453-NENUG
(formerly 453-GNUG)

450/EXPLORATION AND SPACE COMMUNICATIONS PROJECTS DIVISION

Near Earth Network (NEN) Users' Guide

Revision 1

Effective Date: January 15, 2010
Expiration Date: January 15, 2015

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland

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Near Earth Network Users' Guide

Revision 1

January 15, 2010

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Preface

This document is under the configuration management of the Code 453 Ground Network Project Office Configuration Control Board (GN CCB).

Proposed changes to this document should be submitted to the Ground Network Project Office along with supportive material justifying the change. Changes to this document shall be made by document change notice (DCN) or by complete revision. Questions and proposed changes concerning this document shall be addressed to:

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Document History			
Document Number	**Status/Issue**	**Publication Date**	**CCR Number**
STDN 101.3	Retired	June 1980	
530-UGD-GN	Retired	June 1993	530/638
452-GNUG-GN	Original	February 2001	452/035
453-GNUG	Original	April 2003	453/084
	Revision 1	February 2005	453/183
	Revision 2	May 2007	453/168
453-NENUG	Original	May 2009	453/197
453-NENUG	Revision 1	January 15, 2010	453/209

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Section 1. Introduction

1.1 Purpose

The purpose of this document is to describe the technical capabilities of the ground stations that comprise the National Aeronautics and Space Administration (NASA) Near Earth Network (NEN).

This document provides sufficient information to enable project engineers and support personnel to begin interfacing with the NEN. It is not intended to be a technical description of network equipment; rather, it defines NEN capabilities and identifies those parameters of particular interest to the user. For more detailed information, see the documents cited in Section 1.3.

Because NEN capabilities may change (due to budgetary constraints or management decisions, for example), the information presented in this document does not obligate NASA in any way.

1.2 Scope

For the purpose of this document, the NEN consists of both the NASA owned ground stations located in Norway, Florida, Alaska, Antarctica, Virginia and the contracted commercial stations run by the Universal Space Network (Alaska, Australia, Hawaii), Santiago Satellite Stationn (Chile) and Kongsberg Satellite Services (Norway). The NEN also includes support from the Network Integration Center (NIC) located at the Goddard Space Flight Center (GSFC). The NEN scheduling office, WS1 S/Ka-band, and VHF systems are all located at the White Sands Complex, New Mexico.

For each NEN station, with the exceptions of Hartebeesthoek, Kiruna and Weilheim, this document provides the following information:

- General characteristics, including geographic location, transmit/receive capabilities, and scheduling capabilities.
- Detailed performance characteristics.
- User tracking capabilities.
- Baseband data interfaces.

1.3 Reference Documents

The following documents are referenced herein and/or provide background information:

a. EOS Polar Ground Station Project Phase I Functional and Performance Requirements, 452-F&PR1-EPGS, May 1998.

b. Radio Frequency and Modulation Systems, Part 1, Earth Stations, CCSDS 401.0-B-17 , Blue Book. Issue 17. July 2006.

c. AOS Space Data Link Protocol. CCSDS 732.0-B-2, Blue Book. Issue 2. July 2006.

d. Radio Frequency and Modulation Systems—Spacecraft-Earth Station Compatibility Test Procedures, CCSDS 412.0-G-1, Green Book. Issue 1. May 1992.

e. NISN Services Document (NSD), NISN 001-001 (Rev. 4-C).

f. Earth Observing System (EOS) Data and Information System (EOSDIS) Backbone Network (EBnet) Operations Concept, 540-028, Revision 1, GSFC, May 1996.

g. GN Compatibility Matrix, Version 13, August 22 2008.

h. NASA Policy Directive (NPD) 2570.5, NASA Radio Frequency Spectrum.

i. Tracking and Acquisition Data Handbook for the Ground Network, 453-HDBK-GN May 2007.

j. NASA Procedural Requirement (NPR) 2570.1B, NASA Radio Frequency (RF) Spectrum Management Manual.

k. NTIA Manual of Regulations & Procedures for Federal Radio Frequency Management.

l. Interface Control Document Between Landsat 7 Mission Operations Center (MOC) and the Landsat 7 Ground Network (LGN), L7-ICD-40.1, February 2004...

m. Radio Frequency (RF) Interface Control Document (ICD) Between the ICESat Spacecraft and the EOS Polar Ground Station (EPGS), 452-RFICD-EPGS/ICEsat, January 2000.

n. Efficient Spectrum Utilization for Space Science Services on Space-To-Earth Links, SFCG Recommendation 17-2R1, 17 September 1998.

o. Wallops Flight Facility Range User's Handbook, 840-HDBK-0001, Version F, dated June 2003.

p. 450-Catalog-Services, GSFC Mission and Data Services 2003 Catalog.

q. 450-OIP-DSMC, Data Services Management Center (DSMC) Interface Procedures (OIP), dated June 24, 2005.

r. Space Link Extension – Forward CLTU Service Specification. CCSDS 912.1-B-2 Blue Book. Issue 2. November 2004.

s. TM Synchronization and Channel Coding, CCSDS 131.0-B-1, Blue Book. Issue 1. October 2003.

t. NEN Directive Procedure, NENS-GN-PRCD-0208, dated January 24, 2006.

1.4 Document Organization

The remaining portions of this document are organized as follows:

- Section 2 provides an overview of the entire NEN.
- Section 3 describes the Svalbard ground station (SGS) in Norway.

- Section 4 describes the Wallops Flight Facility (WFF) ground stations in Virginia.
- Section 5 describes the McMurdo Ground Station (MGS) in Antarctica.
- Section 6 describes the Universal Space Network ground stations.
- Section 7 describes the Alaska ground stations.
- Section 8 describes the Florida ground stations.
- Section 9 describes the White Sands Complex (WSC) VHF ground stations.
- Section 10 describes the Santiago Satellite Station (AGO) in Chile.
- Section 11 describes the Scheduling Process.
- Section 12 describes Baseband Data Interfaces.
- Section 13 describes Frequency Management Considerations.
- Section 14 describes Link Budget Parameters
- Appendix A is the Acronym List.

Section 2. NEN Overview

This section provides an overview of the NEN, its antenna ground stations, and customer services. The antenna overview provides general characteristics of NEN antenna tracking, telemetry, and command functions and capabilities. Further details on NEN antennas are addressed on a station-by-station basis in the following chapters. The customer service overview describes NEN services and how to obtain NEN services. Further details on services are available from the Exploration and Space Communications (ESC) Projects Division Network Integration Management Office (GSFC Code 450.1).

To help a flight project quickly examine, evaluate, and compare capabilities of NEN ground station antennas, this section contains several tables summarizing antenna capabilities and specifications.

- Table 2-1 summarizes general antenna specifications

2.1 NEN Overview

The NASA NEN is a customer driven organization that provides comprehensive communications services to space assets. The NEN provides telemetry, commanding, and tracking services for orbital missions and occasionally sub-orbital missions. The NEN provides services to a wide variety of mission customers at various low-earth orbits (LEO), geosynchronous orbits (GEO), highly elliptical orbits, Lagrange orbits, Lunar orbits, Lunar surface and transfer, sub-orbital and launch trajectories, at multiple frequency bands through all phases of a mission's lifetime. This diversity of service is listed in Figure 2-1.

NEN Customer Diversity Examples	**Customers**	• NASA • Other Government • International • Commercial
	Phases	• On-orbit • Launch • Early Orbit • Disposal
	Orbits	• Sub-orbital LEO • GEO • Highly Elliptical • Launch
	Frequency	• X-Band • S-Band • UHF • VHF • Ka-Band

Figure 2-1. NEN Services

2.2 NEN Ground Stations Overview

The NEN provides services from a diverse collection of antenna assets located around the world. Many of the NEN sites are located in prime polar locations to provide service to high-inclination polar orbiting spacecraft. Because polar orbiting spacecraft pass over the Earth's poles each orbit, stations in near polar locations, such as Norway, Alaska, and Antarctica, can provide communications to polar orbiting spacecraft nearly every orbit.

NASA's mid-latitude and equatorial ground stations provide support to low-inclination orbital missions, provide support to geosynchronous (GEO) spacecraft, and are located near launch ranges to provide effective launch range tracking services. The Merritt Island Launch Annex (MILA) station in Florida is located to provide launch support to shuttle missions launching from Kennedy Space Center (KSC). The ground station assets located at Wallops Island, Virginia, are in a prime location to provide orbital support to low-inclination customers and launch tracking services to the launch range at Wallops, as well as to provide some coverage to launches from KSC. Stations are distributed around the globe to provide mission-critical event coverage to missions.

This NEN Users' Guide addresses the NASA owned / maintained stations that are dedicated to NASA customer missions and commercially owned stations. The stations NASA owned stations include:

- Svalbard Ground Station (SGS) in Norway, operated by KSAT
- Wallops Ground Stations (WGS) in Virginia, operated by NASA
- McMurdo Ground Station (MGS) in Antarctica, operated by NASA
- Alaska Satellite Facility (ASF) in Alaska, operated by UAF
- Florida Ground Stations, operated by NASA
- White Sands Complex ground stations in New Mexico, operated by NASA

NASA provides a significant portion of its space communications services by contracting commercial ground station providers to support NASA missions. The commercial apertures provided by these contractors are available to NASA's NEN customers through existing contracts. Commercial data service providers currently available include:

- Kongsberg Satellite Services (KSAT) at Svalbard, Norway
- Universal Space Network (USN) with stations in Alaska, Hawaii, and Australia
- Santiago Satelite Station in Santiago, Chile Weilheim (Germany) and Kiruna (Sweden), under USN agreement for LRO support
- Hartebeesthoek, South Africa

These providers and their antenna assets are discussed in detail in this NEN Users Guide, with the exceptions of Weilheim, Kiruna and Hartebeesthoek. The Universal Space Network and the Santiago Satellite Station are wholly owned subsidiaries of the Swedish Space Corporation. Additional information about commercial sites may be acquired on the respective provider's web site:

- Kongsberg Satellite Services – http://www.ksat.no
- Alaska Satellite Facility – http://www.asf.alaska.edu/stgs/
- Universal Space Network – http://www.uspacenetwork.com/
- Swedish Space Corporation – http://www.sscchile.cl/ and http://www.ssc.se/?id=5997 for Kiruna
- Weilheim Tracking Station - http://www.dlr.de/rb/en/desktopdefault.aspx/tabid-4650/4253_read-6299/

- Hartebeesthoek Tracking Station – http://www.csir.co.za/SAC/ttc.html

The NEN stations are summarized in Tables 2.1, 2.2, and 2.3, and detailed in following chapters. Additional information can be found at the following NASA URL http://scp.gsfc.nasa.gov/gn/index.htm, including hours of operations (Link Commitment Schedule).

2.3 NEN Customer Services Overview

The Network Integration Management Office (NIMO) in conjunction with the NEN performs analysis, testing, and simulation services that are of direct benefit to the flight projects. Some are mandatory to validate compatibility and to meet launch readiness requirements. Analysis will address such preliminary questions as projected NEN loading, RF link margins, geometric coverage analyses, and preliminary funding and staffing requirements. The Network Services Request Form 450.1-FORM-0008 is used as a new project questionnaire to assist the initial analysis phase. The results of such analyses will enable an early assessment of the project's compatibility with the NEN.

2.3.1 Network Loading Analysis

To ensure that sufficient NEN resources are available to meet commitments to current and future users, the NIMO provides a representative to each customer flight project as early as possible during mission planning to assist in the definition of customer flight project needs for Exploration and Space Communications (ESC) services. Typical information needed for analyses includes the projected requirements for communications timeline, data rates, and number of data channels. Although this information may initially be of a preliminary nature, the best available information is needed for projecting NEN loading.

2.3.2 RF Link Margin and Coverage Analysis

Information exchange between the customer mission and the NIMO for the RF link margin and coverage analysis begins during the initial flight segment mission analysis phase and continues until firm coverage requirements and flight segment designs are finalized in the mission execution phase. The Communications Link Analysis and Simulation System (CLASS) analysis tool can be used to help achieve a flight segment telecommunications design which is compatible with the NEN, and will achieve the desired level of performance. Design deficiencies and possible trade-offs are defined during these analyses. The results of CLASS are used early in the mission analysis phase to aid in the development of the Radio Frequency Interface Control Document (RFICD), which is a controlling input to the flight segment telecommunications specifications. It should be noted that the RF/ICD is under NASA’s control via the Configuration Control Board (CCB).

2.3.3 Compatibility Testing

Compatibility testing is performed as early as possible after fabrication of the user spacecraft (either the flight model, which is preferred, or the prototype model) is completed. Compatibility tests are normally rerun following resolution of significant problems encountered during the original test or following post-test flight segment design modification. Results of these tests are formally published in the mission-specific Compatibility Test Report. Satisfactory completion of this testing and certification is required to meet the NASA readiness-for-launch criteria.

2.3.4 NEN Interface Testing and Operational Simulations

Mutually agreed upon end-to-end tests are conducted to validate all telecommunications system functions, as defined in the applicable ICDs and Customer Integration and Test Plans. In addition, operational exercises (i.e., simulations, data flows) are conducted to ensure that operations will satisfy requirements and timelines.

2.3.5 Orbit Analysis

Pre-launch orbital error analyses are performed to determine the frequency with which user spacecraft state vectors are needed to achieve the orbital accuracies required by the user flight project.

2.4 NEN Directive and Reporting

The NEN Directive Procedure (NENS-GN-PRCD-0208) provides a formal means of efficiently alerting and/or directing NEN elements to ensure continuity of reliable support in situations that management deems appropriate and/or where other notification methods may not suffice. The NEN Directive will be used as a tool to notify sites of potential systemic conditions that could affect the safety of operations, equipment or personnel and directs sites to implement associated mitigating actions. The decision to implement the mitigating action at the commercial sites remains under their management’s control.

The Significant Event Reporting System (SERS) is used to notify management and network users of site/system failures. An email is generated that details the anomaly, repair efforts, current/future impacts, and closure information. The email distribution is controlled by NEN management.

