102
26-m Antenna Subnet Telecommunications Interfaces

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Change Log

Rev	Issue Date	Affected Paragraphs	Change Summary
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Note to Readers

There are two sets of document histories in the 810-005 document, and these histories 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.

This module supersedes TCI-20 in 810-005, Rev. D.

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1 Introduction

1.1 Purpose

This module provides sufficient information concerning the performance of the Deep Space Network (DSN) 26-meter antennas and their associated acquisition antennas to enable a flight project to design a telecommunications link.

1.2 Scope

The discussion in this module is limited to those parameters that characterize the RF performance of the 26-meter antennas, including the effects of weather that are unique to this type of antenna. Unless otherwise specified, the parameters do not include effects of weather, such as reduction of system gain and increase in system noise temperature, that are common to all antenna types. These are discussed in module 105, Atmospheric and Environmental Effects. This module also does not discuss mechanical restrictions on antenna performance that are covered in module 302, Antenna Positioning.

2 General Information

The three 26-meter deep space station (DSS) antennas form one subnet of the DSN. This subnet provides the primary support for Earth-orbiter spacecraft as well as initial acquisition for all spacecraft. One antenna (DSS 16) is located at Goldstone, California; one (DSS 46) near Canberra, Australia; and one (DSS 66) near Madrid, Spain. The precise station locations are shown in module 301, Coverage and Geometry. The actual antenna diameters are 25.91 meters (85 feet).

Spacecraft initial acquisition is accomplished by using small, wide-beamwidth acquisition antennas attached to the main antenna and aligned with the main antenna beam. The acquisition antennas contain monopulse feeds and downconverters that are compatible with the main antenna receiving equipment. For initial acquisition of S-band spacecraft, the monopulse tracking equipment keeps the antenna pointed at the spacecraft until its signal is within the beamwidth of the main antenna. For X-band acquisition or when S-band acquisition is being performed for another DSN antenna, the angle information from the 26-m antenna is used to correct the remote antenna position predicts. Each 26-m antenna contains an S-band acquisition antenna. An X-band acquisition antenna is permanently installed at DSS 16 (Goldstone), and a similar antenna can be temporarily installed at the other sites.

2.1 Telecommunications Parameters

The significant parameters of the 26-meter antennas, which influence the design of the telecommunications uplink, are listed in Tables 1 and 2. Variations in these parameters, which 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 Wind Effects).

2.1.1 Antenna Gain Variation

2.1.1.1 Frequency Effects

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

2.1.1.2 Elevation Angle Effects

Structural deformation of the antennas in the 26-meter subnet causes a reduction in gain when the antenna is operated with the X or Y axes set at angles other than where the reflector panels were aligned. The effective gain of the antenna is reduced also by atmospheric attenuation, which is a function of elevation. Atmospheric effects are given in module 105. Figure 1 shows the estimated gain and tolerances for all 26-meter antennas as a function of elevation angle, without atmosphere.

2.1.2 System 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 the intrusion of the ground into the sidelobe pattern of the antenna. Figure 2 shows the combined effects of these factors at DSS 16 for the prime low noise amplifier (LNA) designated as 50K-A. Table 3 can be used to adjust the Figure 2 values for other stations or when using alternate LNAs. Figure 2 shows noise temperature adjustments to be made to Figure 1 when operating within about 4 degrees above an elevated horizon mask. The data for this were taken at DSS 16 at an azimuth of 125 degrees, where the horizon mask has an elevation of 5.359 degrees.

2.1.3 Pointing Loss

Figure 4 shows the effects of pointing error on effective transmit and receive gain of the main antenna. Figure 5 shows the effects of pointing error on the effective receive gain of the 1.8-meter diameter acquisition antenna. Data have been normalized to eliminate the effect of structural deformation and elevation angle. The equation describing the curves is provided at the end of this module.

2.2 Recommended Minimum Operating Carrier Signal Levels

Table 4 provides the recommended minimum operating carrier signal levels as a function of receiver tracking-loop bandwidth for the main and acquisition antennas. Values are calculated based on the nominal zenith system temperatures given in Table 2 and assume 25% weather.

