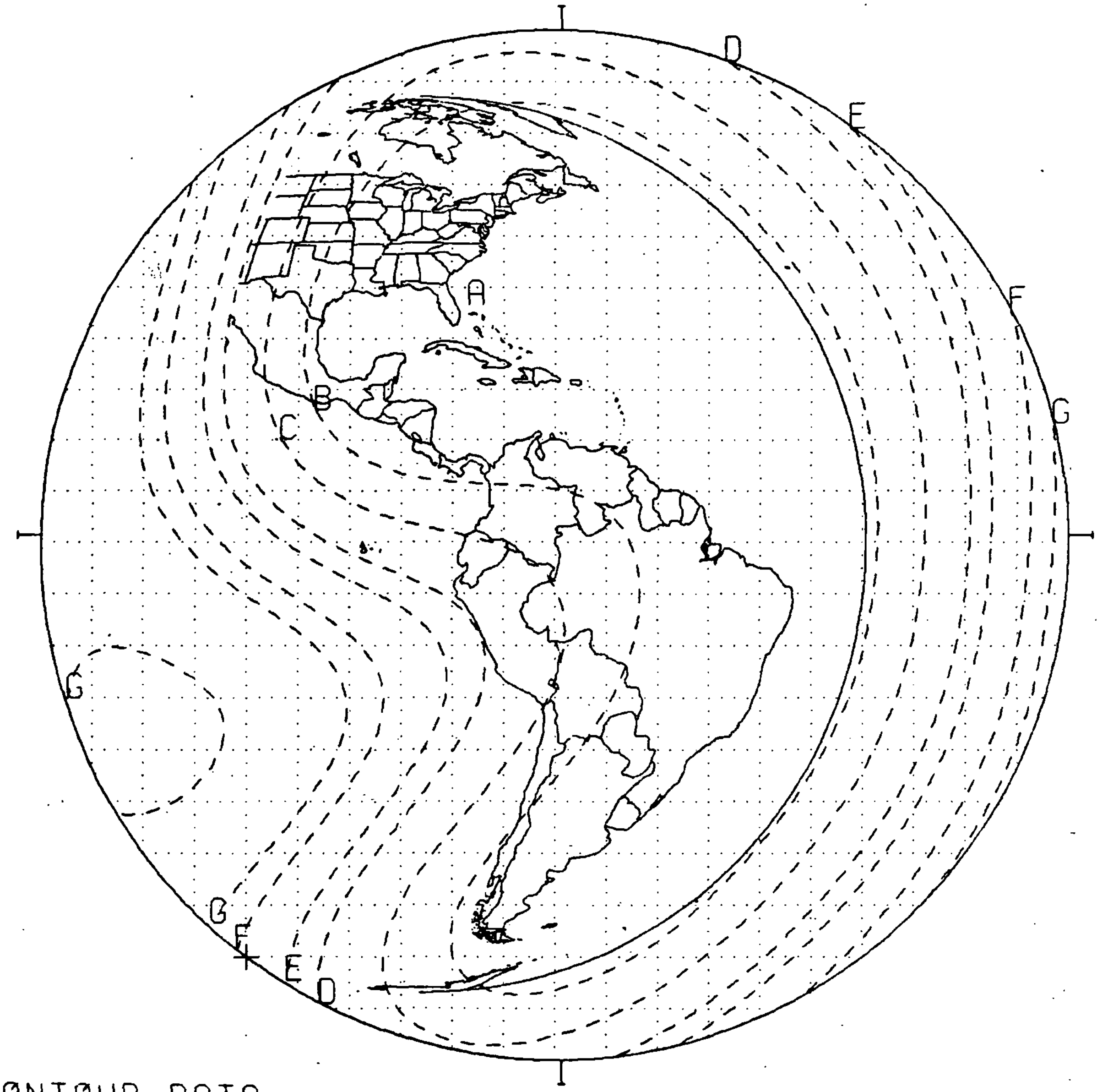


Figure 5.5.3-5 Maritime Antenna Pattern



CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (18.2 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

LHCP antenna is filtered by the input preselector, then amplified and downconverted to the 0.36 GHz intermediate frequency. The IF output is split in a 4-way power divider, and narrow band filtering for the four channels is then provided by SAW filters. The outputs of the SAW filters are combined in a summing amplifier and then upconverted to 4.0 GHz, with final power amplification being supplied by an 8 watt, C-Band SSPA. The downlink signals are filtered by a harmonic/bandpass filter prior to transmission from the LHCP transmit antenna.

5.5.3.3.1 Maritime C/L Receiver

Using low risk technology, this receiver provides for low noise amplification at 6 GHz. It down converts 6 GHz to 1.5 GHz with a Schottky diode mixer. The mixer is followed by bandpass filtering and amplification at 1.5 GHz. The local oscillator is a temperature-controlled crystal oscillator followed by a multiplier chain.

<u>Electrical Performance</u>

Noise Figure	3.0 dB
Gain	70 dB
Output Power @ C/3IM=-40 dBc	+13 dBm
Frequency Stability	+1/-2 ppm
DC Power	8.0 watts

Mechanically, the receiver contains four subassembly trays: a front end, a driver, a local oscillator, and a DC/DC converter.

The trays are assembled in a vertical stack. RF signal connections between the front end, driver and local oscillator trays are made with short loops of semirigid coaxial cable. A selectable coaxial attenuator is included in the RF signal path at the input to the driver to allow for adjustment of the overall gain. Regulated DC voltages are supplied to the front end, driver and local oscillator trays through a DC harness running vertically along the side of the stack.

The microwave tray is an aluminum chassis that contains substrate assemblies that are bonded into the chassis, and substrate/carrier assemblies that are bolted in the chassis. The substrate assemblies consist of MIC isolators, filters and temperature compensation. The substrate/carrier assemblies are MIC amplifiers. These amplifiers are constructed using hermetically packaged semiconductors, chip resistors, and chip capacitors on thin film alumina substrates. The bias circuits are contructed using thick film alumina substrates, hermetically packaged semiconductors, chip resistors and chip capacitors.

Mechanical Parameters

Mass	1.6 kg
Volume	175 cu in

Using high risk technology, the 6 GHz preamp would be updated with the latest low noise GaAs FET. This will improve noise figure from 3.0 dB to 1.5 dB. This mixer should be integrated with the bandpass filtering. This will enhance the mixer performance by improving gain flatness over temperature and reducing test time. The 1.5 GHz amplifiers should be replaced by monolithic gain blocks. These gain blocks are common to this receiver and many other applications. This would reduce test time and improve overall receiver performance. The crystal oscillator chain could be replaced by a dielectric resonator oscillator. The DRO will reduce complexity and cost. The current receiver uses an analog circuit to temperature compensate the receiver gain. Future receivers should use a digital system to improve gain stability. The preamp, mixer/filter, DRO, and digital temperature compensation require development that is geared toward space qualification. The 1.5 GHz gain block would be developed in the commercial market and could be space-qualified. Power consump- tion will be reduced to 5.5 watts, primarily by the use of the DRO.

The use of monolithic gain blocks and dielectric oscilators will reduce the size of the receiver. The number of subassemblies can be reduced from 4 to 3. These would be a DC/DC converter, front end/local oscillator, and driver.

Mechanical Parameters

Mass	0.5 kg
Volume	50 cu in

5.5.3.3.2 Maritime L-Band Power Amplifier

Using low risk technology, the 200 watt power amplifier could readily be achieved with a 200 watt TWTA. An alternate approach would be to utilize three 70 watt solid state amplifiers and field combine the outputs via the multi-element feed network. This approach is preferred to improve long term reliability.

The 70 watt power amplifier operates at 1550 MHz and has seven amplification stages to provide a gain of 60 dB. The unit has very good efficiency and adequate linearity to support simultaneous 125-carrier operation. Bipolar transistors are used for all RF stages except the two FET input stages. A number of special design features are incorporated to protect the output stage transistors, as well as enhance linearity, and permit stable amplifier operation over a 66°C temperature range. The two FET input stages are limiting multi-carrier envelope peaks at a level of 4 dB above nominal input drive to prevent the output stages from being overdriven. The input module also houses a bipolar stage for gain-setting and temperature compensation. A four-pole microstrip filter at the module output restricts the operating bandwidth to 40 MHz. The second module has two medium power class A bipolar stages which are followed by a 3 dB Wilkinson splitter at the output. The following high power section consists of two identical modules in parallel configuration. Each module has an input and an output isolator, and the two output signals are combined with a coaxial in-phase power combiner. The active devices in the high power stages are common base multi-cell transistors, derived from a standard class C part and modified to enable more efficient linear operation. Pre- biasing the power transistors results in a linear dynamic range of better than 18 dB. The design of the bias network is critical; it has to provide low source impedance and prevent thermal runaway as well as maintain stability at very low intermodulation frequencies. The four output stages in each module have individual input/output matching circuits, and a total of six 3 dB interdigital large couplers are used for power splitting and combining. A similar single stage drives the four output stages and is an integral part of the output modules. All RF circuits use thin film metallization on alumina substrates. Individual substrates are bonded to Kovar carriers, which are bolted to the aluminum chassis to avoid expansion coefficient differences. Bias networks are bonded to the bottom side of the carriers. This configuration and the use of feedthrough filters yields very good RF/DC decoupling. All RF modules are tuned and tested in the module chassis prior to amplifier integration. The high power output modules have temporary by-pass circuits which permit the optimization of individual stages prior to power combining. The DC/DC converter is a separate module. It supplies all required voltages and provides proper turn-on/turn-off sequencing and filtering for the various voltages.

Using high risk technology, the 200 watt power amplifier could be a single solid state amplifier.

Bipolar solid stage technology at L-Band frequencies is very refined at this point. State of the art multicell devices employ emitter ballasting and stage metallization systems to achieve high reliability factors. Internal matching to an intermediate impedance level simplifies the complexity of external matching circuits and yields wider bandwidth. It seems that demand will double the present output power level of class A-B transistors to about 30 watts in the near future. By 1994 a device with an output power capability of 50 watts should be available. This appears to be an ideal power level considering thermal size and reliability aspects for a 200 watt amplifier design. Driver stages below 1 watt output can be realized in MMIC technique. This, in connection with the fewer number of required power devices, should reduce the RF section footprint and size to one-half of its present outline. Miniaturization has little impact on the DC/DC converter module; its dimension and weight are largely determined by magnetic circuits and large value capacitors.

Special features such as limiting, temperature compensation and gain setting would make the MMIC input module a custom device that would require some NASA or customer funding to offset the development costs.

5.5.3.3.3 Pre-Select, Harmonic and BP Filters

See 5.2.2.3.5.

5.5.3.3.4 Maritime L/UHF Receiver

Using low risk technology, this receiver provides for low noise amplification at 1.6 GHz. It down converts 1.6 GHz to 360 GHz with a Schottky diode mixer. The mixer is followed by bandpass filtering and amplification at 1.5 GHz. The local oscillator is a temperature controlled crystal oscillator followed by a multiplier chain. Filtering at 360 MHz is done by dividing the signal in a hybrid into 4 parts and filtering each part with a saw filter. The 4 channels are then recombined and further amplified in the 360 MHz driver amplifier.

Electrical Performance

Noise Figure	2.5 dB
Gain	70 dB
Output Power @ C/3IM=-40dBc	+13 dBm
Frequency Stability	+1/-2 ppm
DC Power	8.5 watts

Mechanically, the receiver contains four subassembly trays: a front end, a driver, a local oscillator and a DC/DC converter.

The trays are assembled in a vertical stack. RF signal connections between the front end, driver and local oscillator trays are made with short loops of semirigid coaxial cable. A selectable coaxial attenuator is included in the RF signal path at the input to the driver to allow for adjustment of the overall gain. Regulated DC voltages are supplied to the front end, driver, and local oscillator trays through a DC harness running vertically along the side of the stack.

The microwave tray is an aluminum chassis that contains substrate assemblies that are bonded into the chassis, and substrate/carrier assemblies that are bolted in the chassis. The substrate assemblies consist of MIC isolators, filters and temperature compensation. The substrate/carrier assemblies are MIC amplifiers. These amplifiers are constructed using hermetically packaged semiconductors, chip resistors, and chip capacitors on thin film alumina substrates. The bias circuits are constructed using thick film alumina substrates, hermetically packaged semiconductors, chip resistors and chip capacitors.

Mechanical Parameters

Mass	1.4 kg
Volume	175 cu in

Using high risk technology, the 6 GHz preamp would be updated with the latest low noise GaAs FET. This will improve noise figure from 2.5 dB to 1.5 dB. The mixer should be integrated with the bandpass filtering. The will enhance the mixer performance by improving gain flatness over temperature and reducing test time. The 360 MHz amplifiers should be replaced by monolithic gain blocks. These gain blocks are common to this receiver and many other applications. This would reduce test time and improve overall receiver performance. The crystal oscillator chain could be replaced by a dielectric resonator oscillator. The DRO will reduce complexity and cost. The current receiver uses an analog circuit to temperature compensate the receiver gain. Future receivers should use a digital system to improve gain stability. The preamp, mixer/filter, DRO, and digital temperature compensation require development that is geared toward space qualification. The 360 MHz gain block would be developed in the commerical market and could be space-qualified. Power consumption will be reduced to 7.0 watts, primarily by the use of the DRO.

The use of monolithic gain blocks and dielectric oscillators would reduce the size of the receiver. The number of subassemblies can be reduced from 4 to 3. These would be a DC/DC converter, front end/local oscilator, and driver.

Mechanical Parameters

Mass	0.5 kg
Volume	40 cu in

5.5.3.3.5 Maritime UHF/4 GHz Upconverter

Using low risk technology, this reciever provides for low noise amplification at 360 MHz with a 3 stage amplifier and upconverts to 4 GHz with a Schottky diode mixer. The mixer is followed by bandpass filtering. The local oscillator is a temperature controlled crystal oscillator followed by a multiplier chain.

Electrical Performance

Gain	70 dB
Output Power @ C/3IM=-40dBc	-10 dBm
Frequency Stability	+1/-2 ppm
DC Power	7.5 watts

Mechanically, the receiver contains four subassembly trays: a front end, a driver, a local oscillator, and a DC/DC converter.

The trays are assembled in a vertical stack. RF signal connections between the front end, driver and local oscillator trays are made with short loops of semirigid coaxial cable. Regulated DC voltages are supplied to the front end, driver and local oscillator trays through a DC harness running vertically along the side of the stack.

The microwave tray is an aluminum chassis that contains substrate assemblies that are bonded into the chassis and substrate/carrier assemblies that are bolted in the chassis. The substrate assemblies consist of MIC isolators, filters and temperature compensation. The substrate/carrier assemblies are MIC amplifiers. These amplifiers are constructed using hermetically packaged semiconductors, chip resistors, and chip capacitors on thin film alumina substrates. The bias circuits are contructed using thick film alumina substrates, hermetically packaged semiconductors, chip resistors and chip capacitors.

Mechanical Parameters

Mass	1.2 kg
Volume	100 cu in

Using high risk technology, the 360 MHz preamp will be updated by replacing it with a monolithic amplifier. The mixer will be integrated with bandpass filtering. This will enhance the mixer performance by improving gain flatness over temperature and reducing test time. The crystal oscillator will be replaced by a dielectirc resonator oscillator. The DRO will reduce complexity and cost. The current upconverter uses an analog circuit to temperature compensate upconverter gain. Future upconverters should use a digital system to improve gain stability. The DRO and digital temperature compensation require development that is geared toward space qualification. The power consumption will be reduced to 5.0 watts primarily by the use of the DRO.

The use of dielectric oscillators will reduce the size of the upconverter. The number of subassemblies can be reduced from 3 to 2. These would be a DC/DC converter, front end/local oscillator.

Mechanical Parameters

Mass	0.3 kg
Volume	20 cu in

5.5.3.3.6 C-Band Power Amplifier

See 5.2.2.3.3.

5.5.4 C-Band FSS International Payload

5.5.4.1 Overview of C-Band FSS International Payload

The payload provides a nine times re-use of the 500 MHz C-Band bandwidth and handles all of the projected Intelsat traffic south of the Mexican border. The traffic is processed on board and routed to either an eastern or western-directed ISL or to the U.S., or back to south-of-the-border for intra-Region 2 traffic. The re-use is achieved through nine shaped beams by spatial and polarization isolation. A unique feature of this payload is that the baseband processor accepts FDMA/FDM/FM uplink signal and performs an analog to digital conversion on board to route the signals, and also performs a digital to analog conversion on the downlink so the receiving station maintains its analog characteristics. The switch network and baseband processing would also accept digital modulation techniques, thus allowing SS TDMA operation if so desired. Figure 5.5.4-1 is a block diagram of the C-Band FSS international payload for Scenario VI-A, showing the breakdown to the component level.

Table 5.5.4-1 shows the estimated weight, power, and volume for low risk (emerging) technology and high risk (projected) technology for the transponder and antenna. Also included in the estimates are the coax, waveguide, and harness interconnects, plus an estimate for integration hardware to put the components together and provide necessary brackets for support and mounting. This does not include any structure or satellite mounting hardware, such as between the feed and reflector.

5.5.4.2 C-Band FSS International Antenna Subsystem

The C-Band International Antenna Subsystem provides the transmission at 4 GHz and reception at 6 GHz of dually linear-polarized communications signals. The purpose of the communication antenna is to provide multiple beams to cover

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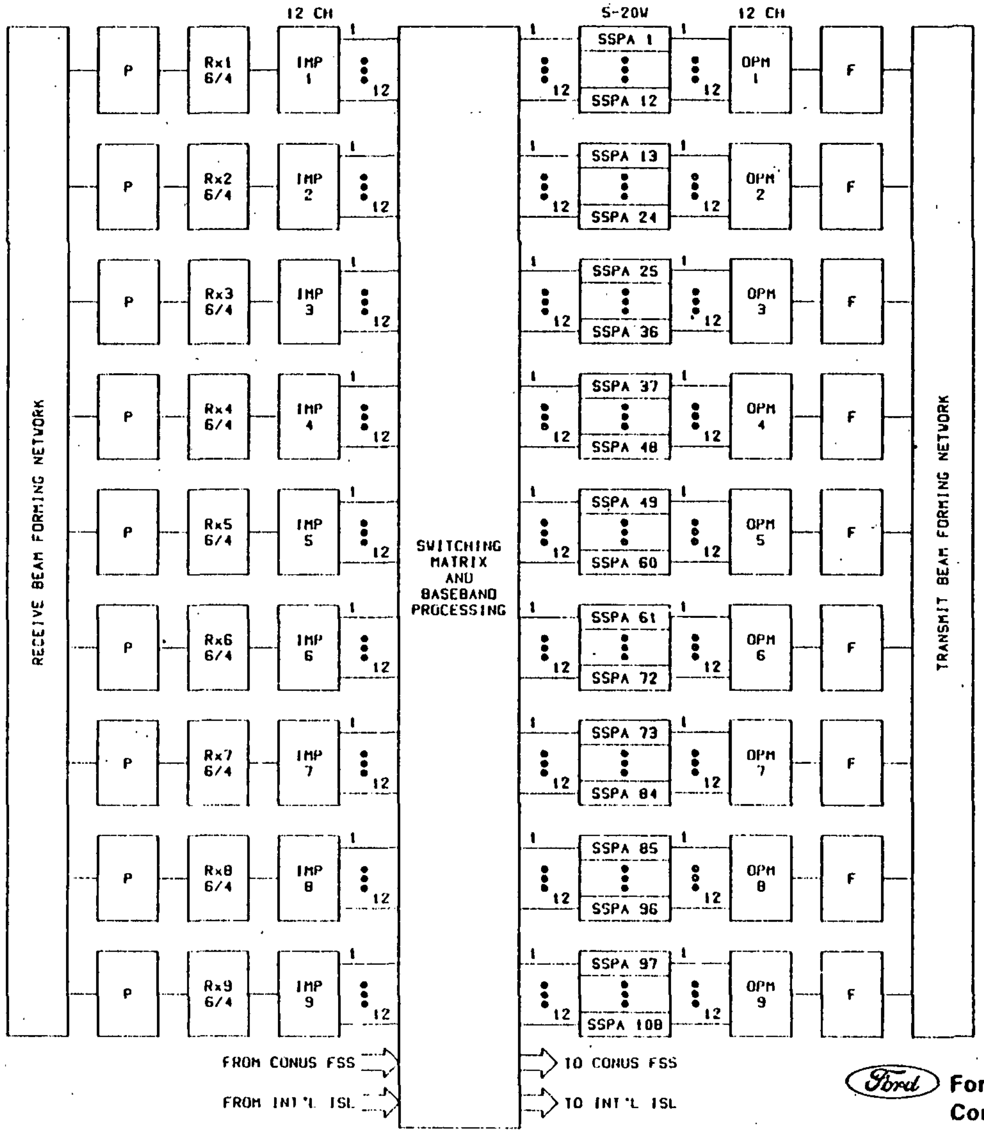
Figure 5.5.4-1 C-Band FSS - Scenario VI-A - International



Ford Aerospace & Communications Corporation

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Table 5.5.4-1

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Scenario VI-A - Payload Summary

				LOW RISK TECHNOLOGY						HIGH RISK TECHNOLOGY						COMMENTS
	ITEM	P/L QTY REQ'D	RED. QTY REQ'D	UNIT			PAYLOAD			UNIT			PAYLOAD			
				WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	
1	6/4 GHz RECEIVER	9	18	1.6	7.5	175	28.8	67.5	3150	0.7	4.8	50	12.6	43.2	900	
2	INPUT MULTIPLEXER, 12 CHANNEL, 36 MHz	9	9	4.2	-	864	37.8		7776	3.4	-	432	30.6	-	3888	
3	BEAM SWITCHING MATRIX 9x9	12	12	1.7	8.1	113	20.4	97.2	1356	0.7	5.4	40	8.4	64.8	480	
4	BASEBAND PROCESSOR (INT'L. ROUTING)	1	1	200	590	11400	200	590	11400	160.1	413	9690	160.1	413	9690	
5	5/4 REDUNDANCY SWITCH MATRIX,4GHz COX(RING)	27	27	1.4	-	160	37.8		4320	0.7	-	25	18.9	-	675	
6	ADDED BBP FOR CONUS KA-BAND	1	1	29.9	156	2448	29.9	156	2448	23.9	109	2081	23.9	109	2081	
7	SSPA, 4GHz, 4.5 WATT(WITH 2 VGAS	108	135	0.7	18	48	94.5	1944	6480	0.4	12.4	20	54	1339.2	2700	
8	5/4 REDUNDANCY SWITCH MATRIX, 4 GHz COAX(RING)	27	27	1.4	-	160	37.8		4320	0.7	-	25	18.9	-	675	
9	OUTPUT MULTIPLEXER, 12 CHANNEL, 36 MHz	9	9	4.2	-	3600	37.8		32400	1.4	-	1200	12.6	-	10800	
10	HARMONIC FILTER	9	9	0.3	-	40	2.7		360	0.3	-	40	2.7	-	360	
11	PRESELECT FILTER & ISOLATOR	9	9	0.5	-	64	4.5		576	0.5	-	64	4.5	-	576	
12	S¼DT SWOTCJ. 6 GHz 4 GHz	9	9	0.08		6	0.72		54	0.08	-	6	0.72	-	54	
13	TRANSFER SWITCH, 6GHz, 4 GHz	4	4	0.15		12	0.60		48	0.15	-	12	0.6	-	48	
14	COAX SET	1	1	27			27			27	-	-	27	-	-	
15	WAVEGUIDE, SET	1	1	13.5			13.5			13.5	-	-	13.5	-	-	
16	HARNESS	1	1	45			45			45	-	-	45	-	-	
17	INTEGRATION HARDWARE, SET	1	1	5%	-	-	30.9	-	-	5%	-	-	21.7	-	-	
18	MARGIN REQUIRED			10%	10%	5%	65	285	3734	15%	10%	5%	68.3	197	1646	
19																
20	TOTAL TRANSPONDER						715	3140	78422				524	2166	34573	
21																
22																
23	ANTENNA REFLECTOR Tx/Rx5.0m(Dual Gridded)	1	1	104	-	-	104	-	-	83	-	-	83	-	-	
24	5.0 m. VERTICAL FEED	1	1	20	-	86400	20	-	86400	18	-	77760	18	-	77760	
25	5.0 m HORIZONTAL FEED	1	1	20	-	86400	20	-	86400	18	-	77760	18	-	77760	
26	ANTENNA REFLECTOR Tx/Rx 4.0m (DUAL GRIDDED)	1	1	83	-	-	83	-	-	67	-	-	67	-	-	
27	4.0 m VERTICAL FEED	1	1	10	-	47360	10	-	47360	9	-	42624	9	-	42624	
28	4.0 m HORIZONTAL FEED	1	1	10	-	47360	10	-	47360	9	-	42624	9	-	42624	
29	MARGIN REQUIRED			10%	-	10%	24.7	-	26752	10%	-	10%	20.5		24077	
30																
31	TOTAL ANTENNA						271.7	-	294272				225.5		264845	
32																
33																
34	TOTAL PAYLOAD						986.7	3140	372694				749.5	2166	299418	

portions of Central and South America, and the Caribbean, as depicted in Figure 5.5.4-2. The combination of co-polarization and cross- polarization isolation among these beams provides the required interbeam isolation for the system. Table 5.5.4-2 summarizes the antenna subsystem requirements.

Table 5.5.4-2

C-Band International Antenna Subsystem Requirements

Parameters	Requirements	
Frequency	Transmit: Receive:	4 GHz band 6 GHz band
Polarization	Dual Linear	
Coverage area	South/Central America	
Co-polarization isolation	27 dB	
Cross-Polarization Isolation	30 dB	

The antenna will consist of two dual-gridded reflectors, one 5 meters and the other 4 meters, as shown in Figures 5.5.4-3 and 5.5.4-4. The 5 meter reflector is used for Central America and the 4 meter, for South America. Normally, a single large reflector is preferred for generating a shaped beam. However, a larger size aperture radiates a narrower constituent beam so that the required scanning range in terms of beamwidths is therefore larger. This results in a more severe phase aberration for the edge beams. Theoretically, the phase aberration can be corrected by using an infinitely size of the feed array. However, such an approach is not practical. The use of a two reflector antenna system increases the beamwidth of the constituent beam and hence reduces the phase aberration for the edge beam. Figures 5.5.4-5 to 5.5.4-13 present the antenna radiation patterns. Table

Figure 5.5.4-2 C-Band International Antenna Coverage Requirements

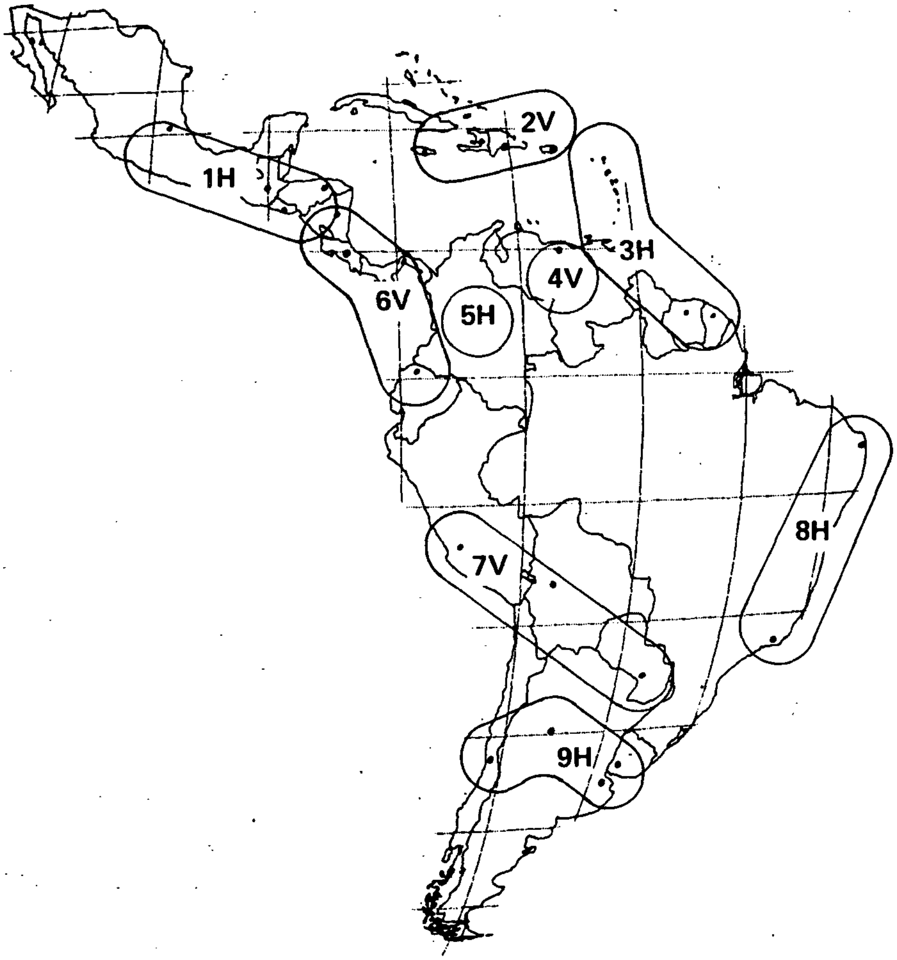
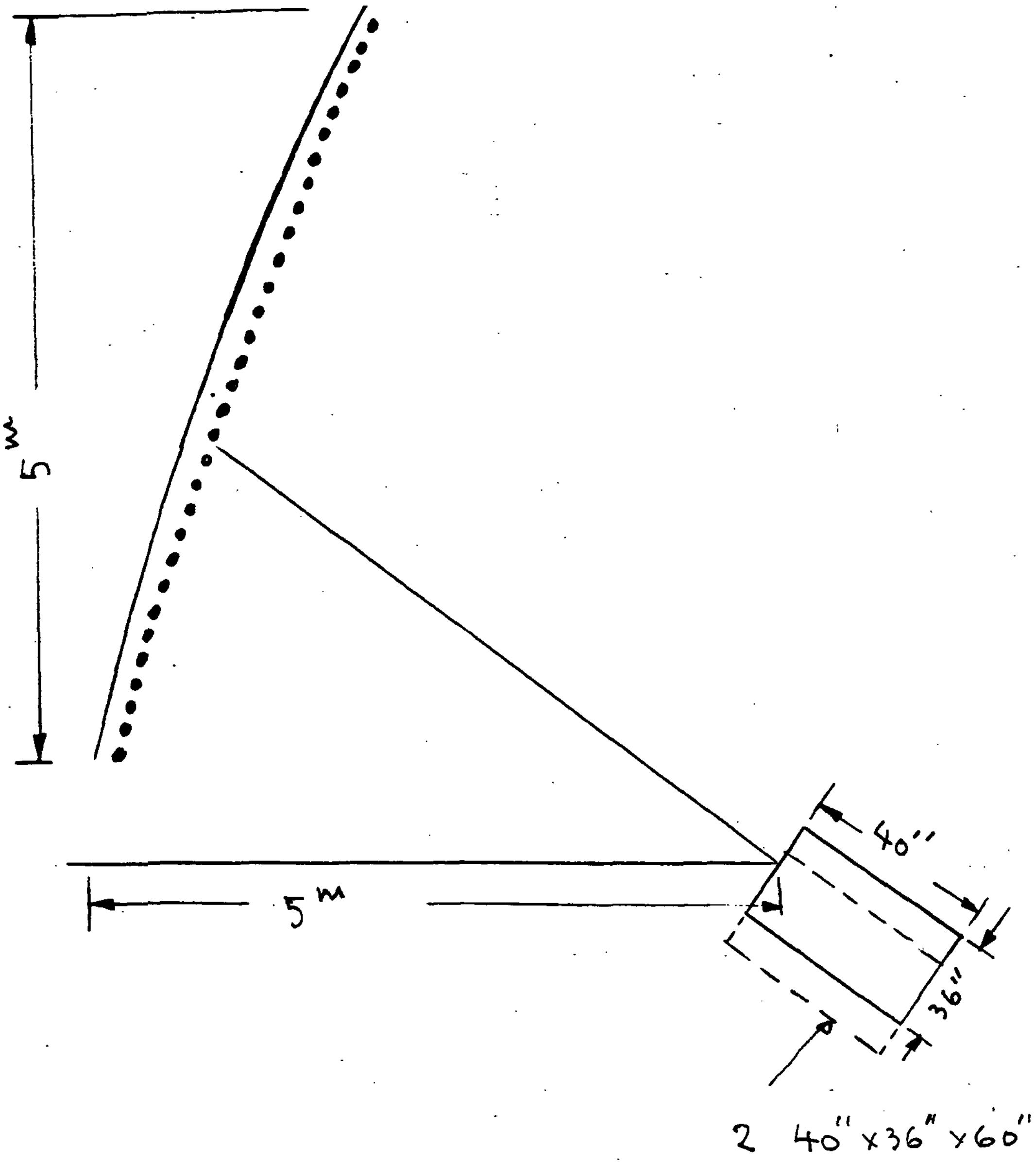


Figure 5.5.4-3 5-Meter Antenna Configuration



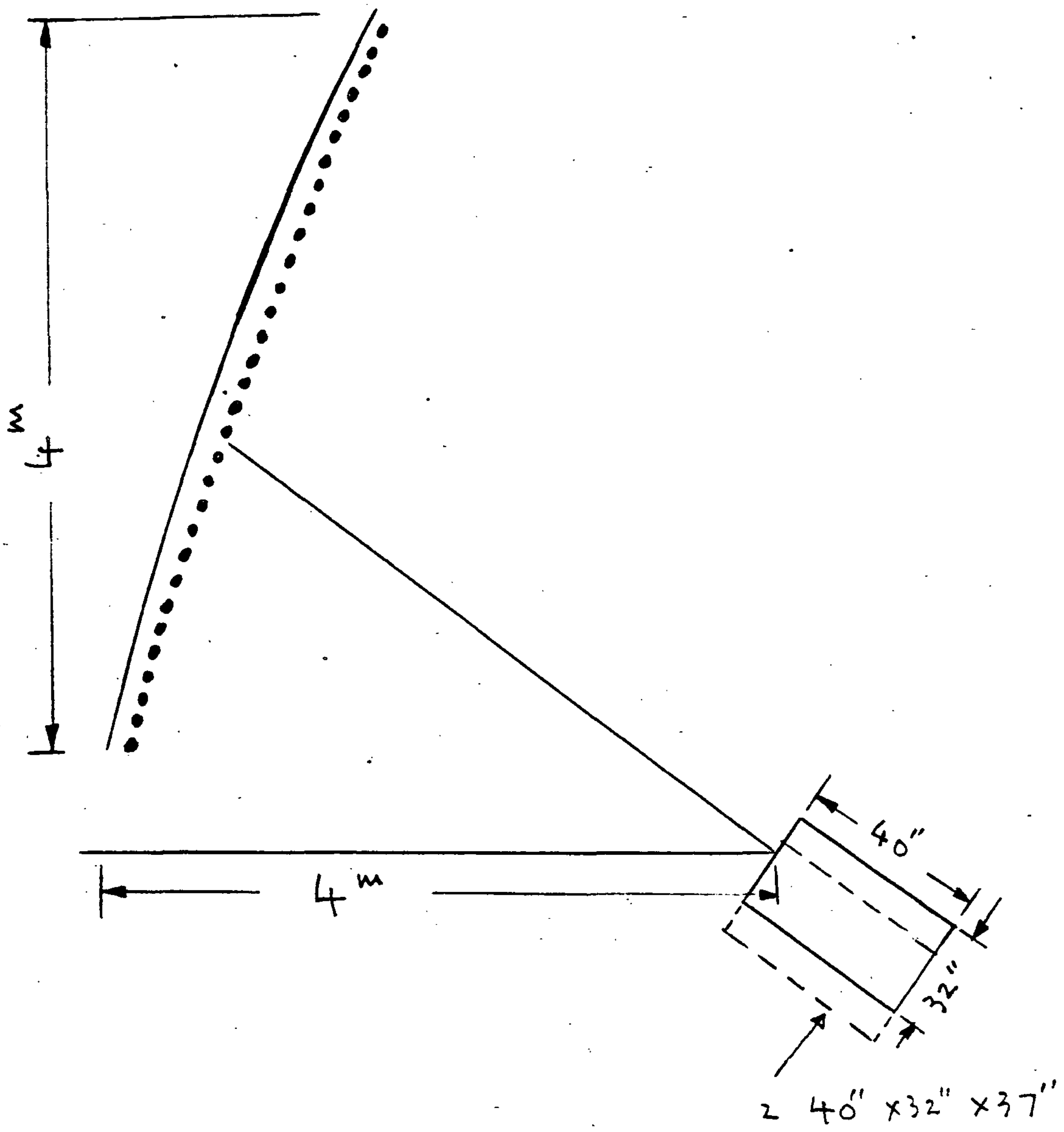
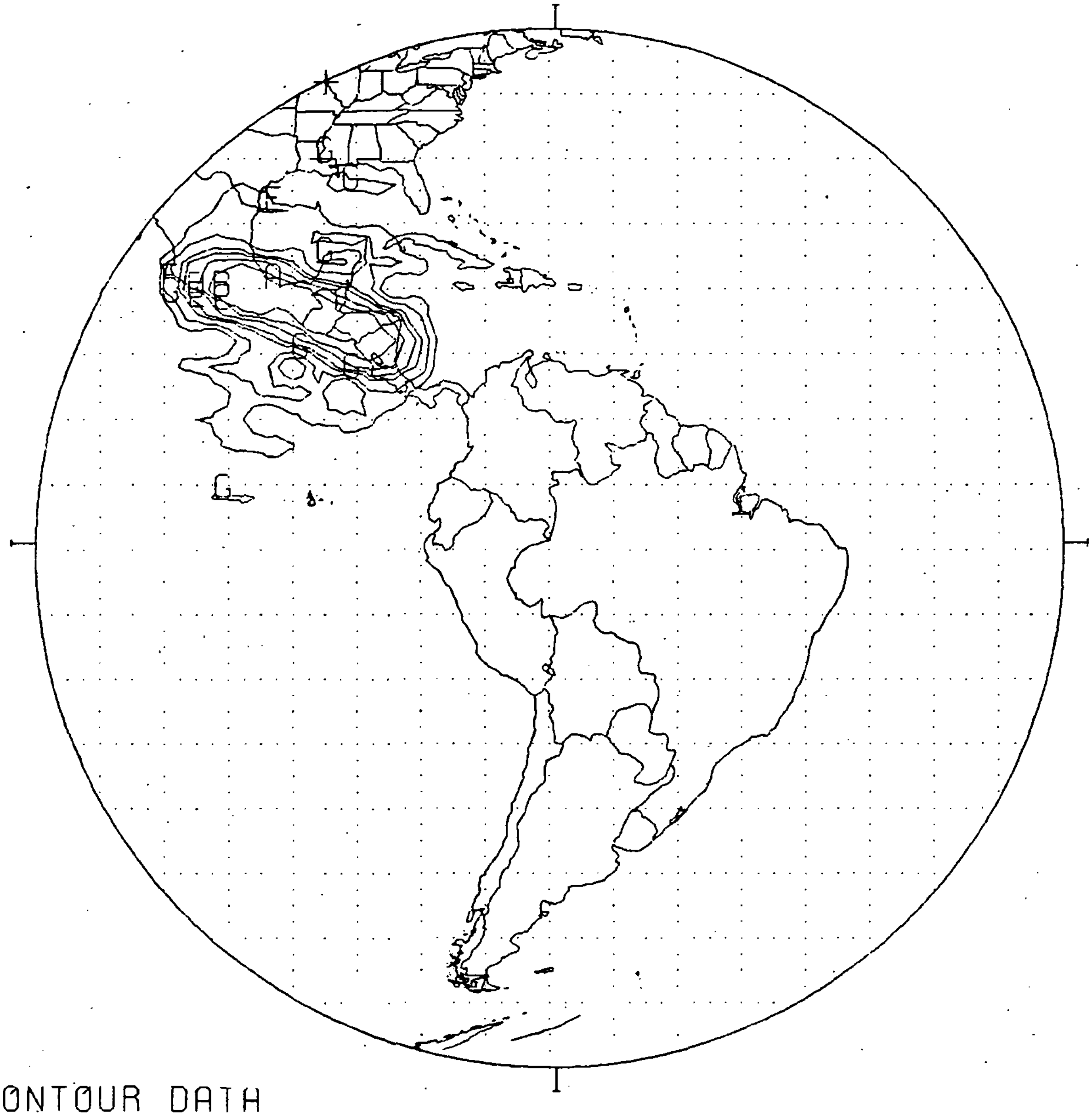

4m
4m
40"
32"
2 40" x32" x37"

Figure 5.5.4-5 C-Band International Beam 1H Antenna Pattern



CONTOUR DATA

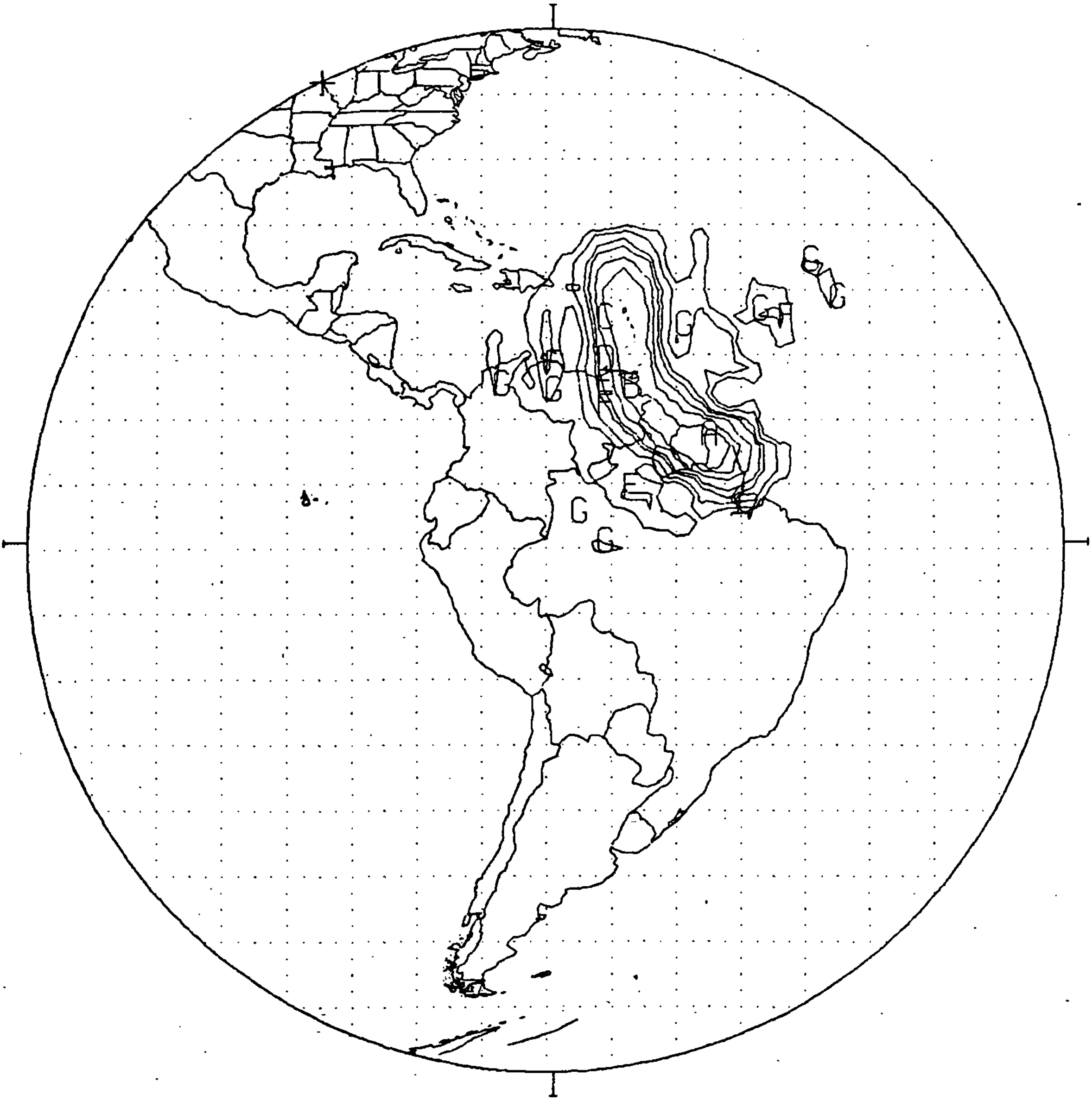
SYMBOL	LEVEL
A	0.000
B	-3.000 (35.6 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

Figure 5.5.4-6 C-Band International Beam 2V Antenna Pattern

CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (39.4 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

Figure 5.5.4-7 C-Band International Beam 3H Antenna Pattern



CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (35.1 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

Figure 5.5.4-8 C-Band International Beam 4V Antenna Pattern

CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (40.0 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

Figure 5.5.4-9 C-Band International Beam 5H Antenna Pattern

CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (40.0 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

Figure 5.5.4-10 C-Band International Beam 6V Antenna Pattern

CONTOUR DATA

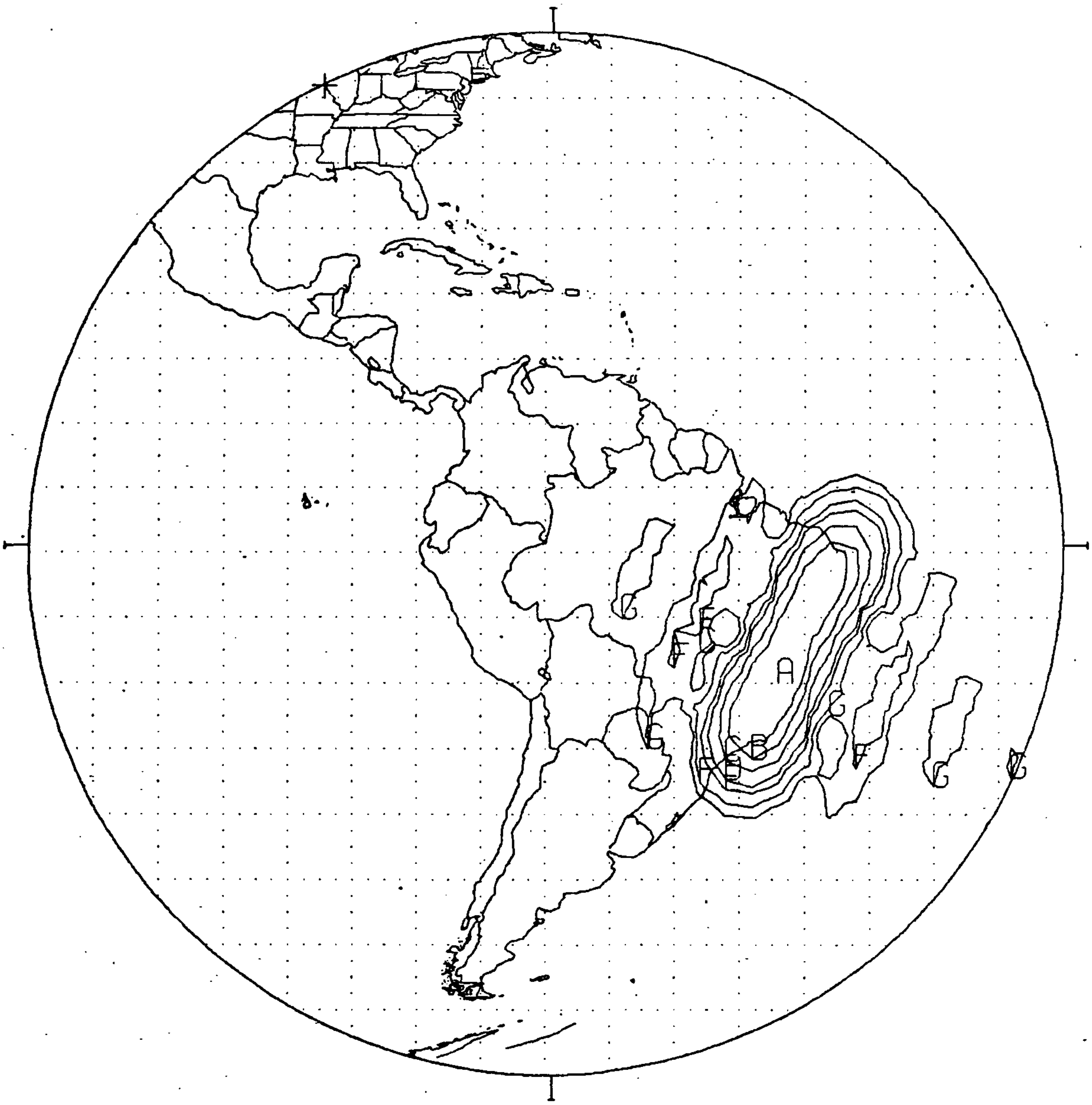
SYMBOL	LEVEL
A	0.000
B	-3.000 (35.1 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

Figure 5.5.4-11 C-Band International Beam 7V Antenna Pattern

CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (33.6 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

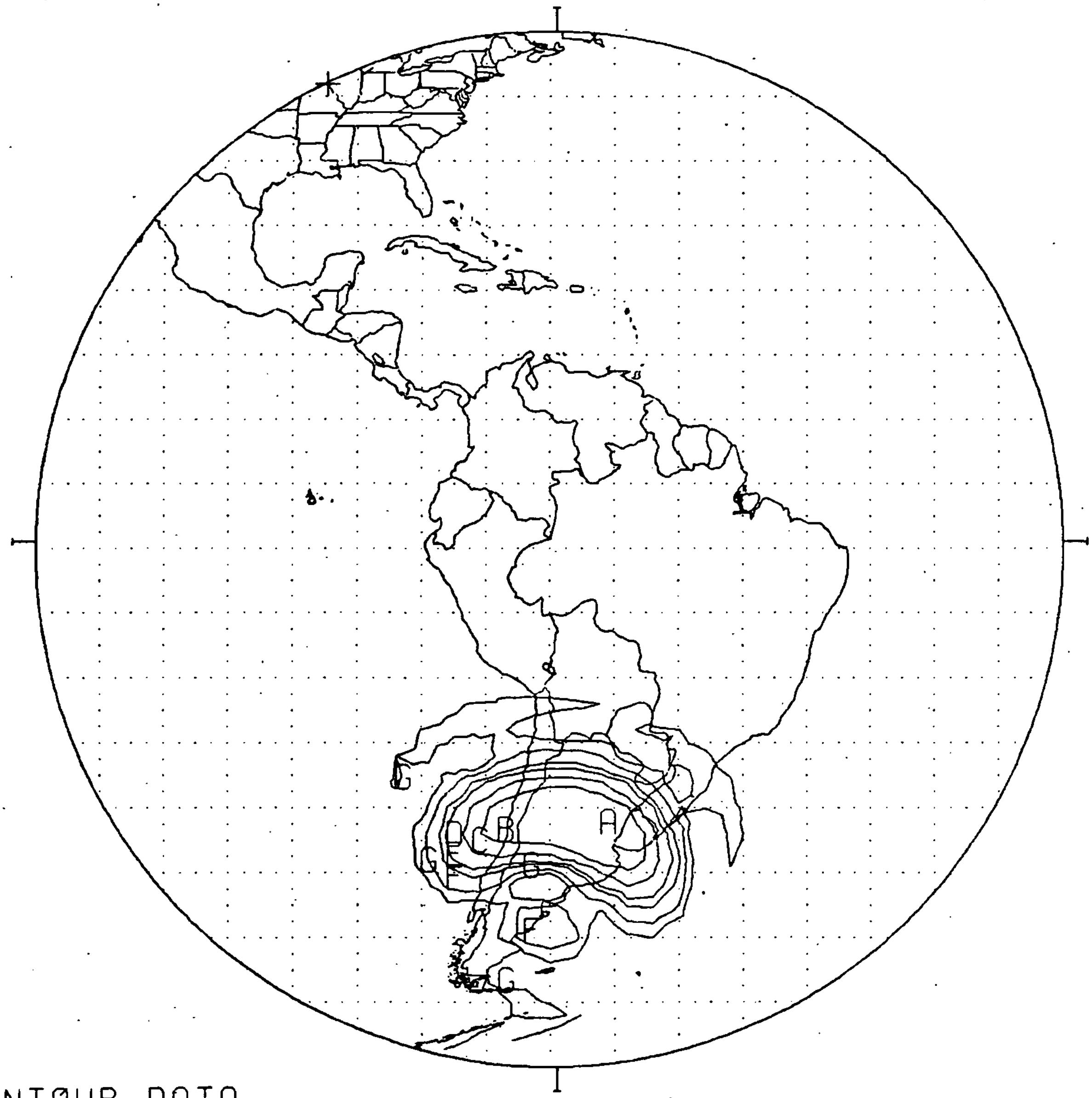
Figure 5.5.4-12 C-Band International Beam 8H Antenna Pattern



CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (33.6 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

Figure 5.5.4-13 C-Band International Beam 9H Antenna Pattern



CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (35.1 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

5.5.4-3 summarizes the edge-of-coverage antenna gain for each beam.

