Figure D-1 Ka Band FSS Frequency Plan

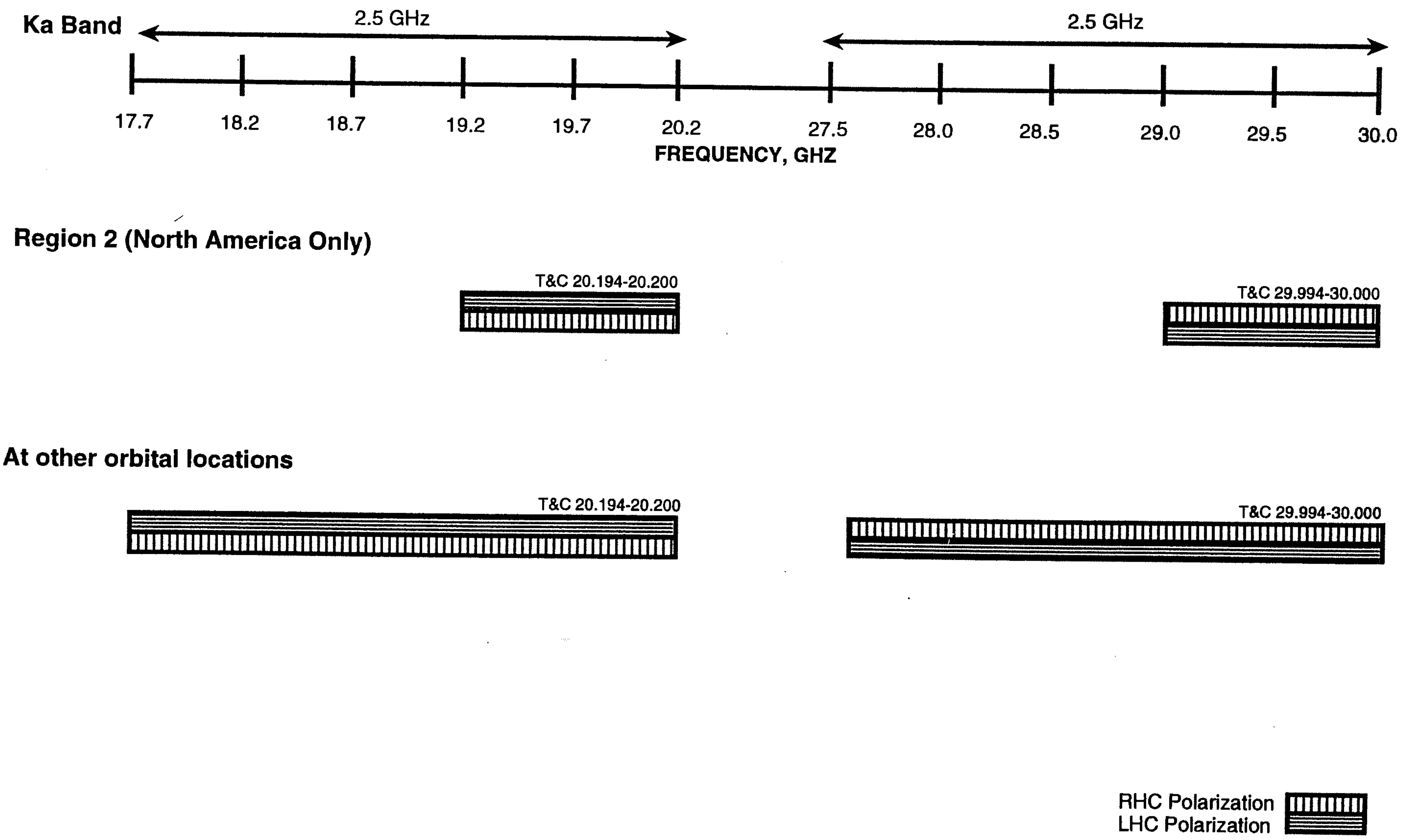
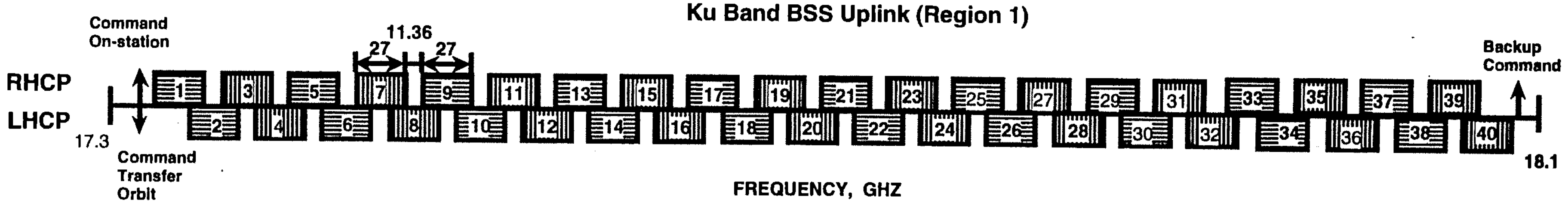


Figure D-2 Ku Band BSS Frequency Plan for Region 1

Ku Band BSS Uplink (Region 1)



Ku Band BSS Downlink (Region 1)

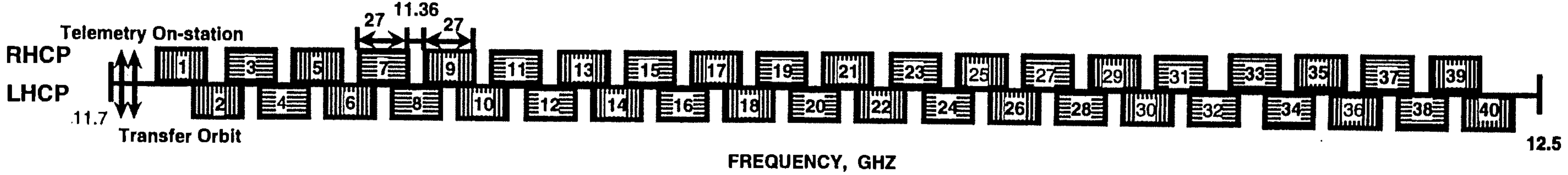
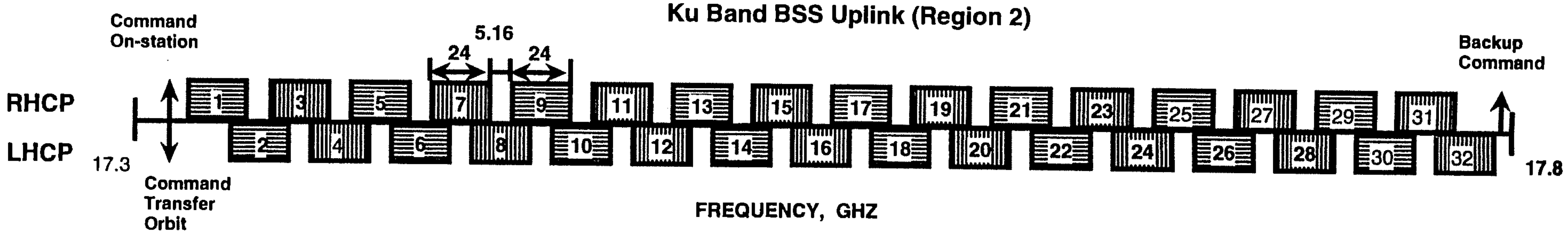


Figure D-3 Ku Band BSS Frequency Plan for Region 2

Ku Band BSS Uplink (Region 2)



Ku Band BSS Downlink (Region 2)