2.5 Obtaining NEN Services

For all NEN stations, flight projects request NEN support through NASA/GSFC, Code 450.1, Network Integration Management Office (NIMO). The NIMO provides its spacecraft and scientific customers with a complement of telecommunications services. NIMO provides options and planning assistance to effectively meet space and ground telecommunications requirements: that is, telemetry, tracking, and command services.

A Network Integration Manager (NIM) is assigned as a single point of contact for customer services throughout the mission lifecycle including formulation of trade studies and cost analyses; implementation of radio frequency compatibility testing; NEN telecommunications service definitions and commitments; customer integration testing and ongoing service coordination. Additional information can be found at http://scp.gsfc.nasa.gov/nimo/index.htm.

Table 2-1. NEN Overview

Station Location	Antenna Name	Antenna Diameter	Transmit Frequency (MHz)	EIRP (dBWi)	Receive Frequency (MHz)	G/T (dB/K)	Location	User Tracking
Norway	**SG1**	11.3 M	2025-2120	66	2200-2400 8025-8500	23.63 35.84	78°N 15°E	1- & 2-Way Dop, Angle
	SG2	11 M	2025-2120	TBD	2200-2400 7500-8500	20.38 32.38	78°N 15°E	1- & 2-Way Dop, Angle
	SG3	13 M	2025-2120	68	2200-2400 7500-8500	24.45 37.76	78°N 15°E	1- & 2-Way Dop, Angle
Wallops Island, Virginia	**WGS 11.3 M**	11.3 M	2025-2120	66	2200-2400 8025-8400	23.63 34.50	38°N 75°W	1- & 2-Way Dop, Angle
	LEO-T	4.7 M	2025-2120	59	2200-2300	16.99	38°N 75°W	—
	WFF VHF-1	N/A (Yagi)	139.208	45.4	143.625	N/A	38°N 75°W	—
	WFF VHF-2	N/A (Yagi)	130.167	45.4	121.750	N/A	38°N 75°W	—
	WFF UHF (Note 5)	NA (Quad Helix)	259.7 Prime 296.8 B/U	34.0	259.7 Prime 296.8 B/U	N/A	37°N 75°W	—

Table 2-1. NEN Overview (cont.)

Station Location	Antenna Name	Antenna Diameter	Transmit Frequency (MHz)	EIRP (dBWi)	Receive Frequency (MHz)	G/T (dB/K)	Location	User Tracking
McMurdo, Antarctica	**MGS**	10 M	2025-2120	63	2200-2400 8025-8400	21.11 32.48	78°S 193°W	—
Alaska (USN)	**PF1**	7.3M	2025-2120	58	2200-2400 8000-8500	19.61 34.56	65.1° N 148.4° W	1- & 2-Way Dop, Angle,
	PF2	11M	2025-2120	65	2200-2300 8100-8500	23.21 37.22	65.1° N 148.4° W	1- & 2-Way Dop, Angle,
	USAK01	13M	1750-1850 2025-2120	69 68	2200-2400 8000-8500	23.5 37.7	64.8° N 147.5° W	1- & 2-Way Dop, Angle, Ranging
	USAK02	5M	2025-2120	56	2200-2400	16.0	64.8° N 147.5° W	1- & 2-Way Dop, Ranging
Hawaii / Australia (USN)	**USHI01**	13M	2025-2120	68 78	2200-2400 8000-8500	23.5 37.7	19.0° N 155.7° W	1- & 2-Way Dop, Angle, Ranging
	USHI02 (2009)	13M	2025-2120 7025-7100	68 86	2200-2400 8000-8500	23.5 37.7	19.0° N 155.7° W	1- & 2-Way Dop, Angle, Ranging
	AUWA01	13M	2025-2120	68	2200-2400 8000-8500	23.5 37.7	29.0° S 115.3° E	1- & 2-Way Dop, Angle, Ranging
	AUWA02 (2009)	7.3M	7025-7100*	85	N/A	N/A	29.0° S 115.3° E	—
Alaska (ASF)	**ASF 10M**	10m	N/A	63	2200 -2400 8025 -8350	22.59 36.36	64°N 147°W	—
	ASF 11M	11.3m	2025-2120	66	2200-2400 8025-8400	23.01 35	64°N 147°W	1- & 2-Way Dop, Angle

Table 2-1. NEN Overview (cont.)

Station Location	Antenna Name	Antenna Diameter	Transmit Frequency (MHz)	EIRP (dBWi)	Receive Frequency (MHz)	G/T (dB/K)	Location	User Tracking
Santiago, Chile	**AGO 3**	9M	2025-2120	72.85	2200-2300	24	33°S 70°W	1- & 2-Way Dop, Angle, 2-Way Ranging
	AGO 4	12M	NA		2200-2300		33°S 70°W	1- & 2-Way Dop, Angle
	AGO 5	7M	2025-2120		2200-2300		33°S 70°W	1-&2-Way Dop. Angle
Florida	**MILA**	9 M (2)	2025-2120	63	2200-2300	24	29°N 81°W	1- & 2-Way Dop, Angle, 2-Way Ranging
	MILA	4.3 M	2025-2120	58	2200-2300	11	29°N 81°W	—
	MILA	Quad-Helix UHF	225-300	28	225-300	11	29°N 81°W	—
	MILA	MILA Relay System	2025-2120	40	2200-2300	11	29°N 81°W	—
	PDL	4.3 M	2025-2120	58	2200-2300	17	29°N 81°W	—
White Sands, New Mexico	**WSC VHF-1**	N/A (Yagi)	139.208	43.4	143.625	N/A	32°N 106°W	—
	WSC VHF-2	N/A (Yagi)	130.167	45.4	121.750	N/A	32°N 106°W	—
	WS1	18 M	2025-2120	80	2200-2300, 25500-27000	29 45	32°N 106°W	1- & 2-Way Dop, Angle, 2-Way Ranging
Hartebeesthoek South Africa	**HBK**	10 M	2025-2100	66	2200-2300 8000-8400 1650-17500	22.4 31.0 19.0	25°S 27°E	1-&2-Way Dop. Angle

Table 2-1. NEN Overview (cont.)

Station Location	Antenna Name	Antenna Diameter	Transmit Frequency (MHz)	EIRP (dBWi)	Receive Frequency (MHz)	G/T (dB/K)	Location	User Tracking
Kiruna, Sweden	**KIR 13M**	13 M	2025-2120	70	2200-2300	23	68°N 21°E	1 & 2-Way Doppler and 2-Way Ranging
Weilheim, Germany	**WAL 15M**	15 M	2025-2120	78	2200-2300	26.7	48°N 11°E	1 & 2-Way Doppler and 2-Way Ranging

Note1: 8450 – 8500 MHz is allocated for Space Science and 8025-8400 MHz is allocated for Earth Science

Note 2: The USN X-Band transmit feeds on AUWA02 and USHI02 will support 7000-8000 MHz. Klystron can be tuned to bands up to 7200 MHz w/ re-tuning.

Note 3: WS1 has a slew rate limitation of 2 deg/sec.

Note 4: The information above describes the typical performance limits of the ground stations. Capabilities are often enhanced and potential users are encouraged to discuss the mission requirements with the NIMO office to ensure that requirements and capabilities are fully understood.

Note 5: WFF UHF is a Wallops Range asset that is used for Shuttle Support only.

Note 6: - All G/T are theoretical at 5 deg clear sky unless noted otherwise in the separate site sections.

Section 3. Norway Ground Station (SGS)

This section describes the Ground Station located in Svalbard, Norway, known as the Svalbard Ground Station (SGS). Three apertures are available at Norway; SG1, SG2, SG3. These apertures are under Kongsberg Satellite Services (KSAT) control and are described in the text below. The URL http://www.ksat.no can be used to link to KSAT website for further information.

3.1 SG1

The general characteristics of SG1 are as follows:

- Location: 78° 13′ 50″ N
  15° 23′ 22″ E
- One 11.3-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 3-1 is a photograph of the SG1 antenna.
- Automatically scheduled by NEN schedulers using WOTIS (see Section 11.3).
- Tracking services: 1- & 2-way Doppler and antenna autotracking angle.
- Baseband data interfaces: Internet Protocol (IP), serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.

Sections 3.1.1 through 3.1.3 describe S- and X-band performance characteristics. Sections 3.1.4 and 3.1.5 describe the tracking services and baseband data interfaces, respectively.

Figure 3-1. SG1 Antenna

3.1.1 SG1 S-Band Command

Table 3-1 identifies the S-band command characteristics of the SG1 antenna.

3.1.2 SG1 S-Band Telemetry

Table 3-2 identifies the S-band telemetry characteristics of the SG1 antenna.

Table 3-1. SG1 S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	≥ 66 dBWi
Polarization	RHC or LHC
Antenna Beamwidth	0.95°
Antenna Gain	44.8 dBi
Output Power	200 W
Carrier Modulation	PM, FM, or BPSK
Modulation Index	PM: 1.5 radians (peak) FM: 50 kHz – 50 MHz deviation BPSK: ±90°
Carrier Data Rate	≤ 200 kbps
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

3.1.3 SG1 X-Band Telemetry

Table 3-3 identifies the X-band telemetry characteristics of the SG1 antenna.

3.1.4 SG1 Tracking Services

3.1.4.1 SG1 Doppler Tracking

The SG1 antenna generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the SGS S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 3-4.

Table 3-2. SG1 S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 23. dB/K
System Noise Temperature	190 K
Polarization	RHC or LHC
Antenna Beamwidth	0.85°
Antenna Gain	45.8 dBi
Carrier Modulation	PM, FM, BPSK, or AM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ: 100 bps - 8 Mbps Biϕ: 100 bps - 4 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

3.1.4.2 SG1 Antenna Autotracking Angle Data

The SG1 antenna can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as Universal Tracking Data Format (UTDF) messages. (See Table 4-1 of Reference [a] in Section 1.3, above.)

3.1.5 SG1 Baseband Data Interfaces

The SG1 antenna can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Section 12). SG1 utilizes the site’s fiber optic (155 Mbps) communication link to support command, telemetry, and ground station control and monitor. SG1 will also mail high-rate, tape-recorded X-band telemetry data to the user as required.

Table 3-3. SG1 X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8025 – 8500 MHz
G/T	≥ 35.84 dB/K with radome (at 60° elevation)
System Noise Temperature	150 K
Polarization	RHC or LHC
Antenna Beamwidth	0.23°
Antenna Gain	57.6 dBi
Modulation	QPSK, SQPSK, UQPSK, or AQPSK
Data Rate	6 – 150 Mbps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon

*The X-Band decoding capability exists for the TERRA project only (mission unique equipment).

Table 3-4. SG1 Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.004 cycles
Doppler Frequency Shift	≤ 0.23 MHz
Doppler Bias Frequency	0.24 MHz
Drift Δf/f)	4 x 10-11 at 0.1 seconds
Accuracy	0.01 Hz
Output Equation	1000 (ftransmit × [240/221] – freceived) + fbias

3.2 SG2

The general characteristics of SG2 are as follows:

- Location: 78° 13′ 50″ N
  15° 23′ 22″ E
- One 11.3-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 3-2 is a photograph of the SG2 antenna.
- Manually scheduled by SG2 staff by input from NEN schedulers (see Section 11.3).
- Tracking services: 1- & 2-way Doppler and antenna autotracking angle.
- Baseband data interfaces: Internet Protocol (IP), serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.

Sections 3.2.1 through 3.2.3 describe S- and X-band performance characteristics. Sections 3.2.4 and 3.2.5 describe the tracking services and baseband data interfaces, respectively.

Figure 3-2. SG2 Antenna

3.2.1 SG2 S-Band Command

Table 3-5 identifies the S-band command characteristics of the SG2 antenna.

3.2.2 SG2 S-Band Telemetry

Table 3-6 identifies the S-band telemetry characteristics of the SG2 antenna.

Table 3-5. SG2 S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	≥ 59 dBWi
Polarization	RHC or LHC
Antenna Beamwidth	0.91 °
Antenna Gain	44,4 dBi
Output Power	50 W
Carrier Modulation	BPSK, FSK, FSK+HBB, BPSK+AM, no blanking, Duty cycle 50/50, Direct PCM.
Modulation Index	0-2,5 Radians
Carrier Data Rate	10 -10000 bps, 100bps-1Mbps,
Subcarrier Frequency	5kHz -> 2 MHz
Subcarrier Modulation	PCM
Subcarrier Data Rate	100bps-250 kbps
Data Format	CCSDS, TDM NRZ-M,S BiP-L, M, S

3.2.3 SG2 X-Band Telemetry

Table 3-7 identifies the X-band telemetry characteristics of the SG2 antenna.

3.2.4 SG2 Tracking Services

3.2.4.1 SG2 Doppler Tracking

The SG2 antenna does not support ranging. The SG2 antenna generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the SG2 S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 3-8.

Table 3-6. SG2 S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 23.80 dB/K
System Noise Temperature	135 K
Polarization	RHC or LHC
Antenna Beamwidth	0.84°
Antenna Gain	45.1dBi
Carrier Modulation	FM. PM, BPSK, QPSK, OQPSK, AQPSK
Modulation Index	0 to 2.5 Radians
Carrier Data Rate	10-25000 bps , 1000-600 kbps
Carrier Data Format	CCSDS, TDM, NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	40Hz-128 Hz, 5kHz-2MHz,
Subcarrier Modulation	BPSK
Subcarrier Data Rate	2x150Mbit
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	BPSK, PCM/PM PCM Decoding : NRZ-L/M/S, BP-L/M/S, DBP-M/S, DM-M/S and R-NRZ

3.2.4.2 SG2 Antenna Autotracking Angle Data

The SG2 antenna can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as Universal Tracking Data Format (UTDF) messages. (See Table 4-1 of Reference [a] in Section 1.3, above.)

