104, Rev. A
34-m BWG Stations
Telecommunications Interfaces

Released: February 5, 2004

Prepared by:

Signature on file at DSMS Library

S. D. Slobin, Date
Antenna System Engineer

Approved by:

Signature on file at DSMS Library

A. J. Freiley Date
Antenna Product Domain Service
System Development Engineer

Released by:

Signature on file at DSMS Library

DSMS Document Release Date

Change Log

Rev	Issue Date	Affected Paragraphs	Change Summary
Initial	11/30/2000	All	All
A	2/5/2004	All	Added performance information for Ka-Band capability at DSS 26 and for new station, DSS 55. Incorporated latest measurements for other stations. Incorporated text improvements.

Note to Readers

There are two sets of document histories in the 810-005 document that are reflected in the header at the top of the page. First, the entire document is periodically released as a revision when major changes affect a majority of the modules. For example, this module is part of 810-005, Revision E. Second, the individual modules also change, starting as an initial issue that has no revision letter. When a module is changed, a change letter is appended to the module number on the second line of the header and a summary of the changes is entered in the module's change log.

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1 Introduction

1.1 Purpose

This module provides the performance parameters for the Deep Space Network (DSN) 34-m Beam Waveguide (BWG) antennas and the 34-m High-speed BWG (HSB) antenna that are necessary to perform the nominal design of a telecommunications link. It also summarizes the capabilities of these antennas for mission planning purposes and for comparison with other ground station antennas.

1.2 Scope

The scope of this module is limited to providing those parameters that characterize the RF performance of the 34-meter BWG and HSB antennas including the effects of weather for a limited number of weather conditions A more complete discussion of weather effects is given in module 105, Atmospheric and Environmental Effects. This module does not discuss mechanical restrictions on antenna performance that are covered in module 302, Antenna Positioning.

2 General Information

The 34-meter diameter BWG (beam waveguide) and HSB (high angular-tracking speed beam waveguide) antennas are the latest generation of antennas built for use in the DSN. These antennas differ from more conventional antennas (for example, the 34-meter HEF antennas, described in module 103) in the fact that a series of small mirrors, approximately 2.5 meters in diameter, direct microwave energy from the region above the main reflector to a location in a pedestal room at the base of the antenna. The pedestal room is located below the azimuth track of the antenna and, with the exception of the HSB antenna, below ground level.

In this configuration, several “positions” of microwave equipment, contained in the pedestal room, can be accessed by rotation of an ellipsoidal mirror located in the center of the pedestal room floor beneath the azimuth axis of the antenna. This enables great versatility of design and allows tracking with equipment at one position while equipment installation or maintenance is carried out at the other positions. Since cryogenic low-noise amplifiers (LNAs) do not tip as they do when located above the elevation axis, certain state-of-the-art, ultra low noise amplifier (ULNA) and feed designs can be implemented.

The HSB antenna differs from the BWG antennas in that the pedestal room is above ground level, the microwave optics design is different, and the subreflector does not focus automatically for the purpose of maintaining gain as the elevation angle of the antenna changes. The HSB antenna has higher tracking rates than do the BWG antennas and is equipped primarily for tracking Earth-orbiting satellites.

The capabilities of each antenna are significantly different depending on the microwave, transmitting, and receiving equipment installed. A summary of these differences is provided in Table 1. Functional block diagrams for each antenna are provided in Figures 1–4. In general, each antenna has one LNA for each supported frequency band. However, stations that can support simultaneous right circular polarization (RCP) and left circular polarization (LCP) in the same band have an LNA for each. In addition, the stations that support Ka-Band contain an additional LNA to enable monopulse tracking. Each antenna also has at least one transmitter. Antennas with more than one transmitter can operate only one of them at a time. DSS 25 is an exception and has a Ka-Band transmitter and RCP transmit feed that can be operated at the same time as its X-Band transmitter.

DSS 24, 34, and 54 can receive selectable (one polarization at a time) RCP or LCP at both S- and X-Bands. DSS-25 can receive both X-Band polarizations simultaneously, however only RCP is available at Ka-Band. The DSS 25 Ka-Band implementation includes a monopulse channel to improve antenna pointing. DSSs 26 and 55 can receive both X-Band and both Ka-Band polarizations simultaneously, however Ka-Band LCP is not available when monopulse tracking is being performed because the second Ka-Band receiver channel is used for monopulse. The feed package does not contain an LNA for the LCP error signal with the result being that LCP monopulse tracking is not available.

The S- and X-Band transmitters at DSSs 24, 25, 27, 34, and 54 are coupled into the microwave path using a frequency-selective diplexer. Because the diplexer increases the operating system temperature, a non-diplexed path for receive-only operation is provided at all of these antennas, except for the DSS 27 HSB antenna. DSSs 26 and 55 accomplish the diplex function using the frequency-selective characteristics of the feed in conjunction with an external polarizing network. They are considered to be always diplexed and no lower-noise, non-diplexed configuration is necessary or available.

When an S-Band uplink is required, it must be of the same polarization as is being received. An X-Band downlink received in conjunction with an S-Band uplink can be of either polarization. X-Band uplinks can be either the same or the opposite polarization from that being simultaneously received. S-Band downlinks are not available in conjunction with X-Band uplinks at DSS 24, 34, and 54 due to bandwidth restrictions of the S/X dichroic plate that must be retracted for X-Band uplink operation.

When simultaneous X-Band uplink and downlink of the same polarization are required at stations with waveguide diplexers (DSS 24, 25, 34, and 54), reception must be through the diplexer and the noise will be increased over that of the non-diplexed path. DSS 25 has two X-Band LNAs and can receive simultaneous RCP and LCP, although one of the signals will be via the non-diplexed path and the other will be via the diplexed path. DSSs 26 and 55 also have two X-Band LNAs, one for each polarization. As these stations do not have waveguide diplexers, the noise level in each polarization is approximately the same.

2.1 Telecommunications Parameters

The significant parameters of the 34-meter BWG and HSB antennas that influence the design of the telecommunications link are listed in Tables 2 through 8. Variations of these parameters that are inherent in the design of the antennas are discussed below. Other factors that degrade link performance are discussed in modules 105 (Atmospheric and Environmental Effects) and 106 (Solar Corona and Solar Wind Effects).

The values in these tables do not include the effects of the atmosphere. However, the attenuation and noise-temperature effects of weather for three specific weather conditions are included in the figures at the end of the module so that they may be used for a quick estimate of telecommunications link performance for those specific conditions, without reference to module 105. For detailed design control table use, the more comprehensive and detailed S, X-, and Ka - Band weather effects models (for weather conditions up to 99% cumulative distribution) in module 105 should be used.

2.1.1 Antenna Gain Variation

Because the gain is referenced to the feedhorn aperture, such items as diplexers and waveguide runs to alternate LNAs, that are “downstream” (below or toward the LNA), do not affect the gain at the reference plane. Dichroic plates that are “upstream” of the feedhorn aperture cause a reduction in gain.

2.1.1.1 Frequency Effects

Antenna gains are specified at the indicated frequency (f_0). For operation at higher or lower frequencies in the same band, the gain (dBi) must be increased or reduced, respectively, by 20 log (f/f_0).

2.1.1.2 Elevation Angle Effects

Structural deformation causes a reduction in gain when the antenna is operated at an elevation angle other than where the reflector panels were aligned. The effective gain of the antenna also is reduced by atmospheric attenuation, which is a function of elevation. Figures 5 through 14 show representative curves of gain versus elevation angle for selected stations and configurations. The curves show the hypothetical vacuum (no atmosphere) condition, and the gain with 0%, 50%, and 90% weather conditions, designated as CD (cumulative distribution) = 0.00, 0.50, and 0.90. 0% means minimum weather effect (exceeded 100% of the time); 90% means that effect which is exceeded only 10% of the time. Qualitatively, 0% corresponds to the driest condition of the atmosphere; 25% corresponds to average clear; 50% corresponds to humid or very light clouds; and 90% corresponds to very cloudy, but with no rain. Appendix A provides the complete set of parameters from which these curves were created. These parameters, in combination with the weather effects parameters from module 105, can be used to calculate the gain versus elevation angle curve for any antenna, in any configuration, for weather conditions up to 99% CD.

2.1.1.3 Wind Loading

The gain reduction at X-Band due to worst-case wind loading is listed in Table 9. The tabular data are for structural deformation only and presume that the antenna is maintained on-point. In addition to structural deformation, wind introduces a pointing error that is related to the antenna elevation angle, the angle between the antenna and the wind, and the wind speed. The effects of pointing error are discussed below. Cumulative probability distributions of wind velocity at Goldstone are given in module 105.

2.1.2 System Noise Temperature Variation

The operating system temperature (T_{op}) varies as a function of elevation angle due to changes in the path length through the atmosphere and ground noise received by the sidelobe pattern of the antenna. Figures 15 through 24 show the combined effects of these factors for the same set of stations and configurations selected above. The figures show the hypothetical vacuum and the 0%, 50%, and 90% weather conditions. The equations and parameters for these curves are provided in Appendix A and can be used, in combination with the weather effects parameters from module 105, to calculate the system temperature versus elevation curve for any antenna, in any configuration, for weather conditions up to 99% CD.

The system temperature values in Tables 6–8 do not include any atmospheric contribution and must be increased for comparison with antennas that are specified with 25% average-clear weather. Table 10 provides adjustments to the hypothetical no-atmosphere (vacuum) operating system temperature ($T_{op,\ vac}$) that were calculated using the weather models in module 105

2.1.3 Antenna Pointing

2.1.3.1 Pointing Accuracy

The pointing accuracy of an antenna, often referred to as its *blind-pointing* performance, is the difference between the calculated (or commanded) beam direction and the actual beam direction. The error is typically random and can be divided into two major categories. The first of these includes the computational errors and uncertainties associated with the radio sources used to calibrate the antenna, and the location of the spacecraft provided by its navigation team. The second has many components associated with converting a calculated beam direction to the physical positioning of a large mechanical structure. Included are such things as atmospheric wind and refraction effects, servo and encoder errors, thermally and gravitationally induced structural deformation, azimuth track leveling (for an azimuth-elevation antenna), and both seismic and diurnal ground tilt.

Blind pointing is modeled by assuming equal pointing performance in the elevation (EL) and cross-elevation (X-EL) directions. That is, the random pointing errors in each direction have uncorrelated Gaussian distributions with the same standard deviation. This results in a Rayleigh distribution for pointing error where the mean radial error is 1.2533 times the standard deviation of the EL and X-EL components. For a Rayleigh distribution, the probability that the pointing error will be less than the mean radial error is 54.4%. Conversely, the probability that the mean radial error will be exceeded is 45.6%.

Table 11 provides the modeled blind-pointing performance and the resulting gain reductions in various wind conditions for the BWG antennas. The wind speeds given in the table are considered to be mean hourly values, thus gusts could exceed these values by a factor of two or more, for short amounts of time. In addition to the mean radial error (CD = 54.4%), pointing errors for the 90%, 95%, and 99% points on the Rayleigh distribution curve are also provided. A CD of 90% implies that 90% of the time, the pointing error or pointing loss will be less than the value shown, and so forth.

2.1.3.2 Pointing Loss

Figures 25 through 27 show the effects of pointing error on effective transmit and receive gain of the antenna. These curves are Gaussian approximations based on measured and predicted antenna beamwidths. Data have been normalized to eliminate elevation and wind loading effects. The equations used to derive the curves are provided in Appendix A.

2.1.3.3 Monopulse-aided Pointing

Ka-Band monopulse-aided pointing uses a monopulse tracking coupler within the cryogenic feed package to establish a feed pattern with a theoretical null on axis. The magnitude of the pointing error is proportional to the magnitude of the signal received by this pattern and the azimuthal error is proportional to the phase difference between the sum and difference outputs of the coupler. Thus, by measuring the complex ratio of the sum and difference signals, pointing corrections can be generated to instruct the antenna servo system to drive the pointing error to zero. The system achieves its specified performance when the ratio of the signal in the sum channel (that is, the signal from which tracking and telemetry information will be derived) to the noise level in the difference channel is 26 dB-Hz.

2.1.3.4 Ka-Band Aberration Correction

The extremely narrow beamwidth at Ka band requires that a Ka-Band uplink signal be aimed at where the spacecraft will be when the signal arrives, while simultaneously receiving a signal that left the spacecraft one light-time previously. This is accomplished by mounting the Ka-Band transmit feed at DSS 25 on a movable X-Y platform that can displace the transmitted beam as much as 30 millidegrees from the received beam. DSS 25 is the only antenna with a Ka-Band transmit capability. The fact that the transmit feed is displaced from its optimum focus causes the gain reduction depicted in Figure 28. The equation used to generate this curve is provided in Appendix A.

3 Proposed Capabilities

The following paragraphs discuss capabilities that have not yet been implemented by the DSN but have adequate maturity to be considered for spacecraft mission and equipment design. Telecommunications engineers are advised that any capabilities discussed in this section cannot be committed to except by negotiation with the Interplanetary Network Directorate (IPN) Plans and Commitments Program Office.

3.1 34-m BWG Ka-Band Implementation

The set of BWG Antennas that support both X-Band and S-Band (DSS 24, 34, and 54), are being equipped with the same X/X/Ka-Band feed that has been installed at DSS 26 and DSS 55. Two modes of operation are anticipated. The first will be an X/Ka configuration similar to DSS 26 and DSS 55 except only one received X-Band polarization will be routed from the antenna at a time. The second will be an S/X configuration that will insert a dichroic plate above the S-Band feed to separate the S-Band and X-Band signals. There are presently no requirements to operate S-Band and Ka-Band simultaneously and the existing dichroic plate that will be retained in this implementation was not designed and has not been tested for such operation.

3.1.1 S-Band Performance

The S-Band uplink and downlink performance of these three stations will be unchanged. Among other things, this means that S-Band reception will not be possible when an X-Band uplink is required.

3.1.2 X-Band Uplink Performance

The X-Band uplink performance of these three stations will be reduced by approximately 0.2 dB to accommodate the additional loss in the uplink polarization and injection components of the X/X/Ka-Band feed.

3.1.3 X-Band Downlink Performance

The non-diplexed X-Band G/T performance of DSS 24 and 54 in average clear weather will be improved by approximately 0.9 dB with respect to the present non-diplexed configuration that uses a MASER low noise amplifier. As the new feed permits uplink radiation without diplexing loss, the G/T performance for the diplexed configuration will be improved by approximately 2.4 dB relative to the existing performance.

The non-diplexed X-Band G/T performance of DSS 34 in average clear weather, will be improved by approximately 1.7 dB with respect to the present non-diplexed configuration that uses a HEMT low noise amplifier. As the new feed permits uplink radiation without diplexing loss, the G/T performance for the diplexed configuration will be improved by approximately 3.0 dB with respect to the existing performance.

3.1.4 Ka-Band Downlink Performance

The Ka-Band performance will be similar to DSS 26 and 55. Polarization capability will be simultaneous RCP and LCP without monopulse or RCP with monopulse.

Table 1. Summary of Available Configurations for Each Antenna.