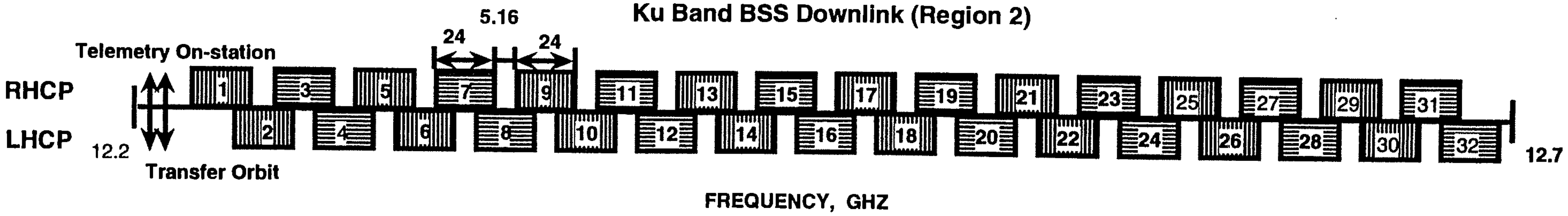
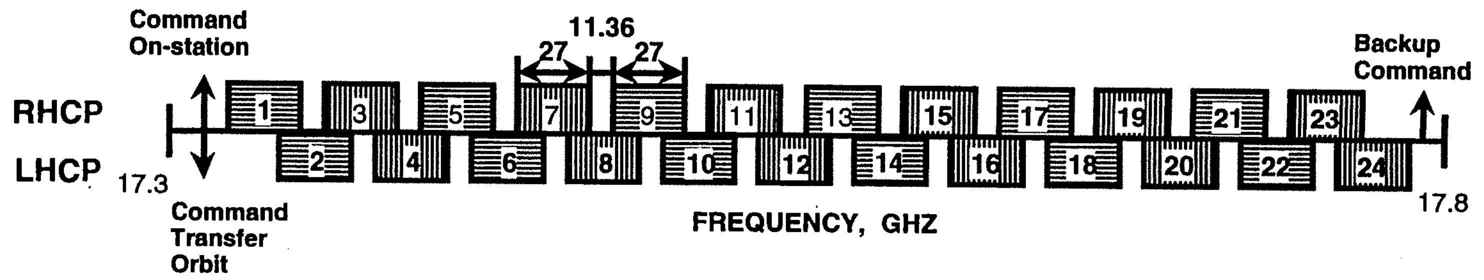
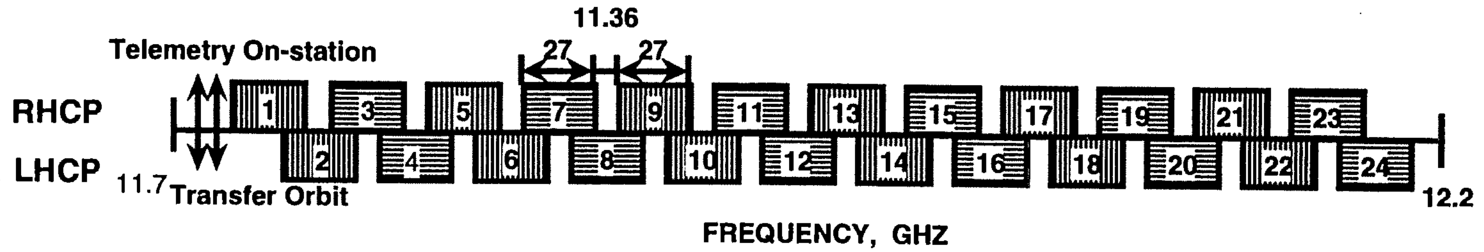


Figure D-4 Ku Band BSS Frequency Plan for Region 3

Ku Band BSS Uplink (Region 3)



Ku Band BSS Downlink (Region 3)



In order to comply with the existing allocations of orbital locations for BSS frequencies, GALAXY/SPACEWAY™ satellites use orbital locations not allocated in the BSS plan. The Spectrum Orbital Utilization Program ("SOUP") program was used to demonstrate that the GALAXY/SPACEWAY™ system will not create unacceptable interference for any BSS plan-conforming system in any region. Polarizations will be chosen per orbital location based on the SOUP program analysis, and HCG will exclude those frequencies and polarizations which are not compatible with the plan.

Each satellite in the network will be equipped with intersatellite link capability in the Ka band and/or V band. Due to the earth's atmospheric absorption, use of frequency spectrum in these ranges will not impact current or planned space-to-earth or terrestrial links. The preferred Ka band frequencies are from 22.55 - 23.55 GHz and 32.0 - 33.0 GHz. The preferred V band frequencies are from 54.25 - 58.2 GHz and 59 - 64 GHz.

In order to take advantage of existing TT&C ground station equipment, TT&C functions will be performed in upper and lower edges of the Ku band assigned to each satellite for transfer orbit. Satellites using Ka band only operation will switch to Ka band TT&C for on station operation. HCG will coordinate with the operation of any Ka band and Ku band satellite at the requested orbital locations prior to using these frequencies for TT&C operation.

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

b. Emissions Designators

Commands to the satellites from the TT&C station will be angle-modulated with a large deviation on the uplink carrier. Each satellite will be equipped with government approved command encryption equipment in order to secure command transmissions. Telemetry data from the satellites will be angle-modulated on the downlink carrier. All command ground equipment will be under HCG control. The emission designators are described in Tables D-2, D-3 and D-4 for the systems with high-powered narrow beams, wide area beams, and housekeeping functions which will reside on all systems.

Table D-2 High Powered Narrow Beams Communication Emission Designators

Signal	Emission Designator
Communication uplink, 384 Kbps	500KG7W
Communication uplink, 768 Kbps	1M00G7W
Communication uplink, 1.544 Mbps	2M00G7W
Communication uplink, 6 Mbps	8M00G7W
Communication downlink	120MG1W

Table D-3 Wide Area Beams Communication Emission Designators

Signal	Emission Designator
FMTV	24M0F3F
SCPC Compressed Digital Video	6M00G1W
MCPC Compressed Digital Video	24M0G7W
MCPC Compressed Digital Video	36M0G7W

Table D-4 Housekeeping Emission Designators

Signal	Emission Designator
Command, transfer orbit	1M50X9D
Command, on-station	1M50X9D
Telemetry, transfer orbit	300KG9D
Telemetry, on-station	300KG9D
Power Control beacon (Ku)	25K0N0N
Power Control beacon (Ka)	1M00G2D
Intersatellite link	500MG1W

c. Communications Coverage

Through the use of intersatellite links and inter-regional beams, GALAXY/SPACEWAY™ provides a fully interconnected global network. The uplink and downlink coverage for each orbital location are depicted in Appendix C. For each orbital location, applicable Ka band high powered narrow spot beams, Ka band wide area beams, and/or shaped Ku band BSS coverages are shown. These coverages will be provided either by packaging multiple payloads on one satellite, or by collocating satellites at each orbital location.

d. Power Flux Density

High Powered Narrow Beams

The maximum EIRP (beam peak) of each GALAXY/SPACEWAY™ satellite is 60 dBW for Ka band high powered narrow beams. The maximum power flux density in any 2 MHz on the ground for a modulated saturated carrier therefore is 60 - 163.3 - 80.8 + 63 = -121.1 dBW/m^2 for Ka band. Thus, for all arrival angles between 0° and 5°, a modulated

Ka band carrier will produce a power flux density at the Earth's surface less than or equal to -115 dBW/m^2.

The maximum power flux density in any 4 kHz on the ground for a modulated saturated carrier is 60 - 162.9 - 80.8 + 36 = -147.7 dBW/m^2 for Ka band. Thus, for all arrival angles between 5° and 25°, a modulated Ka band carrier will produce a power flux density at the Earth's surface less than or equal to -115 dBW/m^2.

And the maximum power flux density in any 1 MHz on the ground for a modulated saturated carrier is 60 - 162.1 - 80.8 + 60 = -122.9 dBW/m^2 for Ka band. Thus, for all arrival angles between 25 ° and 90°, a modulated Ka band carrier will produce a power flux density at the Earth's surface less than or equal to -105 dBW/m^2.

All of the above power flux density limits are specified in Section 25.208 of the Commission's rules. See 47 CFR 25.208(c) (1994).

In the frequency band from 18.6 - 18.8 GHz, the maximum power flux density in any 200 MHz on the ground for a modulated saturated carrier is 60 - 162.1 - 81.0 + 83 = -100.1 dBW/m^2 for Ka band. Thus for all angles of arrival, a modulated Ka band carrier will produce a power flux density at the Earth's surface slightly more than -101 dBW/m^2 specified in Section 2.106 of the Commission's rules. See 47 CFR 2.106 (US255) (1994). For this case where the minimum power flux density limit is exceeded, GALAXY/SPACEWAY™ will restrict the satellite transmit power to conform to applicable Commission requirements.

Wide Area Beams

The maximum EIRP (beam peak) of each GALAXY/SPACEWAY™ satellite is between 48 to 55 dBW for Ka band. The maximum power flux density in any 2 MHz on the ground for a modulated saturated carrier is 55 - 163.3 - 73.8 + 63 = -119.1 dBW/m^2 for

Ka band. Thus, for all arrival angels between 0° and 5°, a modulated Ka band carrier will produce a power flux density at the Earth's surface less than or equal to -115 dBW/m^2.

The maximum power flux density in any 4 kHz on the ground for a modulated saturated carrier is 55 - 162.9 - 73.8 + 36 = -145.7 dBW/m^2 for Ka band. Thus, for all arrival angles between 5° and 25°, a modulated Ka band carrier will produce a power flux density at the Earth's surface less than or equal to -115 dBW/m^2.

And the maximum power flux density in any 1 MHz on the ground for a modulated saturated carrier is 55 - 162.1 - 73.8 + 60 = -120.9 dBW/m^2 for Ka band. Thus, for all arrival angles between 25° and 90°, a modulated Ka band carrier will produce a power flux density at the Earth's surface less than or equal to -105 dBW/m^2.

All of the above power flux density limits are specified in Section 25.208 of the Commission's rules. See 47 CFR 25.208(c) (1994.