Table 5.5.4-3

C-Band International Predicted Antenna Gain

Coverage Area	Gain (dBi)
1H	35.6
2V	39.4
3H	35.1
4V	40.0
5H	40.0
6V	35.1
7V	33.6
8H	33.6
9H	35.1

Each reflector/array system operates in both the transmit and receive bands. The grids of the reflector are selected to run either in the horizontal or vertical direction for horizontal or vertical polarization. They are used to help lower cross-polarization energy that is produced by the field curvature of the asymmetric paraboloid, as well as the cross-polarization radiated from the feed array. The cross-polarization isolation achieved is greater than 30 dB.

Diurnal and seasonal solar variations can cause temperature extremes and gradients on the reflector surface, which, in turn, can mechanically distort the reflector and degrade the electrical performance. Advanced kevlar fiber composite materials are used for the structural elements of the reflector assembly to provide maximum thermal stability and structural strength with minimum weight. Each reflector is a kevlar/epoxy laminate sandwich, thin-shell bonded to a backside or ring reinforcing structure. The sandwich shell supports the gridded system of wire. The largest existing dual-gridded reflector that has ever been built is 72". The current size, 5 meters, presents a challenging mechanical and electrical design problem to the present state-of-the-art. In addition, a 5 meter reflector exceeds the maximum size that can be accomodated on the space shuttle bay with an integral solid reflector. Therefore, the edge of the reflector may be folded. The cross-polarization purity may be degraded due to the intermediate structure of the folded reflector. An unfurlable reflector is not practical, even in the 1994 technology, because of the thermal distortion, manufacturing RMS, and the distorted straight grids on the reflector surface. Table 5.5.4-4 summarizes the assessment of the critical technology items for this subsystem.

Table 5.5.4-4

Assessment Level of Risk of Critical Technology Items

Item	Low Risk	High Risk
Cross-polarization isolation	27 dB	30 dB
Co-polarization isolation	25 dB	27 dB
Reflector	Needs Development	Needs Development
Weight (Reflector)	191 kg	20% less

5.5.4.3 C-Band Transponder Subsystem International Service

The C-Band transponder subsystem consists of nine semi-independent, 12 channel transponders, and hence has a total capacity of 108 channels, each having a bandwidth of 36 MHz. The nine transponders utilize the same 500 MHz FSS band, having an uplink at 6 GHz and a downlink at 4 GHz. The transponders also interconnect with the east and west ISL's and the Ka-Band CONUS and scan beams via switch matrix.

Each of the nine 6 GHz inputs from the antenna feed assembly is filtered by an input preselector and then amplified and down converted to 4 GHz by the receiver. The 500 MHz IF band is subdivided by an input multiplexer into twelve 36 MHz channels. The filters of the input multiplexer also provide the required narrow band receive filtering responses.

Twelve switch matrices enable signals in any uplink channels of one transponder to be connected to the same channel in any of the other eight international transponders, or with the east and west ISLs and the Ka-Band transponders.

The channels are individually amplified by up to 5 watt SSPA's which contain one or more variable gain amplifiers. The latter permit automatic accommodation of varying uplink levels using an AGC loop, and SSPA back off via ground control. The output of the SSPA's in each set of twelve channels are combined in a twelve channel output multiplexer, which also supplies the required narrow band transmit filtering responses. The downlink signals are further filtered by harmonic/bandpass filtering prior to transmission from the transmit antenna feed assembly. The transponder subsystem features four for two receiver redundancy and five for four SSPA redundancy.

5.5.4.3.1 6/4 GHz Receiver

See 5.2.2.3.1.

5.5.4.3.2 4 GHz Input Multiplexer

See 5.2.2.3.2.

5.5.4.3.3. RF Switch Matrix

See 5.2.3.3.3.

5.5.4.3.4 4 GHz 8.5 Watt SSPA

See 5.2.2.3.3.

5.5.4.3.5 4 GHz Output Multiplexer

See 5.2.2.3.4.

5.5.4.3.6 Pre-Select and Harmonic Filter

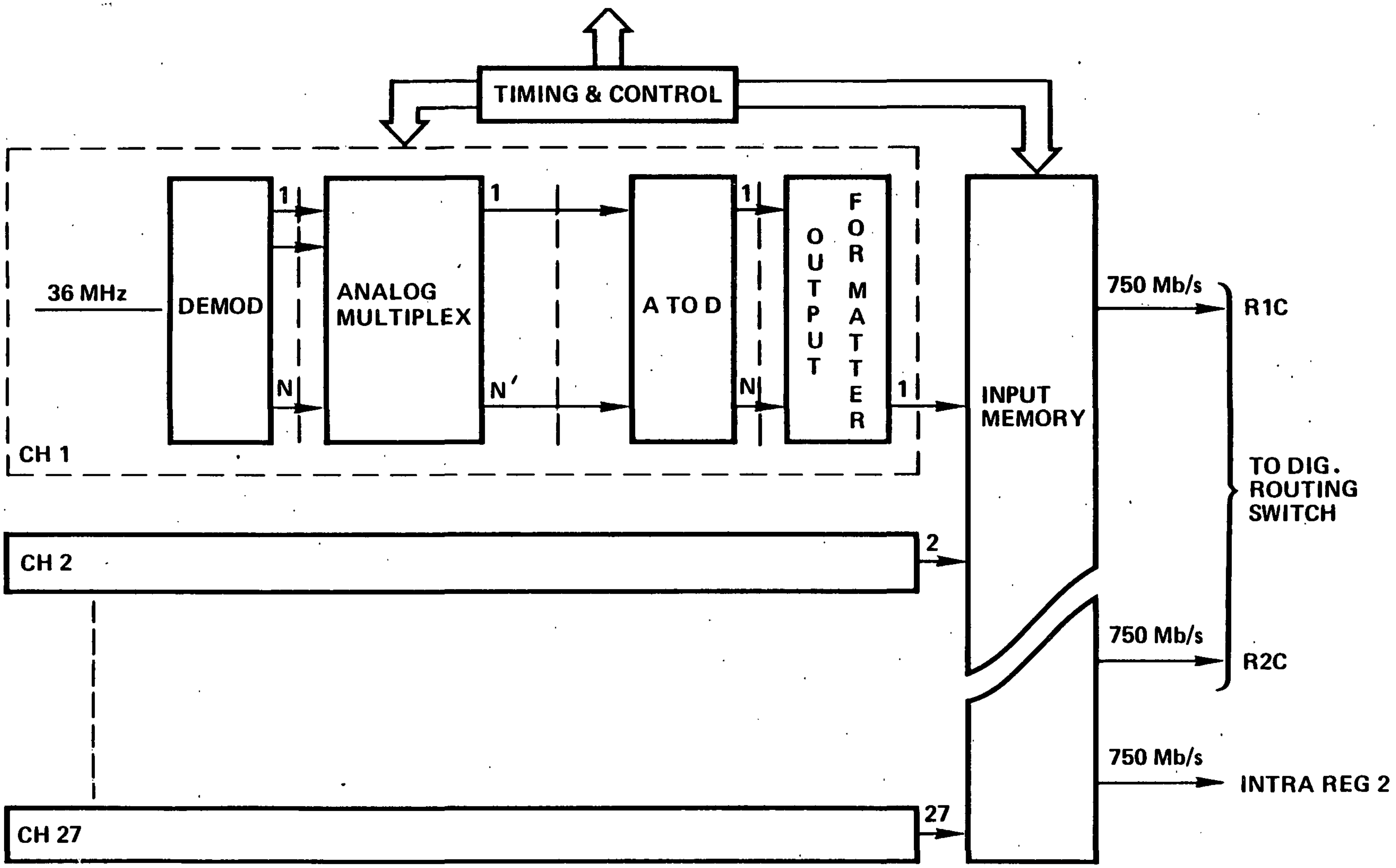
See 5.2.2.3.5.

5.5.4.4 Baseband Processor

A new concept in on-board processing was developed for use in Scenario VI-A, the use of A/D and D/A conversion. Section 4.6.4.5 describes the rationale for providing this capability.

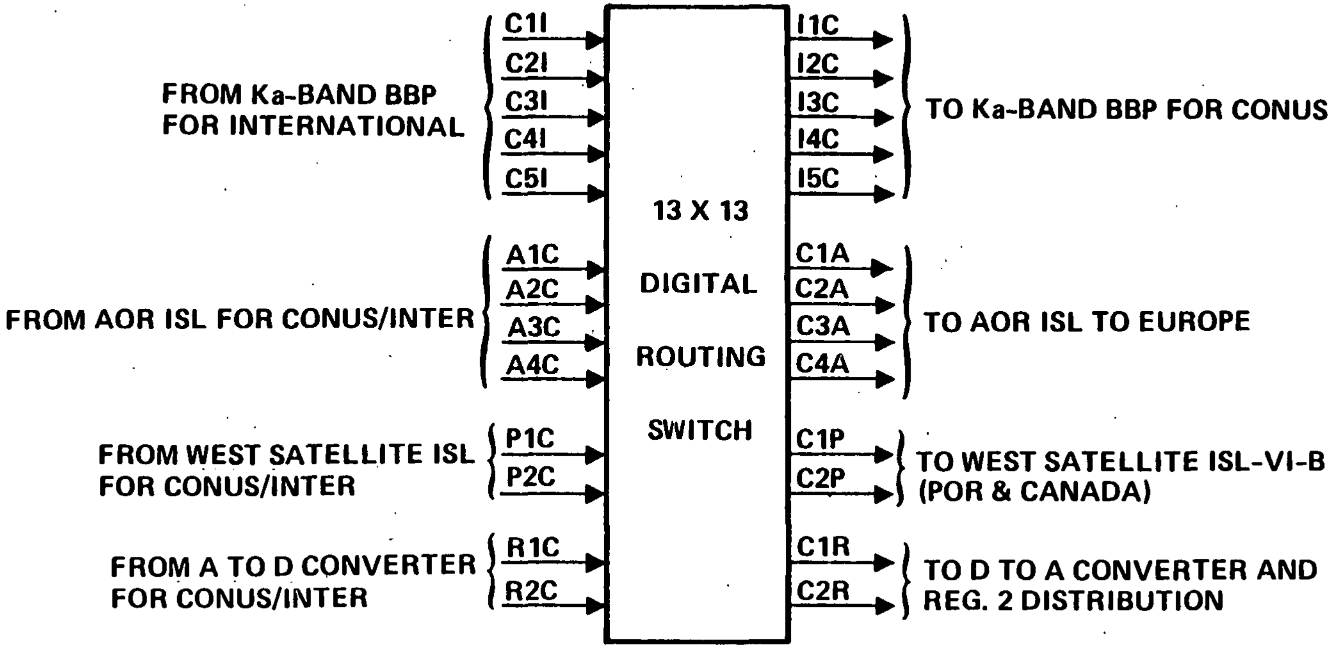
Figure 5.5.4-14 shows the uplink processing performed on the channels carrying international/regional traffic for the Latin America/Caribbean coverage. Each 36 MHz channel consists of several FDMA subchannels (see Figure 4.6-4). Each subchannel is filtered (FDM demux) and connected to a digital signal at a rate dependent on the size of the subchannel. The digital signals are then TDM multiplexed into 750 Mb/s streams and routed to a digital routing switch, which operates in a fashion similar to the Ka-band BBP. In fact, this VI-A routing switch interface with the Ka-band BBP to carry U.S. international/regional traffic; the ISLs are also routed via this switch (see Figure 5.5.4-15). For the downlink, the reverse process is required, as shown in Figure 5.5.4-16.

Figure 5.5.4-14 Scenario VI-A Uplink International Processor



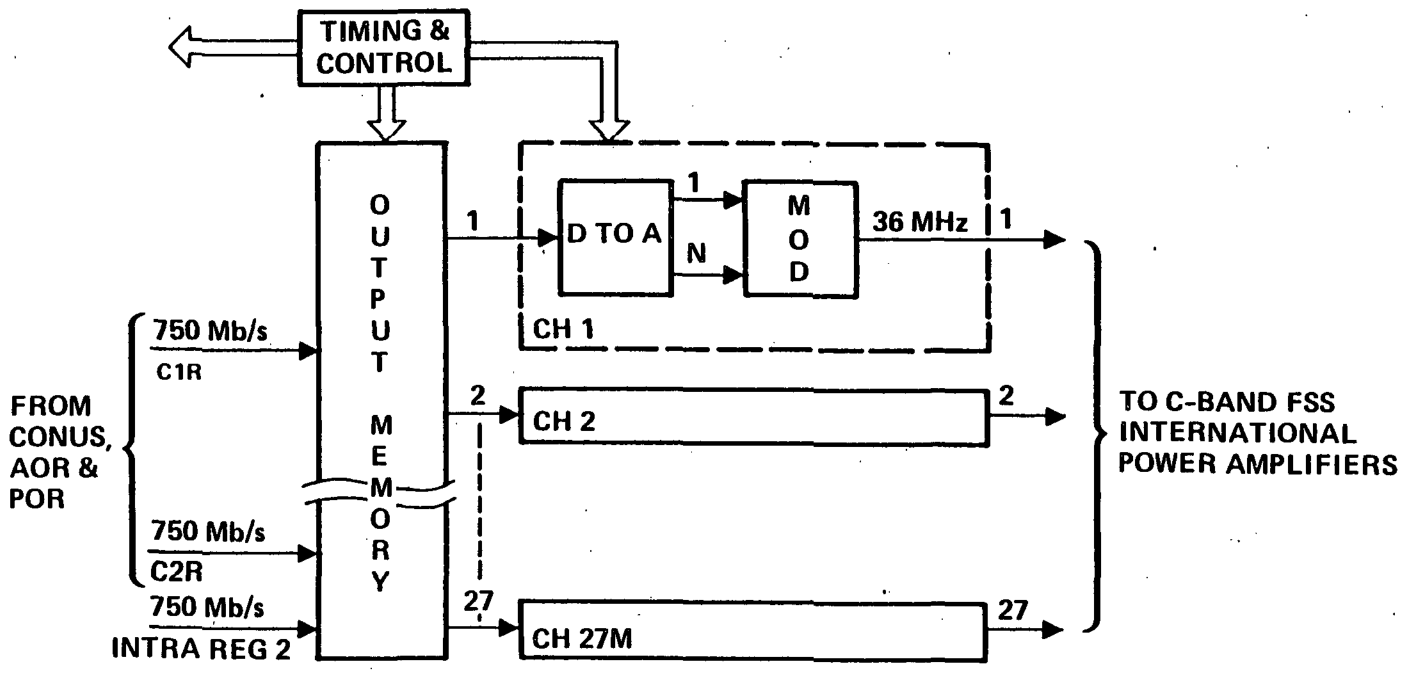
Ford Aerospace & Communications Corporation

Figure 5.5.4-15 Scenario VI-A International Routing Switch



*EACH DATA INPUT/OUTPUT LINE CARRIES 750 Mb/s

Figure 5.5.4-16 Scenario VI-A Downlink International Processor



Because this concept is new, there are several factors which should be analyzed in more detail to ensure feasibility of the design.

a) Bandwidth

As previously noted, it would be desirable to break the 36 MHz transponder band into more than one access size so that traffic bundles of different sizes can be carried as efficiently as possible. In addition, it may be possible to make the division of bandwidth flexible through the use of switched filters, or by means of programmable digital filtering. The bandwidths selected would in turn determine the sampling rate for each access size.

b) Bits per Sample

Standard encoding used in telephony uses 8 bits per sample. A/D converters ranging from 6 to 9 bits resolution are currently available. The greater the number of bits, the better the quality (lower quantization noise); however, the price of this quality is additional requirements for buffers for the same throughput.

c) Buffer Requirements

The total buffer requirements depend on the bits per sample, frame length, and total amount of traffic requiring A/D and D/A processing. Only a relatively small proportion of the traffic on a satellite will require such processing.

d) Control Requirements

The output of an A/D converter is a continuous bit stream. The on-board processing must accomplish the necessary framing, synchronization, and high speed bursting

On-board switching of digital signals can be done either by means of SS/TDMA or baseband processing techniques. The latter is the most flexible approach, but would probably require more mass and power. On the other hand, SS/TDMA switching is performed at IF with very high burst rates. This aspect of the architecture will need to carefully analyzed to ensure functional compatibility.

f) Filtering

In order to separate the accesses within a transponder or channel, some form of filtering or demultiplexing (combining or multiplexing at the payload output) of the demodulated signal is required. This could be done, either before or after A/D conversion. The approach described previously performs the filtering first.

Several factors would have to be considered to ensured the proposed system meets applicable CCITT or AT&T standards. Noise introduced by the A/D and D/A conversions can be affected by the encoding algorithm used, (PCM, Delta-Mod etc.), the sampling rate, and the number of bits per sample. On the analog side, one should evaluate such items as dynamic range, whether low speed data is to be supported, and whether companding is used.

The approach selected should meet end-to-end performance standards. This will require allocation of performance to the uplink, downlink, ISL (if used), and the on-board processing.

For low risk technology. the ACTS BBP weight, power, and volume and engineering estimates are the basis of the estimate. For the high risk technology, it is assumed that additional VLSI development and advances in speed and power would yield lighter weight, lower power and correspondingly lower volume. This is an area where the custom VLSI work would not likely be done without NASA/government subsidized effort such as the ACTS processor and the various NASA LeRC technology development programs.

5.5.5 Ka-Band FSS Payload

This payload is identical to the Ka-Band FSS payload described in Scenario II. See 5.2.3 for detailed description.

5.5.6 Ka-Band Scan Payload

The payload is identical to the Ka-Band Scan payload described in Scenario II. See 5.2.4 for detailed description.

5.5.7 Ku-Band FSS Payload

This payload is identical to the Ku-Band FSS payload descrived in Scenario V. See 5.4.5 for detailed description

5.5.8 60 GHz Inter-Satellite Link (ISL)

The cross link between two geosynchronous satellites with up to 160 degrees of separation (83,000 km) is capable of simultaneous transmission and reception of 1.5 Gbps data through staggered quadrature phase shift keying (SQPSK) modulation using a 5 watt IMPATT diode stable amplifier and a gimbal mounted, 3.0 m parabolic dish Cassegrain antenna with low loss beam waveguide. The communication capability is maintained year round except for the brief periods (less than 0.01% per year total) when the sun is in conjunction with the antenna field of view. During these brief periods, the link is maintained at 300 Mbps. Automated acquisition/reacquisition and monopulse tracking are maintained at all times regardless of sun effect.

A microprocessor controlled automated main beam acquisition algorithm receiver with monopulse tracking is capable of initiating and accomplishing link acquisition at any contactable time regardless of the effect of sun. With this design, high confidence acquisition can be accomplished having an initial attitude plus pointing error as large as ±2.0 degrees.

To accomodate a conglomerate of up to 4.5 Gbps traffic from all links per each satellite requires innovative frequency and polarization planning. In addition, key inter/intra system interference analyses would have to be conducted to ensure adherence to the WARC' 79 frequency allocation for the 60 GHz band.

The links on Scenario VI-A would require two 1.5 Gbps links on the eastern ISL and one 1.5 Gbps on the western ISL. Figure 5.5.8-1 is a block diagram of the single link ISL for Scenario VI-A showing the breakdown to the component level. Table 5.5.8-1 shows the estimated weight, power, and volume for low risk (emerging) technology and high risk (projected) technology for the transponder and antenna. Also included in the estimates are the coax, waveguide, and harness interconnects, plus an estimate for integration hardware to put the components together and provide necessary brackets for support and mounting. This does not include any structure or satellite mounting hardware such as between the feed and reflector.

Figure 5.5.8-1 ISL Block Diagram - Scenario VI-A

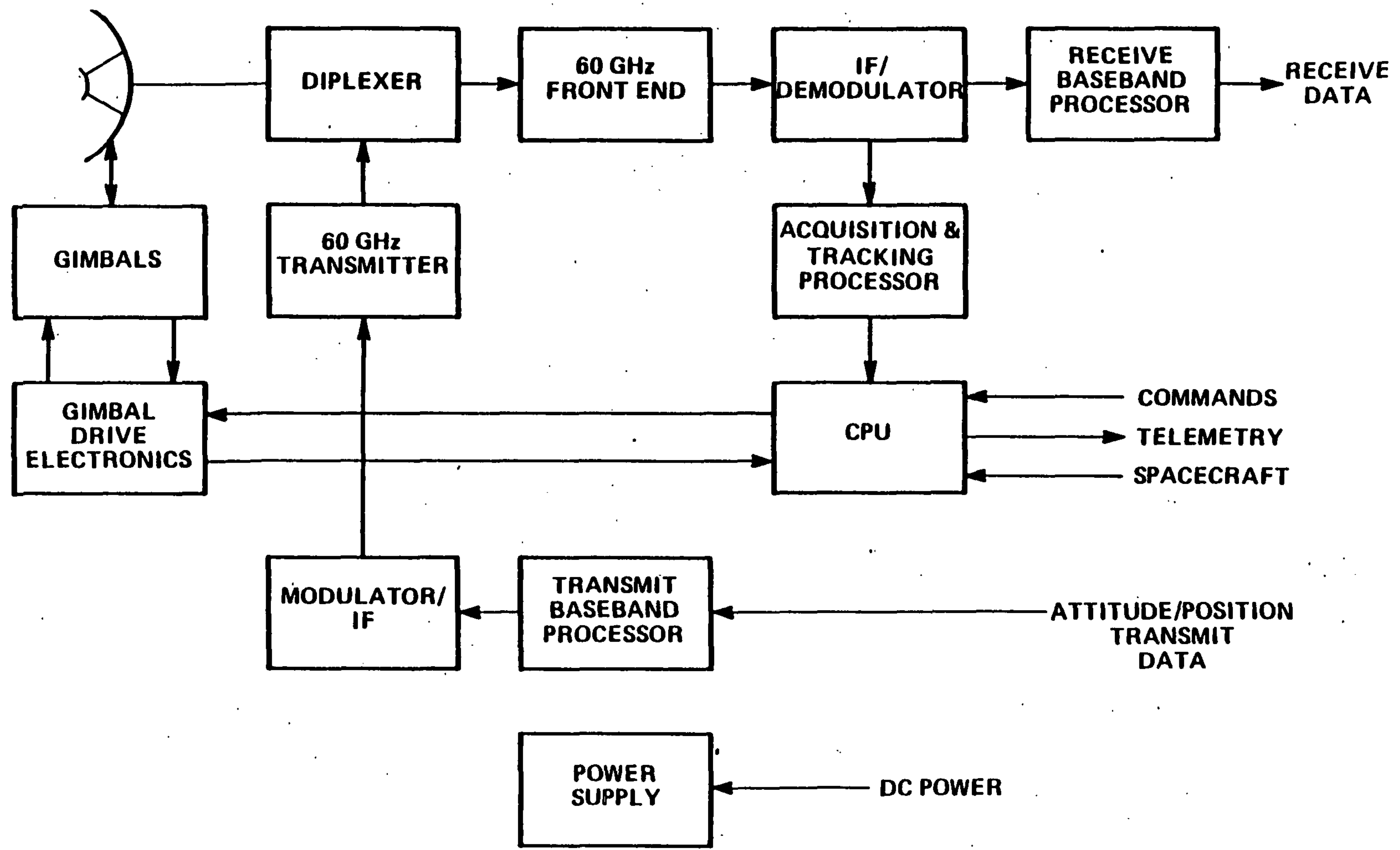


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Table 5.5.8-1

Scenario VI-A Payload Summary

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	ITEM	P/L QTY REQ'D	RED. QTY REQ'D	LOW RISK TECHNOLOGY						HIGH RISK TECHNOLOGY						COMMENTS
				UNIT			PAYLOAD			UNIT			PAYLOAD			
				WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	
1	RECEIVER	3	6	2	15	200	12	45	1200	1	5	50	6	15	300	
2	DIPLEXER	2	2	0.2	-	3	0.4	-	6	0.2	-	3	0.4	-	6	
3	CPU/PROCESSOR	2	4	2	20	200	8	40	800	1.4	10	75	5.6	20	300	
4	GIMBALS	2	2	16	25	20	32	50	40	13	20	15	26	40	30	
5	DRIVE ELECTRONICS	2	4	3	2	300	12	4	1200	2	2	100	8	4	400	
6	TRANSMITTER(5W. IMPATT)	3	6	1	40	150	6	120	900	0.7	20	75	4.2	60	450	
7	ANTENNA ASSY(REFL. SUB REFL. FEED & SUPPORT)	2	2	26	-	-	52	-	-	21	-	-	42	-	-	
8	MARGIN REQUIRED			20%	10%	15%	24.5	26	622	20%	15%	20%	18.4	22	297	
9																
10	TOTAL ISL						146.9	285	4768				110.6	160	1783	
11																
12																
13																
14																
15																
16																
17																
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30																

1 FOLDOUT FRAME

2 FOLDOUT FRAME

5.6 SCENARIO VI-B DEFINITION

5.6.1 Introduction

Scenario VI-B is the second of a complementary pair of satellites designed to handle all of the WARC Region 2 Intelsat traffic, intra-Region 2 traffic AOR and POR traffic and provide all domestic coverages for non-CONUS Region 2 traffic. This satellite is the westerly located satellite and handles the primary processing of Canadian Intelsat traffic and the domestic non-CONUS traffic for Region 2. The satellite also provides the high capacity CONUS FSS payloads described in Scenario V, except the C-Band CONUS which could not be isolated from the Mexican and Canadian domestic service. The Intelsat traffic is routed via the baseband processor to an eastern or western ISL link. The services provided are listed below:

- 38 Channels, 36 MHz, Ku-band non CONUS payload 4 beams, 3.2 x re-use
- 108 channels 36 MHz, C-band, Non-CONUS FSS, 9 beams, 12 channels each, 9 x re-use.
- 108 channels, 36 MHz, Ku-band, CONUS payload, 9 beams, 12 channels each, 9x re-use.
- 38 channels, 500 MHz, Ka-Band, CONUS FSS, 20 beams, 7.6 x re-use.
- 18 channels, 240 MHz, and 14 channels, 500 MHz, Ka-band, CONUS FSS payload, 6 beams, CPS/thin route trunking, 4.6 x re-use.
- C/L-band, Maritime payload, L to C-band - ship to shore; C to L-band - shore to ship.
- Intersatellite link (ISL), 3 links 2 to the east and 1 to the west, each 1.5 Gbps capacity.

The C/L-band Maritime payload is the same as the second generation Marisat that can handle 125 voice circuits. The location of this scenario satelite is assumed to be 101°W for antenna coverage and location further west of 101° W would be acceptable down to about 110°W.

An overview block diagram of the payload elements is shown in Figure 5.6.1-1. Table 5.6.1-1 lists the major bus/payload interface requirements, and Tables 5.6.1-2 and 5.6.1-3 present the major antenna and transponder characteristics respectively. The two Ka-Band antennae require individual gimbal systems for steering the two sub-reflectors to achieve ±0.02° pointing of the RF boresight, as well as the two ISL reflectors. The other antennae will be rigidly mounted to the body and body steered via the bus control system.

Table 5.6.1-1

Scenario VI-B - Payload Summary

o Mass	2926 kg
o Power Required	
Sunlight	11,200 watts
Eclipse	75% min; 100% desired
o Pointing Requirement	±0.05° absolute (ie: RF boresight)
o Temperature Requirements	
Antenna	-90° to +110°C
Transponder	-10°C to +59°C, TWTA's +60°C
o Thermal Dissipation	1.5 kW in EPC's, 8 kW in TWT's & 4 kW in feeds & W/G losses
o Lifetime	10 years without servicing

Figure 5.6.1-1 Scenario VI-B Overview

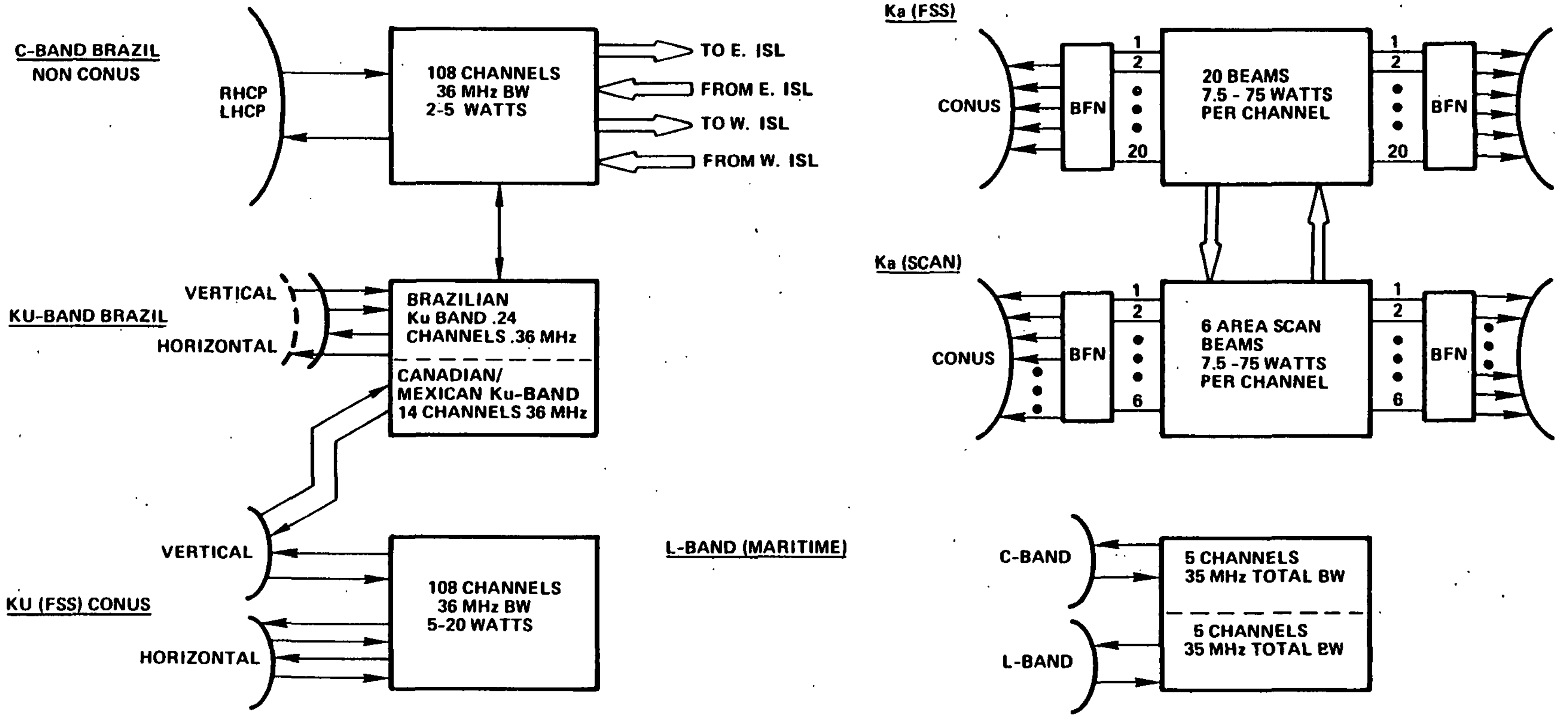


Table 5.6.1-2

Scenario VI-B Antenna Configuration

Antenna System	Freq (GHz)	Reflector	Polarization	Feed Arrays
C-Band FSS (Non-CONUS)	4/6	9m unfurlable reflector	CP	400 feeds plus 400 diplexers
Ku-Band FSS (CONUS & Can.& Mex)	11/14	15'(4.6m)) dual gridded reflector	Linear	2x450+350 feeds.
Ka-Band FSS	20/30	One solid 13' (4.0m) reflector for tx, one solid 9'(2.7m.) reflector for rec (dual shaped reflector each with subreflector)	Linear	Tx:500 feeds, 830 sws, 140 omj's; same for Rec.
Ku-Band (Brazil)	11/14	1m dual gridded reflector	Linear	2x14 Feeds
C/L-Band Maritime	1.5-1.7 3.6-3.65 6.425-6.441	one(1.2m)solid; one(0.5m) solid one(0.35m) solid reflectors	CP	
GEO-GEO	60 GHz	One gimballed 3m reflector for each ISL. One east & one west	CP	Center fed cassegrain

Due to the use of TWTA's for the Ka-band FSS payload, a 10-year life is all that can be envisaged at this time as replacement of TWTA's is not anticipated for the early year 2000 time period. It is estimated that the identified redundancy is compatible with a 10 year life application.

This scenario in similiar to VI-A in that it requires in-orbit assembly and a modular approach to spacecraft assembly. This may allow replacement of the Ka-band transponder package to extend the life to fifteen or twenty years with GEO servicing. If the spacecraft were designed to allow replacement of the transponder package it would probably require an added weight penalty for the modularity. This scenario is clearly a launch concept 2 scenario and thus open the possibility of the modular approach.

Table 5.6.1-4 presents a summary of the high and low risk weight and power for the individual payload elements in Scenario VI-B.

Table 5.6.1-3

Transponder Summary Scenario VI-B

Payload	U/L,D/L Freq. GHz	Number Channels	Channel BW, R/F	RCVR Type (Number)	HPA Type (Number)	HPA Power,W
Ku Band FSS (Non-CONUS)	14/11	38	36	14/4(6)	SSPA(60)	5.0
Ku-Band FSS (CONUS)	14/11	108	36	11/14(18)	SSPA(135)	2
Ka-Band FSS	30/20	38	500	30/4(40)	TWTA(49)	75
Ka-Band Scan	30/20	32	240/500	30/4(12)	TWTA(40)	75
C/L-Band	6/1.5	1	Total 35	6/1.5(2)	SSPA(6)	70
Maritime	1.6/3.6	2	Total 35	1/6/0.35 (2)	SSPA(2)	8.5
ISL	60/60	2	1.5 GHz	60/8(2)	Impatt diode (4)	5

In Appendix K, Tables 1 thru 20 show that all of the payload elements have viable links with the various types of anticipated modulation and access types. While some of the margins are low,

Table 5.6.1-4

Scenario VI-B Weight and Power Summary

	WEIGHT(KG)		POWER(W)	
	Low Risk	High Risk	Low Risk	High Risk
Ku-Band FSS (CONUS)				
Transponder	625	362.4	1164	785
Antenna	187	160.6	-	-
Sub Total	812	523	1164	785
Ka-Band FSS+Scan (CONUS)				
FSS Transponder	751.4	516.3	3305	3043
SCAN Transponder	636.0	447.6	2180	1936
Baseband Processor	355.0	297.4	1360	952
Antenna	264.5	230.4	4	2
Sub Total	2006.9	1491.7	6849	5933
C-Band FSS (NON-CONUS)				
Transponder	461.1	334.3	2231	1573
Baseband Processor	163.4	136.9	473	330
Antenna	121	103	-	-
Sub Total	745.5	574.2	2704	1903
Ku-Band FSS (NON CONUS)				
Transponder	224.9	123.9	2751	1796
Antenna	75.9	62.5	-	-
Sub Total	300.8	186.4	2751	1796
Maritime				
Transponder	58.2	39.9	855	649
Antenna	5.0	4.2	-	-
Sub-Total	63.2	44.1	855	649
ISL's	139.7	106.6	224	131
SCENARIO VI-B TOTAL	4068.1	2926	14547	11197

the links represent the worst case condition. If this scenario were to be studied further for full system definition it is expected that the link margin could be improved.

5.6.2 C/L Band Maritime Payload - Eastern Pacific

5.6.2.1 Overview of C/L-Band Maritime Payload

This payload is the same as the second generation Inmarsat transponders capable of handling 125 voice circuits. This payload provides one-quarter of the worldwide coverage with the eastern satellite, scenario VI-A, providing western Atlantic coverage and a European platform providing eastern Atlantic and on Asian platform providing western Pacific coverage. The less than global coverage beam from each satellite will increase the antenna gain slightly and result in improved performance. Also,splitting the ocean regions in half will double the available circuits for the ocean area. Figure 5.6.2-1 is a block diagram of the Maritime payload for Scenario VI-B showing the breakdown to the component level.

Table 5.6.2-1 shows the estimated weight, power, and volume for low risk (emerging) technology and high risk (projected) technology for the transponder and antenna. Also included in the estimates are the coax, waveguide, and harness interconnects, plus an estimate for integration hardware to put the components together and provide necessary brackets for support and mounting. This does not include any structure or satellite mounting hardware, such as between the feed and reflector.

5.6.2.2 C/L-Band Maritime Antenna Subsystem

The C/L band Maritime antenna subsystem provides communications at 1.5-1.7 GHz, 3.6-3.65 GHz, and 6.425 - 6.441 GHz bands. The polarization is circular. The purpose of the antenna is to

Figure 5.6.2-1 Scenario VI-B - Maritime - C/L

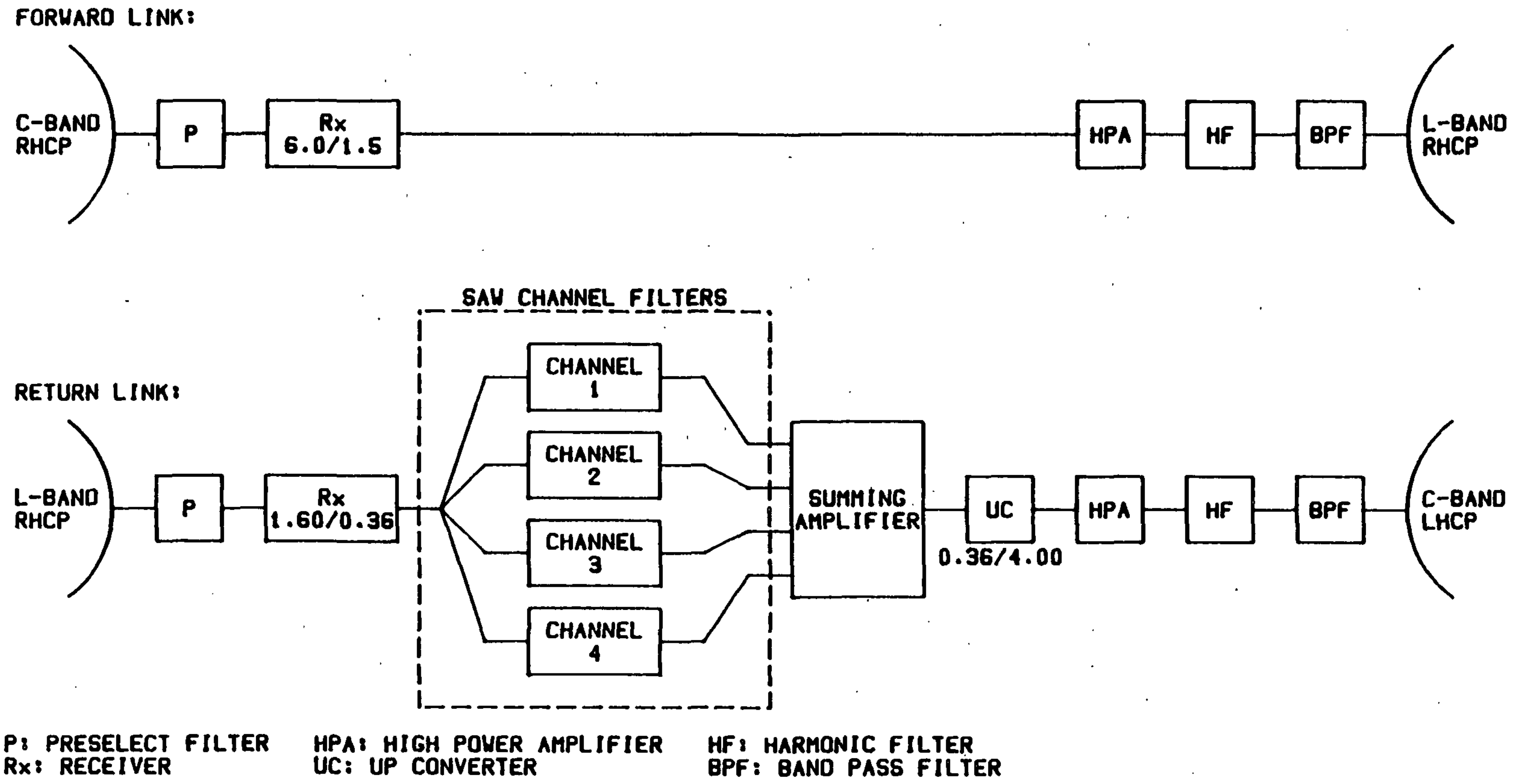


Table 5.6.2-1

Scenario VI-B Payload Summary

Eastern Pacific Maritime C/L-Band

				LOW RISK TECHNOLOGY						HIGH RISK TECHNOLOGY						
	ITEM	P/L QTY REQ'D	REQ. QTY REQ'D	UNIT			PAYLOAD			UNIT			PAYLOAD			COMMENTS
				WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	
1	6.0/1.5 GHz RECEIVER	1	2	1.6	8.0	175	3.2	8	350	0.5	5.5	50	1	5.5	100	
2	L Band HIGH POWER AMPLIFIERS(100W)	1	2	13	700	1300	26.0	700	2600	10	540	1000	20	540	2000	
3	BP/HARMONIC FILTER, 1.5 GHz	1	1	0.5	-	120	0.5	-	120	0.5	-	120	0.5	-	120	
4	CHANNEL FILTER, 1.5 GHz	1	1	0.3	-	50	0.3		50	0.2	-	40	0.2	-	40	
5	PRESELECT FILTER, 6GHz	1	1	0.3	-	50	0.3		50	0.3	-	50	0.3	-	50	
6	COAX SET & WAVEGUIDE	1	1	1.6	-	-	1.6		-	1.6	-	-	1.6	-	-	
7	HARNESS	1	1	6.0	-	-	6.0		-	6.0	-	-	6	-	-	
8																
9	SPDT SWITCH 6GHz CPAX 1.5 GHz COAX	4	4	0.08	-	6	0.3		24	0.08	-	6	0.3	-	24	
10	1.6/0.36 GHz RECEIVER, DUAL CONVERSION	1	2	2.6	16.0	275	5.2	16	550	0.8	12	60	1.6	12	120	
11	(W 4 SAW FILTER, SUMMMING-AMP AND 0.36/4 UPCONVERTER)															
12	C-Band HIGH POWER AMPLIFIER(9W)	1	2	2.0	50	240	4.0	50	480	0.6	30	80	1.2	30	160	
13	PRESELECT FILTER 0.36 GHz	1	1	0.4	-	48	0.8		48	0.4	-	48	0.4	-	48	
14	SPDT SWITCH COAX 0.36 GHz, 4 GHz	4	4	0.08	-	6	0.3		24	0.08	-	6	0.3	-	24	
15	BP/HARMONIC FILTER, 4 GHz, W/G	1	1	0.3	-	48	0.3		48	0.3	-	48	0.3	-	48	
16	CHANNEL FILTER, 4 GHz CAVITY, DIEL	1	1	0.4	-	140	0.4		140	0.3	-	50	0.3	-	50	
17	L BAND LINEARRERIZER	1	2	0.6	3.0	24	1.2	3	48	0.3	2.5	12	0.6	2.5	24	
18	INTEGRATION HARDWARE SET	1	1	5%	-	-	2.5	-	-	5%	-	-	1.7	-	-	
19	MARGIN REQUIRED			10%	10%	5%	5.3	78	227	10%	10%	10%	3.6	59	281	
20																
21	TOTAL TRANSPONDER						58.2	855	4759				39.9	649	3089	
22																
23	L-BAND ANTENNA Tx/Rx 1.2m	1	1	2.8	-	-	2.8	-	-	2.3	-	-	2.3	-	-	
24	L-BAND FEED	1	1	0.5	-	3700	0.5	-	3700	0.45	-	3330	0.45	-	3330	
25	C-BAND Tx 0.5M	1	1	0.5	-	-	0.5	-	-	0.4	-	-	0.4	-	-	
26	C-BAND Tx FEED	1	1	0.3	-	240	0.3	-	240	0.27	-	216	0.27	-	216	
27	C-BAND Rx 0.35 M	1	1	0.25	-	-	0.25	-	-	0.2	-	-	0.2	-	-	
28	C-BAND Rx FEED	1	1	0.2	-	90	0.2	-	90	0.18	-	81	0.18	-	81	
29	MARGIN			10%	-	5%	0.45	-	202	10%	-	5%	0.4	-	181	
30																
31	TOTAL ANTENNA						5.0		4232				4.2	-	3808	
32																
33	TOTAL PAYLOAD						63.2	855	8991				44.1	649	6897	

provide a beam to cover the eastern Pacific Region, as shown in Figure 5.6.2-2.

The antenna will consist of 3 solid reflectors; a 1.2 meter reflector for 1.6 GHz band, a 0.5 meter reflector for 3.6 GHz band, and a 0.35 meter reflector for 6.4 GHz band. Each reflector will be illuminated by a feed. A polarizer is employed at each feed to produce circular polarization. Figure 5.6.2-3 presents the antenna radiation patterns. The edge of coverage gain is 18 dBi.

All technologies required in this system are well developed. The level of risk of the technology items is low.

5.6.2.3 Maritime Transponder Subsystem

See 5.5.3.3.