Table 1. S-Band Transmit Characteristics

Parameter	Value	Remarks
MAIN ANTENNA		Acquisition antenna is not available for transmit
Gain (dBi)	51.4 ±0.5	At 2025 MHz referenced to transmitter or exciter output terminals (includes feedline loss) for matched polarization
Half-Power Beamwidth (deg)	0.40 ±0.03	Angular width (2-sided) between half-power points at 2025 MHz
Polarization	RCP or LCP	One polarization at a time, remotely selected
Ellipticity (dB)	1.0 ±0.4	Peak-to-peak axial ratio
Pointing Loss	See TRK-10	
EXCITER		
Frequency Range Covered (MHz)	2025 to 2120	
Coherent with Earth Orbiter D/L Allocation	2025 to 2108.7	
Coherent with Deep Space S-Band D/L Allocation	2110.2 to 2117.7	
Tunability (Hz)	100	At transmitter output frequency
Output Stability (dB)	±0.25	Over an 8-h period
PRIMARY TRANSMITTER		
Frequency Range Covered (MHz)	2021 to 2119	Center frequency can be preset at 2-MHz intervals (channels) over specified band
Instantaneous 1-dB Bandwidth (MHz)	8	
Maximum time to change channels (s)	30	Drive disabled during channel change

Table 1. S-Band Transmit Characteristics

Parameter	Value	Remarks
PRIMARY TRANSMITTER (Continued)		
Power Output (dBm)	47 to 63	At output flange of transmitter harmonic filter
Settability (dB)	±0.25	
Stability (dB)	±0.35	Over an 8-h period (RSS of transmitter stability and exciter output stability
Spurious Radiation		At maximum output
Noise Power Density (dBm/Hz)		
2.2–2.3 GHz	–130	
8.2–8.6 GHz	–130	
Total Harmonic (dBc)	–30	
Non-harmonic (dBc)	–80	
Group Delay Stability (ns)	≤3	
EMERGENCY (BACKUP) TRANSMITTER		
Frequency Range Covered (MHz)	2025 to 2120	Power amplifier is step-tunable over band in six segments with 5 MHz overlap.
Maximum time to change segments (s)	30	Drive disabled during segment change
Instantaneous 1-dB Bandwidth (MHz)	20	
RF Power Output (dBm)		Referenced to transmitter output terminal
Minimum	53.0 ±0.25	Unsaturated drive
	to	
Maximum	70.0 ±0.5	Saturated drive
Settability (dB)	±0.25	Limited by measurement equipment precision

Table 1. S-Band Transmit Characteristics (continued)

Parameter	Value	Remarks
EMERGENCY (BACKUP) TRANSMITTER (continued		
Power Stability (dB)		
Long-Term (12-h)	±0.25	At maximum output
	±1.0	Below maximum output
Short Term	±0.25	Peak to peak, saturated or unsaturated drive in 1 Hz bandwidth centered about carrier frequency
Incidental Modulation		
PM (deg, rms)	5	
AM (dBc)	60	
Spurious Radiation (dBc)		At maximum output
2nd and 3rd Harmonics	85	
4th Harmonic	170	

Table 2. S- and X-Band Receive Characteristics

Parameter	Value	Remarks
MAIN ANTENNA		
Gain (dBi)	52.5 ±0.5	At all elevation angles, referenced to prime LNA (50K-A) input (includes feedline loss) for matched polarization, at 2295 MHz, without atmosphere; favorable (+) and adverse (–) tolerance with triangular PDF (see also Appendix A)
	52.1 ±0.5	At 2200 MHz
Half-Power Beamwidth (deg)		
	0.37 ±0.03	Angular width (2-sided) between half-power points at 2200 MHz
	0.35 ±0.03	Angular width (2-sided) between half-power points at 2300 MHz

Table 2. S- and X-Band Receive Characteristics (continued)

Parameter	Value	Remarks
MAIN ANTENNA (continued)		
Polarization	RCP and LCP	Simultaneously
	or	
	rotatable linear	Via diversity combining within receiver
Ellipticity (dB)	0.7	Peak-to-peak voltage axial ratio, RCP and LCP
Pointing Loss (dB)		
Angular	See TRK-10	
Auto-Track	0.15	With respect to point of error channel null
System Noise Temperature (K)		See 1 for elevation dependence.
DSS 16	122 ±10	Near zenith, referenced to the prime 50K LNA (50K-A) input (includes feedline loss), average clear weather; adverse (+) and favorable (–) tolerances with triangular PDF (see Table 3 for system noise temperature increases when using alternate LNAs; see also Appendix A)
DSS 46	117 ±10	
DSS 66	120 ±10	
ACQUISITION ANTENNAS		
S-Band		(1.8-m antenna)
Gain (dBi)	25.5 +0.3/–0.7	With RCP or LCP input signal, referenced to acquisition downconverter input terminals (includes polarization and feedline losses); favorable (+) and adverse (–) tolerances with triangular PDF
Half-Power Beamwidth (deg)	5.1 ±0.5	Angular width (2-sided) between half-power points at 2200 MHz
	4.9 ±0.5	Angular width (2-sided) between half-power points at 2300 MHz