In the frequency band from 18.6 - 18.8 GHz, the maximum power flux density in any 200 MHz on the ground for a modulated saturated carrier is 55 - 162.1 - 75.6 + 83 = -99.7 dBW/m^2 for Ka band. Thus for all angles of arrival, a modulated Ka band carrier will produce a power flux density at the Earth's surface slightly more than -101 dBW/m^2 as specified in Section 2.106 of the Commission's rules. See 47 CFR 2.106 (US255) (1994). For this case where the minimum power flux density limit is exceeded, GALAXY/SPACEWAY™ will restrict the satellite transmit power to conform to applicable Commission requirements.

2. Satellite Characteristics

The on-orbit configuration of two typical GALAXY/SPACEWAY™ satellites is illustrated in Figure D-5. The major spacecraft characteristics are shown below in Table

D-5. The satellites will be similar, differing only in the frequencies used and antenna configuration. Characteristics of the various services to be offered are given in Table D-6. Example power budgets are listed in Table D-7, based on a mission life of 15 years and assuming sufficient redundancy to allow for random failures.

Figure D-5 GALAXY/SPACEWAY™ Sample Satellite Configurations

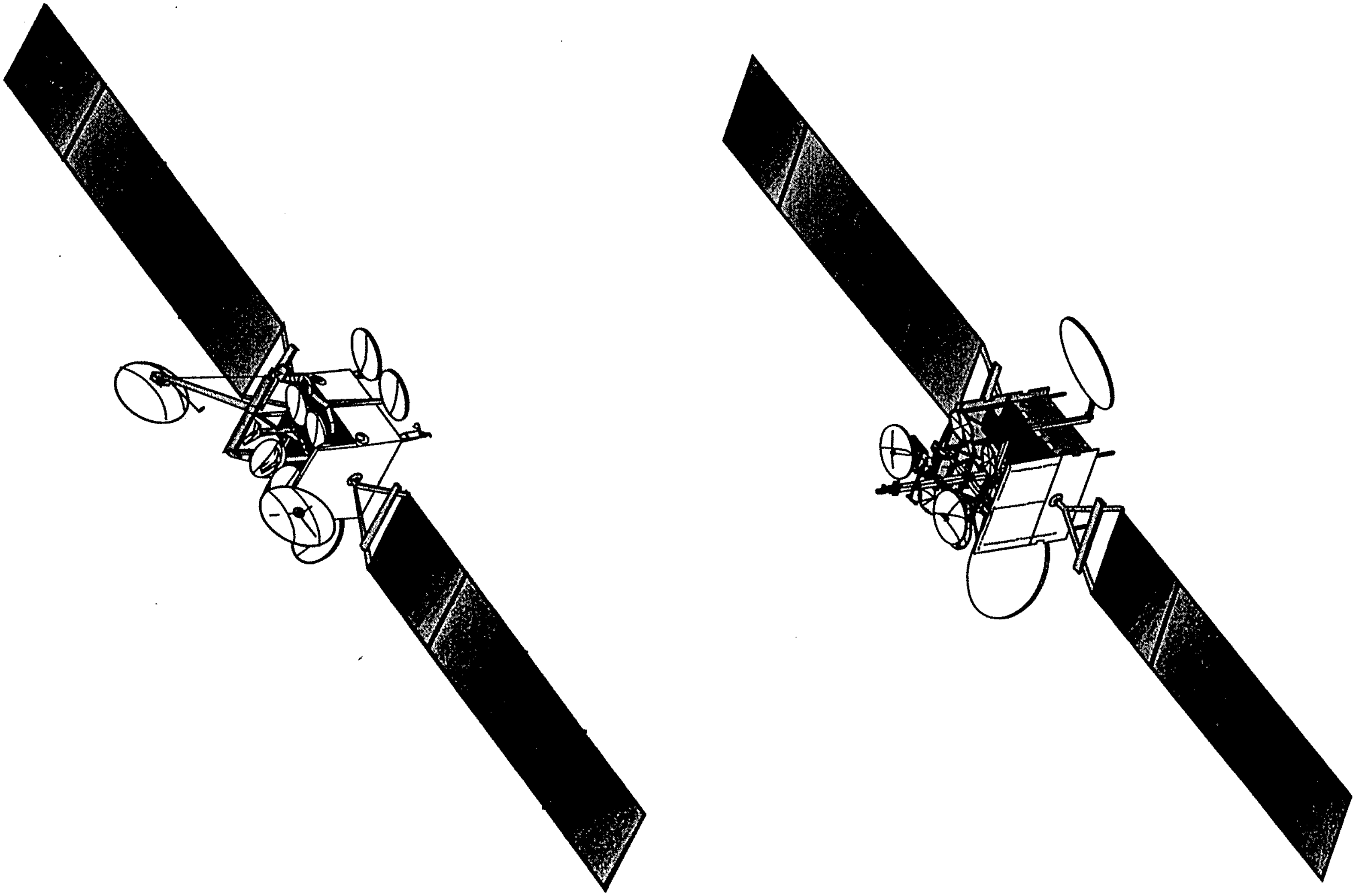


Table D-5 Major Spacecraft Characteristics

Spacecraft bus	HS-601, high power
Stabilization	3 axis
Mission life	15 years
Power	7 kW or greater
Eclipse capability	100 percent
Launch mass	4000 Kg
Stationkeeping	
North-South	±0.05°
East-West	±0.05°
Antenna pointing precision	
Beacon tracking	0.1° N-S and E-W
Earth sensor	0.2° N-S and E-W
Beam rotation	0.25°
Frequency*	
Command and Ranging	
transfer orbit	17305.0 MHz
on-station Ku band	17305.0 MHz
on-station Ka band	29997.0 MHz
Telemetry and Ranging (Region 1 & 3)	
transfer orbit	11700.5 MHz
on-station Ku band	11700.5 MHz
on-station Ka band	29997.0 MHz
Ka band Power Control Beacon 1	27500.0 MHz
Ka band Power Control Beacon 2	29999.0 MHz
Polarization	
Command and Ranging	
transfer orbit	
on-station Ku band	LHCP
on-station Ka band	RHCP
Telemetry and Ranging	LHCP
transfer orbit	
on-station Ku band	LHCP
on-station Ka band	RHCP
Bandwidth	RHCP
Command and Ranging	1.5 MHz
Telemetry and Ranging	300 KHz
Telemetry EIRP	
transfer orbit	10 dBW (max.)
on-station	15 dBW
Command threshold	
transfer orbit	-63 dBW/m$_2$
on-station	-75 dBW/m^2

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*All satellites in a given region will be assigned non-conflicting frequencies in the same bands.

Table D-6 Satellite Services

FSS Communications	
High-powered spot beam service	
Band	Ka
Number of beams (1°)	48
Beam bandwidth	125 MHz
Transmitter redundancy	60 for 48
EIRP	48 to 60 dBW
Wide area beam service ($\geq 3°$)	
Band	Ka
Number of beams	2 or greater
Beam bandwidth	500 MHz
Transponders	24
Bandwidth/transponder	36 MHz
Channels/transponder	6 compressed digital
Commandable step attenuators	0 to 16 dB, 2dB steps
EIRP	48 to 55
BSS Communications	
Band	Ku
Number of beams	2
Amplifier Redundancy	5:4
Beam bandwidth	500 MHz
Transponders	
Region 1	40
Region 2	32
Region 3	24
Bandwidth/transponder	
Regions 1 & 3	27 MHz
Region 2	24 MHz
Channels/transponder	6 compressed digital, TDM
EIRP	50 to 55 dBW
ISL Communications	
Band	Ka or V
Number of beams	2
Beam bandwidth	up to 4 GHz
Transponders	up to 8
Bandwidth/transponder	500 MHz
Channels/transponder	72 compressed digital
EIRP	70 dBW

Table D-7: Example Spacecraft Power Budgets at Equinox

Category	High Powered Narrow Beams (W)	Wide Area FSS and BSS Beams (W)
Communications	6000	7500
Housekeeping	600	600
Distribution loss	145	170
Battery charge	720	880
Total requirement	7465	9150

Tables D-8 and D-9 show the estimated receive antenna gain-to-noise temperature (G/T) of the antennas and downlink EIRP budgets, respectively.