3.2.5 SG2 Baseband Data Interfaces

The SG2 antenna can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Section 12). SG2 utlizes the site's fiber optic (155 Mbps) communication link to support command, telemetry, and ground station control and monitor.

Table 3-7. SG2 X-Band Telemetry Characteristics

Characteristic	Value
Frequency	7500-8500 MHz (Extends down to 7500 for testing)
G/T	≥ 35.7 dB/K with radome (at 60° elevation)
System Noise Temperature	135 K
Polarization	RHC or LHC
Antenna Beamwidth	0.23 deg
Antenna Gain	57 dBi
Modulation	BPSK, QPSK, UQPSK, SQPSK
Data Rate	2 x 150 Mbps <= 2 x 75 Mbps
Data Format	CCSDS, TDM NRZL, M bare
Decoding	BPSK, QPSK, UQPSK, SQPSK, Viterbi Viterbi + R/S kun

Table 3-8. SG2 Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	10 Samp. Pr 1 Sec / 1 Samp. Pr 1 Sec / 1 Sample Pr 10 Sec 0.004 cycles
Doppler Frequency Shift	≤ 0.23 MHz
Doppler Bias Frequency	0.24 MHz
Drift (□f/f)	4 x 10-11 at 0.1 seconds
Accuracy	0.01 Hz
Output Equation	1000 (ftransmit × [240/221] – freceived) + fbias

3.3 SG3

The general characteristics of SG3 are as follows:

- Location: 78° 13′ 53″ N
  15° 24′ 40″ E
- One 13-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 3-3 is a photograph of the SG3 antenna.
- Scheduled by KSAT scheduling office using WOTIS (see Section 11.3).
- Tracking services: 1- & 2-way Doppler and antenna autotracking angle.
- Baseband data interfaces: Internet Protocol (IP), serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.

Sections 3.3.1 through 3.3.3 describe S- and X-band performance characteristics. Sections 3.3.4 and 3.3.5 describe the tracking services and baseband data interfaces, respectively.

Figure 3-3. SG3 Antenna

3.3.1 SG3 S-Band Command

Table 3-9 identifies the S-band command characteristics of the SG3 antenna.

3.3.2 SG3 S-Band Telemetry

Table 3-10 identifies the S-band telemetry characteristics of the SG3 antenna.

Table 3-9. SG3 S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	68 dBW
Polarization	RHC or LHC
Antenna Beamwidth	0. 77 deg
Antenna Gain	45.9 dBi
Output Power	300W
Carrier Modulation	FSK no bit blanking, FSK+hbb, BPSK, BPSK+AM
Modulation Index	0-2,5 radians
Carrier Data Rate	< 256 kb/s
Subcarrier Frequency	<100kHz
Subcarrier Modulation	BPSK, PM, FM
Subcarrier Data Rate	≤ 256kb/s
Data Format	CCSDS, TDM

3.3.3 SG3 X-Band Telemetry

Table 3-11 identifies the X-band telemetry characteristics of the SG3 antenna.

3.3.4 SG3 Tracking Services

3.3.4.1 SG3 Doppler Tracking

The SG3 antenna generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the SG3 S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 3-12.

Table 3-10. SG3 S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 25.35 dB/K
System Noise Temperature	≈ 143 degrees K@2200MHz
Polarization	RHC or LHC
Antenna Beamwidth	≈ 0.71 degrees@2200MHz
Antenna Gain	≈ 46.9dBi
Carrier Modulation	PM, FM, BPSK, QPSK
Modulation Index	0-2,5 Radians
Carrier Data Rate	≤ 20Mbps
Carrier Data Format	CCSDS, TDM
Subcarrier Frequency	5kHz – 2MHz
Subcarrier Modulation	BPSK, PM, FM
Subcarrier Data Rate	≤ 256kb/s
Subcarrier Data Format	CCSDS, TDM
Decoding	FM, PM/NRZ, BPSK, QPSK, Bi-phase

3.3.4.2 SG3 Antenna Autotracking Angle Data

The SG3 antenna can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as Universal Tracking Data Format (UTDF) messages. (See Table 4-1 of Reference [a] in Section 1.3, above.)

3.3.5 SG3 Baseband Data Interfaces

The SG3 antenna can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Section 12). SG3 utlizes the site’s fiber optic (155 Mbps) communication link to support command, telemetry, and ground station monitor and control

Table 3-11. SG3 X-Band Telemetry Characteristics

Characteristic	Value
Frequency	7500 – 8500 MHz (Extends down to 7500 for testing)
G/T	≥ 37.76 dB/K with radome (at 60° elevation)
System Noise Temperature	≈ 133 degrees K @8025MHz
Polarization	RHC or LHC
Antenna Beamwidth	0.19 degrees @8025MHz
Antenna Gain	≈ 59dBi
Modulation	PM,BPSK, QPSK, OQPSK, AQPSK FM,AM,UQPSK,SQPSK,Viterbi
Data Rate	2x150 Mbps
Data Format	CCSDS, TDM
Decoding	BPSK, QPSK, UQPSK, AQPSK, SQPSK, VITERBI

Table 3-12. SG3 Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	Single-precision float?
Doppler Frequency Shift	N/A
Doppler Bias Frequency	N/A
Drift (Δf/f)	N/A
Accuracy	Function of the CNR, IF receiver PLL bandwidth & reference clock accuracy
Output Equation	N/A

Section 4. Wallops Flight Facility (WFF) Ground Stations

This section describes the NEN stations located at WFF.

The primary orbital stations consist of the following ground stations:

- WGS 11M (Section 4.1)
- LEO-T – WFF (Section 4.2)
- Two VHF Ground Stations (Section 4.3)

4.1 WGS

The general characteristics of the WGS ground station at WFF are as follows:

- Location: 37º 55′ 28″ N
  75º 28′ 35″ W
- One 11.3-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 4-1 is a photograph of the WGS antenna.
- Automatically scheduled by NEN schedulers using WOTIS (see Section 11.3).
- Tracking services: 1- & 2-way Doppler, Tone Ranging (undergoing certification) and antenna autotracking angle.
- Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.

Sections 4.1.1 and 4.1.2 describe S-band and X-band performance characteristics. Sections 4.1.3 and 4.1.4 describe the tracking services and baseband data interfaces, respectively.

4.1.1 S-Band Command

S-Band Command Table 4-1 identifies the S-band command characteristics of the WGS.

4.1.2 S-Band Telemetry

Table 4-2 identifies the S-band telemetry characteristics of the WGS.

Figure 4-1. WGS Antenna

Table 4-1. WGS S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	≥ 66 dBWi
Polarization	RHC or LHC
Antenna Beamwidth	0.95°
Antenna Gain	44.8 dBi
Output Power	200 W
Carrier Modulation	PM, FM, BPSK or QPSK / OQPSK & FSK
Modulation Index	PM: 0.1-2.0 Radians(0.01 Radian steps) FM: <500kHz for signal >5 kHz BPSK: ±90°
Carrier Data Rate	≤ 200 kbps
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK PSK & FSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 4-2. WGS S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 23.63 dB/K
System Noise Temperature	165 K
Polarization	RHC or LHC
Antenna Beamwidth	0.85°
Antenna Gain	45.8 dBi
Carrier Modulation	PM/PCM, FM/PCM, BPSK, or QPSK / OQPSK
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Symbol Rate	100ksps-18Msps
Carrier Data Rate (High Rate Telemetry Channel)	10 Mbps for PCM/PM 18Mbps for BPSK, QPSK w/Viterbi 36 Mbps for QPSK 9Mbps for BPSK w/Viterbi
Carrier Data Rate (Medium Rate Telemetry Channel)	100bps-2Mbps for BPSK, QPSK 100bps-1Mbps for BPSK,QPSK w/RS 100bps-1.5Mbps for FM/PCM 100bps-1.5Mbps for PM/PCM 100bps-1 Mbps for PM/PCM w/RS
Carrier Data Format	NRZ-L, M, S or Biφ-L, M, S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L or Biφ-S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

4.1.3 X-Band Telemetry

Table 4-3 identifies the X-band telemetry characteristics of the WGS. Contact NEN management for further details as X-band system upgrades are planned.

4.1.4 Tracking Services

4.1.4.1 Doppler Tracking

WGS generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the WGS S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 4-4.

Table 4-3. WGS X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8000-8500 MHz
G/T	≥ 34.50 dB/K
System Noise Temperature	170 K
Polarization	RHC or LHC
Antenna Beamwidth	0.23°
Antenna Gain	56.8 dBi
Modulation	QPSK, UQPSK, SQPSK, AQPSK
Data Rate	6 – 150 Mbps
Data Format	NRZ-L or M

4.1.4.2 Antenna Autotracking Angle Data

The WGS can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [j] in Section 1.3, above.)

4.1.4.3 Range Tracking

Range capability is in the testing phase, tracking characteristics will eventually be shown in Table 4-5.

4.1.5 Baseband Data Interfaces

The WGS can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Section 12). WGS currently has a T-1 (1.544 Mbps) communications link with GSFC to support command, low-rate telemetry, and ground station control and monitor.

WGS mails high-rate tape-recorded X-band telemetry data to the user if necessary.

Table 4-4. WGS Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.004 cycles
Doppler Frequency Shift	≤ 0.25 MHz
Doppler Bias Frequency	0.24 MHz
Drift (Δf/f)	4x10-11 at 0.1 seconds
Accuracy	0.01 Hz
Output Equation	1000 (ftransmit × [240/221] – freceived) + fbias

Table 4-5 WGS Ranging Characteristics

Characteristic	Value
Modulation	TBD
Major Tone	TBD
Minor Tones	TBD
Modulation Index	TBD
Resolution	TBD

4.2 LEO-T – WFF

The general characteristics of the LEO-T ground station at WFF are as follows:

- Location: 37º 55′ 25″ N
  75º 28′ 34″ W
- One 5-meter antenna for simultaneously transmitting and receiving at S-band. Figure 4-2 is a photograph of the LEO-T antenna.
- Manually scheduled by NEN operations personnel.
- Tracking services: None.
- Baseband data interfaces: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets.

Sections 4.2.1 and 4.2.2 describe S-band performance characteristics, and Section 4.2.3 describes the baseband data interfaces.

4.2.1 S-Band Command

Table 4-6 identifies the S-band command characteristics of the LEO-T – WFF station.

4.2.2 S-Band Telemetry

Table 4-7 identifies the S-band telemetry characteristics of the LEO-T – WFF station.

Figure 4-2. LEO-T WFF Antenna

Table 4-6. LEO-T – WFF S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	≥ 59.2 dBWi
Polarization	RHC or LHC
Antenna Beamwidth	1.8°
Antenna Gain	38.6 dBi
Output Power	200 W
Carrier Modulation	PM, BPSK, or FM
Modulation Index	PM: 0.2 - 1.5 radians (peak)
Carrier Data Rate	≤ 200 kbps
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 4-7. LEO-T – WFF S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	≥ 16.99 dB/K
System Noise Temperature	174 K
Polarization	RHC or LHC
Antenna Beamwidth	1.83°
Antenna Gain	39.4 dBi
Carrier Modulation	PM, FM, BPSK, or QPSK
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	Uncoded: 8 Mbps Rate-½ coded: 4 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 4 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

4.2.3 Baseband Data Interfaces

The LEO-T – WFF station can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Section 12). The station currently has a T-1 (1.544 Mbps) communications link with GSFC to support command, low-rate telemetry, and ground station control and monitor.

4.3 VHF Ground Stations

The two VHF Air/Ground (A/G) Ground Stations at WFF are used only to support the International Space Station and Soyuz spacecraft. The VHF-1 system can transmit and receive voice and support packet data on the uplink. The VHF-2 system supports only voice. The general characteristics of the two VHF A/G Ground Stations at WFF are as follows:

- Location: 37° N
  75° W
- Two Quad Yagi antennas (VHF-1 and VHF-2) for simultaneously transmitting voice at VHF while receiving voice at VHF.
- Manual scheduling by NEN schedulers, but only JSC-MCC is allowed to request support.

- Tracking services: None.
- Baseband interfaces: Dedicated NISN communications voice loops.

Sections 4.3.1 and 4.3.2 describe the VHF-1 and VHF-2 A/G characteristics, respectively. Section 4.3.3 describes the baseband interfaces.

4.3.1 VHF-1 A/G Voice Ground Station

Tables 4-8 and 4-9 identify the A/G Full Duplex uplink and downlink characteristics of the WFF VHF-1 Ground Station, respectively.

Table 4-8. WFF VHF-1 A/G Uplink Characteristics

Characteristic	Value
Frequency	139.208 MHz
EIRP	≥ 43.4 dBWi
Polarization	N/A
Antenna Beamwidth	20°
Antenna Gain	18.0 dBi
Output Power	350 W
Carrier Modulation	FM
FM Deviation	± 10 kHz
Carrier Data Rate	N/A (Voice only on the uplink)

Table 4-9. WFF VHF-1 A/G Downlink Characteristics

Characteristic	Value
Frequency	143.625 MHz
G/T	N/A
System Noise Temperature	N/A
Polarization	RHC
Antenna Beamwidth	20°
Antenna Gain	18.0 dBi
Carrier Modulation	FM
FM Deviation	± 10 kHz
Carrier Data Rate	N/A (Voice only on downlink)

4.3.2 VHF-2 A/G Voice Ground Station

Tables 4-10 and 4-11 identify the A/G Full Duplex voice uplink and downlink characteristics of the WFF VHF-2 Ground Station, respectively.

Table 4-10. WFF VHF-2 A/G Uplink Characteristics

Characteristic	Value
Frequency	130.167 MHz
EIRP	≥ 43.4dBWi
Polarization	N/A
Antenna Beamwidth	20°
Antenna Gain	18.0 dBi
Output Power	350 W
Carrier Modulation	FM
FM Deviation	± 10 kHz
Carrier Data Rate	N/A (Voice only on the uplink)

Table 4-11. WFF VHF-2 A/G Downlink Characteristics

Characteristic	Value
Frequency	121.750 MHz
G/T	N/A
System Noise Temperature	N/A
Polarization	RHC
Antenna Beamwidth	20°
Antenna Gain	18.0 dBi
Carrier Modulation	FM
FM Deviation	± 10 kHz
Carrier Data Rate	N/A (Voice only on downlink)

4.3.3 Baseband Voice Interfaces

The WFF VHF-1 ground station can send and receive baseband voice and receive packet data from only the JSC-MCC via dedicated NISN communications voice loops. The WFF VHF-2 ground station can send and receive baseband voice only from the JSC-MCC via dedicated NISN communications voice loops.

