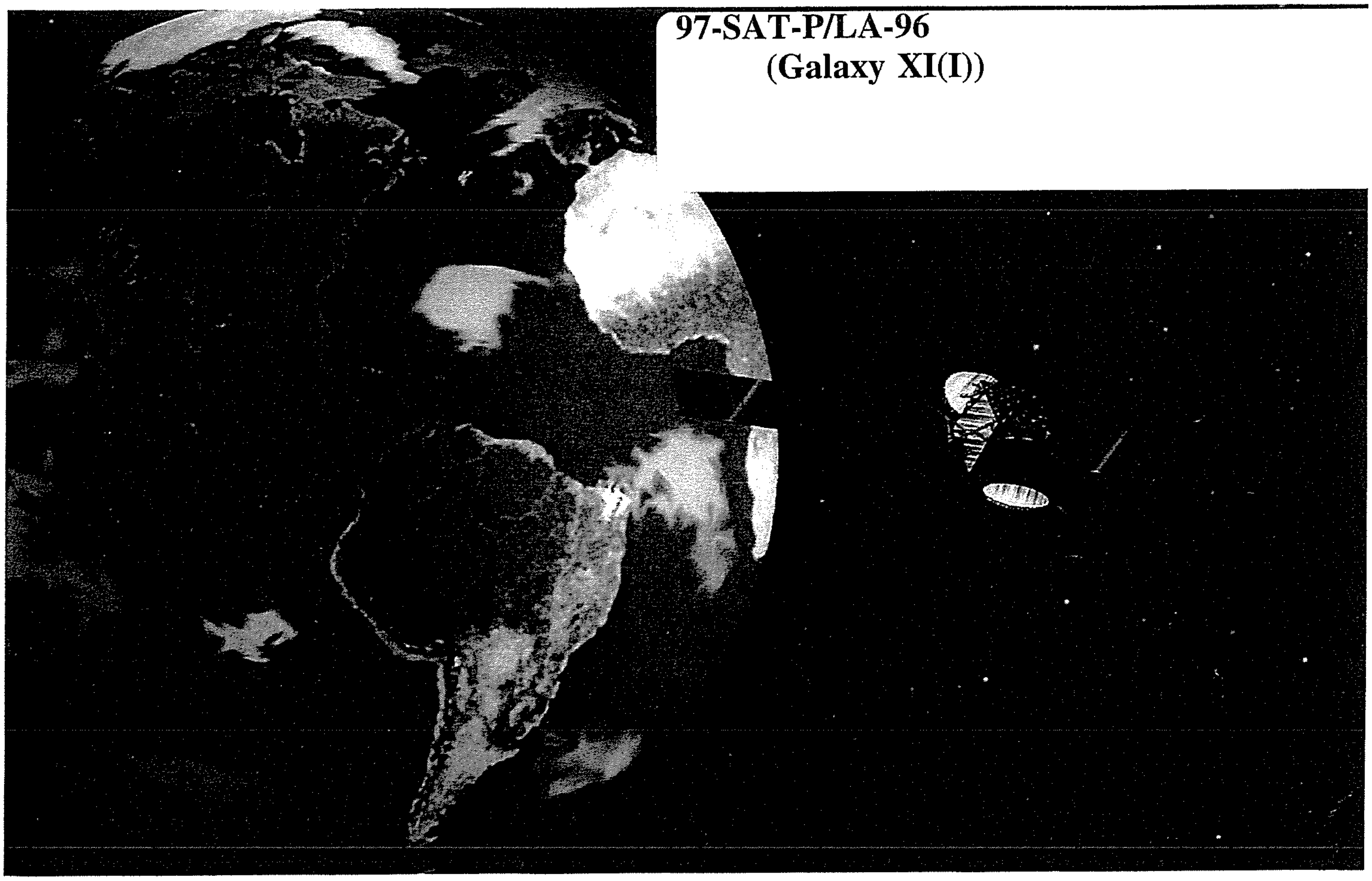
FCC/MELLON APR 19 1996

Application of Hughes Communications Galaxy, Inc. Before the Federal Communications Commission

97-SAT-P/LA-96
(Galaxy XI(I))



For One Fixed Communications Satellite to be Part of the Galaxy Satellite System

Friday, April 19, 1996

HUGHES
COMMUNICATIONS
A HUGHES ELECTRONICS COMPANY

Received

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Satellite Policy Branch
International Bureau

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Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of the Application of HUGHES COMMUNICATIONS GALAXY, INC. For Authority to Construct and Launch A Fixed-Sevice Communications Satellite, and to Operate that Satellite in Geostationary Orbit	)	File No.

APPLICATION

Hughes Communications Galaxy, Inc. ("Hughes"), a wholly-owned subsidiary of Hughes Electronics Corporation, hereby requests authority to construct, launch and operate a fixed-service communications satellite, to be known as "Galaxy XI(I)," which will provide state-of-the-art satellite services at 13.75-14.0 GHz, 11.45-11.70 GHz, 14.0-14.5 GHz and 11.7-12.2 GHz .

Galaxy XI(I) will provide a wide range of affordable satellite services between and among the United States, Mexico, the Caribbean, Central America and South America to a variety of commercial and residential users.

Hughes proposes to operate Galaxy XI(I) at 91° W.L. Operation at this location will provide optimal elevation angles throughout the contiguous United States, Mexico, the Caribbean, and Central and South America for end user terminals, and offer good elevation angles for uplink sites. It also will afford certain operating efficiencies with Hughes' Galaxy VII(H) satellite, which already operates at that location.

In sum, grant of this application will promote efficient use of the spectrum and also will meet the growing demand for satellite services.

BACKGROUND

Hughes operates a fleet of communications satellites that is comprised of the in-orbit Galaxy I-R(S), V-W, and VI C band satellites, the in-orbit SBS-4, SBS-5 and SBS-6 Ku band satellites, and the in-orbit hybrid (combined C and Ku band) Galaxy III(H), IV(H) and VII(H) satellites. In addition, a Hughes affiliate operates the fleet of Leasat satellites that provides essential communications services to the United States Navy.

Through this fleet of satellites, Hughes has provided a wide variety of reliable satellite services for over a decade. Hughes satellites provide the means for commercial television and radio distribution, teleconferencing, video backhaul, high speed image transmission (e.g., medical imaging), and private data networks, among other services. Countless end users across the country rely on these services every day.

Hughes also has launched and now operates the first United States satellite system to provide DBS service. A Hughes affiliate (DIRECTV^sm^) has initiated the first true DBS service in the United States using this system. DIRECTV^sm^ provides direct-to-home video service to 18 inch antennas that are mass marketed and easily installed.

As the United States domestic satellite industry has matured, Hughes has begun to explore new markets for its satellite services and has identified the Latin American region as a market whose needs are inadequately met. Hughes' in-orbit Galaxy III(H) satellite soon will provide the first direct-to-home (DTH) video service to Mexico, the Caribbean and South and Central America. In addition, Hughes currently has pending before the Commission an application for its Galaxy VIII(I) satellite, at 95° W.L., to allow Hughes to provide follow-on Ku band satellite service to the same region.[1] After the launch of Galaxy VIII(I), Hughes anticipates returning the Ku band capacity of Galaxy III(H) to United States service.

The commitment of Hughes and its affiliates to provide satellite services is clearly demonstrated by the years of service that Hughes has provided over its existing fleet of satellites and by the significant investments it has made to continue operation of that fleet into the next century. Galaxy XI(I) represent Hughes' plan to expand its existing services to meet growing user needs.

ITEM A. Name and Address of Applicant

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ITEM C. System Description

1. Generally

Galaxy XI(I) will consist of a space segment and a ground segment. The space segment will consist of an in-orbit satellite and an associated launch vehicle. The satellite will be capable of being launched by one of the currently available commercial

1. FCC File Nos. 33-DSS-ML-94; CSS-94-014-MP/ML.

launch vehicles. The satellite will be located at 91° W.L. and be maintained in geosynchronous orbit (to a tolerance of ±0.05°) and at zero orbital inclination (with a tolerance of ±0.05°). The satellite consists of two Ku-band payloads; one payload will provide coverage to South America in the "standard" Ku band (uplink: 14.0 GHz -- 14.5 GHz, downlink: 11.7 GHz -- 12.2 GHz), and the other payload will provide coverage to North America, the Caribbean, South America, and Central America in the "extended" Ku band (uplink: 13.75 GHz -- 14.0 GHz, downlink: 11.45 GHz -- 11.70 GHz).[2/]

The ground segment for Galaxy XI(I) will consist of: (i) earth stations to perform the necessary telemetry, tracking, and command ("TT&C") functions for the spacecraft, and (ii) transmit/receive or receive-only earth stations to provide communications services.

Hughes already employs a sophisticated network of earth stations to perform TT&C. Hughes owns and operates the Operations Control Center ("OCC") in El Segundo, California, where the complex coordination and integration of the space and terrestrial segments of the satellite network is focused. The Hughes Mission Control Center ("HMCC") directs the satellite through transfer orbit and on-orbit deployment activities and performs in-orbit testing once a satellite is in its geostationary position. Once operational, the spacecraft is station-kept and controlled from the OCC.