Table 2. S- and X-Band Receive Characteristics (continued)

Parameter	Value	Remarks
ACQUISITION ANTENNAS		
S-Band (continued)		
Polarization	Linear X and Y	Simultaneously available, aligned with main antenna axes (orthogonal linear)
Alignment Error	TBD	Aligned with main antenna RF beam
System Temperature (K)	300 ±100	Near zenith
X-Band		(1.2-m antenna)
Gain (dBi)	37.0 ±0.5	Referenced to acquisition downconverter input terminals (includes feedline losses); favorable (+) and adverse (–) tolerances with triangular PDF
Half-Power Beamwidth (deg)	2.0 ±0.3	Angular width (2-sided) between half-power points at 8400 MHz
Polarization	RCP	LCP is available by manual selection at feed.
Alignment Error	TBD	Aligned with main antenna RF beam
System Temperature (K)	83 ±10	Near zenith
RECEIVER	rotatable linear	Via diversity combining within receiver
Frequency Range (MHz)		
S-Band	2200 to 2300	
X-Band	8210–8310 and 8400–8500	Acquisition antenna only
Incremental Tunability (kHz)	10	Continuously variable tuning around center frequency available in ±15 kHz and ±300 kHz ranges
Noise Bandwidth (Hz)	10 ±10%	Effective one-sided threshold noise bandwidth (B_{LO})
	30 ±10%	
	100 ±10%	
	300 ±10%	
	1000 ±10%	
	3000 ±10%	

Table 3. S-Band System Noise Temperature Adjustments to Table 2 Values (for Alternate LNAs)

LNA	DSS 16 Goldstone (K)	DSS 46 Canberra (K)	DSS 66 Madrid (K)
50K-A	0	0	0
50K-A	+5	TBD	–6
85K-A	+36	TBD	TBD
85K-A	+46	TBD	+20

Note: Tolerance of ±2 K (triangular) is to be RSS'd with the tolerances in Table 2 and Figure 1.

Table 4. Recommended Minimum Operating Carrier Signal Levels

Noise Bandwidth (B_{LO})	Minimum Carrier Signal Level (dBm) *					
	10 Hz	30 Hz	100 Hz	300 Hz	1000 Hz	3000 Hz
Main Antenna	–154.7	–150.0	–144.7	–140.0	–134.7	–130.0
S-Band Acquisition Antenna	–150.8	–146.1	–140.8	–136.1	–130.8	–126.1
X-Band Acquisition Antenna	–156.3	–151.5	–146.3	–141.5	–136.3	–131.5

* Levels are 10 dB above loop design threshold with nominal system temperature for specified antenna and nominal loop bandwidths assumed. System temperatures are referenced to prime LNA (50K-A) input for main antenna and input of acquisition receiver downconverter for acquisition antennas. A value given such as "30 Hz" means 30 Hz on each side of carrier frequency for a total bandwidth of 60 Hz, and so forth.