Table D-8: Satellite Uplink G/T Budget

	Narrow Spot Beam		Ka FSS Wide Area Beam		BSS Wide Area Beam	
	Peak	Edge of Cov.	Peak	Edge of Cov.	Peak	Edge of Cov.
Antenna gain (dB)	46.5	41.5	35.0	30.0	35.0	30.0
System noise temperature (dB K)	27.6	27.6	29.6	29.6	27.6	27.6
G/T (dB/K)	18.9	13.9	5.4	0.4	7.4	2.4

Table D-9: Satellite Downlink EIRP Budget

	Narrow Spot Beam		Ka FSS Wide Area Beam		BSS Wide Area Beam	
	Peak	Edge of Cov.	Peak	Edge of Cov.	Peak	Edge of Cov.
Amplifier output power (dBW)	13.0	13.0	20.8	20.8	18.8	18.8
Repeater output losses (dB)	0.5	0.5	2.5	2.5	2.0	2.0
Antenna gain (dB)	46.5	41.5	35.0	30.0	35.0	30.0
EIRP (dBW)	59.0	54.0	53.3	48.3	51.8	46.8

3. Satellite Description

The GALAXY/SPACEWAY™ services will be provided by high power satellites that are capable of supporting multiple payloads on a single spacecraft bus. Although all satellites in the GALAXY/SPACEWAY™ system will be similar, the satellites will be flexible in design in order to best satisfy the requirements of individual markets. The spacecraft bus is based upon the existing Hughes Space and Communications high powered HS-601 series body-stabilized bus.

a. Satellite Design

The GALAXY/SPACEWAY™ system design will be tailored to best serve market demand. When multiple services are demanded from any one orbital location, each satellite payload will be designed to take full advantage of the maximum capabilities of the high powered HS 601. As available satellite resources permit, each satellite may accommodate multiple payloads. In addition, when demand exceeds the capacity of a single satellite, HCG will collocate multiple satellites at one orbital position.

The satellite design is based upon the existing Hughes Space and Communications HS-601 series body-stabilized bus. The HS 601 series is a proven design. Twenty HS 601 satellites are currently operating successfully, and approximately thirty more will be launched over the next three years. The satellite design is compatible with launch by several of the currently available commercial launch vehicles. Final injection into geosynchronous orbit and station keeping are accomplished by integral liquid propulsion and xenon ion propulsion.

b. Satellite Subsystems

(1) Antenna Subsystem

Optimal coverage areas from each orbital location will be enabled by specific antenna designs for each satellite. The GALAXY/SPACEWAY™ communications antenna subsystem provides Ku band BSS, Ka band FSS high powered spot, and Ka band FSS wide area uplink and downlink beams over multiple coverage regions.

For high-powered spot beam service, the satellite antenna configuration will provide up to 48 spot beams. Each of these spot beams will operate in two polarizations, right hand and left hand circular polarization. An earth-pointing antenna subsystem consisting of up to eight solid parabolic reflectors will be utilized. The transmit spot beams are divided among four of the eight reflectors and the twenty-four receive spot beams are divided among the remaining four reflectors with all eight reflectors using right hand and left hand circular polarization. Antenna pointing is determined by means of RF and optical sensors located on the satellite.

BSS and FSS wide beam service will be provided by steerable beams at Ku band and Ka band frequencies, respectively. The Ku band antennas are located outboard of the east and west faces of the satellite body. The Ka receive and transmit antennas are located on the earth facing side of the satellite body.

Two Ka band and/or V band ISL beams are also provided, with one beam serving satellites to the east and the other serving satellites to the west. The ISL antennas are located on the nadir face of the spacecraft. After deployment, gimbal mechanisms and autotracking are used to maintain proper pointing.

(2) Communications Subsystem

High Powered Narrow Beam Service

For high-powered spot beam service, each of the 24 receive antenna beams takes in 500 MHz wide signals, with both right hand and left hand circular polarizations. The two polarizations are then separated by orthomode-transducers. The 48 RF signals are then amplified by LNAs, channelized to 125 MHz, and downconverted to an Intermediate Frequency (IF). The on-board processor demodulates the IF signal and demultiplexes and routes the baseband signals to one of 48 downlink streams. The 48 time-division multiplexed streams are QPSK modulated and amplified by traveling wave tube amplifiers. The modulated signals are then given right hand and left hand circular polarizations and combined by orthomode-transducers for retransmission on 24 Ka band spot beams.

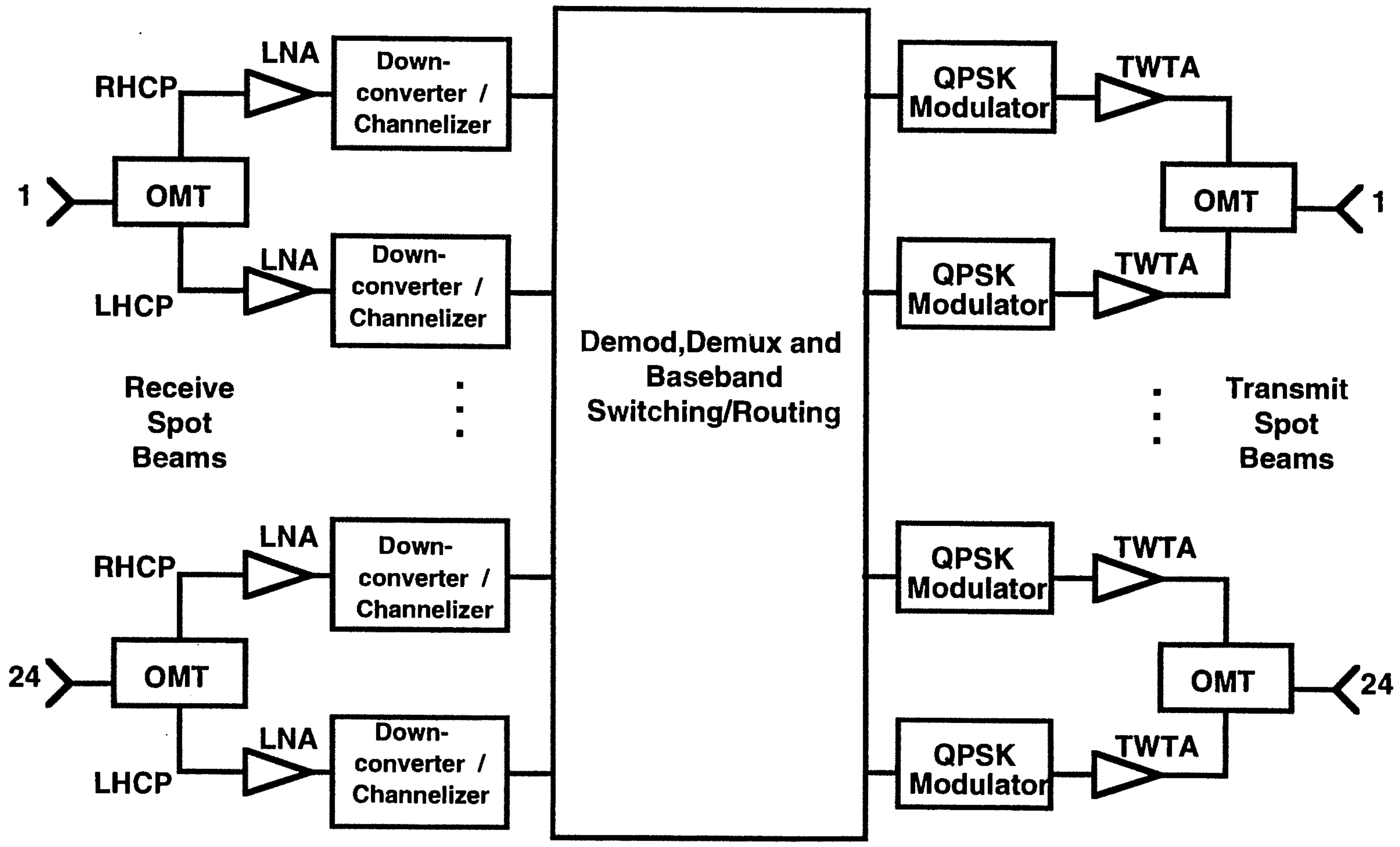
A block diagram of the high-powered spot beam communication subsystem is given in Figure D-6. Not shown are the connections between the on-board processor and the intersatellite link subsystem.

The concept of saturating flux density ("SFD") applies to transponded systems where the nonlinear amplifier has an output power that depends on the uplink drive level. The SFD is defined as the incident power per unit area that maximizes the transponded signal power. The GALAXY/SPACEWAY™ communications channels are demodulated and digitally multiplexed on-board the satellite in the high powered spot beam configuration. Because of this remodulation, the downlink power is independent of the uplink signal level and the SFD concept does not apply in this configuration.

This payload uses on-board baseband processing, thus there is no fixed RF connectivity between communications uplinks and downlinks. The on-board processor requires an automatic gain control circuit ("AGC") to keep the A/D converters maximally loaded. The AGC incorporates 30 dB of range in place of fixed gain step attenuators.

Since the payload is based on an on-board remodulation of the downlink signals using a shaped QPSK format, the close-in signal filtering is done in the shaping network of the modulator. The main filtering requirements at the TWTA output are those to handle harmonic suppression. Second and third harmonic suppression will be -50 dB.