Telemetry data from the satellite is received by TT&C earth stations in Castle Rock, Colorado and Spring Creek, New York. This information is then transmitted to the

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2. The Commission recently has proposed to adopt for U.S. licensing purposes the existing ITU allocations for FSS use of the 13.75 - 14.0 GHz band. In the Matter of Amendment of Parts 2 and 25 of the Commission's Rules to Allocate the 13.75-14.0 GHz Band to the Fixed-Satellite Service, Notice of Proposed Rulemaking, ET Docket No. 96-20, FCC 96-55 (released February 23, 1996).

OCC over communications lines where it is processed, archived, and analyzed. Commands to control the spacecraft are issued from the OCC and subsequently routed to the TT&C earth stations for processing and uplinking to the satellite. Although the earth stations are under the overall control of the OCC, each earth station may operate independently of the OCC, if necessary.

Hughes' existing TT&C stations and the OCC will be modified to provide the necessary services for Galaxy XI(I). Each TT&C station will include two antennas that are 9.1 meters in diameter, two 13 GHz transmitters and two 11 GHz receivers. In addition, a beacon-tracking carrier will be provided by the Castle Rock TT&C station for satellite antenna pointing control.

It is anticipated at this time that the vast majority of the transmit/receive or receive-only earth stations used to communicate with Galaxy XI(I) will be owned by the end users of the service. They will be owned and licensed in accordance with local law, and, in most cases, will be located at the premises of the end users.

2. Demand for Services

Over the past several years, a number of factors have stimulated an interest in the provision of satellite service to and from Latin America. Among other things, the proximity of Latin America to the U.S. has exposed that region to the vast entertainment information and other business resources available in the U.S. In fact, many C band satellite services that are intended primarily for U.S. distribution are received and redistributed in Latin America and many U.S. VSAT networks include connection points in Latin America. All of these factors contribute to an atmosphere that will support a burgeoning Latin American satellite service market.

The demand for Latin American satellite capacity is demonstrated by the fact that capacity on Hughes' Galaxy III(H) and VIII(I) satellites already is fully committed. Thus, Galaxy XI(I) will be capable of providing services that Hughes otherwise would be unable to provide. The demand for Galaxy XI(I) transponder capacity is expected to come not only from the traditional users of satellites (i.e., television and radio networks and common carriers) but also from universities, corporations, medical and scientific associations, and governmental bodies.

Galaxy XI(I) also supports the continuing demand for satellite capacity that can serve the U.S. Hughes' Galaxy VII(H) satellite already supports a large, installed base of U.S. customers at the 91° W.L. location, which includes many cable and broadcasting programmers. As the Commission is aware, the demand for satellite capacity to distribute programming is being fueled by the development of many new delivery methods for video and audio programming, including DBS, DAB, wireless cable, and open video systems (OVS). The extended Ku band payload on Galaxy XI(I) (13.75-14.0 GHz, 11.45-11.7 GHz) will provide valuable expansion capacity for existing users at 91° W.L. Significantly, existing "standard" Ku band earth station equipment can be used to communicate with the "extended" Ku band payload on Galaxy XI(I). Thus, Galaxy XI(I) offers users of Galaxy VII(H) the ability to meet future growth needs without the need for an additional antenna or other costly upgrades.

Galaxy XI(I) will be capable of providing the wide range of satellite services typically provided today at Ku band, including programming distribution, VSAT service, video backhaul, teleconferencing, and high-speed image transmissions, among others. Uplinks for this service will be located in Latin America as well as in the United States.

Thus, Hughes anticipates that the capacity of Galaxy XI(I) will provide international (*e.g.*, United States to and from Mexico), domestic (*e.g.*, intra-U.S. and intra-Brazil) and foreign regional (*e.g.*, Central American) service. In sum, Galaxy XI(I) will allow Hughes to meet the growing demand for domestic and international communications services.

Grant of this application will foster the development of new markets for U.S. businesses, information providers, and equipment manufacturers and will foster increased competition in the provision of international communications services.

ITEM D. General Technical Information

1. Operational Characteristics

a. Frequency Plan

Galaxy XI(I) will operate using the 13.75 to 14.0 GHz and 14.0 to 14.5 GHz frequency bands for ground-to-space (uplink) transmissions and the 11.45 to 11.7 GHz and 11.7 and 12.2 GHz frequency bands for space-to-ground (downlink) transmissions.

The satellite will contain 48 active transponder channels, consisting of 27 MHz channels. It will employ full frequency reuse by using dual polarization for both uplink and downlink frequencies. Twenty-four of the transponders will transmit horizontally polarized signals, and the other twenty-four will transmit vertically polarized signals. The radio frequency and polarization plans for the spacecraft are shown in Figures D-1 and D-2. Center frequencies and polarization assignments are listed in Tables D-1 and D-2.

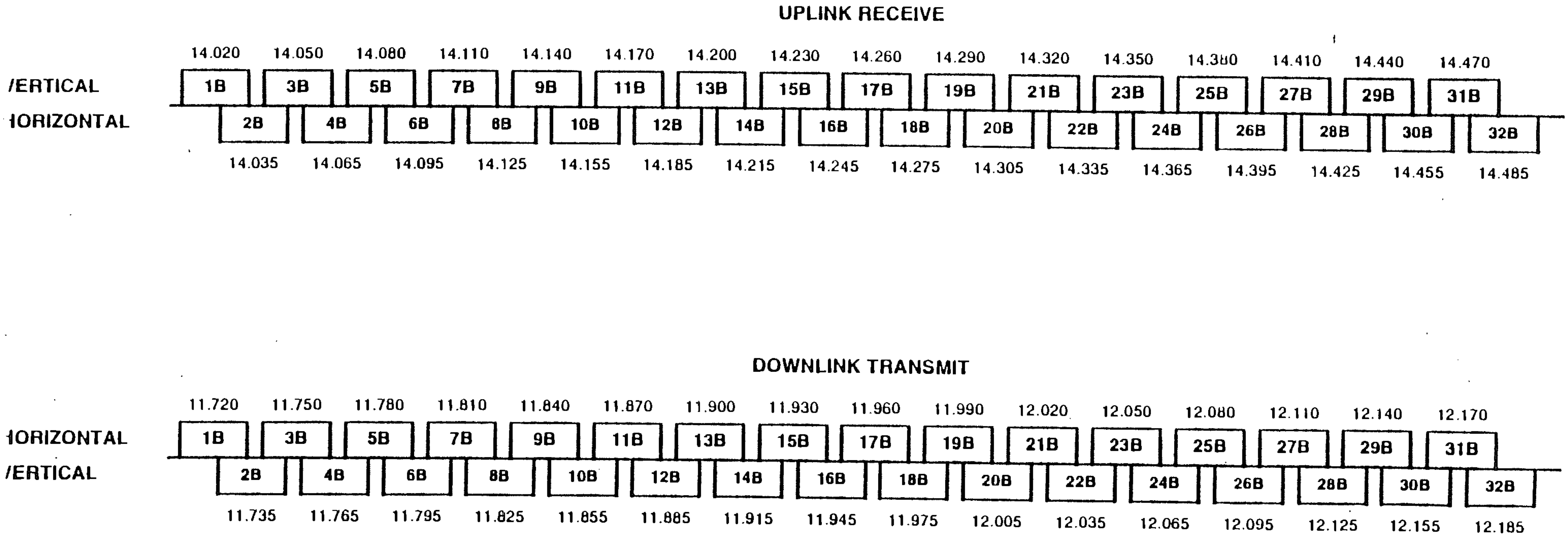


FIGURE D-1
STANDARD Ku-BAND
FREQUENCY AND POLARIZATION PLAN
GALAXY XI(I) - 91° W.L.

TABLE D-1
STANDARD Ku BAND
FREQUENCY AND POLARIZATION ASSIGNMENTS
GALAXY XI(I) - 91° W.L.

Channel	Uplink Polarization	Uplink Center Frequency (GHz)	Downlink Polarization	Downlink Center Frequency (GHz)	Transponder Bandwidth (MHz)
1B	V	14.020	H	11.720	27
2B	H	14.035	V	11.735	27
3B	V	14.050	H	11.750	27
4B	H	14.065	V	11.765	27
5B	V	14.080	H	11.780	27
6B	H	14.095	V	11.795	27
7B	V	14.110	H	11.810	27
8B	H	14.125	V	11.825	27
9B	V	14.140	H	11.840	27
10B	H	14.155	V	11.855	27
11B	V	14.170	H	11.870	27
12B	H	14.185	V	11.885	27
13B	V	14.200	H	11.900	27
14B	H	14.215	V	11.915	27
15B	V	14.230	H	11.930	27
16B	H	14.245	V	11.945	27
17B	V	14.260	H	11.960	27
18B	H	14.275	V	11.975	27
19B	V	14.290	H	11.990	27
20B	H	14.305	V	12.005	27
21B	V	14.320	H	12.020	27
22B	H	14.335	V	12.035	27
23B	V	14.350	H	12.050	27
24B	H	14.365	V	12.065	27
25B	V	14.380	H	12.080	27
26B	H	14.395	V	12.095	27
27B	V	14.410	H	12.110	27
28B	H	14.425	V	12.125	27
29B	V	14.440	H	12.140	27
30B	H	14.455	V	12.155	27
31B	V	14.470	H	12.170	27
32B	H	14.485	V	12.185	27