Section 5. McMurdo Ground Station (MGS)

This section describes the MGS in Antarctica. The general characteristics of the station are as follows:

- Location: 77° 50′ 21″ S
  166° 40′ 01″ W
- One 10-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 5-1 is a photograph of the MGS antenna.
- Automatically scheduled by NEN schedulers using WOTIS.
- Tracking services: None.
- Baseband data interfaces: IP, 4800-bit blocks encapsulated in IP packets, and mail.
- MGS cannot be considered a launch MANDATORY project required site.

Sections 5.1 through 5.3 describe the current S- and X-band performance characteristics. Section 5.4 describes the baseband data interfaces.

Figure 5-1. MGS Antenna

5.1 S-Band Command

Table 5-1 identifies the S-band command characteristics of the MGS.

5.2 S-Band Telemetry

Table 5-2 identifies the S-band telemetry characteristics of the MGS.

Table 5-1. MGS S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	≥ 63 dBWi
Polarization	RHC or LHC
Antenna Beamwidth	1.05°
Antenna Gain	44 dBi
Output Power	200 W
Carrier Modulation	PM, FM, or PSK
Modulation Index	FM: 50 kHz – 50 MHz deviation BPSK: ±90°
Carrier Data Rate	≤ 200 kbps
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biφ-L, M, or S

Table 5-2. MGS S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 21.11 dB/K
System Noise Temperature	245 K
Polarization	RHC or LHC
Antenna Beamwidth	0.91°
Antenna Gain	45 dBi
Carrier Modulation	PM, FM, AM, or BPSK
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	10 bps – 15 Mbps
Carrier Data Format	NRZ-L, M, or S; Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	Passes all NRZ, Biφ, or DM
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

5.3 X-Band Telemetry

Table 5-3 identifies the X-band telemetry characteristics of the MGS.

5.4 Baseband Data Interfaces

MGS can send and receive baseband data in either of the following formats: IP or 4800-bit blocks encapsulated in IP packets (see Section 12). MGS currently has a 384 kbps slice of the National Science Foundation's communications link for McMurdo Station to support operations. This includes command, low-rate telemetry, ground station monitor/control and Goddard voice link.

Due to the limited outbound bandwidth, high-rate X-band telemetry data recorded by MGS can be transferred to Ultrium LTO-2 tape (200 GB capacity) and then shipped to the end user via international carrier from Christchurch New Zealand.

5.5 Future Upgrade/Depot Level Maintnenace (DLM)

The 10M is scheduled to undergo an Upgrade/DLM in mid November 2010. The upgrade will include an AVTEC TT&C solution for S-band and CORTEX XXL upgrade for X-band. The DLM will incorporate new electronic controls, motors, and rebuilt gearboxes. Some functionality may be available during the engineering test phase targeted for January 2011. Target completion date is mid March, 2011.

Table 5-3. MGS X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8025 – 8500 MHz
G/T	≥ 32.48 dB/K
System Noise Temperature	225 K
Polarization	RHC or LHC
Antenna Beamwidth	0.26°
Antenna Gain	56 dBi
Modulation Type	QPSK or UQPSK
Demodulator Data Rate	QPSK: 45 – 110 Mbps BPSK: 22.5 – 55 Mbps UQPSK [higher-rate channel]: 75 – 90 Mbps UQPSK [lower-rate channel]: 10 – 23 Mbps
Available Bitsynchronizers	Aqua MODIS: 7.25 Mbps Terra MODIS: 15 Mbps JERS-1: 60 Mbps Radarsat-1: 85 Mbps Envisat: 100 Mbps Radarsat-1/ERS-2 SAR: 105 Mbps Aqua High-rate: 150 Mbps
Data Format	NRZ-L, M, or S

Section 6. Universal Space Network Stations

The Universal Space Network (USN), a wholly owned subsidiary of the Swedish Space Corporation, is a commercial service provider with 4 primary stations; Poker Flat, North Pole, Hawaii and Australia. USN also has collaborative agreements for access to other stations located at various sites around the world. Further details concerning these sites are available at http://www.uspacenetwork.com/sites.html .

This section describes the NEN stations at Poker Flat, North Pole, Hawaii and Australia. The station at Poker Flat also has NASA Range antenna systems not covered in this document. URL can be found at: www.pfrr.alaska.edu

6.1 PF1

This section describes the Poker Flat, Alaska, Datron, 7.3-meter system referred to as PF1. The antenna manufacturer support is provided by L-3/Datron.

The general characteristics of the station are as follows:

- Location: 65° 7′ 4″ N
  148° 26′ 53″ W
- One 7.3-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 6-1 is a photograph of the antenna.
- Tracking services: 1- & 2-way Doppler and antenna auto tracking Angles.
- Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.
- Site Power: Commercial power. UPS power to RF and baseband equipment only. No Generator.

Figure 6-1. PF1 Antenna

6.1.1 PF1 S-Band Command

Table 6-1 identifies the S-band command characteristics of the PF1 aperture.

6.1.2 PF1 S-Band Telemetry

Table 6-2 identifies the S-band telemetry characteristics of the PF1 aperture.

Table 6-1. PF1 S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	58.4 dBW
Polarization	RHC or LHC
Antenna Beam-width	1.39°
Antenna Gain	42.1 dBi
Transmitter Output Power	20 dB W (SSPA)
Carrier Modulation	PM, FM, or BPSK
Modulation Index	PM: 1.5 radians (peak) FM: 50 kHz – 50 MHz deviation BPSK: ±90°
Carrier Data Rate	100 bps - 1 Mbps
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 6-2. PF1 S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 19.61 dB/K
System Noise Temperature	190 K
Polarization	RHC and LHC
Antenna Beam-width	1.25°
Antenna Gain	42.4 dBi
Carrier Modulation	PM, FM, BPSK, or QPSK
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ: 100 bps - 20 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon

6.1.3 PF1 X-Band Telemetry

Table 6-3 identifies the X-band telemetry characteristics of the PF1 aperture.

Table 6-3. PF1 X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8000 – 8500 MHz
G/T	≥ 34.56 dB/K (at 60° elevation)
System Noise Temperature	92 K
Polarization	RHC or LHC
Antenna Beam-width	0.29°
Antenna Gain	54.2 dBi
Modulation	BPSK, QPSK, SQPSK or PM
Data Rate	40 Mbps – 150 Mbps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon

6.1.4 PF1 Tracking Services

6.1.4.1 PF1 Doppler Tracking

The PF1 generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the PF1 S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 6-4

Table 6-4. PF1 UTDF Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.004 cycles
Doppler Frequency Shift	≤ 0.23 MHz
Doppler Bias Frequency	0.24 MHz
Drift (Δf/f)	4×10^{-11} at 0.1 seconds
Accuracy	0.01 Hz
Output Equation	$1000 (f_{transmit} \times [240/221] - f_{received}) + f_{bias}$

6.1.4.2 PF1 Antenna Autotracking Angle Data

The PF1 records the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages.

6.1.5 PF1 Baseband Data Interfaces

The PF1 can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Section 12). PF1 currently has a 768 Kbps TCP/IP communications link and 52 Mbps (clock and data) fiber communications link with GSFC to support command, telemetry, and ground station control and monitor. PF1 will also mail high-rate, tape-recorded X-band telemetry data to the user as required.

6.2 PF2

This section describes the Poker Flat, Alaska, EMP 11-meter system referred to as PF2. The antenna manufacturer support is provided by L-3/Datron.

The general characteristics of the station are as follows:

- Location: 65° 7′ 4″ N
  148° 27' 01″ W
- One 11-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 6-2 is a photograph of the PF2 antenna.
- Automatically scheduled by NEN schedulers using WOTIS (see Section 11.3).
- Tracking services: 1- & 2-way Doppler and antenna auto tracking Angles.
- Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.
- Site Power: Commercial power. UPS power to RF and baseband equipment only. No back-up power generator.

Figure 6-2. PF2 Antenna Radome

Figure 6-2a. PF2 Antenna Before Radome Installation

6.2.1 PF2 S-Band Command

Table 6-5 identifies the S-band command characteristics of the PF2.

6.2.2 PF2 S-Band Telemetry

Table 6-6 identifies the S-band telemetry characteristics of the PF2 aperture.

Table 6-5. PF2 S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	65.4 dBW
Polarization	RHC or LHC
Antenna Beam-width	0.92°
Antenna Gain	45.7 dBi
Output Power	23 dBW (SSPA)
Carrier Modulation	PM, FM, or BPSK
Modulation Index	PM: 1.5 radians (peak) FM: 50 kHz – 50 MHz deviation BPSK: ±90°
Carrier Data Rate	100 bps - 1 Mbps
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 6-6. PF2 S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	≥ 23.21 dB/K
System Noise Temperature	190 K
Polarization	RHC and LHC
Antenna Beam-width	0.85°
Antenna Gain	46.0 dBi
Carrier Modulation	PM, FM, BPSK, or QPSK
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ: 100 bps - 36 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon

6.2.3 PF2 X-Band Telemetry

Table 6-7 identifies the X-band telemetry characteristics of the PF2 aperture.

Table 6-7. PF2 X-Band Telemetry Characteristics

Characteristic	Value
Frequency	7000 - 9000 MHz Receive 8100 – 8400 MHz Autotrack
G/T	≥ 37.22 dB/K
System Noise Temperature	92 K
Polarization	RHC or LHC
Antenna Beam-width	0.20°
Antenna Gain	56.86 dBi
Modulation	BPSK,QPSK,SQPSK or AQPSK
Data Rate	40 – 150 Mbps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon

6.2.4 PF2 Tracking Services

6.2.4.1 PF2 Doppler Tracking

The PF2 generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the PF2 S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 6-8.

6.2.4.2 PF2 Antenna Autotrack Angle Data

The PF2 records the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages

Table 6-8. PF2 UTDF Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.004 cycles
Doppler Frequency Shift	≤ 0.23 MHz
Doppler Bias Frequency	0.24 MHz
Drift (Δf/f)	4×10^{-11} at 0.1 seconds
Accuracy	0.01 Hz
Output Equation	$1000 (f_{transmit} \times [240/221] - f_{received}) + f_{bias}$

6.2.5 PF2 Baseband Data Interfaces

The PF2 can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Section 12). PF2 currently has a 768 Kbps TCP/IP communications link and 52 Mbps (clock and data) fiber communications link with GSFC to support command, telemetry, and ground station control and monitor. PF2 will also mail high-rate, tape-recorded X-band telemetry data to the user as required.

6.3 USAK01

This section describes the North Pole, Alaska, 13-meter system referred to as USAK01. The antenna manufacturer support is provided by L-3/Datron.

The general characteristics of the USAK01 aperture are as follows:

- Location: 64° 48′ 15" N
  147° 30′ 00" W
- 13-meter antenna for simultaneously transmitting at L-Band or S-band while receiving at S- and X-band. Figure 6-3 is a photograph of the USAK01 antenna.
- Supports S-Band and X-Band CCSDS services. Supports L-Band SGLS (USAF) services.
- Automatically scheduled by NEN schedulers using WOTIS or scheduled directly with USN.
- Tracking services: 1- & 2-way Doppler, Ranging, and antenna auto tracking angles.
- Baseband data interfaces: TCP/IP, 4800-bit blocks encapsulated in IP packets, and mail.
- Site Power: Commercial power. UPS power to RF and baseband equipment only. 200KW back-up power generator.

Figure 6-3. USAK01

6.3.1 USAK01 L/S-Band Command

Table 6-9 identifies the L/S-band command characteristics of the USAK01 aperture.

6.3.2 USAK01 S-Band Telemetry

Table 6-10 identifies the S-band telemetry characteristics of the USAK01 aperture.

Table 6-9. USAK01 L/S-Band Command Characteristics

Characteristic	Value
Frequency	L-Band: 1750-1850 MHz S-Band: 2025 – 2120 MHz
EIRP	L-Band: 69 dBW S-Band: 68 dBW
Polarization	RHC or LHC
Antenna Beam-width	L-Band: 0.90 deg S-Band: 0.78 deg
Antenna Gain	L-Band: 45.9 dBi S-Band: 47.1 dBi
Transmitter Power	L-Band: 27.7 dBW SSPA S-Band: 24.7 dBW SSPA
Carrier Modulation	PM, FM, or BPSK
Modulation Index	PM: 1.5 radians (peak) BPSK: ±90°
Carrier Data Rate	10 bps - 10 Mbps
Subcarrier Frequency	≤ 5 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 6-10. USAK01 S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 23.5 dB/K
Polarization	RHC and LHC
Antenna Beam-width	0.70°
Antenna Gain	48.0 dBi
Carrier Modulation	PM, FM, BPSK, or QPSK
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ: 10 sps - 20 Msps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 1.2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 256 Ksps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon

6.3.3 USAK01 X-Band Telemetry

Table 6-11 identifies the X-band telemetry characteristics of the USAK01 aperture

Table 6-11. USAK01 X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8000 - 8500 MHz
G/T	≥ 37.7 dB/K
Polarization	RHC or LHC
Antenna Beam-width	0.17°
Antenna Gain	59.1 dBi
Modulation	PM/BPSK, BPSK,QPSK,SQPSK or AQPSK
Data Rate	10sps – 102 Msps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon

6.3.4 USAK01 Tracking Services

The USAK01 aperture can provide Doppler, Ranging, and Angular tracking measurements. The measurement message format can be delivered in the native USN format or in customer defined formats such as the NASA UTDF format.