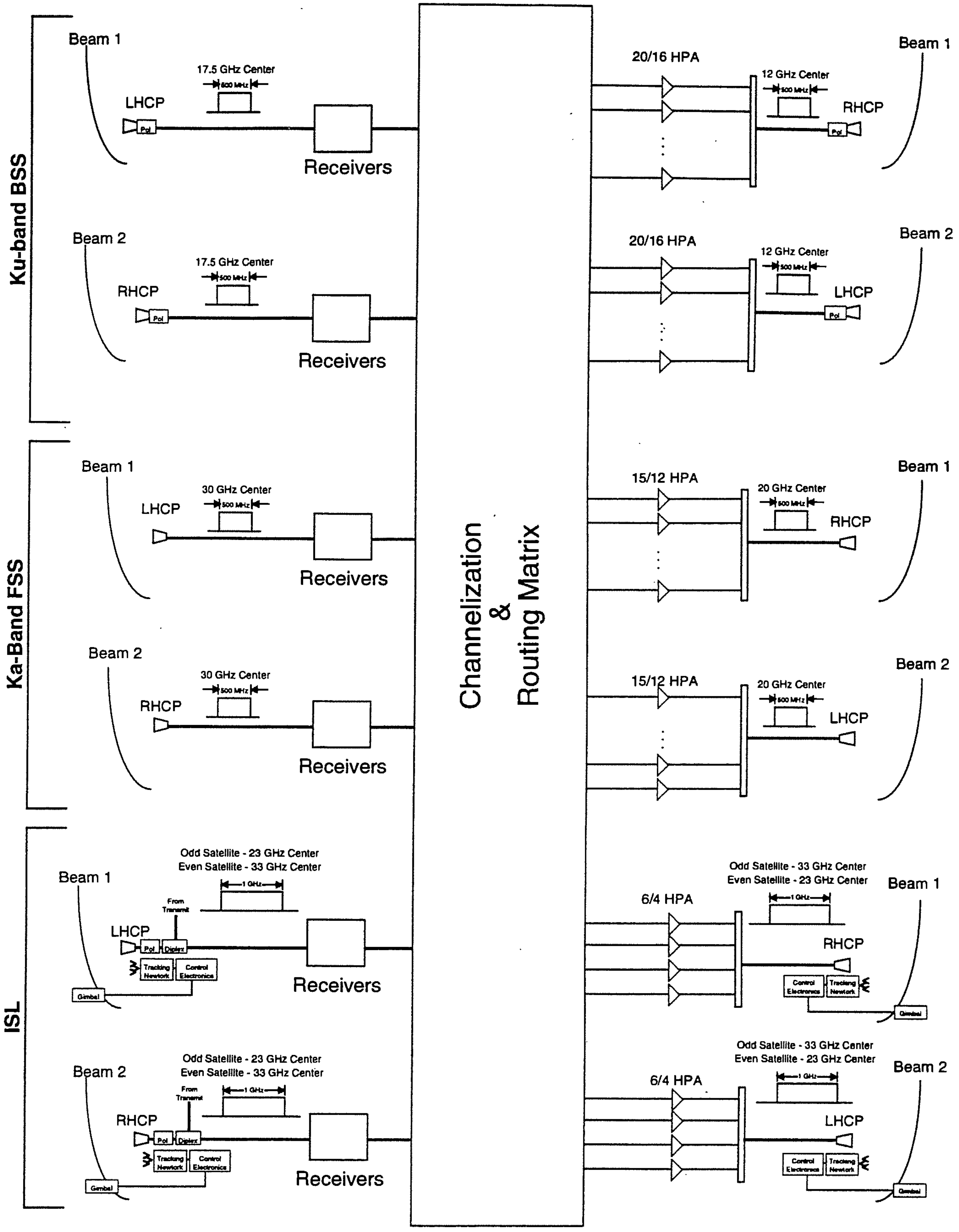
Figure D-6 Narrow Beam Communications Block Diagram



Wide Area Service and ISLs

For wide area service, each satellite can accommodate a combination of up to 2 Ku band BSS, and 2 Ka band FSS wide area transmit and receive beams. The Spectrum Orbit Utilization Program (SOUP) was used to handle protection margin computations for the current BSS ITU plan at Ku band. The results in Appendix B describe multiple beams at some orbital locations. The simulation analysis required definition of ellipses (called "beams" in the Appendix B results) of different sizes to encompass particular land masses with a given EIRP, 55 dBW in most cases. In actual implementation, a shaped reflector will be designed which will encompass multiple "beam" designations and the EIRP delivered to each coverage area will be bound by 55 dBW or less as specified in the Appendix B analysis. Two intersatellite link Ka band and/or V band beams are also available on each satellite. Signals can be routed up through Ku band or Ka band and transmitted on a Ku band beam, Ka band beam, or crosslink in either a clockwise or counter-clockwise direction around the earth. A signal flow diagram for a typical wide area beam service is given in Figure D-7.

FIGURE D-7 Signal Flow Diagram for a Typical Wide Area Beam System



At Ku band, forty 27 MHz transponders are provided in Region 1, thirty-two 24 MHz transponders are provided in Region 2, and twenty-four 27 MHz transponders are provided in Region 3. The transponders will be configured half on each polarization consistent with the BSS plan. It is shown in Item G and Appendix B that GALAXY/SPACEWAY™ BSS allocations do not interfere with the existing BSS plan in those regions. At Ka band, twenty-four 36 MHz transponders are provided, 12 on each polarization. Signals are channelized where available and routed to the desired amplifier and beam for transmission. The Ku band BSS channels are then amplified by at least 75 W.L. traveling wave tube amplifiers (TWTAs) and transmitted. At Ka band, 12 channels for each beam are amplified by approximately 120 W.L. TWTAs. The amplifiers and beamwidths at both Ku band and Ka band are sized to produce the required EIRPs for the proposed services. Each beam is isolated either by frequency separation or by orthogonal polarization from its contiguous beam.

The crosslinks are designed to enable traffic uplinked into one satellite to be routed to and downlinked from other satellites in the constellation. A total of 2 GHz can be uplinked into any given satellite with another 2 GHz of crosslink traffic from adjacent satellites in both directions. Up to 2 GHz of the traffic can be routed to the Ka band crosslinks in both directions. An additional 1 GHz can be transmitted at both Ku band and Ka band (500 MHz on each polarization). V band ISLs will be capable of supporting as much as 5 GHz in a direction to support bandwidth demands of a large satellite constellation.

(3) Thermal Control

Thermal control is accomplished with thermal blankets, heaters, mirrored radiators, 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 as well as heaters.

(4) Electrical Power

Satellite electrical power will be provided by solar arrays that convert solar energy to electrical power. The GALAXY/SPACEWAY™ satellites will use gallium arsenide solar cells to provide the high power required for this application. The arrays are deployed after the satellite attains synchronous orbit.

Nickel-Hydrogen batteries provide electrical power during eclipse to operate the full communications and housekeeping loads. Similar batteries are being used on Intelsat VI and many other HCG satellites. Nickel-Hydrogen battery cells have been under test since 1975.

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 active transponder channels and the housekeeping loads.

(5) Attitude Control

The satellite will employ the proven Hughes HS 601 Attitude Control Subsystem (ACS) to maintain the spacecraft attitude during the transfer orbit, initial acquisition period, and geostationary operations. The ACS employs sun and earth sensors augmented by the spacecraft processor to perform all attitude determination functions. Control of attitude and spacecraft orbit is accomplished by using momentum wheels and by pulsed or continuous firing of selected thrusters.

(6) Propulsion

The spacecraft will use liquid bipropellant propulsion and xenon ion propulsion. The liquid bipropellant subsystem is based on proven technology from the Leasat and Intelsat VI and HS 601 programs. It provides high performance through the use of hypergolic propellant; nitrogen-tetroxide oxidizer and monomethyl-hydrazine fuel.

(7) Structural Design

The spacecraft is divided into three modules for ease of manufacturing and integration:

- Communications equipment is mounted on the payload module that forms the nadir facing wall and the north and south faces. Heat pipes are embedded in the north and south faces to distribute TWTA heat dissipation over these prime radiating surfaces.
- Propulsion equipment is mounted on a central structure with launch loads being carried by a cylinder into the launch vehicle interface adapter.
- A bus module is formed by the anti-nadir surface and is used for mounting bus electronic equipment.

c. Satellite Useful Lifetime

The design lifetime of the satellite in orbit 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, the configuration of the communications payload and the redundancy of payload and bus equipment. The mass allocation of propellant for spacecraft stationkeeping is 15 years. To enhance the probability of survival, spacecraft equipment will not adversely affect spacecraft performance over the estimated life. The following parameters discuss dominant lifetime factors.

(1) Propellant

A conservative mission analysis indicates a 15 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 mass margin can be converted to mission life.

(2) Battery

Life testing to date indicates that a longevity of 15 years can be achieved with a maximum depth of discharge of 80%. In order to ensure this longevity, the spacecraft design incorporates thermal control during all phases, and proper selection of cell components. Extra cells and bypass circuits provide protection from cell failures.