5.6.3 C-Band Non-CONUS FSS Payload

5.6.3.1 Overview of C-Band Non-CONUS FSS Payload

This payload provides a nine-times re-use of the 500 MHz C-Band FSS bandwidth and provides all of the projected non-CONUS domestic demand for Region 2, except Canada, Brazil and Mexico. These three countries require the use of the Ku-Band Payload described subsequently. Also provided is the international routing of all Region 2 Intelsat traffic via the POR-ISL. The Canadian domestic traffic is also routed to the on-board baseband processor for routing to the eastern ISL, the western (POR) ISL, or back to Canadian domestic. It is assumed that the Canadian system would operate in a SS TDMA digital format from the ground. However, added flexibility could be provided via on board A-to-D conversion, as discussed in Scenario VI-A. Due to the interconnectivety of the C and Ku-Bands, the block diagrams

Figure 5.6.2-2 C/L Band Maritime Antenna Coverage Requirement

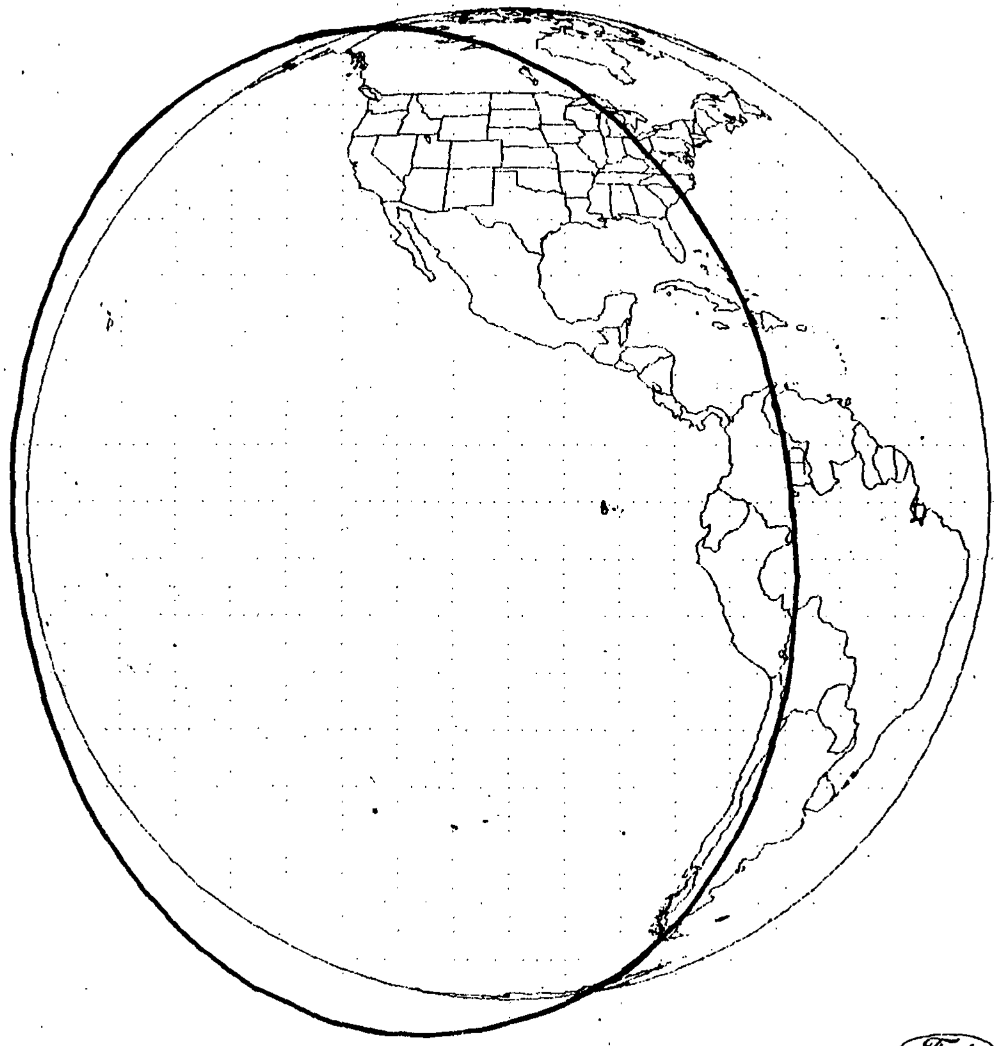
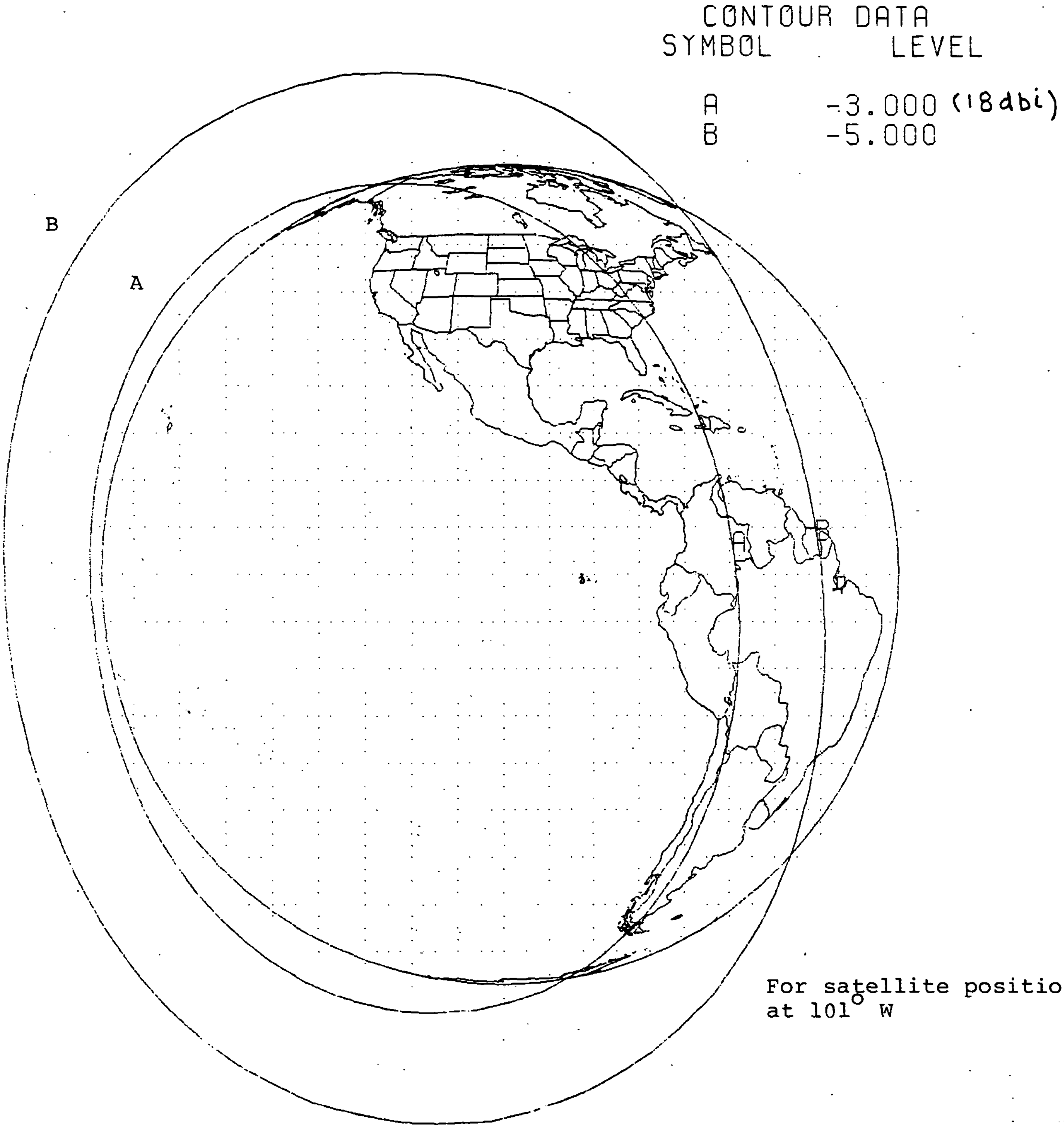


Figure 5.6.2-3 C-Band Antenna Pattern



For satellite position
at 101° W

have been combined and it was easier to break the block diagrams in areas of coverage: Canadian, Mexican and Caribbean, and South American. The block diagrams for these three areas are shown in Figures 5.6.3-1, 5.6.3-2 and 5.6.3-3, respectively. The subsequent subsections describe only the C-Band antenna and transponder subsystem.

Table 5.6.3-1 shows the estimated weight, power, and volume for low risk (emerging) technology and high risk (projected) technology for the transponder and antenna. Also included in the estimates are the coax, waveguide, and harness interconnects, plus an estimate for integration hardware to put the components together and provide necessary brackets for support and mounting. This does not include any structure or satellite mounting hardware, such as between the feed and reflector.

5.6.3.2 C-Band Non-U.S. Antenna Subsystem

The C-band non-U.S. antenna subsystem provides transmission at 4 GHz and reception at 6 GHz of dually circular-polarized communications signals.

The purpose of the C-band antenna is to provide 9 beams to cover the North and South American continents, excluding the United States, as shown in Figure 5.6.3-4. The combination of co-polarization and cross-polarization isolations among these beams provides the required interbeam isolation for the system. Table 5.6.3-2 summarizes the C-Band antenna subsystem requirements.

The C-Band antenna will consist of a 9 meter unfurlable reflector illuminated by an array of feed elements. A polarizer is employed in each feed to produce circular polarization. The incorporation of a diplexer at each feed allows the feed array to operate in both the transmit and receive bands. Figure 5.6.3-5 shows the C-band antenna configuration. Figures 5.6.3-6 to

Figure 5.6.3-1 Canadian Domestic, Regional And International

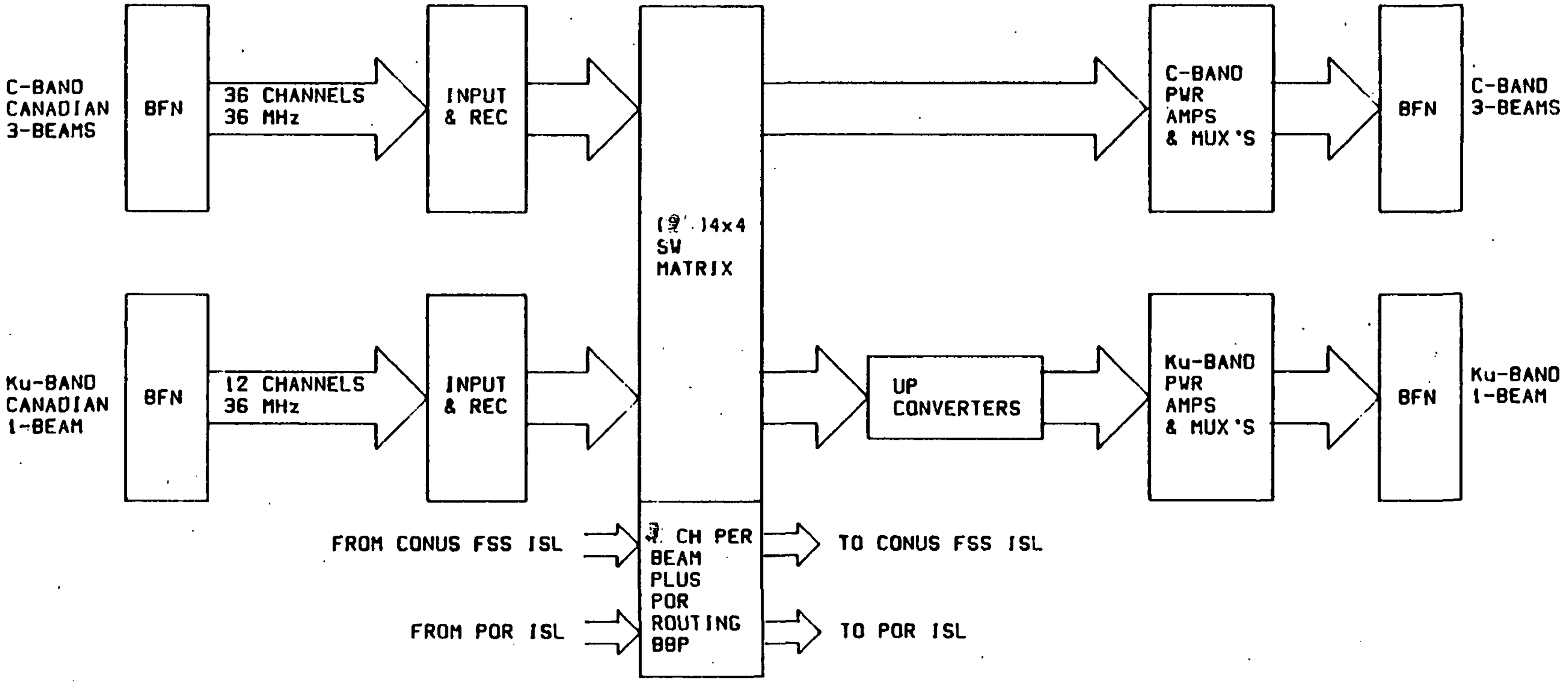


Figure 5.6.3-2 Mexican/Caribbean Domestic And Regional Block Diagram

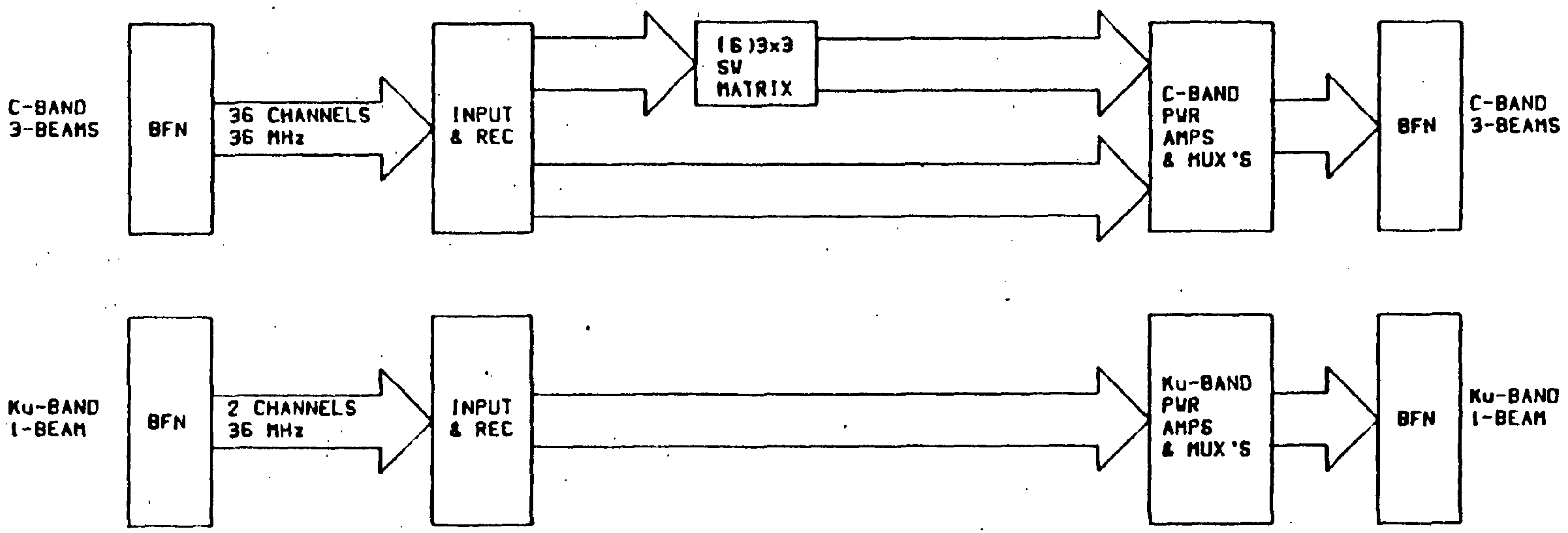


Figure 5.6.3-3 Scenario VI-B - South American Domestic and Regional

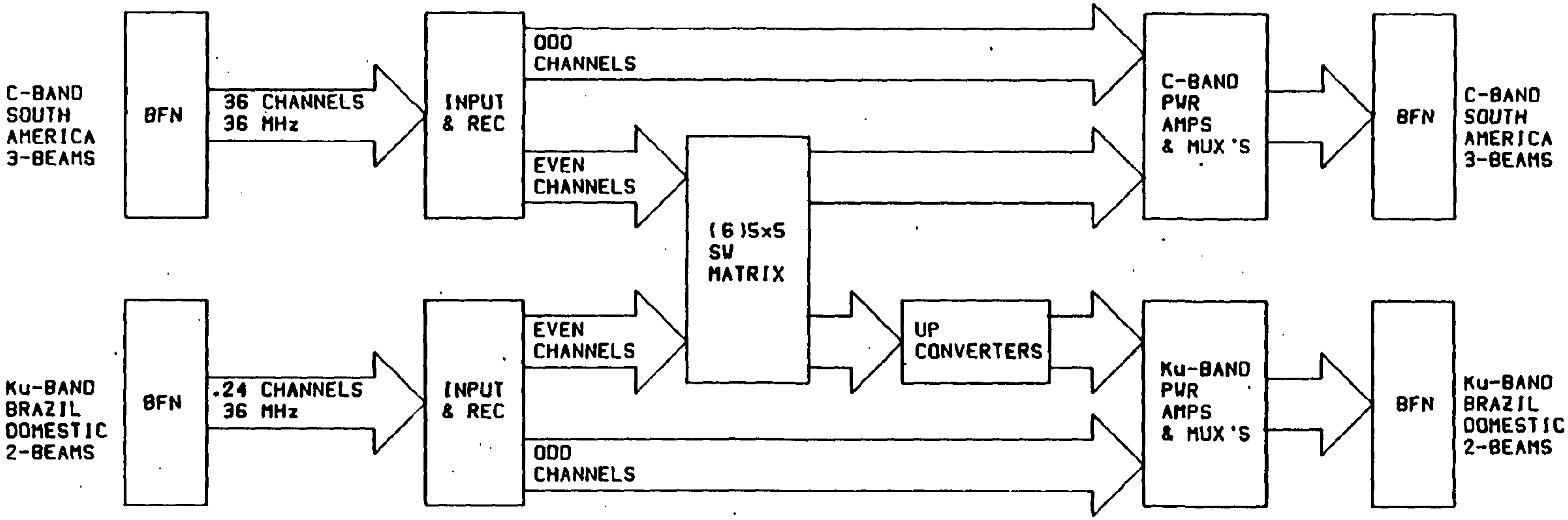


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Table 5.6.3-1

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Scenario VI-B Transponder Summary

C-Band Non-U.S. Domestic & Regional

				LOW RISK TECHNOLOGY						HIGH RISK TECHNOLOGY						
				UNIT			PAYLOAD			UNIT			PAYLOAD			
	ITEM	P/L QTY REQ'D	RED. QTY REQ'D	WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	COMMENTS
1	6/4 GHZ RECEIVER	9	18	1.6	7.5	175	28.8	67.5	3150	0.7	4.8	50	12.6	43.2	900	
2	36 MHz INPUT MULTIPLEXER, 4 GHz, 12 Channel	16	10	4.2	--	864	42	--	8640	3.4	--	500	34	-	5000	
3	36 MHz INPUT MULTIPLEXER, 4 GHz, 6 Channel	2	2	2.1	--	432	4.2	--	864	1.7	--	250	3.4	-	500	
4	BEAM SWITCHING MATRIX, 4 GHz, 4x4 Coax	12	12	1.8	--	192	21.6	--	2304	1.0	1.0	10	12	12	120	
5	5/4 REDUNDANCY SWITCH MATRIX, 4 GHx, Coax (ring)	33	33	1.4	--	160	46.2	--	5280	0.7	--	25	23.1	-	825	
6	BEAM SWITCHING MATRIX, 4 GHz, 5x5 Coax	6	6	3.1	--	320	18.6	--	1920	1.7	1.7	17	10.2	10.2	102	
7	BEAM SWITCHING MATRIX, 4 GHz, 3x3 Coax	6	6	0.9	--	96	5.4	--	576	0.5	0.5	5	3	3	30	
8	BASEBAND PROCESSOR	1	1	141.5	430	7050	141.5	430	7050	113.4	300	6000	113.4	300	6000	
9	SSPAs, 4 GHz, 4 SW	108	135	0.7	18	48	94.5	1944	6480	0.4	12.5	20	54	1350	2700	
10	OUTPUT MULTIPLEXER, 4 GHz, 12 channel, (36 MHz)	9	9	4.2	--	3600	37.8	--	32400	2.8	--	2400	25.2	-	21600	
11	HARMONIC FILTER, 4 GHz	9	9	0.3	--	40	2.7	--	360	0.3	--	40	2.7	-	360	
12	PRESELECT FILTER, 6 GHz, with Isolator	9	9	0.5	--	64	4.5	--	576	0.5	--	64	4.5	-	576	
13	SPDT SWITCHES, 6 GHz, 4 GHz, Coax	21	21	0.08	--	6	1.68	--	126	0.08	--	6	1.68	-	126	
14	TRANSFER SWITCHES, 6 GHz, 4 GHz,	9	9	0.14	--	12	1.26	--	108	0.14	--	12	1.26	-	108	
15	COAX, SET	1	1	27	--	--	27	--	--	27	--	--	27	-	-	
16	WAVEGUIDE, SET	1	1	14	--	--	14	--	--	14	--	--	14	-	-	
17	HARNESS	1	1	45	--	--	45	--	--	45	--	--	45	-	-	
18	INTEGRATION HARDWARE, SET	1	1	5%	--	--	27	--	--	5%	--	--	19.5	-	-	
19	COMM CONTROL & INTERFACE	1	2	2	16	400	4	16	800	1.6	12	300	3.2	12	600	
20	MARGIN REQ'D.			10%	10%	5%	56.8	246	3532	15%	10%	5%	61.5	173	1977	
21																
22	TOTAL TRANSPONDER						624.5	2704	74166				471.2	1903	41524	
23																
24																
25																
26	ANTENNA REFLECTOR	1	1	50	-	-	50	-	-	40	-	-	40	-	-	
27	ANTENNA FEED NETWORK(Tx/Rx)	1	1	60	-	277981	60	-	277981	54	-	250183	54	-	250183	
28	MARGIN REQUIRED			10%	-	10%	11	-	27798	10%	-	10%	9	-	25018	
29																
30	TOTAL ANTENNA						121	-	305779				103	-	275201	
31																
32	TOTAL PAYLOAD						745.5	2704	379945				574.2	1903	316725	

Figure 5.6.3-4 C-Band Non-U.S. Antenna Coverage Area Requirement

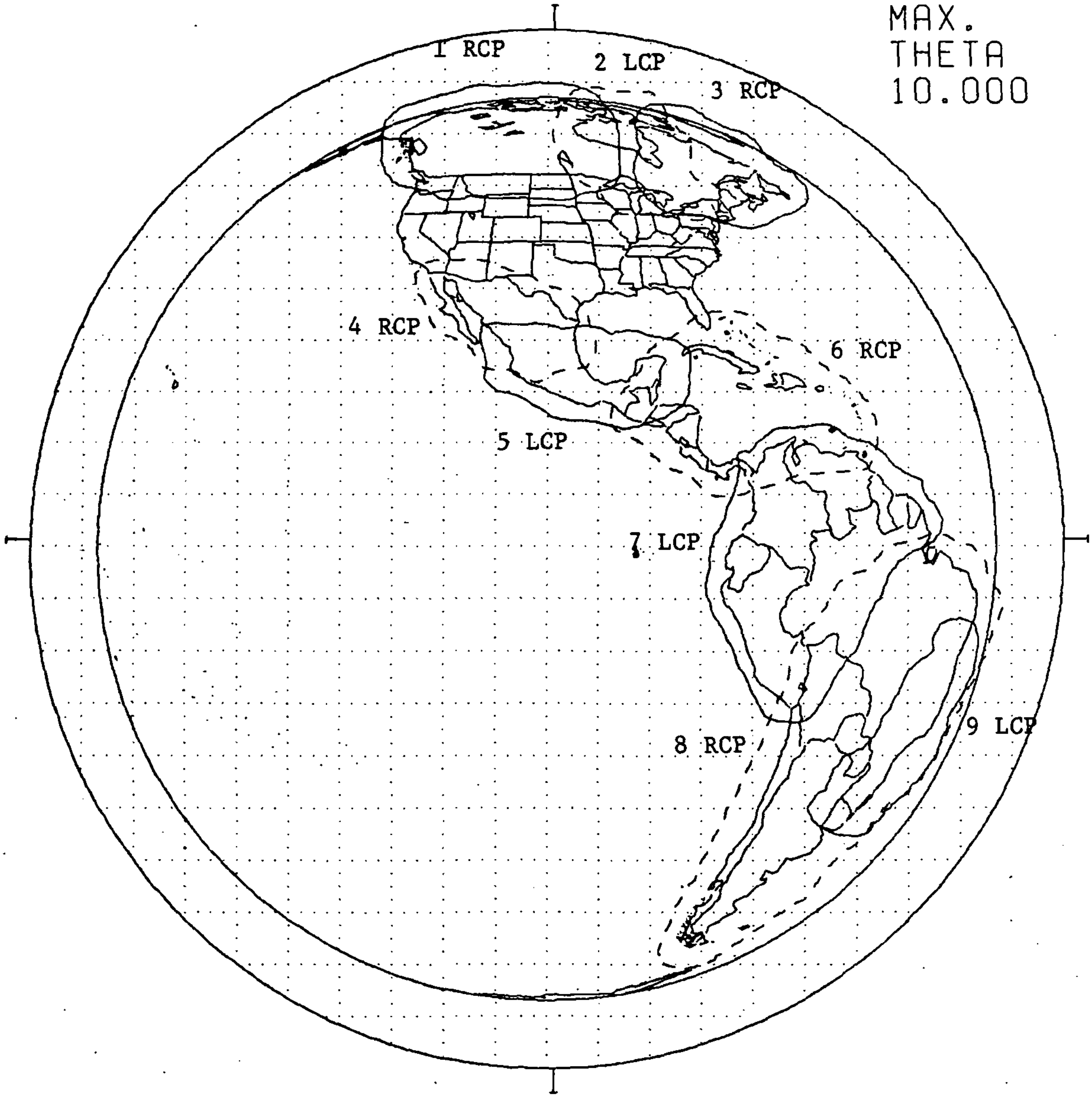
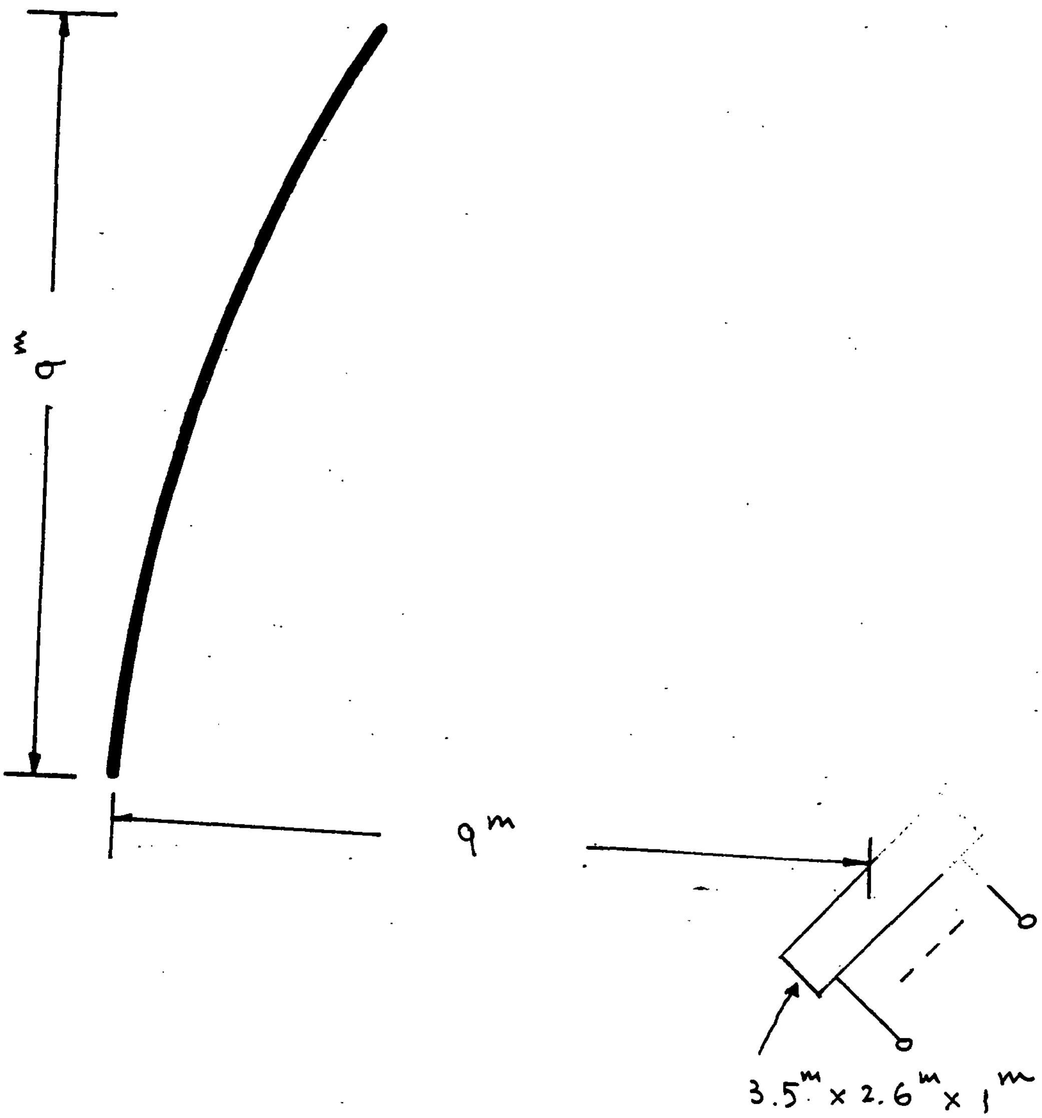


Figure 5.6.3.5 C-Band Non-U.S. Unfurlable Reflector Antenna Configuration



5.6.3-14 present the antenna radiation for each beam. The predicted edge-of-coverage gain in given in Table 5.6.3-3.

Table 5.6.3-2

C-Band Non-U.S. Antenna Subsystem Requirements

Parameters	Requirements	
Frequency	Transmit: Receive:	4 Ghz 6 Ghz
Polarization	Dual CP	
Coverage Area	3 beams for Canada 6 Beams for Central/South America	
Isolation	27 dB	

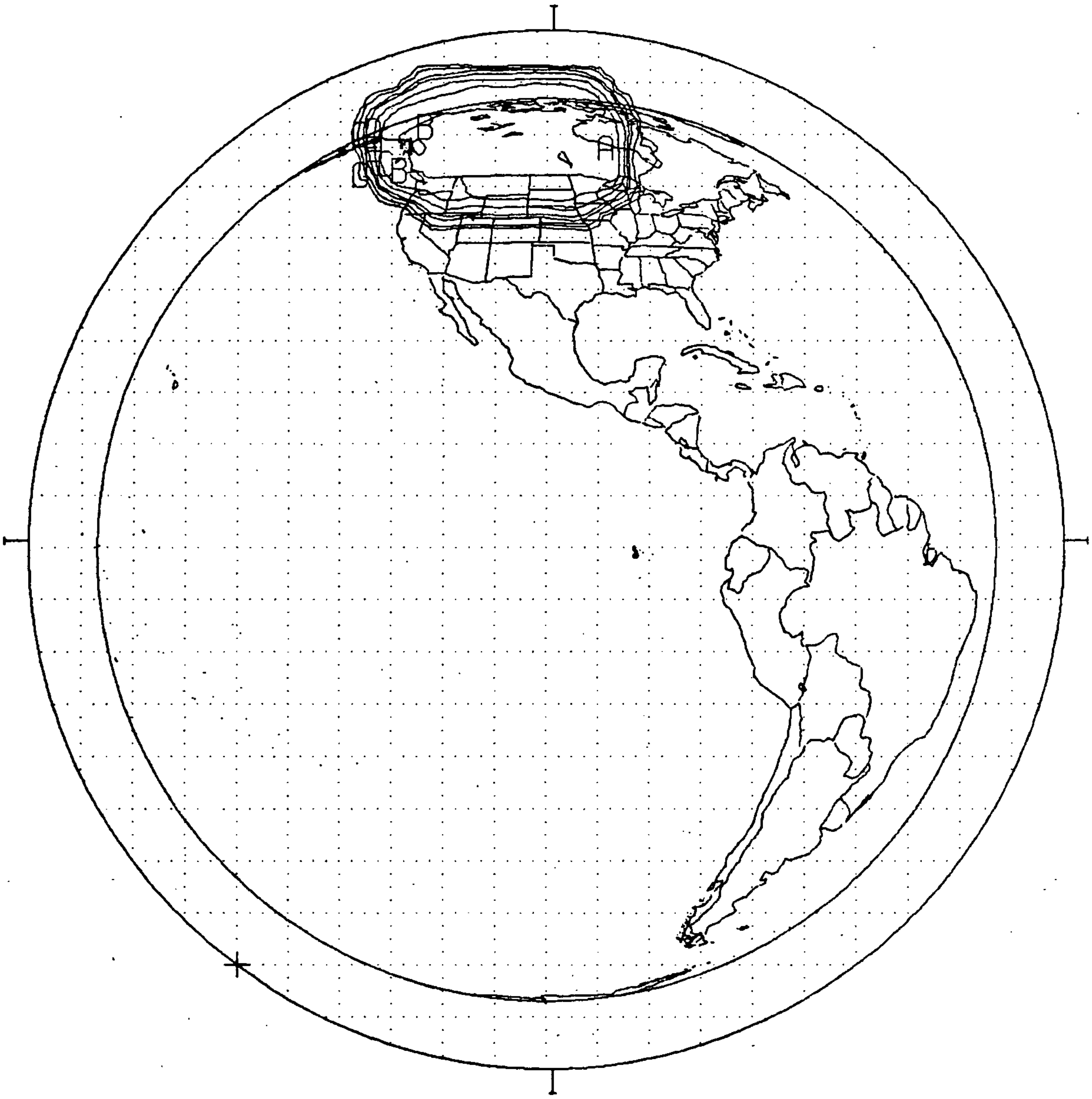
Table 5.6.3-3

C-Band Non-U.S. Antenna Gain

Coverage	Gain
1 RCP	29.0
2 LCP	31.6
3 RCP	31.5
4 RCP	31.5
5 LCP	30.7
6 RCP	27.5
7 LCP	26.3
8 RCP	24.7
9 LCP	31.6

Theoretically, the surface tolerance of an unfurlable reflector can be controlled to meet the antenna gain and cross-polarization requirements. In practice, the increase in costs and weight to meet certain electrical requirements may be astronomical and impractical. In addition, the requirements on the surface tolerance for a multiple beam antenna system are more stringent

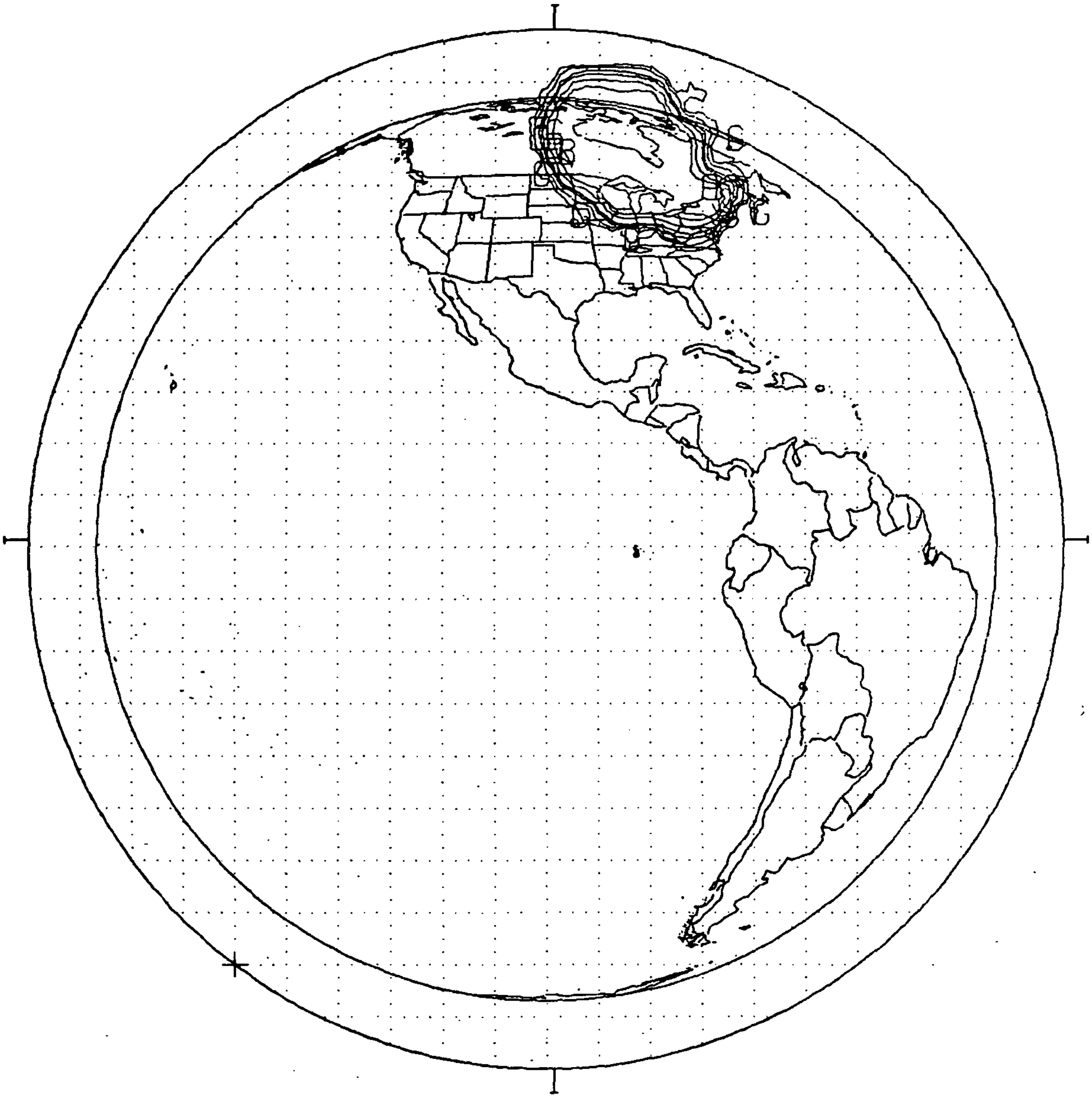
Figure 5.6.3-6 Western Canadian Contour Plot



CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (29.0 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

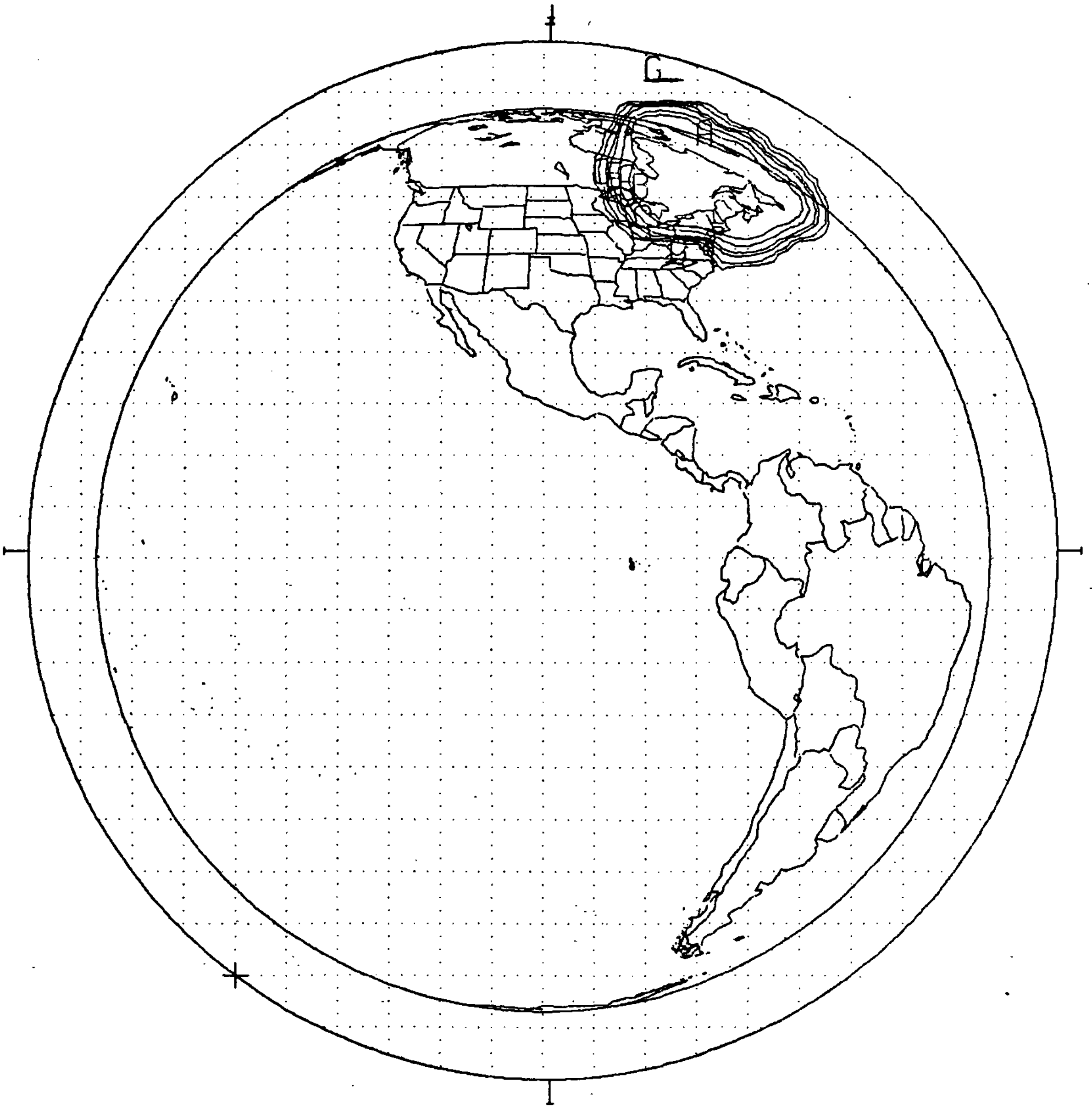
Figure 5.6.3-7 Central Canadian Contour Plot



CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (31.6 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

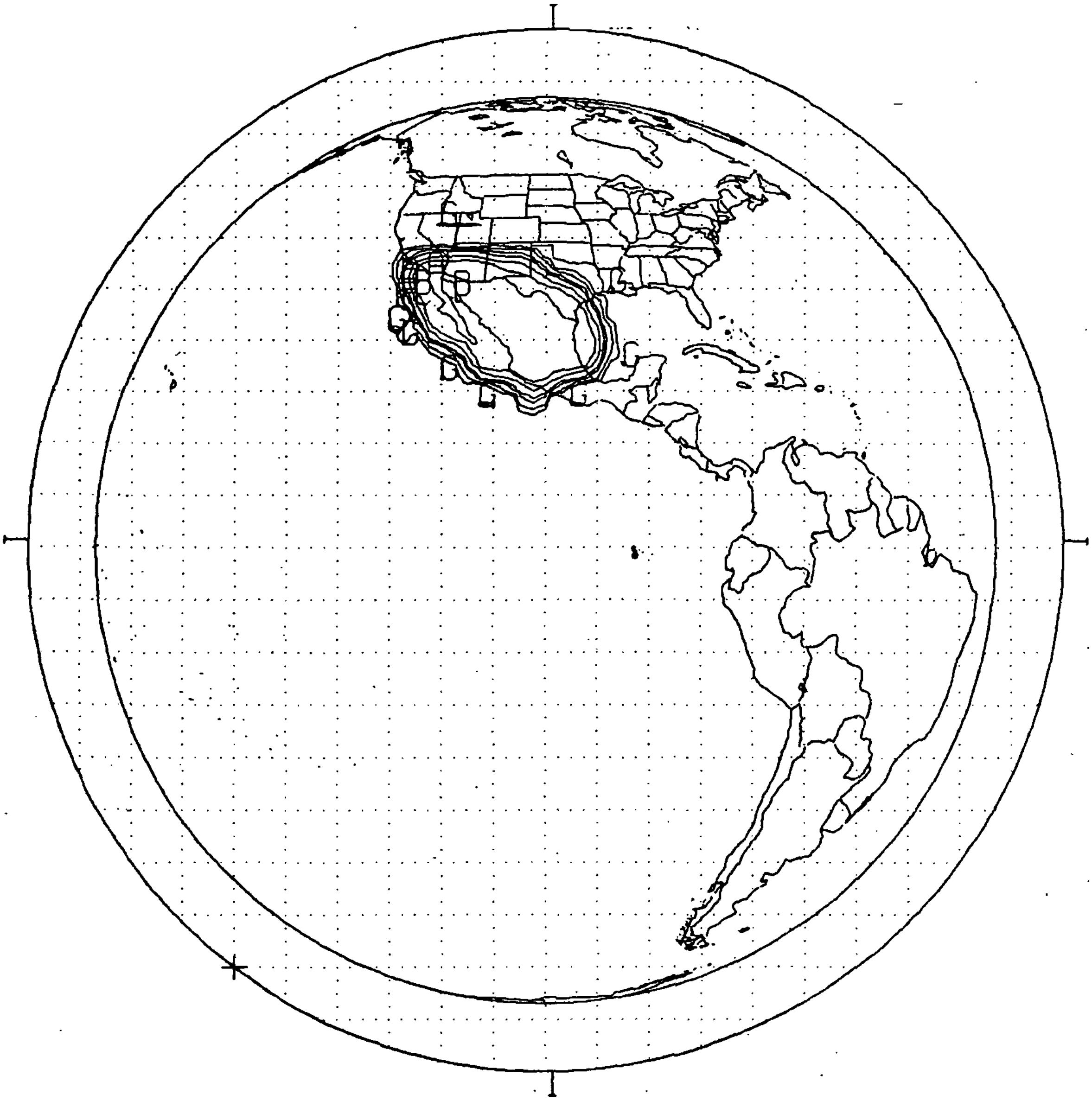
Figure 5.6.3-8 Eastern Canadian Contour Plot



CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (31.5 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

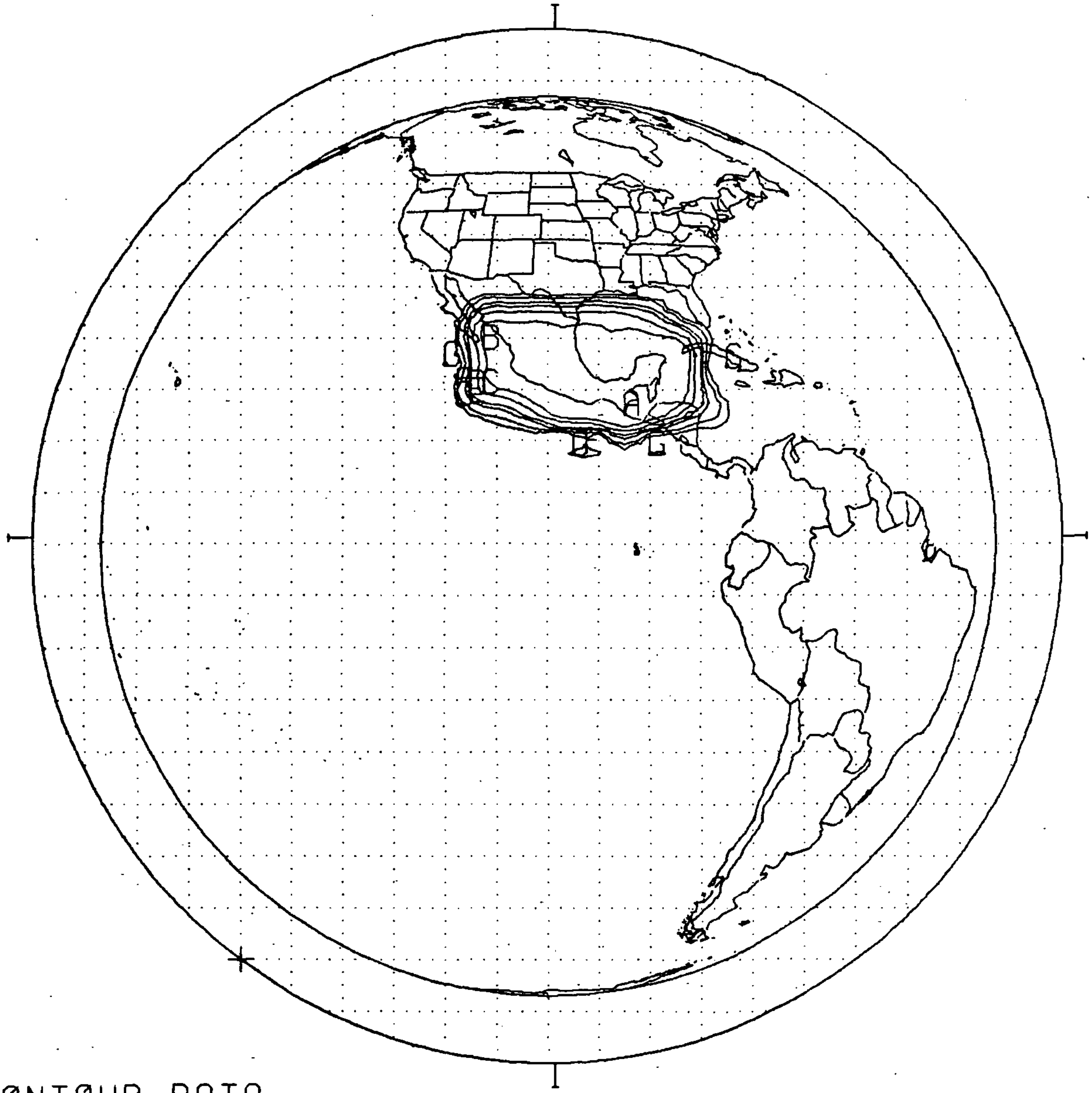
Figure 5.6.3-9 Northern Mexico Contour Plot



CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (31.5 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