6.3.4.1 USAK01 Doppler Tracking

The USAK01 aperture can collect 1-way and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier.

6.3.4.2 USAK01 Ranging

The USAK01 aperture can collect 2-way ranging measurements. Ranging can be accomplished with either tone ranging or ESA code ranging. Cortex-NT or Cortex-XL equipment is used to collect these measurements.

6.3.4.3 USAK01 Antenna Autotrack Angle Data

The USAK01 aperture records the angle of the ground antenna as it autotracks.

6.3.5 USAK01 Baseband Data Interfaces

The USAK01 aperture sends and receives baseband data using the TCP/IP protocol. The NASA legacy standard of 4800 bit blocks is supported by encapsulating the blocks into TCP/IP frames.

The North Pole site is supported by a 3-Mbps Multiprotocol Label Switching (MPLS) service for transporting the TCP/IP data to the USN Network Management Centers (NMC) in California and Pennsylvania.

NASA accesses the USAK01 ground station via the Restricted IONet interface between GSFC and the NMC in Horsham, Pennsylvania.

Additional services are available at the USAK01 site as required. Services available in the area include open Internet, MPLS, and private line via fiber and copper media.

6.4 USAK02

This section describes the North Pole, Alaska, 5-meter system referred to as USAK02. The antenna manufacturer support is provided by L-3/Datron.

The general characteristics of the USAK02 aperture are as follows:

- Location : 64° 48’ 15” N
  147° 30’ 00” W
- 5-meter antenna for simultaneously transmitting S-band while receiving at S-band. Figure 6-4 is a photograph of the USAK02 antenna.
- Supports S-Band CCSDS services.
- Automatically scheduled by NEN schedulers using WOTIS or scheduled directly with USN.
- Tracking services: 1- & 2-way Doppler and Ranging available (not certified by NASA FDF at this time)
- Baseband data interfaces: TCP/IP, 4800-bit blocks encapsulated in IP packets, and mail.
- Site Power: Commercial power. UPS power to RF and baseband equipment only. 200KW back-up power generator.

Figure 6-4. North Pole ground station. (USAK02 in foreground within radome, USAK01 in background)

6.4.1 USAK02 S-Band Command

Table 6-12 identifies the S-band command characteristics of the USAK02 aperture.

6.4.2 USAK02 S-Band Telemetry

Table 6-13 identifies the S-band telemetry characteristics of the USAK02 aperture.

Table 6-12. USAK02 S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	56 dBWi
Polarization	RHC or LHC
Antenna Beam-width	2.03°
Antenna Gain	38.8 dBi
Transmitter Power	20 dBW SSPA
Carrier Modulation	PM, FM, or BPSK
Modulation Index	PM: 1.5 radians (peak) BPSK: ±90°
Carrier Data Rate	10 bps – 32Kbps
Subcarrier Frequency	≤ 1.2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 10 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 6-13. USAK02 S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 16.0 dB/K
Polarization	RHC and LHC
Antenna Beam-width	1.83°
Antenna Gain	39.7 dBi
Carrier Modulation	PM, FM, BPSK, or QPSK
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ: 10 sps - 10 Msps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 1.2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 256 Ksps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon

6.4.3 USAK02 Tracking Services

The USAK02 aperture can provide Doppler and Ranging measurements, but it is not certified by any flight dynamics facilities at this time. Angular measurements (autotrack) are also available, but the small aperture's beam-width may not provide the necessary tolerances for certification. The measurement message format can be delivered in the native USN format or in customer defined formats such as the NASA UTDF format.

6.4.3.1 USAK02 Doppler Tracking

The USAK02 aperture can collect 1-way and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier.

6.4.3.2 USAK02 Ranging

The USAK02 aperture can collect 2-way ranging measurements. Ranging can be accomplished with either tone ranging or ESA code ranging. Cortex-NT or Cortex-XL equipment is used to collect these measurements.

6.4.3.3 USAK02 Antenna Autotrack Angle Data

The USAK02 aperture records the angle of the ground antenna as it autotracks.

6.4.4 USAK02 Baseband Data Interfaces

The USAK02 aperture sends and receives baseband data using the TCP/IP protocol. The NASA legacy standard of 4800 bit blocks is supported by encapsulating the blocks into TCP/IP frames.

The North Pole site is supported by a 3-Mbps Multiprotocol Label Switching (MPLS) service for transporting the TCP/IP data to the USN Network Management Centers (NMC) in California and Pennsylvania.

NASA accesses the USAK01 ground station via the Restricted IONet interface between GSFC and the NMC in Horsham, Pennsylvania.

Additional services are available at the USAK02 site as required. Services available in the area include open Internet, MPLS, and private line via fiber and copper media.

6.5 USHI01

This section describes the South Point, Hawaii, 13-meter system referred to as USHI01. The antenna manufacturer support is provided by L-3/Datron.

The general characteristics of the USHI01 aperture are as follows:

- Location: 19° 00’ 50” N

  155° 39’ 47” W
- 13-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 6-5 is a photograph of the USHI01 antenna.
- High Power S-Band uplink (2500W Transmitter)
- Automatically scheduled by NEN schedulers using WOTIS or scheduled directly with USN.
- Tracking services: 1- & 2-way Doppler, Ranging, and antenna auto tracking angles.
- Baseband data interfaces: TCP/IP, 4800-bit blocks encapsulated in IP packets, and mail.
- Site Power: Commercial power. UPS power to RF and baseband equipment only. 350KW back-up power generator.

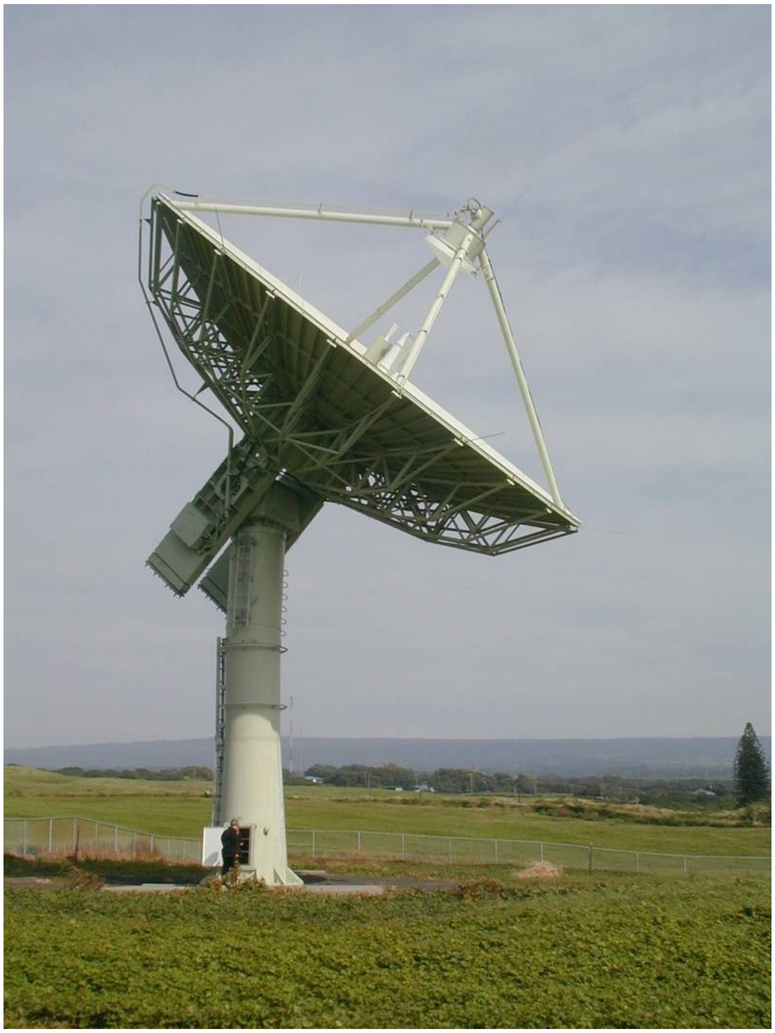

Figure 6-5. USHI01

6.5.1 USHI01 S-Band Command

Table 6-14 identifies the S-band command characteristics of the USHI01 aperture.

6.5.2 USHI01 S-Band Telemetry

Table 6-15 identifies the S-band telemetry characteristics of the USHI01 aperture.

Table 6-14. USHI01 S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	68 dBW (SSPA), 78 dBW (Klystron)
Polarization	RHC or LHC
Antenna Beam-width	0.78 deg
Antenna Gain	47.1 dBi
Transmitter Power	23 dBW SSPA 33.9 dBW Klystron
Carrier Modulation	PM, FM, or BPSK
Modulation Index	PM: 1.5 radians (peak) BPSK: ±90°
Carrier Data Rate	10 bps - 10 Mbps
Subcarrier Frequency	≤ 5 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 6-15. USHI01 S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 23.5 dB/K
Polarization	RHC and LHC
Antenna Beam-width	0.70°
Antenna Gain	48.0 dBi
Carrier Modulation	PM, FM, BPSK, or QPSK
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ: 10 sps - 20 Msps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 1.2 MHz
Subcarrier Demodulation	BPSK
Subcarrier Data Rate	≤ 256 Ksps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon

6.5.3 USHI01 X-Band Telemetry

Table 6-16 identifies the X-band telemetry characteristics of the USHI01 aperture

Table 6-16. USHI01 X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8000 - 8500 MHz
G/T	≥ 37.7 dB/K
Polarization	RHC or LHC
Antenna Beam-width	0.17°
Antenna Gain	59.1 dBi
Modulation	PM/BPSK, BPSK,QPSK,SQPSK or AQPSK
Data Rate	10sps – 102 Msps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon

6.5.4 USHI01 Tracking Services

The USHI01 aperture can provide Doppler, Ranging, and Angular tracking measurements. The measurement message format can be delivered in the native USN format or in customer defined formats such as the NASA UTDF format.

6.5.4.1 USHI01 Doppler Tracking

The USHI01 aperture can collect 1-way and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier.

6.5.4.2 USHI01 Ranging

The USHI01 aperture can collect 2-way ranging measurements. Ranging can be accomplished with either tone ranging or ESA code ranging. Cortex-NT or Cortex-XL equipment is used to collect these measurements.

6.5.4.3 USHI01 Antenna Autotrack Angle Data

The USHI01 aperture records the angle of the ground antenna as it autotracks.

6.5.5 USHI01 Baseband Data Interfaces

The USHI01 aperture sends and receives baseband data using the TCP/IP protocol. The NASA legacy standard of 4800 bit blocks is supported by encapsulating the blocks into TCP/IP frames.

The South Point site is supported by a 3-Mbps Multiprotocol Label Switching (MPLS) service for transporting the TCP/IP data to the USN Network Management Centers (NMC) in California and Pennsylvania.

(NASA accesses the USHI01 ground station via the Restricted IONet interface between GSFC and the NMC in Horsham, Pennsylvania.)

Additional services are available at the USHI01 site as required. Services available in the area include open Internet and private line via copper media. Back-up communications services are available at the site via 128Kbps ISDN lines.

6.6 USHI02

This section describes the South Point, Hawaii, 13-meter system referred to as USHI02. The antenna manufacturer support is provided by L-3/Datron.

The general characteristics of the USHI02 aperture are as follows:

- Location: 19° 00’ 50" N

  155° 39’ 47" W
- 13-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 6-6 is a photograph of the USHI02 antenna.
- High Power X-Band uplink (3000W Transmitter). X-Band transmit – OR – X-Band receive.
- Automatically scheduled by NEN schedulers using WOTIS or scheduled directly with USN.
- Tracking services: 1- & 2-way Doppler, Ranging, and antenna auto tracking angles.
- Baseband data interfaces: TCP/IP, 4800-bit blocks encapsulated in IP packets, and mail.
- Site Power: Commercial power. UPS power to RF and baseband equipment only. 350KW back-up power generator.

Figure 6-6. USHI02

6.6.1 USHI02 S-Band Command

Table 6-17 identifies the S-band command characteristics of the USHI02 aperture.

6.6.2 USHI02 X-Band Command

Table 6-18 identifies the X-band command characteristics of the USHI02 aperture.

Table 6-17. USHI02 S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	68 dBW
Polarization	RHC or LHC
Antenna Beam-width	0.78 deg
Antenna Gain	47.1 dBi
Transmitter Power	24.7 dBW SSPA
Carrier Modulation	PM, FM, or BPSK
Modulation Index	PM: 1.5 radians (peak) BPSK: ±90°
Carrier Data Rate	10 bps – 32Kbps
Subcarrier Frequency	≤ 1.2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 10 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 6-18. USHI02 X-Band Command Characteristics

Characteristic	Value
Frequency	7025 – 7200 MHz
EIRP	86 dBW
Polarization	RHC or LHC
Antenna Beam-width	0.19 deg
Antenna Gain	57.8 dBi
Transmitter Power	34.8 dBW Klystron
Carrier Modulation	PM, FM, or BPSK
Modulation Index	PM: 1.5 radians (peak) BPSK: ±90°
Carrier Data Rate	10 bps – 32Kbps
Subcarrier Frequency	≤ 1.2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 10 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

6.6.3 USHI02 S-Band Telemetry

Table 6-19 identifies the S-band telemetry characteristics of the USHI02 aperture.

Table 6-19. USHI02 S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 23.5 dB/K
Polarization	RHC and LHC
Antenna Beam-width	0.70°
Antenna Gain	48.0 dBi
Carrier Modulation	PM, FM, BPSK, or QPSK
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ: 10 sps - 20 Msps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 1.2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 256 Ksps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon

6.6.4 USHI02 X-Band Telemetry

Table 6-20 identifies the X-band telemetry characteristics of the USHI02 aperture

Table 6-20. USHI02 X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8000 - 8500 MHz
G/T	≥ 37.7 dB/K
Polarization	RHC or LHC
Antenna Beam-width	0.17°
Antenna Gain	59.1 dBi
Modulation	PM/BPSK, BPSK,QPSK,SQPSK or AQPSK
Data Rate	10sps – 102 Msps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon

6.6.5 USHI02 Tracking Services

The USHI02 aperture can provide Doppler, Ranging, and Angular tracking measurements. The measurement message format can be delivered in the native USN format or in customer defined formats such as the NASA UTDF format.