Configuration	Uplink*	Downlink	Polarization	Remarks
DSS 24, DSS 34, DSS 54 (BWG)				
S-Up, S-Down	S, 17.4 kW	S	RCP or LCP	• Transmit and receive polarizations must be the same
S-Up, S/X-Down	S, 17.4 kW	S and X	RCP or LCP	• S-band transmit and receive polarizations must be the same. • X-band may use low noise (non-diplexed) or diplexed path.
S-Down Low Noise	None	S	RCP or LCP	• Non-diplexed path
X-Up, X-Down	X, 18.2 kW	X	RCP or LCP	• Transmit and receive polarizations are independent. • (requires S/X dichroic plate to be retracted – no S-band).
X-Down Low Noise	None	X	RCP or LCP	• Non-diplexed path with S/X dichroic plate retracted
DSS 25 (BWG)				
X-Up, X-Down	X, 18.2 kW	X	RCP and LCP	• Both receive polarizations are available simultaneously. • Opposite (to transmit) polarization is available via low noise (non-diplexed) path.
X-Down Low Noise	None	X	RCP and LCP	• Non-diplexed path. • Opposite polarization is available via higher noise (diplexed) path..
X-Up, X/Ka-Down, Ka-Monopulse	X, 18.2 kW	X and Ka	X-band (RCP and LCP) Ka-band (RCP only)	• Both X-band receive polarizations are available simultaneously.. • Opposite (to transmit) X-band polarization is available via low noise (non-diplexed) path.
X/Ka-Up, X/Ka-Down, Ka-Monopulse	X, 18.2 kW Ka, 755 W	X and Ka	X-band (RCP and LCP) Ka-band (RCP only)	• Both X-band receive polarizations are available simultaneously. • Both transmitters are available simultaneously. • Opposite (to transmit) X-band polarization is available via low noise (non-diplexed) path.
Ka-Up, X/Ka-Down, Ka-Monopulse	Ka, 755 W	X	X-band (RCP and LCP) Ka-band (RCP only)	• One X-band polarization uses low noise (non-diplexed) path. • Opposite polarization is available via higher noise (diplexed) path.
Ka-Up, Ka-Down, Ka-Monopulse	Ka, 755 W	Ka	RCP only	• Lowest noise configuration (X/Ka dichroic plate retracted)

* The power listed in this column refers to the maximum available uplink power at the feedhorn aperture, accounting for waveguide loss between transmitter output and feedhorn aperture

Table 1. Summary of Available Configurations for Each Antenna (Continued).

Configuration	Uplink*	Downlink	Polarization	Remarks
DSS 26 and DSS 55 (BWG)				
X-Up, X-Down	X, 17.4 kW	X	RCP and LCP	• transmit and receive polarizations are independent. • Both X-band receive polarizations are available with similar noise characteristics.
X-Up, X/Ka-Down, Ka-Monopulse	X, 17.4 kW	X and Ka	X-band (RCP and LCP) Ka-band (RCP only)	• X-band transmit and receive polarizations are independent. • Both X-band receive polarizations are available with similar noise characteristics. • Only Ka-band RCP is available.
X-Up, X/Ka-Down, Dual Polarization	X, 17.4 kW	X and Ka	X-band (RCP and LCP) Ka-band (RCP and LCP)	• X-band transmit and receive polarizations are independent. • Both X-band receive polarizations are available with similar noise characteristics. • Both Ka-band receive polarizations are available with similar noise characteristics. • Ka-band monopulse tracking is not available.
X/Ka-Down, Ka-Monopulse	None	X and Ka	X-band (RCP and LCP) Ka-band (RCP only)	• Both X-band receive polarizations are available with similar noise characteristics. • Only Ka-band RCP available.
X/Ka-Down, Dual Polarization	None	X and Ka	X-band (RCP and LCP) Ka-band (RCP and LCP)	• Both X-band receive polarizations are available with similar noise characteristics. • Both Ka-band receive polarizations are available with similar noise characteristics. • Ka-band monopulse tracking is not available.
DSS 27 (HSB)				
S-Up, S-Down	S, 174 W	S	RCP or LCP	• Transmit and receive polarizations must be the same.

* The power listed in this column refers to the maximum available uplink power at the feedhorn aperture, accounting for waveguide loss between transmitter output and feedhorn aperture

Table 2. S-Band Transmit Characteristics, DSS 24, 34, and 54

Parameter	Value	Remarks
ANTENNA		
Gain at 2115 MHz	56.1 +0.2,–0.3 dBi	At peak of gain versus elevation curve, referenced to feedhorn aperture for matched polarization; no atmosphere included; triangular probability density function (PDF) tolerance.
Transmitter Waveguide Loss	0.6 ±0.1 dB	20-kW transmitter output terminal (waterload switch) to feedhorn aperture
Half-Power Beamwidth	0.263 ±0.020 deg	Angular width (2-sided) between half-power points at specified frequency
Polarization	RCP or LCP	One polarization at a time, remotely selected. Polarization must be the same as received polarization.
Ellipticity	1.0 dB (max)	Peak-to-peak axial ratio defined as the ratio of peak-to-trough received voltages with a rotating linearly polarized source and the feed configured as a circularly (elliptically) polarized receiving antenna.
Pointing Loss		
Angular	See module 302	Also see Figure 25.
CONSCAN	0.01 dB	X-Band CONSCAN reference set for 0.1 dB loss
	0.1 dB	S-Band CONSCAN reference set for 0.1 dB loss
EXCITER AND TRANSMITTER		
Frequency Range Covered	2025–2120 MHz	Power amplifier is step-tunable over the specified range in six 20-MHz segments, with 5-MHz overlap between segments. Tuning between segments can be accomplished in 30 seconds.
Instantaneous 1-dB Bandwidth	20 MHz	

Table 2. S-Band Transmit Characteristics, DSS 24, 34, and 54 (Continued)

Parameter	Value	Remarks
EXCITER AND TRANSMITTER (Continued)		
Coherent with earth orbiter S-Band D/L allocation	2028.8–2108.7 MHz	240/221 turnaround ratio
Coherent with deep space S-Band D/L channels	2110.2–2117.7 MHz	240/221 turnaround ratio
Coherent with deep space X-Band D/L channels	2110.2–2119.8 MHz	880/221 turnaround ratio
RF Power Output		Referenced to 20-kW transmitter output terminal (waterload switch). Settability is limited to 0.25 dB by measurement equipment precision.
2025–2070 MHz	53.0–73.0 +0.0,–1.0 dBm	
2070–2090 MHz	53.0–67.0 +0.0,–1.0 dBm	S-Band uplink is restricted to 5 kW over 2070–2090 frequency range
2090–2120 MHz	53.0–73.0 +0.0,–1.0 dBm	
Power output varies across the bandwidth and may be as much as 1 dB below nominal rating. Performance will also vary from tube to tube. Normal procedure is to run the tubes saturated, but unsaturated operation is also possible. The point at which saturation is achieved depends on drive power and beam voltage. The 20-kW tubes are normally saturated for power levels greater than 60 dBm (1 kW). Minimum power out of the 20-kW tubes is about 53 dBm (200 W). Efficiency of the tubes drops off rapidly below nominal rated output.		
EIRP (maximum)	128.5 +0.2, –1.0 dBm	At gain set elevation angle, referenced to feedhorn aperture
Tunability		At transmitter output frequency
Phase Continuous Tuning Range	2.0 MHz	
Maximum Tuning Rate	±12.1 kHz/s	

Table 2. S-Band Transmit Characteristics, DSS 24, 34, and 54 (Continued)

Parameter	Value	Remarks
EXCITER AND TRANSMITTER (Continued)		
Tunability (Continued)		
Frequency Error	0.012 Hz	Average over 100 ms with respect to frequency specified by predicts
Ramp Rate Error	0.001 Hz/s	Average over 4.5 s with respect to rate calculated from frequency predicts
Stability		At transmitter output frequency
Output Power Stability		Over 12-h period
Saturated Drive	0.5 dB	
Unsaturated Drive	1.0 dB	
Incidental AM	60 dB	Below carrier
Group Delay Stability	≤ 3.3 ns	Ranging modulation signal path (see module 203) over 12 h period
Frequency Stability	5.0×10^{-14}	Allan deviation, 1000 s integration time
Spurious Output		Below carrier
2nd Harmonic	-85 dB	
3rd Harmonic	–85 dB	
4th Harmonic	–140 dB	At input to X-Band horn, with transmitter set for 20-kW output

Table 3. S-Band Transmit Characteristics, DSS 27

Parameter	Value	Remarks
ANTENNA		
Gain at 2070 MHz	54.2 +0.2, –0.3 dBi	At peak of gain versus elevation angle curve, referenced to feedhorn aperture for matched polarization; no atmosphere included; triangular PDF tolerance.
Transmitter Waveguide Loss	0.6 ±0.1 dB	200-W transmitter output terminal (waterload switch) to feedhorn aperture
Half-Power Beamwidth	0.269 ±0.020 deg	Angular width (2-sided) between half-power points at specified frequency
Polarization	RCP or LCP	One polarization at a time, remotely selected. Polarization must be the same as received polarization.
Ellipticity	1.0 dB (max)	Peak-to-peak axial ratio. See Table 2 for definition.
Pointing Loss		
Angular	See module 302	See also Figure 25.
EXCITER AND TRANSMITTER		
Frequency range covered	2025–2120 MHz	
Coherent with earth orbiter S-Band D/L allocation	2028.8–2108.7 MHz	240/221 turnaround ratio
Coherent with deep space S-Band D/L channels	2110.2–2117.7 MHz	240/221 turnaround ratio
RF Power Output	47.0–53.0, ±0.5 dBm	Referenced to 200 W transmitter output terminal (power load switch). Settability is limited to 0.25 dB by measurement equipment precision.
Power output varies across the bandwidth and may be as much as 1 dB below nominal rating. The 200 W tube is a fixed beam klystron designed to saturate at its rated power. Operation at less than the nominal 200 W is accomplished by operating the tube unsaturated. Minimum power out of is about 47 dBm (50 W).		

Table 3. S-Band Transmit Characteristics, DSS 27 (Continued)

Parameter	Value	Remarks
EXCITER AND TRANSMITTER (Continued)		
EIRP (maximum)	106.6 ±0.6 dBm	At gain set elevation angle, referenced to feedhorn aperture
Tunability		At transmitter output frequency
Phase Continuous Tuning Range	2.0 MHz	
Maximum Tuning Rate	±12.1 kHz/s	
Frequency Error	0.012 Hz	Average over 100 ms with respect to frequency specified by predicts
Ramp Rate Error	0.001 Hz/s	Average over 4.5 s with respect to rate calculated from frequency predicts
Output Power Stability	±0.25 dB	Worst case over 8-h period using 30-m sample intervals
Frequency Stability	6.0×10^{-14}	Allan deviation, 1000 s integration time
Spurious Output		Below carrier
2025–2120 MHz	–88 dB	
2200–2300 MHz	–94 dB	
2nd Harmonic	–60 dB	
3rd Harmonic	–60 dB	
8400–8500 MHz	–94 dB	

Table 4. X-Band Transmit Characteristics, DSS 24, 25, 26, 34, 54, and 55

Parameter	Value	Remarks
ANTENNA		
Gain at 7145 MHz	66.9 +0.2,–0.3 dBi	At peak of gain versus elevation angle curve, referenced to feedhorn aperture for matched polarization; no atmosphere included; triangular PDF tolerance.
Transmitter Waveguide Loss		20-kW transmitter output terminal (waterload switch) to feedhorn aperture
DSS 24, 25, 34, 54	0.4 ±0.1 dB	
DSS 26, 55	0.6 ±0.1 dB	
Half-Power Beamwidth	0.077 ±0.004 deg	Angular width (2-sided) between half-power points at specified frequency
Polarization	RCP or LCP	One polarization at a time, remotely selected, independent of received polarization.
Ellipticity	1.0 dB (max)	Peak-to-peak axial. See Table 2 for definition.
Pointing Loss		
Angular	See module 302	See also Figure 26.
CONSCAN	0.1 dB	X-Band CONSCAN reference set for 0.1 dB loss
EXCITER AND TRANSMITTER		
Frequency range covered	7145–7235 MHz	S-Band downlink is not available with X-Band uplink because S/X Dichroic Plate will not pass X-Band uplink frequencies
Coherent with deep space X-Band D/L channels	7149.6–7188.9 MHz	880/749 turnaround ratio
Coherent with deep space Ka-Band D/L allocation	7149.6–7234.6 MHz	3344/749 turnaround ratio. Note: X-Band uplink frequencies greater than 7190 MHz are outside deep space X-Band uplink allocation.

Table 4. X-Band Transmit Characteristics, DSS 24, 25, 26, 34, 54, and 55 (Continued)

Parameter	Value	Remarks
EXCITER AND TRANSMITTER (Continued)		
RF Power Output		Referenced to 20-kW transmitter output terminal (waterload switch). Settability is limited to 0.25 dB by measurement equipment precision.
7145.0–7190.0 MHz	53.0–73.0 ±0.5 dBm	Deep space uplink allocation
7190.0–7235.0 MHz	53.0–67.6 ±0.5 dBm	Earth orbiter uplink allocation
Power output varies across the bandwidth and may be as much as 1 dB below nominal rating. The 20 kW tubes are fixed beam klystrons designed to saturate at their rated power however performance varies from tube to tube. Operation at less than the nominal 20 kW is unsaturated. Minimum power output is about 53 dBm (200 W). Efficiency of the tubes drops off rapidly below nominal rated output.		
EIRP (maximum)		At gain set elevation angle, referenced to feedhorn aperture
DSS 24, 25, 34, 54		
7145.0–7190.0 MHz	139.5 ±0. 7 dBm	Deep space allocation
7190.0–7235.0 MHz	134.1 ±0. 7 dBm	Earth orbiter allocation
DSS 26, 55		
7145.0–7190.0 MHz	139.3 ±0.7 dBm	Deep space allocation
7190.0–7235.0 MHz	133.9 ±0. 7 dBm	Earth orbiter allocation
Tunability		At transmitter output frequency
Phase Continuous Tuning Range	2.0 MHz	
Maximum Tuning Rate	±12.1 kHz/s	
Frequency Error	0.012 Hz	Average over 100 ms with respect to frequency specified by predicts
Ramp Rate Error	0.001 Hz	Average over 4.5 s with respect to rate calculated from frequency predicts

Table 4. X-Band Transmit Characteristics, DSS 24, 25, 26, 34, 54, and 55 (Continued)

Parameter	Value	Remarks
EXCITER AND TRANSMITTER (Continued)		
Stability		At transmitter output frequency
Output Power Stability	0.2 dB	First Differences, 10–1000 s intervals over 12 h period
Output Power Variation		Across frequency band over 12 h period
Saturated Drive	0.25 dB	
Unsaturated Drive	1.0 dB	
Group Delay Stability	≤ 1.0 ns	Ranging modulation signal path over 12 h period (see module 203)
Frequency Stability		Allan deviation
1 s	3.3×10^{-13}	
10 s	5.0×10^{-14}	
1000–3600 s	2.7×10^{-15}	
Spurious Output		Below carrier
1–10 Hz	–50 dB	
10 Hz–1.5 MHz	–60 dB	
1.5 MHz–8 MHz	–45 dB	
2nd Harmonic	–75 dB	
3rd, 4th & 5th Harmonics	–60 dB	

Table 5. Ka-Band Transmit Characteristics, DSS 25

Parameter	Value	Remarks
ANTENNA		
Gain at 34300 MHz	79.5 +0.2 –0.3 dBi	At peak of gain versus elevation angle curve, referenced to feedhorn aperture for matched polarization; no atmosphere included; triangular PDF tolerance.
Transmitter Waveguide Loss	0.25 ±0.1 dB	800W transmitter output terminal (waterload switch) to feedhorn aperture
Half-Power Beamwidth	0.016 ±0.001 deg	Angular width (2-sided) between half-power points at specified frequency
Polarization	RCP	
Ellipticity	1.0 dB (max)	Peak-to-peak axial ratio. See Table 2 for definition.
Pointing Loss	0.12 dB	Monopulse aided tracking with minimum required signal level
Angular	See module 302	Also see Figures 27 and 28
EXCITER AND TRANSMITTER		
Frequency range covered		
Exciter	34200-34700 MHz	
Transmitter	34266-34366 MHz	Bandwidth is limited by narrow band klystron
Coherent with deep space Ka-Band D/L channels	34343.2-34365.5 MHz	3344/3599 turnaround ratio
Coherent with deep space X-Band D/L channels	34354.3-34365.5 MHz	880/3599 turnaround ratio
RF Power Output	47.0–59.0 ±0.5 dBm	Referenced to 800 W transmitter output terminal (waterload switch). Settability is limited to 0.25 dB by measurement equipment precision.
Power output varies across the bandwidth and may be as much as 1 dB below nominal rating. The 800 W tube is a fixed beam klystron designed to saturate at its rated power. Operation at less than the nominal 800 W is unsaturated. Minimum power output is about 47 dBm (50 W).		