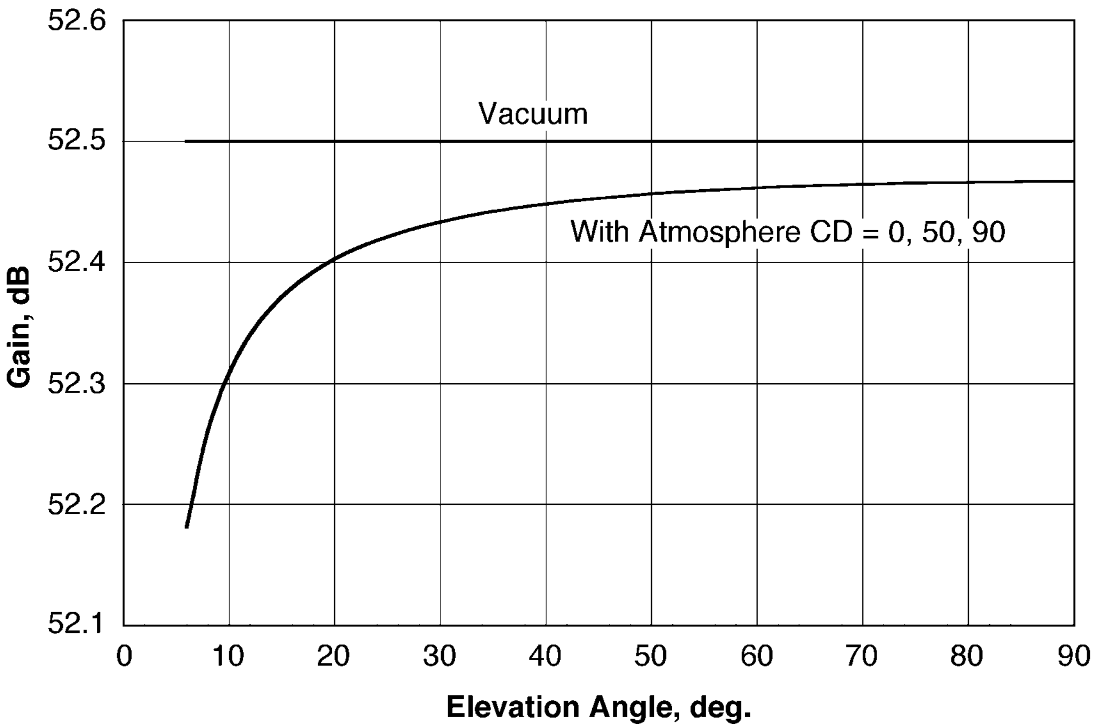

Figure 1. Main Antenna S-Band Receive Gain With and Without Atmosphere

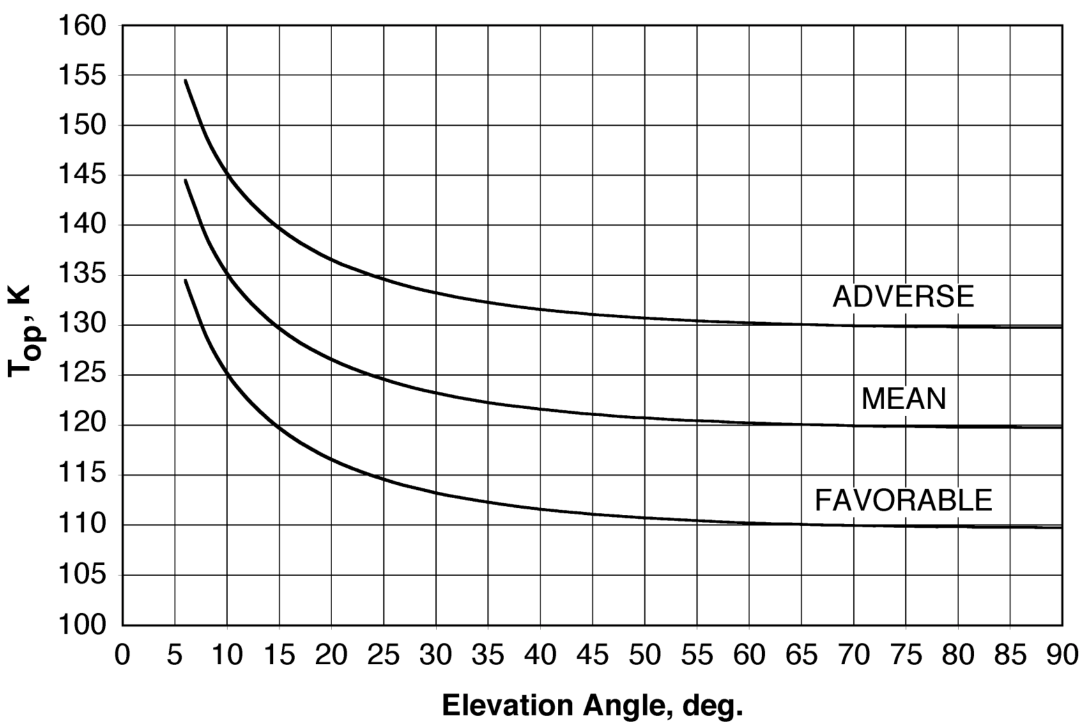

Figure 2. S-Band System Temperature Versus Elevation Angle (50K-A LNA at DSS 16)

