TCI-10; REV. A
DSN TELECOMMUNICATIONS INTERFACES, 64-METER ANTENNA SUBNET

(Insert this modular document in your 810-5; Rev. D Handbook)

EFFECTIVE DATE: 1 October 1977 Change 1: 15 January 1978

Approved by: BDL Mulhall

A. PURPOSE.

This module describes the primary telecommunications parameters pertaining to the DSN 64-meter antenna station subnet.

B. SCOPE.

The intent of this document is to provide the significant telecommunications parameters for system noise temperature, transmitter, and other RF-related data in sufficient detail to allow the telecommunications engineer to calculate link performance.

C. LOCATION OF MATERIAL.

1. Contents.

2. Illustrations.

3. Tabular Data.

D. GENERAL INFORMATION.

1. Deep Space Network.

The DSN includes three basic subnets as follows:

(a) 64-meter diameter antenna subnet (DSS 14, 43, 63)
(b) 26-meter diameter antenna subnet (DSS 11, 44, 62)
(c) 26-meter diameter antenna subnet (DSS 11, 42, 61) which will be upgraded to a 34-meter subnet per the schedule in Figure 1 of TCI-30

Other elements of the DSN include a Compatibility Test Area (CTA 21) at JPL, Pasadena, and a similar configuration of equipment in the Spaceflight Tracking and Data Network (STDN) station at Merritt Island, Florida.

2. Telecommunications Parameters, S- and X-Band.

The more significant telecommunications parameters for the 64-meter antenna subnet are given in Table 1. They include (1) S-band transmit characteristics for 20 and 100 kilowatts, (2) S- and X-band receive characteristics for traveling wave maser operation and Block III or Block IV receiver configurations, and (3) characteristics for frequency and timing. See TCI-40 for S- and X-band weather-induced system degradations.

The operating system noise temperature (T_{op}) varies as a function of elevation angle, and typical values for the 64-meter antenna stations are given Figure 1. Nominal reduction in 64-meter antenna gain as a function of angle off boresight is given for S-band transmission and S-and X-band reception in Figure 2.

The degradation of system noise temperature as a function of Sun-Earth-probe angle is given in TCI-40.

S-band and X-band gain reduction due to wind loading is listed in Table 2. Cumulative probability distributions of wind conditions are given in TCI-40.

Variation in 64-meter antenna gain at X-band are given in Table 3. These data include atmosphere attenuation which can be calculated by formulas given in TCI-40. The variation in antenna gain at S-band is a loss of 0.4 dB at 10 degrees elevation. This loss decreases and is negligible ($<$0.1 dB) between 30 to 70 degrees elevation. At 80 degrees elevation the loss is 0.1 dB.