Table 5. Ka-Band Transmit Characteristics, DSS 25 (Continued)

Parameter	Value	Remarks
EXCITER AND TRANSMITTER (Continued)		
EIRP (maximum)	138.2 +0.6,–0.5 dBm	At gain set elevation angle, referenced to feedhorn aperture
Stability		At transmitter output frequency
Output Power Variation		Across frequency band over 12 h
Saturated Drive	0.25 dB	
Unsaturated Drive	≤ 1.0 dB	
Frequency Stability		Allan deviation
1 s	3.3×10^{-13}	
10 s	5.2×10^{-14}	
1000–3600 s	3.1×10^{-15}	
1000–3600 s	3.1×10^{-15}	
Spurious Output		Below carrier
1–10 Hz	–50 dB	
10 Hz–1.5 MHz	–60 dB	
1.5 MHz–8 MHz	–45 dB	

Table 6. S- and X-Band Receive Characteristics, DSS 24, 34, and 54

Parameter	Value	Remarks
ANTENNA		
Gain		At peak of gain versus elevation angle curve, referenced to feedhorn aperture (feed and feedline losses are accounted for in system temperature), for matched polarization; no atmosphere included; triangular PDF tolerance. See Figures 5, 9, and 10 for representative gain versus elevation curves.
S-Band (2295 MHz)	56.8 +0.1,–0.2 dBi	
X-Band (8420 MHz)	68.2 +0.1,–0.2 dBi	
Half-Power Beamwidth		Angular width (2-sided) between half-power points at specified frequency
S-Band	0.242 ±0.020 deg	
X-Band	0.066 ±0.004 deg	
Polarization		Remotely selected
S-Band	RCP or LCP	Same as transmit polarization
X-Band	RCP or LCP	Same as or opposite from transmit polarization
Ellipticity		Peak-to-peak voltage axial ratio, RCP and LCP. See definition in Table 2.
S-Band	≤1.0 dB	
X-Band	≤0.7 dB	
Pointing Loss		
Angular	See module 302	See also Figures 25 and 26.
CONSCAN		
S-Band	0.03 dB	Loss at S-Band when using X-Band CONSCAN reference set for 0.1 dB loss at X-Band
	0.1 dB	Recommended value when using S-Band CONSCAN reference
X-Band	0.1 dB	Recommended value when using X-Band CONSCAN reference

Table 6. S- and X-Band Receive Characteristics, DSS 24, 34, and 54 (Continued)

Parameter	Value	Remarks
RECEIVER		
Frequency Ranges Covered		
S-Band	2200–2300 MHz	
X-Band	8400–8500 MHz	
Recommended Maximum Signal Power	-90.0 dBm	At LNA input terminal
System Noise Temperature		Near zenith, no atmosphere included. . See Figures 15, 19, and 20 for representative system temperature versus elevation curves. Tolerances have a triangular PDF.
S-Band (2200–2300 MHz) Non-Diplexed Path		Referenced to feedhorn aperture. LNA = HEMT
DSS 24	28.4 –1.0,+2.0 K	
DSS 34	30.7 –1.0,+2.0 K	
DSS 54	28.9 –1.0,+2.0 K	
S-Band (2200–2300 MHz) Diplexed Path		Referenced to feedhorn aperture. LNA = HEMT
DSS 24	34.8 –1.0,+2.0 K	
DSS 34	39.3 –1.0,+2.0 K	
DSS 54	37.5 –1.0,+2.0 K	
X-Band (8400–8500 MHz) Non-Diplexed Path		X-Band-only operation (S/X-Band dichroic plate retracted). Referenced to feedhorn aperture.
DSS 24	23.2 –1.0,+2.0 K	LNA = MASER
DSS 34	28.0 –1.0,+2.0 K	LNA = HEMT
DSS 54	21.1 –1.0,+2.0 K	LNA = MASER

Table 6. S- and X-Band Receive Characteristics, DSS 24, 34, and 54 (Continued)

Parameter	Value	Remarks
RECEIVER (Continued)		
System Noise Temperature (Continued)		
X-Band (8400–8500 MHz) Diplexed Path		X-Band-only operation (S/X-Band dichroic plate retracted). Referenced to feedhorn aperture.
DSS 24	30.7 –1.0,+2.0 K	LNA = MASER
DSS 34	35.5 –1.0,+2.0 K	LNA = HEMT
DSS 54	28.6 –1.0,+2.0 K	LNA = MASER
X-Band (8400–8500 MHz) Non-Diplexed Path		S/X-Band operation (S/X-Band dichroic plate extended). Referenced to feedhorn aperture.
DSS 24	24.6 –1.0,+2.0 K	LNA = MASER
DSS 34	29.7 –1.0,+2.0 K	LNA = HEMT
DSS 54	22.8 –1.0,+2.0 K	LNA = MASER
X-Band (8400–8500 MHz) Diplexed Path		S/X-Band operation (S/X-Band dichroic plate extended). Referenced to feedhorn aperture.
DSS 24	32.1 –1.0,+2.0 K	LNA = MASER
DSS 34	37.2 –1.0,+2.0 K	LNA = HEMT
DSS 54	30.2 –1.0,+2.0 K	LNA = MASER
Tunability	Continuous	
Carrier Tracking Loop Noise B/W (Hz)	0.25 – 200	Effective one-sided, noise-equivalent carrier loop bandwidth (B_L)

Table 7. X- and Ka-Band Receive Characteristics, DSS 25, 26, and 55

Parameter	Value	Remarks
ANTENNA		
Gain		At peak of gain versus elevation angle curve, referenced to feedhorn aperture (feed and feedline losses are accounted for in system temperature), for matched polarization; no atmosphere included; triangular PDF tolerance. See Figures 7, 8, 11, 12, 13, and 14 for representative gain versus elevation curves.
X-Band (8420 MHz)	68.4 +0.1,–0.2 dBi	DSS 25, X/Ka-Band operation (X/Ka-Band dichroic plate extended).
	68.3 +0.1,–0.2 dBi	DSS 26, X/Ka-Band operation.
	68.3 +0.1,–0.2 dBi	DSS 55, X/Ka-Band operation.
Ka-Band (32000 MHz)	79.0 +0.3,–0.3 dBi	DSS-25, Ka-Band only operation (X/Ka-Band dichroic plate retracted).
	78.8 +0.3,–0.3 dBi	DSS-25, X/Ka-Band operation (X/Ka-Band dichroic plate extended).
	79.1 +0.3,–0.3 dBi	DSS-26, X/Ka-Band operation.
	79.1 +0.3,–0.3 dBi	DSS-55, X/Ka-Band operation.
Half-Power Beamwidth		Angular width (2-sided) between half-power points at specified frequency
X-Band	0.066 ±0.004 deg	
Ka-Band	0.017 ±0.002 deg	
Polarization		
X-Band DSS 25	RCP and LCP	Both polarizations simultaneously available; polarization using diplexed path is remotely selected
X-Band DSS 26 and 55	RCP and LCP	Simultaneously
Ka-Band DSS 25	RCP	Only RCP monopulse available.
Ka-Band DSS 26 and 55	RCP and LCP	Only RCP monopulse available.
Ellipticity		Peak-to-peak voltage axial ratio. See definition in Table 2.
X-Band	≤0.7 dB	RCP and LCP.
Ka-Band	≤1.0 dB	

Table 7. X- and Ka-Band Receive Characteristics, DSS 25, 26, and 55 (Continued)

Parameter	Value	Remarks
ANTENNA (Continued)		
Pointing Loss		
Angular	See module 302	See also Figures 26 and 27.
CONSCAN		.
X-Band	0.1 dB	Recommended value when using X-Band CONSCAN reference
Ka-Band	N/A	Use of CONSCAN at Ka-Band is not recommended.
Monopulse		
X-Band	0.007 dB	Using Ka-Band monopulse reference
Ka-Band	0.11 dB	Sum channel signal to error channel noise ratio ≥ 26 dB-Hz
RECEIVER		
Frequency Ranges		
X-Band	8400–8500 MHz	
Ka-Band	31800–32300 MHz	Tracking receiver covers bandwidth with 5 overlapping bands of ≈ 160 MHz
Recommended Maximum Signal Power	–90.0 dBm	At LNA input terminal
System Noise Temperature		Near zenith, no atmosphere included. See Figures 17, 18, 21, 22, 23, and 24 for system temperature versus elevation curves. Tolerances have a triangular PDF.
X-Band (8400–8500 MHz)		Non-diplexed path, referenced to feedhorn aperture.
DSS 25, MASER	22.1 –1.0,+2.0 K	RCP or LCP
DSS 25, HEMT	35.9 –1.0,+2.0 K	RCP or LCP
X-Band (8400–8500 MHz)		Diplexed path, referenced to feedhorn aperture.
DSS 25, MASER	29.6 –1.0,+2.0 K	RCP or LCP
DSS 25, HEMT	43.4 –1.0,+2.0 K	RCP or LCP

Table 7. X- and Ka-Band Receive Characteristics, DSS 25, 26, and 55 (Continued)

Parameter	Value	Remarks
RECEIVER (Continued)		
X-Band (8400–8500 MHz)		Feed diplexed, with or without transmitter operating. Referenced to feedhorn aperture.
DSS 26 (RCP)	18.8 –1.0,+2.0 K	LNA = HEMT
DSS 26 (LCP)	17.9 –1.0,+2.0 K	LNA = HEMT
DSS 55 (RCP)	19.9 –1.0,+2.0 K	LNA = HEMT
DSS 55 (LCP)	20.3 –1.0,+2.0 K	LNA = HEMT
Ka-Band (31800–32300 MHz)		Ka-Band only operation (X/Ka-Band dichroic plate at DSS 25 retracted), referenced to feedhorn aperture,
DSS 25 (RCP)	30.3 –1.0,+2.0 K	LNA = HEMT
DSS 25 (RCP Error)	29.7 –1.0,+2.0 K	LNA = HEMT
Ka-Band (31800–32300 MHz)		X/Ka-Band operation (X/Ka-Band dichroic plate at DSS 25 extended), referenced to feedhorn aperture,
DSS 25 (RCP)	33.8 –1.0,+2.0 K	LNA = HEMT
DSS 25 (RCP Error)	37.9 –1.0,+2.0 K	LNA = HEMT
DSS 26 (RCP)	21.9 –1.0,+2.0 K	LNA = HEMT
DSS 26 (RCP Error)	27.0 –1.0,+2.0 K	LNA = HEMT
DSS 26 (LCP)	23.3 –1.0,+2.0 K	LNA = HEMT
DSS 55 (RCP)	23.3 –1.0,+2.0 K	LNA = HEMT
DSS 55 (RCP Error)	24.4 –1.0,+2.0 K	LNA = HEMT
DSS 55 (LCP)	22.3 –1.0,+2.0 K	LNA = HEMT
Carrier Tracking Loop Noise B/W	0.25 – 200 Hz	Effective one-sided, noise-equivalent carrier loop bandwidth (B_L). See module 202

Table 8. S-Band Receive Characteristics, DSS 27

Parameter	Value	Remarks
ANTENNA		
Gain (2250 MHz)		At peak of gain versus elevation angle curve, referenced to feedhorn aperture (feed and feedline losses are accounted for in system temperature), for matched polarization; no atmosphere included; triangular PDF tolerance. See Figure 6 for elevation dependency.
S-Band	54.9 +0.1,–0.2 dBi	
Half-Power Beamwidth		Angular width (2-sided) between half-power points at specified frequency
S-Band	0.247 ±0.020 dB	
Polarization		Remotely selected
S-Band	RCP or LCP	Same as transmit polarization
Ellipticity		Peak-to-peak voltage axial ratio, RCP and LCP. See definition in Table 2.
S-Band	≤1.0 dB	
Pointing Loss		
Angular	See module 302	See also Figure 25
RECEIVER		
Frequency Range Covered	2200–2300 MHz	S-Band
Recommended Maximum Signal Power	–90.0 dBm	At LNA input terminal
S-Band System Noise Temperature (2200–2300 MHz)	101 –1.0,+2.0 K	With respect to feedhorn aperture, near zenith, no atmosphere included. See Figure 16 for elevation dependency. Tolerances have a triangular PDF. LNA = Room temperature HEMT
Carrier Tracking Loop Noise B/W	0.25 – 200 Hz	Effective one-sided, noise-equivalent carrier loop bandwidth (B_L) when using standard DSN receiver. See module 202. Bandwidths less than 1 Hz are not recommended due to frequency reference instability.

Table 9. Gain Reduction Due to Wind Loading, 34-m BWG Antennas

Wind Speed		Gain Reduction (dB)*	
(km/hr)	(mph)	X-Band	Ka-Band
16	10	0.2	2.9
48	30	0.3	4.3
72	45	0.4	5.8

* Assumes antenna is maintained on-point using CONSCAN at X-Band or monopulse at Ka-Band. S-Band gain reduction is negligible for wind speeds up to 72 km/h (45 mph). Worst case with antenna in most adverse orientation for wind.

Table 10. Zenith System Noise Temperature Contributions due to 25% Average Clear Weather

Location	Noise Temperature Contribution (K)*		
	S-Band	X-Band	Ka-Band
Goldstone (DSS 24, 25, 26, & 27)	1.930	2.305	9.150
Canberra (DSS 34)	2.112	2.629	12.539
Madrid (DSS 54 & 55)	2.028	2.506	10.860

* From Tables 1 – 9 in module 105.