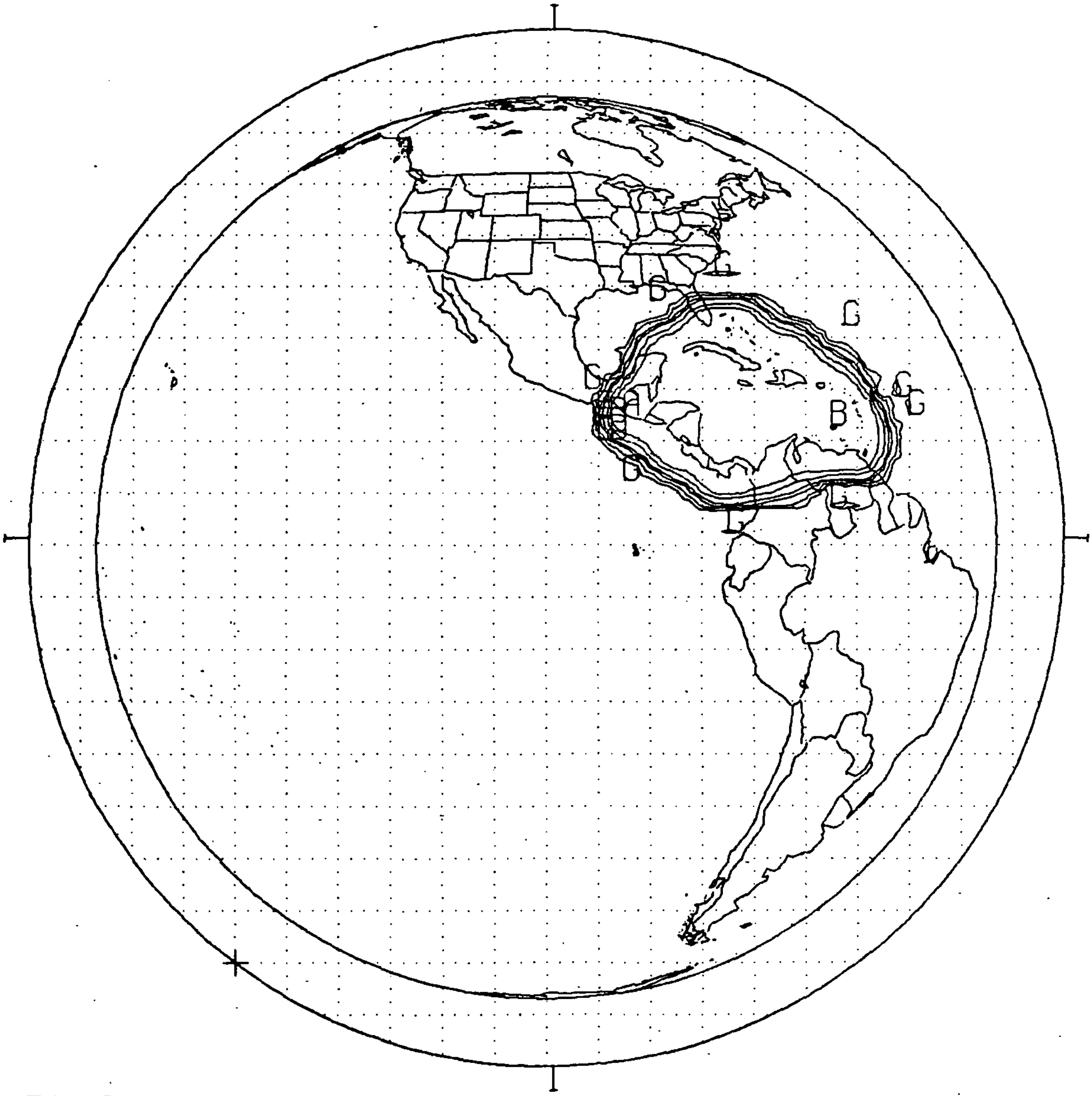
Figure 5.6.3-10 Southern Mexico Contour Plot



CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (30.7 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

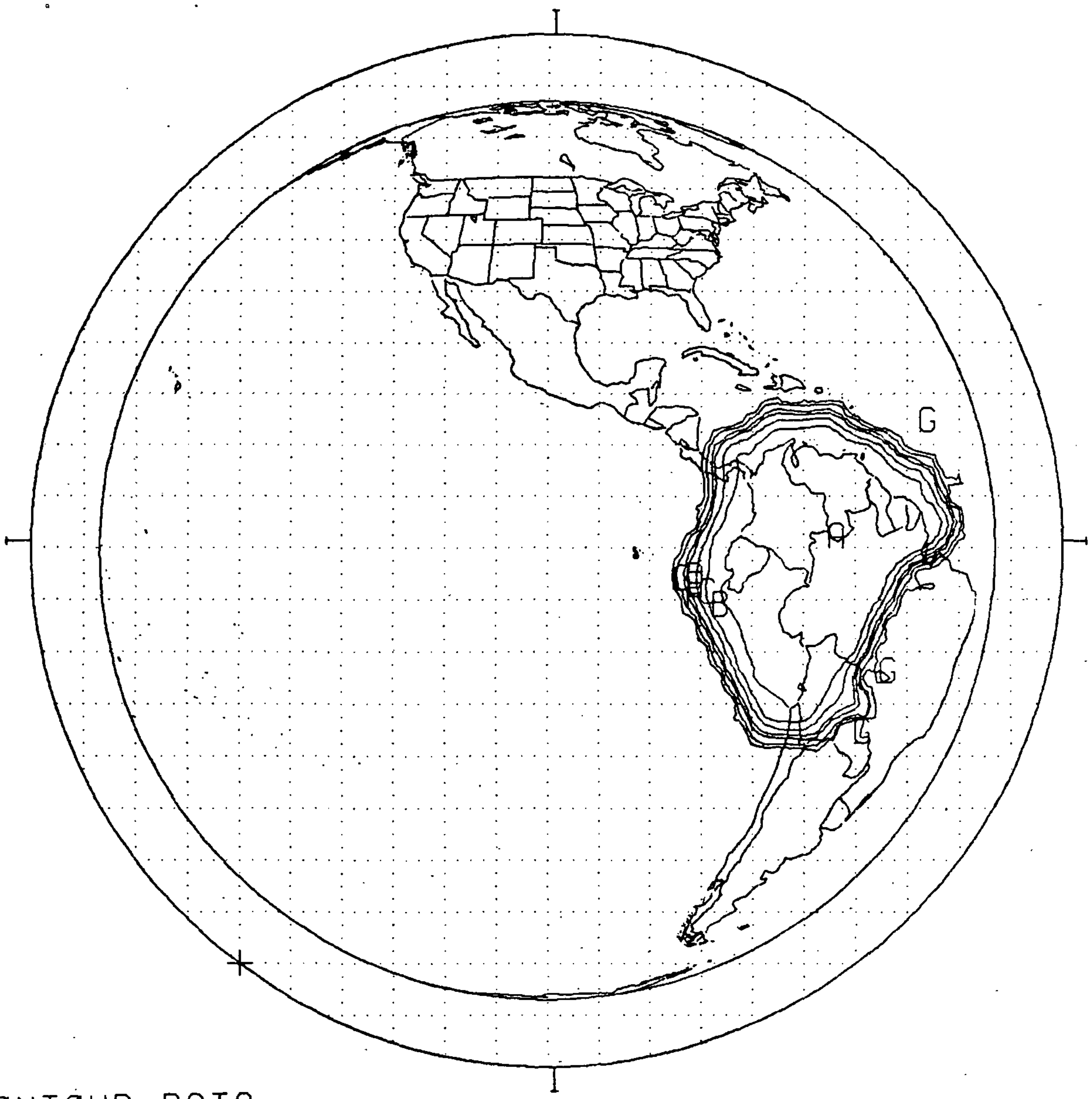
Figure 5.6.3-11 Central American/Caribbean Contour Plot



CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (27.5 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

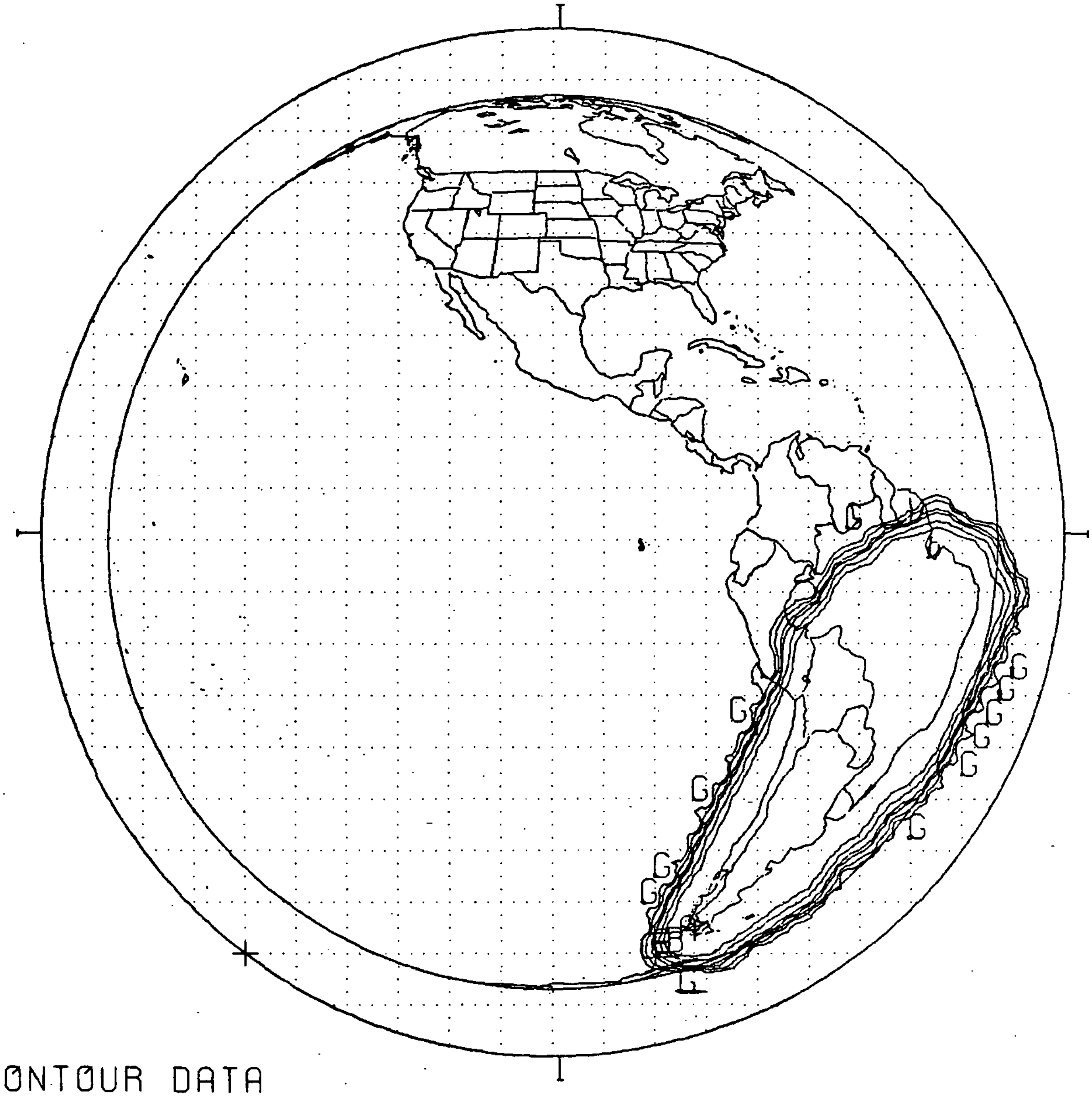
Figure 5.6.3-12 Western South American Contour Plot



CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (26.3 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

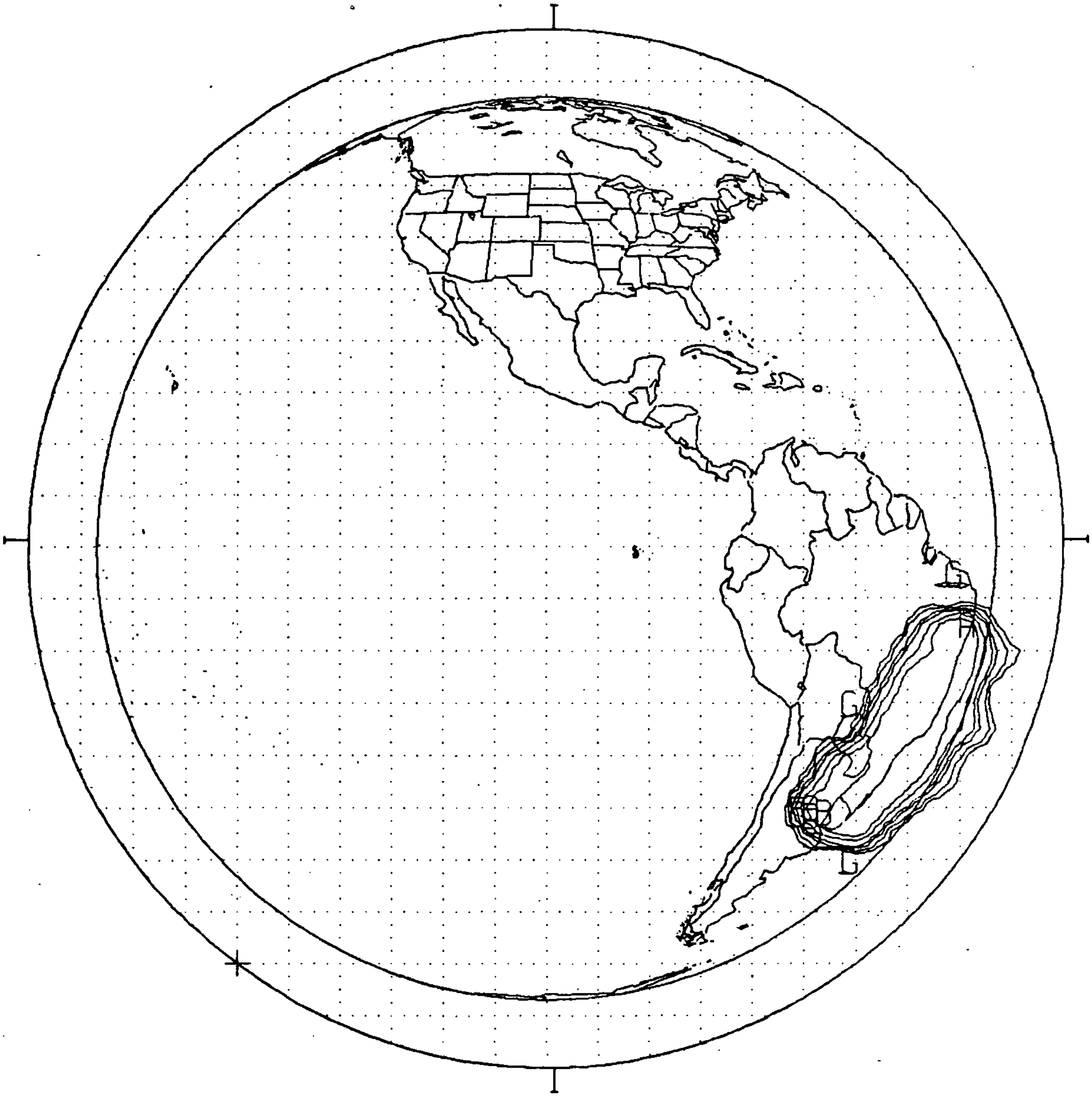
Figure 5.6.3-13 Eastern South American Contour Plot



CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (24.7 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

Figure 5.6.3-14 Eastern Brazil Contour Plot



CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 (31.6 dBi)
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

than those for a pencil beam. Further study should be conducted to evaluate the impact of the costs and weight for the system on the cross-polarization degradation, change of the beam shape, and the antenna gain. Another critical technology item is the dual-band polarizer for 6/4 GHz band. In order to meet the 27 dB cross-polarization isolation, the axial ratio levels of less than 0.2 dB over the frequency band are required. From mechanical and integration points of view, it should also be compact and light weight. The assessment of these two critical technology items is given in Table 3.6.3-4.

Table 5.6.3-4

Assessment of Level of Risk
of the Critical Technology Items

Item	Low Risk	High Risk
Unfurlable Reflector	Needs development	Needs development
Dual Band Polarizer	Needs Development	Needs development

5.6.3.3 C-Band Transponder, Non-U.S., Domestic and Regional Service

The C-Band transponder subsystem consists of nine independent, 12 channel transponders. Hence, it has a total capacity of 108 channels, each having a bandwidth of 36 MHz. The nine trans- ponders utilize the same 500 MHz FSS band, having an uplink at 6 GHz and a downlink at 4 GHz. Three of these transponders provide service to Canada, three to Mexico and the Carribean, and three to South America. Crosslinks between all channels of the Canadian C-band and Ku-band transponders, between the even channels of the Mexican and Carribean transponders, and between the even channels of the

C-Band South American and Ku-band Brazil transponders, are made at the 4 GHz IF by switch matrices.

Each of the nine 6 GHz inputs from the antenna feed assembly is filtered by an input preselector and then amplified and downconverted to 4 GHz by the receiver. The 500 MHz IF band is subdidived by an input multiplexer into twelve, 36 MHz channels. The filters of the input multiplexer also provide the required narrow band receive filtering responses.

For the three Canadian transponders, twelve 4x4 switch matrices enable signals in any uplink channel of one transponder to be connected to the same channel in any of the other two C-Band transponders, or with the same channel in the Canadian Ku-Band transponder. For the three Mexican/Carribean transponders, six 3x3 switch matrixes provide even channel interconnections. The even channels of the three C-Band South American transponders and the even channels of the two Brazilian transponders are interconnected via six, 5x5 switch matrices.

The channels are individually amplified by up to 8.5 watt SSPA's which contain one or more variable gain amplifiers. The latter permit automatic accommodation of varying uplink levels using an AGC loop, and SSPA back-off via ground control. The output of the SSPA in each set of twelve channels are combined in a twelve channel output multiplexer, which also supplies the required narrow band transmit filtering responses. The downlink signals are further filtered by harmonic/bandpass filters prior to transmission from the transmit antenna feed assembly. The transponder subsystem features four for two receiver redundancy and five for four SSPA redundancy.

5.6.3.3.1 6/4 GHz Receiver

See 5.2.2.3.1.

5.6.3.3.2 4 GHz Input Multiplexer

See 5.2.2.3.2.

5.6.3.3.3 RF Switch Matrix

See 5.2.3.3.3.

5.6.3.3.4 4 GHz 8.5 Watt SSPA

See 5.2.2.3.3.

5.6.3.3.5 4 GHz Output Multiplexer

See 5.2.2.3.4.

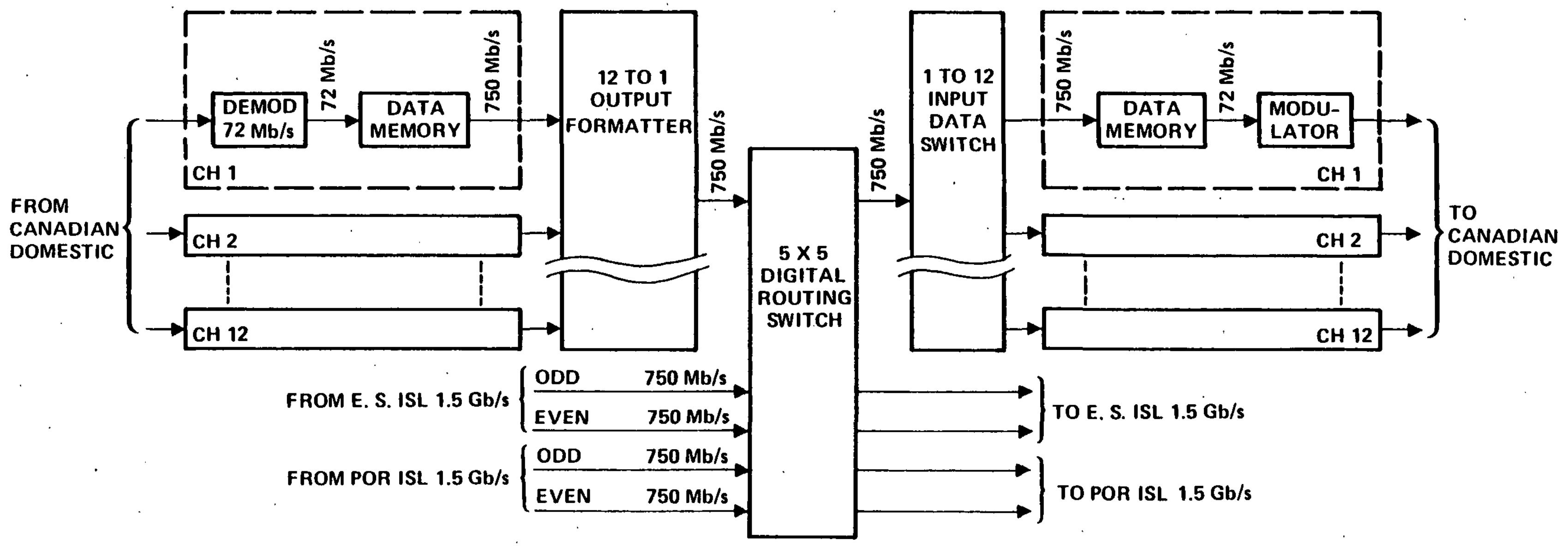
5.6.3.3.6 Pre-Select and Harmonic Filters

See 5.2.2.3.5.

5.6.3.4 Baseband Processing

The baseband processor for this payload accepts 12, 72 Mb/s input channels, demodulates them, and formats them into a TDMA 750 Mb/s data stream. This 750 Mb/s data stream is then routed via the digital routing switch and routed with the odd and even 750 Mb/s data streams from the eastern satellite ISL and the POR ISL. The five data streams are TDMA switched to the appropriate downlink data stream. The odd and even 750 Mb/s data streams for the eastern satellite ISL are fed to the associated ISL modulator to transmit the 1.5 Gb/s data link. The 750 Mb/s data stream routed to the Canadian downlink processor is then TDMA routed to the appropriate data memory and modulator to construct the downlink modulated spectrum in the appropriate 36 MHz bandwidth transponder. Figure 5.6.3-15 is the block diagram of the baseband processor and switch.

Figure 5.6.3-15 Scenario VI-B Baseband Processor and Switch



Since this processor is operating on the C-Band links, no provision for FEC, variable power, or variable data rates have been provided. The digital routing switch and data memories are however, operating at about twice current state-of-the-art switching speeds to handle the 750 Mb/s data streams. In order to be implemented in low risk technology, the system would have to double the switch size and split the data into lower rate components.

For high risk technology, it is assumed that additional VLSI development and advances in speed and power would yield lighter weight, lower power, and correspondingly lower volume. This is an area where the custom VLSI work would not likely be done without NASA/government subsidized effort.

5.6.4 Ku-Band Non-CONUS FSS Payload

5.6.4.1 Overview of Ku-Band Non-CONUS FSS Payload

This payload provides the remaining domestic coverage that could not be accommodated on the C-Band payload described in Section 5.6.3. This results in a spot beam in Canada, use of two Ku-band channels not used in the U.S. domestic beam 8H of the Ku-Band payload described in Section 5.4.5, and dual polarization use of domestic-Brazil coverage. Due to the complexity of the interconnectivety, the block diagrams contain both the C and Ku-Band elements. The block diagrams are broken down by area of coverage, Canada, Mexico and Caribbean, and South America. The block diagrams for these three areas of coverage are shown in Figures 5.6.4-1, 5.6.4-2, and 5.6.4-3 respectively. The Ku-Band antenna subsystem uses the Ku-Band U.S. domestic reflector with additional feed elements for the Canadian spot beam and the Mexican coverage. The Brazil system is an independent antenna system. The subsequent sub-sections describe only the Ku-Band antenna and transponder subsystems.

Figure 5.6.4-1 Canadian Domestic, Regional and International

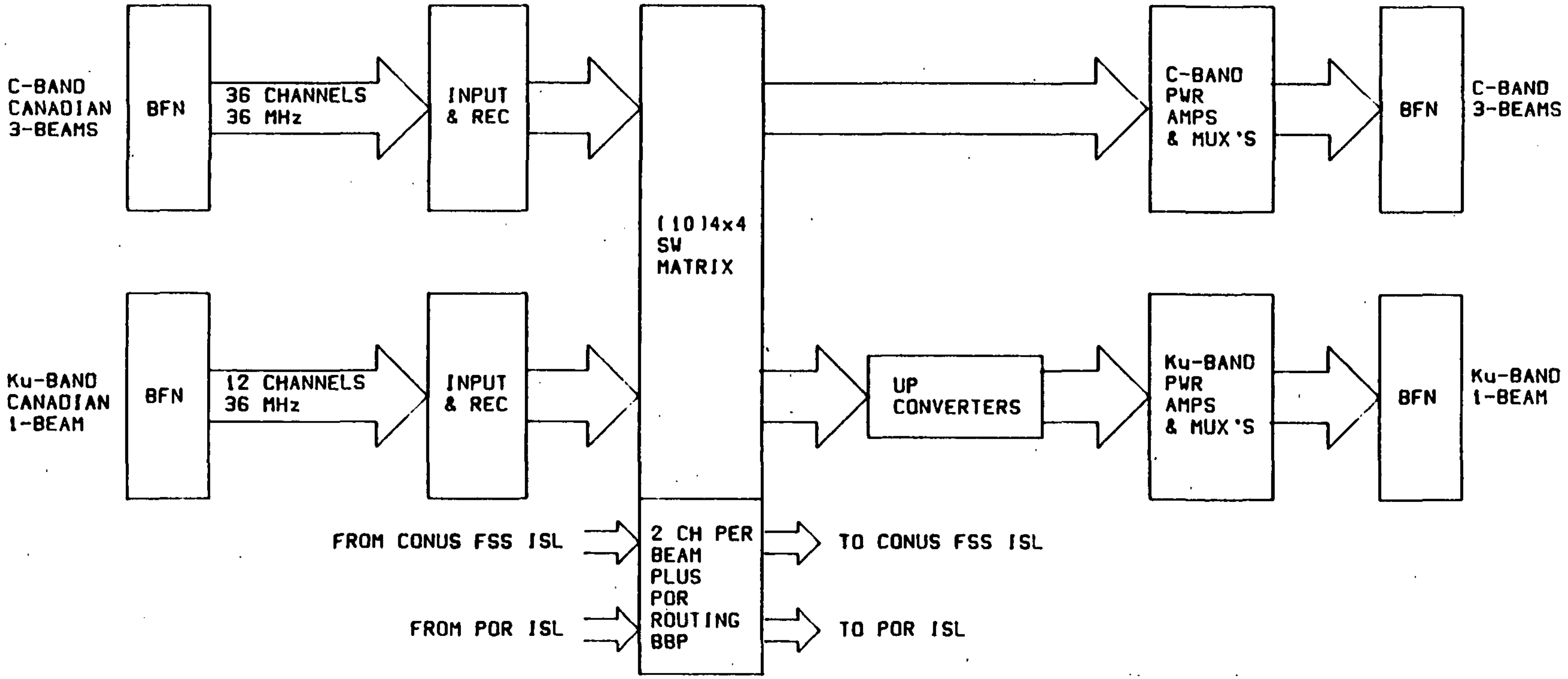


Figure 5.6.4-2 Mexican/Caribbean Domestic And Regional Block Diagram

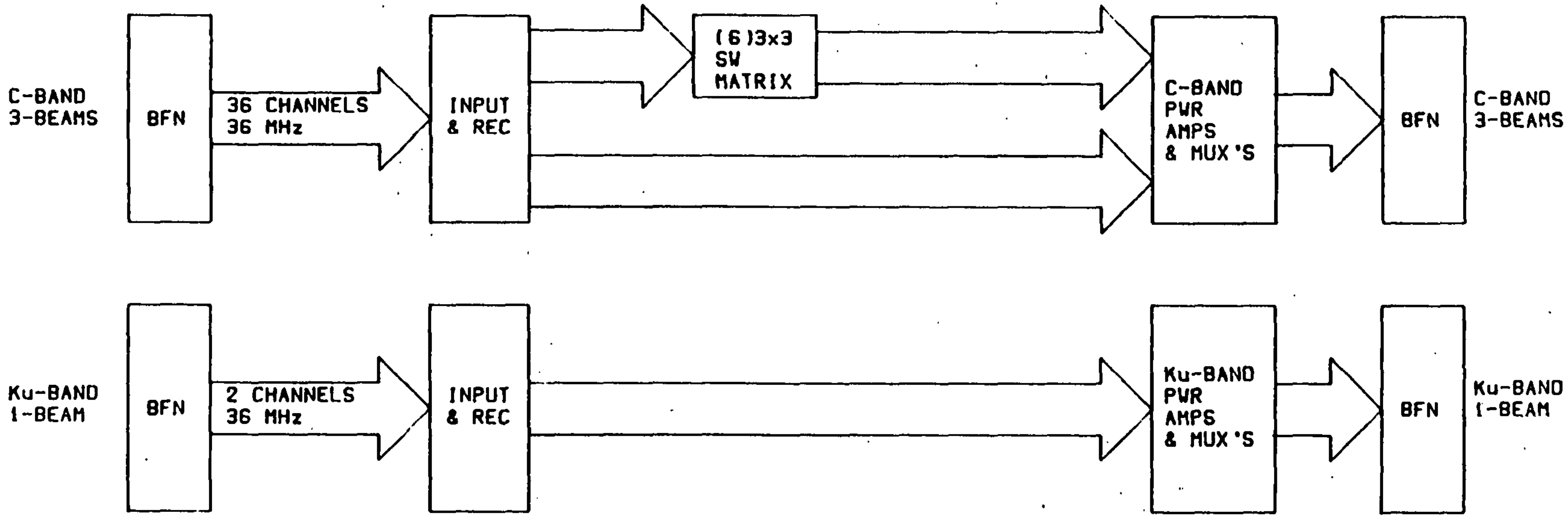


Figure 5.6.4-3 South American Domestic and Regional

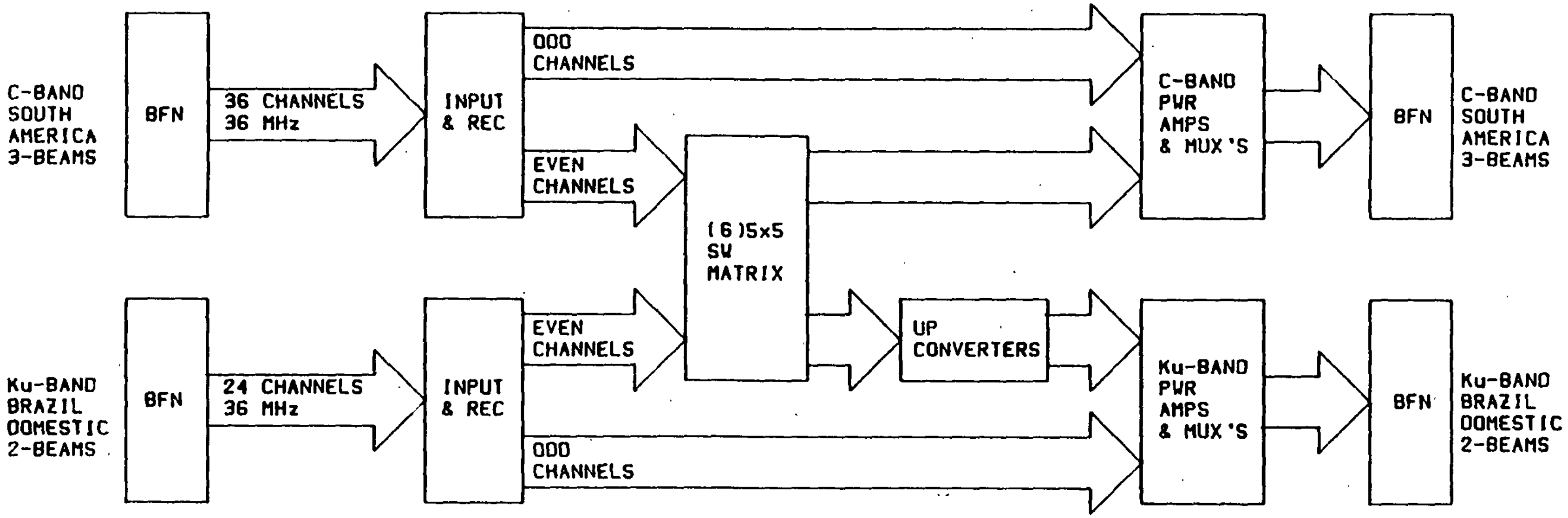


Table 5.6.4-1 shows the estimated weight, power, and volume for low risk (emerging) technology and high risk (projected) technology for the transponder and antenna. Also included in the estimates are the coax, waveguide, and harness interconnects, plus an estimate for integration hardware to put the components together and provide necessary brackets for support and mounting. This does not include any structure or satellite mounting hardware, such as between the feed and reflector.

5.6.4.2 Ku-Band Non-CONUS Antenna Subsystem

The Ku-Band non-CONUS antenna subsystem provides transmission at 11 GHz and reception at 14 Ghz of dually linear polarized communications signals for Ku-Band.

The purpose of the Ku-Band non-CONUS antenna is to provide a spot beam in Canada, a shaped beam to cover Mexico, and another one to cover Brazil, as depicted in Figure 5.6.4-4. The Canada spot beam and Mexico beam will be generatd by adding additional feed array to the 15' Ku-band FSS CONUS antenna system. Theoreti- cally, another feed array might also be added to produce the Brazil beam. However, the constituent beam of the Brazil beam will be too far away from the on-axis beam. As indicated in subsection 5.5.4.2, this will result in severe phase aberration. Therefore, a 1.0 meter dual-gridded reflector will be used to generate the Brazil beam. Figures 5.6.4-5 and 5.6.4-6 present the antenna radiations for the Mexico and Brazil beams. The predicted antenna gain at the edge-of-coverage is given in Table 5.6.4-2.

5.6.4.3 Ku-Band Transponder, Non-U.S., Domestic and Regional

The Ku-Band Transponder subsystem consists of one 12 channel Canadian transponder, one 2 channel Mexican transponder, and two 12 channel Brazilian transponders, and hence has a total

Table 5.6.4-1

Scenario VI-B Payload Summary

Ku-Band Non-U.S. Domestic and Regional

	ITEM	P/L QTY REQ'D	RED. QTY REQ'D	LOW RISK TECHNOLOGY						HIGH RISK TECHNOLOGY						COMMENTS
				UNIT			PAYLOAD			UNIT			PAYLOAD			
				WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	
1	14/4 GHz RECEIVER	3	6	1.8	8.0	175	10.8	18.0	1050	0.9	5.5	50	5.4	16.5	300	
2	14/11 GHz RECEIVER	3	6	1.8	9.0	175	10.8	27.0	1050	0.9	6	50	5.4	18	300	
3	36 MHz INPUT MULTIPLEXER, 11 GHz, 6 channel	2	2	2.7	-	1152	5.4	-	2304	1.8	-	768	3.6	-	1536	
4	36 MHz INPUT MULTIPLEXER, 11 GHz, 2 Channel	1	1	0.9	-	384	0.9	-	384	0.6	-	256	0.6	-	256	
5	5/4 REDUNDANCY SWITCH MATRIX, 11 GHz, Coax,	3	3	1.4	-	160	4.2	-	480	0.7	-	25	2.1	-	75	
6	Ring															
7	UPCONVERTER (4/11 GHz)	24	30	1.3	6	120	39	144	360	0.6	3	35	18	72	1050	
8	SSPAs, 11 GHz, 20 W (24)	24	30	1.4	80	48	42	1920	1440	0.5	54	40	15	1296	1200	
9	SSPAs, 11 GHz, 10 W (2)	2	3	1.2	40	40	3.6	80	120	0.4	27	35	1.2	54	105	
10	SSPAs, 11 GHz, 5 W (12)	12	15	1.0	20	40	15	240	600	0.4	14	35	6	168	525	
11	OUTPUT MULTIPLEXER, 11 GHz, 2 channel	1	1	1.0	-	160	1.0	-	160	0.4	-	85	0.4	-	85	
12	(36 MHz)															
13	OUTPUT MULTIPLEXER, 11 GHz, 12 channel	3	3	6.0	-	1536	18.0	-	4608	2	-	512	6	-	1536	
14	(36 MHz)															
15	HARMONIC FILTER, 11 GHz	4	4	0.1	-	14	0.4	-	56	0.1	-	14	0.4	-	56	
16	PRESELECT FILTER, 14 GHz	4	4	0.1	-	14	0.4	-	56	0.1	-	14	0.4	-	56	
17	SPDT SWITCHES, 14 GHz, Waveguide	6	6	0.15	-	16	0.9	-	96	0.15	-	16	0.9	-	96	
18	TRANSFER SWITCHES, 14 GHz W/G	2	2	0.18	-	16	0.36	-	32	0.18	-	16	0.36	-	32	
19	COAX, SET	1	1	7	-	-	7	-	-	7	-	-	7	-	-	
20	WAVEGUIDE, SET	1	1	17	-	-	17	-	-	17	-	-	17	-	-	
21	HARNESS	1	1	15	-	-	15	-	-	15	-	-	15	-	-	
22	COMM CONTROL & INTERFACE	1	2	1.5	12	300	3	12	600	1.2	9	225	2.4	9	450	
23	INTEGRATION HARDWARE, SET	1	1	5%	-	-	9.7	-	-	5%	-	-	5.4	-	-	
24	MARGIN REQUIRED			10%	10%	5%	20.4	250	670	10%	10%	10%	11.3	163	766	
25																
26	TOTAL TRANSPONDER						224.9	2751	14066				123.9	1796	8424	
27																
28																
29	BRAZIL ANTENNA REFLECTOR (DUAL GRIDDED)	1	1	4	-	-	4	-	-	3.2	-	-	3.2	-	-	
30	BRAZIL FEED NETWORK, VERTICAL	1	1	7.5	-	1372	7.5	-	1372	6.8	-	1235	6.8	-	1235	
31	BRAZIL FEED, NETWORK, HORIZONTAL	1	1	7.5	-	1372	7.5	-	1372	6.8	-	1235	6.8	-	1235	
32	MEX/CANADIAN FEED NETWORK, HORIZONTAL	1	1	50	-	17280	50	-	17280	40	-	15552	40	-	15552	Uses CONUS REFLECTOR
33	MARGIN REQUIRED			10%	-	10%	6.9	-	2002	10%	-	10%	5.7	-	1802	
34																
35	TOTAL ANTENNA						75.9	-	22026				62.5	=	19824	
36																
37																
38	TOTAL PAYLOAD						300.8	2751	36092				186.4	1796	28248	

Figure 5.6.4-4 Ku-Band Non-Conus Antenna Coverage Requirement

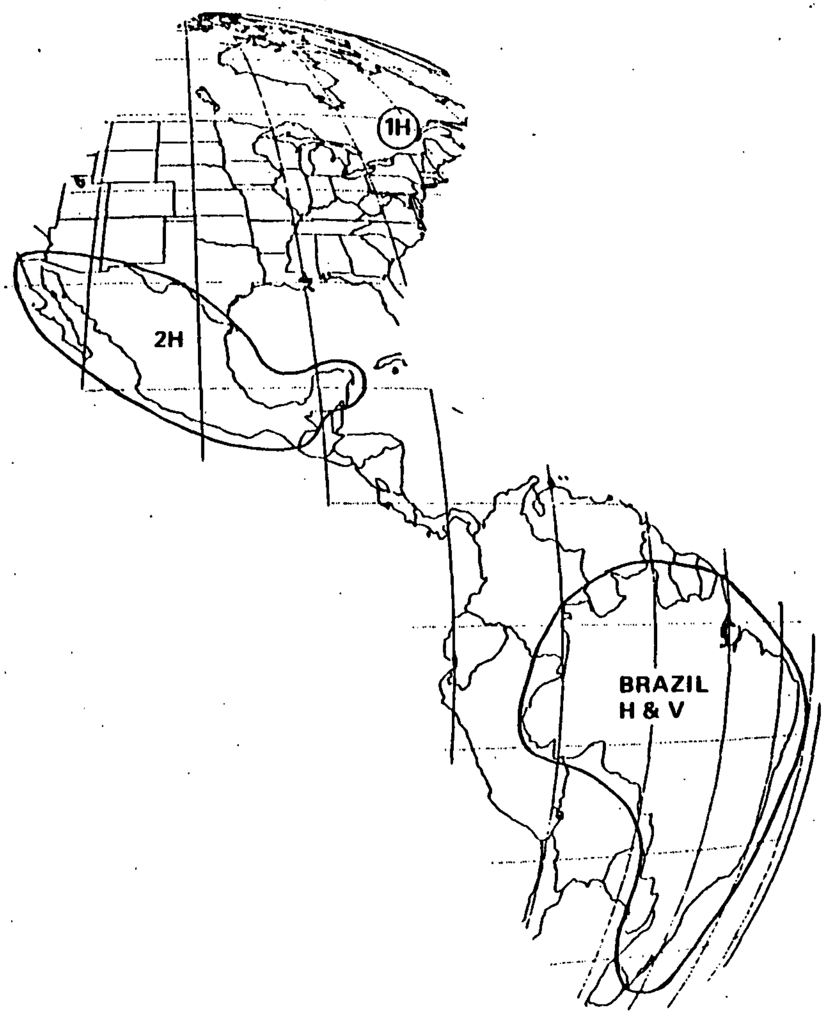
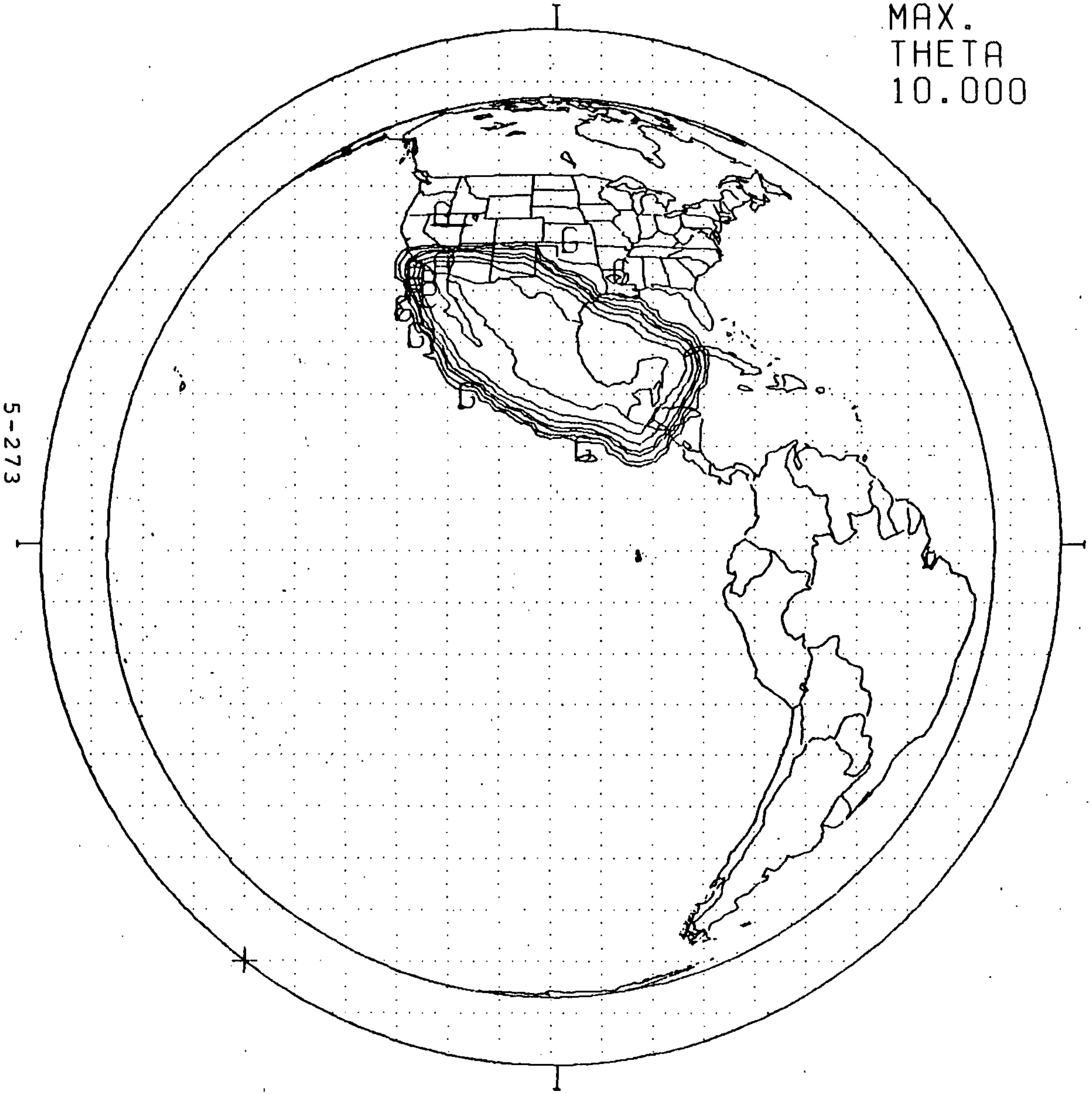


Figure 5.6.4-5 Ku-Band Mexican Contour Plot

CASE FREQ = 11.803 GHZ, 120.0 INCH REFL., C-10

04/26/85 13.662

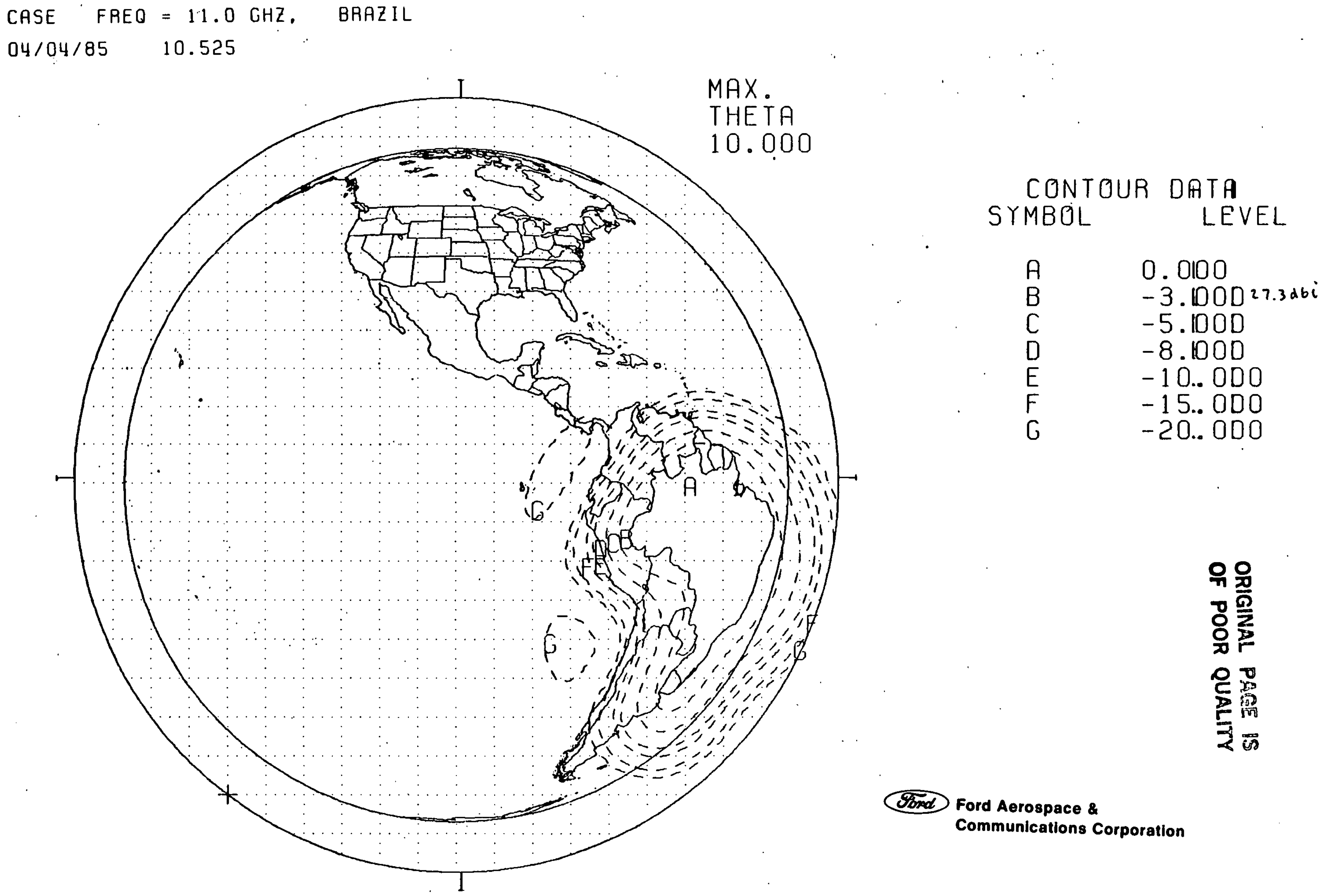


CONTOUR DATA

SYMBOL	LEVEL
A	0.000
B	-3.000 29.8dbi
C	-5.000
D	-8.000
E	-10.000
F	-15.000
G	-20.000

Ford Aerospace &
Communications Corporation

Figure 4.6.4-6 Ku-Band Brazil Contour Plot



Ford Aerospace &
Communications Corporation

Table 5.6.4-2

Ku-Band Non-CONUS Antenna Gain

Coverage	Gain dBi
Canada Spot Beam	48.8
Mexico	29.8
Brazil	27.3

capacity of 38 channels, each having a bandwidth of 36 Mhz. The four transponders utilize the same 500 MHz FSS band, having uplinks at 14 Ghz and downlinks at 11 Ghz. Crosslinks between all channels of the Canadian Ku-Band transponder and the three Canadian C-Band transponders are made at the 4 Ghz IF via a switch matrix. Similar configurational switching is provided between the even channels of the two Brazillian Ku-Band transponders and the three South American C-Band transponders. The 14 Ghz inputs from the beam forming network of the Mexican receive antenna are filtered by an input preselector, then amplified and down converted to 11 GHz by the receiver. For the Canadian and Brazilian trans- ponders; however, the 14 Ghz signals are downconverted to a 4 Ghz IF to facilitate beam switching with C-Band transponders. In all cases, the receiver output is fed to an input multiplexer which subdivides the 500 MHz IF band into twelve 36 MHz channels, while also providing the required narrow band receive filtering responses.