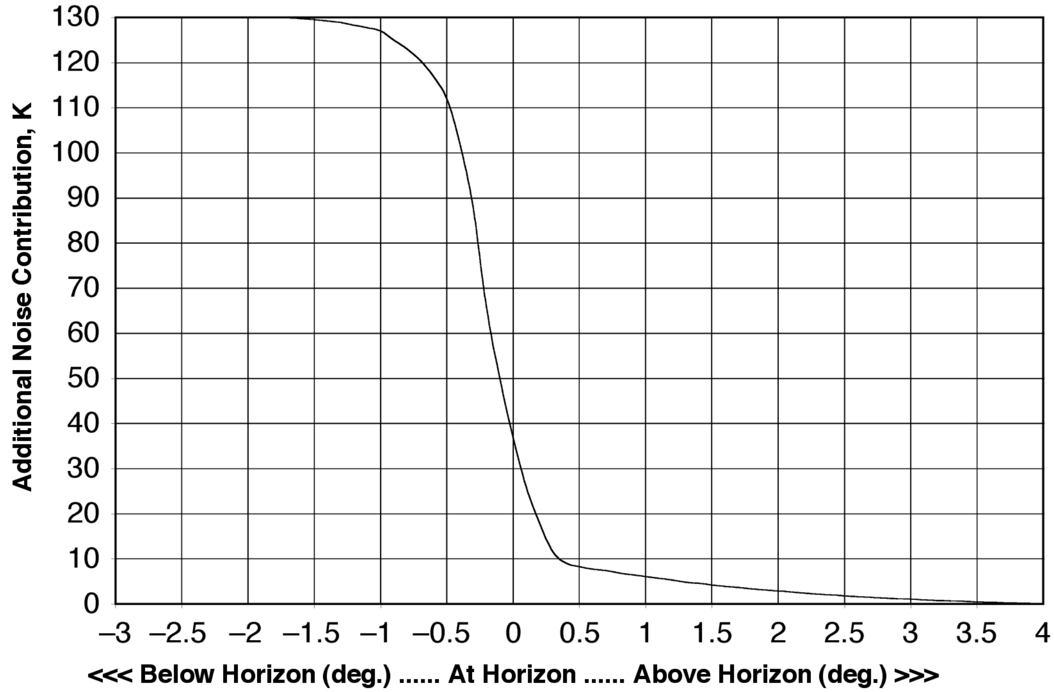

Figure 3. S-Band System Temperature Increase at Optical Horizon Mask (DSS 16 with 5.359 deg. Terrain Elevation)