Table 11. Pointing Accuracy and Pointing Loss in Various Wind Conditions

Mean Hourly Wind Speed = 4.5 m/s (10 mph)				
Cumulative Distribution (CD)	Pointing Error, mdeg	Pointing Loss, dB		
		S-Band	X-Band	Ka-Band
Mean (54.4%)	1.670	0.001	0.008	0.111
90%	2.825	0.002	0.022	0.319
95%	3.251	0.002	0.029	0.422
99%	3.997	0.003	0.044	0.639
Mean Hourly Wind Speed = 8.9 m/s (20 mph)				
Cumulative Distribution (CD)	Pointing Error, mdeg	Pointing Loss, dB		
		S-Band	X-Band	Ka-Band
Mean (54.4%)	3.330	0.002	0.031	0.443
90%	5.633	0.007	0.088	1.268
95%	6.483	0.009	0.116	1.679
99%	7.971	0.013	0.176	2.539
Mean Hourly Wind Speed = 13.4 m/s (30 mph)				
Cumulative Distribution (CD)	Pointing Error, mdeg	Pointing Loss, dB		
		S-Band	X-Band	Ka-Band
Mean (54.4%)	5.000	0.005	0.069	0.999
90%	8.458	0.015	0.198	2.858
95%	9.734	0.019	0.262	3.786
99%	11.968	0.029	0.396	5.724

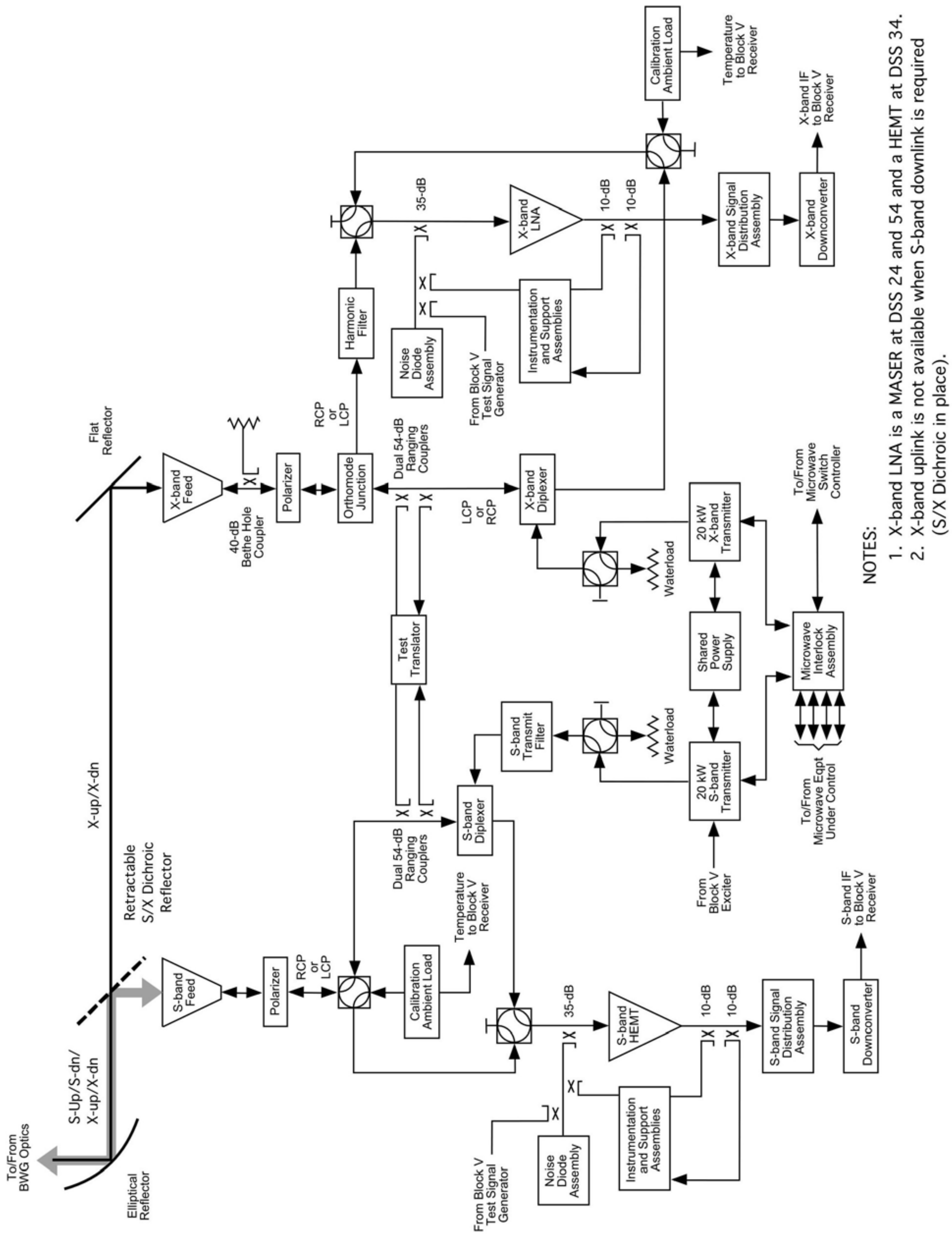

Figure 1. Functional Block Diagram of the DSS 24, 34, and 54 Antennas.

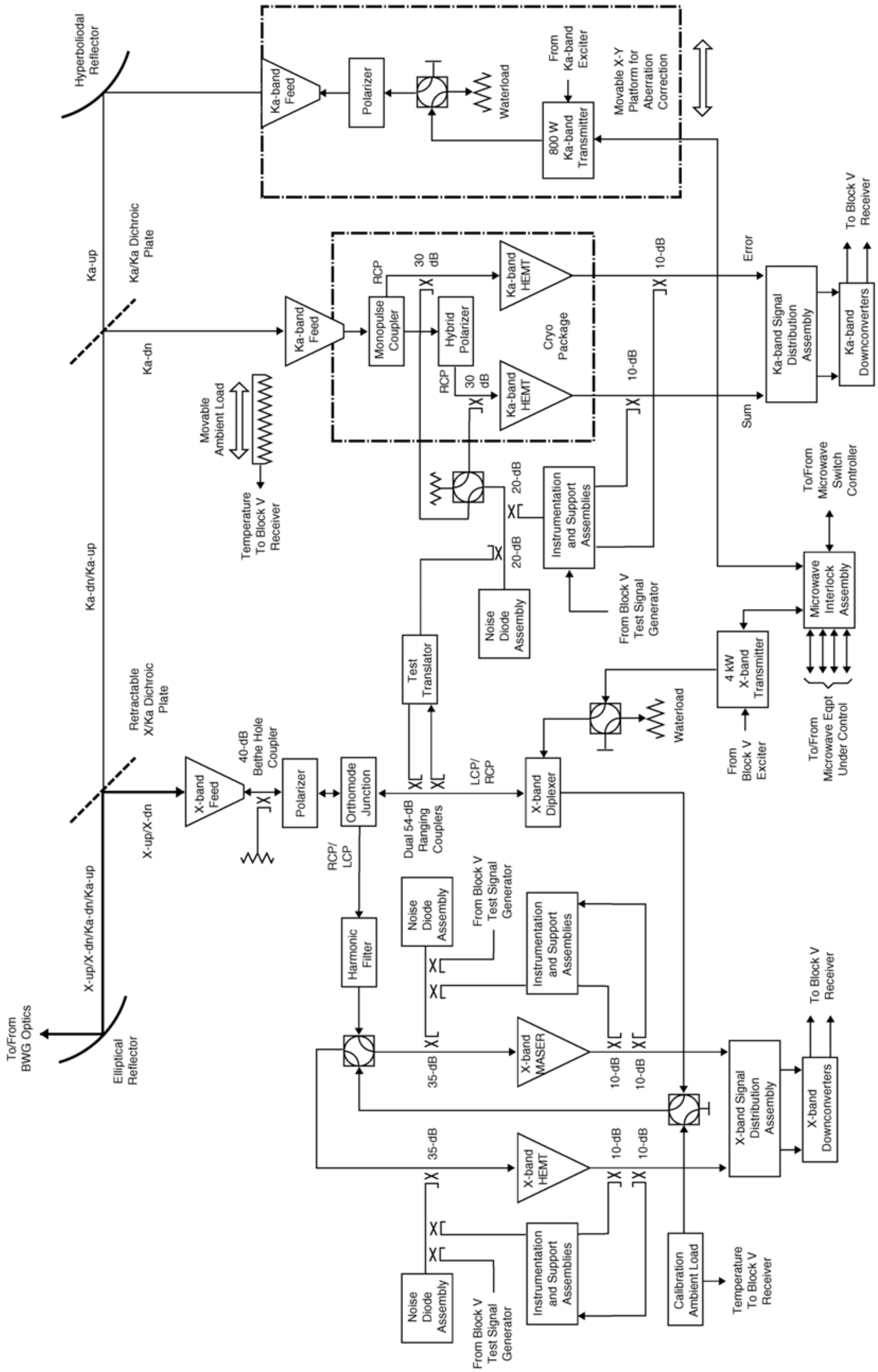

Figure 2. Functional Block Diagram of the DSS 25 Antenna.