The Brazilian input multiplexers are followed by six 5x5 switch matrices. The latter permit signals in any uplink channels of the two Brazilian Ku-Band transponders to be re-transmitted via any of the three South America C-Band transponder output sections. Similarly, all twelve channels of the Canadian Ku-band transponder can be connected to the corresponding channels of the three Canadian C-Band transponders.

With the exception of the two Mexican channels which have an 11 Ghz IF, each channel is first individually upconverted to 11 Ghz and then amplified by SSPAs. The latter contain one or more variable gain amplifiers, which permit automatic accommodation of varying uplink levels using an AGC loop, and also up to 16 db of power amp back-off via ground control. For the non-U.S. Domestic and regional Services, from 1 to 5 watt SSPA's are necessary to ensure sufficient EIRP.

The outputs of the SSPA's in each transponder are combined in an output multiplexer, which also provides the required narrow band transmit filtering responses. The downlink signals are further filtered by a harmonic bandpass filter prior to transmission from the antenna feed assembly. The transponder subsystem features 4 for 2 redundancy for the receivers and 5 for 4 redundancy for the SSPAs.

5.6.4.3.1 Ku-Band Receiver

5.6.4.3.1.1 14/11 GHz Receiver

See 5.2.5.3.

5.6.4.3.1.2 14/4 GHz Receiver

See 5.3.2.3.1.

5.6.4.3.2 Input Multiplexers

5.6.4.3.2.1 11 GHz Input Multiplexers

See 5.2.5.3.2.

5.6.4.3.2.2 4 GHz Input Multiplexers

See 5.2.2.3.2.

5.6.4.3.3 RF Switch Matrix

See 5.2.3.3.3.

5.6.4.3.4 4/11 GHz Upconverter

See 5.2.6.3.4.

5.6.4.3.5 11 GHz SSPAs

See 5.2.5.3.

5.6.4.3.6 11 GHz Output Multiplexers

See 5.2.5.3.6.

5.6.4.3.7 Pre-Select and Harmonic Filters

See 5.2.2.3.5.

5.6.5 Ka-Band FSS Payload

This payload is identical to the Ka-Band FSS payload described in Scenario II. See 5.2.3 for detailed description.

5.6.6 Ka-Band Scan Payload

This payload is identical to the Ka-Band Scan payload described in Scenario II. See 5.2.4 for detailed description.

5.6.7 Ku-Band FSS Payload

This payload is identical to the Ku-Band Payload described in Scenario V. See 5.4.5 for detailed description.

5.6.8 60 GHz Inter-Satellite Link (ISL)

The ISL's on ths payload are identical to those defined in 5.5.8, with the exception that the both the east and west ISL's only require 1 each duplex channel. Each ISL carries a 1.5 Gbps data link in each direction. These ISL links are currently being developed on a NASA Goddard technology contract. Assuming this development continues to completion, no other funding would be required. Table 5.6.8-1 shows the weight power, and volume for low risk (emerging) technology and high risk (projected) technology for the transponder and antenna. Also included in the estimates are the coax, waveguide, and harness intaerconnects, plus an estimate for integration hardware to put the components together and provide necessary brackets for support and mounting. This does not include any structure or satellite mounting hardware, such as between the feed and reflector.

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Table 5.6.8-1

Scenario VI-B - Payload Summary

60 GHz ISL

	ITEM	P/L QTY REQ'D	RED. QTY REQ'D	LOW RISK TECHNOLOGY						HIGH RISK TECHNOLOGY						COMMENTS
				UNIT			PAYLOAD			UNIT			PAYLOAD			
				WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	WT.	PWR.	VOL.	
1	RECEIVER	2	4	2	15	200	8	30	800	1	5	50	4	10	200	
2	DIPLEXER	2	2	0.2	-	3	0.4	-	6	0.2	-	3	0.4	-	6	
3	CPU/PROCESSOR	2	4	2	20	200	8	40	800	1.4	10	75	5.6	20	300	
4	GIMBALS	2	2	16	25	20	32	50	40	13	20	15	26	40	30	
5	DRIVE ELECTRONICS	2	4	3	2	300	12	4	1200	2	2	100	8	4	400	
6	TRANSMITTER(5W. IMPATT)	2	4	1	40	150	4	80	600	0.7	20	75	2.8	40	300	
7	ANTENNA ASSY(REFL. SUB REFL. FEED & SUPPORT)	2	2	26	-	-	52	-	-	21	-	-	42	-	-	
8	MARGIN REQUIRED			20%	10%	15%	23.3	20	345	20%	15%	20%	17.8	17	247	
9																
10	TOTAL ISL						139.7	224	3791				106.6	131	1483	
11																
12																
13																
14																
15																
16																
17																
18																
19																
20																
21																
22																
23																
24																
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30																

SECTION INDEX

6.0 PAYLOAD COSTING (TASK 5)

6.1 OVERVIEW

The purpose of task 5 is to provide costing information for the five scenario payloads developed in task 4. All costs are expressed in terms of constant 1984 dollars. Sufficient detail is included in order to provide cost information on individual payload elements as well as the assembled payload as a whole. A qualitative assessment of associated ground segment costs is subsequently provided in section 8 in order to evaluate the impact upon full system costs.

Section 6.2 describes the Ford Aerospace cost forecasting methodology. Extensive use of the PRICE H model is included.

Fine structure cost details on individual payload elements, i.e., C-band FSS or Ku-band DBS etc., down to the component level is presented in section 6.3.

A summary of total individual scenario composite payloads and associated integration costs is presented in section 6.4.

A summary of total flight system costs for each of the five scenarios is presented in section 6.5. This is the composite of definitive scenario payload cost and qualitative assessment, bus costs, and launch costs.

6.2 COST FORECASTING METHODOLOGY

6.2.1 Approach

Basic data in the form of quantity, weight, volume, cost, and etc., from an FACC produced C-band payload (transponder and antenna) system, and a Ku-Band payload system, were used for the calibration and validation of the PRICE H model. The data, for each component of the payload system, was formatted for the PRICE H model. The model then predicted the cost, in constant 1984 dollars, for each component. Data on purchased components was formatted from recent actual purchase cost or current quotation estimates. All components for a given frequency band were then combined together, integration and test data added, and the whole data set input to the model.

Actual cost history for each frequency band system was then compared to the total cost just predicted through PRICE H.

Once the FACC cost factors input to the model were output to the exact actual cost, the factors were noted and then applied to the equivalent frequency band scenario of the study. Scenario data was extracted from the payload sheets of section 5 of this report. The resulting output from the PRICE H model is a prediction of the recurring cost to build that whole system at FACC. Since the factors were applied at the system level the costs of individual assemblies and components will vary, but over all they will balance for a valid output.

In the case of the Ka-band equipment, no current flight data was available so the relative complexity to Ku-band equipment was estimated and the resulting PRICE H output compared with engineering estimates for reasonableness.

6.2.2 PRICE Cost Model

The PRICE (Parametric Review of Information for Costing and Evaluation) Hardware Model is a computerized method for deriving cost estimates of electromechanical hardware assemblies and systems. It was developed by RCA in the early 1960's, and has been used at Ford Aerospace since 1976 to estimate space system costs.

The method used in PRICE H to model the estimating procedure is parametric. Therefore, when the model calculates a cost for manufacturing, it does not use a parts list and labor resource chart, but rather a parametric representation of the parts and labor costs.

The fundamental data used in the PRICE Hardware Model are as follows:

- Quantities of equipment to be developed, produced, modified, purchased, furnished and/or integrated and tested.
- Schedules for development, production, procurement, modification, integration and testing, including lead time for set-up, parts procurement, and redesign.
- Hardware geometry consisting of size, weight of electronic and structural elements, and electronic packaging density.
- Amount of new design required and complexity of the development engineering task.
- Hardware structural and electronic design repeat.
- Operational environment and specification requirements of the hardware.
- Type and manufacturing complexity of the structural/ mechanical and electronics portions of the hardware.
- Fabrication process to be used for production.
- Pertinent escalation rates and mark-ups for General and Administrative charges, profit, IR&D, cost of money, and purchased item handling.
- Technological improvement.
- Yield considerations for hardware development.

The fundamental characteristic of the parametric inputs is that of interrelationship. A change in any one parameter is usually not localized to one cost element, but rather, may have a direct effect on a few cost elements, and an indirect effect on many more. Consider the impact of a change in quantity. Certainly this would cause a change in manufacturing cost. But, it might also affect the fabrication process and, hence, the cost of tooling equipment. In addition, a change in quantity would probably have a schedule effect and so the cost due to escalation would differ. A filtered impact on integration and testing, sustaining engineering, and project management would almost certainly result from a change in quantity. This dynamic effect is characteristic of most input variables.

Conducting a PRICE H analysis is, therefore, a two step process. The first step being the creation and storage of the hardware parametric data; and the second step being the conversational dialogue between the user and the PRICE H Model when the stored data is used to estimate costs.

Adaptation of the model to new products and new situations is facilitated by the ability to run PRICE H in reverse on existing equipment or past programs, using actual costs as inputs. In this mode, the output is not cost, but the manufacturing complexity that matches the cost and other input parameters. Once a user has performed this process on a number of case histories, a discernable pattern usually emerges with respect to the manufacturing complexities. This pattern is then refined and tested on other programs to yield the accounting and product calibrations that properly adapts PRICE H to the new situation.

The inescapable conclusion to be drawn from all of this is that since PRICE H must be adapted, and since successful adaptation is accomplished with sound data, the user must validate the data used for calibration. Although this is usually a tedious and arduous task, its performance will ultimately save more time than it takes.

The PRICE H Model is actually a group or system of cost estimating and evaluation models and auxiliary programs. In addition to estimating costs to develop, produce, modify, integrate, and test hardware, the PRICE H system also includes methods for:

- Calculating complexity factors from any known cost
- Thru-putting costs not estimated by PRICE H
- Estimating the costs of multiple lot productions
- Calculating manufacturing complexities of non-homogeneous assemblies
- Calculating field reliability

6.3 PAYLOAD COST DETAILS

6.3.1 Summary

A summary of the projected costs derived from the PRICE H outputs associated with each of the various payload elements is shown in Table 6.3-1.

6.3.2 Payload Cost Sheets

The output of PRICE H is an abbreviated format which lists the total cost of each assembly and a system cost summary. An explanation of the output format is as follow:

Header Lines. Most of the header lines on each portion of the output are self-explanatory. The metric units of measure are: weight in kilograms and volume in cubic decimeters. The Global File contains calibration factors used to cause the model to operate in the manner FACC accumulates cost, e.g., tooling and test equipment costs are included in recurring (manufacturing) production costs. The Escalation filename is blank, since we did not escalate the costs through the model on these runs.

Table 6.3-1

Costs of Payload Subsystems

Subsystem	Cost ($M)	Used In Scenarios	Table Reference For Details
C-Band, FSS	4.5	II	6.3-2
C-Band, FSS	7.8	V, VI-A	6.3-3
C-Band, Maritime Atlantic	3.4	VI-A	6.3-4
C-Band, Maritime Pacific	2.4	VI-B	6.3-5
C-Band, International	27.8	VI-A	6.3-6
C-Band, Non U.S.	27.1	VI-B	6.3-7
Ku-Band, Non U.S.	15.7	VI-B	6.3-8
Ku-Band, FSS	15.2	II	6.3-9
Ku-Band, FSS	28.7	IV	6.3-10
Ku-Band, FSS	32.0	V, VI-A, VI-B	6.3-11
Ku-Band, DBS	11.3	II	6.3-12
Ku-Band, DBS	38.5	IV	6.3-13
Ka-Band, FSS	20.0	II, V, VI-A, VI-B	6.3-14
Ka-Band, SCAN	30.1	II, V, VI-A, VI-B	6.3-15
60 GHz, ISL	5.1	VI-A	6.3-16A
60 GHz, ISL	4.3	VI-B	6.3-16B

Also shown is the Julian date the model was run to generate the output.

System Cost Detail. The upper portion of the output is a descriptive listing of each assembly or component used in a payload with it's associated total cost. The total cost for system integration and test is also listed here. The descriptive detail and basic data for each output was extracted from the payload sheets of section 5 of this report.

System Cost Summary. This lower portion of the output sheet displays the total production-engineering and production-manufacturing costs calculated by PRICE H, with each broken into the cost categories shown. Engineering production costs are those engineering costs associated with the recurring production run only. Production-production costs are the touch labor and material costs to produce the whole assembly. Tooling and test equipment costs are included in the production-production cost. Also shown is the total of all purchased items. In all payloads, except the 60 GHz ISLs, purchased items include the antenna reflectors. The ISL antenna assembly was costed as though it was manufactured completely in-house.

Cost Ranges. This section shows a cost spread for the total cost. All of the algorithms which are used in the PRICE H model have been developed through regression analysis and therefore have an inherent statistical error. When these errors are added up over all the algorithms used in the cost calculations, they produce a cost distribution around a mean (or center) value. The From and To costs include the one sigma variation from that mean.

The detailed PRICE cost model estimates are shown in Tables 6.3-2 through 6.3-16 for each of the payload configurations.

Table 6.3-2

Cost Of C-band FSS Payload For Scenario II

```
INPUT FILENAME: CPPS1M        16-JUN-85 17:24
                                  (185147)      ESCALATION FILENAME:

PROGRAM COST($ 1000)       DEVELOPMENT        PRODUCTION         TOTAL COST
RCVR, C-BAND, 6/4 GHZ, SCENARIO II, C-BAND FSS   HUNTER   MAY
  TOTAL COST                          -           282.               282.
INPUT MUX, 6 CHAN, 36 MHZ
  TOTAL COST                          -           177.               177.
MATRIX, REDUNDANCY SWITCH (RING) 5/4, COAX
  TOTAL COST                          -           152.               152.
COMM CONTROL & INTERFACE, 2 EA
  TOTAL COST                          -           200.               200.
SSPA, 4GHZ, 8.5W WITH 2 VGAS
  TOTAL COST                          -          2044.              2044.
MUX, OUTPUT, 6 CHAN
  TOTAL COST                          -           174.               174.
HYBRID, 3DB
  TOTAL COST                          -             3.                 3.
SWITCH, SPDT, COAX, DWG 278395
  TOTAL COST                          -             9.                 9.
SWITCH, TRANSFER, COAX, DWG 278399
  TOTAL COST                          -             3.                 3.
FILTER, 4 GHZ, HARMONIC, DWG 278423
  TOTAL COST                          -            33.                33.
FILTER, 6GHZ, PRESELECT, DWG 278420
  TOTAL COST                          -             8.                 8.
FEED, ANT, VERT & HOR
  TOTAL COST                          -           219.               219.
REFLECTOR, ANT DUAL GRIDDED
  TOTAL COST                          -           700.               700.
 I & T, SCENARIO II, C-BAND FSS   HUNTER   MAY 85
  TOTAL COST                          0.          474.               474.
```

Table 6.3-2 (Continued)

Cost Of C-band FSS Payload For Scenario II

```
INPUT FILENAME: CPPS1M          16-JUN-85 17:24
                                    (185147)        ESCALATION FILENAME:


 TOTAL COST, WITH INTEGRATION COST
PROGRAM COST($ 1000)         DEVELOPMENT        PRODUCTION        TOTAL COST
   ENGINEERING
      DRAFTING                       0.                84.               84.
      DESIGN                         0.               402.              402.
      SYSTEMS                        0.                 -                0.
      PROJ MGMT                      0.               227.              227.
      DATA                           0.               109.              109.
        SUBTOTAL(ENG)                0.               822.              822.

   MANUFACTURING
      PRODUCTION                     -               2900.             2900.
      PROTOTYPE                      0.                 -                0.
      TOOL-TEST EQ                   0.                0.                0.
      PURCH ITEMS                    0.               756.              756.
        SUBTOTAL(MFG)                0.              3655.             3655.

         TOTAL COST                  0.              4478.             4478.

COST RANGES                  DEVELOPMENT        PRODUCTION         TOTAL COST
      FROM                           0.              4178.             4178.
      CENTER                         0.              4478.             4478.
      TO                             0.              4722.             4722.

**************************************************************************
* SYSTEM   WT                     87.84         SYSTEM   WS          82.72  *
* SYSTEM SERIES MTBF HRS.         2800          AV SYSTEM COST        4478  *
**************************************************************************
```

Table 6.3-3

Cost Of C-band FSS Payload For Scenario V And VI-A

```
INPUT FILENAME: CPPS2M          19-JUN-85 20:24
                                     (185147)      ESCALATION FILENAME:

PROGRAM COST($ 1000)         DEVELOPMENT        PRODUCTION         TOTAL COST
RCVR, 6/4 GHZ; SCENARIO V & VI-A, C-BAND FSS  HUNTER  MAY 85
  TOTAL COST                           -            462.                462.
MUX, INPUT, 12 CHAN, 36 MHZ
  TOTAL COST                           -            315.                315.
MATRIX, BEAM SWITCHING, 4X4, 12 EA
  TOTAL COST                           -            660.                660.
MATRIX, REDUNDANCY SWITCH (RING) 5/4, COAX
  TOTAL COST                           -            263.                263.
COMM CONTROL & INTERFACE, 2 EA
  TOTAL COST                           -            200.                200.
SSPA, 4 GHZ, 4.0 W. WITH 2 VGAS
  TOTAL COST                           -           2976.               2976.
MUX, OUTPUT, 12 CHAN, 36 MHZ
  TOTAL COST                           -            311.                311.
SWITCH, SPDT, COAX, DWG 278395
  TOTAL COST                           -             35.                 35.
SWITCH, TRANSFER, COAX, DWG 278399
  TOTAL COST                           -              6.                  6.
FILTER, 4 GHZ, HARMONIC, DWG 278423
  TOTAL COST                           -            224.                224.
FILTER, 6 GHZ, PRESELECT, DWG 278420
  TOTAL COST                           -             16.                 16.
FEED, ANTENNA, VERTICAL & HORIZONTAL
  TOTAL COST                           -            465.                465.
REFLECTOR, ANTENNA, DUAL GRIDDED, 4.6M
  TOTAL COST                           -           1100.               1100.
I & T, SCENARIO V & VI-A, C-BAND   HUNTER   MAY 85
  TOTAL COST                           0.           835.                835.
```

Table 6.3-3 (Continued)

Cost Of C-band FSS Payload For Scenario V And VI-A

```
INPUT FILENAME: CPPS2M           19-JUN-85 20:24
                                      (185147)         ESCALATION FILENAME:


 TOTAL COST, WITH INTEGRATION COST
PROGRAM COST($ 1000)          DEVELOPMENT          PRODUCTION          TOTAL COST
   ENGINEERING
      DRAFTING                         0.               126.                126.
      DESIGN                           0.               591.                591.
      SYSTEMS                          0.                 --                  0.
      PROJ MGMT                        0.               352.                352.
      DATA                             0.               168.                168.
        SUBTOTAL(ENG)                  0.              1238.               1238.

   MANUFACTURING
      PRODUCTION                       --              5249.               5249.
      PROTOTYPE                        0.                 --                  0.
      TOOL-TEST EQ                     0.                 0.                  0.
      PURCH ITEMS                      0.              1381.               1381.
        SUBTOTAL(MFG)                  0.              6631.               6631.

          TOTAL COST                   0.              7869.               7869.

COST RANGES                   DEVELOPMENT          PRODUCTION           TOTAL COST
      FROM                             0.              7326.               7326.
      CENTER                           0.              7869.               7869.
      TO                               0.              8320.               8320.


****************************************************************************
* SYSTEM  WT                      251.40         SYSTEM  WS            240.00  *
* SYSTEM SERIES MTBF HRS.          1112          AV SYSTEM COST          7869  *
****************************************************************************
```

Table 6.3-4

Cost Of C/L-band Maritime Payload For Scenario VI-A

```
INPUT FILENAME: CPPS13M        16-JUN-85 17:48
                                (185147)      ESCALATION FILENAME:

PROGRAM COST($ 1000)        DEVELOPMENT       PRODUCTION       TOTAL COST
RCVR, 6.0/1.5 GHZ, SCEN VI-A, W. ATLANTIC MARITIME C/L BAND
  TOTAL COST                      -              264.              264.
L-BAND HIGH POWER AMPLIFIER 100W
  TOTAL COST                      -             1200.             1200.
BP/HARMONIC FILTER 1.5 GHZ
  TOTAL COST                      -                5.                5.
CHANNEL FILTER 1.5 GHZ
  TOTAL COST                      -                5.                5.
PRESELECT FILTER 6 GHZ
  TOTAL COST                      -                4.                4.
SPDT SWITCH 6 GHZ CPAX 1.5 GHZ COAX
  TOTAL COST                      -               18.               18.
RECEIVER, DUAL CONVERSION, 1.6/0.36
  TOTAL COST                      -              381.              381.
C-BAND HIGH POWER AMPLIFIER 9W
  TOTAL COST                      -                2.                2.
PRESELECT FILTER 0.36 GHZ
  TOTAL COST                      -                4.                4.
SPDT SWITCH COAX 0.36 GHZ, 4 GHZ
  TOTAL COST                      -               18.               18.
BP/HARMONIC FILTER 4 GHZ W/G
  TOTAL COST                      -                5.                5.
CHANNEL FILTER 4 GHZ CAVITY DIEL
  TOTAL COST                      -                4.                4.
L-BAND LINEARIZER
  TOTAL COST                      -                2.                2.
L-BAND ANTENNA REFLECTOR TX/RX 3M
  TOTAL COST                      -              350.              350.
L-BAND FEED
  TOTAL COST                      -              353.              353.
C-BAND ANTENNA REFLECTOR TX 1M
  TOTAL COST                      -               39.               39.
C-BAND TX FEED
  TOTAL COST                      -              199.              199.
C-BAND ANTENNA REFLECTOR RX 0.75M
  TOTAL COST                      -               22.               22.
C-BAND RX FEED
  TOTAL COST                      -              116.              116.
I & T, SCENARIO VI-A, W. ATLANTIC MARITME C/L-BAND   HUNTER
  TOTAL COST                      0.             395.              395.
```

Table 6.3-4 (Continued)

Cost Of C/L-band Maritime Payload For Scenario VI-A

```
INPUT FILENAME: CPPS13M       16-JUN-85 17:48
                                  (185147)        ESCALATION FILENAME:


 TOTAL COST, WITH INTEGRATION COST
PROGRAM COST($ 1000)          DEVELOPMENT       PRODUCTION        TOTAL COST
   ENGINEERING
      DRAFTING                       0.             109.              109.
      DESIGN                         0.             533.              533.
      SYSTEMS                        0.              -                  0.
      PROJ MGMT                      0.             235.              235.
      DATA                           0.             120.              120.
        SUBTOTAL(ENG)                0.             997.              997.

   MANUFACTURING
      PRODUCTION                     -              711.              711.
      PROTOTYPE                      0.              -                  0.
      TOOL-TEST EQ                   0.               0.                0.
      PURCH ITEMS                    0.            1676.             1676.
        SUBTOTAL(MFG)                0.            2387.             2387.

          TOTAL COST                 0.            3384.             3384.

COST RANGES                   DEVELOPMENT       PRODUCTION         TOTAL COST
      FROM                           0.            3299.             3299.
      CENTER                         0.            3384.             3384.
      TO                             0.            3456.             3456.


**************************************************************************
* SYSTEM  WT                   85.14          SYSTEM  WS             84.30  *
* SYSTEM SERIES MTBF HRS.       2477          AV SYSTEM COST          3384  *
**************************************************************************
```

Table 6.3-5

Cost Of C/L-band Maritime Payload For Scenario VI-B

```
INPUT FILENAME: CPPS14M        16-JUN-85 17:49
                                    (185147)      ESCALATION FILENAME:

PROGRAM COST($ 1000)        DEVELOPMENT        PRODUCTION        TOTAL COST
RCVR, 6.0/1.5 GHZ,  SCENARIO VI-B, E. PACIFIC MARITIME C/L-B
  TOTAL COST                          -            264.               264.
L-BAND HIGH POWER AMPLIFIER 100W
  TOTAL COST                          -           1200.              1200.
BP/HARMONIC FILTER 1.5 GHZ
  TOTAL COST                          -              5.                 5.
CHANNEL FILTER 1.5 GHZ
  TOTAL COST                          -              5.                 5.
PRESELECT FILTER 6 GHZ
  TOTAL COST                          -              4.                 4.
SPDT SWITCH 6 GHZ CPAX 1.5 GHZ COAX
  TOTAL COST                          -             18.                18.
RECEIVER, DUAL CONVERSION, 1.6/0.36
  TOTAL COST                          -            381.               381.
C-BAND HIGH POWER AMPLIFIER 9W
  TOTAL COST                          -              2.                 2.
PRESELECT FILTER 0.36 GHZ
  TOTAL COST                          -              4.                 4.
SPDT SWITCH COAX 0.36 GHZ, 4 GHZ
  TOTAL COST                          -             18.                18.
BP/HARMONIC FILTER 4 GHZ W/G
  TOTAL COST                          -              5.                 5.
CHANNEL FILTER 4 GHZ CAVITY DIEL
  TOTAL COST                          -              4.                 4.
L-BAND LINEARIZER
  TOTAL COST                          -             40.                40.
L-BAND ANTENNA REFLECTOR TX/RX 1.2M
  TOTAL COST                          -             56.                56.
L-BAND FEED
  TOTAL COST                          -             42.                42.
C-BAND REFLECTOR TX 0.5M
  TOTAL COST                          -             10.                10.
C-BAND TX FEED
  TOTAL COST                          -             26.                26.
C-BAND ANTENNA REFLECTOR RX 0.35M
  TOTAL COST                          -              5.                 5.
C-BAND RX FEED
  TOTAL COST                          -             19.                19.
I & T, SCENARIO VI-A, W. ATLANTIC MARITME C/L-BAND   HUNTER
  TOTAL COST                          0.           330.               330.
```

Table 6.3-5 (Continued)

Cost Of C/L-band Maritime Payload For Scenario VI-B

```
INPUT FILENAME: CPPS14M          16-JUN-85 17:49
                                     (185147)        ESCALATION FILENAME:


 TOTAL COST, WITH INTEGRATION COST
PROGRAM COST($ 1000)          DEVELOPMENT         PRODUCTION        TOTAL COST
   ENGINEERING
      DRAFTING                        0.                74.               74.
      DESIGN                          0.               362.              362.
      SYSTEMS                         0.                 -                 0.
      PROJ MGMT                       0.               148.              148.
      DATA                            0.                76.               76.
        SUBTOTAL(ENG)                 0.               661.              661.

   MANUFACTURING
      PRODUCTION                      -                400.              400.
      PROTOTYPE                       0.                 -                 0.
      TOOL-TEST EQ                    0.                 0.                0.
      PURCH ITEMS                     0.              1374.             1374.
        SUBTOTAL(MFG)                 0.              1774.             1774.

         TOTAL COST                   0.              2435.             2435.

COST RANGES                   DEVELOPMENT         PRODUCTION         TOTAL COST
      FROM                            0.              2383.             2383.
      CENTER                          0.              2435.             2435.
      TO                              0.              2481.             2481.


*************************************************************************
* SYSTEM  WT                       46.99          SYSTEM  WS          46.15   *
* SYSTEM SERIES MTBF HRS.           2776          AV SYSTEM COST       2435   *
*************************************************************************
```

Table 6.3-6

Cost Of C-band International Payload For Scenario VI-A

```
INPUT FILENAME: CPPS3M          10-JUL-85 13:52
                                  (185147)        ESCALATION FILENAME:

PROGRAM COST($ 1000)        DEVELOPMENT       PRODUCTION        TOTAL COST
RCVR, 6/4 GHZ, 18 EA,     SCENARIO VI-A, C-BAND INTL
  TOTAL COST                      -               835.              835.
MUX, INPUT, 12 CHAN, 36 MHZ, 9 EA
  TOTAL COST                      -               617.              617.
MATRIX, BEAM SWITCHING, 9X9, 12 EA
  TOTAL COST                      -              2400.             2400.
BASEBAND PROCESSOR, INTERNATIONAL ROUTING, 1 EA
  TOTAL COST                      -              8001.             8001.
MATRIX, REDUNDANCY SWITCH (RING) 5/4, COAX, 27 EA
  TOTAL COST                      -               290.              290.
BASEBAND PROCESSOR, ADDED FOR CONUS KA-BAND, 1 EA
  TOTAL COST                      -              2000.             2000.
SSPA, 4 GHZ, 4.5W. WITH 2 VGAS, 135 EA
  TOTAL COST                      -              5504.             5504.
MATRIX, REDUNDANCY SWITCH (RING) 5/4, COAX, 27 EA
  TOTAL COST                      -               290.              290.
MUX, OUTPUT, 12 CHAN, 36 MHZ, 9 EA
  TOTAL COST                      -               614.              614.
FILTER, 4 GHZ, HARMONIC, DWG278423, 9 EA
  TOTAL COST                      -                42.               42.
FILTER, 6 GHZ, PRESELECT, DWG 278420-03, 9 EA
  TOTAL COST                      -                36.               36.
SWITCH, SPDT, COAX, DWG 278395, 9 EA
  TOTAL COST                      -                40.               40.
SWITCH, TRANSFER, COAX, DWG 278399, 4 EA
  TOTAL COST                      -                 6.                6.
FEED, ANTENNA, VERTICAL & HORIZONTAL, 2 EA
  TOTAL COST                      -              1643.             1643.
REFLECTOR, ANTENNA TX/RX, 5.0M, DUAL GRIDDED, 1 EA
  TOTAL COST                      -              1500.             1500.
FEED, ANTENNA, 4.0M, VERTICAL & HORIZONTAL, 2 EA
  TOTAL COST                      -               515.              515.
REFLECTOR, ANTENNA TX/RX, 4.0M, DUAL GRIDDED, 1 EA
  TOTAL COST                      -               990.              990.
I & T, SCENARIO VI-A, C-BAND INTERNATIONAL   HUNTER  MAY 85
  TOTAL COST                      0.             2499.             2499.
```

Table 6.3-4 (Continued)

Cost Of C-band International Payload For Scenario VI-A

```
INPUT FILENAME: CPPS3M          10-JUL-85 13:52
                                      (185147)      ESCALATION FILENAME:


 TOTAL COST, WITH INTEGRATION COST
PROGRAM COST($ 1000)          DEVELOPMENT         PRODUCTION          TOTAL COST
   ENGINEERING
      DRAFTING                         0.               659.                659.
      DESIGN                           0.              3346.               3346.
      SYSTEMS                          0.                 -                   0.
      PROJ MGMT                        0.              1401.               1401.
      DATA                             0.               664.                664.
         SUBTOTAL(ENG)                 0.              6070.               6070.

   MANUFACTURING
      PRODUCTION                       -              19137.              19137.
      PROTOTYPE                        0.                 -                   0.
      TOOL-TEST EQ                     0.                0.                   0.
      PURCH ITEMS                      0.              2614.               2614.
         SUBTOTAL(MFG)                 0.             21751.              21751.

           TOTAL COST                  0.             27821.              27821.

COST RANGES                   DEVELOPMENT         PRODUCTION           TOTAL COST
      FROM                             0.             25913.              25913.
      CENTER                           0.             27821.              27821.
      TO                               0.             29341.              29341.


**************************************************************************************
* SYSTEM   WT                    820.32          SYSTEM   WS               775.40   *
* SYSTEM SERIES MTBF HRS.         957           AV SYSTEM COST            27821    *
**************************************************************************************
```

C-7

Table 6.3-7

Cost Of C-band Non-U.S. Payload For Scenario VI-B

```
INPUT FILENAME: CPPS4M        16-JUN-85 17:35
                                 (185147)       ESCALATION FILENAME:

PROGRAM COST($ 1000)        DEVELOPMENT       PRODUCTION        TOTAL COST
RCVR, 6/4GHZ, SCEN VI-B, C-BAND NON-CONUS  HUNTER  MAY 85
  TOTAL COST                     -               835.              835.
MUX, 36MHZ INPUT, 4GHZ, 12 CHAN, SCEN VI-B, C-BAND, NON-CONU
  TOTAL COST                     -               675.              675.
MUX, 36MHZ INPUT, 4GHZ, 6 CHAN, SCEN VI-B, C-BAND, NON-CONUS
  TOTAL COST                     -               105.              105.
MATRIX, BEAM SWITCHING, 4 GHZ, 4X4 COAX, 9EA
  TOTAL COST                     -               500.              500.
MATRIX, REDUND SW (RING) 5/4, COAX, HUNTER/EDRIDGE   MAY85
  TOTAL COST                     -               341.              341.
MATRIX, BEAM SWITCHING, 4 GHZ, 5X5 COAX, 6 EA
  TOTAL COST                     -               390.              390.
MATRIX, BEAM SWITCHING, 4 GHZ, 3X3 COAX, 6 EA
  TOTAL COST                     -               299.              299.
BASEBAND PROCESSOR, 1EA
  TOTAL COST                     -              3001.             3001.
SSPA, 4 GHZ, 4 SW, SCEN VI-B, C-BAND, NON-CONUS   HUNTER  MA
  TOTAL COST                     -              5504.             5504.
MUX, OUTPUT, 4 GHZ, 12 CHAN (36 MHZ), SCEN VI-B, C-BAND NON-
  TOTAL COST                     -               614.              614.
FILTER, 4GHZ, HARMONIC, DWG 278423   INSAT   LIMBURG 5/30/85
  TOTAL COST                     -                42.               42.
FILTER, 6 GHZ, PRESELECT, DWWG 278420-03   INSAT   LIMBURG
  TOTAL COST                     -                36.               36.
SWITCH, SPDT, COAX, DWG 278395-XX  INSAT  LIMBURG  5/30/85
  TOTAL COST                     -                92.               92.
SWITCH, TRANSFER, COAX, DWG 278399-XX    INSAT  LIMBURG 5/30
  TOTAL COST                     -                14.               14.
COMM CONTROL & INTERFACE
  TOTAL COST                     -               200.              200.
FEED,ANT, NETWORK (TX/RX), SCEN VI-B,C-BAND, NON-U.S.   HUNT
  TOTAL COST                     -              2700.             2700.
REFL, ANT, UNFURL 9.0M, SCEN VI-B, C-BAND   HUNTER  MAY 85
  TOTAL COST                     -             10000.            10000.
I & T, SCEN VI-B, C-BAND, NON-U.S. DOMESTIC & REGIONAL  HUNT
  TOTAL COST                     0.             1760.             1760.
```

Table 6.3-7 (Continued)

Cost Of C-band Non-U.S. Payload For Scenario VI-B

```
INPUT FILENAME: CPPS4M          16-JUN-85 17:35
                                   (185147)       ESCALATION FILENAME:


 TOTAL COST, WITH INTEGRATION COST
PROGRAM COST($ 1000)        DEVELOPMENT           PRODUCTION        TOTAL COST
   ENGINEERING
      DRAFTING                       0.                 405.              405.
      DESIGN                         0.                1964.             1964.
      SYSTEMS                        0.                  -                  0.
      PROJ MGMT                      0.                 941.              941.
      DATA                           0.                 447.              447.
        SUBTOTAL(ENG)                0.                3758.             3758.

   MANUFACTURING
      PRODUCTION                     -                13167.            13167.
      PROTOTYPE                      0.                  -                  0.
      TOOL-TEST EQ                   0.                   0.                0.
      PURCH ITEMS                    0.               10184.            10184.
        SUBTOTAL(MFG)                0.               23351.            23351.

         TOTAL COST                  0.               27108.            27108.

COST RANGES                 DEVELOPMENT           PRODUCTION        TOTAL COST
      FROM                           0.               25790.            25790.
      CENTER                         0.               27108.            27108.
      TO                             0.               28183.            28183.


**************************************************************************
* SYSTEM  WT                   557.34          SYSTEM  WS         321.82  *
* SYSTEM SERIES MTBF HRS.        924           AV SYSTEM COST     27108   *
**************************************************************************
```

Table 6.3-8

Cost Of Ku-band Non-U.S. Payload For Scenario VI-B

```
INPUT FILENAME: CPPS10M        19-JUN-85 20:50
                                   (185147)       ESCALATION FILENAME:

PROGRAM COST($ 1000)         DEVELOPMENT         PRODUCTION         TOTAL COST
RCVR, 14/4GHZ, SCENARIO VI-B, KU-BAND NON-CONUS    HUNTER   MA
  TOTAL COST                          -              239.                239.
RCVR, 14/11 GHZ    HUNTER   MAY 85
  TOTAL COST                          -              239.                239.
MUX, INPUT 36 MHZ, 11GHZ, 6 CHAN    HUNTER MAY 85
  TOTAL COST                          -              543.                543.
MUX, INPUT,36 MHZ, 11 GHZ, 2 CHAN
  TOTAL COST                          -              148.                148.
MATRIX, REDUNDANCY SWITCH, 5/4, 11 GHZ, COAX   HUNTER  MAY 8
  TOTAL COST                          -               88.                 88.
UPCONVERTER, 4/11 GHZ   HUNTER   MAY 85
  TOTAL COST                          -              775.                775.
SSPA, 11 GHZ, 20W   HUNTER   MAY 85
  TOTAL COST                          -             2748.               2748.
SSPA, 11 GHZ, 10W   HUNTER   MAY 85
  TOTAL COST                          -              551.                551.
SSPA, 11 GHZ, 5W   HUNTER   MAY 85
  TOTAL COST                          -             1349.               1349.
MUX, OUTPUT, 11 GHZ, 2 CHAN, 36 MHZ
  TOTAL COST                          -              165.                165.
MUX, OUTPUT, 11 GHZ, 12 CHAN, 36 MHZ
  TOTAL COST                          -             1382.               1382.
FILTER, HARMONIC, 11 GHZ, 30W, 278424-02  I-V  LIMBURG  6-04
  TOTAL COST                          -               15.                 15.
FILTER, PRESELECT, 14 GHZ, WG, 278419-01, I-V  LIMBURG 6/04/
  TOTAL COST                          -               18.                 18.
SWITCH, SPDT, 14 GHZ, WG, 278397-05  I-V  LIMBURG  6/02/85
  TOTAL COST                          -               49.                 49.
SWITCH, XFER, WG, 14 GHZ, 10W, 278396-02 I-V LIMBURG 6/03/85
  TOTAL COST                          -                7.                  7.
COMM CONTROL & INTERFACE, 2 EA
  TOTAL COST                          -              200.                200.
REFLECTOR, 1.0M, ANTENNA BRAZIL (DUAL GRIDDED)
  TOTAL COST                          -              660.                660.
FEED NETWORK, ANTENNA BRAZIL, VERTICAL & HORIZONTAL
  TOTAL COST                          -             1183.               1183.
FEED NETWORK, MEX/CANADIAN, HORIZONTAL
  TOTAL COST                          -             3506.               3506.
I & T, SCENARIO VI-B, KU-BAND, NON-US DOMESTIC AND REGIONAL
  TOTAL COST                          0.            1817.               1817.
```

Table 6.3-8 (Continued)

Cost Of Ku-band Non-U.S. Payload For Scenario VI-B

```
INPUT FILENAME: CPPS10M        19-JUN-85 20:50
                                   (185147)       ESCALATION FILENAME:


 TOTAL COST, WITH INTEGRATION COST
PROGRAM COST($ 1000)         DEVELOPMENT        PRODUCTION        TOTAL COST
   ENGINEERING
      DRAFTING                      0.               534.              534.
      DESIGN                        0.              2766.             2766.
      SYSTEMS                       0.                --                0.
      PROJ MGMT                     0.              1408.             1408.
      DATA                          0.               701.              701.
        SUBTOTAL(ENG)               0.              5409.             5409.

   MANUFACTURING
      PRODUCTION                    --              9524.             9524.
      PROTOTYPE                     0.                --                0.
      TOOL-TEST EQ                  0.                0.                0.
      PURCH ITEMS                   0.               750.              750.
        SUBTOTAL(MFG)               0.             10274.            10274.

         TOTAL COST                 0.             15683.            15683.

COST RANGES                  DEVELOPMENT        PRODUCTION         TOTAL COST
      FROM                          0.             14679.            14679.
      CENTER                        0.             15683.            15683.
      TO                            0.             16453.            16453.


*************************************************************************
* SYSTEM  WT                   211.16            SYSTEM  WS        195.58  *
* SYSTEM SERIES MTBF HRS.       1580             AV SYSTEM COST    15683   *
*************************************************************************
```

Table 6.3-9

Cost Of Ku-band FSS Payload For Scenario II

```
INPUT FILENAME: CPPS5M          19-JUN-85 20:42
                                    (185147)       ESCALATION FILENAME:

PROGRAM COST($ 1000)        DEVELOPMENT        PRODUCTION         TOTAL C
RCVR, 14/11GHZ, SCENARIO II, KU-BAND FSS   HUNTER  MAY 85
  TOTAL COST                     -              239.                239.
MUX, INPUT, 8 CHAN, 54 MHZ, SCENARIO II, KU-BAND FSS HUNTER
  TOTAL COST                     -              923.                923.
MATRIX, BEAM SWITCHING, 3X3, 8 EA
  TOTAL COST                     -              400.                400.
DRIVER AMPLIFIER, VARIABLE GAIN, 11 GHZ
  TOTAL COST                     -              518.                518.
TWTA, 11GHZ, 50W, SCEN II, KU-BAND, FSS   HUNTER  MAY 85
  TOTAL COST                     -             7800.               7800.
MUX, OUTPUT, 8 CHAN, 54MHZ, SCEN II, KU-BAND FSS,   HUNTER
  TOTAL COST                     -              986.                986.
MATRIX, REDUND SW (RING) 5/4, COAX, HUNTER/EDRIDGE   MAY85
  TOTAL COST                     -              115.                115.
MATRIX, REDUND SW (RING) 5/4, WG, HUNTER/EDRIDGE   MAY85
  TOTAL COST                     -              392.                392.
FILTER, HARMONIC, 11 GHZ, 30W, 278424  I-V   LIMBURG  6-04-8
  TOTAL COST                     -               89.                 89.
FILTER, PRESELECT, 11 GHZ, WG, 278419, I-V  LIMBURG  6/04/85
  TOTAL COST                     -               14.                 14.
SWITCH, SPDT, WG, 278397, I-V LIMBURG 6/02/85
  TOTAL COST                     -               25.                 25.
SWITCH, SPDT, COAX, 278395, I-V LIMBURG  67/05/85
  TOTAL COST                     -               13.                 13.
COMM CONTROL & INTERFACE
  TOTAL COST                     -              200.                200.
SWITCH, XFER, SPDT, WG, 11 GHZ, 10W, 278396
  TOTAL COST                     -                4.                  4.
SWITCH, XFER, COAX, 278399, I-V
  TOTAL COST                     -                2.                  2.
FEED, ANT VERT & HOR,
  TOTAL COST                     -              982.                982.
REFLECTOR, ANTENNA 4.0M (DUAL GRID),
  TOTAL COST                     -              990.                990.
I & T, SCENARIO II, KU-BAND FSS   HUNTER   MAY 85
  TOTAL COST                     0.            1498.               1498.
```

Table 6.3-9 (Continued)

Cost Of Ku-band FSS Payload For Scenario II

```
INPUT FILENAME: CPPS5M           19-JUN-85 20:42
                                     (185147)        ESCALATION FILENAME:


 TOTAL COST, WITH INTEGRATION COST
PROGRAM COST($ 1000)          DEVELOPMENT        PRODUCTION       TOTAL COST
   ENGINEERING
      DRAFTING                      0.              240.             240.
      DESIGN                        0.             1187.            1187.
      SYSTEMS                       0.               -                0.
      PROJ MGMT                     0.              623.             623.
      DATA                          0.              311.             311.
        SUBTOTAL(ENG)               0.             2361.            2361.

   MANUFACTURING
      PRODUCTION                    --             3892.            3892.
      PROTOTYPE                     0.               --               0.
      TOOL-TEST EQ                  0.               0.               0.
      PURCH ITEMS                   0.             8936.            8936.
        SUBTOTAL(MFG)               0.            12828.           12828.

         TOTAL COST                 0.            15189.           15189.

COST RANGES                   DEVELOPMENT        PRODUCTION        TOTAL COST
      FROM                          0.            14752.           14752.
      CENTER                        0.            15189.           15189.
      TO                            0.            15546.           15546.


****************************************************************************
* SYSTEM  WT                  247.91          SYSTEM  WS              242.17  *
* SYSTEM SERIES MTBF HRS.       522           AV SYSTEM COST          15189   *
****************************************************************************
```

Table 6.3-10

Cost Of Ku-band FSS Payload For Scenario IV

```
INPUT FILENAME: CPPS7M        16-JUN-85 17:39
                                  (185147)      ESCALATION FILENAME:

PROGRAM COST($ 1000)       DEVELOPMENT       PRODUCTION       TOTAL COST
RCVR, 14/4GHZ, SCEN IV, KU-BAND FSS   HUNTER  MAY 85
  TOTAL COST                      -              250.              250.
MUX,INPUT, 16 CHAN, 24MHZ, SCEN IV, KU-BAND, DBS   HUNTER  M
  TOTAL COST                      -             1371.             1371.
MATRIX, BEAM SWITCHING, 7X7, 8 EA
  TOTAL COST                      -              750.              750.
MATRIX, REDUND SW (RING) 5/4, COAX, HUNTER/EDRIDGE   MAY85
  TOTAL COST                      -              171.              171.
UPCONVERTER (+VGAS), 4/11 GHZ, SCEN IV, KU-BAND FSS  HUNTER
  TOTAL COST                      -             1295.             1295.
TWTA, 12GHZ, 50W, SCEN IV, KU-BAND FSS  HUNTER  MAY 85
  TOTAL COST                      -            13200.            13200.
MATRIX, REDUND SW (RING) 5/4, COAX, HUNTER/EDRIDGE   MAY85
  TOTAL COST                      -              373.              373.
MUX,OUTPUT, 16 CHAN, 24GHZ-11GHZ, SCEN IV, KU-BAND FSS  HUNT
  TOTAL COST                      -             3148.             3148.
FILTER, HARMONIC, 11 GHZ, 30W, 278424-02  I-V  LIMBURG  6-04
  TOTAL COST                      -              178.              178.
FILTER, PRESELECT, 11 GHZ, WG, 278419-01, I-V  LIMBURG 6/04/
  TOTAL COST                      -               14.               14.
SWITCH, SPDT, WG, 278397-05  I-V  LIMBURG  6/02/85
  TOTAL COST                      -               25.               25.
SWITCH, XFER, SPDT, WG, 17 OR 14 GHZ, 10W, 278396-02 I-V LIM
  TOTAL COST                      -                4.                4.
SWITCH, XFER, COAX, 278399-02  I-V  LIMBURG  6/05/85
  TOTAL COST                      -                2.                2.
SWITCH, SPDT, COAX, 278395-XX  I-V  LIMBURG  6/05/85
  TOTAL COST                      -               13.               13.
COMM CONTROL & INTERFACE, 2 EA
  TOTAL COST                      -              200.              200.
FEED, ANT, VERT & HOR, SCEN IV, KU-BAND FSS   HUNTER  MAY 85
  TOTAL COST                      -             3994.             3994.
REFLECTOR, ANT(DUAL GRID), 4.0M, SCEN IV, KU-BAND FSS   HUNT
  TOTAL COST                      -              990.              990.
I & T, SCENARIO IV, KU-BAND FSS   HUNTER MAY 85
  TOTAL COST                      0.            2718.             2718.
```

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Table 6.3-10 (Continued)

Cost Of Ku-band FSS Payload For Scenario IV

```
INPUT FILENAME: CPPS7M          16-JUN-85 17:39
                                    (185147)        ESCALATION FILENAME:


 TOTAL COST, WITH INTEGRATION COST
PROGRAM COST($ 1000)         DEVELOPMENT        PRODUCTION        TOTAL COST
   ENGINEERING
      DRAFTING                        0.              457.              457.
      DESIGN                          0.             2343.             2343.
      SYSTEMS                         0.               -                  0.
      PROJ MGMT                       0.             1245.             1245.
      DATA                            0.              615.              615.
        SUBTOTAL(ENG)                 0.             4660.             4660.

   MANUFACTURING
      PRODUCTION                      -              9609.             9609.
      PROTOTYPE                       0.               -                  0.
      TOOL-TEST EQ                    0.                0.                0.
      PURCH ITEMS                     0.            14425.            14425.
        SUBTOTAL(MFG)                 0.            24035.            24035.

         TOTAL COST                   0.            28695.            28695.

COST RANGES                  DEVELOPMENT        PRODUCTION         TOTAL COST
      FROM                            0.            27696.            27696.
      CENTER                          0.            28695.            28695.
      TO                              0.            29468.            29468.


*************************************************************************************
* SYSTEM  WT                     601.51          SYSTEM  WS              571.07  *
* SYSTEM SERIES MTBF HRS.         293            AV SYSTEM COST          28695   *
*************************************************************************************
```