H = Horizontal Polarization
V = Vertical Polarization

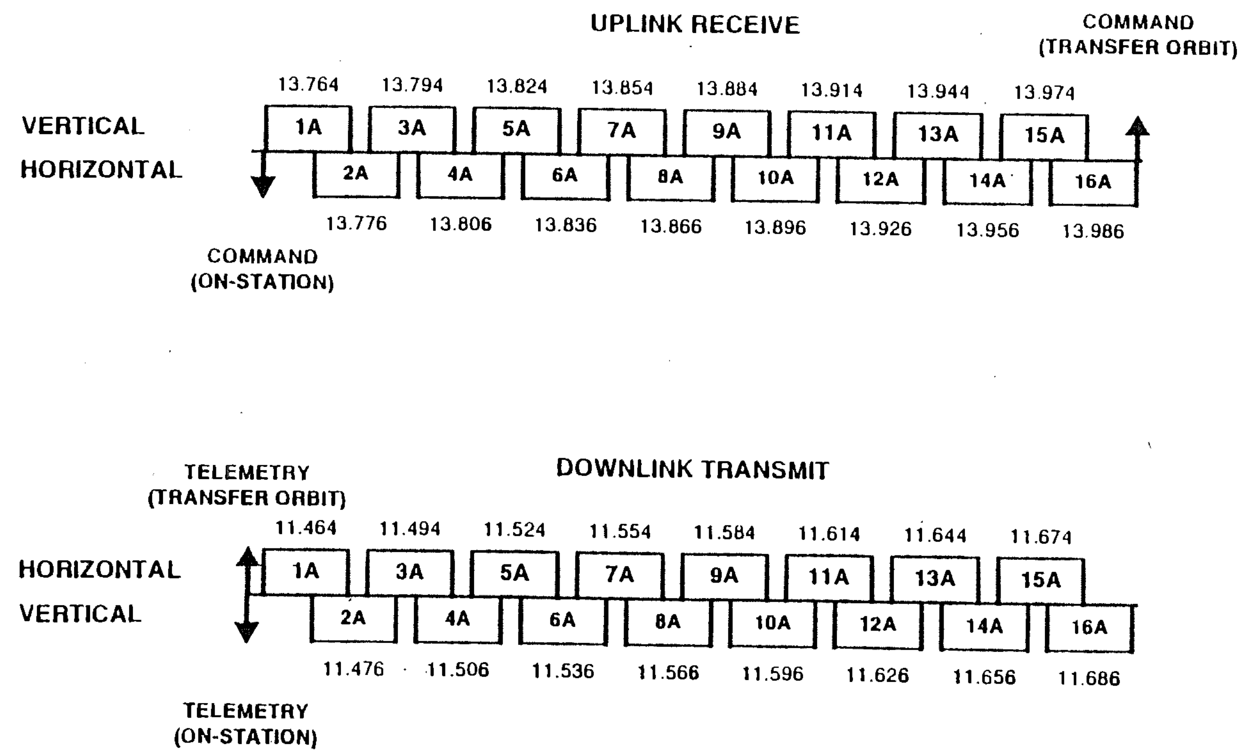


FIGURE D-2
EXTENDED Ku-BAND
FREQUENCY AND POLARIZATION PLAN
GALAXY XI(I) - 91° W.L.

TABLE D-2
EXTENDED Ku BAND
FREQUENCY AND POLARIZATION ASSIGNMENTS
GALAXY XI(I) - 91° W.L.

Channel	Uplink Polarization	Uplink Center Frequency (GHz)	Downlink Polarization	Downlink Center Frequency (GHz)	Transponder Bandwidth (MHz)
1A	V	13.764	H	11.464	27
2A	H	13.776	V	11.476	27
3A	V	13.794	H	11.494	27
4A	H	13.806	V	11.506	27
5A	V	13.824	H	11.524	27
6A	H	13.836	V	11.536	27
7A	V	13.854	H	11.554	27
8A	H	13.866	V	11.566	27
9A	V	13.884	H	11.584	27
10A	H	13.896	V	11.596	27
11A	V	13.914	H	11.614	27
12A	H	13.926	V	11.626	27
13A	V	13.944	H	11.644	27
14A	H	13.956	V	11.656	27
15A	V	13.974	H	11.674	27
16A	H	13.986	V	11.686	27

H = Horizontal Polarization
V = Vertical Polarization

In addition to the 48 uplink and downlink channel frequencies, two command uplink and two telemetry downlink frequencies are shown in the plan. During transfer orbit, command signals will be received through a bicone antenna at the higher band-edge frequency. When the satellite is at its final orbit position, the primary command uplink will be at the lower band-edge frequency through the large communications reflector, with the bicone link available as a backup. The command uplink will use government-approved command encryption. The two telemetry frequencies shown in the plan will allow simultaneous transmission of two telemetry data streams during transfer orbit or separate transmission of telemetry data streams.

The satellite communication subsystem will include appropriate filtering at the inputs and outputs of the satellite to minimize internal interchannel interference, noise effects outside the satellite frequency band, and out-of-band spurious transmissions.

b. Emission Designators

Commands to the satellite from the TT&C station will be angle-modulated with a large deviation on the uplink carrier. The satellite will be equipped with government-approved command encryption equipment in order to secure command transmission. Telemetry data from the satellite will be angle-modulated on the downlink carrier. The emission designators for the various signals are as follows:

Signal	Emission Designator
Command	300KF9D
Telemetry/Ranging	120KF9D
Single carrier TV	24M0F3F
Digital (T1) data	1M17G1W
Digital (64 kbps) data	48K6G1W
Digital TV (24 Mbps)	24MOG7W
Digital TV (30 Mbps)	24M0G7W

c. Communications Coverage

The "standard" Ku band payload (11.7 - 12.2 and 14.0 - 14.5 GHz) will provide coverage of South America, and the "extended" Ku band payload (11.45 - 11.7 and 13.75 - 14.0 GHz) will provide coverage of North America, the Caribbean, Central America and South America. The standard Ku band payload is limited to South American coverage in order to ensure adequate spatial separation from Hughes' standard Ku band payload on Galaxy VII(H) at 91° W.L. The satellite uses shaped receive and transmit beams for both polarizations.

Figures D-3 and D-6 illustrate the coverage areas of the Galaxy XI(I). Representative G/T and EIRP patterns as a function of satellite antenna azimuth and elevation are shown in more detail in Figures D-4, D-5, D-7 and D-8. Satellite SFD may be calculated by using the equations specified at the top of Figures D-4 and D-7.