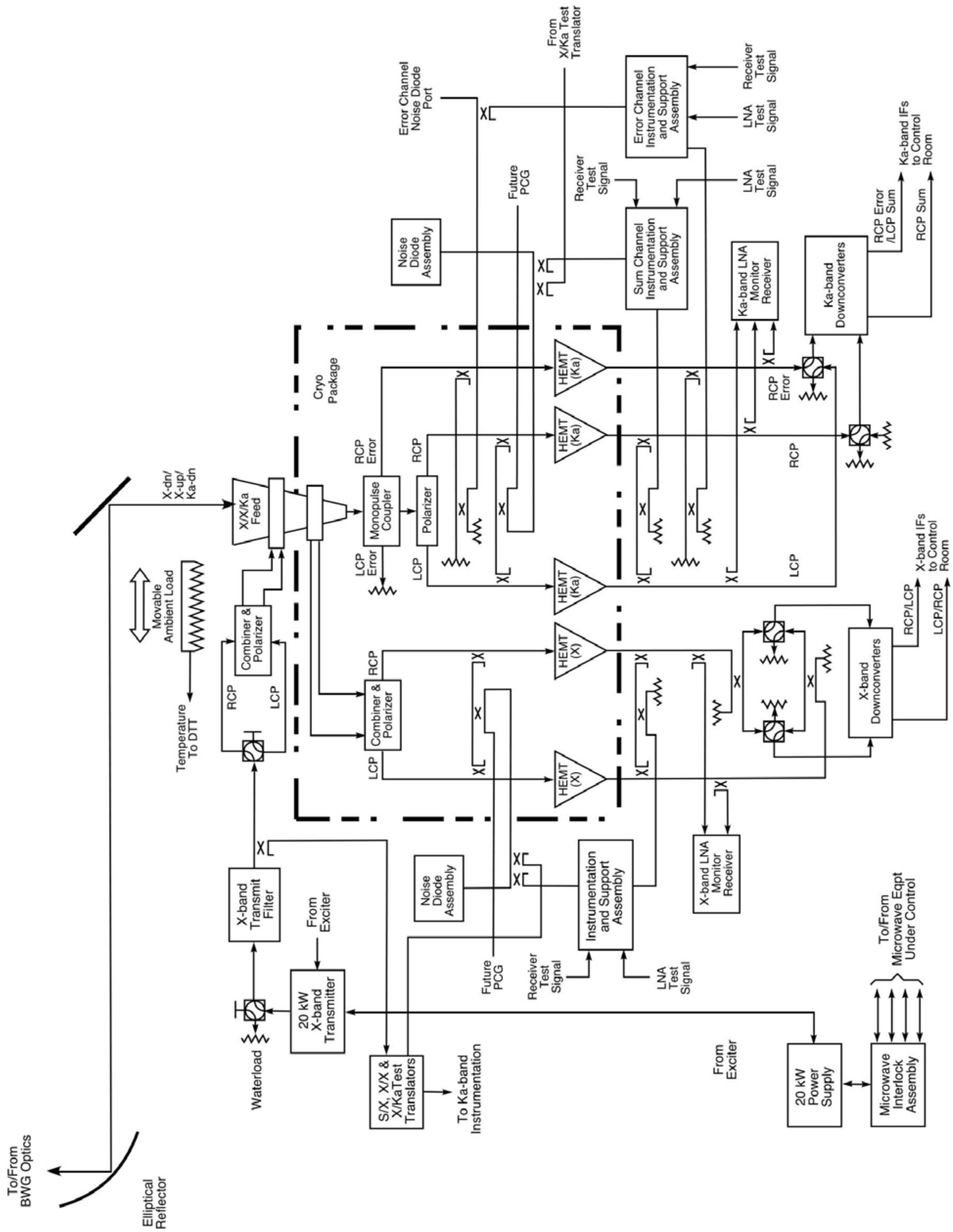

Figure 3. Functional Block Diagram of DSS 26 and DSS 55 Antennas

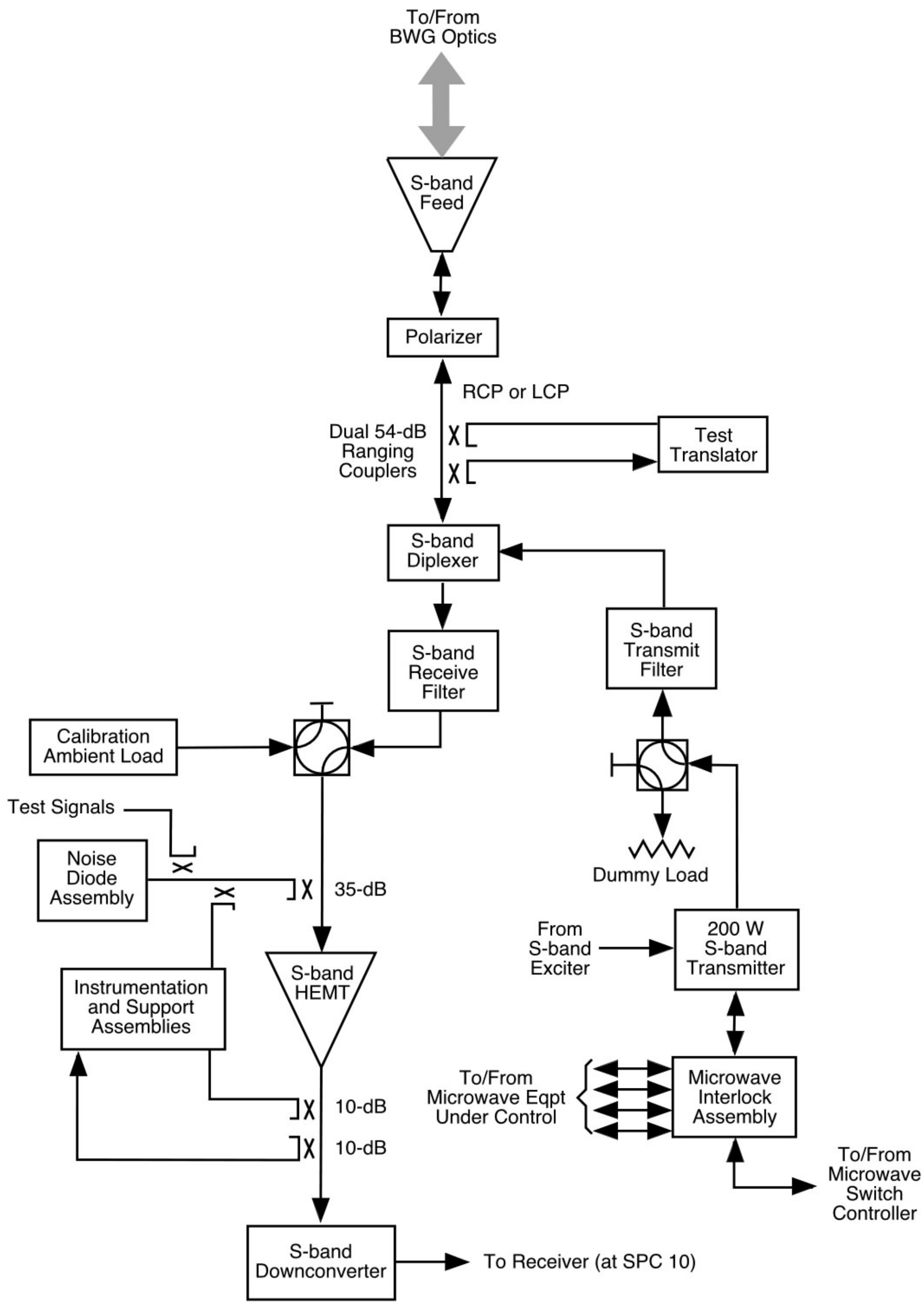

Figure 4. Functional Block Diagram of the DSS 27 Antenna

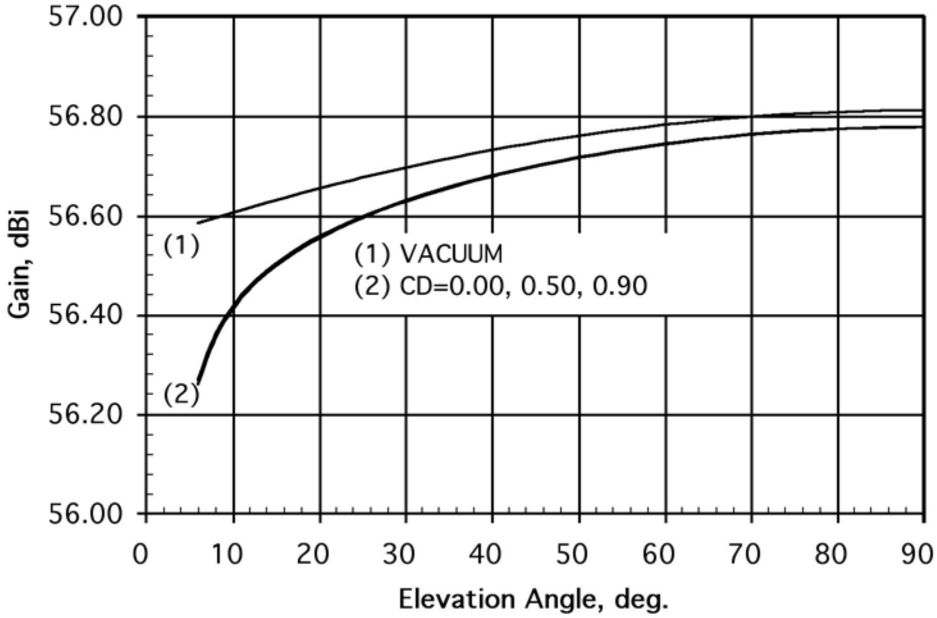

Figure 5. DSS 24 (Goldstone) S-Band Receive Gain Versus Elevation Angle, S/X Mode (S/X Dichroic In Place), 2295 MHz

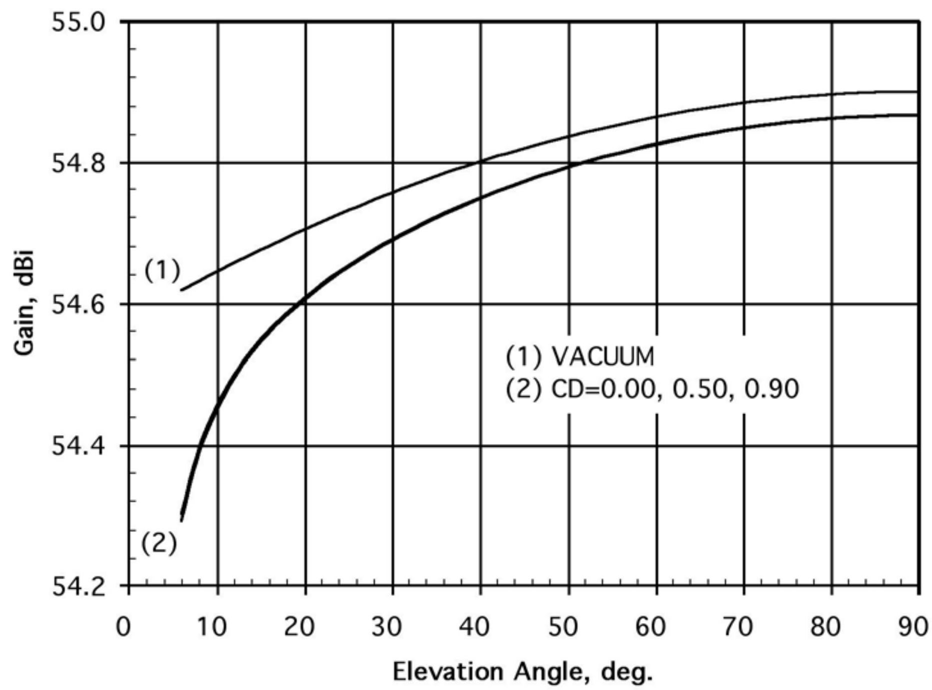

Figure 6. DSS 27 (Goldstone) S-Band Receive Gain Versus Elevation Angle, 2250 MHz

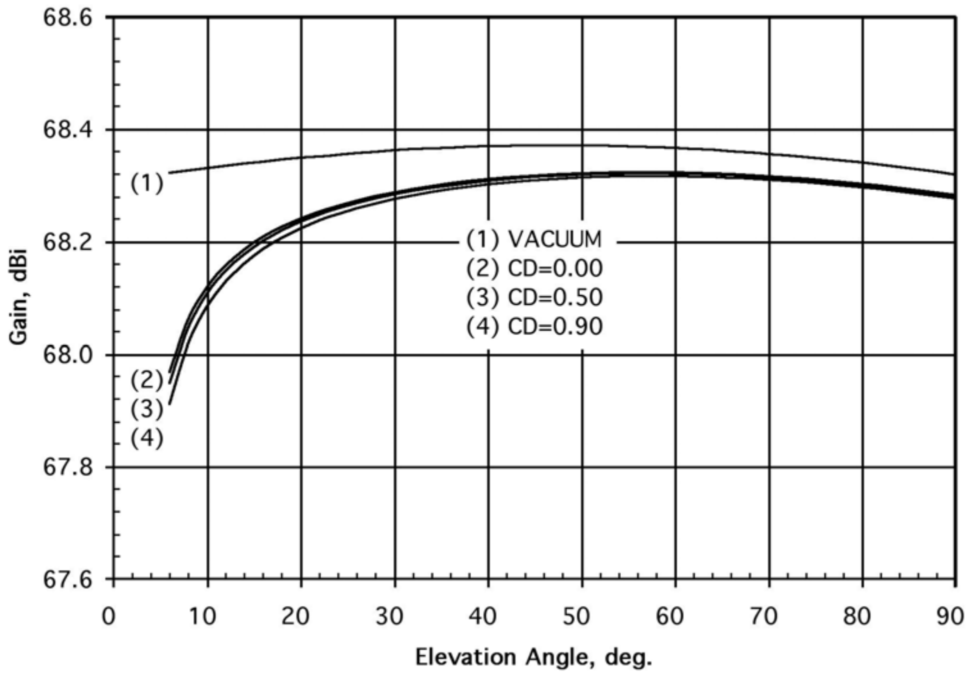

Figure 7. DSS 25 (Goldstone) X-Band Receive Gain Versus Elevation Angle, X/Ka Mode (X/Ka Dichroic In Place), 8420 MHz

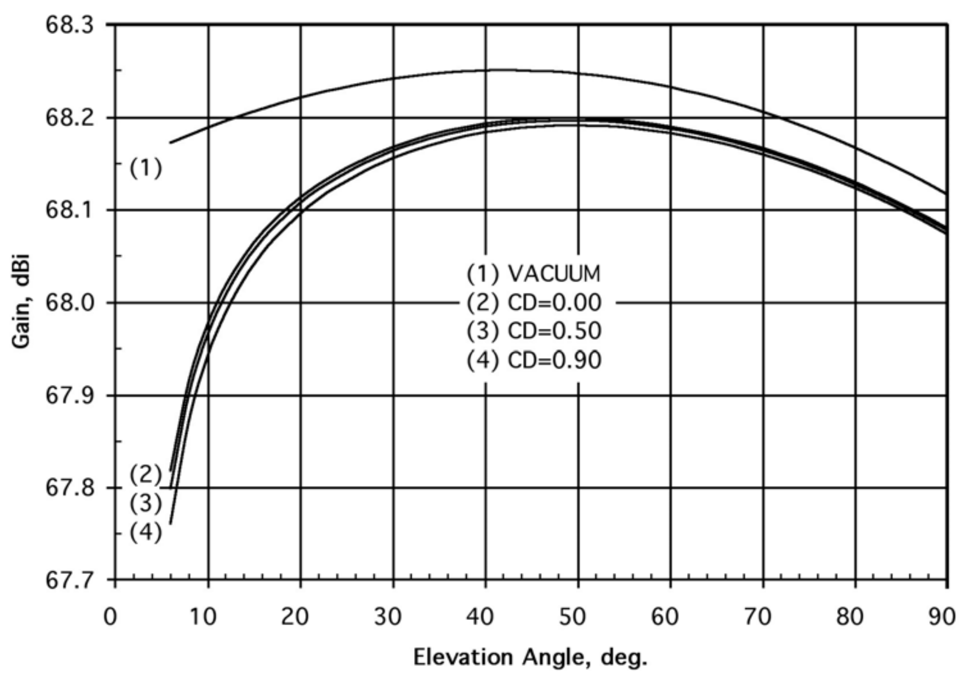

Figure 8. DSS 26 (Goldstone) X-Band Receive Gain Versus Elevation Angle, X/Ka-Mode, 8420 MHz

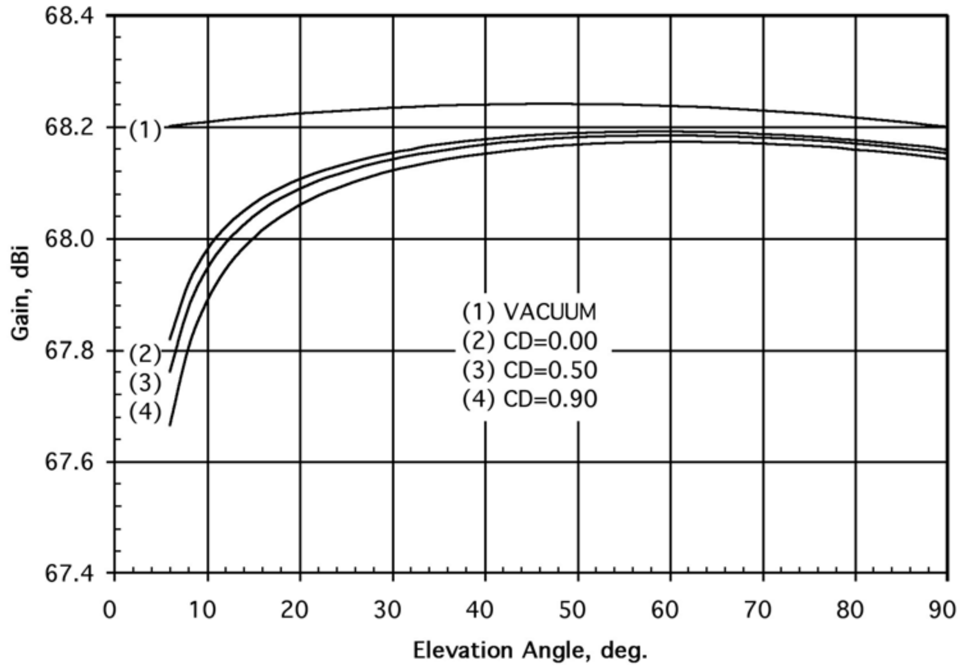

Figure 9. DSS 34 (Canberra) X-Band Receive Gain Versus Elevation Angle, S/X Mode (S/X Dichroic In Place), 8420 MHz

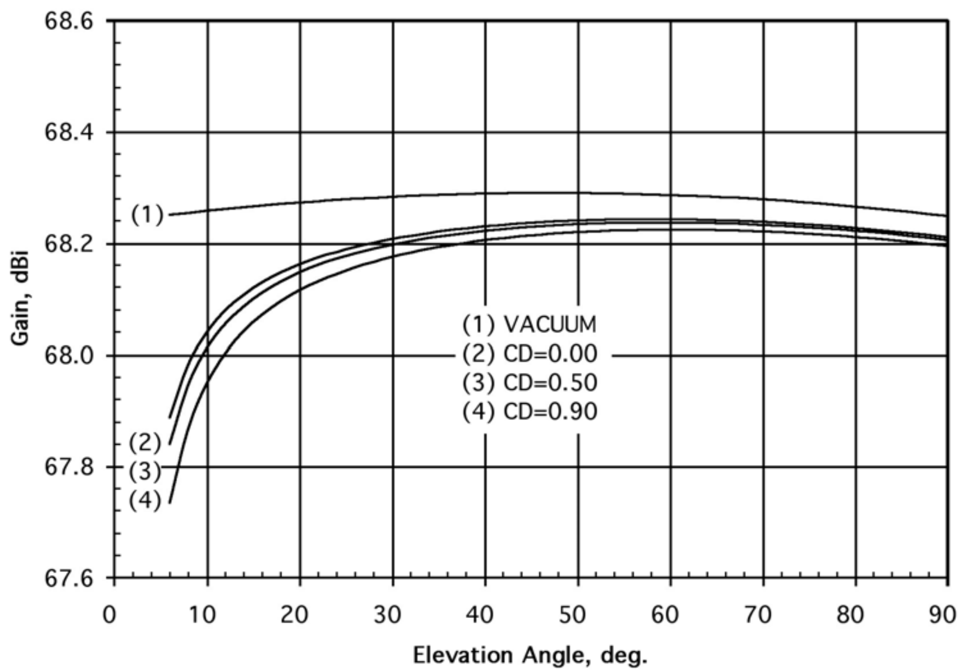

Figure 10. DSS 54 (Madrid) X-Band Receive Gain Versus Elevation Angle, X-Only Mode (S/X Dichroic Retracted), 8420 MHz

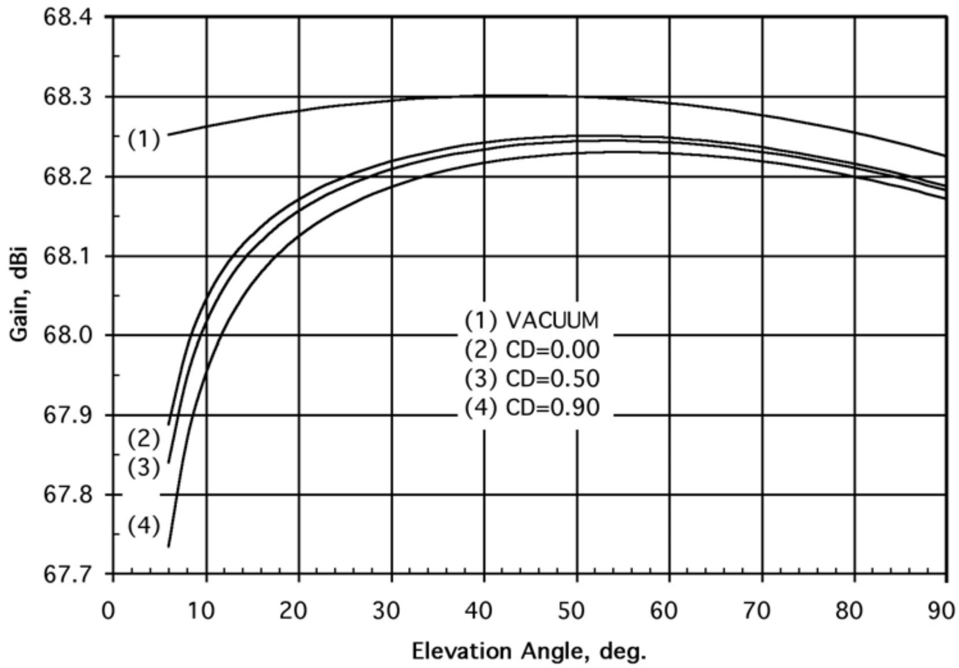

Figure 11. DSS 55 (Madrid) X-Band Receive Gain Versus Elevation Angle, X/Ka-Mode, 8420 MHz