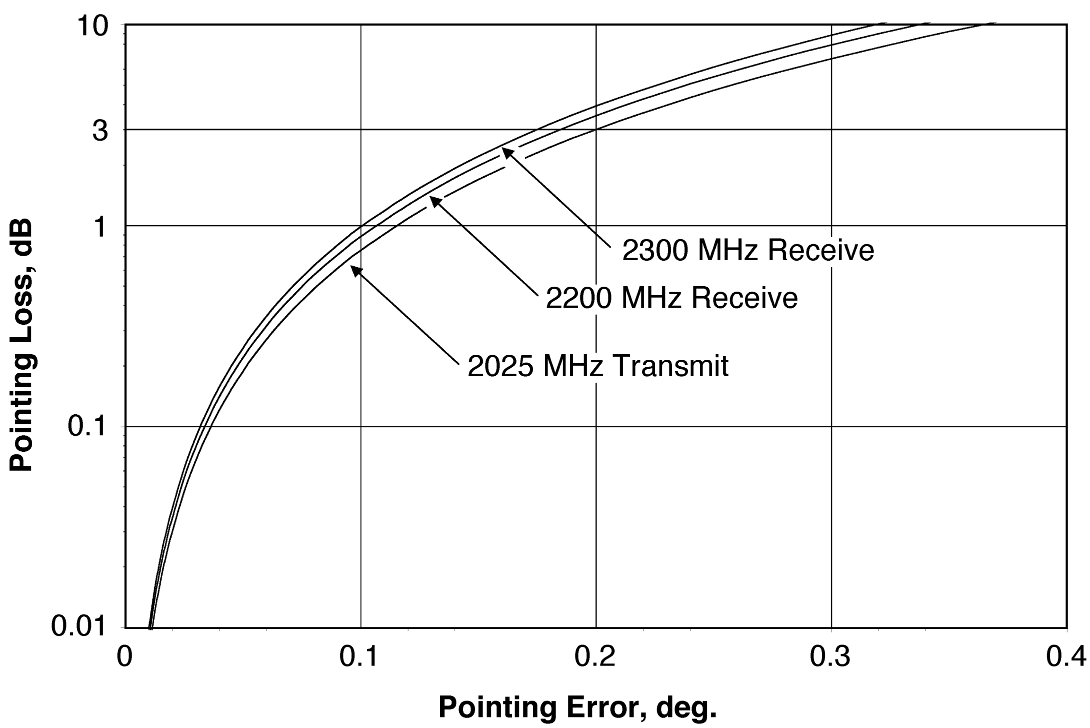

Figure 4. Main Antenna Pointing Loss Versus Pointing Error

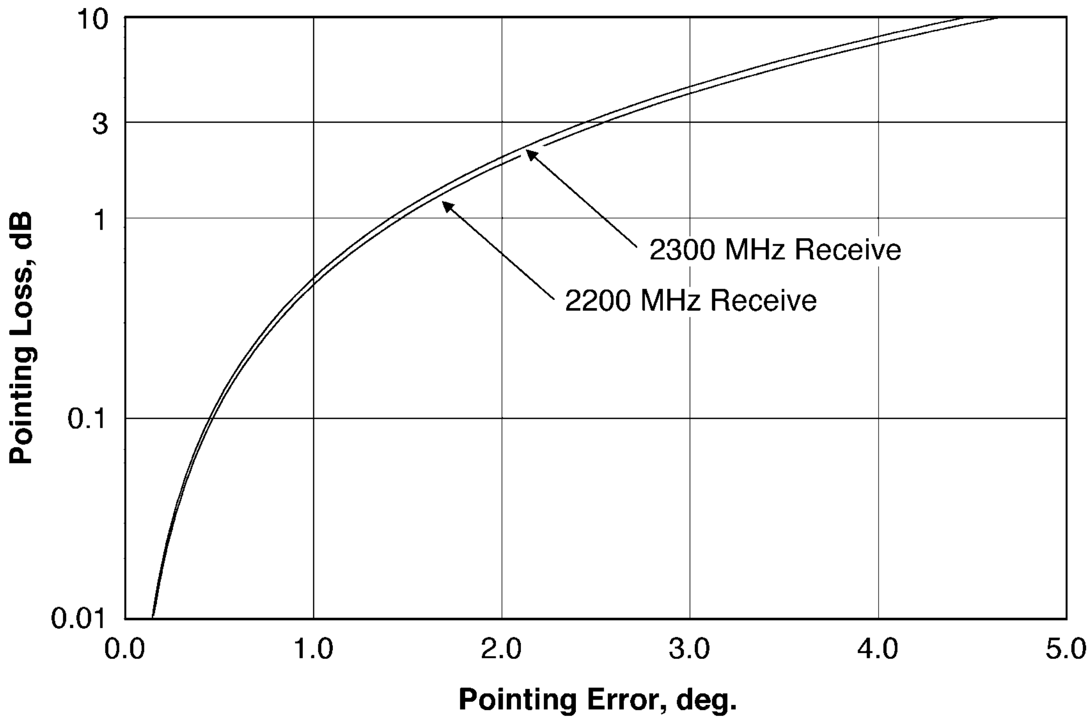

Figure 5. S-Band Acquisition Antenna Pointing Loss Versus Pointing Error

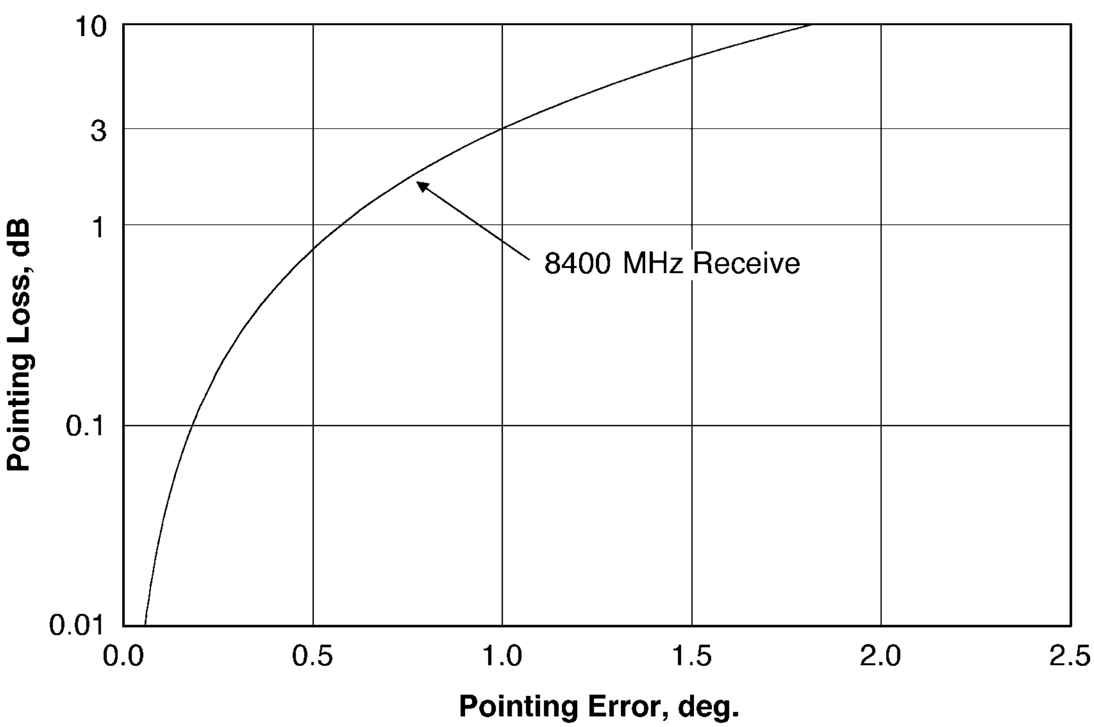

Figure 6. X-Band Acquisition Antenna Pointing Loss Versus Pointing Error

Appendix A
Equations for Modeling

A.1 Equation for Gain Versus Elevation Angle

The following equation can be used to generate S-band transmit and receive gain versus elevation angle curves, an example of which is depicted in Figure 1. 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.

$$G(\theta) = G_0 - G_0(\theta - \gamma)^2 - \frac{A_Z}{\sin\theta}, \quad \text{dBi} \tag{1}$$

where

θ = antenna elevation angle (deg.) $0 \le \theta \le 90$

G_0, G_1, γ = parameters from Table A-1

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

A.2 Equation for System Temperature Versus Elevation Angle

The following equation can be used to generate S-band system temperature versus elevation angle curves, an example of which is depicted in Figure 3. See module 105 for atmospheric attenuation at weather conditions other than 0%, 50%, and 90% cumulative distribution.

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

where

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

T_1, T_2, a = parameters from Table A-3

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