FIGURE D-3
GALAXY XI(I) STANDARD KU-BAND COVERAGE
91° WEST LONGITUDE

FIGURE D-4
GALAXY XI(I) STANDARD KU-BAND G/T PATTERN
HORIZONTAL/VERTICAL POLARIZATION
14.0 - 14.5 GHz
91° WEST LONGITUDE

PEAK GAIN = 33.9 dBi

PEAK G/T = 4.0 dB/K, SFD = -(G/T + 93) @ 5 dB COMMANDABLE STEP ATTENUATION

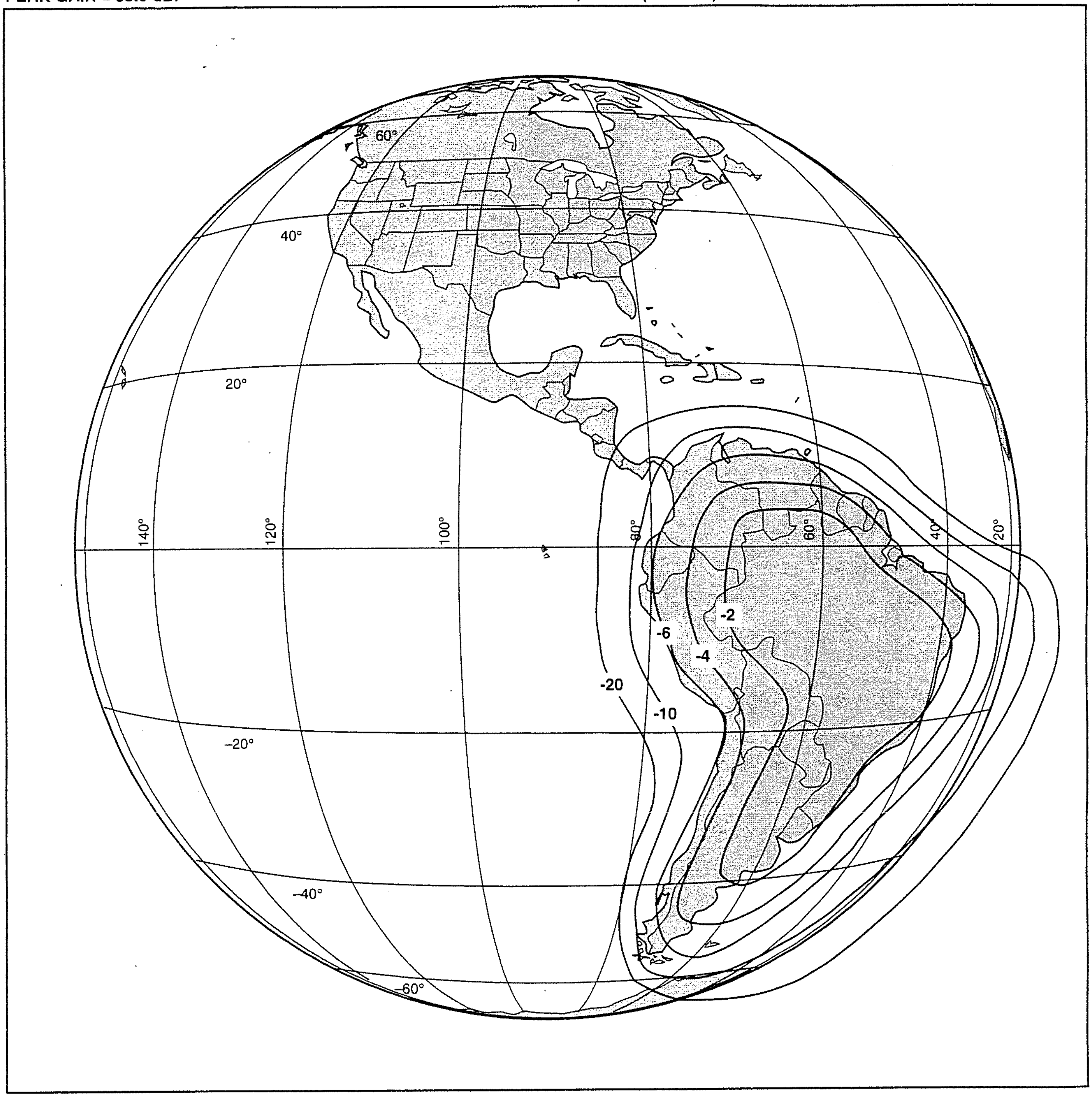


FIGURE D-5
GALAXY XI(I) STANDARD KU-BAND EIRP PATTERN
HORIZONTAL/VERTICAL POLARIZATION
11.7 - 12.2 GHz
91° WEST LONGITUDE

PEAK GAIN = 32.9 dBi

PEAK EIRP = 53.0 dBW

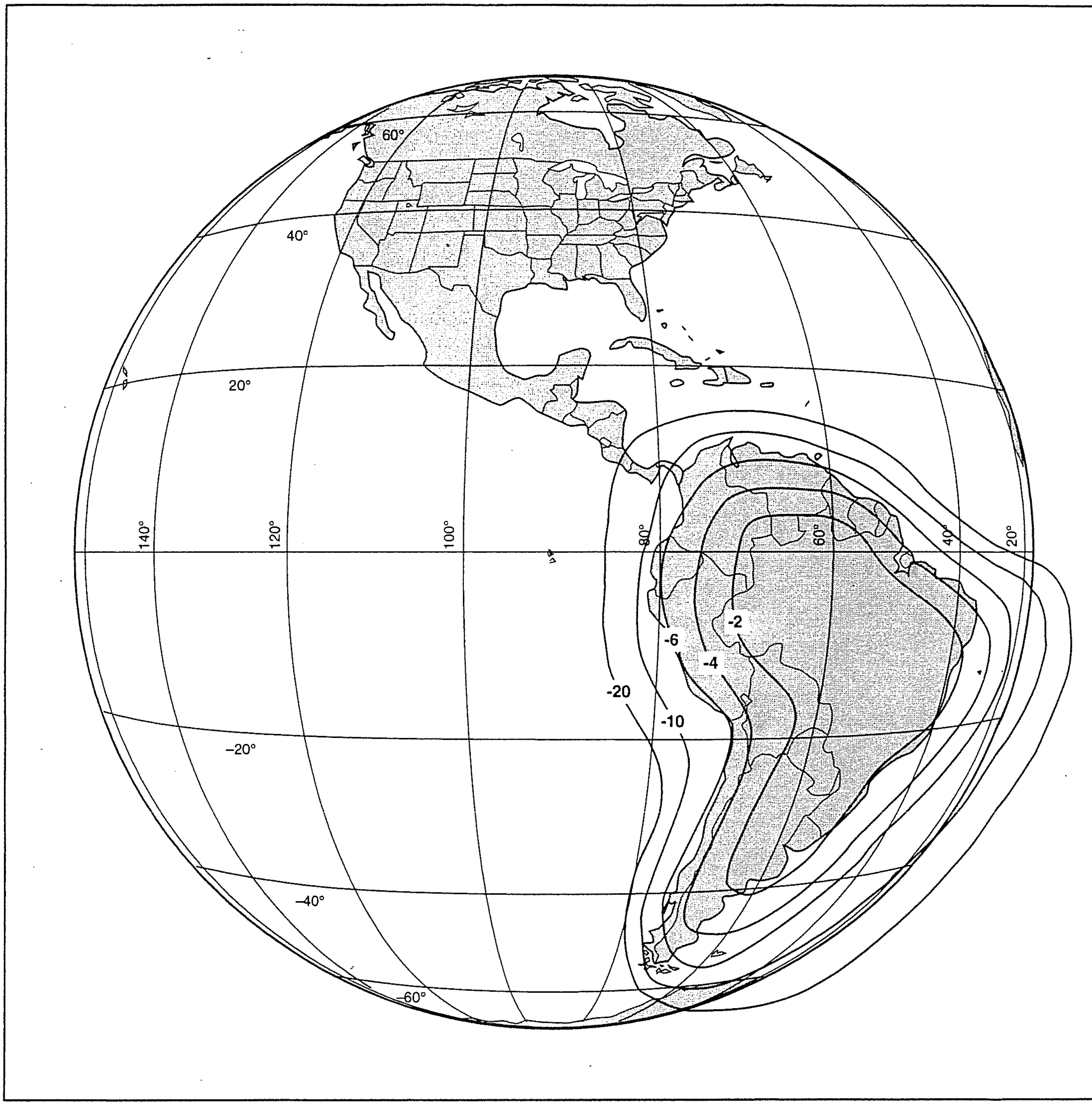


FIGURE D-6
GALAXY XI(I) EXTENDED KU-BAND COVERAGE
91° WEST LONGITUDE

FIGURE D-7
GALAXY XI(I) EXTENDED KU-BAND G/T PATTERN
HORIZONTAL/VERTICAL POLARIZATION
13.75 - 14.0 GHz
91° WEST LONGITUDE