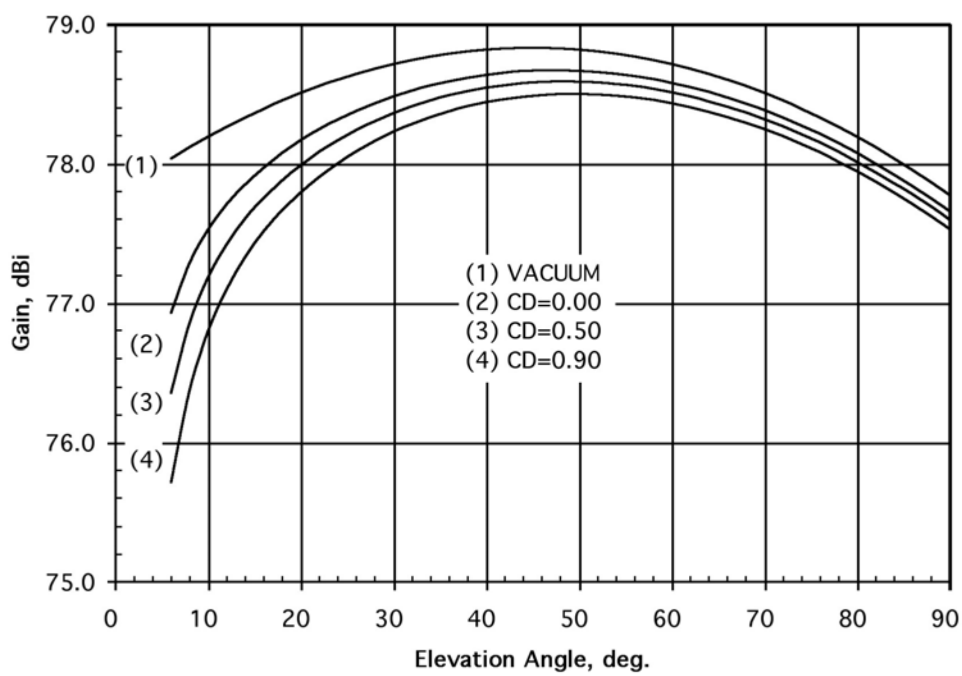

Figure 12. DSS 25 (Goldstone) Ka-Band Receive Gain Versus Elevation Angle, X/Ka-Mode (X/Ka Dichroic In-Place), 32000 MHz

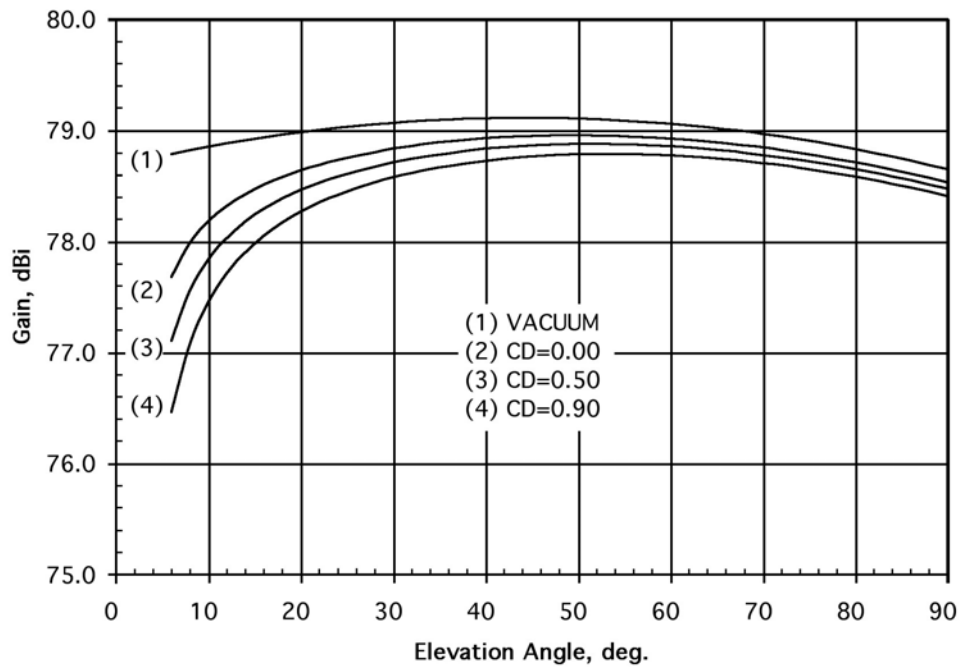

Figure 13. DSS 26 (Goldstone) Ka-Band Receive Gain Versus Elevation Angle, X/Ka-Mode, 32000 MHz

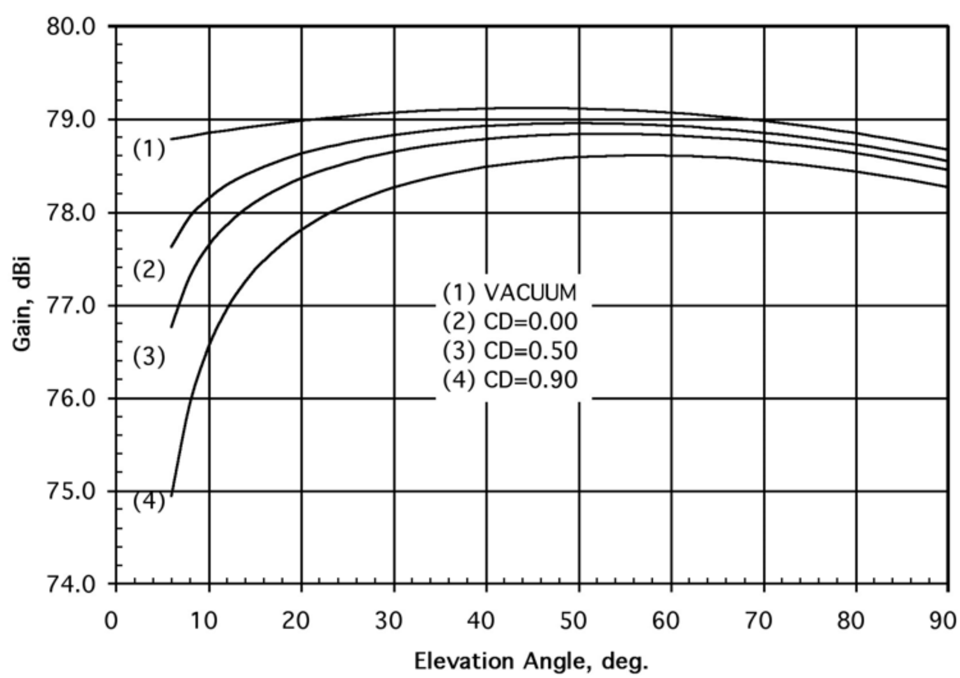

Figure 14. DSS 55 (Madrid) Ka-Band Receive Gain Versus Elevation Angle, X/Ka-Mode, 32000 MHz

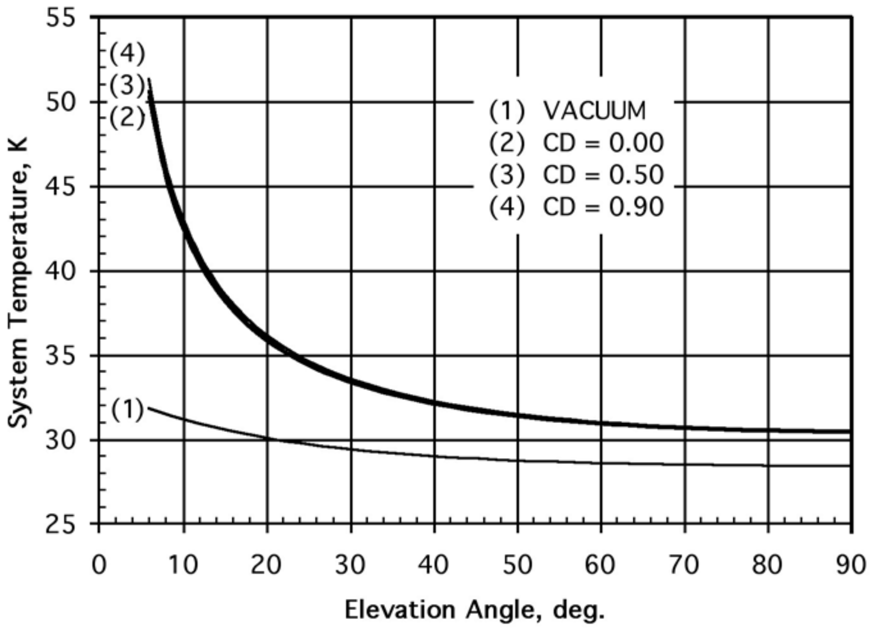

Figure 15. DSS 24 (Goldstone) S-Band System Temperature Versus Elevation Angle, S/X-Mode (S/X Dichroic In Place), Non-Diplexed Path

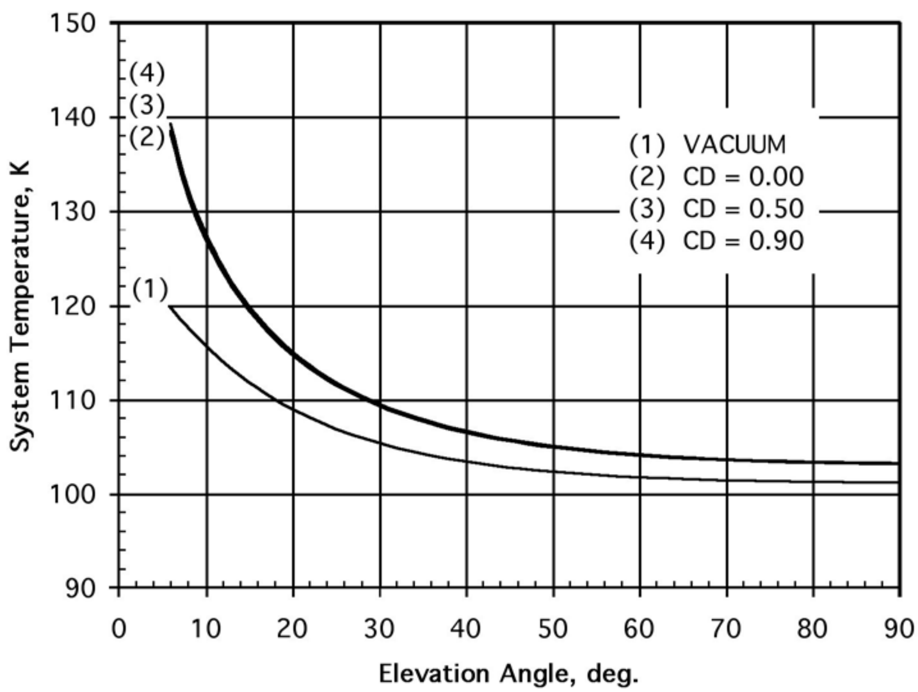

Figure 16. DSS 27 (Goldstone) S-Band System Temperature Versus Elevation Angle, Diplexed Path

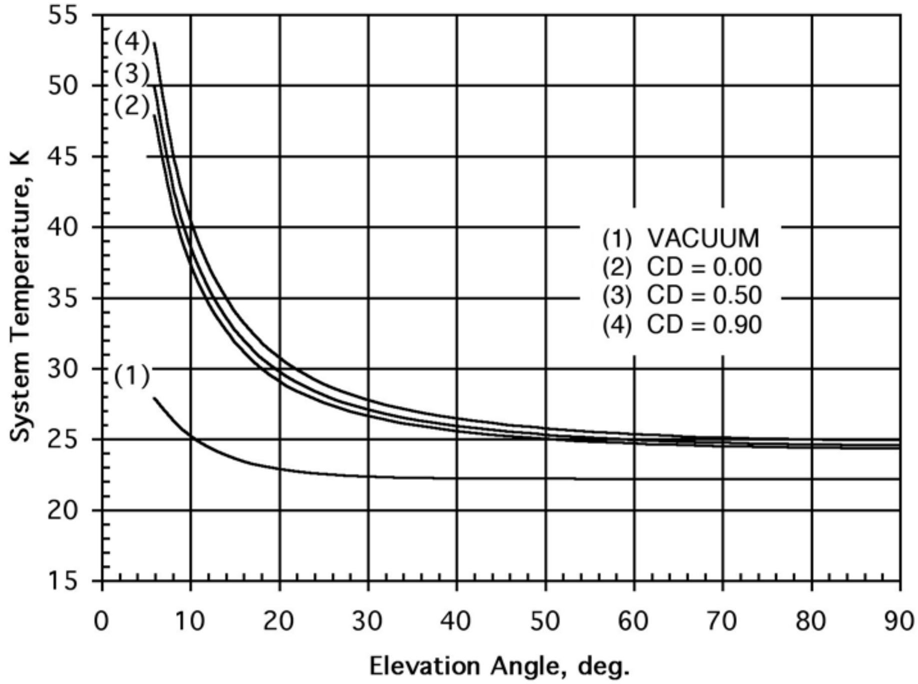

Figure 17. DSS 25 (Goldstone) X-Band System Temperature Versus Elevation Angle, X/Ka-mode (X/Ka Dichroic In Place), Non-Diplexed Path

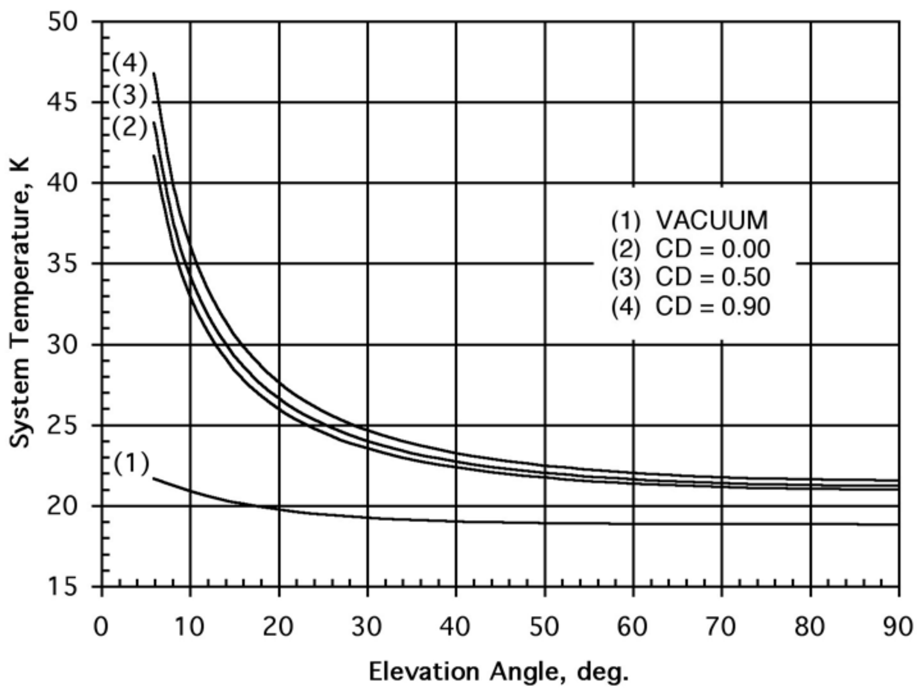

Figure 18. DSS 26 (Goldstone) X-Band RCP System Temperature Versus Elevation Angle, X/Ka-Mode