(3) Solar Panel

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

(4) Electronics

All critical electronics units and components are redundant. The electrical design follows well-established criteria regarding parts selection, testing and design. Most electronic units are modeled after their counterparts in HS-376 spacecraft, which have already experienced a significant number of highly successful years in orbit.

(5) Satellite Reliability

The satellite will be designed for an operational and mission life of 15 years. To ensure highly reliable performance, TWTA ring redundancy is provided for Ku band, Ka band and the intersatellite links.

Life 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 and in the communications subsystem. 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. A satellite reliability of 0.80 is projected for each of the GALAXY/SPACEWAY™ satellites for the 15 year lifetime.

d. Orbital Characteristics

(1) Elevation Angle Considerations.

The orbital positions were chosen to maximize the coverage of populated regions of the world. Elevation angles from user terminals are generally greater than 15° which is desirable from the standpoint of siting of antennas and rain attenuation. Criteria for the selection of the orbital positions is given in ITEM G Orbital Locations.

(2) 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° 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, satellite spin control during transfer, and one orbital repositioning maneuver at a drift rate of 1 degree per day and disposal of the satellite to a higher orbit at the end of its service life.

e. Telemetry and Command

The TT&C subsystem will perform the monitoring and command functions necessary for spacecraft control.

(1) 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 telemetry data mode will be PCM. For normal on-station operation, the telemetry transmitters will be connected via a filter to the transmit feed of the selected antenna.

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

(2) Command

The command system will control spacecraft operation through all phases of the mission by receiving and decoding commands to the spacecraft. The command uplink will employ government-approved command encryption. The command signals will be fed through a filter diplexer into a redundant pair of track 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 Ku band command bicone antenna will be used in transfer orbit, while the reflector antenna will be used on station for command and ranging.

(3) TT&C Performance Characteristics

A telemetry and command summary is given in Table D-10. The satellite system requires a command receiver input power of about -135 dBW for command execution. Transfer orbit command and telemetry functions will be performed via a Ku band bicone antenna. Depending on the satellite configuration, on-station command and telemetry functions will be handled through either a Ka band or Ku band reflector (spot) antenna. With a nominal ground station EIRP around 87 dBW, the command threshold requirements are met through the bicone and reflector antennas. See Table D-11. The telemetry link budget for on-station operation is given in Table D-12.

(4) Eclipse Consideration

The spacecraft bus will be designed to support 100% of the communication capacity during normal daylight operation and in eclipse. Throughout the spacecraft mission lifetime, the battery capacity will support all communications and housekeeping functions during eclipse.

Table D-10 TT&C System Parameters

Parameter	Bicone	Ku Spot	Ka Spot
Command frequency*, MHz	17305.0	17305.0	29997.0
Earth station command EIRP (typical), dBW	90.0	87.0	85.0
Command carrier modulation	FM	FM	FM
Telemetry frequency (Regions 1 & 3), MHz	11700.5	11700.5	20197.0
Telemetry frequency (Region 2), MHz	12200.5	12200.5	20197.0
Telemetry modulation	PCM	PCM	PCM
Telemetry EIRP, dBW	15.0	15.0	15.9
On-station ranging accuracy, meters	21.0	21.0	21.0

* Co-located satellites will be assigned non-conflicting frequencies in the same bands.

Table D-11 Command RF Link Budget

Parameter	Bicone	Ku Spot	Ka Spot
Ground station amplifier output power, dBW	37.0	25.0	28.0
Loss to antenna input, dB	1.0	1.0	1.0
Ground station EIRP, dBW	90.0	87.0	85.0
Polarization loss, dB	0.1	0.1	0.2
Dispersion loss, dB/m^2	162.5	162.5	162.5
Incident power density, dBW/m^2	-72.6	-75.6	-77.7
Isotropic area, dB-m^2	-46.2	-46.2	-51.0
Antenna gain, ± 20° on omni, dBi	-1.0	35.0	35.0
RF losses to command receiver, dB	-5.0	-20.0	-20.0
Receiver input power, dBW	-124.8	-106.8	-113.7
Receiver command threshold, dB	-135.0	-135.0	-135.0
Margin above command threshold, dB	10.2	28.2	21.3

Table D-12 Telemetry RF Link Budget

Parameter	Ku Spot	Ka Spot
Telemetry transmitter final output power, dBW	-19.0	-29.6
Loss to antenna input, dB	1.0	1.0
Telemetry EIRP min., dBW	15.0	15.9
Dispersion loss, dB/m^2	162.5	162.5
Incident Power Density, dBW/m^2	-147.5	-146.6
Isotropic area, dB-m^2	-42.8	-47.5
Atmospheric absorption (clear sky), dB	-0.1	-0.2
TT&C station G/T, dB/K	35.0	33.7
Receive system noise temperature, dBK	20.0	20.3
Link C/T, dBW/K	-155.3	-160.4
Link C/No, dB-Hz	73.3	68.2
Subcarrier modulation index loss, dB	4.1	4.1
Subcarrier C/No, dB-Hz	69.2	64.1
Telemetry Eb/No (bit rate = 1 Kbps)	39.2	34.1
Eb/No required for 10E-5 BER	13.4	13.4
Margin, dB	25.8	20.7

(5) 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. Similarly, brief crosslink outages will occur due to solar conjunction during the equinox season.

ITEM E. Performance Requirements and Operational Characteristics of GALAXY/SPACEWAY™

1. Communication Links

The characteristics and associated link analysis for the representative Ku band and Ka band services offered within HCG's GALAXY/SPACEWAY™ satellite system are presented in Appendix A. The link budgets demonstrate that the GALAXY/SPACEWAY™ satellite system will allow all potential services to meet their respective performance objectives while maintaining sufficient link margin.

2. Intersatellite Link Analysis

The GALAXY/SPACEWAY™ satellites are networked with intersatellite links in the Ka Band and/or V Band of frequencies. Each satellite has east and west looking crosslink antennas that are 1.25 m in diameter. Tables E-1 and E-2 present intersatellite link calculations for a medium range and a long range transmission.

ITEM F. Interference Analysis

The interference analysis for the GALAXY/SPACEWAY™ satellite network is presented below. The analysis addresses the potential for interference both internally and between GALAXY/SPACEWAY™ spacecraft and adjacent spacecraft. As shown in the analysis, GALAXY/SPACEWAY™ will be capable of operation without appreciable risk of unacceptable electronic interference.

Table E-1. Ka Band Intersatellite Link Calculations

Longitudinal Separation	90.0	160.0	degrees
Path Distance	59628.0	83047.0	km
Frequency	23000.0	23000.0	MHz
Saturated Power	120.0	120.0	Watts
HPA output Backoff	4.0	3.0	dB
Number of carriers/TWTA	72.0	72.0	#
Output Losses	3.0	3.0	dB
Transmit Antenna Gain	53.0	53.0	dBi
EIRP/Carrier	48.2	49.2	dBW
Space Loss	215.2	218.1	dB
Receive Antenna Gain	53.0	53.0	dBi
Receive Noise Temperature	27.8	27.8	dBK
Channel Bandwidth	67.6	67.6	dBHz
Boltzmann Constant	-228.6	-228.6	dBW/Hz/K
Eb/No Performance	19.2	17.4	dB
Eb/No Requirement	15.0	15.0	dB
System Margin	4.2	2.4	dB

Table E-2. V Band Intersatellite Link Calculations

Longitudinal Separation:	90.0	160.0	degrees
Path Distance	59628.0	83047.0	km
Frequency	60000.0	60000.0	MHz
Saturated Power	25.0	25.0	Watts
HPA output Backoff	4.0	3.0	dB
Number of carriers/TWTA	72.0	72.0	#
Output Losses	1.5	1.5	dB
Transmit Antenna Gain	56.4	56.4	dBi
EIRP/Carrier	46.3	47.3	dBW
Space Loss	223.5	226.4	dB
Receive Antenna Gain	56.4	56.4	dBi
Receive Noise Temperature	27.8	27.8	dBK
Channel Bandwidth	67.6	67.6	dBHz
Boltzmann Constant	-228.6	-228.6	dBW/Hz/K
Eb/No Performance	12.4	10.5	dB
Eb/No Requirement	10.0	10.0	dB
System Margin	2.4	0.5	dB

1. Internal Interference

a. Cross-polarization Interference

Cross-polarization interference can result from either ground terminal or spacecraft polarization imperfections or from atmospheric effects such as rain. The combined cross-polarization E_b/I of the spacecraft and ground terminal with rain de-polarization which is used for the link analysis of high powered narrow beam services is 17.4 dB. The combined cross-polarization C/I of the spacecraft and ground terminal with rain de-polarization which is used for the link analysis of wide area services is 22.3 dB.