At the time of this publication the USHI02 aperture is awaiting tracking data certification by NASA FDF.

6.6.5.1 USHI02 Doppler Tracking

The USHI02 aperture can collect 1-way and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier.

6.6.5.2 USHI02 Ranging

The USHI02 aperture can collect 2-way ranging measurements. Ranging can be accomplished with either tone ranging or ESA code ranging. Cortex-NT or Cortex-XL equipment is used to collect these measurements.

6.6.5.3 USHI02 Antenna Autotrack Angle Data

The USHI02 aperture records the angle of the ground antenna as it autotracks.

6.6.6 USHI02 Baseband Data Interfaces

The USHI02 aperture sends and receives baseband data using the TCP/IP protocol. The NASA legacy standard of 4800 bit blocks is supported by encapsulating the blocks into TCP/IP frames.

The South Point site is supported by a 3-Mbps Multiprotocol Label Switching (MPLS) service for transporting the TCP/IP data to the USN Network Management Centers (NMC) in California and Pennsylvania.

NASA accesses the USHI02 ground station via the Restricted IONet interface between GSFC and the NMC in Horsham, Pennsylvania.

Additional services are available at the USHI02 site as required. Services available in the area include open Internet and private line via copper media. Back-up communications services are available at the site via 128Kbps ISDN lines.

6.7 AUWA01

This section describes the Dongara, Western Australia, 13-meter system referred to as AUWA01. The antenna manufacturer support is provided by L-3/Datron.

The general characteristics of the AUWA01 aperture are as follows:

- Location: 29° 02’ 44.780” S
  115° 20’ 55.240” E
- 13-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 6-7 is a photograph of the AUWA01 antenna.

- Automatically scheduled by NEN schedulers using WOTIS or scheduled directly with USN.
- Tracking services: 1- & 2-way Doppler, Ranging, and antenna auto tracking angles.
- Baseband data interfaces: TCP/IP, 4800-bit blocks encapsulated in IP packets, and mail.
- Site Power: Commercial power. UPS power to RF and baseband equipment only. 100KW back-up power generator.

Figure 6-7. AUWA01

6.7.1 AUWA01 S-Band Command

Table 6-21 identifies the S-band command characteristics of the AUWA01 aperture.

6.7.2 AUWA01 S-Band Telemetry

Table 6-22 identifies the S-band telemetry characteristics of the AUWA01 aperture.

Table 6-21. AUWA01 S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	68 dBW
Polarization	RHC or LHC
Antenna Beam-width	0.78 deg
Antenna Gain	47.1 dBi
Transmitter Power	23 dBW SSPA
Carrier Modulation	PM, FM, or BPSK
Modulation Index	PM: 1.5 radians (peak) BPSK: ±90°
Carrier Data Rate	10 bps - 10 Mbps
Subcarrier Frequency	≤ 5 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Data Format	NRZ-L, M, or S; or Biφ-L, M, or S

Table 6-22. AUWA01 S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 23.5 dB/K
Polarization	RHC and LHC
Antenna Beam-width	0.70°
Antenna Gain	48.0 dBi
Carrier Modulation	PM, FM, BPSK, or QPSK
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ: 10 sps - 20 Msps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 1.2 MHz
Subcarrier Demodulation	BPSK
Subcarrier Data Rate	≤ 256 Ksps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon

6.7.3 AUWA01 X-Band Telemetry

Table 6-23 identifies the X-band telemetry characteristics of the AUWA01 aperture

Table 6-23. AUWA01 X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8000 - 8500 MHz
G/T	≥ 37.7 dB/K
Polarization	RHC or LHC
Antenna Beam-width	0.17°
Antenna Gain	59.1 dBi
Modulation	PM/BPSK, BPSK,QPSK,SQPSK or AQPSK
Data Rate	10sps – 102 Msps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon

6.7.4 AUWA01 Tracking Services

The AUWA01 aperture can provide Doppler, Ranging, and Angular tracking measurements. The measurement message format can be delivered in the native USN format or in customer defined formats such as the NASA UTDF format.

6.7.4.1 AUWA01 Doppler Tracking

The AUWA01 aperture can collect 1-way and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier.

6.7.4.2 AUWA01 Ranging

The AUWA01 aperture can collect 2-way ranging measurements. Ranging can be accomplished with either tone ranging or ESA code ranging. Cortex-NT or Cortex-XL equipment is used to collect these measurements.

6.7.4.3 AUWA01 Antenna Autotrack Angle Data

The AUWA01 aperture records the angle of the ground antenna as it autotracks.

6.7.5 AUWA01 Baseband Data Interfaces

The AUWA01 aperture sends and receives baseband data using the TCP/IP protocol. The NASA legacy standard of 4800 bit blocks is supported by encapsulating the blocks into TCP/IP frames.

The Dongara site is supported by a 2-Mbps VPN/Internet service for transporting the TCP/IP data to the USN Network Management Centers (NMC) in California and Pennsylvania.

NASA accesses the AUWA01 ground station via the Restricted IONet interface between GSFC and the NMC in Horsham, Pennsylvania.

Additional services are available at the AUWA01 site as required. Services available in the area include open Internet and private line via copper or fiber media. Back-up communications services are available at the site via 128Kbps ISDN lines.

6.8 AUWA02

This section describes the Dongara, Western Australia, 7.3-meter system referred to as AUWA02. The antenna manufacturer support is provided by Viasat.

The general characteristics of the AUWA02 aperture are as follows:

- Location: 29° 02’ 44” S
  115° 20’ 55” E
- 7.3-meter antenna X-band uplink only. Figure 6-8 is a photograph of the AUWA02 antenna.
- High Power X-Band uplink (3000W Transmitter)
- Program track or slaved to AUWA01 13-Meter for tracking satellites services:

- Baseband data interfaces: TCP/IP, 4800-bit blocks encapsulated in IP packets,
- Site Power: Commercial power. UPS power to RF and baseband equipment only. 100KW back-up power generator.

Figure 6-8. AUWA02 (left) and AUWA01 (right)

6.8.1 AUWA02 X-Band Command

Table 6-24 identifies the X-band command characteristics of the AUWA02 aperture.

Table 6-24. AUWA02 X-Band Command Characteristics

Characteristic	Value
Frequency	7025 – 7200 MHz
EIRP	85 dBW
Polarization	RHC or LHC
Antenna Beam-width	0.34 deg
Antenna Gain	52.8 dBi
Transmitter Power	34.8 dBW Klystron
Carrier Modulation	PM, FM, or BPSK
Modulation Index	PM: 1.5 radians (peak) BPSK: ±90°
Carrier Data Rate	10 bps - 10 Mbps
Subcarrier Frequency	≤ 5 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Data Format	NRZ-L, M, or S; or Biφ-L, M, or S

6.8.2 AUWA02 Baseband Data Interfaces

The AUWA02 aperture sends and receives baseband data using the TCP/IP protocol. The NASA legacy standard of 4800 bit blocks is supported by encapsulating the blocks into TCP/IP frames.

The Dongara site is supported by a 2-Mbps VPN/Internet service for transporting the TCP/IP data to the USN Network Management Centers (NMC) in California and Pennsylvania.

NASA accesses the AUWA02 ground station via the Restricted IONet interface between GSFC and the NMC in Horsham, Pennsylvania.

Additional services are available at the AUWA02 site as required. Services available in the area include open Internet and private line via copper and fiber media. Back-up communications services are available at the site via 128Kbps ISDN lines.

Section 7. Alaska Satellite Facility

This section describes the University of Alaska Ground Station in Fairbanks, Alaska known as the Alaska Satellite Facility (ASF). The station is operated by the University and consists of 2 NASA antenna systems. The NASA owned systems at ASF include:

- ASF 10 – (Section 7.1) additional information available at http://www.asf.alaska.edu/stgs/tracking10m
- ASF 11 – (Section 7.2) additional information available at http://www.asf.alaska.edu/stgs/tracking11m

7.1 ASF 10-meter

The general characteristics of the ASF 10-meter antenna system are as follows:

- Location: 64 ° 51' 35" N
  147 ° 50' 50" W
- 10-meter antenna for receiving at S-band and X-band. Figure 7-1 is a photograph of the ASF 10-meter antenna.
- Manually scheduled by NEN schedulers using WOTIS (see Section 11).
- Tracking services: None.
- Baseband data interface: IP.

Sections 7.1.1 through 7.1.3 describe the S-band and X-band performance characteristics, and Section 7.1.4 describes the baseband data interface.

7.1.1 S-Band Command

N/A.

7.1.2 S-Band Telemetry

Table 7-2 identifies the S-band telemetry characteristics of the ASF 10-meter antenna.

7.1.3 X-Band Telemetry

Table 7-3 identifies the X-band telemetry characteristics of the ASF 10-meter antenna

Figure 7-1. ASF 10-meter Antenna

Table 7-1. ASF 10-meter S-Band Command Characteristics

N/A to ASF. 10-meter space held for table for future needs

Table 7-2. ASF 10 – Alaska S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 22.59 dB/K
System Noise Temperature	174 K
Polarization	RHC or LHC
Antenna Beamwidth	.91°
Antenna Gain	45 dBi
Carrier Modulation	PM, FM, BPSK, or QPSK
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	100 bps – 8 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 4 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

Table 7-3. ASF 10-meter X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8025 – 8400 MHz
G/T	≥ 36.36 dB/K (at 60° elevation)
System Noise Temperature	92 K
Polarization	RHC or LHC
Antenna Beamwidth	0.26°
Antenna Gain	56 dBi
Modulation	BPSK, QPSK, or UQPSK,
Data Rate	6 – 150 Mbps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon

7.1.4 Baseband Data Interfaces

The ASF-10-meter can send baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Sections 12). ASF 10-meter currently has a T-1 (1.544 Mbps) communications link with GSFC to support telemetry, ASF 10-meter can also mail high-rate, tape-recorded X-band telemetry data to the user as required.

7.2 ASF 11-meter

This section describes the Alaska Satellite Facility 11.3-meter system referred to as ASF 11-meter

The general characteristics of the system are as follows:

- Location: 64° 51' 31" N
  147° 51' 18" W
- The 11.3-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 7-2 is a photograph of the ASF 11-meter antenna.
- Automatically scheduled by NEN schedulers using WOTIS (see Section 11).
- Tracking services: 1- & 2-way Doppler and antenna auto tracking Angles.
- Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.

Sections 7.2.1 through 7.2.3 describe S- and X-band performance characteristics. Sections 7.2.4 and 7.2.5 describe the tracking services and baseband data interfaces, respectively.

7.2.1 S-Band Command

Table 7-4 identifies the S-band command characteristics of the ASF 11-Meter.

7.2.2 S-Band Telemetry

Table 7-5 identifies the S-band telemetry characteristics of the ASF 11-Meter.

7.2.3 X-Band Telemetry

Table 7-6 identifies the X-band telemetry characteristics of the ASF 11-Meter.

Figure 7-2. ASF 11-Meter Antenna

Table 7-4. ASF 11-Meter S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	≥ 66 dBWi
Polarization	RHC or LHC
Antenna Beamwidth	0.95°
Antenna Gain	44.8 dBi
Output Power	200 W
Carrier Modulation	PM, FM, or PSK
Modulation Index	PM: 1.5 radians (peak) FM: 50 kHz – 50 MHz deviation BPSK: ±90°
Carrier Data Rate	≤ 200 kbps
Subcarrier Frequency	1Khz- 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 7-5. ASF 11-Meter S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 23.01 dB/K
System Noise Temperature	190 K
Polarization	RHC or LHC
Antenna Beamwidth	0.85°
Antenna Gain	45.8 dBi
Carrier Modulation	PM, FM, BPSK, or AM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ: 100 bps - 8 Mbps Biϕ: 100 bps - 4 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

7.2.4 Tracking Services

7.2.4.1 Doppler Tracking

The ASF 11-Meter generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the ASF 11-Meter S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 7-7.

7.2.4.2 Antenna Autotrack Angle Data

The ASF 11-Meter can record the angle of the ground antenna as it autotracks. This data is provided to the user as UTDF messages. (See *Table 4-1* of Reference [j] in Section 1.3, above.)

Table 7-6. ASF 11-Meter X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8025 – 9000 MHz
G/T	≥ 37.16 dB/K
System Noise Temperature	92 K
Polarization	RHC or LHC
Antenna Beamwidth	0.23°
Antenna Gain	56.8 dBi
Modulation	SQPSK, UQPSK, or AQPSK
Data Rate	6 – 150 Mbps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon

7.2.5 Baseband Data Interfaces

The ASF 11-Meter can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Sections 12). ASF 11-Meter currently has a T-1 (1.544 Mbps) communications link with GSFC to support command, telemetry, and ground station control and monitor. ASF 11-Meter will also mail high-rate, tape-recorded X-band telemetry data to the user as required.

Table 7-7. ASF 11-METER Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.004 cycles
Doppler Frequency Shift	≤ 0.23 MHz
Doppler Bias Frequency	0.24 MHz
Drift (□f/f)	4 x 10-11 at 0.1 seconds
Accuracy	0.01 Hz
Output Equation	1000 (ftransmit × [240/221] – freceived) + fbias

Section 8. Florida Ground Station

This section describes the two NEN stations in Florida:

- MILA (Section 8.1)
- PDL (Section 8.2)

8.1 MILA

This section describes the MILA ground station, located in the Kennedy Space Center (KSC) on Merritt Island, Florida. MILA is a part of NASA's NEN, and was formerly part of the Spaceflight Tracking and Data Network (STDN).