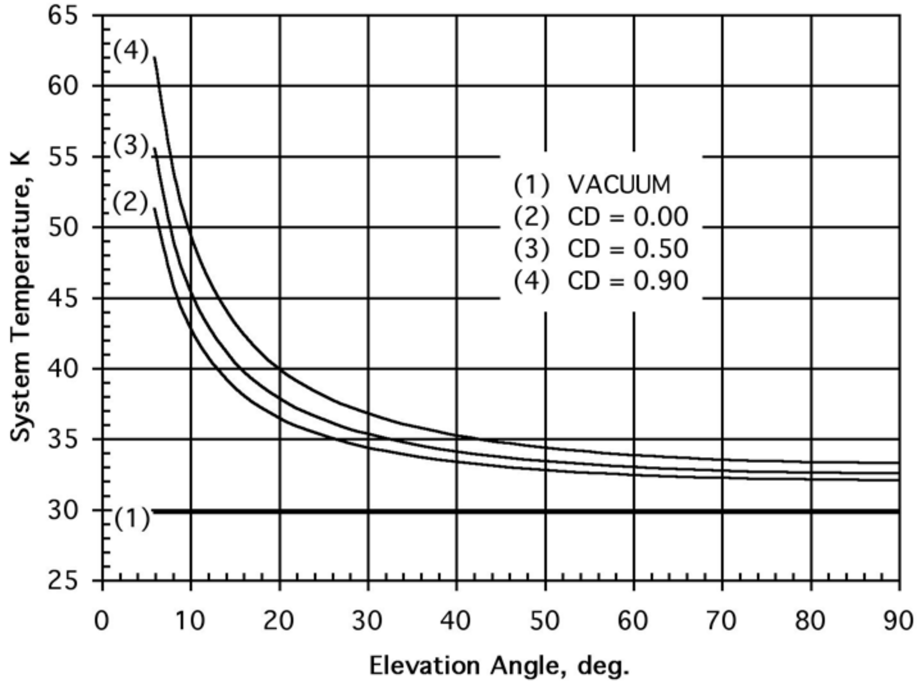

Figure 19. DSS 34 (Canberra) X-Band System Temperature versus Elevation Angle, S/X-Mode (S/X Dichroic In Place), Non-Diplexed Path

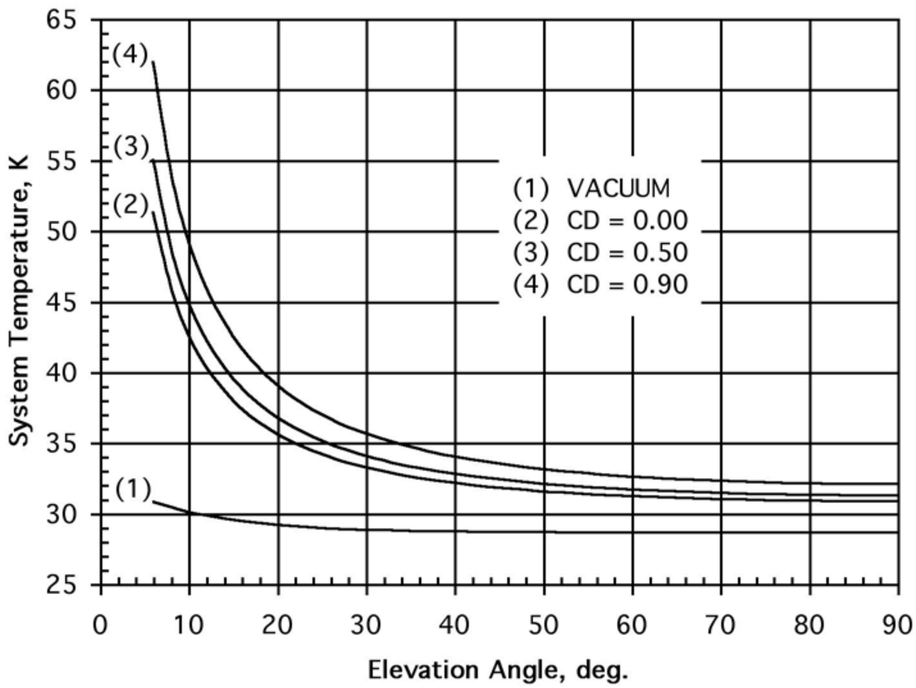

Figure 20. DSS 54 (Madrid) X-Band System Temperature Versus Elevation Angle, X-Only Mode (S/X Dichroic Retracted), Diplexed Path

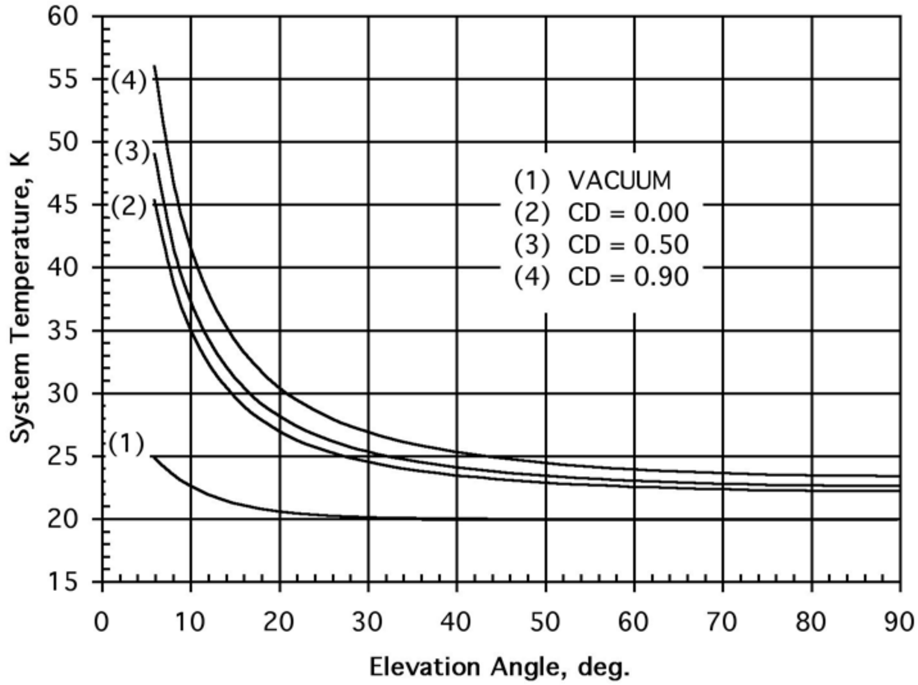

Figure 21. DSS 55 (Madrid) X-Band RCP System Temperature Versus Elevation Angle, X/Ka-Mode

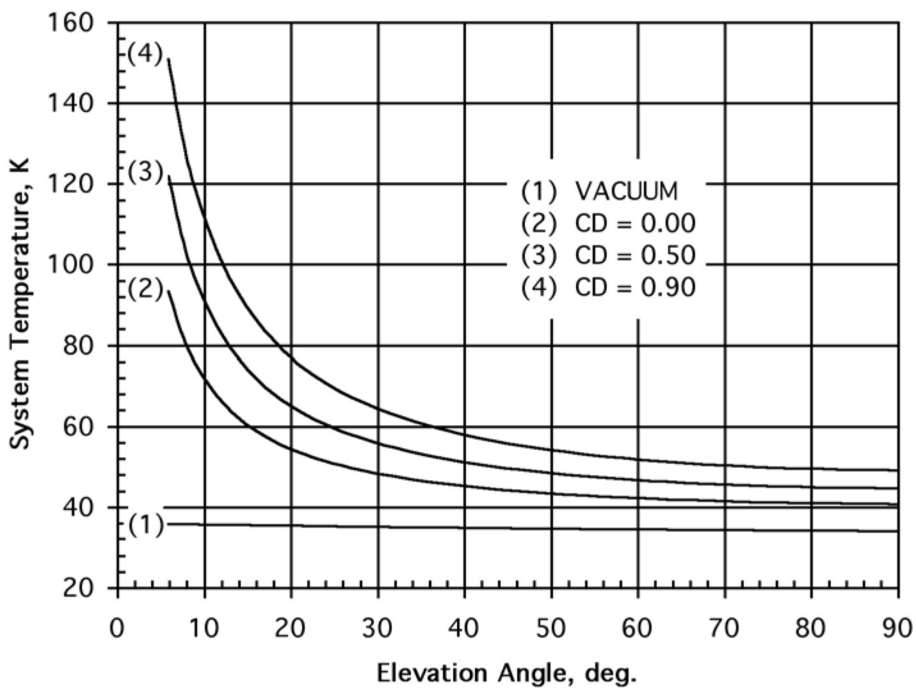

Figure 22. DSS 25 (Goldstone) Ka-Band System Temperature Versus Elevation Angle, X/Ka-Mode (X/Ka Dichroic in Place)

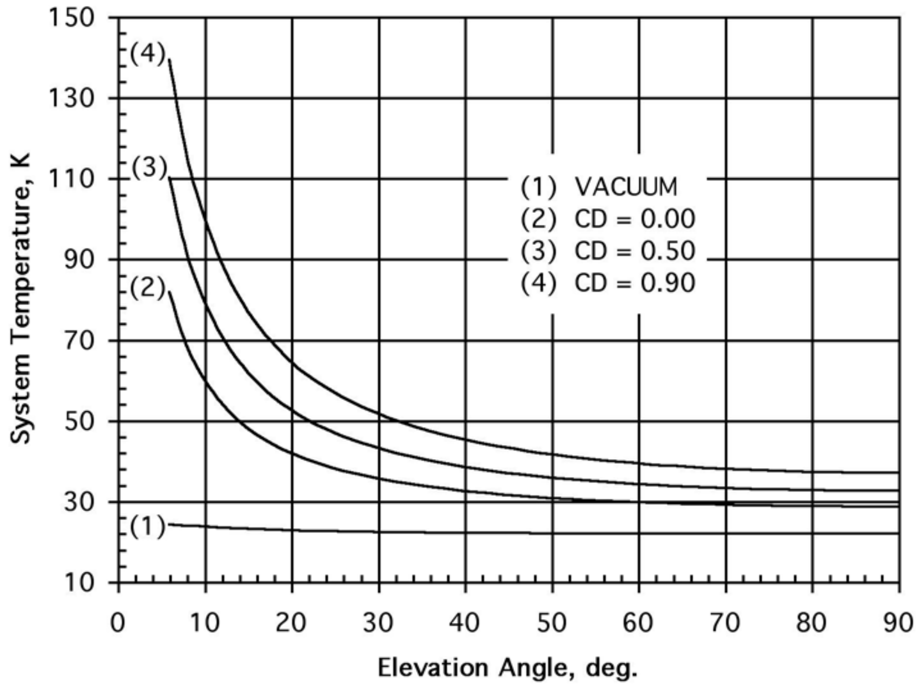

Figure 23. DSS 26 (Goldstone) Ka-Band RCP System Temperature Versus Elevation Angle, X/Ka-Mode

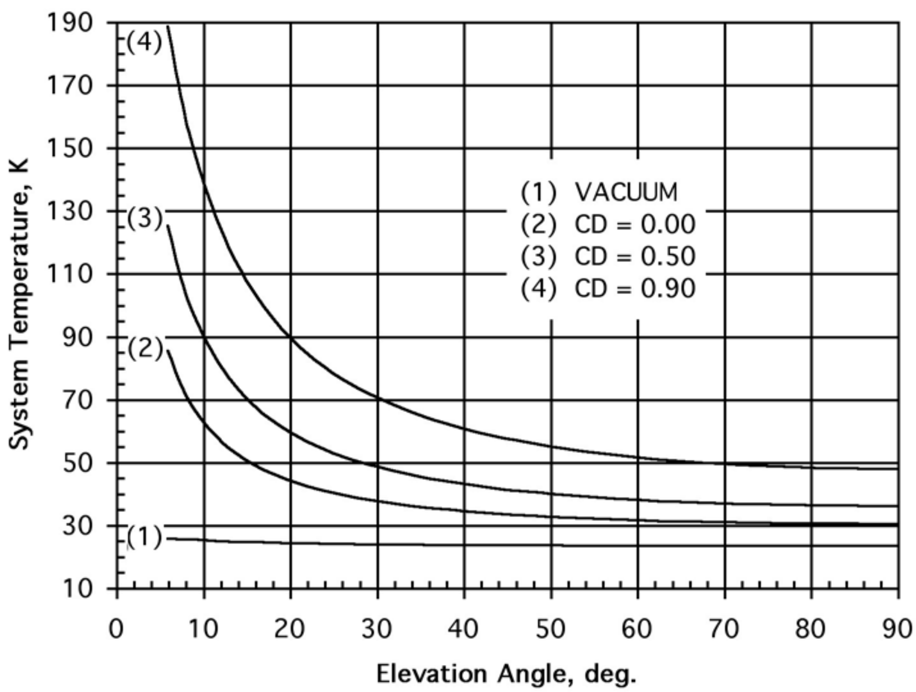

Figure 24. DSS 55 (Madrid) Ka-Band RCP System Temperature Versus Elevation Angle, X/Ka-Mode