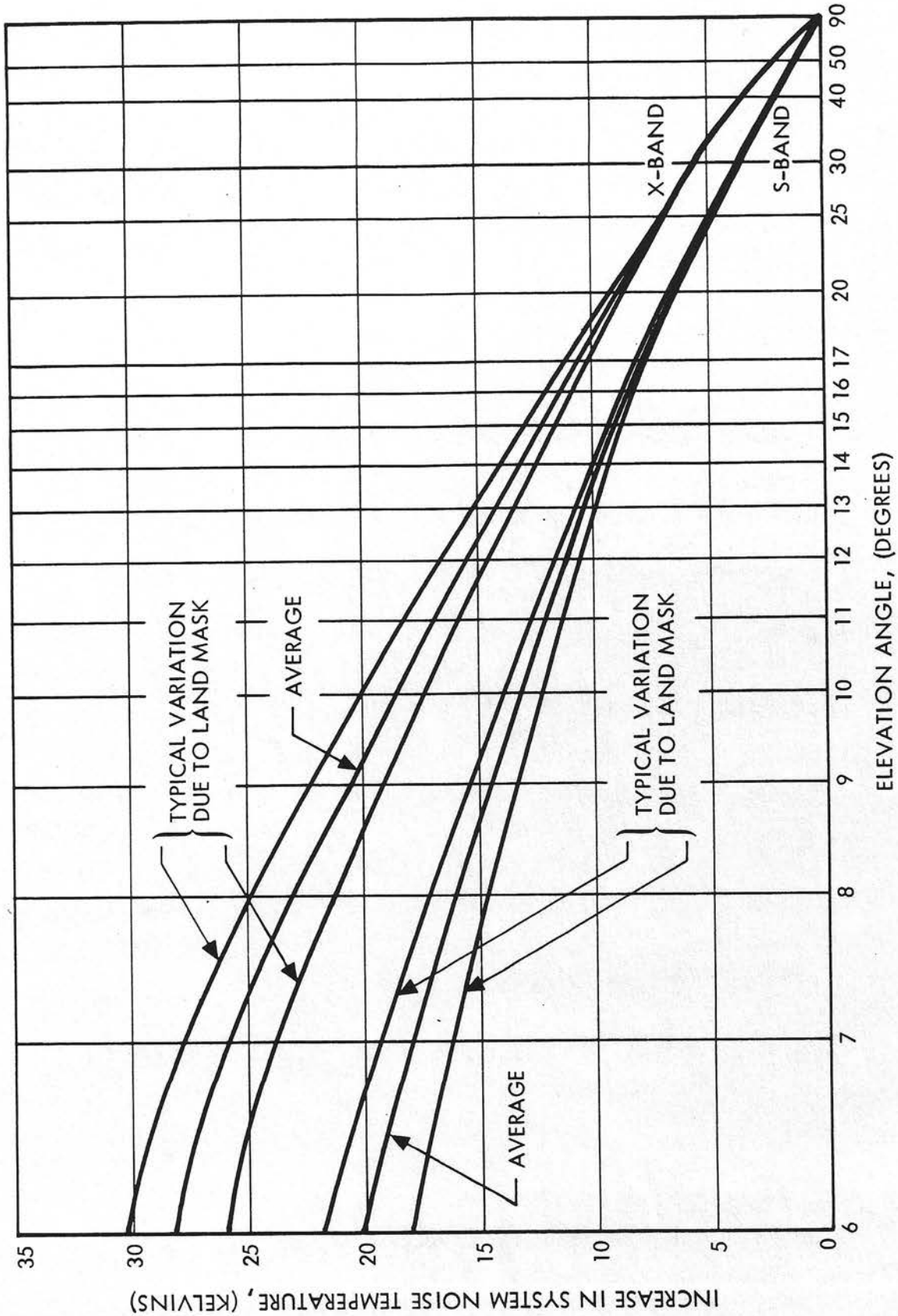

Figure 1. Increase in System Noise Temperature vs Elevation Angle for 64-Meter Antennas, S- and X-Band

Table 1. Primary Telecommunication Parameters for 64-Meter Subnet (Sheet 1 of 9)

Antenna		
Transmit Characteristics	Value	Remarks
Gain (dBi)	$60.6^{+0.3}_{-0.7}$ (at 20 kW)	Calculated for matched polarization; referenced to transmitter output terminal (includes feedline losses)
	$60.7^{+0.3}_{-0.7}$ (at 100 kW)	
	$60.9^{+0.2}_{-0.6}$	Referenced to feed
Beamwidth (deg)	$0.150^{+0.01}_{-0.004}$	Half-power angular width
Polarization	RCP/LCP/Rotatable linear	One polarization at a time, remotely selected
Ellipticity		
RCP or LCP (dB)	2.2 ±0.4	Calculated peak-to-peak voltage axial ratio
Rotatable linear (dB)	12.5 ±1.5	
Pointing loss		
Angular	See TRK-10	--
Power (dB, 3 sigma)	0.03	For conical scan on an X-band received signal set at 0.1 dB loss.
	0.1	For conical scan on an S-band received signal set at 0.1 dB loss.

Table 1. Primary Telecommunication Parameters for 64-Meter Subnet (Sheet 2 of 9)

Transmitter Exciter		
Transmit Characteristics	Value	Remarks
RF power output	20 kW power amplifier +73 ±0.5 dBm max Down to +53 ±1.5 dBm -or- 100 kW power amplifier[2] +80 ±0.5 dBm max Down to +70 ±1.5 dBm	Calculated with klystron saturated drive[1] Unsaturated drive Saturated drive[1] Unsaturated drive
Total bandwidth (-1 dB)	8 MHz nominal (2110 to 2118 MHz) TBD	Combined exciter transmitter tuned bandwidth under saturated drive conditions Unsaturated drive
Power stability Long term (12 hour period) (dB)	±0.25 ±1.0	Saturated drive Unsaturated drive
Short term (dB)	≤0.1	Peak-to-peak for 20 kW capability, saturated or unsaturated drive conditions in ±0.5 Hz bandwidth about the carrier frequency, under fixed primary (400 Hz) voltage conditions
Frequency range (MHz)	2100 to 2120	Two-way coherent mode and 100 kW amplifier 1 dB bandwidth extend from 2110 to 2118 MHz only

[1] Across VCO tuning range: Referenced to klystron transmitter output terminal

[2] High power radiation automatically switched off below 10 degrees elevation.