Table 6.3-11

Cost of Ku-band FSS Payload for Scenarios V, VI-A and VI-B

```
INPUT FILENAME:  CPPS9M       24-JUL-85 19:57
                                 (185147)      ESCALATION FILENAME:

PROGRAM COST ($ 1000)       DEVELOPMENT    PRODUCTION   TOTAL COST

RECEIVER, 14/11 GHZ, 18EA; SCENARIO V, VI-A & B, KU-BAND FSS
   TOTAL COST                     0.           483.          483.
MUX, INPUT, 12 CHAN, 11GHZ, 36GHZ, 9EA
   TOTAL COST                     0.          3149.         3149.
MATRIX, BEAM SWITCHING, 9X9,12EA
   TOTAL COST                     0.          2400.         2400.
MATRIX, REDUND SWITCH, 5/4, 11 GHZ, COAX, 27 EA
   TOTAL COST                     0.           341.          341.
COMM CONTROL & INTERFACE, 2 EA
   TOTAL COST                     0.           200.          200.
SSPA, 11GHZ, 2W, (+2 VGAS), 135EA
   TOTAL COST                     0.         10615.        10615.
MATRIX, REDUNDANCY SWITCH, 5/4, 11 GHZ WG, (RING), 27EA
   TOTAL COST                     0.           320.          320.
MUX, OUTPUT, 12 CHANNEL, 36MHZ, 9EA
   TOTAL COST                     0.          3308.         3308.
FILTER, HARMONIC, DWG 278423, 9EA
   TOTAL COST                     0.            42.           42.
FILTER, PRESELECT, DWG 278420-03,9EA
   TOTAL COST                     0.            36.           36.
SWITCH, WG, 14 GHZ, DWG 278397-05, 9EA
   TOTAL COST                     0.            74.           74.
SWITCH, XFER, WG, 14 GHZ, 10W, DWG 278396, 4EA
   TOTAL COST                     0.            14.           14.
SWITCH, XFER, COAX, DWG 278399, 4EA
   TOTAL COST                     0.             6.            6.
SWITCH, SPDT, COAX, 11 GHZ, DWG 278395, 9EA
   TOTAL COST                     0.            40.           40.
REFLECTOR, ANT. DUAL GRID, 4.6M, 1EA
   TOTAL COST                     0.          1100.         1100.
FEED NETWORK, VERTICAL & HORIZONTAL, 2EA
   TOTAL COST                     0.          5730.         5730.
I & T SCENARIO V, VI-A & B
   TOTAL COST                     0.          4156.         4156.
```

Table 6.3-11 (Continued)

Cost of Ku-Band FSS Payload for Scenarios V, VI-A and VI-B

```
INPUT FILENAME:  CPPS9M      24-JUL-85 19:57
                                (185147)     ESCALATION FILENAME:

TOTAL COST, WITH INTEGRATION COST

PROGRAM COST ($1000)        DEVELOPMENT    PRODUCTION   TOTAL COST

   ENGINEERING
       DRAFTING                  0.           631.          631.
       DESIGN                    0.          3240.         3240.
       SYSTEMS                   0.                           0.
       PROJ MGMT                 0.          2082.         2082.
       DATA                      0.          1014.         1014.
          SUBTOTAL(ENG)          0.          6967.         6967.

   MANUFACTURING
       PRODUCTION                -          23735.        23735.
       PROTOTYPE                 0.             -             0.
       TOOL - TEST EQ            0.             0.            0.
       PURCH ITEMS               0.          1312.         1312.
          SUBTOTAL(MFG)          0.         25047.        25047.

               TOTAL COST        0.         32014         32014.

COST RANGES                 DEVELOPMENT    PRODUCTION  TOTAL COST

       FROM                      0.         29576.        29576.
       CENTER                    0.         32014.        32014.
       TO                        0.         33873         33873.
```

```
o  SYSTEM WT                  597.15      SYSTEM WS       565.01
o  SYSTEM SERIES MTBF HRS.       716      AV SYSTEM COST  32014
```

Table 6.3-12

Cost Of Ku-band DBS Payload For Scenario II

```
INPUT FILENAME: CPPS6M        18-JUN-85 17:34
                                  (185147)      ESCALATION FILENAME:

PROGRAM COST($ 1000)        DEVELOPMENT       PRODUCTION        TOTAL COST
RCVR, 17/4GHZ, SCENARIO II, KU-BAND DBS   HUNTER  MAY 85
  TOTAL COST                      -              194.              194.
MUX,INPUT, 8 CHAN, 24MHZ, SCEN II, KU-BAND, DBS   HUNTER  MA
  TOTAL COST                      -              688.              688.
MATRIX, BEAM SWITCHING, 2X2, 8 EA
  TOTAL COST                      -              360.              360.
MATRIX, REDUND SW (RING) 5/4, COAX, HUNTER/EDRIDGE   MAY85
  TOTAL COST                      -               91.               91.
DRVR AMP, VARI GAIN/RCVR, SCEN II, KU-BAND DBS,   HUNTER  MA
  TOTAL COST                      -              908.              908.
TWTA, DBS 100W       HUNTER   MAY 85
  TOTAL COST                      -             5200.             5200.
MATRIX, REDUND SW (RING) 5/4, WG, HUNTER/EDRIDGE   MAY85
  TOTAL COST                      -              304.              304.
MUX, OUTPUT, 8 CHAN, 12GHZ, SCEN II, KU-BAND DBS,   HUNTER
  TOTAL COST                      -             1033.             1033.
FILTER, HARMONIC, 11 GHZ, 30W, 278424-02  I-V  LIMBURG  6-04
  TOTAL COST                      -               59.               59.
FILTER, PRESELECT, 11 GHZ, WG, 278419-01, I-V  LIMBURG 6/04/
  TOTAL COST                      -                9.                9.
SWITCH, SPDT, WG, 278397-05  I-V  LIMBURG  6/02/85
  TOTAL COST                      -               16.               16.
SWITCH, XFER, SPDT, WG, 11 GHZ, 10W, 278396-02 I-V LIMBURG 6
  TOTAL COST                      -                4.                4.
SWITCH, XFER, COAX, 278399-02  I-V  LIMBURG  6/05/85
  TOTAL COST                      -                2.                2.
SWITCH, SPDT, COAX, 278395-XX  I-V  LIMBURG  6/05/85
  TOTAL COST                      -                9.                9.
COMM CONTROL & INTERFACE, 2 EA
  TOTAL COST                      -              200.              200.
FEED, ANT, SCEN II, KU-BAND DBS   HUNTER  MAY 85
  TOTAL COST                      -              912.              912.
REFLECTOR, ANT, (1.8 X 1.4M), SCEN II, KU-BAND DBS   HUNTER
  TOTAL COST                      -              125.              125.
I & T, SCENARIO II, KU-BAND DBS   HUNTER  MAY 85
  TOTAL COST                      0.            1147.             1147.
```

Table 6.3-12 (Continued)

Cost Of Ku-band DBS Payload For Scenario II

```
INPUT FILENAME: CPPS6M          18-JUN-85 17:34
                                    (185147)       ESCALATION FILENAME:


 TOTAL COST, WITH INTEGRATION COST
PROGRAM COST($ 1000)        DEVELOPMENT        PRODUCTION        TOTAL COST
   ENGINEERING
      DRAFTING                     0.              251.              251.
      DESIGN                       0.             1231.             1231.
      SYSTEMS                      0.               -                 0.
      PROJ MGMT                    0.              615.              615.
      DATA                         0.              308.              308.
        SUBTOTAL(ENG)              0.             2405.             2405.

   MANUFACTURING
      PRODUCTION                   -              3433.             3433.
      PROTOTYPE                    0.               -                 0.
      TOOL-TEST EQ                 0.               0.                0.
      PURCH ITEMS                  0.             5424.             5424.
        SUBTOTAL(MFG)              0.             8857.             8857.

         TOTAL COST                0.            11262.            11262.

COST RANGES                 DEVELOPMENT        PRODUCTION         TOTAL COST
      FROM                         0.            10871.            10871.
      CENTER                       0.            11262.            11262.
      TO                           0.            11587.            11587.


*****************************************************************************
* SYSTEM  WT                  224.18            SYSTEM  WS           218.74  *
* SYSTEM SERIES MTBF HRS.        790            AV SYSTEM COST       11262   *
*****************************************************************************
```

Table 6.3-13

Cost Of Ku-band DBS Payload For Scenario IV

```
INPUT FILENAME: CPPS8M          16-JUN-85 17:40
                                    (185147)      ESCALATION FILENAME:

PROGRAM COST($ 1000)        DEVELOPMENT       PRODUCTION        TOTAL COST
RCVR, 17/4 GHZ, SCENARIO IV, KU-BAND DBS   HUNTER  MAY 85
  TOTAL COST                      -                282.               282.
MUX, INPUT, 16 CHAN, 4 GHZ, 24MHZ
  TOTAL COST                      -               1706.              1706.
MATRIX, REDUND SW (RING) 5/4, COAX, HUNTER/EDRIDGE   MAY85
  TOTAL COST                      -                217.               217.
UPCONVERTER (+VGAS), 4/12 GHZ, SCEN IV, KU-BAND DBS  HUNTER
  TOTAL COST                      -               1616.              1616.
MATRIX, REDUND SW (RING) 5/4, WG, HUNTER/EDRIDGE   MAY85
  TOTAL COST                      -               1257.              1257.
TWTA, 11GHZ, 200W, SCEN IV, KU-BAND DBS  HUNTER  MAY 85
  TOTAL COST                      -              24000.             24000.
MUX, OUTPUT, 16 CHAN, 24 GHZ, 12GHZ
  TOTAL COST                      -               3945.              3945.
FILTER, HARMONIC, 11 GHZ, 30W, 278424-02  I-V  LIMBURG  6-04
  TOTAL COST                      -                238.               238.
FILTER, PRESELECT, 11 GHZ, WG, 278419-01, I-V  LIMBURG 6/04/
  TOTAL COST                      -                 18.                18.
SWITCH, SPDT, WG, 278397-05  I-V  LIMBURG  6/02/85
  TOTAL COST                      -                 33.                33.
SWITCH, XFER, SPDT, WG, 17 GHZ, 10W
  TOTAL COST                      -                  7.                 7.
SWITCH, XFER, COAX, 278399-02  I-V  LIMBURG  6/05/85
  TOTAL COST                      -                  3.                 3.
SWITCH, SPDT, COAX, 278395-XX  I-V  LIMBURG  6/05/85
  TOTAL COST                      -                 18.                18.
COMM CONTROL & INTERFACE, 2 EA
  TOTAL COST                      -                200.               200.
FEED, TX NETWORK, SCEN IV, KU-BAND DBS   HUNTER  MAY 85
  TOTAL COST                      -                455.               455.
REFL, ANT, TX, 2.5M,    HUNTER  MAY 85
  TOTAL COST                      -                250.               250.
FEED, RX NETWORK, SCEN IV, KU-BAND DBS   HUNTER  MAY 85
  TOTAL COST                      -                877.               877.
REFLECTOR, ANTENNA, RX, 1.9M
  TOTAL COST                      -                200.               200.
I & T, SCENARIO IV, KU-BAND DBS   HUNT  MAY 85
  TOTAL COST                      0.              3167.              3167.
```

Table 6.3-13 (Continued)

Cost Of Ku-band DBS Payload For Scenario IV

```
INPUT FILENAME: CPPS8M        16-JUN-85 17:41
                                  (185147)       ESCALATION FILENAME:


 TOTAL COST, WITH INTEGRATION COST
PROGRAM COST($ 1000)       DEVELOPMENT       PRODUCTION       TOTAL COST
   ENGINEERING
      DRAFTING                    0.             433.             433.
      DESIGN                      0.            2180.            2180.
      SYSTEMS                     0.               -                0.
      PROJ MGMT                   0.            1155.            1155.
      DATA                        0.             570.             570.
        SUBTOTAL(ENG)             0.            4337.            4337.

   MANUFACTURING
      PRODUCTION                  -             9383.            9383.
      PROTOTYPE                   0.               -                0.
      TOOL-TEST EQ                0.               0.               0.
      PURCH ITEMS                 0.           24767.           24767.
        SUBTOTAL(MFG)             0.           34151.           34151.

         TOTAL COST               0.           38488.           38488.

COST RANGES                DEVELOPMENT       PRODUCTION        TOTAL COST
      FROM                        0.           37493.           37493.
      CENTER                      0.           38488.           38488.
      TO                          0.           39281.           39281.


**************************************************************************
* SYSTEM  WT                 995.56           SYSTEM  WS         957.24  *
* SYSTEM SERIES MTBF HRS.       211           AV SYSTEM COST     38488    *
**************************************************************************
```

Table 6.3-14

Cost Of Ka-band FSS Payload For Scenarios II, V, VI-A, And VI-B

```
INPUT FILENAME: CPPS11M         16-JUN-85 17:45
                                    (185147)       ESCALATION FILENAME:

PROGRAM COST($ 1000)       DEVELOPMENT       PRODUCTION        TOTAL COST
RECEIVER, 30/4 GHZ, SCENARIO II, V, & VI-A&B, KA-BAND FSS
  TOTAL COST                     -              747.              747.
MUX, INPUT 5 CHANNEL
  TOTAL COST                     -              396.              396.
MUX, INPUT, 3 CHANNEL
  TOTAL COST                     -              179.              179.
MUX,INPUT, 2 CHANNEL
  TOTAL COST                     -              506.              506.
MUX, INPUT 1 CHANNEL
  TOTAL COST                     -              309.              309.
MATRIX, BEAM SWITCHING, 6X6, 1 EA
  TOTAL COST                     -               75.               75.
MATRIX, BEAM SWITCHING, 7X7, 2 EA
  TOTAL COST                     -              150.              150.
MATRIX, BEAM SWITCHING, 22X22 (DYNAMIC), 1 EA
  TOTAL COST                     -              100.              100.
UPCONVERTER, CHANNEL 1, 4/20 GHZ
  TOTAL COST                     -              215.              215.
UPCONVERTER, CHANNEL 2, 4/20 GHZ
  TOTAL COST                     -              324.              324.
UPCONVERTER, CHANNEL 3, 4/20 GHZ
  TOTAL COST                     -              324.              324.
UPCONVERTER, CHANNEL 4, 4/20 GHZ
  TOTAL COST                     -              324.              324.
UPCONVERTER, CHANNEL 5, 4/20 GHZ
  TOTAL COST                     -              764.              764.
SWITCH MATRIX, 5/4 REDUNDANCY (RING) COAX
  TOTAL COST                     -              140.              140.
SWITCH MATRIX, 7/5 REDUNDANCY (RING) COAX
  TOTAL COST                     -               90.               90.
SWITCH MATRIX, 5/4 REDUNDANCY (RING) W/G
  TOTAL COST                     -              155.              155.
SWITCH MATRIX, 7/5 REDUCNDANCY (RING) W/G
  TOTAL COST                     -               97.               97.
MUX, OUTPUT 5 CHANNEL
  TOTAL COST                     -              334.              334.
MUX, OUTPUT 3 CHANNEL
  TOTAL COST                     -              152.              152.
MUX, OUTPUT 2 CHANNEL
  TOTAL COST                     -              423.              423.
MUX, OUTPUT 1 CHANNEL
  TOTAL COST                     -              259.              259.
HARMONIC FILTER
  TOTAL COST                     -               74.               74.
PRESELECT FILTER
  TOTAL COST                     -               92.               92.
```

Table 6.3-14 (Continued)

Cost Of Ka-band FSS Payload For Scenarios II, V, VI-A, And VI-B

```
INPUT FILENAME: CPPS11M        16-JUN-85 17:45
                                 (185147)        ESCALATION FILENAME:


SPDT SWITCH W/G 30 GHZ
  TOTAL COST                       -              165.               165.
TRANSFER SWITCH W/G 30 GHZ
  TOTAL COST                       -               36.                36.
SPDT SWITCH COAX 4 GHZ
  TOTAL COST                       -               88.                88.
TRANSFER SWITCH COAX 4 GHZ
  TOTAL COST                       -               15.                15.
TWTA 20 GHZ 30W AVE.
  TOTAL COST                       -            11270.             11270.
COMM CONTROL & INTERFACE, 2 EA
  TOTAL COST                       -              200.               200.
I & T, SCENARIO II, V, & VI-A & B, KA-BAND FSS   HUNTER  MAY
  TOTAL COST                       0.            1951.              1951.


INPUT FILENAME: CPPS11M        16-JUN-85 17:45
                                 (185147)        ESCALATION FILENAME:



 TOTAL COST, WITH INTEGRATION COST
PROGRAM COST($ 1000)        DEVELOPMENT       PRODUCTION        TOTAL COST
   ENGINEERING
      DRAFTING                     0.              379.               379.
      DESIGN                       0.             1766.              1766.
      SYSTEMS                      0.               -                  0.
      PROJ MGMT                    0.              888.               888.
      DATA                         0.              448.               448.
        SUBTOTAL(ENG)              0.             3481.              3481.

   MANUFACTURING
      PRODUCTION                   -              4737.              4737.
      PROTOTYPE                    0.               -                  0.
      TOOL-TEST EQ                 0.               0.                 0.
      PURCH ITEMS                  0.            11741.             11741.
        SUBTOTAL(MFG)              0.            16478.             16478.

         TOTAL COST                0.            19958.             19958.

COST RANGES                 DEVELOPMENT       PRODUCTION         TOTAL COS
      FROM                         0.            19404.             19404.
      CENTER                       0.            19958.             19958.
      TO                           0.            20442.             20442.
```

Table 6.3-15

Cost Of Ka-band Scan Payload For Scenarios II, V, VI-A, And VI-B

```
INPUT FILENAME: CPPS12M        18-JUN-85 22:14
                                 (185147)       ESCALATION FILENAME:

PROGRAM COST($ 1000)         DEVELOPMENT        PRODUCTION        TOTAL COST
RCVR, 30/4 GHZ SCENARIO II, V, VI-A&B, KA-BAND SCAN  HUNTER
  TOTAL COST                     -                337.                337.
MUX, INPUT 5 CHANNEL
  TOTAL COST                     -                643.                643.
MUX, INPUT 6 CHANNEL
  TOTAL COST                     -                460.                460.
BASEBAND PROCESSOR, 1EA
  TOTAL COST                     -               7000.               7000.
REDUNDANCY SWITCH MATRIX, 5/4, (RING) COAX
  TOTAL COST                     -                153.                153.
UPCONVERTER (+VGAX)
  TOTAL COST                     -               1026.               1026.
TWTA 20 GHZ 15W & 30W
  TOTAL COST                     -               9200.               9200.
OUTPUT MULTIPLEXER 5 CHANNEL
  TOTAL COST                     -                525.                525.
OUTPUT MULTIPLEXER 6 CHANNEL
  TOTAL COST                     -                839.                839.
REDUNDANCY SWITCH MATRIX, 5/4 (RING) COAX
  TOTAL COST                     -                170.                170.
HARMONIC FILTER
  TOTAL COST                     -                119.                119.
PRESELECT FILTER
  TOTAL COST                     -                 28.                 28.
SPDT SWITCH 30 GHZ W/G
  TOTAL COST                     -                 49.                 49.
TRANSFER SWITCH 30 GHZ W/G
  TOTAL COST                     -                 11.                 11.
TRANSFER SWITCH 4 GHZ COAX
  TOTAL COST                     -                  5.                  5.
SPDT SWITCH 4 GHZ COAX
  TOTAL COST                     -                 26.                 26.
PROGRAMMABLE FREQUENCY SHIFTER
  TOTAL COST                     -                250.                250.
COMM CONTROL & INTERFACE, 2 EA
  TOTAL COST                     -                200.                200.
MATRIX, DYNAMIC SWITCH, 4 GHZ, 20X20, 1 EA
  TOTAL COST                     -                 95.                 95.
ANTENNA REFLECTORS (2 MAIN & 2 SUB), 1.0M
  TOTAL COST                     -               3000.               3000.
ANTENNA FEED NETWORK (1 RX + 1 TX)
  TOTAL COST                     -               3497.               3497.
I & T, SCENARIO II, V, VI-A&B, KA-BAND SCAN   HUNTER  MAY 85
  TOTAL COST                     0.              2485.               2485.
```

Table 6.3-15 (Continued)

Cost Of Ka-band Scan Payload For Scenarios II, V, VI-A, And VI-B

```
INPUT FILENAME: CPPS12M        18-JUN-85 22:14
                                   (185147)        ESCALATION FILENAME:


 TOTAL COST, WITH INTEGRATION COST
PROGRAM COST($ 1000)       DEVELOPMENT        PRODUCTION        TOTAL COST
   ENGINEERING
      DRAFTING                   0.               900.              900.
      DESIGN                     0.              4201.             4201.
      SYSTEMS                    0.                -                  0.
      PROJ MGMT                  0.              1781.             1781.
      DATA                       0.               887.              887.
        SUBTOTAL(ENG)            0.              7768.             7768.

   MANUFACTURING
      PRODUCTION                 -               9910.             9910.
      PROTOTYPE                  0.                -                  0.
      TOOL-TEST EQ               0.                0.                 0.
      PURCH ITEMS                0.             12438.            12438.
        SUBTOTAL(MFG)            0.             22348.            22348.

         TOTAL COST              0.             30116.            30116.

COST RANGES                DEVELOPMENT        PRODUCTION         TOTAL COST
      FROM                       0.             28967.            28967.
      CENTER                     0.             30116.            30116.
      TO                         0.             31145.            31145.


*************************************************************************
* SYSTEM  WT                  1021.49         SYSTEM  WS          973.17  *
* SYSTEM SERIES MTBF HRS.        358          AV SYSTEM COST      30116   *
*************************************************************************
```

Table 6.3-16A

Cost Of 60 GHz ISL Payload For Scenario VI-A

```
INPUT FILENAME: CPPS15M        18-JUN-85 20:55
                                   (185147)      ESCALATION FILENAME:

PROGRAM COST($ 1000)         DEVELOPMENT       PRODUCTION       TOTAL COST
RECEIVER,   SCENARIO VI-A, 60 GHZ, ISL,     HUNTER  MAY 85
  TOTAL COST                      -              351.              351.
DIPLEXER, 60 GHZ, ISL
  TOTAL COST                      -              100.              100.
CPU/PROCESSOR, 60 GHZ, ISL
  TOTAL COST                      -              800.              800.
GIMBALS, 60 GHZ, ISL
  TOTAL COST                      -              360.              360.
DRIVE ELECTRONICS, 60 GHZ, ISL
  TOTAL COST                      -              240.              240.
TRANSMITTER, 5 W, IMPATT, 60 GHZ, ISL
  TOTAL COST                      -             1800.             1800.
ANTENNA ASSY (REFL, SUB-REFL, FEED & SUPPORT), 3.0M, 60 GHZ,
  TOTAL COST                      -              700.              700.
I & T,   SCENARIO VI-A, 60 GHZ, ISL
  TOTAL COST                      0.             782.              782.
```

Table 6.3-16A (Continued)

Cost Of 60 GHz ISL Payload For Scenario VI-A

```
INPUT FILENAME: CPPS15M       18-JUN-85 20:55
                                  (185147)      ESCALATION FILENAME:


 TOTAL COST, WITH INTEGRATION COST
PROGRAM COST($ 1000)        DEVELOPMENT        PRODUCTION        TOTAL COST
   ENGINEERING
      DRAFTING                       0.              289.              289.
      DESIGN                         0.             1362.             1362.
      SYSTEMS                        0.                -                 0.
      PROJ MGMT                      0.              760.              760.
      DATA                           0.              414.              414.
        SUBTOTAL(ENG)                0.             2824.             2824.

   MANUFACTURING
      PRODUCTION                     -              2082.             2082.
      PROTOTYPE                      0.                -                 0.
      TOOL-TEST EQ                   0.              226.              226.
      PURCH ITEMS                    0.                0.                0.
        SUBTOTAL(MFG)                0.             2308.             2308.

         TOTAL COST                  0.             5132.             5132.

COST RANGES                 DEVELOPMENT        PRODUCTION         TOTAL COST
      FROM                           0.             4821.             4821.
      CENTER                         0.             5132.             5132.
      TO                             0.             5394.             5394.


***************************************************************************
* SYSTEM  WT                   122.40          SYSTEM  WS            118.60
* SYSTEM SERIES MTBF HRS.       6824           AV SYSTEM COST         5132
***************************************************************************
```

Table 6.3-16B

Cost Of 60 GHz ISL Payload For Scenario VI-B

```
INPUT FILENAME: CPPS16M         18-JUN-85 21:19
                                    (185147)       ESCALATION FILENAME:

PROGRAM COST($ 1000)        DEVELOPMENT        PRODUCTION          TOTAL COST
RECEIVER,    SCENARIO VI-B, 60 GHZ, ISL,    HUNTER  MAY 85
  TOTAL COST                     -               297.                297.
DIPLEXER, 60 GHZ, ISL
  TOTAL COST                     -               100.                100.
CPU/PROCESSOR, 60 GHZ, ISL
  TOTAL COST                     -               800.                800.
GIMBALS, 60 GHZ, ISL
  TOTAL COST                     -               360.                360.
DRIVE ELECTRONICS, 60 GHZ, ISL
  TOTAL COST                     -               240.                240.
TRANSMITTER, 5 W, IMPATT, 60 GHZ, ISL
  TOTAL COST                     -              1200.               1200.
ANTENNA ASSY (REFL, SUB-REFL, FEED & SUPPORT), 3.0M, 60 GHZ,
  TOTAL COST                     -               700.                700.
I & T,   SCENARIO VI-B, 60 GHZ, ISL
  TOTAL COST                     0.              600.                600.
```

Table 6.3-16B (Continued)

Cost Of 60 GHz ISL Payload For Scenario VI-B

```
INPUT FILENAME: CPPS16M        18-JUN-85 21:19
                                   (185147)       ESCALATION FILENAME:


 TOTAL COST, WITH INTEGRATION COST
PROGRAM COST($ 1000)          DEVELOPMENT        PRODUCTION        TOTAL COST
   ENGINEERING
      DRAFTING                         0.              261.              261.
      DESIGN                           0.             1226.             1226.
      SYSTEMS                          0.                -                0.
      PROJ MGMT                        0.              670.              670.
      DATA                             0.              368.              368.
        SUBTOTAL(ENG)                  0.             2526.             2526.

   MANUFACTURING
      PRODUCTION                       -              1601.             1601.
      PROTOTYPE                        0.                -                0.
      TOOL-TEST EQ                     0.              170.              170.
      PURCH ITEMS                      0.                0.               0.
        SUBTOTAL(MFG)                  0.             1771.             1771.

         TOTAL COST                    0.             4297.             4297.

COST RANGES                   DEVELOPMENT        PRODUCTION         TOTAL COST
      FROM                             0.             4058.             4058.
      CENTER                           0.             4297.             4297.
      TO                               0.             4501.             4501.


*****************************************************************************
* SYSTEM  WT                     116.40          SYSTEM  WS          113.20
* SYSTEM SERIES MTBF HRS.         6891           AV SYSTEM COST       4297
*****************************************************************************
```

6.4 SCENARIO PAYLOAD COST

The payload costs associated with each of the five payload configuration scenarios is summarized in Table 6.4-1. It is also to be noted that the costs are for "recurring" units and do not include pro-rata share of development costs.

The costs of each of the payload subsystems is shown to range from $2.4 million for a C/L-band maritime package for use in scenario VI-B up to $38.5 million for a Ku-band DBS package for use in scenario IV.

6.5 SCENARIO PLATFORM COST

The total platform and launch costs associated with each of the five payload configuration scenarios is summarized in Table 6.5-1. The recurring cost for each payload scenario, expressed in 1984 dollars, is expected to range from $67 million for scenario IV up to $132 million for scenario VI-B.

After including estimates for the platform bus and launch costs the total is raised to $250 million for a scenario IV platform on-orbit and to $372 million for a scenario VI-B platform on-orbit.

Table 6.4-1

Projected Costs of Payload Elements ($M)

Payload Element	Incorporated in Following Scenarios				
	II	IV	V	VI-A	VI-B
C-Band, FSS	4.5				
C-Band, FSS			7.9	7.8	
C/L-Band Maritime (Atlantic)				3.4	
C/L-Band Maritime (Pacific)					2.4
C-Band, Internat'l				27.8	
C-Band, Non-U.S.					27.1
Ku-Band, Non-U.S.					15.7
Ku-Band, FSS	15.2				
Ku-Band, FSS		28.7			
Ku-Band, FSS			32.0	32.0	32.0
Ku-Band, DBS	11.3				
Ku-Band, DBS		38.5			
Ka-Band, FSS	20.0		20.0	20.0	20.0
Ka-Band, SCAN	30.1		30.1	30.1	30.1
60 GHz, ISL				5.1	4.3
TOTAL	81.1	67.2	90.0	126.2	131.6

SECTION INDEX

7.0 CRITICAL TECHNOLOGY (TASK 6)

7.1 OVERVIEW

The purpose of Task 6 - Critical technology is to identify both the enabling and supporting technologies critical to the eventual implementation and operation of each of the payload scenarios. Items of large economic uncertainty as well as great technical risk are highlighted. Primary inputs to this task were based on Ford Aerospace experience gained from participation in:

- Technology demonstration programs leading up to the NASA ACTS Program
- Milstar technology requirements definition programs

Details of the antenna technology are presented in section 7.2, the RF transponder technology in 7.3, the on-board processing technology in 7.4, the payload on-orbit servicing technology in 7.5, and frequency reuse technology issues in 7.7.

A summary of key technology developments which are recommended to support a successful implementation of a 1990's era space communications platform is shown in Table 7.1-1. Additional detail in presented in section 7.8.

7.2 ANTENNA TECHNOLOGY

7.2.1 Background

Communication satellite antenna technology will undergo a significant advancement by the year 1998. This progress will be due to enormous pressures imposed by the burgeoning growth in the demands placed upon existing services and from a host of new services that will become available.

Table 7.1-1

Key Technology Drivers

- Baseband Processing
  - High efficiency demod/modulators
  - A to D format conversion
  - High speed programmable frequency source
  - Scanning and processing algorithms.
- Antennas
  - Dynamic beam
  - Polarization tracking at Ka-Band for H and V re-use.
  - Dual polarizer for receive and transmit bands
- Transponder
  - High power Ku and Ka-Band SSPA's
  - High speed switching at 11 and 20 GHz
  - Dielectric resonator filters and oscillators
- Intersatellite Links
  - Optical
  - RF
- Support Technology
  - Materials technology
  - MMIC and VLSI development
  - Device development: GaAs, CMOS-SOS, etc.
  - Radiation hardening development
- Transportation and Space Station Support
  - Deployment
  - Assembly
  - Alignment
  - Servicing
  - Check-out at LEO
  - Transportation to GEO

The increase in communications satellite traffic will place ever-increasing burdens on the scarce orbital arc and frequency spectrum resources. These must be used more efficiently by continuing the great strides in the advancement of antenna technology that have made today's systems possible and also to make use of frequency bands that are not yet fully exploited. Some capacity increase is still possible in the crowded 6/4 GHz bands, but the most significant future increases will be in the 14/11 GHz and 30/20 GHz bands as well as in the 44 GHz band. In 1983 the FCC approved a U. S. Domestic DBS uplink band of 17.3 to 17.8 GHz and a downlink band of 12.2 to 12.7 GHz. Many new services will employ frequencies that may be as low as the HF range and as high as S-band. Other frequencies that are not used by satellites either have not been allocated or represent bands that are already in use for terrestrial services. Eventually, these bands may also come into use for special satellite services.

The geostationary platform offers a solution that will alleviate the problems of orbital arc congestion and saturation of the available frequency spectrum by making it possible to place many high-performance antennas operating over several frequency bands at a single orbital location. Onboard signal processing will allow interconnections between all frequency bands. Several such platforms would be interconnected through intersatellite links. Severe pressure will be placed upon the antenna designs to make the maximum use of these platforms.

7.2.2 Limitations Imposed on Communications Satellite Antennas

Before the specific advancements in communications antenna technology can be predicted, it is necessary to consider their limitations. The performance capabilities of current communications satellite antennas are restricted by both inherent and external factors. The inherent factors have to do with physical limitations and restrictions that are dictated by the current technology. For a given size and configuration, gain is limited by the physical capture area of the aperture, by losses within the feed system, and by dimensional deviations. Likewise, polarization and sidelobe isolation levels are dependent upon available feeds and polarizers and on antenna dimensional stability. In the case of shaped-beam and multibeam antennas, performance is also limited by the size and degree of complexity that can be tolerated for specific cases. Except for those inherent limitations that depend upon the laws of physics, improvements in antenna technology should raise the threshold of limitations over the next several years.

External antenna-related factors that limit the performance of satellite antennas include the regulatory constraints upon frequency bandwidths, the nonuniform distribution of traffic over the terrestrial coverage region, and cross-polarization isolation degradation due to rain and other atmospheric effects. In terms of aperture size, the antenna is squeezed in opposite directions by external forces. Factors that tend to increase antenna size include satellite transmit power limitations and constraints on ground equipment such as antenna diameter, receiver noise temperature, and transmit power. The key factors constraining the maximum size of spacecraft antennas have been the limited available space within the launch vehicle and the unwillingness of satellite designers to use what has been perceived to be an immature unfurlable antenna technology.

The performance of space antennas is also limited by beam-pointing errors due to spacecraft instabilities and alignment uncertainties caused by structural/thermal support structure movements and tolerances. These pointing uncertainties cause the defined coverage areas to be enlarged, thereby lowering the achievable gain over the coverage region.

Future satellite antenna systems will also be required to limit interference outside of the desired coverage region in a manner similar to the recommendations of the WARC-77 for the 12 GHz band. The interference limitation will demand low sidelobes, low cross-polarization levels, and sharp beam rolloffs, not only in the coverage area of interest but everywhere on the earth. This problem has been exacerbated by the 1983 FCC ruling that fixed-service communications satellites in geosynchronous orbit may be spaced every 2° along the orbital arc instead of the previous 4°. These requirements will tend toward less efficient antennas and will thus require larger apertures.

7.2.3 Communication Satellite Antenna Technology in 1998.

The state of antenna technology in 1998, is predicted to evolve through three general categories of development:

- Further refinements in existing technology
- Maturation of current experimental work
- New antenna concepts

The first category will result from many modest improvements in antennas and their associated components, as well as from the development of more powerful analytical techniques. The net result from these improvements will be such features as higher antenna gain, better interference characteristics, increased frequency reuse, more flexible in-orbit reconfigurability, and higher levels of reliability.

The second category includes those technologies that are of great interest today, but for the most part are still in the experimental stage with regard to space applications. Those will include the marriage of antennas, microprocessors, active components, monolithic microwave integrated circuits (MMICs), and IF beam forming.

The third category of antenna technology development is more difficult to predict since it includes ideas that either have not yet been conceived or have not been advanced in the literature.

7.2.3.1 Further Refinements in Existing Technology

In order to predict future improvements in communication satellite technology, it is useful to describe the basic classes of antennas that are currently in service. The major types of antennas, more or less in their order of ascending complexity, are briefly discussed in the following paragraphs.

a. Global Coverage Antennas. Global coverage antennas provide radiation over the entire surface of the earth visible from synchronous orbit with as much gain as possible. A slight amount of beam shaping is often used to maximize the edge-of-coverage (EOC) gain, and orthogonal polarizations can be used for two-times frequency reuse.

b. Spot Beam Antennas. Spot beam antennas provide circular or elliptical coverage beams over limited regions on the earth and are sometimes gimballed to make possible limited mechanical scanning. High-efficiency feeds are usually used to maximize gain and sidelobe performance. Frequency reuse is made possible through the use of orthogonal polarizations. Often the same antenna is used for both transmit and receive functions.

c. Shaped Beam Antennas. Shaped beam antennas are designed to concentrate as much energy as possible over carefully specified coverage areas and as little as possible everywhere else. Coverage areas can be as small as certain regions within a single country or as large as the area encompassed by the major population centers within an entire hemisphere. A single shaped beam antenna may produce one or several independent shaped beams for each orthogonal polarization, all being connected to different transponders. The more advanced shaped beam antennas are reconfigurable in orbit in order to select the correct set of coverages for each of several possible satellite orbital positions. It also may be desirable to change coverage patterns to adjust to variations in communications traffic.

Key to the success of multiple shaped-beam coverage for a particular beam is the achievement of very low levels of cross-polarized energy and sidelobes outside of the specified coverage region in order to avoid deleterious interference with and from other beams.

The most common antenna that is used for shaped-beam antennas is a large (6 to 10 ft) offset reflector fed by arrays of feed horns. Beam shaping is achieved by beam-forming networks (BFNs) that provide the appropriate phase and amplitude coefficients to the feed array elements. In the case of circularly polarized antennas, a single reflector is used for both RHCP and LHCP and separate BFNs form the proper coefficients for each polarization. Separate antennas are used for transmit and receive, and high-quality polarizers provide low axial ratios to ensure low levels of cross-polarization.

Linearly polarized shaped beam antennas are in common use in the 14/11 GHz frequency bands. Separate antenna systems are used for the two polarizations, horizontal and vertical, and grids of parallel wires are embedded on the surfaces of the reflectors to act as polarization purifiers. Because of limited room on the spacecraft, the horizontal and vertical gridded reflectors often overlap. Transmit and receive coverage is provided by the same reflector.

Multibeam antennas that are reconfigurable currently employ two methods to change beam shapes. The first uses a stack of fixed power dividing networks and multiple switches to select the appropriate combinations for different orbital positions. The second method employs variable power dividers (VPDs) and variable phase shifters (VPSs) to reconfigure the beams upon ground command.

d. Multiple Scanning Beam Antennas. Multiple scanning beam antennas produce many narrow spot beams that can be electronically scanned anywhere over the coverage region. The dwell time of a spot beam at each location is made proportional to the demand for service from that location. The antenna includes a switching matrix that provides rapid interconnections between any satellite beam and any transponder.

Refinements in existing technology for the types of antennas previously described that will result in improved technology for 1998 are discussed in the following paragraphs.

(1) Larger Antenna Reflectors. The development of large antenna technology will be the key to the accommodation of increased communications satellite traffic by the year 1998. Current antenna systems are often limited in size and are relatively complex due to present launch vehicle packaging constraints. The size restriction and complexity have resulted in fundamental performance and reliability limitations of satellite antennas. By 1998, antenna farms utilizing deployed, unfurled, and space-erected antennas will be possible. This development will dramatically alter antenna designs and will

enable favorable tradeoffs to be made between antenna size and complexity. The result will be simpler antennas with improved electrical characteristics and reliability.

Antennas that are deployed are likely to see continued use, especially at the higher frequency ranges where modest aperture sizes are adequate. What is meant by deployed antennas are those that are of solid construction but are stowed for launch and have main reflectors, subreflectors, and/or feed systems that are repositioned in-orbit by hinging or some other mechanical mechanism. These antennas will be of the same composite materials construction that is currently in use. However, fabrication techniques must be improved in order to produce a reflector surface roughness suitable for 30 dB sidelobes, high gain, and low cross-polarization levels in the frequency range above 30 GHz. The antenna alignments achieved after deployment must also receive attention so that antenna beams with widths of a few tenths of a degree can be accurately pointed at their targets.

To date, the largest solid reflector that has been placed in space has a diameter of 12 feet. Reflectors that must significantly exceed that size will be unfurlable. Communications antennas operating in the standard frequency bands might require reflector diameters in the range of 15 to 30 ft.

However, large multiple-beam antenna missions envisioned for the 1990s have diameters up to 4600 ft for applications in the 15 MHz to 2000 MHz frequency range.

For example, a proposed system that will require large satellite antennas is the Land Mobile Satellite System (LMSS). This will be a direct user-to-user system where users constantly move about. Therefore the user antenna must be small and inexpensive, forcing the satellite antenna to be large and complex. One scenario for this system uses a 180 ft frequency-reuse multiple-beam satellite antenna operating in the UHF band.

Several types of large unfurlable antenna concepts are in various stages of development. These include wrap-rib, hoop/column, geotruss, box truss, inflatable, and electrostatically figured membrane designs. These antennas employ surfaces that are mesh, membrane, solid, and segments. They could be packaged for launch and then be unfurled or assembled in space. It will be possible to design these antennas for zero gravity and thereby significantly reduce weight. By 1998, it is likely that only a few of the concepts under study will emerge as those offering the best solutions to the problem of designing large space antennas.

The largest unfurled reflector that has been used in space is a wrapped rib design with a diameter of 30 ft. Experience has shown that achieving the high-precision surface accuracies that are needed for high antenna performance is very difficult, and considerable development work remains to be done. Most of the demonstrated techniques for deploying large reflectors have a discrete number of control points for shaping the surface, which causes distortions from true parabolical shape and thereby degrades gain, sidelobes, and cross-polarization levels. It is probably safe to predict that by 1998, the more serious problems will have been overcome, making large, high-performance antenna systems a reality for frequency bands below Ku-band..

(2) Improved Components. Better performance will be available from satellite antennas as a result of improved components, including beam-forming networks, feed elements, polarizers, diplexers, and gridded reflectors.

- Fixed Beam-Forming Networks. Improvements will be made in beam-forming networks that will make possible better beam shaping with less RF loss, less weight, smaller size, and greater reliability. Low-loss printed circuit techniques will probably continue to be favored.

- Variable Beam-Forming Networks. The key to variable beam-forming networks is the use of ferrite variable power dividers (VPDs) and variable phase shifters (VPSs), as well as low-loss switches. These components will be improved to provide lower loss, smaller size, less weight, lower temperature sensitivities, more accurate control of amplitude and phase characteristics, and less power consumption over larger bandwidths.

- Feed Elements. Feed element improvements will probably focus on the further development of broadband multimode horns and microstrip patch radiators.

- Polarizers. Polarizer improvements will be needed to produce low axial ratios over broad bandwidths, and new concepts will be developed for the very high and very low frequency bands.

- Diplexers. Diplexers must be developed for new frequency bands with the emphasis on high rejection and low loss.

- Gridded Reflectors. More dimensionally stable gridded reflectors are needed in order to achieve high levels of isolation for linearly polarized frequency-reuse antennas.

(3) Reflector Antenna Systems. Improvement in reflector antenna systems will provide better flexibility and higher capacities for communications satellite systems. These improvements will result from refined components and more accurate analytical tools. Broadband multiple beam antennas

operating with up to 1 GHz of bandwidth will be available. The off-axis performance of dual-reflector antennas will be considerably improved by specially shaping both reflectors to minimize phase errors. The feasibility of this technique has been demonstrated on a NASA-sponsored contract with Ford Aerospace, but much work remains to convert the experimental antenna design into one that is flight worthy.

Reconfigurable beam antennas with coverage contours that are adjustable in-orbit will have higher gains and improved inter-beam isolation due to better components and superior design techniques. It will be possible to reconfigure beam coverages in orbit to provide communications under a variety of coverage scenarios.

Improvements will be made in electronic beam scanning capabilities in order to meet the requirements for global coverage with high EIRP beams for low-cost, small-diameter-antenna ground terminals. Multiple, rapidly scanned, narrow beams will be provided for widely scattered users.

Antenna systems will also need to handle higher power levels for DBS and for other communications systems that include small user antennas.

(4) <u>RF Sensing and Pointing</u>. RF sensing and pointing will become increasingly important as the antenna beamwidths get narrower and antenna performance becomes more critical. Attitude errors in the platform and thermal distortions in structures can cause significant antenna pointing errors, particularly for users near the edges of beam coverage. The current spacecraft pointing accuracies are about ±0.1°. Narrow beams, with beamwidths around 0.1°, will come into use by 1998, particularly for satellite-switched time-division multiple access (SS-TDMA) systems.

Thus it is important for all types of communications antennas to point their beams with great accuracy. One method by which this can be achieved is to use each antenna as a sensor to steer its own radiation pattern and continuously correct any pointing errors. By this means, it will be possible to use the antennas themselves in either a monopulse or step-track mode of operation to actively track one or more ground-based beacons.

There are, however, problems to be overcome in order to employ this technique. First, the antenna configuration must be such that the sensing signal that is obtained through the receiving mode will track with the transmitted beam, which may use a different antenna. A second problem is that of implementing RF sensing in shaped-beam antennas. Possible autotrack implementation schemes might include separately gimballing each antenna, movable feed systems, movable reflectors, and electronic scanning.

(5) Array Antenna Improvements. Array antennas will also undergo significant advancements over the next 15 years. In some applications, there may be performance benefits to be gained by using a phased array directly rather than as a feed system. In principle, phased arrays can precisely produce the desired phase and amplitude excitation of each element to achieve any physically realizable tradeoff between gain and sidelobe levels and can also produce rapid, inertialess scanning. Arrays can form fixed, low-sidelobe beams or multiple beams, and their theory is well developed.

A problem that has limited the use of large phased arrays is that enormous numbers of feeds and dissipative components are needed. To produce adequate performance without the use of large numbers of array elements, research has been performed with arrays that comprise a relatively small number of large radiating elements.

Another attractive array development is the development of printed circuit antennas, whereby the entire antenna system is implemented with a few layers of circuit boards and stripline or microstrip radiating elements. Stripline elements can be developed with bandwidths up to an octave, but microstrip elements are relatively narrow band. Printed-circuit techniques are attractive for low frequency arrays, where conventional array elements would be large, and at high frequencies, where hundreds or even thousands of elements could be needed.

(6) Lens Antenna Improvements. Lens antennas have been studied for several decades, but, with the exception of the waveguide type, the technology for satellite communications antennas is immature. Lenses are attractive, however, because of their exemplary scan characteristics, which can produce well-shaped beams at large scan angles. The major limitations of lenses have been their complexity and weight. As frequencies of application become higher and space-erectable antennas become possible, lenses are more likely to find their way into space.

Although solid dielectric lenses are heavy for conventional communications frequency bands, interest in higher frequencies has made them attractive candidates for use in high performance antennas. For frequency bands above Ku-band, the weight penalty associated with dielectric lens antennas is relatively small. They are also inexpensive and reliable, and recent advances in the development of low-loss materials make their future use certain.

(7) Multifeed Antennas. Single antennas operating at several frequency bands have been employed by using such techniques as frequency selective surfaces (FSSs) and multifrequency feeds. For example, the ATS F&G antenna reflector operated at VHF, UHF, L-band, S-band, and C-band frequencies. The CS antenna produced shaped beams from a single reflector at both the 6/4 GHz and 30/20 GHz bands.

Multifeed antennas are expected to be used in the future because of the benefits of multifrequency coverage from a single aperture. A concept that appears to have merit for future applications is a dual-reflector system with four subreflectors, one for each operating frequency band. The subreflectors overlap, each being made up of frequency sensitive elements, except for the one in the back, which is solid. Each of the three front subreflectors is reflecting at its own frequency and is transparent to the other three frequencies. The subreflectors are positioned so as to allow for feed separation in the focal region for the four feeds. This scheme requires sufficient separation between the bands for the FSS to operate properly, such as combined use of L, C, X, and K bands.

(8) Mechanical and Materials Improvements. Improvements in antenna mechanical and materials design will be required for the stable construction of large antenna systems. The effects of different antenna locations, active and passive thermal control systems, and basic materials technology must be further developed for 1998 antenna systems.

(9) Reduction in RF Interference. A large structure that includes many antennas of various types and sizes and operates over a large range of frequencies could cause deleterious RF interference and scattering that would reduce the achievable isolation between beams. These effects need to be evaluated analytically during the antenna design phase in order to achieve the required 30-40 dB isolation in orbit. The analytical consideration of proximity interference must be part of the mechanical and structural design of the antenna farm configuration.

(10) Improved Analysis Programs. The sophistication of today's satellite antenna technology was made possible by the development of excellent computer analysis programs. These programs and the models they employ must be vastly improved so

that future antenna systems, which will be too large to test and develop on the ground, can be assembled in space with full confidence that they will perform as predicted. The complex radiation patterns, low sidelobes, and low cross-polarization levels needed must be achievable in the antenna farm environment.

(11) <u>Space Measurement Techniques</u>. Testing and characterizing large antennas in space will require the development of new measurement techniques.

7.2.3.2 Maturation of Current Experimental Work

The second category of communications antenna advancements will come from technology that is currently in the experimental stage but will be mature by 1998. The areas of special interest include antennas combined with solid-state devices and MMICs to form active antennas and the incorporation of microprocessors to form adaptive antennas. Antennas with electronically controllable radiation characteristics will produce steerable beams, multiple beams, shaped beams, and adaptive radiation characteristics.

(1) <u>Active Transmitting Antennas</u>. A method of obtaining high downlink effective radiated power that appears attractive for future applications is to incorporate solid-state microwave power sources at each antenna array element. The arrays can be used as either large aperture direct radiators or as feeds for reflectors or lenses. These active transmitting antennas will produce higher output power levels than can be generated by the single devices now in use and will also eliminate the effects of associated power-dividing networks.

The active array combines miniature GaAs FET or beryllium low-power amplifiers that are preceded by diode phase shifters on MMIC substrates using batch process techniques. These solid-state amplifiers and phase shifters are assembled as individual modules with one pair per feed element. The modules provide variable phase and variable power amplification for each of two orthogonally polarized beams. The variable phase shifters are digital and can have 5 or more bits of resolution for dynamic phase control. The variable power amplification function is used for dynamic amplitude control.

The use of MMIC modules will allow for fast beam switching (10-100 nanoseconds) for TDMA systems and will make phased arrays practical for communication satellite applications. They also provide the benefit of significant reductions in weight, size, and costs. One of the key challenges will be to produce large numbers of amplifiers with closely matched and stable amplitude and phase characteristics.