The satellite design does not technically provide 30 dB cross-polarization over the entire coverage area as required by Section 25.210(g) of the Commission's rules. However, cross-polarization interference is an intra-system design issue and does not affect inter-system coordination. Use in the GALAXY/SPACEWAY™ network of digital modulation with forward error control coding on both polarization senses reduces the system sensitivity to cross-polarization interference. Specifically, polarization isolation, directivity and antenna implementation losses are jointly optimized to yield the best overall link performance. These factors are statistically combined with a contribution due to earth terminal imperfections to yield the single-entry polarization interference level shown in the system link budgets. Since the required overall carrier-to-interference level is less than 8 dB, cross-polarization interference accounts for less than 15% of the total link noise. Thus, the system will adequately achieve the goals of Section 25.210(g).

b. Intermodulation Interference

The GALAXY/SPACEWAY™ narrow spot beam design performs on-board conversion between an FDM uplink format and TDM downlink format. This re-formatting allows the high power amplifiers to operate in single carrier mode which is inherently free from intermodulation distortion products.

The MCPC services on the wide area design operate in single carrier mode, making them inherently free from intermodulation distortion products. Use of linearizers and a 2 dB TWT output back-off will keep C3IM for the SCPC services to a minimum of 20.2 dB.

c. Frequency Re-use Interference

The GALAXY/SPACEWAY™ narrow spot beam services employs six-fold re-use of each frequency on each polarization, resulting in an effective bandwidth of 6 GHz for each satellite. Frequency re-use is simplified since the system operates with homogenous digital traffic. Moreover, the powerful error correcting codes used throughout the system reduce vulnerability to frequency re-use interference. The uplink antennas provide at least 24 to 29 dB of isolation between regions of frequency re-use, depending on user location with respect to the beam center. If we assume 23 dB of isolation for a user at edge of beam with 5 dB of beam rolloff, and we further assume the worst case of four such identical interfering neighbors, then the total Eb/I due to frequency reuse is 18.0 dB.

This interference is insignificant for the wide area services where the number of beams reusing the same frequency is minimal.

2. Adjacent Satellite Interference

The GALAXY/SPACEWAY™ network has been designed to operate in a 2 degree orbital spacing environment for Ka band FSS. For Ku band BSS, orbital locations for GALAXY/SPACEWAY™ were selected so as to minimize interference into adjacent BSS satellite systems and meet all of the rules and regulations set forth by the ITU concerning such operations. Details and analysis concerning orbital location selections are discussed in ITEM G and Appendix B.

a. Interference Into the GALAXY/SPACEWAY™ System

For the purpose of uplink interference, a satellite system with a relatively low sensitivity implied by having a CONUS-size antenna coverage is assumed. Specifically, we assume a 3.9 dB/K G/T that might result from 31.5 dBi edge-of-coverage antenna gain and an overall noise figure of 3 dB. As with the GALAXY/SPACEWAY™ system, HCG assumes adjacent satellites will utilize uplink power control to provide acceptable availability without causing undue interference under clear sky conditions. The resulting interference spectral flux densities for representative services, along with uplink signal and SNR requirements, are shown in Table F-1. The worst-case interference occurs with analog TV, shown in the right-hand column. An interference spectrum of -73 dBc/Hz is assumed, implying coordination between system operators, as the interference level will be considerably higher in the center 3.5 MHz of the band.

Table F-1: Uplink Interference Signal Models

Service	Digital SCPC	Digital TV	Analog TV
Bandwidth (MHz)	2.0	24.0	24.0
Required Uplink SNR (dB)	10.0	22.5	30.0
Required Flux Density (dBW/m^2)	-108.8	-85.5	-78.0
Uplink Antenna Diameter (m)	1.2	4.0	10.0
Sidelobe Protection (dB)	28.9	39.4	47.3
Adjacent System Flux Density (dBW/m^2)	-137.8	-125.0	-125.3
Interference Spectral Flux Density($dBW/m^2/Hz$)	-200.8	-198.8	-198.4

Tables A-1a and A-1b in Appendix A show the typical value of Eb/I interference into the high powered narrow beam uplink is 20.8 dB. Tables A-2a and A-2b in Appendix A show the typical interference into the wide area data beams on the uplink is 29.7 dB. Typical adjacent C/I values into wide area services are shown in Table F-2 below.

The nominal narrow beam user antenna diameter has been selected to minimize sensitivity to adjacent system interference on the downlink. Figure F-1 illustrates the performance of a 26 inch (66 cm) antenna using a simple, inexpensive and producible conical feed horn. As can be seen, this antenna provides at least 25 dB of sidelobe isolation from adjacent satellites that would appear at least 2.2 degrees separated in topocentric angle. Because this desirable performance can be achieved at no impact to terminal cost, HCG has used these predicted antenna characteristics in computing the downlink interference into the GALAXY/SPACEWAY™ system.

Table F-2: Uplink Interference Into Wide Area System

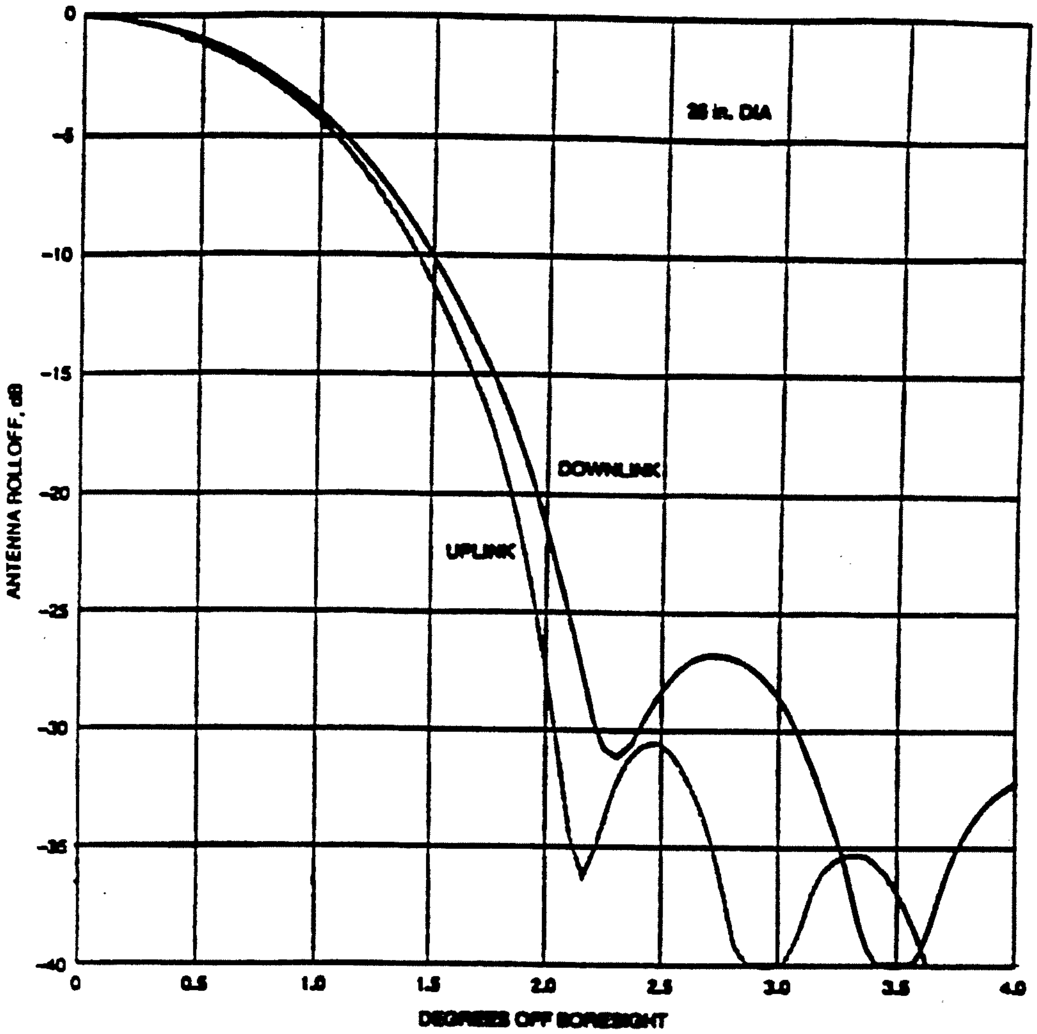
Interferor:	
FMTV flux density	-78.0 dBW/m^2
bandwidth	73.1 dB Hz
sidelobe protection	47.3 dB
Interferor spectral flux density	-198.4 dBW/Hz/m^2
Wide Area System:	
FMTV flux density	-80.5 dBW/m^2
bandwidth	75.6 dB Hz
C/I due to Interferor	42.3 dB
Cable flux density	-80.5 dBW/m^2
bandwidth	75.6 dB Hz
C/I due to Interferor	42.3 dB
DTH flux density	-95.3 dBW/m^2
bandwidth	67.6 dB Hz
C/I due to Interferor	35.5 dB
SNG flux density	-95.3 dBW/m^2
bandwidth	67.6 dB Hz
C/I due to Interferor	35.5 dB

On the downlink, we have assumed an adjacent satellite transmitting an EIRP of 60 dBW and transponders spaced at 27 MHz. The resulting typical interference Eb/I into the high powered narrow beams is 18.5 dB. Typical adjacent C/I values into the wide area services are shown in Table F-3 below. For wide area services, HCG assumed an equal powered adjacent satellite interferor of 54 dBW.