Table 1. Primary Telecommunication Parameters for 64-Meter Subnet (Sheet 3 of 9)

Transmitter Exciter		
Transmit Characteristics	Value	Remarks
VCO frequency setting	0.96 Hz increments 0.002 Hz increments	Block III exciter Block IV exciter
Manual VCO operation frequency stability	1 part in 10^7 3 parts in 10^6	For 20 min } Block III For 10 hr } exciter
VCO tuning range	±9 parts in 10^5	Block III exciter
Synthesizer tuning range	Total frequency range	Block IV exciter
Spurious radiation		
Phase modulation (degrees, rms)	5	
Amplitude modulation (dB)	60	Below carrier
2nd harmonic (dB)	85	Below carrier
3rd harmonic (dB)	85	Below carrier
4th harmonic (dB)	TBD	
Antenna		
Receive Characteristics	Value	Remarks
Frequency range		
S-band (MHz)	2270 to 2300	--
X-band (MHz)	8400 to 8440	Block IV receiver required for X-band reception

Table 1. Primary Telecommunication Parameters for 64-Meter Subnet (Sheet 4 of 9)

Antenna		
Receive Characteristics	Value	Remarks
Gain		
S-band (dBi)		
Receive matched (diplex) or orthogonal polarization	$61.7^{+0.3}_{-0.4}$	Calculated with reference to TWM 1 input terminal[3] (Includes feedline losses.)
	$61.6^{+0.3}_{-0.4}$	Calculated with reference to TWM 2 input terminal[3] (Includes feedline losses.)
	$61.8^{+0.2}_{-0.4}$	Referenced to feed
X-band (dBi)		
DSS 14	71.3 ±0.6	Referenced to TWM input terminal at optimum elevation angle. See Table 3 for elevation angle dependence.
DSS 43 & 63	71.8 ±0.6	
Antenna pattern beamwidth (deg)		Calculated half-power angular width
S-band	$0.140^{+0.007}_{-0.000}$	
X-band	$0.038^{+0.005}_{-0.000}$	
Polarization		
S-band	RCP, LCP, or rotatable linear	Orthogonal pairs at a time
X-band	RCP or LCP	
Ellipticity		
S-band		
RCP or LCP (dB)	0.28 ±0.28	Peak-to-peak voltage axial ratio
Rotatable linear (dB)	30.0 ±5	

[3] See Tables 2 and 3 for gain reduction due to wind and elevation angle effects.

Table 1. Primary Telecommunication Parameters for 64-Meter Subnet (Sheet 5 of 9)

Antenna		
Receive Characteristics	Value	Remarks
Ellipticity (cont'd) X-band RCP or LCP (dB)	$1.0^{+0.2}_{-0.5}$	Peak-to-peak voltage axial ratio
Pointing loss Angular	See Module TRK-10 for angular loss	
S- and X-band power loss (dB, 3 sigma)	0.1	S-band loss is 0.03 dB if conical scan is performed on an X-band received signal set at 0.1 dB loss.
Total System Noise Temperature		
S-band system temperature TWM 1 Receive matched (diplex) polarization (Kelvins)	22 ±3	Calculated with reference to TWM 1 input terminal[4] (Includes feedline losses.)
Receive orthogonal polarization (Kelvins)	18 ±3	
TWM 2 Receive matched (diplex) polarization (Kelvins)	26 ±3	Calculated with reference to TWM 2 input terminal[4] (Includes feedline losses.)
Receive orthogonal polarization (Kelvins)	23 ±3	

[4] Antenna directed to cold sky (near zenith) and for signal input value of less than -110 dBm

Table 1. Primary Telecommunication Parameters for 64-Meter Subnet (Sheet 6 of 9)