The general characteristics of the station are as follows:

- Location (each antenna): 28º 30′ 29″ N
  80º 41′ 34″ W

  28º 30′ 29″ N
  80º 41′ 36″ W
- Two 9-meter antennas for simultaneously transmitting and receiving at S-band. Figure 8-1 is a photograph of the MILA Ground Station.
- 4.3M S-band (See Tables 8-5 and 8-6).

  (Also: two UHF antennas, one Quad-Helix and one Teltrac, for voice communications with the Space Shuttle Orbiter. For further information reference table 2-1 or telephone the MILA Operations Manager: 321-867-1068.)
- MILA Relay System (MRS) consisting of two 3M antennas (one User and one TDRS Relay) capable of spacecraft pre-launch testing and relaying data through TDRS to WSC. (The user antenna supports S and Ku-band forward and return, reference table 2-1).
- Scheduled by the NEN schedulers at WSC (see Section 11).
- Tracking services: 1- & 2-way Doppler, ranging, and antenna autotracking angle.
- Baseband data interfaces: IP and 4800-bit blocks encapsulated in IP packets.

Sections 8.1.1 and 8.1.2 describe the S-band performance characteristics. Sections 8.1.3 and 8.1.4 describe the tracking services and baseband data interfaces, respectively.

Figure 8-1. MILA Ground Station

8.1.1 S-Band Command

Table 8-1 identifies the S-band command characteristics of MILA.

8.1.2 S-Band Telemetry

Table 8-2 identifies the S-band telemetry characteristics of MILA.

Table 8-1. MILA S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	16 W:≥ 55 dBWi 200 W: ≥ 63 dBWi
Polarization	RHC or LHC
Antenna Beamwidth	1 °
Antenna Gain	44 dBi
Output Power	16 W and 200 W (continuously variable from 100 W to 200 W)(variable from 200 mW to 2nW for testing)
Carrier Modulation	PM, FM, or PSK
Modulation Index	PM: 1 – 3 radians (peak) FM: 1 MHz
Carrier Data Rate	32 kbps, 72 kbps, 96 kbps, or 216 kbps
Carrier Data Format	NRZ-L, M, or S; Biϕ-L, M, or S
Subcarrier Frequency	2 – 16 kHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	100 bps – 8 kbps
Subcarrier Data Format	NRZ-L, M, or S; Biϕ-L, M, or S

8.1.3 Tracking Services

8.1.3.1 Doppler Tracking

MILA generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the MILA S-band uplink signal. Doppler tracking characteristics are shown in Table 8-3.

8.1.3.2 Range Tracking

MILA range tracking service is available only for coherent two-way operation using a ranging code. Range tracking characteristics are shown in Table 8-4.

Table 8-2. MILA S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	24 dB/K (at zenith)
System Noise Temperature	100 K
Polarization	RHC or LHC
Antenna Beamwidth (3-dB)	1 °
Antenna Gain	44 dBi
Carrier Modulation	PCM/PSK/PM, PCM/PSK/FM, PSK/FM, PCM/FM, PCM/PM, or FM/FM
Modulation Index	PM: 0.2 – 1.4 radians (peak)
Carrier Data Rate	NRZ: 100 bps – 10 Mbps Biφ: 100 bps – 5 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	1 – 5000 kHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	100 bps – 2 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v) and/or STS-TDRS mode Viterbi decoders (Rate-1/3)

Table 8-3. MILA Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.001 cycles
Doppler Frequency Shift	≤ 0.23 MHz
Doppler Bias Frequency	240 MHz

Table 8-4. MILA Range Tracking Characteristics

Characteristic	Value
Operational Mode	Coherent
Range Code Waveform	Sine wave
Modulation Index	0.2 – 1.5 radians (peak) on main carrier 0.3 – 1.2 radians (peak) on 1.7-MHz subcarrier
Major Tone Frequencies	500 kHz, 100 kHz, and 20 kHz
Minor Tone Frequencies	100 kHz, 20 kHz, and 4 kHz on carrier 800 Hz, 160 Hz, 40 Hz, and 10 Hz on 4-kHz subcarrier (800-Hz tone transmitted single-sideband suppressed, other tones transmitted double-sideband suppressed)
Received C/N	≥ 10 dB
Acquisition Sequence	Major tone first, then high-to-low for minor tones
Acquisition Threshold, Range Tone SNR	15 dB-Hz
Accuracy	1.0 m
Unambiguous Range	≤ 644,000 km (one-way)

8.1.3.3 Antenna Autotracking Angle Data

MILA can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [j] in Section 1.3, above.)

8.1.4 Baseband Data Interfaces

MILA can send and receive baseband data in either of the following formats: IP and 4800-bit blocks encapsulated in IP packets (see Sections 12). MILA currently has two 224 kbps communications links with GSFC to support commanding, low-rate telemetry, and ground station control and monitor.

8.2 PDL

This section describes the PDL ground station in Florida. Like MILA, PDL is a part of the NEN. The station provides communications to the Space Shuttle Orbiter during launch, when the plume from the solid rocket motor blocks radio signals to MILA.

The general characteristics of the station are as follows:

- Location: 29° 4′ 00″ N
  80° 54′ 47″ W
- One 4.3-meter antenna for simultaneously transmitting and receiving at S-band. Figure7-2 is a photograph of the PDL Ground Station.

(Also: one fixed UHF cross-dipole antenna, optimized for high inclination launches, backup voice communications with the Space Shuttle Orbiter. The UHF system is used to backup the S-band system. For further information, telephone the MILA Operations Manager: 321-867-3515.)

- Scheduled by the NEN schedulers at WSC (see Section 11).
- Tracking services: None.
- Baseband data interfaces: IP and 4800-bit blocks encapsulated in IP packets.

Sections 8.2.1 and 8.2.2 describe the S-band performance characteristics, and Section 8.2.3 describes the baseband data interfaces.

Figure 8-2. PDL Ground Station

8.2.1 S-Band Command

Table 8-5 identifies the S-band command characteristics of PDL.

8.2.2 S-Band Telemetry

Table 8-6 identifies the S-band telemetry characteristics of the PDL.

8.2.3 Baseband Data Interfaces

PDL can send and receive baseband data in either of the following formats: IP and 4800-bit blocks encapsulated in IP packets (see Sections 12). The station currently has two 224 kbps communications links with the GSFC to support command.

Table 8-5. MILA and PDL 4.3M S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	16 W:≥ 47 dBWi 200 W: ≥ 58 dBWi
Polarization	RCP or LCP
Antenna Beamwidth	2.5°
Antenna Gain	37 dBi
Output Power	16 W and 200 W (continuously variable from 100 W to 200 W)
Carrier Modulation	PM
Modulation Index	0 – 3.0 radians (peak)
Subcarrier Frequency	2 kHz, 4 kHz, 8 kHz, or 16 kHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	16 bps – 8 kbps
Data Format	NRZ-L, M, or S; or Biφ-L, M, or S

Table 8-6. MILA and PDL 4.3M S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	11.02 dB/K (at 45°)
System Noise Temperature	250 K
Polarization	RCP or LCP
Antenna Beamwidth	2.5°
Antenna Gain	35 dBi
Carrier Modulation	PCM/PSK/PM, PCM/PM, PCM/PSK/FM, PSK/FM, PCM/FM, or FM/FM
Modulation Index	PM: 0.2 – 1.4 radians (peak)
Carrier Data Rate	4 bps – 2000 kbps
Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	1 – 2000 kHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	(Subcarrier Frequency)/(Subcarrier Data Rate) > 1.5
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v) and/or STS-TDRS Mode Viterbi decoders (Rate-1/3)

Section 9. White Sands Complex Ground Stations

9.1 WS1

This section describes the White Sands Complex 18-meter system referred to as WS1. WS1 is an S/Ka-Band satellite ground station located at the White Sands Complex. The Lunar Reconnaissance Orbiter (LRO) is the primary mission supported by WS1. LRO's primary objective is Lunar mapping and scientific investigation in support of future human exploration of the Moon. WS1 may be multi-mission capable in the future, when the Moon is not in view from WSC and after LRO mission is complete.

The general characteristics of the station are as follows:

- Location: 32 ° 32′ 26″ N
  106 ° 36′ 44″ W
- 18-meter azimuth/elevation antenna for simultaneously transmitting at S-band while receiving at S and Ka bands. Figure 9-1 is a photograph of the antenna.
- Tracking services: 1 & 2-way Doppler, Range, and antenna auto tracking angles.
- Baseband data interfaces: IP (SMEX/LEO-T and CCSDS SLE)

Sections 9.1.1 through 9.1.3 describe WS1 S-band and Ka-band performance characteristics. Sections 9.1.4 and 9.1.5 describe WS1 tracking services and baseband data interfaces, respectively.

Figure 9-1. WS1 Antenna

9.1.1 WS1 S-Band Command

Table 9-1 identifies the S-band command characteristics of the WS1.

9.1.2 WS1 S-Band Telemetry

Table 9-2 identifies the S-band telemetry characteristics of the WS1.

Table 9-1. WS1 S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	81 dBW with 2KW HPA 72 dBW with 300 Watt SSPA
Polarization	RHC or LHC
Antenna Beamwidth	0.5 Deg.
Antenna Gain	49 dBi
Output Power	Redundant 300 and 2000 Watt
Carrier Modulation	PCM Encoding FM or PM[1] FSK, BPSK[2] CCDS Recommendations
Modulation Index	FM: 50 kHz – 50 MHz deviation PM: 1.5 radians (peak) BPSK: ±90°
Carrier Data Rate	100 bps - 1 Mbps
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

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[1] IF Modulation

[2] Modulation at baseband

Table 9-2. WS1 S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	30.46 db/K
System Noise Temperature	90.0 K
Polarization	RHC or LHC
Antenna Beamwidth	0.5 Deg.
Antenna Gain	50 dBi
Carrier Modulation	PM, FM, BPSK, or QPSK
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ: 100 bps - 20 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver. 1 & 2)

9.1.3 WS1 Ka-Band Telemetry

Table 9-3 identifies the Ka-band telemetry characteristics of the WS1.

Table 9-3. WS1 Ka-Band Telemetry Characteristics

Characteristic	Value
Frequency	25.5 – 27 GHz
G/T	46.98 dB/K
System Noise Temperature	225.0 K
Polarization	RHC or LHC
Antenna Beamwidth	0.04 Deg.
Antenna Gain	70.5 dBi
Demodulation	PSK, BPSK, QPSK, SQPSK, AQPSK, AUQPSK, AUSQPSK
Data Rate	1 GS/s Max sample rate 470 MS/s Max Symbol rate
Data Format	Frame Synchronization Bit Synchronization
Decoding	Reed Solomon Viterbi decoding (½, ¼) 4D-TCM

9.1.4 WS1 Tracking Services

9.1.4.1 WS1 Doppler Tracking

The WS1 generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the WS1 S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 9-4.

Table 9-4. WS1 Doppler Tracking Characteristics

Characteristic	Value
Ranging Accuracy	10 Meters (1 sigma)
Doppler Accuracy	1 millimeter per second (1 sigma), 5 second integration time
Angle Accuracy	0.1 Degrees
Data Format	NASA UTDF
Maximum Velocity	2.0 Degrees/second (az and el)

9.1.4.2 WS1 Antenna Autotracking Angle Data

The WS1 can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [i] in Section 1.3, above.)

9.1.4.3 Range Tracking

Range tracking characteristics are shown in Table 9-5.

Table 9-5. WS1 Range Tracking Characteristics

Characteristic	Value
Operating Modes	2-way coherent
Ranging Tone Modulation Index	Uplink: 0.35 – 0.7 radians (single tone) Downlink: 0.35 – 1.5 radians peak (single tone with uplink ranging S/N $\geq$ 20 dB in the post detection bandwidth); 0.2 – 1.5 radians peak for lower uplink ranging S/N
Major Tone Frequencies	500 kHz , 100 kHz, and 20 kHz
Minor Tone Frequencies	100 kHz, 20 kHz, 4 kHz on carrier 800 Hz, 160 Hz, 40 Hz, and 10 Hz on 4 kHz tone
Tone Power/No (including implementation loss)	$\geq$19.5 dB-Hz
Accuracy	$\leq$ 10.0 m (for 1 σ)
Unambiguous Range	$\leq$ 644,000 km

9.1.5 WS1 Baseband Data Interfaces

The WS1 sends and receives baseband data IP formats. Real-time data and commands are sent using SMEX/LEO-T or CCSDS SLE formats. Post-pass playbacks are via FTP or SFTP. Data lines TBD.

9.2 VHF A/G Stations at WSC

The two VHF Air/Ground (A/G) Ground Stations at the White Sands Complex (WSC) are used only to support the International Space Station and Soyuz spacecraft. The VHF-1 system can transmit and receive voice and support packet data on the uplink. The VHF-2 system supports only voice. The general characteristics of the two VHF A/G Ground Stations at WSC are as follows:

- Location: 32° 00′ 00″ N
  106° 00′ 00″ W
- Single Yagi antenna (VHF-1) and Quad Yagi (VHF-2) for simultaneously transmitting voice at VHF while receiving voice at VHF.
- Manual scheduling, but only JSC-MCC is allowed to request support.
- Tracking services: None.
- Baseband interfaces: Dedicated NISN communications voice loops.

Sections 9.2.1 and 9.2.2 describe the VHF-1 and VHF-2 A/G characteristics, respectively. Section 9.3 describes the baseband interfaces.

9.2.1 VHF-1 A/G Ground Station

Tables 9-6 and 9-7 identify the A/G Full Duplex uplink and downlink characteristics of the WSC VHF-1 Ground Station, respectively.

Table 9-6. WSC VHF-1 A/G Uplink Characteristics

Characteristic	Value
Frequency	139.208 MHz
EIRP	≥ 43.4 dBWi
Polarization	RHC
Antenna Beamwidth	20°
Antenna Gain	18.0 dBi
Output Power	350 W
Carrier Modulation	FM
FM Deviation	± 10 kHz
Carrier Data Rate	TBD for packet data

Table 9-7. WSC VHF-1 A/G Downlink Characteristics

Characteristic	Value
Frequency	143.625 MHz
G/T	N/A
System Noise Temperature	N/A
Polarization	RHC
Antenna Beamwidth	20°
Antenna Gain	18.0 dBi
Carrier Modulation	FM
FM Deviation	± 10 kHz
Carrier Data Rate	N/A (Voice only on downlink)

9.2.2 VHF-2 A/G Voice Ground Station

Tables 9-8 and 9-9 identify the A/G Full Duplex voice uplink and downlink characteristics of the WSC VHF-2 Ground Station, respectively.