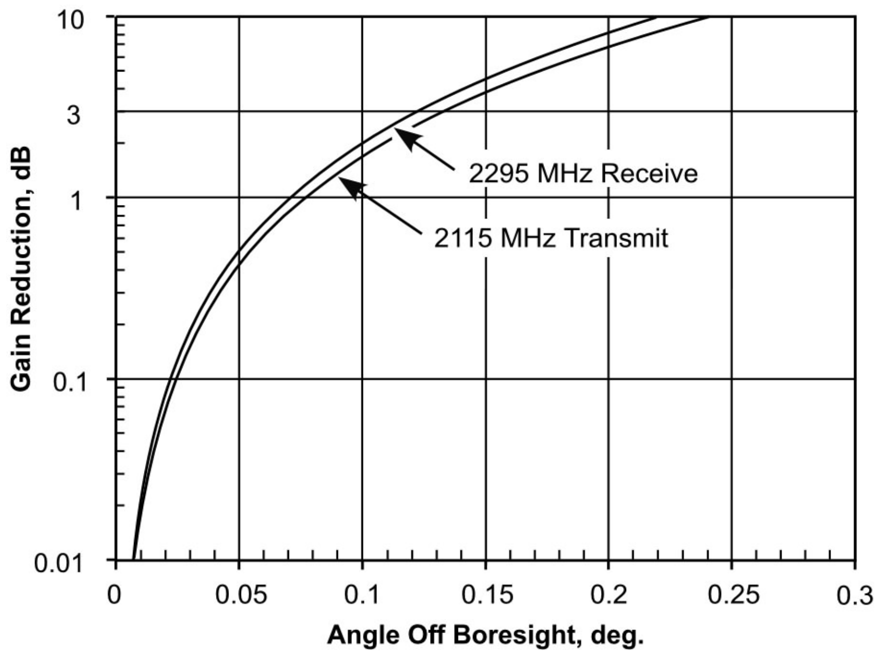

Figure 25. S-Band Gain Reduction versus Angle off Boresight

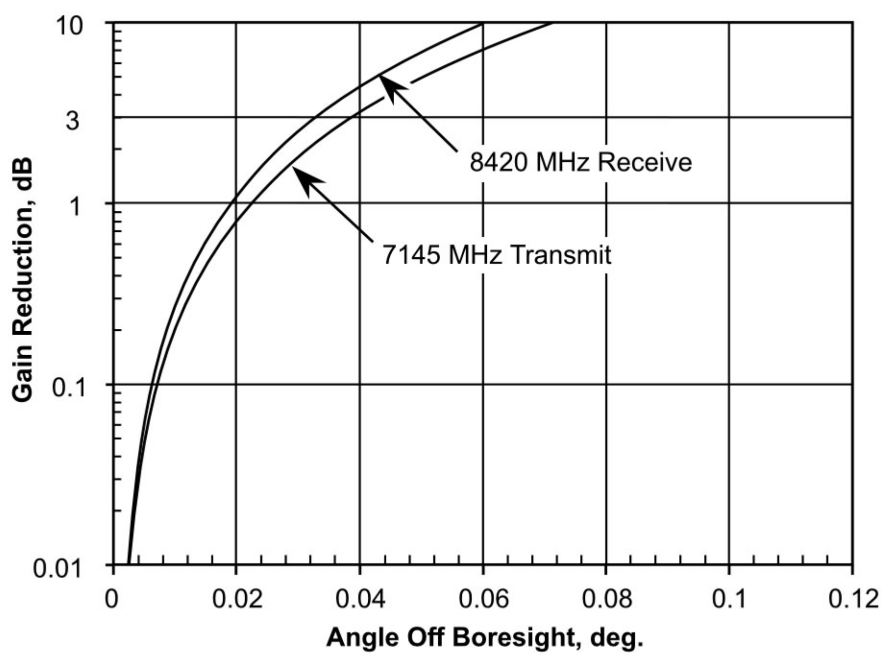

Figure 26.X-Band Gain Reduction versus Angle off Boresight

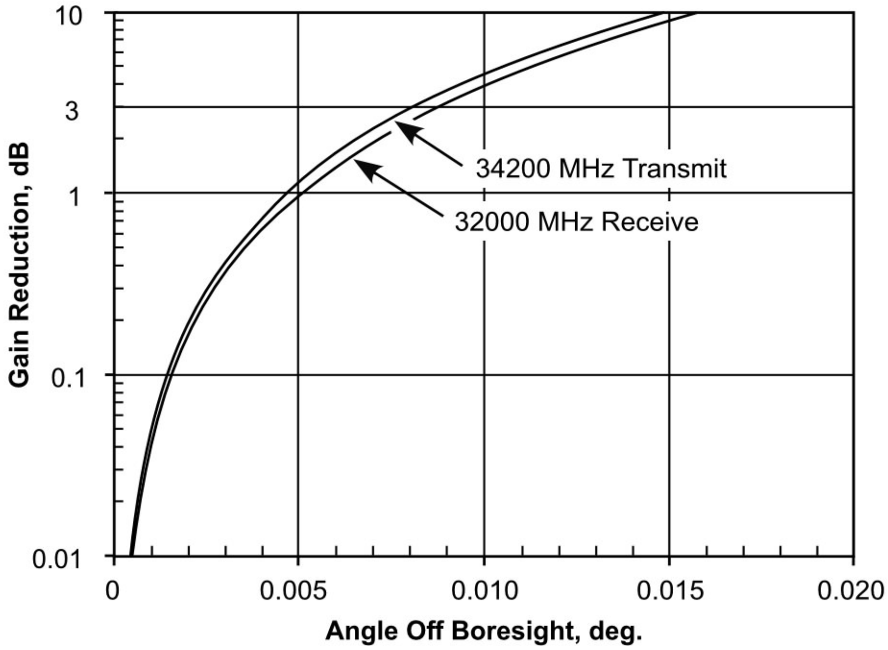

Figure 27. Ka-Band Gain Reduction versus Angle off Boresight

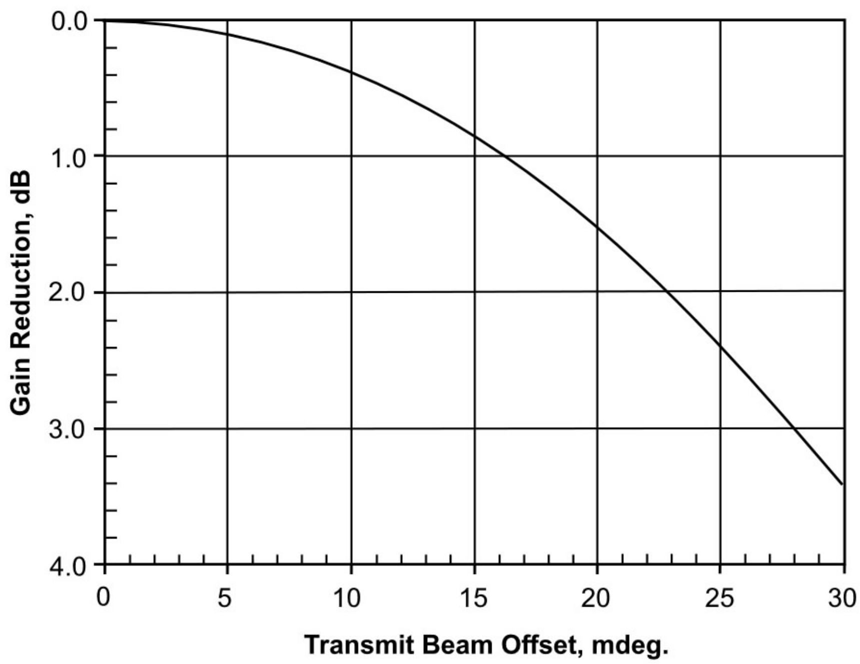

Figure 28. Ka-Band Transmit Gain Reduction Due to Aberration Correction

Appendix A
Equations for Modeling

A.1 Equations for Gain Versus Elevation Angle

The following equation can be used to generate S-, X-, and Ka-Band transmit and receive gain versus elevation angle curves. Examples of these curves for selected stations and configurations are shown in Figures 5–14. See paragraph 2.1.1.1 for frequency effect modeling and module 105 for atmospheric attenuation at weather conditions other than 0%, 50% and 90% cumulative distribution..

$$G(\theta) = G_0 - G_1(\theta - \gamma)^2 - \frac{A_{ZEN}}{\sin\theta}, \text{ dBi} \quad \text{(A-1)}$$

where

θ = antenna elevation angle (deg.) $6 \le \theta \le 90$

G_0, G_1, γ = parameters from Tables A1, A2, and A3

A_{ZEN} = zenith atmospheric attenuation from Table A-4 or from Table 2 in module 105, dB.

A.2 Equations for System Temperature Versus Elevation Angle

The following equation can be used to generate S-, X, and Ka-Band system temperature versus elevation angle curves. Examples of these curves are shown in Figures 15–24. See module 105 for atmospheric attenuation at weather conditions other than 0%, 50% and 90% cumulative distribution..

$$T_{op}(\theta) = T_1 + T_2 e^{-a\theta} + (255 + 25 \cdot \text{CD})\left(1 - \frac{1}{10^{\frac{A_{ZEN}}{10\sin\theta}}}\right), \text{ K} \quad \text{(A-2)}$$

where

θ = antenna elevation angle (deg), $6 \le \theta \le 90$

T_1, T_2, a = parameters from Tables A-1, A-2, or A-3

CD = cumulative distribution used to select A_{ZEN} from Table A-4 or from Table 2 in module 105, $0 \le CD \le 0.99$

A_{ZEN} = zenith atmospheric attenuation from Table A-4 or from Table 2 in module 105, dB.

A.3 Equation for Gain Reduction Versus Pointing Error

The following equation can be used to generate gain reduction versus pointing error curves examples of which are depicted in Figures 25, 26, and 27.

$$\Delta G(\theta) = 10 \log \left(e^{\frac{2.773\theta^2}{HPBW^2}} \right), \text{ dB} \qquad \text{(A-3)}$$

where

θ = pointing error, deg

$HPBW$ = half-power beamwidth (from Tables 2 through 8)

A.4 Equation for Transmit Aberration Gain Reduction

The following equation can be used to generate the Ka-Band transmit gain reduction curve depicted in Figure 28.

$$\Delta G(\phi) = -0.0038\phi^2, \text{ dB} \qquad \text{(A-4)}$$

where

ϕ = transmit beam offset, mdeg

Table A-1. S-Band Vacuum Gain and System Noise Temperature Parameters

Station and Configuration	Vacuum Gain Parameters				Vacuum System Noise Temperature Parameters			Figures
	G_0† Transmit	G_0† Receive	G_1	γ	T_1	T_2	a	
DSS 24 (Goldstone)								
S/X, Non-Diplexed (HEMT)	—	56.81	0.000032	90.0	28.34	4.7	0.05	5, 15
S/X, Diplexed (HEMT)	56.1	56.81	0.000032	90.0	34.79	4.7	0.05	
DSS 27 (Goldstone)								
S-Only, Diplexed (R/T HEMT)	54.2	54.9	0.00004	90.0	101.00	27.0	0.061	6, 16
DSS 34 (Canberra)								
S/X, Non-Diplexed (HEMT)	—	56.75	0.000037	52.5	30.68	0.0	0.0	
S/X, Diplexed (HEMT)	56.1	56.75	0.000037	52.5	39.28	0.0	0.0	
DSS 54 (Madrid)								
S/X, Non-Diplexed (HEMT)	—	56.75	0.000037	45.0	28.88	0.0	0.0	
S/X, Diplexed (HEMT)	56.1	56.75	0.000037	45.0	37.48	0.0	0.0	

Notes:

† G_0 values are nominal at the frequency specified in Tables 2, 3, 6, or 8. Other parameters apply to all frequencies within the same band.

Table A-2. X-Band Vacuum Gain and System Noise Temperature Parameters

Station and Configuration	Vacuum Gain Parameters				Vacuum System Noise Temperature Parameters			Figures
	G_0† Transmit	G_0† Receive	G_1	γ	T_1	T_2	a	
DSS 24 (Goldstone)								
X-Only, Non-Diplexed (MASER)	—	68.11	0.000027	51.5	23.18	0.0	0.0	
X-Only, Diplexed (MASER)	66.75	68.11	0.000027	51.5	30.68	0.0	0.0	
S/X, Non-Diplexed (MASER)	—	68.06	0.000027	51.5	24.58	0.0	0.0	
S/X, Diplexed (MASER)	—	68.06	0.000027	51.5	32.08	0.0	0.0	
DSS 25 (Goldstone)								
X/Ka, Non-Diplexed (MASER)	—	68.37	0.000028	47.5	22.13	14.0	0.15	7, 17
X/Ka, Non-Diplexed (HEMT)	—	68.37	0.000028	47.5	35.93	14.0	0.15	
X/Ka, Diplexed (MASER)	67.01	68.37	0.000028	47.5	29.63	14.0	0.15	
X/Ka, Diplexed (HEMT)	67.01	68.37	0.000028	47.5	43.43	14.0	0.15	
DSS 26 (Goldstone)								
X/Ka, Diplexed (HEMT, RCP)	66.89	68.25	0.000059	42.46	18.78	4.6	0.08	8,18
X/Ka, Diplexed (HEMT, LCP)	66.89	68.25	0.000059	42.46	17.93	4.6	0.08	

Notes:

† G_0 values are nominal at the frequency specified in Tables 4, 6, and 7. Other parameters apply to all frequencies within the same band.

Table A-2. X-Band Vacuum Gain and System Noise Temperature Parameters (Continued)

Station and Configuration	Vacuum Gain Parameters				Vacuum System Noise Temperature Parameters			Figures
	G_0† Transmit	G_0† Receive	G_1	γ	T_1	T_2	a	
DSS 34 (Canberra)								
X-Only, Non-Diplexed (HEMT)	—	68.29	0.000023	47.5	28.00	0.0	0.0	
X-Only, Diplexed (HEMT)	66.93	68.29	0.000023	47.5	35.50	0.0	0.0	
S/X, Non-Diplexed (HEMT)	—	68.24	0.000023	47.5	29.70	0.0	0.0	9, 19
S/X, Diplexed (HEMT)	—	68.24	0.000023	47.5	37.20	0.0	0.0	
DSS 54 (Madrid)								
X-Only, Non-Diplexed (MASER)	—	68.29	0.000023	40.0	21.07	4.0	0.1	
X-Only, Diplexed (MASER)	66.93	68.29	0.000023	40.0	28.62	4.0	0.1	10, 20
S/X, Non-Diplexed (MASER)	—	68.24	0.000023	40.0	22.82	4.0	0.1	
S/X, Diplexed (MASER)	-----	68.24	0.000023	40.0	30.22	4.0	0.1	
DSS 55 (Madrid)								
X/Ka, Diplexed (HEMT, RCP)	66.94	68.30	0.000035	43.55	19.90	12.0	0.15	11,21
X/Ka, Diplexed (HEMT, LCP)	66.94	68.30	0.000035	43.55	20.30	12.0	0.15	

Notes:

† G_0 values are nominal at the frequency specified in Tables 4, 6, and 7. Other parameters apply to all frequencies within the same band.

Table A-3. Ka-Band Vacuum Gain and System Noise Temperature Parameters

Station and Configuration	Vacuum Gain Parameters				Vacuum System Noise Temperature Parameters			Figures
	G_0† Transmit	G_0† Receive	G_1	γ	T_1	T_2	a	
DSS 25 (Goldstone)								
Ka-Only, Diplex RCP (HEMT)	79.5	78.98	0.00052	45.0	29.41	2.9	0.013	
Ka-Only, RCP Error (HEMT)	—	—	—	—	28.81	2.9	0.013	
X/Ka, Diplex RCP (HEMT)	79.5	78.83	0.00052	45.0	32.91	2.9	0.013	12, 22
X/Ka, RCP Error (HEMT)	—	—	—	—	37.01	2.9	0.013	
DSS 26 (Goldstone)								
X/Ka, RCP (HEMT)	—	79.11	0.00022	44.38	21.84	3.5	0.07	13, 23
X/Ka, RCP Error (HEMT)	—	—	—	—	27.01	3.5	0.07	
X/Ka, LCP (HEMT)	—	79.11	0.00022	44.38	23.24	3.5	0.07	
DSS 55 (Madrid)								
X/Ka, RCP (HEMT)	—	79.11	0.00022	45.00	23.25	3.5	0.07	14, 24
X/Ka, RCP Error (HEMT)	—	—	—	—	24.42	3.5	0.07	
X/Ka, LCP (HEMT)	—	79.11	0.00022	45.00	22.28	3.5	0.07	

Notes:

† G_0 values are nominal at the frequency specified in Tables 5 and 7. Other parameters apply to all frequencies within the same band.

Table A-4. S-, X, and Ka-Band Zenith Atmospheric Attenuation (A_{ZEN})

Station	A_{ZEN}, dB*		
	CD† = 0.00	CD† = 0.50	CD† = 0.90
S-Band			
Goldstone	0.033	0.032	0.031
Canberra	0.036	0.035	0.034
Madrid	0.034	0.033	0.033
X-Band			
Goldstone	0.037	0.039	0.043
Canberra	0.040	0.046	0.056
Madrid	0.038	0.043	0.054
Ka-Band			
Goldstone	0.116	0.176	0.243
Canberra	0.126	0.243	0.404
Madrid	0.121	0.211	0.401

Notes:

* From Tables 10-18 in module 105,

† CD = cumulative distribution.