Total System Noise Temperature		
Receive Characteristics	Value	Remarks
X-band TWM received matched polarization (Kelvins)	25.0 ±3.0	Referenced to TWM input terminal (includes feedline losses). At zenith, cold sky, clear dry weather, received with S-band simultaneously. Dichroic reflector effect is included.
S- and X-band noise temperature dependence	See Figure 1	For angles 10 deg and less, the characteristic is dependent on azimuth and the terrain of site, see GEO-10. For seasonal and diurnal variations, see TCI-40.
Reference Channel RF Noise Bandwidth		
Noise bandwidth (Hz)	Block III / Block IV $12^{+0}_{-20\%}$ / 1 ±10%* $48^{+0}_{-20\%}$ / 3 ±10% $152^{+0}_{-20\%}$ / 10 ±10% 30 ±10% 100 ±10% 300 ±10%	Effective two-sided threshold (design point) noise bandwidth $2B_{L_o}$ Block III has only S-band capability Block IV has capability for both S- and X-band.
*S-band only		

Table 1. Primary Telecommunication Parameters for 64-Meter Subnet (Sheet 7 of 9)

Recommended Minimum Operating Carrier Signal Levels[5] (dBm)									
Bandwidth	1 Hz	3 Hz	10 Hz	12 Hz	30 Hz	48 Hz	100 Hz	152 Hz	300 Hz
Receiver	Block IV	Block IV	Block IV	Block III	Block IV	Block III	Block IV	Block III	Block IV
S-Band TWM 1									
Receive and transmit	TBS	-170.4	-165.2	-164.4	-160.4	-158.4	-155.2	-153.4	-150.4
Receive orthogonal polarization	TBS	-171.3	-166.1	-165.3	-161.3	-159.3	-157.1	-154.3	-151.3
S-Band TWM 2									
Receive and transmit	TBS	-169.7	-164.5	-163.7	-159.7	-157.7	-154.5	-152.7	-149.7
Receive orthogonal polarization	TBS	-170.2	-165.0	-164.2	-160.2	-158.2	-155.0	-153.2	-150.2
X-Band TWM	NA	TBS	-164.6	NA	-159.9	NA	-154.6	NA	-149.9

[5] Levels are 10 dB above RF loop design threshold, with nominal system noise temperature and loop bandwidths assumed, referenced to TWM input terminals.

Table 1. Primary Telecommunication Parameters for 64-Meter Subnet (Sheet 8 of 9)

Frequency and Timing		
Characteristics	Value	Remarks
Frequency stability Rubidium standard	5 parts in 10^{12} for 1 second 5 parts in 10^{13} for 100 seconds 5 parts in 10^{13} for 1000 seconds 5 parts in 10^{13} for 12 hours 1 part in 10^{11} for 1 year	
Hydrogen maser	3 parts in 10^{13} for 1 second 2 parts in 10^{14} for 100 seconds 2 parts in 10^{14} for 12 hours 2 parts in 10^{13} for 1 year	Projected operational by July 1978
Cesium beam standard	5 parts in 10^{12} for 1 second 8 parts in 10^{13} for 100 seconds 2.5 parts in 10^{13} for 1000 seconds 8 parts in 10^{14} for 10^{4} seconds TBD for > 12 hours	
Station time relative to DSN master clock	20 microseconds 3 milliseconds	Rubidium standard synchronized by OTS Calibration by HF radio

Table 1. Primary Telecommunication Parameters for 64-Meter Subnet (Sheet 9 of 9)

Frequency and Timing		
Characteristics	Value	Remarks
DSN master clock relative to NBS	50 microseconds	Calibrated by portable cesium clock
DSS frequency offset relative to DSN master reference frequency		
Rubidium or Cesium beam standard	1 part in 10^{11}	
Hydrogen maser	2 parts in 10^{13}	Projected operational by July 1978