PEAK GAIN = 31.5 dBi

PEAK G/T = 4.0 dB/K, SFD = -(G/T + 93) @ 5 dB COMMANDABLE STEP ATTENUATION

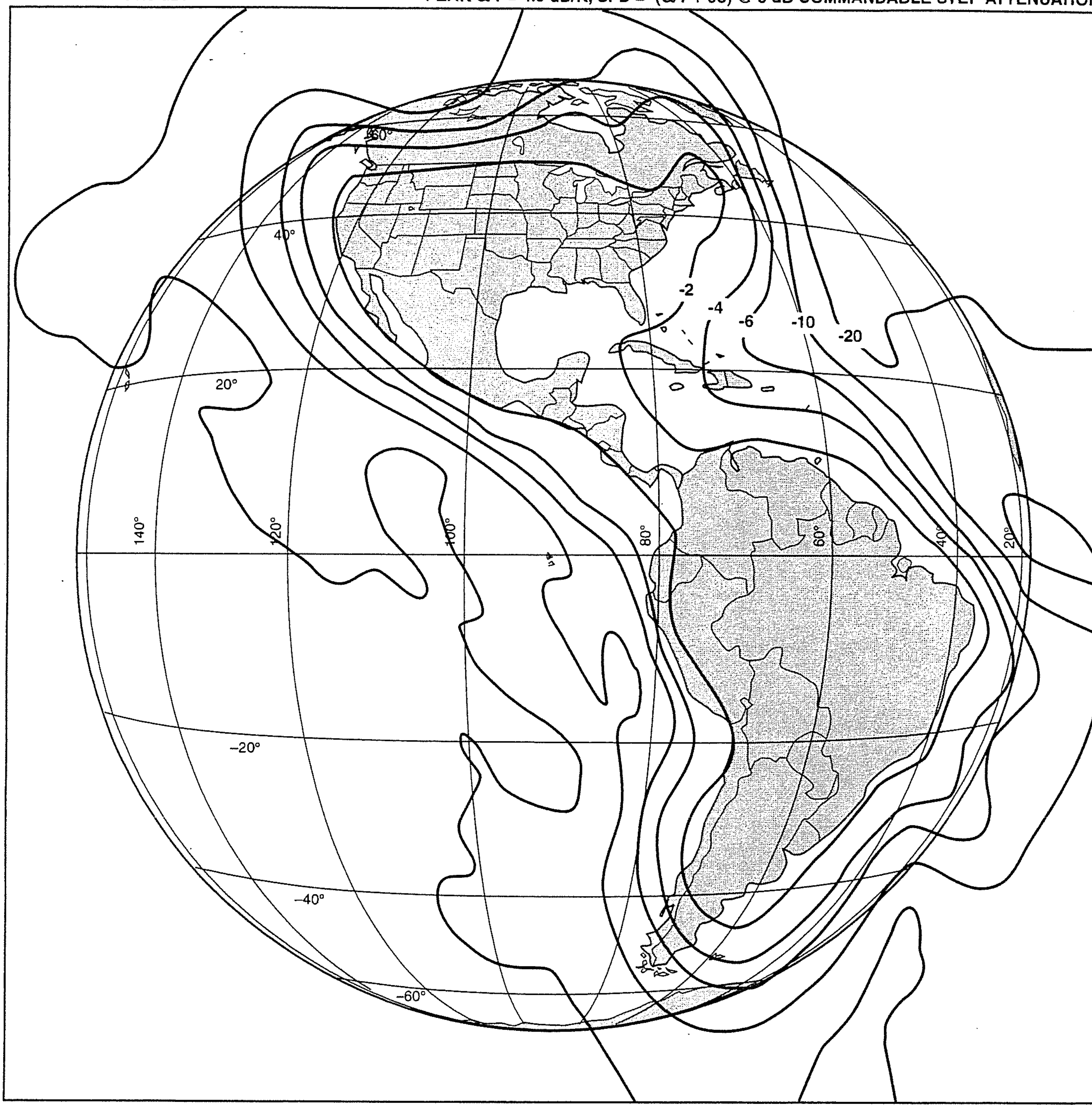
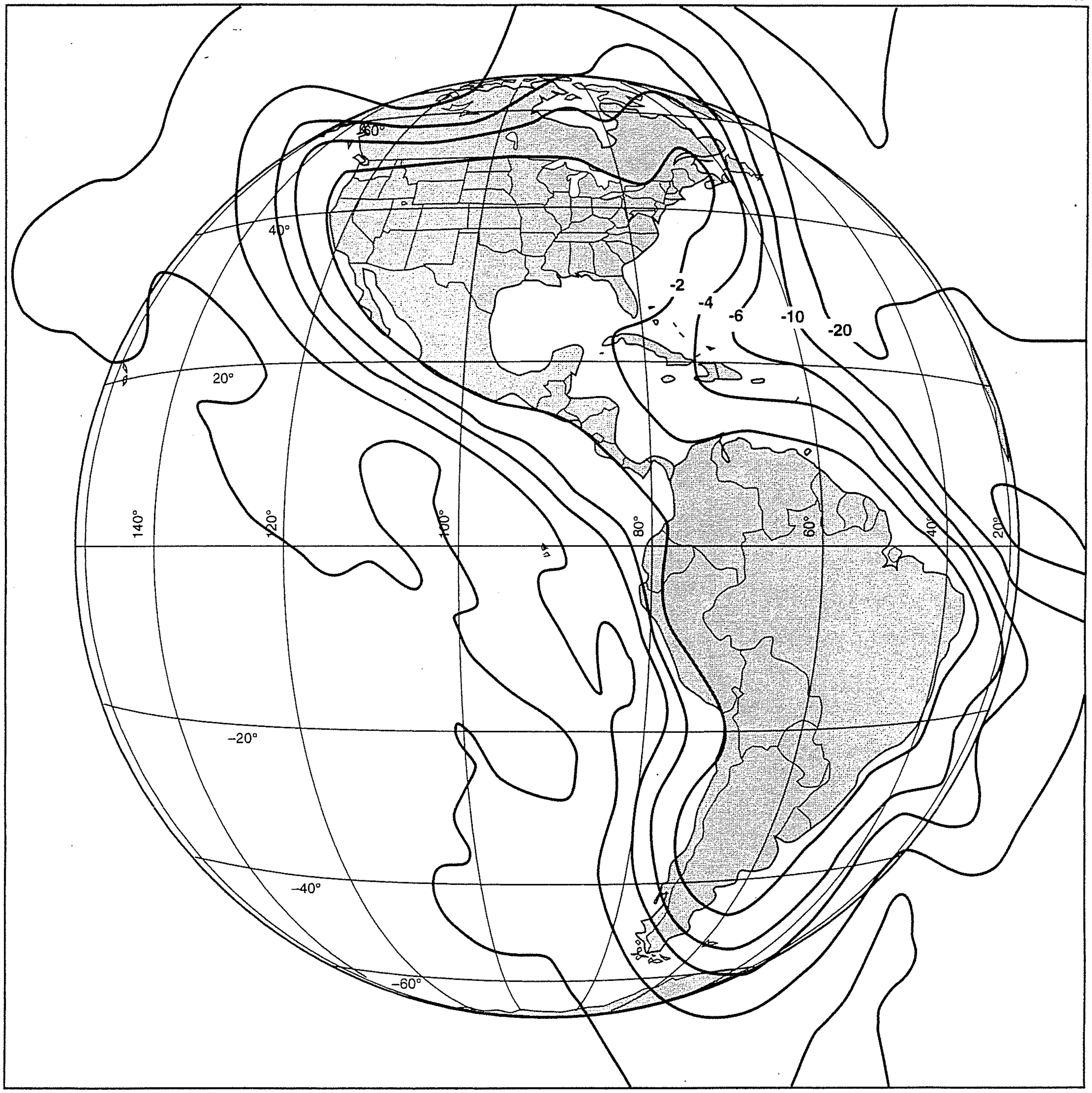


FIGURE D-8
GALAXY XI(I) EXTENDED KU-BAND EIRP PATTERN
HORIZONTAL/VERTICAL POLARIZATION
11.45 - 11.7 GHz
91° WEST LONGITUDE

PEAK GAIN = 30.5 dBi

PEAK EIRP = 50.6 dBW



d. Power Flux Density

The maximum power flux densities for frequencies 11.45 - 11.7 GHz are specified in Section 25.208 of the Commission's rules. 47 CFR § 25.208(b). Because power flux density level may be exceeded when the carrier of a single carrier system (such as FM - TV) is temporarily unmodulated, Hughes plans to employ appropriate energy dispersal techniques for such carriers. For FM - TV, a 4 MHz peak-to-peak energy dispersal deviation is used. From the transmit antenna gain contours of Figure D-8 and the elevation angle computations, it is found that the worst scenario for the maximum flux density requirment occurs for Galaxy XI(I) emitting toward Alaska, in which case:

saturated EIRP	=	42 dBW
path loss	=	163.3 dBm^2
elevation angle	=	5°

The total flux density in 4 MHz band at that location is 42 - 163.3 = -121.3 dBW/m^2. For an energy dispersal bandwidth of 4 MHz, the amount of flux density in an 4 kHz band is -121.3 - 10xlog(4 MHz/4kHz) = -151.3 dBW/m^2, thus being below the FCC limitation by a margin of 1.3 dB. More typically the margin is considerably higher, mainly due to higher elevation angles and predominant use of digital carriers which have larger spreading and/or operate in nonsaturated environments.

2. Satellite Characteristics

The major spacecraft characteristics of the spacecraft are shown below in Table D-3. The estimated weight and power budgets, listed in Tables D-4 and D-5, are based on a mission life of 12 years and assume sufficient redundancy to allow for random failures.

Tables D-6 and D-7 show the estimated receive gain-to-noise temperature (G/T) and EIRP budgets, respectively.

TABLE D-3

SPACECRAFT CHARACTERISTICS

General	
Spacecraft bus	Hughes, HS-702
Stabilization	
Transfer orbit	Spin stabilization
On station	3 axis, momentum bias
Mission life	12 years
Design life	15 years
Eclipse capability	100 percent (48 channels)
Stationkeeping	
North-South (orbital inclination)	±0.05°
East-West (longitudinal drift)	±0.05°
Antenna pointing	
Normal (Precision two-axis RF beacon tracking)	±0.1° N-S and E-W
Backup (Earth sensor)	±0.2° N-S and E-W
Beam rotation (antenna axis attitude)	±0.25°

TABLE D-3 (cont'd.)

Communications	
Frequency	
Receive	14000 to 14500 MHz 13750 to 14000 MHz
Transmit	11700 to 12200 MHz 11450 to 11700 MHz
Polarization	Uplink: Horizontal and Vertical, linear Downlink: Horizontal and Vertical, linear
Number of transponders	48
Transponder bandwidth	27 MHz
Receive G/T	2 dB/K, edge of coverage
Saturated Transponder gain	180 to 197.5 dB with automatic level control
Receive saturation	-100 to -82.5 dBW/m^2 at 2 dB/K contour and adjustable by ground command in 2.5 dB steps
Transmit EIRP	53.0 dBW (peak)
Transmitter (TWTA) RF power	135W (per transponder)
Transmitter redundancy	Six rings of 10 for 8
Emission limitations (percentage of authorized bandwidth)	
50 to 100%	>20 dB attenuation in any 4 KHz
100 to 250%	>40 dB attenuation in any 4 KHz
Greater than 250%	>50 dB attenuation in any 4 KHz

Tracking, Telemetry and Command	
Frequency	
Command, Ranging and Tracking Beacon	13997 to 14000 MHz transfer orbit 13750 to 13753 MHz on station
Telemetry and Ranging	2 signals within 11450.0 to 11452.5 MHz
Polarization	
Command, Ranging and Tracking	
Transfer Orbit	Vertical, linear
On Station	Horizontal, linear
Telemetry/Ranging	Vertical and horizonal, linear
Peak Deviation	
Command, Ranging and Tracking Beacon	$\pm$300 KHz
Modulation Index	
Telemetry/Ranging	1.0 $\pm$ 0.1 radians
Telemetry EIRP	
Transfer Orbit	7.0 dBW maximum
On Station	22.0 dBW maximum
Command Threshold (flux density)	
Transfer Orbit	-82.0 dBW/m^2
On Station	-111.0 dBW/m^2

TABLE D-3 (cont'd.)