Table F-3: Downlink Interference Into Wide Area System.

Interferor:	
Interferor downlink EIRP	54.0 dBW
Interferor bandwidth	74.3 dB Hz
Interferor power spectral density	-20.3 dBW/Hz
Wide Area System:	
FMTV sidelobe protection	33.7 dB
FMTV system EIRP	50.0 dBW
FMTV system bandwidth	75.6 dB Hz
C/I due to Interferor	28.4 dB
Cable sidelobe protection	33.7 dB
Cable system EIRP	50.0 dBW
Cable system bandwidth	75.6 dB Hz
C/I due to Interferor	28.4 dB
DTH sidelobe protection	25.7 dB
DTH system EIRP	40.2 dBW
DTH system bandwidth	67.6 dB Hz
C/I due to Interferor	18.6 dB
SNG sidelobe protection	39.8 dB
SNG system EIRP	50.0 dBW
SNG system bandwidth	67.6 dB Hz
C/I due to Interferor	42.5 dB

Figure F-1 User Terminal Antenna Discrimination



b. Interference Into Other Satellite Systems

Table F-4 contains uplink interference analysis into adjacent satellite systems caused by the narrow beam system. This system will be interference- friendly because it will use uplink power control and digital signaling. For uplink interference into adjacent satellite systems, HCG again assumes the same signal characteristics shown in Table F-1. When operating with 4 dB of thermal SNR margin on the uplink, the flux density of a 500 kHz, 384 Kbps carrier at the GALAXY/SPACEWAY™ satellite is -121 dBW/m^2. When the 30 dB sidelobe protection shown in Figure F-4 is factored in, the interference spectral density is -208 dBW/m^2/Hz per carrier at the adjacent satellite. Thus, with 6-fold frequency re-use in each of two polarizations, the worst case interference level is less than -200 dBW/m^2/Hz. Based on the signal assumptions shown in Table F-1, the SNRs due to high powered narrow beam uplink interference are 28 dB for SCPC digital, 41 dB for digital TV, and 48 dB for analog TV. Calculations are shown for the 66 cm uplink antenna since this is the worst-case narrow beam interference source.

Table F-5 contains uplink interference analysis into adjacent satellite systems caused by the wide area system. This system will be interference-friendly because it will use uplink power control and digital signaling. For uplink interference into adjacent satellite systems, HCG again assumes the signal characteristics shown in Table F-1. The flux density of a 6 MHz, 8.2 Mbps carrier is -95.3 dBW/m^2. Applying the 29 -25 log(Ø) guideline, the transmit antenna has about 35.2 dB of sidelobe protection at 29.75 GHz and the interference spectral density is -198.1 dBW/m^2/Hz per carrier at the adjacent satellite. Based on the signal assumptions shown in Table F-1, the SNR's due to wide area uplink interference are 26 dB for

SCPC digital, 39 dB for digital TV, and 46 dB for analog TV. Calculations are shown for a 2.4 m uplink antenna since this is the worst-case interference source.

Table F-4: High Powered Narrow Beam System Uplink Interference Into Adjacent System

High Powered Narrow Beam:	
High powered narrow beam flux density	-121.0 dBW/m^2
High powered narrow beam terminal uplink discrimination	30.0 dB
bandwidth	57.0 dB Hz
six-fold freq. reuse	7.8 dB
worst case high powered narrow beam spectral density	-200.2 dBW/m^2/Hz
Adjacent System:	
Digital SCPC flux density	-108.8 dBW/m^2
bandwidth	63.0 dB Hz
C/I due to GALAXY/SPACEWAY™	28.4 dB
Digital TV flux density	-85.5 dBW/m^2
Digital TV bandwidth	73.8 dB Hz
C/I due to GALAXY/SPACEWAY™	40.9 dB
Analog TV flux density	-78.0 dBW/m^2
Analog TV bandwidth	73.8 dB Hz
C/I due to GALAXY/SPACEWAY™	48.4 dB

Table F-5: Wide Area Beam System Uplink Interference Into Adjacent System

Wide Area Beam:	
Wide area beam flux density	-95.3 dBW/m^2
Wide area beam terminal uplink antenna	35.2 dB
bandwidth	67.6 dB Hz
worst case wide area beam spectral flux density	-198.1 dB/m^2/Hz
Adjacent System:	
Digital SCPC flux density	-108.8 dBW/m^2
bandwidth	63.0 dB Hz
C/I due to GALAXY/SPACEWAY™	26.3 dB
Digital TV flux density	-85.5 dBW/m^2
Digital TV bandwidth	73.8 dB Hz
C/I due to GALAXY/SPACEWAY™	38.8 dB
Analog TV flux density	-78.0 dBW/m^2
Analog TV bandwidth	73.8 dB Hz
C/I due to GALAXY/SPACEWAY™	46.3 dB

Downlink interference from high powered narrow beam services into adjacent systems, as shown in Table F-6, will be highest for applications that utilize very small aperture terminals. The television broadcasting examples shown in Table F-1 are typical of these most vulnerable applications. A typical system might utilize a 24 inch receive antenna. Applying the 29 - 25 log(Ø) guideline, the receive antenna would have about 19.6 dB of sidelobe protection at the worst-case low end of the 19.2 to 20.2 GHz band. In this frequency band, a satellite EIRP of at least 54 dBW would be needed to achieve reasonable availability for digital transmission. Assuming a satellite EIRP of 54 dBW and a transponder bandwidth of 24 MHz, the C/I due to interference from narrow beams is 21.6 dB. Analog TV would require somewhat higher EIRP and would have a correspondingly better C/I.

Table F-6: High Powered Narrow Beam System Downlink Interference Into Adjacent System

High Powered Narrow Beam downlink EIRP	59.0 dBW (peak)
High Powered Narrow Beam bandwidth	80.8 dB Hz
High Powered Narrow Beam power spectral density	-21.8 dBW/Hz
sidelobe protection	19.6 dB
adjacent system EIRP	54.0 dBW
adjacent system bandwidth	73.8 dB Hz
adjacent system power spectral density	-19.8 dBW/Hz
C/I due to GALAXY/SPACEWAY™	21.6

Downlink interference from wide area beam services into adjacent systems, as shown in Table F-7, will be highest for applications that utilize very small aperture terminals. The television broadcasting examples shown in Table F-1 are typical of these most vulnerable applications. A typical system might utilize a 24 inch receive antenna. Applying the 29 - 25 log(Ø) guideline, the receive antenna would have about 19.9 dB of sidelobe protection at 20 GHz. In this frequency band, a satellite EIRP of at least 54 dBW would be needed to achieve reasonable availability for digital transmission. Assuming a satellite EIRP of 54 dBW and a transponder bandwidth of 24 MHz, the C/I due to interference from wide beams is 24.3 dB. Analog TV would require somewhat higher EIRP and would have a correspondingly better C/I.

Table F-7: Wide Area Beam System Downlink Interference Into Adjacent System

Wide Area Beam downlink EIRP	52.0 dBW (peak)
Wide Area Beam bandwidth	76.2 dB Hz
Wide Area Beam power spectral density	-24.2 dBW/Hz
sidelobe protection	19.9 dB
adjacent system EIRP	54.0 dBW
adjacent system bandwidth	73.8 dB Hz
adjacent system power spectral density	-19.8 dBW/Hz
C/I due to GALAXY/SPACEWAY™	24.3

ITEM G. Orbital Locations

The orbital locations requested below satisfy the GALAXY/SPACEWAY™ system requirements for optimizing coverage, elevation angles and service availability, and ensure that the maximum operational, economic and public interest benefits are derived from the system. Thus, assignment of the orbital locations described below would constitute the most efficient use of the orbital arc.

Because of its selection of orbital locations to comply with the present BSS plan and to protect existing BSS systems from interference, HCG proposes to change the previous SPACEWAY™ position which covers Central and South America from 50° W.L. to 49° W.L. and the position which covers Papua New Guinea, Australia and New Zealand from 175° E.L. to 173° E.L. (175° E.L. previously was referred to as "the Pacific Interconnect"). As in its original SPACEWAY™ application, HCG continues to request the 99° W.L. and 101° W.L. positions over North America, 25° E.L. over Europe and Africa, and 110° E.L. over Asia-Pacific. In addition, to provide global BSS coverage with interconnected Ka band FSS capabilities, HCG proposes to add nine more positions: 36° E.L. for service to Western