Another application of amplifiers will be to combine them with conventional beam-forming networks. Reconfigurable beam-forming networks that contain several layers of variable power dividers or a switching matrix suffer from high RF losses. This loss can be overcome by including a power amplifier at the terminals of each BFN port.

(2) Active Receive Antennas. A multiple-beam receive antenna could include low-noise amplifiers at the terminal of each array feed element to overcome the effect of BFN and switch matrix loss.

Another approach is under development for multiple scanning beams, where rapid connections must be made between any satellite transponder and any antenna beam. The conventional approach to this problem is to employ a complex RF switching tree, which can have significant insertion loss before the noise figure has been established in the receiver front ends. Also, many of these switching structures impose constraints on the possible combinations of beams that can be simultaneously selected. The alternate approach is to connect a separate receiver front end to each feed where the signal is mixed to an intermediate frequency (IF). Beam selection is made after the noise figure has been established. All of the various methods of scanning are then possible, including beam switching, and can be carried out at IF where amplification is readily available and lumped constant circuits may be used.

In addition, the flexibility of the IF switch matrix places no limits on the combinations of beams that may be simultaneously selected and also permits the addition of beams if phase coherence is maintained in the receiver. This will allow for beam positions intermediate to the discrete contiguous beams. Equivalent techniques of mixing are possible for transmit antenna applications.

(3) Adaptive Antennas. Adaptive antennas use microprocessors to control the radiation characteristics of the antenna and to produce some predetermined coverage performance during changing conditions. Although adaptive antennas are usually thought of in their military application of nulling out interfering signals, they are certain to see widespread use over the next 15 years in the field of satellite communications. The primary application will be to maximize signal strength and minimize interference. Antenna patterns can be adaptively modified to accomplish the following.

- o Change coverage patterns to accommodate variations in communications traffic.
- o Change feed coefficients between adjacent multiple beams to reduce interference between them that varies with time.
- o Change EIRP footprints to reduce the effects of rain fading and other atmospheric degradations.
- o Compensate for spacecraft instabilities by slightly varying pattern shapes.
- o Produce pattern minimums toward terrestrial interfering sources.
- o Compensate for thermally or dynamically introduced antenna shape changes.

As an example of adaptive antenna control, consider the problem of providing adequate coverage during localized rain fading. Currently for shaped-beam coverage at higher frequencies, a significant power margin must be incorporated in communication satellites to prevent excessive outages due to rain fades. This margin could be reduced if the coverage beams were adaptively controlled to temporarily provide higher antenna gains to the small regions that are suffering from rain attenuation. This power would come from the larger portion of the coverage region where conditions are clear. Relative signal strengths to each ground station would be monitored and the information transmitted to the onboard microprocessor that would appropriately adjust the phase and amplitude coefficients of the antenna via a reconfigurable BFN to reshape the gain contours.

(4) Intersatellite Links. By 1998, it is likely that there will be a number of space platforms, each with its own antenna farm. To add to the total communications network flexibility, these platforms will be interconnected in space by intersatellite links. The interconnections will

be through tracking antennas that will probably operate at frequencies not suitable for ground-to-space communications because of high atmospheric attenuation, such as 60 GHz or optical laser links.

7.2.3.3 New Antenna Concepts

The antenna technology of 1998 is not possible to foresee because most of the ideas have not yet been conceived or, if they have been, are not widespread knowledge. One idea that has been advanced in the literature is the use of CO_2 laser communication systems that would link satellites in synchronous orbit to each other and to low-orbiting satellites. Another idea that may produce results is the combination of antennas and fiber optics within the space platforms. Also, it is likely that many new combinations of active devices and microprocessors will enable antennas to become more and more closely associated with the signal processing portions of the satellite.

7.2.4 Summary of Antenna Technology

The critical technical and cost saving technologies for future space communication platform antenna system are expected to include:

- MMIC Technology. Large phased arrays capable of rapid scanning will require MMIC technology to be cost effective and technically feasible.

- Wide Angle Scanning. Electronic scanning is required for TDMA scanning beam systems. However, the problem is to be able to use one antenna to scan a large area. In the limit, earth scanning of ± 10° from GEO is required. For a scanning beam size of 0.3° this is ± 30 beamwidths. Ford Aerospace has achieved ± 14 beamwidths scanning with less than 1 dB scan loss in the 20 GHz POC Antenna for NASA/LeRC. However, requirements for increased scanning will require a novel approach to the problem.

- <u>High-Speed Processor Technology.</u> Control of possibly tens of thousands of elements in microseconds will require great advances in computation speed and memory access time.

The integration of a 1990's technology spacecraft antenna with other payload equipment items is shown in Figure 7.2-1. Much of the electronics may be combined within a relatively few physical packages.

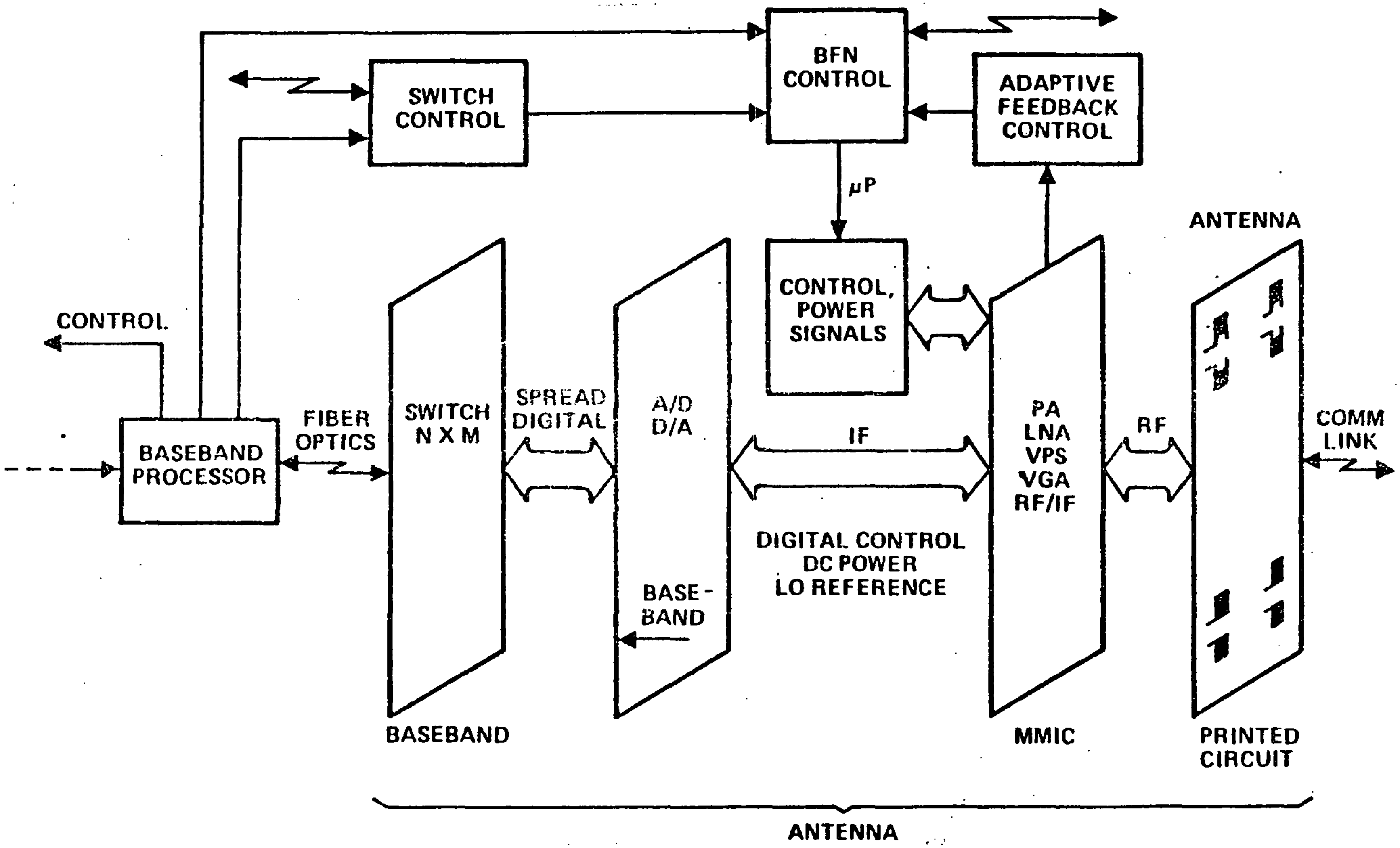
The risks associated with various antenna applications is given in Table 7.2-1.

Table 7.2-1

Risk Associated With Various Antenna Applications

Application	Considerations	Risks
C-Band	Solid Reflector, BFN	Low
Ku-Band	Solid Reflector, BFN	Low
Ka-Band, FSS	Active Switching, BFN	Moderate
Ka-Band, CPS	Scanning, MBA	Moderate-High
Maritime	Helical	Low
Mobile	Large Reflector, Many Beams	Moderate
ISL	Pointing, Acquisition	Moderate
DBS	Reflector, BFN	Low

Figure 7.2-1 Integration Of 1993 Technology Antenna With Other Payload Elements



Ford Aerospace &
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An estimate of the current and future limitations on spacecraft antenna reflector size is shown in Table 7.2-2.

Table 7.2-2

Spacecraft Reflector Size Limitations (ft.)

	Application	Current	1985	1993
C-Band	Solid	15	-	-
	Flex	30	40	75
Ku-Band	Solid	15	-	-
	Flex	15	20	30
Ka-Band	Solid	15	-	-
	Flex	-	-	20
UHF	Solid	15	-	-
	Flex	100	200	300

Note: Solid Reflector Limited by Shuttle.
- C-Band appx. 1.25° (15 ft STS diameter)
- Ku-Band appx. 0.45° (15 ft STS diameter)
- Ka-Band appx. 0.30° (Overall Pointing Constraint)

7.3 RF TRANSPONDER TECHNOLOGY

7.3.1 Background

The technology base for transponder implementation in the year 2000 must be directed to high performance and long term reliability. A relatively small quantity of the spacecraft units is required and hence cost may be assigned a lower priority in elevation assessment.

The key technology developments to support space platform communications are projected as follows:

- Improved TWT efficiency and extended life
- Development of higher power SSPA's at Ku- and Ka-bands
- Development of dielectric resonator materials for use in filters and oscillators
- Continued application of GaAs MMIC technology
- Improvement in receiver noise figure
- Development of optical interconnects between components

7.3.2 Power Amplifier

TWTA Technology The projected power output from TWT amplifiers for various frequency bands is given in Table 7.3-1. It should be noted that current amplifiers in the C and Ku-bands are already high enough power output given the ground flux density limitations for CONUS coverage. The TWTA efficiency is expected to increase with time as shown in Figure 7.3-1. It is predicted that the efficiency of Ka-band TWTA's will reach 50% by the year 2000.

Table 7.3-1

TWTA Output Power For Selected Frequency Bands

Frequency (GHz)	Present - 1985	1985 - 1990	1990 - 1995
2 (Maritime)	150 W	300 W	400 - 600 W
12 (DBS)	200 W	260 W	300 - 500 W
20	4*, 5/50 W	100 W	200 - 400 W
30	3*, 20 W	100 W	150 - 250 W
60	5**, 10 W	20 W	80 - 200 W

* Slow-wave Helix

** Coupled Cavity

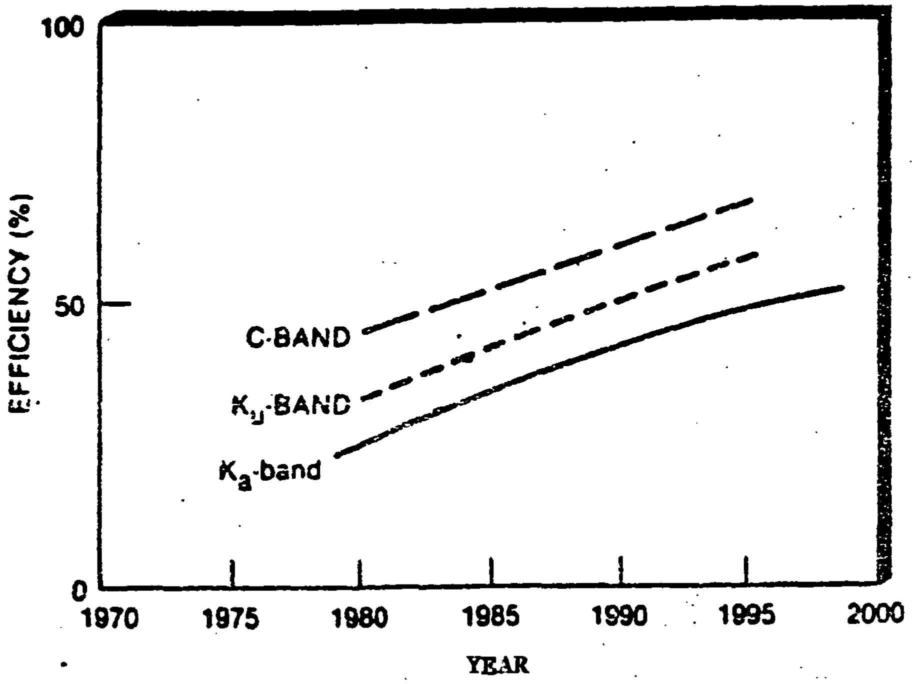


Figure 7.3-1 TWTA Efficiency Predictions

The TWTA on-orbit operating lifetime is of key economic concern in determining sparing and replenishment strategies. As shown in Figure 7.3-2, the most probable lifetime is about 10 years in year 2000 using M type dispenser cathodes. A lifetime of 20 years is projected for field emission cathodes. However, the associated risk associated with achieving that life is very high.

Solid State Amplifiers The projection of output power capability for impatt diode amplifier technology is shown in Figure 7.3-3. Power levels of 10 watts per device are expected at 20 GHz frequency for 1990 implementation. The projected output power for GaAs FET devices is shown in Figure 7.3-4. In the 10 to 20 GHz frequency range the output power per device is expected to roughly double in the eight years from 1985 to 1993.

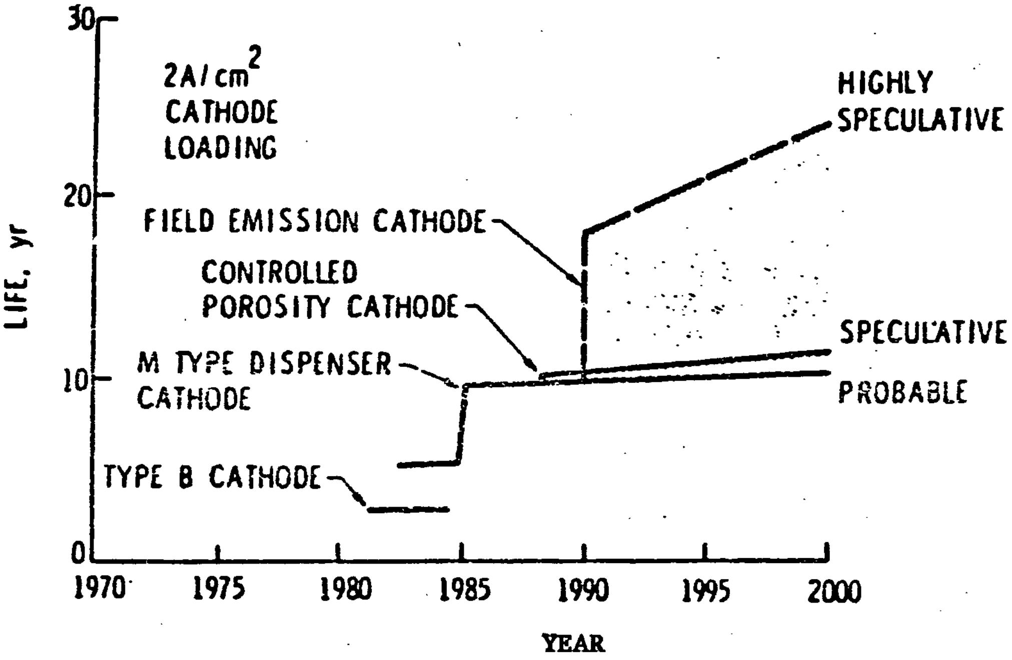


Figure 7.3-2 TWTA Life Projections

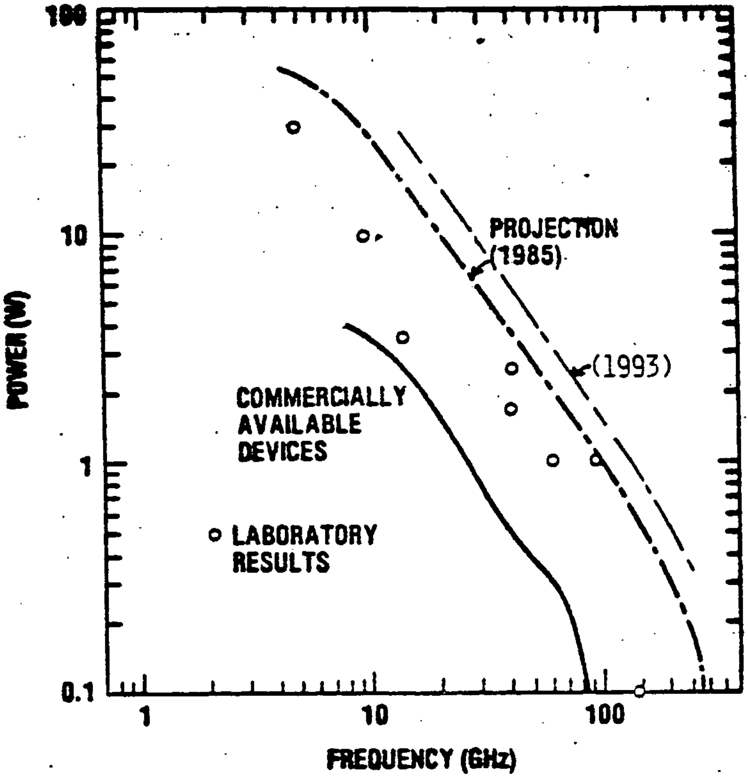


Figure 7.3-3 Projection For IMPATT Diode Devices

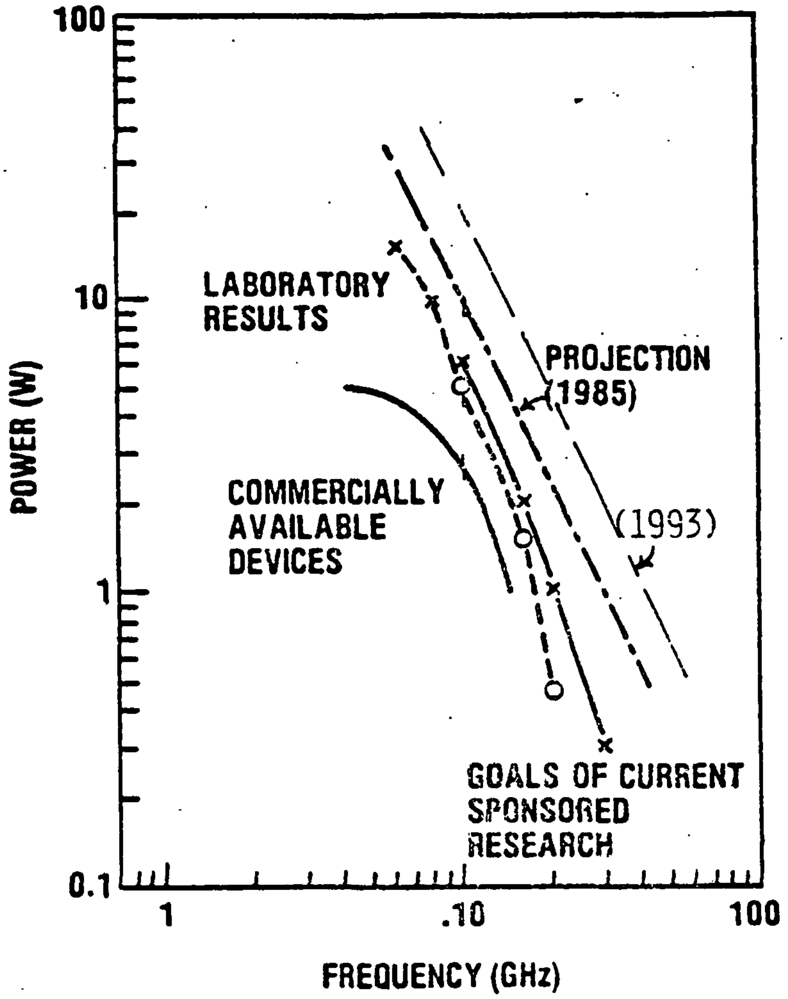


Figure 7.3-4 Projection For GaAs FET Devices

7.3.3 Power Combining Techniques

The available techniques for combining power of separate amplifier devices is shown in Figure 7.3-5. In addition, non-resonant combining techniques are expanding and provide a number of advantages. The relative advantages and disadvantages of the power combining techniques are summarized in Table 7.3-2. All of the techniques have been used in various applications depending on the primary requirement. All of the techniques require relatively good control of absolute phase shift as well as phase variation with temperature. The temperature between devices must be controlled also in order to control phase.

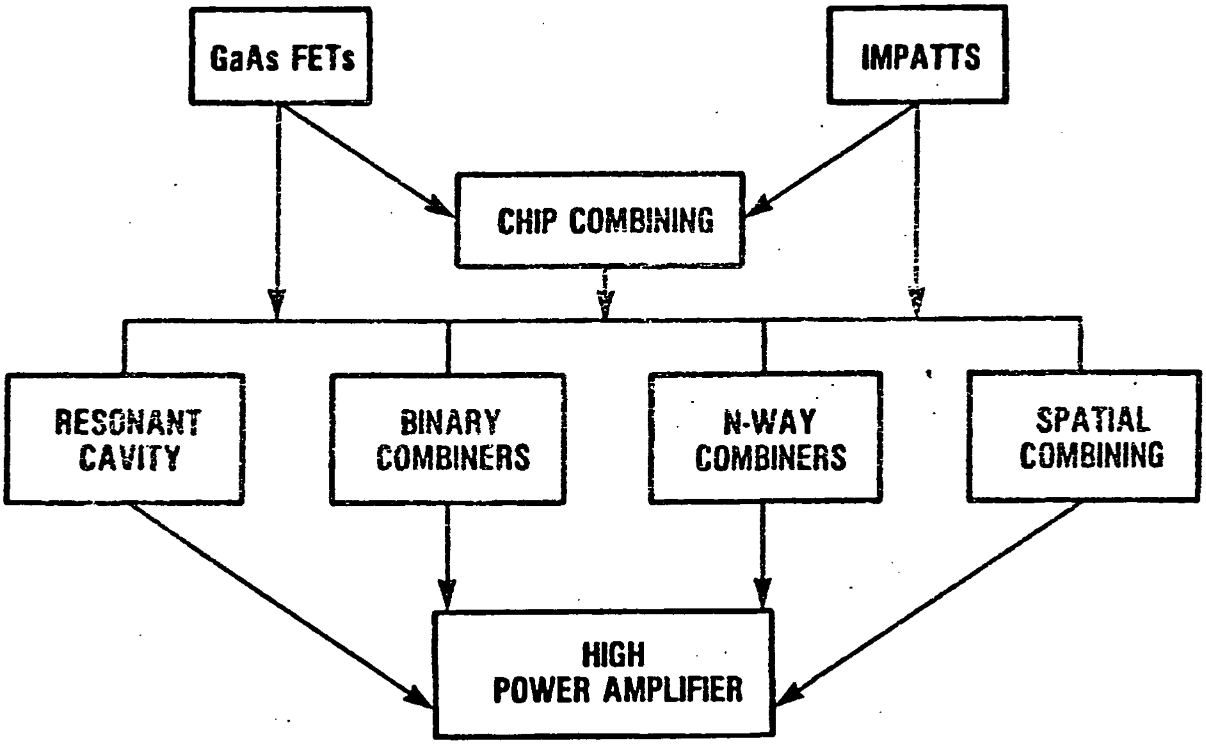


Figure 7.3-5 Power Combining Techniques

Table 7.3-2

Relative Merits Of Power Combining Techniques

TYPE	ADVANTAGES	DISADVANTAGES
NON-RESONANT	BROAD BANDWIDTH AMPLIFIERS ISOLATED GRACEFUL DEGRADATION	
BINARY COMBINER	EASE OF IMPLEMENTATION	HIGHEST INSERTION LOSS LARGEST SIZE AND WEIGHT LIMITED TO ≤ 16 DEVICES
N-WAY COMBINER	LOWER INSERTION LOSS SMALLER SIZE AND WEIGHT USEFUL FOR ANY VALUE OF N	DIFFICULT TO IMPLEMENT REQUIRES DEVELOPMENT LESS ISOLATION
SPATIAL COMBINING	LOWEST INSERTION LOSS EASE OF IMPLEMENTATION	REQUIRES COMPATIBLE ANTENNA DESIGN
RESONANT	HIGHEST EFFICIENCY SMALLEST SIZE AND WEIGHT	CATASTROPHIC FAILURE NARROW BANDWIDTH LIMITED TO ≤ 10 DEVICES

7.3.4 Receiver Technology

The current state-of-the-art noise figures for various receiver devices is shown Figure 7.3-6. GaAs FET and parametric amplifier implementations are expected to yield the lowest noise figure at all frequency bands as presented in the figure. While some improvement will be achieved over equipment available today, no significant improvement in noise figure is likely to emerge in the time frame of interest.

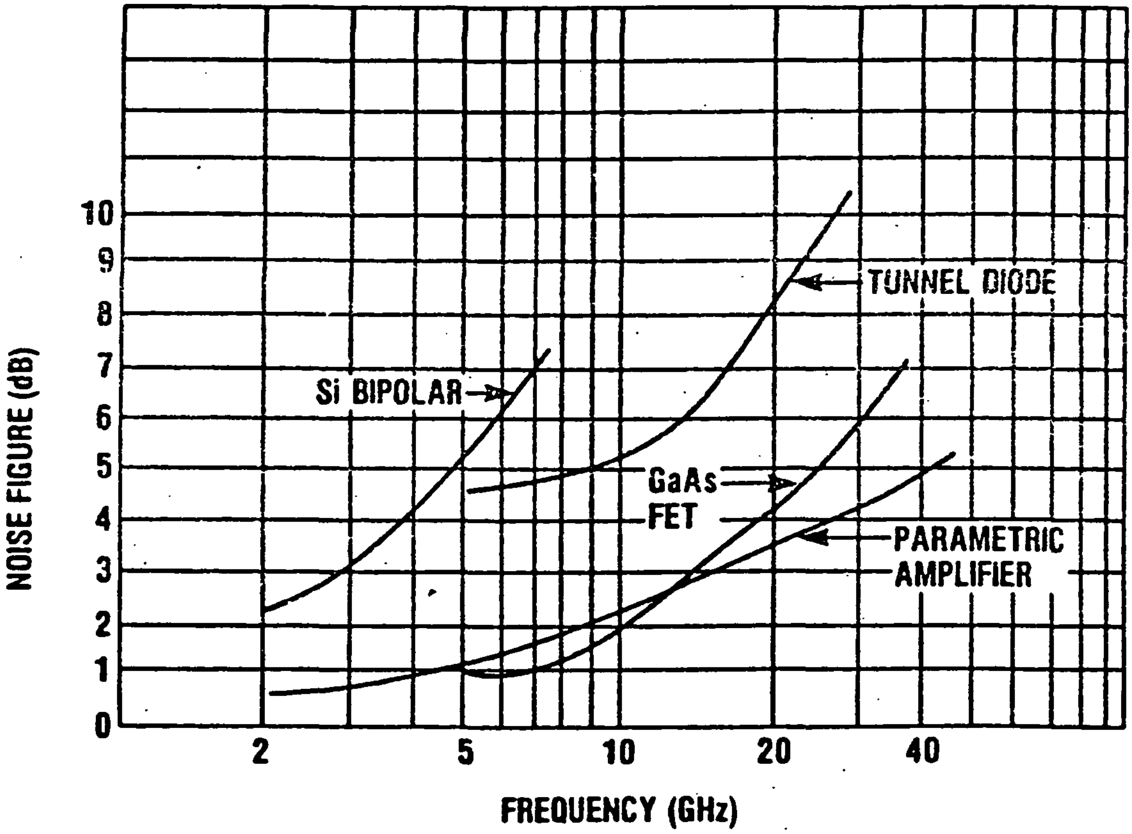


Figure 7.3-6 Noise Figure For Receiver Devices

The overall mixer noise figure performance for various implementation techniques is shown in Table 7.3-3. The use of GaAs image enhanced mixers is expected to yield a noise figure of 6db for 20 GHz operation.

Table 7.3-3

Comparative Mixer Noise Figures

FREQ. (GHz)	BALANCED		DBM		IRM		IM. ENH.	
	Si	GaAs	Si	GaAs	Si	GaAs	Si	GaAs
10 - 18	7.0	6.5	7.0	6.5	7.5	7.0	6.0	5.5
18 - 26	7.5	7.0	7.5	7.0	8.0	7.5	7.0	6.0
26 - 40	8.5	7.5	8.5	7.5	9.0	8.0	8.0	6.5
REL. COST	1.0	1.2	1.1	1.3	3.0	3.2	5.0	5.2

NOTE: (SSB NF.N_F = 1.5 dB)

The projected future performance, physical characteristics and costs of an advanced microwave receiver implementation are presented in Table 7.3-4. It can be seen that while there are sizeable reductions in size, weight, and cost, the improvement in noise figure performance is not that dramatic. In general, the trend will be to lighter, lower cost hardware but not significant improvement in performance.

Table 7.3-4

Advanced Receiver Characteristics

Parameter	Microwave IC	Advanced Microwave IC	Monolithic Microwave IC
Noise Figure (dB)	3.1	1.9	1.9
Bandwidth (GHz)	0.5	2.0	2.5
Size (Inches)	0.43x2.25x0.5	0.2x0.8x0.17	0.1x0.2x0.1
Weight (Grams)	17.7	8.0	3.0
Cost/Amplifier	$4,600	$3,400	$920

7.4 ON-BOARD PROCESSING TECHNOLOGY

The use of advanced on-board processing technology can significantly enhance the performance of the total communications system. Several areas of expected benefits include:

- Increased Connectivity - This can be achieved by changing the transmission path dynamically by SS TDMA switching or demodulation/remodulation schemes.
- Increased Capacity - This is accomplished by improving satellite fill factors.
- Increased Communications Link Efficiency - This can be accomplished by separating the uplink and downlink using regeneration.
- Increased Flexibility - Permits potential ability to combine FDMA/FM and TDMA uplink traffic on the spacecraft as part of the same network.

A summary of the application of various processing technologies by payload transponder element is shown in Table 7.4-1.

The configuration of an advanced satellite transponder incorporating a base-band processor is shown in Figure 7.4-1. It is anticipated that the processor developments associated with the ACTS program will be applicable to space platform applications.

An example of A/D conversion processing as used in Scenario VI-A configuration for spot beam frequency reuse at C-band is shown in Figure 7.4-2. This technique provides flexible interconnectivity, improves fill factors, and is transparent to user operations.

Table 7.4-1

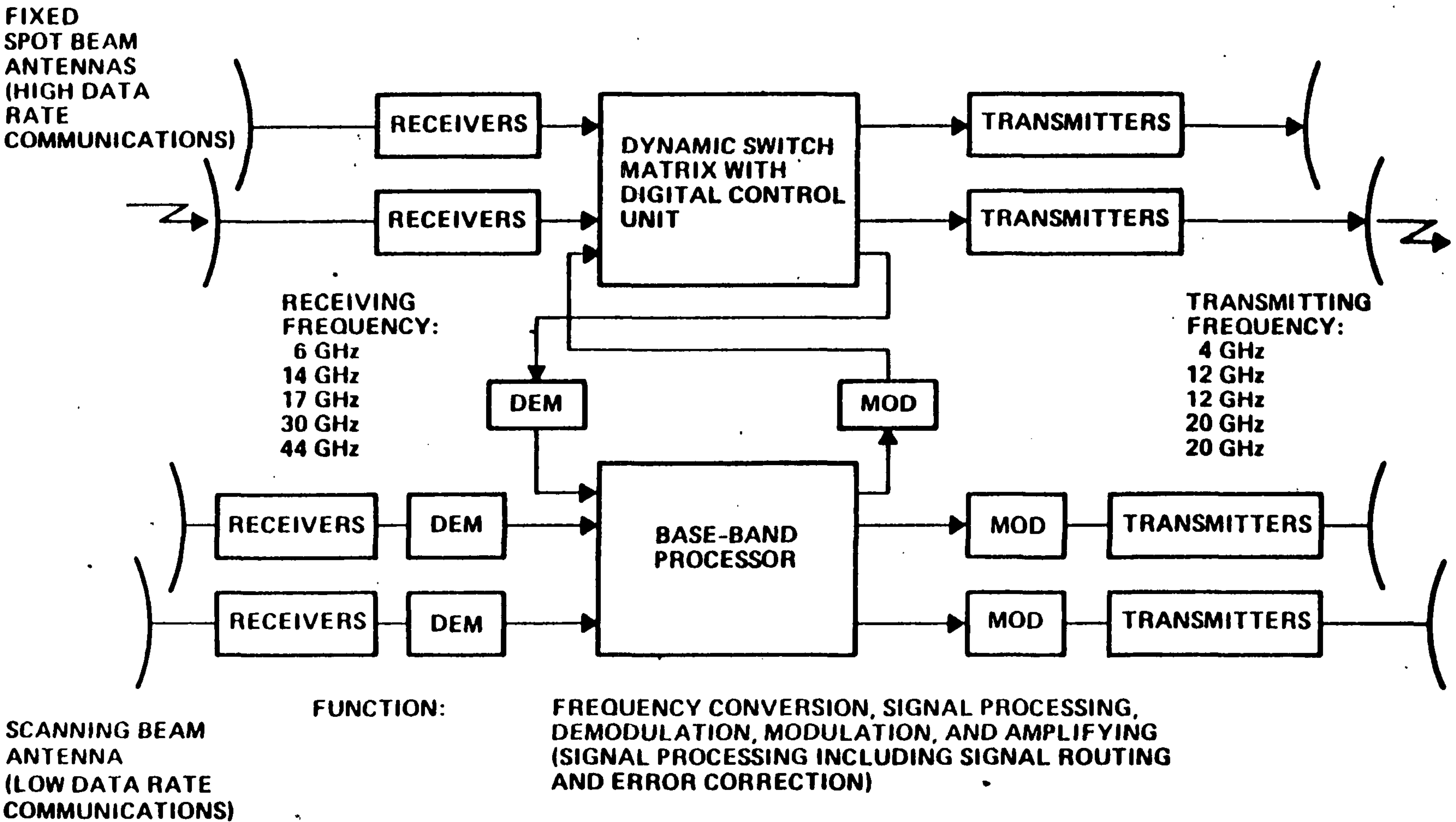
Application of On-Board Processing Technology

Technology / Function	VHSIC	SAW	MSM	MICRO-PROC-	NON-VOLATILE MEMORY	OPTICAL	MULTI-PROC.	GaAs	SEU-RESISTENT VOLATILE MEMORY
SS-TDMA			X						
IF PROCESSING		X	X						
MOD/DEMOD		X						X	
A/D, D/A	X						X	X	
RFCOMPONENTS								X	
ENCODE/DECODE	X							X	
MUX/DEMUX	X	X					X	X	
SWITCHING	X						X	X	
CONTROL				X	X		X		X
DATA DIST'N						X			

Baseband prcessing technology is currently moving at a rapid pace. The efforts of NASA LeRC and Motorola, Inc. in the technology contracts to develop the processor for the NASA ACTS program have made great strides in the device area, as well as high speed burst modulators and demodulators. The basic concept of on-board demodulation, baseband digital switching, and remodulation has been demonstrated by the proof-of-concept model built by Motorola for NASA LeRC and documented in (Ref. 45).

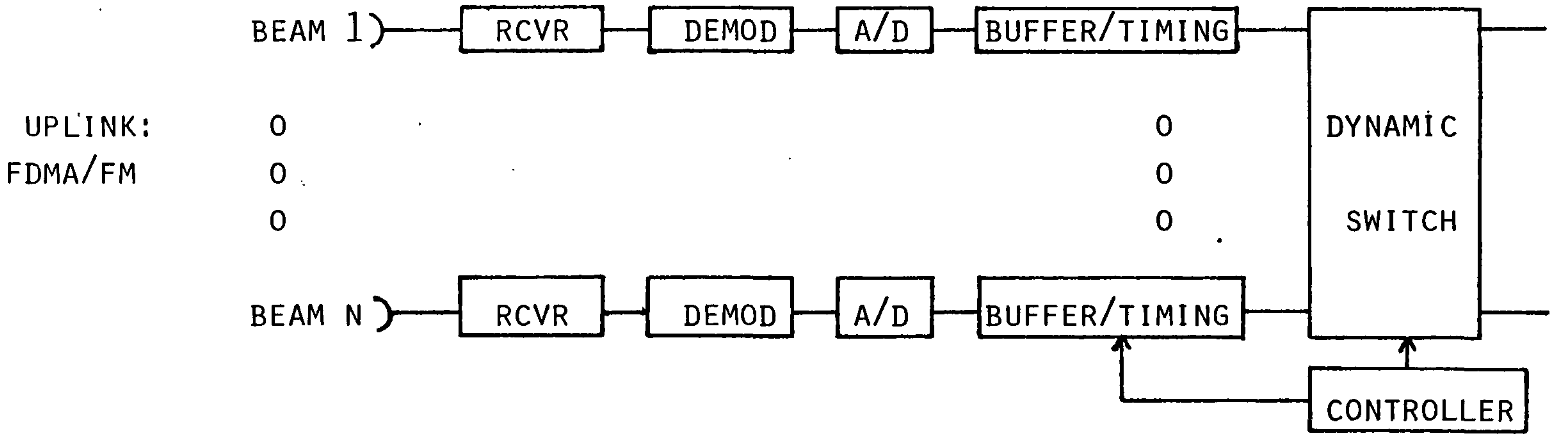
As part of the program, Motorola developed burst demodulators at 27.5, 110, 220 and 550 Mbps. It also demonstrated an architecture that could be expanded to handle digital switching of up to 10 Gbps of capacity, which is all that is required for the scenarios developed in this study.

Figure 7.4-1 Advanced Satellite Transponder Incorporating Base-Band Processor



FUNCTION:	FREQUENCY CONVERSION, SIGNAL PROCESSING, DEMODULATION, MODULATION, AND AMPLIFYING (SIGNAL PROCESSING INCLUDING SIGNAL ROUTING AND ERROR CORRECTION)
COMMUNICATION MODE:	SATELLITE-SWITCHED TIME DIVISION MULTIPLE ACCESS
SATELLITE:	MILITARY, NASA, INTELSAT VII

Figure 7.4-2 Example of A/D Processing Implementation



While further improvement in high data rates, reductions in mass and power, and improvement in space radiation hardening are required for implementation into the platform, the concept designs have been proven by the ACTS work.

Table 7.4-2 provides the performance characteristics of the current state-of-the-art in microwave switches. The data is based on the Ford Aerospace work performed for NASA LeRC (Ref. 41) on the technology development contract for the NASA ACTS program. Current work is on-going in the development of a monolithic switch module for a 10x10 chip, and should be available in the time frame of interest in this study.

7.5 PAYLOAD ON-ORBIT SERVICING TECHNOLOGY

A geostationary platform represents a significant investment in a single element of a communications system. Therefore, high reliability of the system is desirable in order to achieve the desired payload lifetime. One method of achieving high reliability is to design the payload to allow for in-orbit servicing and/or repair.

A modular design of the payload facilitates in-orbit servicing. However, designing for modularity impacts both the cost and weight of the payload.

Three elements must be considered in assessing the economic viability of in-orbit servicing of the payload: (1) modular design impacts on the payload, (2) design impacts on the platform bus, and (3) costs of the servicing module (including operations and transportations costs). The major emphasis of this study was the design impacts on the payload. Several of the potential payload servicing concepts are shown in Table 7.5-1.

Table 7.4-2

Specification VS Performance of RF Switch Matrix

PARAMETER		SPECIFICATION	PERFORMANCE
MATRIX SIZE		20 x 20	20 x 20
CONNECTIVITY		76 ACTIVE X-POINTS	76 12 ACTIVE INPUTS 8 ACTIVE OUTPUTS
FRAME DURATION		1 ms	1 ms
NUMBER OF STATES PER FRAME		N/A	256
RECONFIGURATION RATE		2 μs	1 μs
SWITCHING SPEED		10 ηs	5 ηs
IF FREQUENCY		3.5 TO 6.00 GHz	3.5 TO 6.0 GHz
IF BANDWIDTH		2.5 GHz	2.5 GHz
INSERTION LOSS		18 dB	20 dB
GAIN/INSERTION LOSS RIPPLE		1.0 dB PER 1 GHz	< 1 dB PER 1 GHz
PHASE LINEARITY		± 5 DEGREES	± 5 DEGREES
ISOLATION		40 dB	> 45 dB
INPUT VSWR		1.5:1	< 1.5:1
OUTPUT VSWR		1.5:1	1.5:1
INPUT SIGNAL LEVEL		-30 dBm → -10 dBm	-15 dBm → +10 dBm
1 dB COMPRESSION POINT		N/A	+16 dBm
MAX INPUT SIGNAL		+10.0 dBm	> +16 dBm
NOISE LEVEL (BELOW OUTPUT LEVEL)		35 dB	> 50 dB AT -5 dBm INPUT
	MATRIX	N/A	18.75" x 19" x 3.25"
	DCU	N/A	17" x 17" x 3.25"
CONSUMPTION (76 CROSSPOINTS)			
	MATRIX	N/A	5.7 WATTS
	DCU	N/A	6.25 WATTS
WEIGHT (76 CROSSPOINTS)			
	MATRIX	N/A	8.685 kg (19 lb, 3 oz)
	DCU	N/A	4.900 kg (10 lb, 13 oz)

Table 7.5-1

System Impact Of In-Flight Servicing Concepts

CONCEPT	8-YEAR LIFETIME	16-YEAR LIFETIME	LEO SERVICING & REPAIR BEFORE TRANSFER TO GEO	SERVICING/REPAIR* AT 1-3 YEAR INTERVALS	SERVICING/REPAIR AT 8-YEAR INTERVALS
A	X				
B		X			
C**		X	X	X	
D**		X	X		X
E	X		X		
F		X	X		

* SERVICING IMPLIES REFUELING OF SATELLITE.
REPAIR IMPLIES REPLACEMENTOF FAILED COMPONENTS.

** CONCEPTS C AND D IMPLY GEO SERVICING OF THE PAYLOAD FORD AEROSPACE BELIEVES THE DEVELOPMENT OF GEO SERVICING CAPABILITIES AND DEFINITION WILL NOT BE AVAILABLE BY THE EARLY 1990'S, THE TIME AT WHICH INCORPORATION OF GEOSERVICING OF THE PLATFORM WILL HAVE TO BE DEFINED.

A review of on-orbit servicing resulted in the following forecast for payload servicing technology:

- GEO payload servicing considered unlikely due to service outages.
- No "Shirt Sleeve" LEO facility provided
- Only EVA and remote manipulator capability
- LEO operations for deployment, check-out, and repair or return to Earth
- No payload assembly at LEO

From the limited review during the study, LEO servicing for platform fueling and mating of space based transfer stages appear to be the most beneficial aspects of on-orbit servicing envisioned in the mid to late 1990's time frame. The possibility of LEO repair of failed components prior to transfer to GEO may also have future benefits. However, the economics are difficult to assess at this point given the large uncertainty in both the capability and the cost associated with these functions.

7.6 GROUND TERMINAL TECHNOLOGY

This section addresses the technology development areas that should be pursued in order to achieve high performance, low-cost terminal implementation which would operate in concert with future space platform systems.

Among the key technology drivers would be the following:

- Advanced modulation techniques for high bandwidth efficiency, ie, greater than 2 bits per hertz.
- High speed modems incorporating MMIC and LSI implementation.

- Combining techniques to achieve 6000 voice circuits per channel.
- Combining techniques to permit multiple video circuits per channel.

Other developments for the antenna, RF subsystem, digital equipment and user interface equipment are detailed subsequently.

7.6.1 Terminal Antenna Development

The technology development of the Ku-band and Ka-band antenna subsystem centers on providing "low cost" equipment within the constraints of the EIRP and G/T performance requirements.

Low Cost Reflector Panel Recommended areas for technology development include investigation of alternate manufacturing methods. Techniques to be examined should include closed die molding of fiber reinforced plastic for grid stiffened panels, die stamping and warm forming of aluminum for single skin panels, and stretch forming of aluminum for either frame and skin panels or stamped single skin panels.

The most feasible method should be determined with consideration of required accuracy, recurring costs, nonrecurring tooling and development cost, consistent production accuracy, and scrap rate. A development plan would fabricate sample panels and test for structural characteristics and surface accuracy under various environmental conditions.

Feed Horn The technology development should investigate alternate corrugation designs and horn concepts. Cost-effective manufacturing techniques to be evaluated would include investment casting, electroforming, machining, and die casting. A test program would evaluate performance of promising concepts.

Orthomode Junction and Receive Filter A similar plan to that of the feed horn should be followed for the filters. Manufacturing techniques would include electroforming, investment casting, and split block machining.

Dielcone Feed A development plan would investigate the cost/performance benefits that may be achieved from the use of a dielcone feed. This includes less RF blockage, no struts, and weather tight configuration. The design must be broadband with low loss and low VSWR. Fabrication and electrical/mechanical testing would be required.

Severe Weather Environment Controls A technology development effort could be implemented to investigate alternate deicing methods. Topics to be examined include temperature distribution and gradients, power requirements, chemical deicing agents and potential corrosive effects, and durability of various coatings.

7.6.2 RF Subsystem Development

There are no RF equipment items that fall in the "must invent" category. The basic technical capabilities exist in the industry partly as a result of continuing intensive development of millimeter wave missile guidance and ECM technologies. What is currently lacking is a significant thrust specifically towards Ka-band commercial communications needs.

For receivers, GaAs FET development is yielding transistors with noise figures of 2.7 dB at 20 GHz, which is believed compatible with the goal of a 4 dB overall noise figure for the receiving system. This latter figure is in the region where improvements of any significance in overall system noise performance come at the expense of relatively major enhancements in the noise characteristics of the low noise solid state devices themselves. This is largely due to the swamping effect of external noise sources at these frequencies; items such as IR losses, antenna noise and added noise due to rain activity. As a result, the cost benefit for the further development of improved low noise devices will be marginal.

Two areas for significant development improvement would be: a) integration of the low noise front end coupled with the first downconversion stage to provide a single moderate cost low noise receiver module, and b) development of local oscillator modules specifically for the Ka-band requirements.

A continuation of solid state power amplifier development would be beneficial. A parallel combination of devices should yield an output power of 20 W or more. The cost efficiency and reliability comparisons of solid state versus the traveling wave tube approach are not well established at this time.

7.6.3 Digital Equipment Development

No new technology needs to be developed for implementation of either the TDMA or the FDMA terminal modem and processor. However, although extensive use has already been made of large scale integration (LSI) circuitry implementation previously developed, additional usage of LSI can further reduce the piece parts count. This parts list reduction would result in a net recurring cost savings for a production terminal. In addition, the reliability of the terminal would be improved due to an increased MTBF.

Several other areas have been identified to reduce terminal development and recurring costs. The first area where costs should be significantly reduced is the integration of the user interface and DAMA controller functions into the baseband processor. The application appears to be ideal for another custom LSI to significantly reduce the size and complexity of the DAMA controller.

A second area where costs could be reduced is the increased use of newly evolving high speed analog LSI. Use of this technology would further reduce the complexity of the demodulator and modulator.

A third area for potential cost savings is the terminal reliability. The reliability of a TDMA terminal is significantly influenced by the use of parts with different packaging and screening levels.

The overall software architecture requires additional definition. Although this is an overall system problem, much of the operational software resides in the terminal processor. The software requirements must be properly addressed before committing to station hardware; otherwise, increased costs will be incurred as the software/hardware interactions develop.

7.6.4 User Interface Development

This subsystem of an advanced ground terminal may be most affected by ongoing technological change.

The International Telecommunications Union, (ITU) through the International' Telegraph and Telephone Consultative Committee (CCITT), is currently devoting considerable effort towards the definition of network standards for the future Integrated Services Digital Network (ISDN). The activities are being closely monitored by national PTTs, which are also progressing in adapting their own networks to ISDN compatible digital connectivity. They are also developing subscriber interconnect concepts that will extend this to the user Digital Subscriber Line (DSL). The "basic" ISDN access is at 64 Kbps and the "primary rate" access is at 1.544 Mbps.

The low rate terminals should be configured in an ISDN compatible way. The benefits would be:

- Standardization of interfaces and protocols
- Alleviation of current conceptual/technical difficulties in providing dial-up data service

Many low cost key elements of the user interface will become available as IC/LSI components for ISDN development.

7.7 FREQUENCY REUSE

The capacity of a communications satellite can be increased by use of spatially isolated or polarization isolated antenna beams. The required isolation between reused bandwidth is typically 25 to 30 dB, but may be lower than 10 dB, depending on the signal characteristics and type of modulation.