A_{ZEN} = zenith atmospheric attenuation for selected CD from Table A-2 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 4–6.

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

where

θ = pointing error (deg.)

$HPBW$ = half-power angular beamwidth in degrees (from Tables 1 and 2).

Table A-1. Vacuum Component of S-Band Gain Parameters

Station	Parameters†			
	G_0 (Transmit)	G_0 (Receive)	G_1	γ
Main Antenna				
DSS 16	51.4	52.6	0.0	45.0
DSS 46	TBD	TBD	TBD	TBD
DSS 66	TBD	TBD	TBD	TBD

Notes:

† Favorable tolerance on G_0 values = +0.5 dB, adverse tolerance = –0.5 dB, with a triangular PDF.

G_0 values are nominal at the frequency specified in Table 1 or Table 2. Other parameters apply to all frequencies within the same band.

Table A-2. S-Band Zenith Atmosphere Attenuation Above Vacuum (A_{ZEN})

Weather Condition	A_{ZEN}, dB*		
	DSS 16	DSS 46	DSS 66
Vacuum	0.000	0.000	0.000
CD = 0.00	0.033	0.036	0.034
CD = 0.50	0.032	0.035	0.033
CD = 0.90	0.031	0.034	0.033

* From Table 2 in module 105

Table A-3. Vacuum Component of S-Band System Noise Temperature Parameters

Parameters	DSS 16	DSS 46	DSS 66
T_1 (K)*	120	115	118
T_2 (K)	12	12	12
a	0.07	0.07	0.07

Notes:

* Favorable tolerance = –10 K, adverse tolerance = +10 K, with a triangular PDF

Values shown are for the prime 50K LNA (50K-A). See Table 3 for system noise temperature increases when using alternate LNAs.