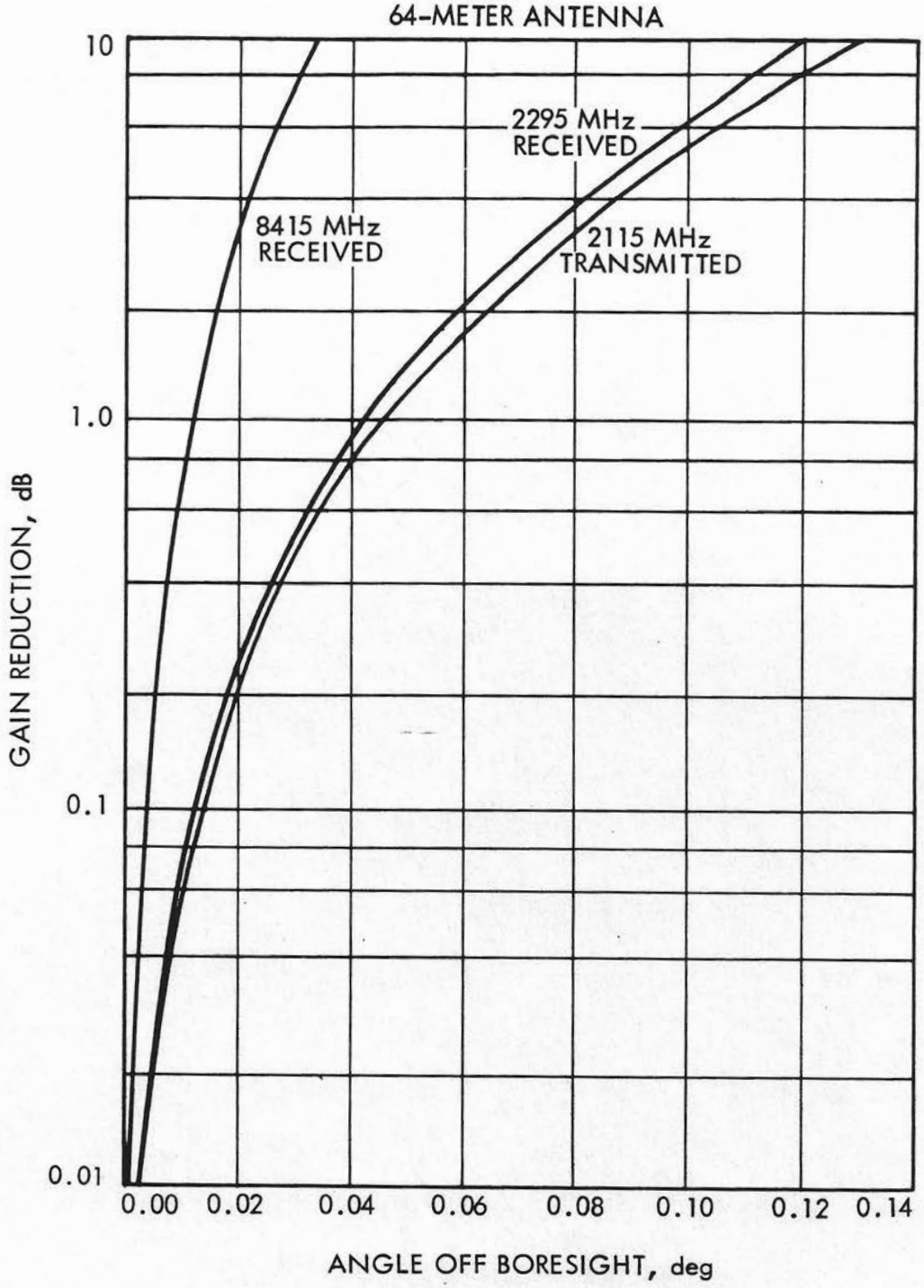

Figure 2. Calculated Gain Reduction at Transmitted and Received Frequencies vs Angle Off Boresight for 64-Meter Antenna Stations

Table 2. Loss Due to Wind Loading, 64-Meter Antenna Station

Wind Speed		S band Loss (dB)	X band Loss (dB)
(Km/hr)	(mph)		
32	20	Negligible	0.05
48	30	Negligible	0.3
72	45	0.2	1.5

Table 3. X-Band Antenna Gain for 64-Meter Antenna Subnet Including Atmospheric Effects*

Elevation Angle (degrees)	DSS 14		DSS 43 and 63	
	System Efficiency	Gain (dBi)	System Efficiency	Gain (dBi)
10	.376	70.8	.363	70.6
15	.390	70.9	.393	71.0
20	.402	71.1	.417	71.2
25	.412	71.2	.437	71.4
30	.419	71.3	.452	71.6
35	.423	71.3	.464	71.7
40	.426	71.3	.470	71.7
45	.426	71.3	.471	71.8
50	.423	71.3	.471	71.8
55	.418	71.2	.465	71.7
60	.411	71.2	.454	71.6
65	.401	71.1	.439	71.5
70	.389	70.9	.419	71.3
75	.375	70.8	.397	71.0
80	.358	70.6	.368	70.7

*1. See TCI-40 for procedures for estimating atmospheric effects on antenna gain.

2. Refocusing of the subreflector as antenna elevation angle changes is required to achieve these values. If refocusing is not performed, from 0.8 to 1.2 dB, loss in gain will occur.