There will always be some amount of signal energy transferred from one polarization to the other during the transmission. This is called the cross-polarization effect, and results in some level of interference when there is a second signal transmitted in the other polarization. It is specified by the cross-polarization isolation (XPI). Crosspolarization in transmission or reception can occur for any of the following reasons:

- Antennas (due to the reflector, the offset feed, phase errors, etc)
- Polarizers (used for circular polarizations)
- Misalignment of antenna axes (linear polarizations)
- Orthomode transducer
- Precipitation on the antenna

The cross-polarization effects of the propagation medium can occur from either of the following sources:

- Raindrops. The rain cross-polarization is due primarily to the nonspherical shape of raindrops, which fall as flattened, oblate spheroids. The cross-polarization due to clouds and snow is much smaller.
- Faraday rotation. This effect is due to the charged particles in the ionosphere, and only is a problem for linearly polarized signals.

In order to achieve optimum communications performance it may be desirable to develop antennas for ground applications which would track the desired polarization orientation.

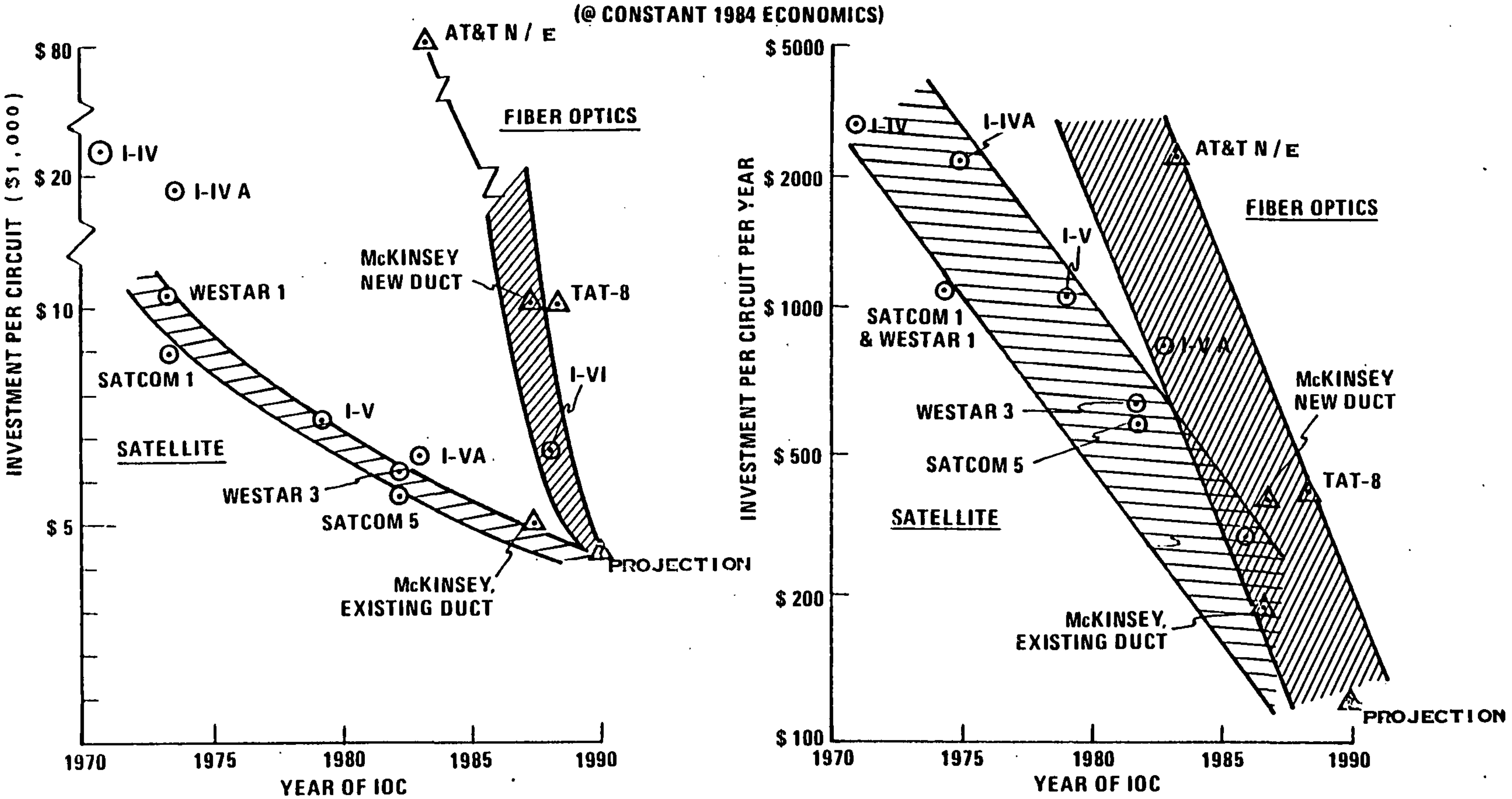
7.8 IDENTIFICATION OF KEY TECHNOLOGY DRIVERS

7.8.1 Overall Technology

Major strides in transponder utilization have been made with systems that carry an order of magnitude more voice circuits than just 10 years ago, ie, from 600 half-voice circuits per 36 MHz transponder to 6000 half-voice circuits today (see Table 7.8-1 for current use capacities). While this trend will flatten out, additional capacity gain will be made in systems that have higher utilization with better interconnectivity and distribution on-board. Packet switching, better access methods and system algorithm software with high capacity computers will improve the effective throughput of a given transponder channel. In addition, improvements in antenna sidelobe performance and "smart" receivers on the ground will allow closer spacing of satellites should it be required.

The major competitive technology, fiber optic terrestrial systems, is developing very rapidly and will be a significant influence in the future communications market. Figure 7.8-1 shows a comparison of investment cost and operating cost comparison of trades for satellites and fiber optics. It can be

Figure 7.8-1 Fiber Optics VS Satellite Communications Voice and Data Trunking Applications Trends



SOURCES: AT&T FCC FILINGS; AT&T OPTIC FIBER TRANSMISSION SYSTEM - WPC 5011, APRIL 14, 1983; McKINSEY INTERVIEWS AND ANALYSIS; WDL ANALYSIS OF I-VI & TAT-8; FASSC MESSERS R.A. LOVELL AND S.W. FORDYCE; A FIGURE OF MERIT FOR COMPETING COMMUNICATIONS SATELLITE DESIGN, INTERNATIONAL JOURNAL OF SPACE COMMUNICATION AND BROADCASTING, APRIL, 1983

Table 7.8-1

Comparative Capacities of Communication Satellite Transponders for Various Techniques in Current Use (1)

	Source Coding	Baseband Multiplexing	Carrier Modulation	Transponder Access	Number Equivalent (Voice Channels
A.		(SCPC)	FM	FD (SCPC)	500
B.		FDM	FM	FDMA (MultiCarriers)	600-800
C.		FDM	FM	Single Carrier	1800
D.	Companding	FDM	FM	Single Carrier	2800
E.	Companding/SSB	FDM	AM	(FDMA)	6000-7000 (3
F.	64 kbps PCM	(SCPC)	QPSK	FDMA (MultiCarriers)	600-800
G.	64 kbps PCM	TDM	QPSK	TDMA	800
H.	32 kbps PCM	TDM	QPSK	TDMA	1400
I.	32 kbps PCM-Delta	TDM/DSI	QPSK	TDMA	2800

---

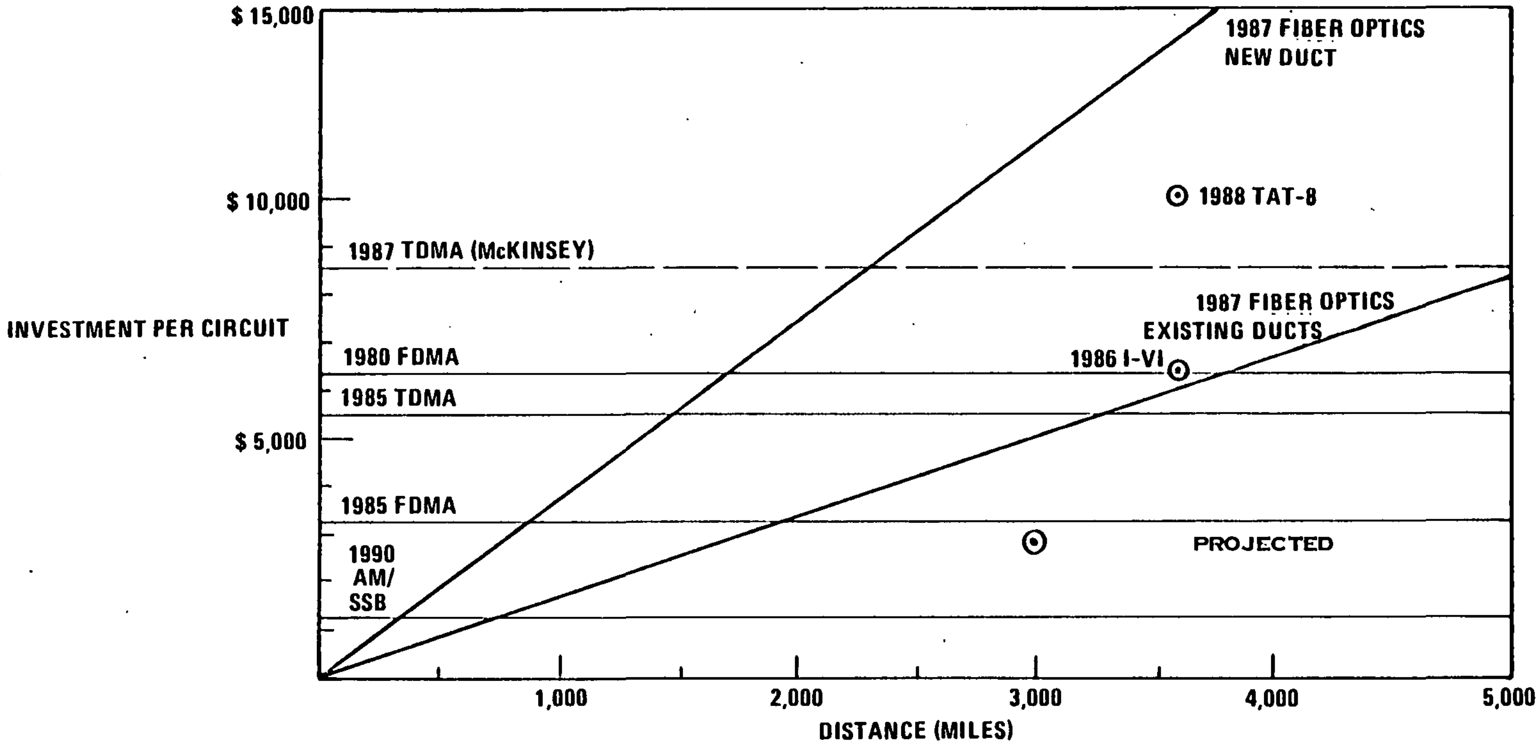
(1) Capacities shown are for comparison purposes and based on typical 36 MHz bandwidth transponders with C-Band earth station antenna diameters of approximately 10m.

(2) Number refers to one-way voice channels.

(3) Somewhat less with more than 2 frequency reuses.

seen that in the 1985-1995 time period the trend shows fiber optics falling at a faster rate than current day satellites. This leads to the need for a high capacity, high utilization satellite system to reduce the per circuit costs of satellite circuits to be competitive with fiber optics. Figure 7.8-2 shows the equivalent crossover distance for various modulation and access types versus fiber optics and it can be seen that for distances in excess of the 500-800 mile range, high capacity satellite systems are still more cost effective.

Figure 7.8-2 Fiber Optics VS Satellite Communications
(Voice and Data Trunking Applications)
Break Even Distance
Medium Capacity 20,000 Circuit Capacity



SOURCES: AT&T FCC FILINGS; AT&T OPTIC FIBER TRANSMISSION SYSTEM - WPL 5011, APRIL 14, 1983; McKINSEY INTERVIEWS AND ANALYSIS; WDL ANALYSIS OF I-VI & TAT-8

7.8.2 Component Technology

During the study, care has been taken in the definition of the payloads to utilize technology and advancement consistent with a 1994 mature basis. This is consistent with a schedule that has an operational platform launch in the 1998-2000 time period. The items identified in the next section, 7.8.2, would have to be developed prior to 1994. The component designs should start in approximately 1986-87 to define the detail device requirements by the 1989-90 time frame, with subsequent proof-of-concept models to be built and tested in the 1990-94 time frame.

During the payload definition task each of the identified component areas described the current level technology and the projected technology and this is included in Section 5 of this report. In reviewing these inputs, the following major new component drivers were identified:

a. Programmable frequency shifters to allow second tier switching at a packet level in a SS-TDMA architecture. This allows switching on a TDMA basis and routing without demodulation and remodulation to a circuit level as is done in some baseband processors.

b. Baseband processor to service the small user and direct to user applications. The capacities used in the previously defined payloads range up to 9.0 Gb/s of capacity, which is about 3 times the capacity of the planned ACTS processor.

c. High speed analog to digital converters to provide on-board format conversion from FDM/FM to digital to allow on-board switching and routing at a packet level or even to the voice ground facilities with new generation on-board systems.

d. Development of a methodology to track polarization variation at Ka-band yields the capability to re-use the 2.5 GHz of bandwidth in high density traffic areas such as New York and the Chicago/Detroit area. This re-use is one of the highest payoff factors for CONUS systems due to the distributional characteristics of the CONUS traffic. A study to evaluate its economic and the concept systems should be started soon.

e. Dual polarizers for RHCP/LHCP, receive and transmit are utilized in Scenario VI-B so that only one large 9 meter reflector is required. Given the large cost of the unfurlable reflectors, development in their area to allow use of the single reflector appears economic but should be evaluated further.

f. Intersatellite links are an emerging technology in the RF area with NASA funding the TDAS systems and the military funding numerous projects. These links look adequate for the near term capacities of 1.5-2.0 Gb/s, but future growth to higher capacities will require funding in the optical links. Laser ISL's also offer other advantages for interference immunity and smaller aperature. The payload in this study assumed RF links given the current available data. However, if adequate funding in the next 10 years could be provided, laser links could replace the RF ISL's and would provide a better base for future growth, increased capabilities and flexibility.

Table 7.8-2 identifies the above listed items, and the scenarios in which they are used. As mentioned previously, the use of a polarization tracking scheme for use at Ka-band to allow the full reuse of the Ka-band frequencies in the high density trunking areas of New York and the Chicago/Detroit area is the highest pay-off technology item identified. This

Table 7.8-2

Critical Technology Use by Scenario

TECHNOLOGY	SCENARIO			
	II	V	VI-A	VI-B
BASEBAND PROCESSING				
- HIGH EFFICIENCY MOD/DEMOD	X	X	X	X
- A TO D FORMAT CONVERSION			X	
ANTENNAS				
- POLARIZATION TRACKING OF Ka-BAND FOR H AND V REUSE	X	X	X	X
- DUAL POLARIZER FOR RECEIVE AND TRANSMIT BANDS			X	X
TRANSPONDERS				
- HIGH SPEED PROGRAMMABLE FREQUENCY SOURCE	X	X	X	X
ISL			X	X
- RF OR OPTICAL				

technique would track the polarization phase disturbed by rain and other atmospheric disturbances discussed in Section 7.7. It would then realign the antenna polarization with the received signal to maintain the necessary cross-polarization isolation between the orthogonal signals, allowing the two times reuse based on polarization isolation. This techique is used in all four communication scenarios in all of the Ka-band payloads.

Of the remaining items, the prioritized list of critical technology items is as follows:

1) Polarization tracking
2) Programmable frequency source
3) Baseband processing - modulation/demodulation
4) ISL's
5) A to D format conversion
6 Dual polarizers for receive and transmit

The programmable frequency shifter is an alternate to a significantly expanded baseband processor. The savings in weight, power, and cost are significant advantages. Since this item is used in all of the Ka-band payloads, it also has high payoff in the utilization of the frequency band.

Another high payoff item is the high efficiency modulators and demodulators. The bit rates used in the scenarios are based on 960 Mbps. This is almost twice the current ACTS rate, and of course has a direct ratio effect on the capacity per orbital locaation, or requires almost twice the number of transponders, thus impacting the cost comparisons.

The next most significant item is the ISL's. Without ISL's, the Scenario VI-A and VI-B platforms are almost meaningless. The use of ISL's and the ability to eliminate double-hop transmissions and the associated waste of spectrum, power and ground equipment make it a high payoff technology item.

The next significant technology item is the high speed A to D and D to A converters, to allow on-band digital routing while still accommodating the existing analog ground plant-in-place. This item adds flexibility to the system, but it is hard to put an economic value on it without a defined user community to be addressed or a basis for comparison. Further study of this item to try and quantify its benefit is required.

As with the above item, dual polarizers are hard to evaluate. The cost of two reflectors is well definable as a should cost for comparison, but the cost of developing the dual polarizers is not well defined. The overall comparison also needs to consider the costs associated with launching and supporting the second reflector from the platform.

7.8.3 Support Technology

There are a number of support technology areas that enhance all of the above technology studies and also yield reductions in weight and power for the other major components. A list of the key items is shown in Table 7.8-3.

Table 7.8-3

Key Technology Support Item

- Device Processing (CMOS-SOS, etc.)
- Discrete (GaAs) Power amps, Receivers, other
- MMIC (RF components)
- VLSI (digital components)
- Materials Technology (DRO's Structural, etc.)
- Optical (interconnects, switching, etc.)
- Radiation Hardening (all for long life)

In addition to the hardware support area, there is a potential cost reduction approach which is emerging that will have implications on GEO platforms in the middle 90's. This is the use of the Space Station and the associated space based capabilities. While it is difficult to quantify at this point, there appears to be potential savings for GEO platforms in the following areas:

- Deployment of large appendages at LEO
- Assembly of modular payloads at LEO that would be difficult or impossible to package as one item in the STS
- Alignment of antennas in zero-G environment at LEO
- LEO Check-out of payloads prior to transfer to GEO
- Servicing of modularized payloads at LEO in the event of a detected fault
- Space based fueling and transportation

During the study, servicing at GEO was also evaluated but it was determined that for payloads out to year 2000 it was unlikely that services at GEO would be available. It is recommended that the economic viability of GEO servicing be examined in detail.

SECTION INDEX

8.0 SYSTEM COMPARISONS (TASK 7)

8.1 OVERVIEW AND SUMMARY COMPARISON OF SCENARIOS

The purpose of Task 7, System Comparison, is to provide an evaluation of the benefits, advantages, disadvantages and probability of implementation as well as ranking of the communications payloads defined in the study. The approach used by Ford Aerospace incorporated the following inputs:

- From Task 4: Candidate definitions
- From Task 5: Corresponding cost assessments for each payload definition
- From Task 6: Corresponding critical technology requirement for each payload definition

The following evaluation criteria were considered in order to assess the overall benefits of each candidate scenario:

- Frequency spectrum utilization
  - Bandwidth
  - Re-use
  - Modulation efficiency
- Inter-system interference
- Communications service reliability and availability
- Growth potential/flexibility
- Complexity (risk)
- Percent payload capacity utilization
- Compatibility with plant-in-place spacecraft and ground segment equipment forecasted for 1998
- Cost assessment

A discussion of some of the evaluation criteria and the scenario rankings are highlighted in what follows:

8.2 PHYSICAL PARAMETER COMPARISON

8.2.1 Weight and Power for All Scenarios

Table 8.2-1 provides a summary of the weight and power for scenarios II, IV and V, and Table 8.2-2 is the same for scenarios VI-A and VI-B. Included in the estimates are the coax, waveguide, and harness interconnects, plus an estimate for integration hardware to put the components together and provide necessary brackets for support and mounting. Not included are any structure or satellite mounting hardware such as between the feed and reflector. Both tables are based on projected (high risk) technology. It is anticipated that Table 8.2-1 payload could fit launch concept 1 and Table 8.2-2 payloads would fall into launch concept 2. Table 8.2-2 payloads would also require some LEO assembly due to the number of reflectors.

Table 8.2-1

Characteristics of Scenario Payloads Using Projected Technology
(Integration Hardware Included)

	Scenario II		Scenario IV		Scenario V	
Payload	Wt(kg)	Pwr(W)	Wt(kg)	Pwr(W)	Wt(kg)	Pwr(W)
C-Band FSS	89	659	-	-	246	708
Ku-Band FSS	261	2522	605	5075	523	785
Ku-Band DBS	223	3876	1012	29960	-	-
Ka-Band	1492	5933	-	-	1492	5933
TOTAL SCENARIO	2065	12990	1617	35035	2261	7426

Table 8.2-2

Characteristics of Scenario Payloads Using Projected Technology
(Integration Hardware Included)

	Scenario VI-A		Scenario VI-B	
Payload	Wt(kg)	Pwr(W)	Wt (kg)	Pwr(W)
C-Band FSS(Domestic)	246	708	-	-
C-Band FSS(Int'l)	750	2166	-	-
C-Band FSS(Non-CONUS)	-	-	574	1903
Ku-Band FSS(CONUS)	523	785	523	785
Ku-Band FSS(Non-CONUS)	-	-	186	1796
Ka-Band FSS(CONUS)	1492	5933	1492	5933
Maritime	79	649	44	649
Inter Satellite Links	111	160	107	131
TOTAL SCENARIO	3201	10401	2926	11197

8.2.2 Weight and Power of Payloads used in Scenarios

Table 8.2-3 provides a summary of the weight and power required by each of the 16 different payload elements used in the five scenarios based on projected (high risk) technology. Table 8.2-4 is the same breakdown using emerging (low risk) technology. Use of the low risk technology would make scenario V and possibly scenario II exceed the single shuttle to GEO capability without fuel servicing or augmented perigee boost.

Table 8.2-3

Weight and Power of Payload Elements Using High Risk Technology

Payload Element	Used in Scenarios	Weight(kg)	Power(W)
C-Band FSS(2 x reuse)	II	89	659
C-Band FSS(4 x reuse)	V, VI-A	246	708
C/L Band Maritime	VI-A	79	649
C/L Band Maritime	VI-B	63	649
C-Band Intn'l(9 x reuse)	VI-A	750	2166
C-Band Non-CONUS(9 x reuse)	VI-B	574	1903
Ku-Band FSS(3 x reuse)	II	261	2522
Ku-Band FSS(3 x reuse)	IV	605	5075
Ku-Band FSS(9 x reuse)	V, VI-A, VI-B	523	785
Ku-Band Non-CONUS	VI-B	186	1796
Ku-Band DBS(no reuse)	II	223	3876
Ku-Band DBS(4 x reuse)	IV	1012	29960
Ka-Band FSS(CONUS)	II, V, VI-A, VI-B	1492	5933
60 GHz Inter-Sat	VI-A	111	160
60 GHz Inter-Sat	VI-B	107	131

8.3 SPECTRUM/ORBIT UTILIZATION

The comparison of spectrum/orbit utilization among payload concepts is complicated because regulatory issues as well as technical ones are involved.

The FCC intends to address this matter in a future proceeding, but it has developed an interim solution so that potential benefit of hybrids can be demonstrated in actual operation at the earliest practical date. It believes that if 2° spacing intervals are generally utilized, then maximum

Table 8.2-4

Weight and Power of Payload Elements Using Low Risk Technology

Payload Element	Used in Scenarios	Weight(kg)	Power(Watts)
C-Band FSS	II	121	922
C-Band FSS	V, VI-A	327	1001
C/L Band Maritime	VI-A	105	855
C/L Band Maritime	VI-B	63	855
C-Band International	VI-A	987	3140
C-Band Non-U.S.	VI-B	745	2704
Ku-Band FSS	II	315	3444
Ku-Band FSS	IV	751	7052
Ku-Band FSS	V, VI-A, VI-B	812	1164
Ku-Band Non U.S.	VI-B	301	2751
Ku-Band DBS	II	278	4554
Ku-Band DBS	IV	1227	34060
Ka-Band FSS	II, V, VI-A, VI-B	2007	6849
Ka-Band Scan	II, V, VI, VI-B	2007	6849
60 GHz Inter-Sat	VI-A	147	285
60 GHz Inter-Sat	VI-B	140	224

efficiency of orbital arc in both C and Ku-band is achieved under current circumstances. The FCC sees an urgent need to authorize without protracted administrative delays additional domestic satellite capacity to satisfy growing demand. Based on its present policy and precedents, the FCC has already made a tentative orbit deployment plan. A description of which was published in the July 29, 1985 issue of Satellite News. From this article it is clear the C-band arc is saturated and the Ku-band arc is heavily committed. This allocation made the new orbital slot assignments in order to bring C-band satellites into conformity with the FCC's 2° spacing order of April 1983.

These proceedings and the results of international frequency coordination and future international conferences are likely to affect how each payload concept is to be implemented.

Projection of regulatory issues concerning the 1998 era has its uncertainties. Ford Aerospace's approach here is to analyze the likelihood of each spectrum/orbit allocation associated with the payload concept based on last and current policy philosophy of FCC and WARC-79.

Since most payload concepts in this study include a mixture of the C, Ku, and Ka-bands, some difficulties may arise because of the different orbital spacing criteria currently used by FCC for different bands.

On the technical aspects, the geostationary orbit's well-known attractiveness is that it alleviates satellite tracking and acquisition problems and eliminates the need for routine satellite handover. A major drawback is that coverage in the polar area is not provided, and users operating in the higher northern latitudes view the satellite at very low elevation angles. Low elevation angles induce a host of problems to users such as:

- Refractive index anomalies
- Interference with other terminals
- Probability of detecting signals radiated by other terminals

Although this study concerns mainly CONUS users, there are cases involving low-elevation-angle users. For payload concepts involving such cases, there is a higher ground segment cost impact because earth station requirements are more strict with respect to such performance parameters as EIRP and sidelobes.

8.3.1 Bandwidth and Reuse

A comparison of the effective bandwidth provided for each of the five scenarios is shown in Table 8.3-1.

Table 8.3-1

Effective Bandwidth (GHz)

Communication Band	Scenario II	IV	V	VI-A	VI-B
Ka	30.3	--	30.3	30.3	30.3
Ku (FSS)	1.3	1.2	3.9	3.9	5.2
Ku (DBS)	.4	1.5	--	--	--
C	.9	--	1.7	5.6	3.
L	--	--	--	.035	.035
ISL	--	--	--	4.5	3.0

8.3.2 Modulation Efficiency

The modulation efficiences used in the traffic loading are identified in Table 8.3-2 and the types of modulation by payload are shown in each of the transponder loading printouts provided in the Addendum to the final report.

Table 8.3-2

Summary of Modulation Capacity Assumptions

Modulation Technique	Capacity (36 MHz)
8 PSK	72 Mb/s
CSSB	6000 HVC
FDM/FM	2800 HVC
SCPC	1800 HVC
Video-FM	2.5 Channels
SQPSK (ISL)	1.5 Gb/s*

* per ISL channel

8.3.3 Throughput Comparison

The throughput by payload element for the four communications scenarios is shown in Table 8.3-3. The fifth scenario, scenario IV, is a video distribution satellite and does not lend itself to this comparison.

Table 8.3-3

Maximum Throughput (Gb/s) By Scenario

	Scenario			
Application	II	V	VI-A	VI-B
Ka-Trunking	49.9	49.9	49.9	49.9
Ka-CPS	8.6	8.6	8.6	8.6
Ku-FSS	5.2	15.6	15.6	17.5
C	3.5	6.9	14.2	5.7
ISL	--	--	4.5	3.0
Total	67	81	93	85

8.3.4 Utilization Factor Comparison

The development of the utilization factor for each of the communications payloads is discussed in Section 4.8.5 and summarized in Table 8.3-4. As can be seen, the factors only vary from 0.756 to 0.774.

8.4 COST COMPARISONS

8.4.1 Payload Costs

The payload costs were prepared from a component basis as described in Section 6. Table 8.4-1 provides a payload by scenario cost and total cost for each scenario.

Table 8.3-4

Summary of Utilization

Application	Scenario II	V	VI-A	VI-B
Ka Trunking	.76	.76	.76	.76
Ka-CPS	.76	.76	.76	.76
Ku (U.S-FSS)	.62	.83	.83	.83
Ku (Non-U.S.)	-	-	-	.81
C (U.S.)	.92	.62	.62	-
C (International)	-	-	.61	-
C (Non-U.S.)	-	-	-	.75
ISL		-	.84	.70
Weighted Average	.760	.765	.756	.774

8.4.2 Space Segment Costs

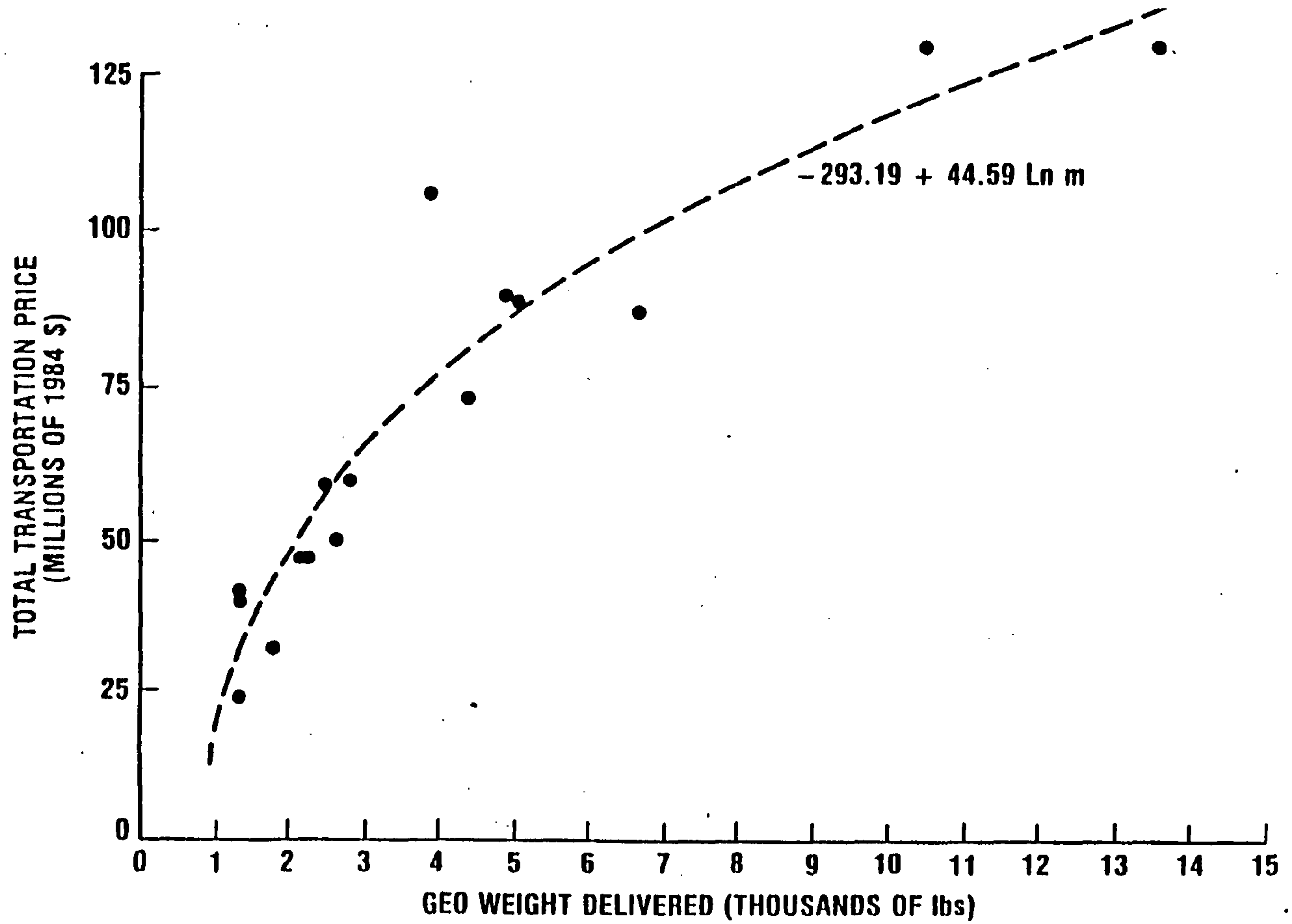
In order to compare platforms against the current method of providing services with multiple satellites, a total space segment cost was necessary. A number of assumptions were made, as shown in Table 8.4-2, to arrive at a total space segment cost. The launch cost for transportation to GEO was estimated based on the Rockwell study results shown in Figure 8.4-1. This curve assumes that for payloads that are larger than a single STS can lift in one mission, fueling at LEO would be provided at the same marginal cost as the last pound of lifted payload on the STS is provided. This allows the dry platform to be fueled at LEO and the STS only has to lift the dry platform weight for launch. This approach applies to scenarios VI-A and VI-B and may be required for scenario V.

Table 8.4-1

Projected Costs of Payload Elements ($M)

Payload Element	Incorporated in Following Scenarios				
	II	IV	V	VI-A	VI-B
C-Band, FSS	4.5				
C-Band, FSS			7.9	7.8	
C/L-Band Maritime (Atlantic)				3.4	
C/L-Band Maritime (Pacific)					2.4
C-Band, Internat'l				27.8	
C-Band, Non-U.S.					27.1
Ku-Band, Non-U.S.					15.7
Ku-Band, FSS	15.2				
Ku-Band, FSS		28.7			
Ku-Band, FSS			32.0	32.0	32.0
Ku-Band, DBS	11.3				
Ku-Band, DBS		38.5			
Ka-Band, FSS	20.0		20.0	20.0	20.0
Ka-Band, SCAN	30.1		30.1	30.1	30.1
60 GHz, ISL				5.1	4.3
TOTAL	81.1	67.2	90.0	126.2	131.6

Figure 8.4-1 Transportation Price as a Function of Geosat Weight



Rockwell International

Ford Aerospace & Communications Corporation

Table 8.4-2

Cost Assumptions

- No development costs are included.
- Spacecraft weight allocation at beginning of life (BOL)

-- Payload	31%
-- Bus	47%
-- Stationkeeping fuel (10 yrs)	22%

- Bus Costs
  - For large S/C: $40 million recurring + $20 million for integration and launch operations.
  - For very large S/C: $60 million recurring + $30 million for integration, launch, and LEO operations.
- Perigee and apogee stage costs are included in launch costs.
- Use of Rockwell study for estimating launch costs:
  launch cost($M) = 44.6 Ln (BOL wt lbs) - 293.2

Using the bus cost assumptions and the estimated launch cost, the total space segment cost for each scenario was derived, as shown in Table 8.4-3.

Table 8.4-3

Comparison Costs (1984 $M)

Scenario	Recurring Payload	Bus	Launch	Total Cost
II	81	60	134	275
IV	67	60	123	250
V	90	60	138	288
VI-A	126	90	154	370
VI-B	132	90	150	372

8.4.3 Transponder Cost per Year Comparison

In order to use the above space segment costs for comparison to today's provided services, each scenario cost was converted to cost per 36 MHz bandwidth per year, as shown in Table 8.4-4. This led to a transponder cost from 26 to 32K dollars per year. It must be noted that the 26 to 32K dollars does not include any profit for the manufacturer, operating costs, recovery of non-recurring, or profit for the operator. It is reasonable that the cost to the user would be at least double the recurring cost. Thus, the lease cost to a user would be 52 to 64K dollars per year which still appears attractive compared to the 190K to 280K dollars per year shown in Table 3.3-1 as estimated prices for 1982 to 1987 time frame. Thus, a factor of 4 or 5 to one reduction in transponder lease costs could be recognized based on an aggregated platform payload compared to todays costs.

Table 8.4-4

Transponder Costs Per Year

	SCENARIO			
COMMUNICATIONS	II	V	VI-A	VI-B
Cost/Satellite ($M)	237*[1]	288	370	372
EFF B/W (GHz)	32.5	35.9	44.3	42.4
Cost/36 MHz/Year ($K)*[2]	26	29	30	32

VIDEO CHANNELS	II	IV
Cost/Satellite ($M)	38*[1]	250
No. Channels	16	112
Cost/24 MHz/Year ($K)*[2]	238	223

*[1] Bus and launch costs prorated, based on payload costs for DBS and communications.

*[2] 10 year life

8.4.4 Alternative Approach Cost Comparison

Using each scenario as a baseline for comparison, and estimating the number and recurring cost of current day satellites to provide equivalent band width, then adding the launch cost for the current day satellites from the Rockwell study, a total cost of providing the equivalent service by individual current day satellite was derived. Table 8.4-5 presents the comparison of these numbers for evaluation. It can be seen that the aggregated payloads are 4-5 times less expensive. This is equivalent to the reduced per transponder costs shown in Table 8.4-4.

Table 8.4-5

Alternative Approaches To Providing Equivalent Capacity

SCENARIO II

($237M)

Payload	"Equivalent" Satellite	Number Required	Costs ($M) (Satellite + Launch)
C - 24 @ 36	SATCOM	1	40 + 35
Ku - 24 @ 54	GTE	1.6	50 + 35
Ka - 52 @ 500	HUGHES	5.9	90 + 75
18 @ 240	32 x 160 MHz		
		TOTAL COST =	$1185M

SCENARIO V

($287M)

Payload	"Equivalent" Satellite	Number Required	Costs ($M) (Satellite + Launch)
C - 48 @ 36	SATCOM	2	40 + 35
Ku - 108 @ 36	GTE	4.8	50 + 35
Ka - 52 @ 500	HUGHES	5.9	90 + 75
18 @ 240			
		TOTAL COST =	$1531M

Table 8.4-5

Alternative Approaches (Continued)

SCENARIO VI-A

($370M)

Payload	"Equivalent" Satellite	Number Required	Costs ($M) (Satellite + Launch)
C= 48 @ 36	SATCOM	2	40 + 35
Ku - 108 @ 36	GTE	4.8	50 + 75
Ka - 52 @ 500 18 @ 240	HUGHES	5.9	90 + 75
C - INT'L	I-VI	2	65 + 75
C/L	INMARSAT	1	35 + 35
		TOTAL COST =	$1881M

SCENARIO IV-B

($372M)

Payload	"Equivalent" Satellite	Number Required	Costs ($M) (Satellite + Launch)
Ku - 108 @ 36	GTE	4.8	50 + 35
Ka - 52 @ 500 18 @ 240	HUGHES	5.9	90 + 75
Domestic			
Canada	ANIK	2	40 + 35
Mexico	MORALES	1	30 + 35
Brazil	BRAZILSAT	2	40 + 35
Other LAM/C	PAN AM SAT	1	40 + 35
C/L	INMARSAT	1	35 + 35
		TOTAL COST =	$1901M

8.5 Ground Segment Impact

The degree by which satellite service aggregation affects the terrestrial communication system of the 1990s is dependent to a large extent upon the performance enhancement provided by this new utilization of technology. As a minimum it will overcome the growing problem of orbital arc saturation and permit greater utilization of satellite resources both within the United States and in the Third World countries of Central and South America. This in turn will greatly increase the number of earth terminals as the benefits of satellite communications are spread throughout the Western Hemisphere.

Within the United States the effect may be less pronounced, due to a larger portion of the traffic being carried by fiber optic cable systems and expanded local area networks. However, international traffic, thin route regional traffic, and direct broadcast services are areas sensitive to potential expansion. Increases in platform reflector sizes and/or transmit power would reduce terminal requirements and, coupled with technological advances in LSI digital circuitry and solid-state receivers and amplifiers, would substantially reduce the cost of individually owned terminals. This cost reduction coupled with the desire for increased services such as provided by direct broadcasting, for example, could cause major growth in satellite telecommunication services offered via geostationary platforms.

8.5.1 Ground Segment Cost Estimates

Table 8.5-1 provides an estimated cost for a particular frequency and size (type) of service. A number of factors affect the actual terminal cost, such as availability (on line redundancy vs. sparing), environment (wind, sun, temperature, etc.), and location (edge of beam, low elevation angle, etc.); thus only ranges of costs by frequency band could be provided.

Table 8.5-1

Estimated Cost Of Earth Terminals

	Type	Recurring Cost
C-band		
	10m - 15m (Tx. Rx)	$200 - $1000K
	2m - 8m (Tx, Rx)	$10K -50K
	2m - 5m (RECEIVE ONLY)	$2K - 10K
Ku-band		
	7m -10m (TDMA, Tx, Rx)	$150K -500K
	2m - 3m (FDMA, Tx, Rx)	$4K -5K
	1m (DBS, RECEIVE ONLY)	$0.4K -0.6K
Ka-band		
	5m -7m(TDMA, Tx, Rx)	$250 - 300K
	2m -3m (TDMA, Tx, Rx)	$100K -170K

Also, the type of modulation and access have effects on the terminal cost. It was assumed that C-band would remain primarily an FM (analog) system, and the digital systems used at Ku and Ka-bands, with TDMA used at Ka-band.

8.5.2 Ground Segment Cost Comparison

Although actual cost comparison of ground segment costs are almost impossible without a hypothesized system, it is clear significent cost saving will be recognized for the large platforms in the trunking application. For comparison purposes, assume a Scenario V satellite replaces its equivalent capacity; i.e., 12.7 satellites. In this instance there are three frequency bands; therefore, a given terminal location to operate with total connectivity would require only 3 antennas as opposed to 13 for the equivalent employment of satellites. While it is not clear precisely what actual population of terminals would be required, a look at the current ratios for the Intelsat network is useful. It is estimated that approximately 40% of the locations require total connectivity; about 30% more require 2 of 3, and only 30% have one antenna for the trans-Atlantic satellites. This, of course, is very traffic sensitive from a distribution standpoint. However, using these numbers, and the costs from Table 8.5-1, an equivalent normalized cost for total interconnectivity can be calculated. Table 8.5-2 shows the resulting equivalent cost for a given location, which requires an equivalent 8.15 ground terminals at an equivalent price of $2,965,000, as opposed to the 3 terminals, 1 C-band ($600K),1 Ku-band ($325K), and 1 Ka-band ($275K), at an equivalent price of $1,200,000, or roughly 40% of the cost.

Table 8.5-2

Scenario V Equivalent Ground Costs
For Total Interconnectivity

Band	% Term. Req'd.	No. of Term. Req'd.	Equiv. # of Term.	Avg. Cost of Term.($K)	Equiv. Cost of Term.($K)
C-Band	70%	2	1.4	600	840
	30%	1	.3	600	180
Ku-Band	40%	4 or 5 (4.5)	1.8	325	585
	30%	2 or 3 (2.5)	.75	325	244
	30%	1	.30	325	98
Ka-Band	40%	5 or 6 (5.5)	2.20	275	605
	30%	3 or 4 (3.5)	1.05	275	289
	30%	1 or 2 (1.5)	.45	275	124
		TOTALS	8.15		2,965

The costs derived above are on a per node basis, and if an extensive network is envisaged, the savings in ground costs could be extensive, roughly $1.7M per node. While this estimate does not consider that multiple terminals at a single location should not cost the multiple times the per station cost, if a 30% savings per station were recognized, the savings per node would still be $875K. This comparison is only for one Scenario V satellite and its equivalent satellite complement. If the total complement of eight satellites were all to be interconnected, the numbers escalate as a squared function and really multiply rapidly.

8.6 OVERALL RANKING OF SCENARIOS

As with our prior evaluations, the five Scenarios were ranked against each other and no ties were allowed. The criteria ranked were the criteria established in Task 1. Table 8.6-1 presents the results of this ranking. Scenario V ranks the highest, and Scenario VI-A and VI-B tie for the lowest ranking. Table 8.6-2 then provides the key features and the advantages of each of the Scenarios.

Table 8.6-1

Ranking Of Payload Scenarios

Payload Concept	Scenario				
Criteria	II	IV	V	VI-A	VI-B
Bandwidth-Reuse	4	5	3	1	2
Modulation Efficiency	4	5	1	2	3
Interference	2	1	3	4	5
Reliability/Availability	2	1	3	4	5
Growth	2	1	1	1	2
Complexity	2	1	3	5	4
Utilization	4	3	2	5	1
TOTAL	20	17	16	22	22
RANKING	3	2	1	4+	4-

Table 8.6-2

Overall Ranking Of Scenarios

1 SCENARIO V (HIGH CAPACITY CONUS)

- Optimized to CONUS FSS distribution
- All Rigid Reflectors
- Seven satellite constellation satisfies demand through 2008
- Limited barriers

2 SCENARIO IV (HIGH CAPACITY DBS)

- Single location for multiple users
- Minimizes ground assets
- FSS payload tailored to DBS
- On-board networking

3 SCENARIO II (MEDIUM CAPACITY CONUS)

- Replacement of mid-90's payloads
- High capacity digital Ka-band
- Poor analog balance for CONUS (87% digital)
- No major barriers (orbital location restricted)

4+ SCENARIO VI-A (INTERNATIONAL TRAFFIC)

- Highest throughput scenario
- Lowest utilization/capacity
- Major institutional barriers
- Suitable for integration with scenarios V and VI-B

4- SCENARIOS VI-B (NON-CONUS DOMESTIC)

- Efficient use of orbital arc
- Extremely difficult institutional barriers
- Suitable for integration with scenarios V and VI-A

8.7 ASSESSMENT OF PROBABILITY OF IMPLEMENTATION

In summarizing the comparisons, an assessment of the probability of implementation was also evaluated. It seems likely that a platform similar to Scenario V is a very probable payload to be implemented. It requires that there is a sizeable growth in the market to warrant the large capacity, and that the development of the Ka-band ACTS hardware reduces the risk of use to an acceptable level for commercial implementation. The use of the Ka-band payload is one of the largest contributions to the reduction in per channel cost.

Scenario IV, while ranked second, may actually be the most likely scenario to be developed. This scenario is probably the most technically sound application of satellites. Yet it faces resistance from the extensive plant-in-place in the U.S., and as a result, the DBS industry has been faltering in getting started.

Both Scenarios IV and V are capable of implementation within the regulatory bounds of the U.S., and both could be operated by a single entity.

It is not likely that a Scenario II satellite would be implemented as the Ka-band digital capacity is too large compared to the analog capacity, and the DBS package limits the potential orbital locations.

The remaining two scenarios, VI-A and VI-B, while technically a very sound and efficient use of the arc, would be nearly impossible to implement due to; the number of users involved, the international coordination of governments, the necessary licenses, and nationalistic considerations. The extent of political coordination, and the commonality of system implementation over currently diverse systems, make it unlikely these platforms could be implemented.

SECTION INDEX

9.0 SUMMARY/RECOMMENDATIONS

9.1 OBJECTIVES ACCOMPLISHED

The specific goals of the Communications Platform Payload Definition Study were as follows:

- Determine types of geostationary communications payloads applicable to a large platform, circa 1998.
- Provide concept system architecture.
- Provide payload concept and description.
- Provide comparisons, including estimated cost and technology risk.
- Identify high payoff technology.

All of the above objectives were accomplished. Four of the five scenarios developed demonstrate the capability of significantly reducing the number of required orbital locations to satisfy all of the projected WARC Region 2 satellite communications traffic through the year 2008.

Although the results of this study must be considered preliminary, certain conclusions can be drawn:

- Large platforms may provide significant economies of scale.
- Scenarios VI-A and VI-B can serve all Region 2 non-U.S. year 2008 traffic with one platform of each type.
- A constellation of seven Scenario V, or combinations of Scenarios V, VI-A and VI-B, could serve all U.S. satellite traffic, with the exception of broadcast video, in the year 2008.
- Major institutional, regulatory and insurance issues, exist, especially for Scenarios VI-A and VI-B.

Given the apparent economies of reduction in per circuit cost, the platform warrants further effort, even given the significant barriers to be addressed. The demand for efficient utilization of the geostationary arc, and ultimately the formation of a Region 2 communications organization, could lead to implementation of these large platforms.

9.2 ANSWERS TO STUDY QUESTIONS

The study evaluates the impact of new traffic forecasts, and estimates of new services to be provided, in order to provide NASA quidance in answering the following questions:

- Is the existence of one or more large scale geostationary facilities, each consisting of a payload, providing a single communications service or a variety of communications services, desirable in the mid to late 1990's?
- If so, what are the most viable operational systems (payload, spacecraft, transportation, and space operations) for that time frame?
- For those operational systems, what enabling and supporting technologies are required prior to implementation, and, in particular, which of those technologies is of high technical and/or economic risk?

The results of the study detailed in the prior sections of this report provide NASA the following guidance in answering the questions raised at the outset of the study:

- Economically and technologically, a constellation of large geostationary facilities are desirable in the mid to late 1990's. However, institutional and other factors may be insurmountable barriers to implementation.

- The most commercially viable payload would be similar to the Scenario V payload. This payload can be replicated as many times as necessary to satisfy the total CONUS demand.

- The major payload technological risks are dual polarization reuse at Ka-band, high efficiency modulators and demodulators, high speed programmable frequency shifters, large rigid reflectors for high frequency dual polarization, lightweight on-board baseband processors and RF equipment, and spacecraft bus technogies to support the large platform.

9.3 RECOMMENDED FUTURE ACTIONS

During the study, a number of items that required further study effort, as well as technology development, were identified. Among the more signifiant of these items were:

- The economics for using space station capabilities need to be evaluated as they mature.

- Continued development of baseband processing capacity and flexibilities as more direct to user systems are implemented.

- The next step to continue the payload development is to select a concept and institute detailed system implementation. The traffic distributional characteristics need to be validated, and further optimization of the antenna and transponder configuration should be performed.

- Subsequently, the integration of the payload to a specific bus and transportation interface is required. Then the specific platform is ready for hardware development.

Given the potential economic benefits, and the long term need to minimize the number of orbital locations utilized, a continued development of a large geostationary communications facility is an appropriate application of national resources. Even using the large capacity payloads defined in this study, assuming that only 50 orbital slots are available to CONUS, and that traffic will double every 10 years, the orbital arc will be saturated before 2030; thus, there is a continuing need to increase capacity per orbital location in the long term, and the proliferation of small satellites will not make economic sense.

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