Coverage		
Command		
	Transfer Orbit	Omni
	On Station	Reflector
Telemetry		
	Transfer Orbit	Omni
	On Station	Reflector

TABLE D-4
WEIGHT BUDGET

Category	Weight, Kgs.
Communications subsystem weight	1,000
Bus weight	1,300
Estimated spacecraft dry weight	2,300
Fuel, expendables	1,400
Total launch weight	3,700

TABLE D-5
POWER BUDGET

Category	Power, Watts
Communications subsystem power	11,510
Bus power	1,200
Total Power Requirement	12,710
Beginning-of-Life array capability	14,670
Beginning-of-Life Margin	1,960
End-of-Life array capability (12 years)	13,180
End-of-Life Margin	470

TABLE D-6
SATELLITE UPLINK G/T BUDGET

Parameter	Value
Antenna gain (-2dB contour)	29.5 dBi
System noise temperature	27.5 dB-K
G/T	2.0 dB/°K

TABLE D-7
SATELLITE DOWNLINK EIRP BUDGET

Parameter	Value
TWTA output power (135 W)	21.3 dBW
Output losses	1.2 dB
Effective antenna gain (-2dB contour)	28.5 dB
	48.6 dBW

3. Satellite Description

a. Generally

The on-orbit satellite configuration is shown in Figure D-9. The spacecraft bus is based upon the Hughes Space and Communications Company HS-702 series body-stabilized bus. The satellite design is compatible with launch by one of the currently available commercial launch vehicles. Final injection into geosynchronous orbit is accomplished by an integral liquid propulsion system.

Deployment of antennas and solar cell arrays takes place in four separate operations. The first operation consists of erecting the omni antenna for the command, telemetry, and ranging functions to its transfer orbit configuration. After the spacecraft has been injected into synchronous orbit, the large communications antennas are deployed and the solar cell arrays are extended. Finally, the omni antenna is deployed to its final on-orbit configuration.

b. Structural Design

The spacecraft takes advantage of a modular design for ease of manufacturing and integration. Communications equipment is mounted on the payload module that forms the forward portion of the spacecraft. Heat pipes are embedded in the north and south faces to distribute thermal dissipation over these prime radiating surfaces. Propulsion equipment is mounted on a central structure with tank loads being carried by a cylinder into the launch vehicle interface. A bus module forms the aft portion of the spacecraft. The propulsion equipment is integrated into the bus module.

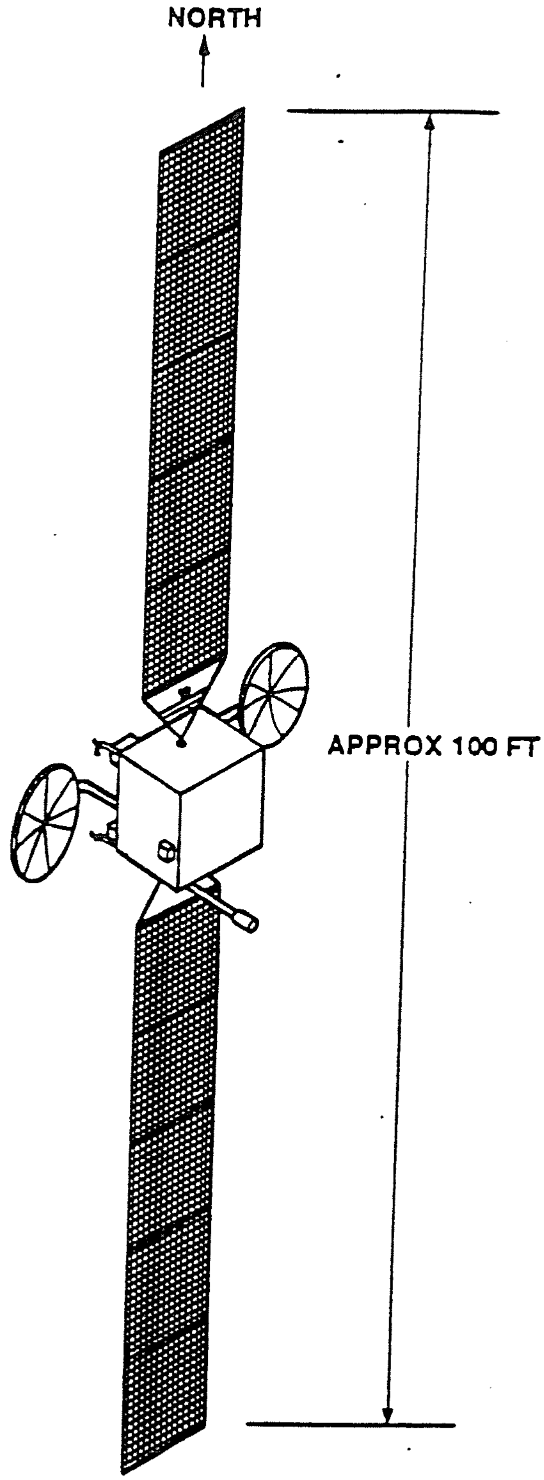


FIGURE D-9

ON ORBIT CONFIGURATION

HC940608

c. Thermal Control

Thermal control is accomplished with heaters and heat pipes. The primary payload heat rejection surfaces are the north and south facing radiators, which have been sized using flight data for quartz mirror degradation predictions. Battery temperatures are maintained within limits dictated by life consideration using direct dedicated radiating surfaces on the north and south faces plus heaters.

d. Power

Satellite power will be provided by solar arrays of fused silica-covered gallium arsenide solar cells that convert solar energy to the required electrical power. The arrays are deployed after the satellite attains synchronous orbit.

Nickel-Hydrogen batteries provide sufficient electrical power during eclipse to operate the full communications and housekeeping loads.

The electrical power subsystem has been designed so that no single failure in the subsystem will cause a spacecraft failure. Sufficient power will be available at the end of the satellite's life to support all 48 active transponder channels and the housekeeping loads.

e. Attitude Control

The Attitude Control Subsystem (ACS) maintains the spacecraft attitude during the transfer orbit, initial acquisition period, and geostationary operations. The ACS employs sun and earth sensors to perform all attitude determination functions. Beacon tracking is the prime pointing mode providing steady-state accuracy of ± 0.5 degrees. Control of attitude and spacecraft orbit is accomplished by using momentum wheels and by pulsed or continuous firing of selected thrusters by the ACS during ground controlled maneuvers.

f. Propulsion

The spacecraft will use both a liquid bipropellent and a Xenon Ion propulsion system (XIPS). The liquid bipropellant system is based on proven technology from the Leasat and Intelsat VI programs. XIPS technology is being incorporated into Galaxy VIII(I). High performance is achieved through the use of a hypergolic propellant: nitrogen-tetroxide ($N_2 0_4$) oxidizer and monomethyl-hydrazide (MMH) fuel, or by applying electrostatic forces to positively charged ions of Xenon, respectively.

g. Communication Payload

(i) Antenna Subsystem

The satellite antenna subsystem contains two solid, circular shaped surface reflectors. One of these reflectors is used for standard Ku band communications; the other reflector is used for extended Ku band communications. Each reflector is fed by two feed horns which are frequency diplexed to allow each horn to be used for transmit and receive functions.

Relative to the desired polarization, the cross-polarization component of the receive and transmit signals will be at most -30 dB over the required coverage regions.

(ii) Antenna Pointing

The spacecraft antenna will have autonomous on-board pointing controllers, which will use the RF beacon tracking data to control the antenna positioning mechanism. In case of loss of beacon lock, the spacecraft attitude control reference will revert to earth sensors.

h. Satellite Communications Subsystem

The communications subsystem consists of two communications repeaters: a 32 channel standard Ku band repeater and a 16 channel extended Ku band repeater. Both repeaters employ 135 watt traveling wave tube amplifiers (TWTAs). Subsystem components, including the high power TWTAs, were selected to optimize performance in conjunction with ground terminals on customer premises.

A block diagram of the communication subsystem is given in Figures D-10 and D-11.

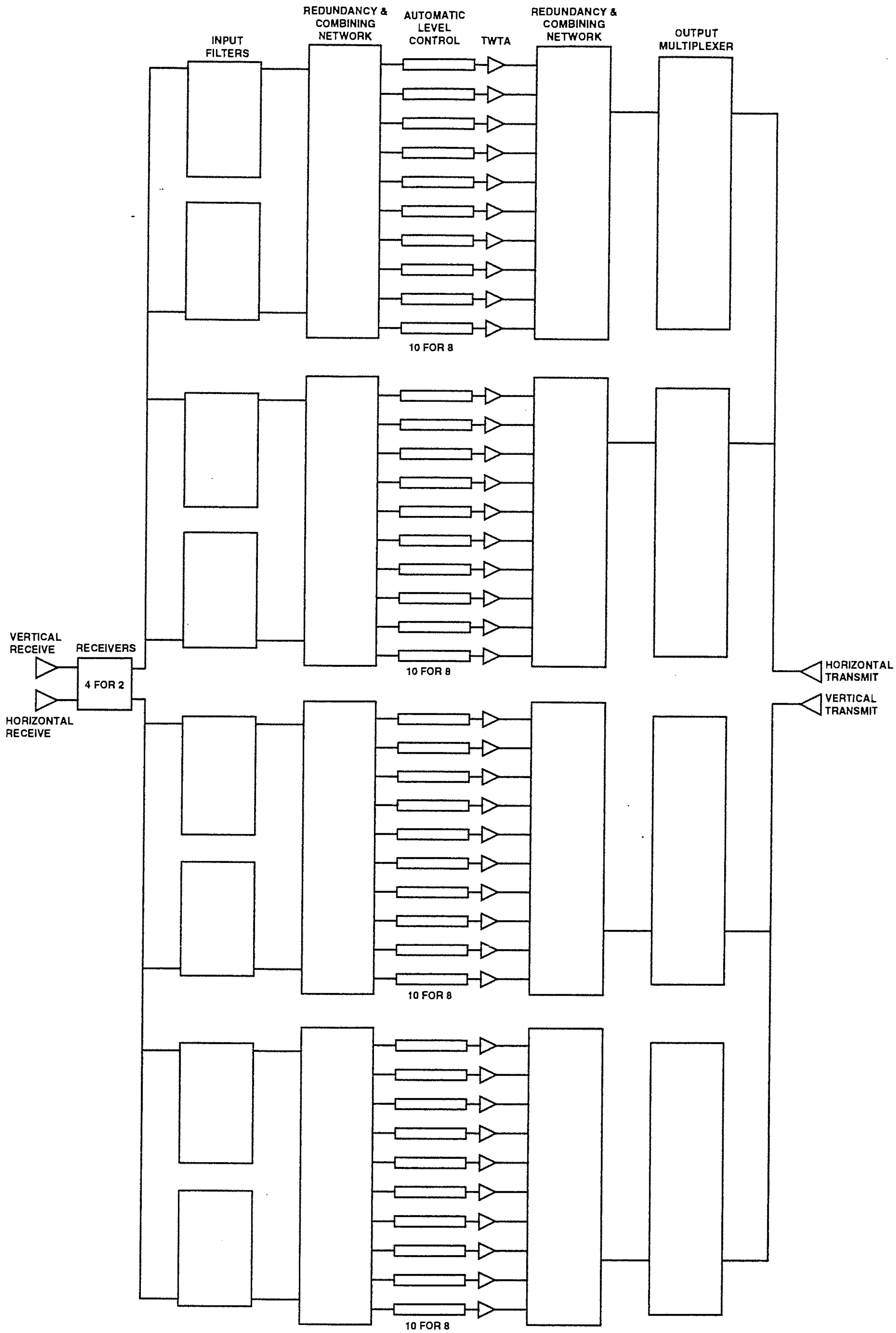


Figure D-10 STANDARD KU-BAND COMMUNICATIONS SUBSYSTEM SIMPLIFIED BLOCK DIAGRAM

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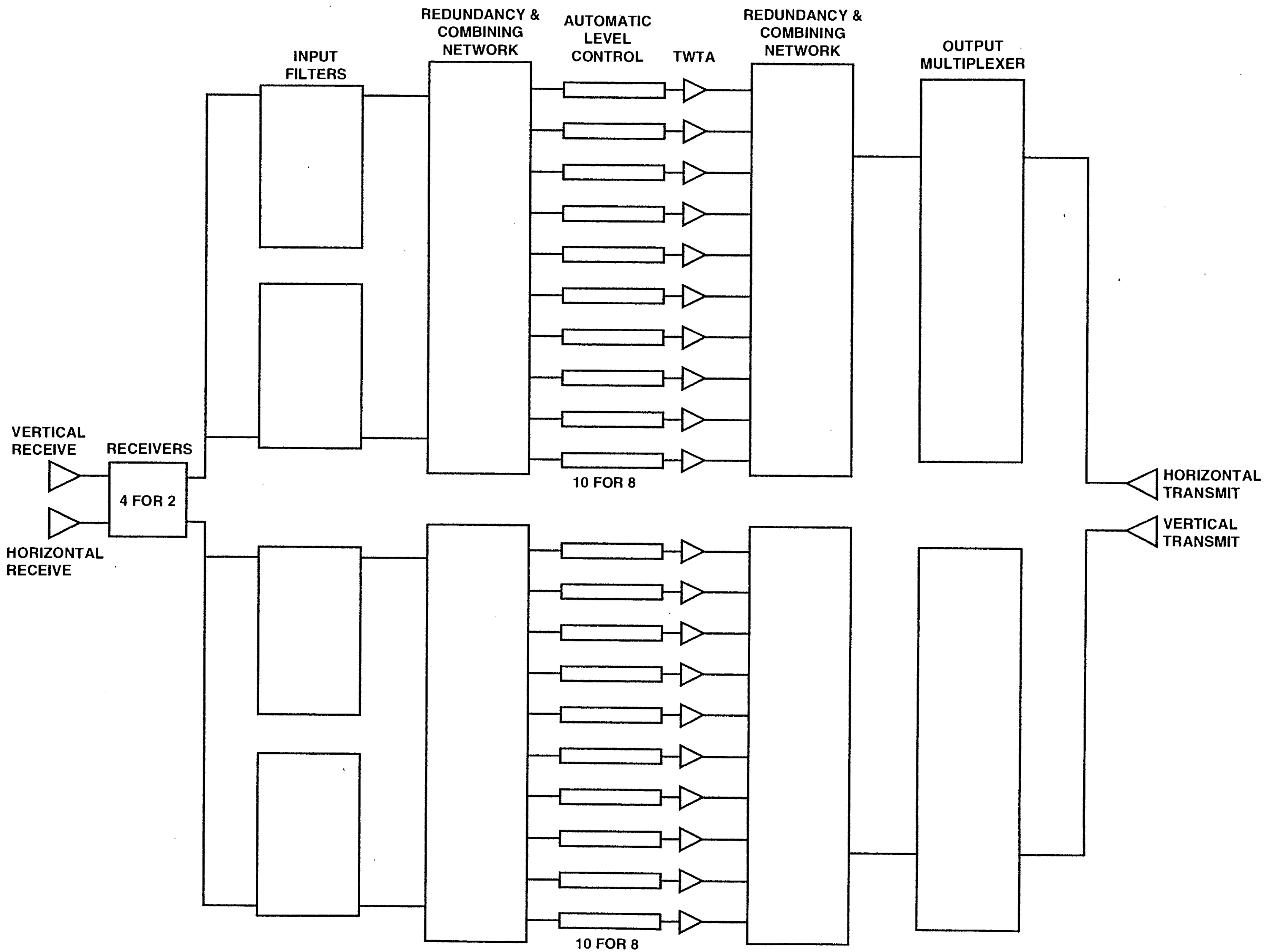

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Figure D-11 EXTENDED KU-BAND COMMUNICATIONS SUBSYSTEM SIMPLIFIED BLOCK DIAGRAM

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The redundant wideband receivers will be connected directly to the receive antenna. The receiver output is then channelized with the input filters and amplified by the channel amplifiers and multiplexed into two shaped surface reflector antennas.

Each wideband receiver has been designed to have high sensitivity (good noise performance) and low crosstalk coefficients (good linearity characteristics). The high sensitivity is required for detection and amplification of extremely low-level signals received by the satellite from the earth station transmitters. The low crosstalk coefficients are necessary since eight separate signals pass through the wideband receivers prior to channelization by the narrow bandpass filters. A highly linear receiver is necessary in order to minimize coupling of interference among these signals in the receiver.

The wideband receiver will consist of a low noise amplifier followed by a downconverter that will translate the input frequencies to the satellite transmit frequencies through a net frequency subtraction of 2300 MHz without frequency inversion, and with a net translation error including initial tolerance, not greater than $\pm$ 10 parts in 10^6 over the operating lifetime of the satellite. Variations in net translation frequency over one day will not exceed a total of one part in 10^6, including eclipse effects. Following the downconverter will be a medium-level amplifier that will amplify the translated signals sufficiently to drive the channel amplifier in each transponder. This medium-level drive amplifier has been designed for highly linear operation.

Following the input filters is a bank of redundancy switches and combine hardware which form the channel amplifier redundancy combining network. Four and two rings of ten for eight redundancy are provided for the standard Ku band and extended Ku band payloads. The commandable step attenuators provides ground commandable attenuation of up to 17.5 dB in 2.5 dB increments. Following the HPAs is an output redundancy combining network which is the mirror image of the input redundancy network.

Spurious emissions that are beyond the usable bandwidth of each transponder and within the 11.45 to 11.7 GHz and 11.7 to 12.2 GHz bands are attenuated by a combination of the input and output multiplexer filters. Out-of-band emissions beyond the 11.45 to 11.7 GHz and 11.7 to 12.2 GHz bands, including harmonics, are attenuated by a combination of the output multiplexer filter and low pass filtering.

The telemetry system will have two identical links consisting of two encoders that modulate either of two transmitters via a cross-strap switch. Data pertaining to unit status, spacecraft attitude, and spacecraft performance will be transmitted continuously for spacecraft management and control. The telemetry transmitters will also serve as the downlink transmitter for ranging tones and command verification. The primary telemetry data mode will be PCM. For normal on-station operation, the telemetry transmitters will be connected via a filter to the transmit feeds of the communications antenna. In transfer orbit, each telemetry transmitter will drive the omni antenna.

The command system will control spacecraft operation through all phases of the mission by receiving and decoding commands to the spacecraft. Additionally, it will serve as the uplink receiver for ranging signals and provide closed loop tracking of a ground beacon for spacecraft pointing. It will perform the latter function without interfering with the command function. The command uplink will employ government approved command encryption. The command signals will be fed through a filter diplexer into a redundant pair of tracking command receivers. The composite signal of the receivers' total output will drive a pair of redundant decoders. The decoders will provide command outputs for all satellite functions. The command bicone antennas will be used in transfer orbit for command and ranging, while the reflector antenna will be used on-station for ground RF beacon tracking, command and ranging.

i. Satellite Useful Lifetime

The design lifetime of the satellite in orbit (other than with respect to stationkeeping) is 15 years. This has been determined by a conservative evaluation of the effect of the synchronous orbit environment on the solar array, the effect of the charge-discharge cycling on the life of the batteries, and the wearout of the TWTAs. The mass allocation of propellant for spacecraft stationkeeping is 12 years. To enhance the probability of survival, spacecraft equipment will be redundant wherever possible. Materials and processes will be selected so that aging or wearing effects will not adversely affect spacecraft performance over the estimated life. The following paragraphs discuss dominant lifetime factors.

(i) Fuel

A conservative mission analysis indicates a 12 year lifetime. The mission has not yet been optimized since the exact sequence of maneuvers will be determined after the actual selection of the launch vehicle. Any remaining spacecraft weight margin can be converted to mission life.

(ii) Battery

Life testing to date indicates that a longevity of 12 years can easily be achieved. In order to ensure this longevity, the spacecraft design incorporates the following required provisions: C/20 minute charge rate at end of life, thermal control during all phases, and proper selection of cell components.

(iii) Solar Panel

Predictions concerning the useful life of the solar panels are backed by decades of Hughes experience in predicting and measuring in-orbit solar panel performance. These predictions are based on conservative assumptions concerning the radiation environment.

(iv) Electronics

All critical electronics units and components are redundant. There is a four-for-two receiver redundancy employed for each communications payload and six ten-for-eight redundancy rings employed for the power amplifier chains. For other electronic units a minimum of two-for-one redundancy is employed. The electrical design follows well-established criteria regarding parts selection, testing and design, among others.

(v) Non-Electronic

Full redundancy has been employed for non-electronic components wherever possible.

(vi) Eclipse Considerations

The satellite battery capacity will be more than adequate to power all 48 output TWTAs during eclipses throughout mission life.

(vii) Sun Outages.

During predictable twice-yearly periods of approximately eight days, the sun briefly transits the field of view of an earth station pointing at a geostationary satellite. The rise in thermal noise in the earth station receivers caused by the sun's radiation disrupts satellite reception (i.e., causes sun outage). Such disruption of satellite reception is predictable and is well understood by satellite users.

j. Satellite Stationkeeping

Inclination of the satellite orbit will be maintained to ± 0.05 degrees or less, and the satellite will be maintained to within ± 0.05 degrees of the nominal longitude position. Attitude of the satellite will be maintained to an accuracy consistent with the achievement of the specified communications performance, after taking into account all error sources (e.g., attitude perturbations, thermal distortions, misalignments, orbital tolerances, and thruster perturbations).

In addition to the propellant required for operational attitude and orbital control, extra propellant will be incorporated to provide correction of the initial orbit, initial attitude acquisition, and one orbital repositioning maneuver at a drift rate of 1 degree per day. Sufficient propellant will be included in the satellite to permit a 12-year operational life.

k. Telemetry, Tracking and Command ("TT&C")

The telemetry, tracking and command ("TT&C") subsystem will perform the monitoring and command functions necessary for spacecraft control.

(i) Telemetry

The telemetry system will have two identical links consisting of two encoders that modulate either of two transmitters via a cross-strap switch. Data pertaining to unit status, spacecraft attitude, and spacecraft performance will be transmitted continuously for spacecraft management and control. The telemetry transmitter will also serve as the downlink transmitter for ranging tones and command verification. The primary telemetry data mode will be PCM. For normal on-station operation, the telemetry transmitters will be connected via a filter to the transmit feeds of the communications antenna.

In transfer orbit, each telemetry transmitter will drive the bicone antenna to provide adequate telemetry coverage. Selection of this high level mode, which may also be used for emergency backup on station, will be by ground command.

(ii) Command

The command system will control spacecraft operation through all phases of the mission by receiving and decoding commands to the spacecraft. Additionally, it will serve as the uplink receiver for ranging signals and provide closed loop tracking of a ground beacon for antenna pointing. It will perform the latter function without interfering with the command function. The command uplink will employ government-approved command encryption. The command signals will be fed through a filter diplexer into a redundant pair of tracking/command receivers. The composite signal of the receivers' total output will drive a pair of redundant decoders. The decoders will provide command outputs for all satellite functions. The command bicone antenna will be used in transfer orbit for command and ranging, while the reflector antenna will be used on-station for ground RF beacon tracking, command and ranging.

(iii) TT&C Performance Characteristics

A telemetry and command summary is given in Table D-8. The satellite system requires a command receiver input power of about -135 dBW for command execution. With a nominal ground station EIRP of 83.5 dBW, the command threshold requirements are met with margin through the bicone and reflector antennas, respectively. See Table D-9 for the command link budget for transfer orbit and on-station operations. The telemetry link budget for on-station operation is given in Table D-10.

TABLE D-8

TT&C SYSTEM PARAMETERS

Parameter	Spacecraft Antenna	
	Bicone	Reflector
Command frequency	13997 - 14000 MHz	13750 - 13753 MHz
Earth station command EIRP (typical)	83.5 dBW	83.5 dBW
Command carrier modulation	FM	FM
Telemetry beacon frequency	11450 to 11452.5 MHz	11450 to 11452.5 MHz
Beacon modulation	PM	PM
Beacon EIRP (max)	7.0 dBW	22.0 dBW
On-station ranging accuracy	21 m	21 m

TABLE D-9

COMMAND RF LINK BUDGET

Parameter	Bicone Antenna Transfer Orbit, 13997.5 MHz	Spot Beam On-Station, 13750.5 MHz
Ground station, EIRP, dBW	83.5	83.5
Polarization loss, dB	-0.1	-0.1
Path loss, $1/(4\Pi r^2)$, dB/m^2	-162.5	-162.5
Incident power, dBW/m^2	-79.0	-79.1
Isotropic area, $\lambda^2/4\pi$, dB-m^2	-44.4	-44.2
Antenna gain, ±20° on omni, dBi	-0.6	38.6
RF losses to tracking command receiver, dB	-1.55	-10.0
Receiver input power, dBW	-125.5	-94.8
Receiver command threshold, dBW	-135	-135
Margin above command threshold, dB	9.5	40.2

TABLE D-10

TELEMETRY LINK BUDGET (ON-STATION)

Parameter	Value
Telemetry EIRP, min. at Castle Rock, CO	15.9 dBW
Path loss	-162.5 dB/m^2
Isotropic area	-42.6 dBm^2
Atmospheric absorption (clear sky)	-0.2 dB
TT&C station G/T	37.2 dB/K
Link C/T	-155.9 dBW/K
Link C/N_0	76.6 dB-Hz
Subcarrier modulation index	-5.0 dB
Subcarrier C/N_0	71.6 dB-Hz
Implementation Loss	-2.5 dB
Telemetry Eb/N_0 (bit rate = 4 kbps)	33.1 dB
Eb/N_o required for 10^{-6} BER	11.0 dB
Margin	22.1 dB

1. System Reliability

The satellite will be designed for an operational and mission life of 12 years. Mission lifetime is determined primarily by the amount of stationkeeping propellant that can be loaded into the tanks within the allowable launch weight and by the wearout mechanism of the TWTAs. To ensure highly reliable performance, six 10 for 8 redundancy rings of TWTAs are provided.

Life and reliability will be maximized by using proven reliability concepts in equipment design. All subsystems and units have a minimum design life of 15 years; standby redundancy is used in the attitude control subsystem and in the communications receiver, and active redundancy is used in the power subsystem. All avoidable single-point failure modes will be eliminated. All components and subsystems will be flight-qualified, and all components will be derated in accordance with design guidelines.

ITEM E. Performance Requirements and Operational Characteristics

1. Introduction

Galaxy XI(I) will be capable of transmitting communication signals in a number of different traffic modes. Representative traffic modes are:

1) Digital television (30 and 22.8 Mbps);
2) Frequency modulated television with one carrier per transponder (FM-TV);
3) Digital signal carrier per channel (SCPC) with data carriers carrying wideband T1 data (1.544 Mbps); and
4) Digital single channel per carrier with data channels carrying 64 kbps data.