Table 9-8. WSC VHF-2 A/G Uplink Characteristics

Characteristic	Value
Frequency	130.167 MHz
EIRP	≥ 37.4dBWi
Polarization	RHC
Antenna Beamwidth	20°
Antenna Gain	12.0 dBi
Output Power	350 W
Carrier Modulation	FM
FM Deviation	± 10 kHz
Carrier Data Rate	N/A (Voice only)

Table 9-9. WSC VHF-2 A/G Downlink Characteristics

Characteristic	Value
Frequency	121.750 MHz
G/T	N/A
System Noise Temperature	N/A
Polarization	RHC
Antenna Beamwidth	20°
Antenna Gain	12.0 dBi
Carrier Modulation	FM
FM Deviation	± 10 kHz
Carrier Data Rate	N/A (Voice only)

9.3 Baseband Voice Interfaces

The WSC VHF-1 ground station can send and receive baseband voice and receive packet data from only the JSC-MCC via dedicated NISN communications voice loops. The WSC VHF-2 ground station can send and receive baseband voice only from the JSC-MCC via dedicated NISN communications voice loops.

Section 10. Santiago Satellite Station

This section describes the Santiago Satellite Station, a wholly owned subsidiary of the Swedish Space Corporation, located in Santiago, Chile. These URLs, http://www.ssc.se/?id=5070 and http://www.sscchile.cl can be used to link further information about the Swedish Space Corporation's assets.

10.1 AGO 9-Meter

The general characteristics of the 9-m ground station at AGO are as follows:

- Location: 33º 09′ 04″ S
  70º 39′ 59″ W
- One 9-meter antenna for simultaneously transmitting at S-band while receiving at S-band. Figure 10-1 is a photograph of the 9-m ground station.
- Routine supports are automatically scheduled by NEN schedulers using WOTIS (see Section 11.3).
- Real-time tracking services include: 1- & 2-way Doppler, Ranging, and antenna autotracking angles.
- Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets.

Sections 10.4 and 10.5 describe S-band performance characteristics. Sections 10.5.1 and 10.5.2 describe the tracking services and baseband data interfaces, respectively.

10.2 AGO 7-Meter

The general characteristics of the 7-m ground station at AGO are as follows:

- Location: 33º 09′ 06″ S
  70º 40′ 02″ W
- One 7-meter antenna for simultaneously transmitting at S-band while receiving at S-band. Figure 10-2 is a photograph of the 7-m ground station.
- Routine supports are automatically scheduled by NEN schedulers using WOTIS (see Section 11.3).
- Real-time tracking services include: 1- & 2-way Doppler, Ranging, and antenna angles in conjunction with the 12-m antenna.
- Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets.

Sections 10.4 and 10.5 describe S-band performance characteristics. Sections 10.5.1 and 10.5.2 describe the tracking services and baseband data interfaces, respectively.

10.3 AGO 12-Meter

The general characteristics of the 12-m ground station at AGO are as follows:

- Location: 33º 09′ 05″ S
  70º 40′ 05″ W
- One 12-meter antenna for receiving at S-band. Figure 10-3 is a photograph of the 12-m ground station.
- Able to perform ranging in conjunction with the 7-m antenna.
- Routine supports are automatically scheduled by NEN schedulers using WOTIS (see Section 11.3).
- Real-time tracking services include: 1- & 2-way Doppler, Ranging, and antenna angles in conjunction with the 7-m antenna.
- Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets.

Sections 10.4 and 10.5 describe S-band performance characteristics. Sections 10.5.1 and 10.5.2 describe the tracking services and baseband data interfaces, respectively.

Figure 10-1 AGO 9-m Antenna

Figure 10-2 AGO 7-m Antenna

Figure 10-3 AGO 12m ANTENNA

10.4 AGO S-Band Command

Table 10-1 identifies the S-band command characteristics of the AGO 9-m antenna.

Table 10-2 identifies the S-band command characteristics of the AGO 7-m antenna.

Table 10-1. AGO 9-m S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	82.75 dBw
Polarization	RHC or LHC
Antenna Beamwidth	1.12°
Antenna Gain	43.8 dBi
Output Power	10 Kw
Carrier Modulation	PM or PSK
Modulation Index	PM: 3.0 radians (peak) BPSK
Subcarrier Frequency	≤16 kHz
Subcarrier Modulation	PSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 10-2. AGO 7-m S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	58.5 dBw
Polarization	RHC or LHC
Antenna Beamwidth	1.44°
Antenna Gain	40 dBi
Output Power	200 w
Carrier Modulation	PM or PSK
Modulation Index	PM: 3.0 radians (peak) BPSK
Subcarrier Frequency	≤16 kHz
Subcarrier Modulation	PSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

10.5 AGO S-Band Telemetry

Table 10-3 identifies the S-band telemetry characteristics of the AGO 9-m antenna.

Table 10-4 identifies the S-band telemetry characteristics of the AGO 12-m antenna.

Table 10-5 identifies the S-band telemetry characteristics of the AGO 7-m antenna.

Table 10-3. AGO 9-m S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	≥ 23.59 dB/K
System Noise Temperature	110 K
Polarization	RHC or LHC
Antenna Beamwidth	1.0°
Antenna Gain	44.0 dBi
Carrier Modulation	PM, FM, or AM
Modulation Index	PM: 0.2 – 1.4 radians (peak)
Carrier Data Rate	NRZ-L : ≤ 5 Mbps Biφ-L : ≤ 5 Mbps
Carrier Data Format	NRZ-L, M, or S; Biφ-L, M, or S; DM-M or S; M2M, RZ, and PN Randomized
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; Biφ-L, M, or S; DM-M or S; M2M, RZ, and PN Randomized
Decoding	Viterbi and/or Reed-Solomon (CCSDS)

Table 10-4. AGO 12-m S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	≥ 25.71 dB/K
System Noise Temperature	120 K
Polarization	RHC or LHC
Antenna Beamwidth	0.75°
Antenna Gain	46.5 dBi
Carrier Modulation	PM, FM, or AM
Modulation Index	PM: 0.2 – 1.4 radians (peak)
Carrier Data Rate	NRZ-L : ≤ 5 Mbps Biφ-L : ≤ 5 Mbps
Carrier Data Format	NRZ-L, M, or S; Biφ-L, M, or S; DM-M or S; M2M, RZ, and PN Randomized
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; Biφ-L, M, or S; DM-M or S; M2M, RZ, and PN Randomized
Decoding	Viterbi and/or Reed-Solomon (CCSDS)

Table 10-5. AGO 7-m S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	20 dB/K
System Noise Temperature	100 K
Polarization	RHC or LHC
Antenna Beamwidth	1.3°
Antenna Gain	40 dBi
Carrier Modulation	PM, FM, or AM
Modulation Index	PM: 0.2 – 1.4 radians (peak)
Carrier Data Rate	NRZ-L : ≤ 5 Mbps Biφ-L : ≤ 5 Mbps
Carrier Data Format	NRZ-L, M, or S; Biφ-L, M, or S; DM-M or S; M2M, RZ, and PN Randomized
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; Biφ-L, M, or S; DM-M or S; M2M, RZ, and PN Randomized
Decoding	Viterbi and/or Reed-Solomon (CCSDS)

10.5.1 Tracking Services

10.5.1.1 Doppler Tracking

The 9-m ground station generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the 9-m S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 10-6.

The 7-m antenna with the 12-m antenna generates 1- and 2-way Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn around of the 7-m S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 10-6.

10.5.1.2 Range Tracking

Range tracking characteristics are shown in Table 10-7.

10.5.1.3 Antenna Autotracking Angle Data

The 9-m ground station can record the angle of the ground antenna as it autotracks the user. This data is provided to the Flight Dynamics Facility as UTDF messages.

10.5.2 Baseband Data Interfaces

The 9-m, 7-m and 12-m ground station can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets.

Table 10-6. AGO 9-m and 7-m/12-m Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.001 cycles
Doppler Frequency Shift	≤ 0.25 MHz
Doppler Bias Frequency	0.24 MHz
Drift (Δf/f)	4x10-11 at 0.1 seconds
Accuracy	0.01 Hz
Output Equation	1000 (ftransmit × [240/221] – freceived) + fbias

Table 10-7. 9-m and 7-m/12-m Range Tracking Characteristics

Characteristic	Value
Operating Modes	2-way coherent and non-coherent
Modulation Index	Carrier: 0.2 – 1.5 radians (peak) Subcarrier (1.7 MHz): 0.3 – 1.2 radians (peak)
Major Tone Frequencies	500 kHz, 100 kHz, and 20 kHz
Minor Tone Frequencies	100 kHz, 20 kHz, and 4 kHz on carrier or 1.7-MHz subcarrier. 800 Hz, 160 Hz, 40 Hz, and 10 Hz on 4-kHz tone
Received C/N	≥ 10 dB
Tone Power/N0	> 15 dB-Hz
Accuracy	1.0 m
Unambiguous Range	≤ 644,000 km

Section 11. Scheduling

11.1 Scheduling Purpose and Need

With the NEN supporting a wide variety of spacecraft on a diverse collection of shared NEN antennas, effective scheduling of mission passes on those antennas is critical. NEN Scheduling Office (NENSO) strives to meet all of its customer requirements as efficiently as possible, while also responding to issues such as spacecraft emergencies and antenna maintenance needs. NENSO collects user requirements and requests, considers antenna loading, antenna status, and weighs mission customer priority. The NENSO then develops a schedule of antenna pass supports that efficiently supports customer needs.

The NEN Performance Analyst Office (NENPAO) is located at Wallops Island, Virginia. The NENPAO works with the NENSO to coordinate launch support schedules and testing activities. The office also assists both the projects and ground station sites in scheduling downtime for preventive and/or corrective maintenance activities and spacecraft special support requests.

11.2 NEN Scheduling System

In order to schedule all of its assets, the NEN relies on schedulers and a scheduling system located at the White Sands Complex (WSC) in New Mexico. The scheduling system is called the Wallops Orbital Tracking Information System (WOTIS). WOTIS, depicted in Figure 11-1, is composed of three elements: an interface/message handling system, a core scheduling system, and a database.

In addition to scheduling antenna time, scheduling staff at White Sands handle equipment configurations, conflict resolution, emergency scheduling, scheduling of network testing support, and forwarding MOC-provided Improved Interrange Vectors (IIRVs) to the ground stations. The NENSO can use either manual or automated processes to schedule customer contacts.

11.3 Scheduling Process

11.3.1 Mission pass requirements development and input

The scheduling process is initiated when missions specify their pass requirements. Missions can establish generic (rule-based) scheduling requirements, which is the recommended method for requesting passes. Missions may also request specific antennas and pass times.

Generic scheduling requirements establish a prearranged minimum level of service, yet enable flexibility in meeting requirements, and allow for schedule optimization across all missions. Typical generic scheduling requirements include a subset of the following:

- Minimum number of supported passes per day.

- Minimum amount of time supported per pass (specified separately for telemetry and command).
- Minimum and/or maximum amount of time between supported passes.
- NEN station(s) providing support.
- Minimum number of NEN stations required to support a pass during a specified time interval (for example: "At least two different NEN stations for the period between 2200Z and 0500Z").
- Minimum ground antenna elevation angle.

For missions unable to establish generic requirements, the Mission Operations Center (MOC) may submit a weekly schedule request for a specific NEN station and the specific start and end time of each pass. If making specific requests, the MOC must submit a requested schedule every week, three weeks ahead of schedule execution. The NEN prefers generic scheduling to specific scheduling because it optimizes the use of shared NEN resources.

11.3.2 Weekly schedule development

NENSO develops weekly pass schedules starting weeks in advance of when the schedules will be executed, and refines them through an ongoing iterative process that allows for customer feedback. A schematic of the general schedule development timeline is shown in Figure 9-2.

The three-week advance schedule is called the "Strawman Schedule". Schedulers begin to build the Strawman Schedule on a Monday, three weeks before it is to begin execution. The Strawman Schedule is a rough schedule that collects mission requirements and identifies all possible antenna view periods.

The two-week advance schedule is called the "Forecast Schedule". Schedulers compile customer requirements and specific requests and deconflict the schedules, seeking workable schedules that enable antennas to meet customer requirements. Mission priority is factored into scheduling to ensure that higher priority missions meet their scheduling requirements first in the case where multiple missions seek the same antenna pass. Mission priority is defined in the NEN Priority List, which is maintained by the Exploration and Space Communications (ESC) Projects Division Network Integration Management Office (NIMO) http://scp.gsfc.nasa.gov/gn/plistnew.htm

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The one-week advance schedule is called the "Operations Schedule". The Operations Schedule is compiled from the de-conflicted Forecast Schedule. Only changes due to absolute priorities listed in the NEN Priority List (e.g., spacecraft emergencies, launch support, critical support) are accommodated.

The current weeks schedule for execution is called the "Real-Time Schedule". No changes may be made to the Real-Time Schedule except during spacecraft or ground station emergency situations.

11.3.3 Customer review

Customers typically receive draft schedules for each of the next three weeks, once a week (generally Thursday). Customers may provide feedback on the schedules and request changes. Changes should ideally be submitted by the following Monday, and not later than close of business on Wednesday of the week before schedule execution. No response is considered to be schedule acceptance.

11.3.4 Schedule execution

The NEN implements the Real-Time schedule, sending schedules to the antennas. The antenna ground stations send post-pass results information to NEN scheduling, which is then sent to the customer MOC. Figure 11-1 shows WOTIS inputs and outputs.

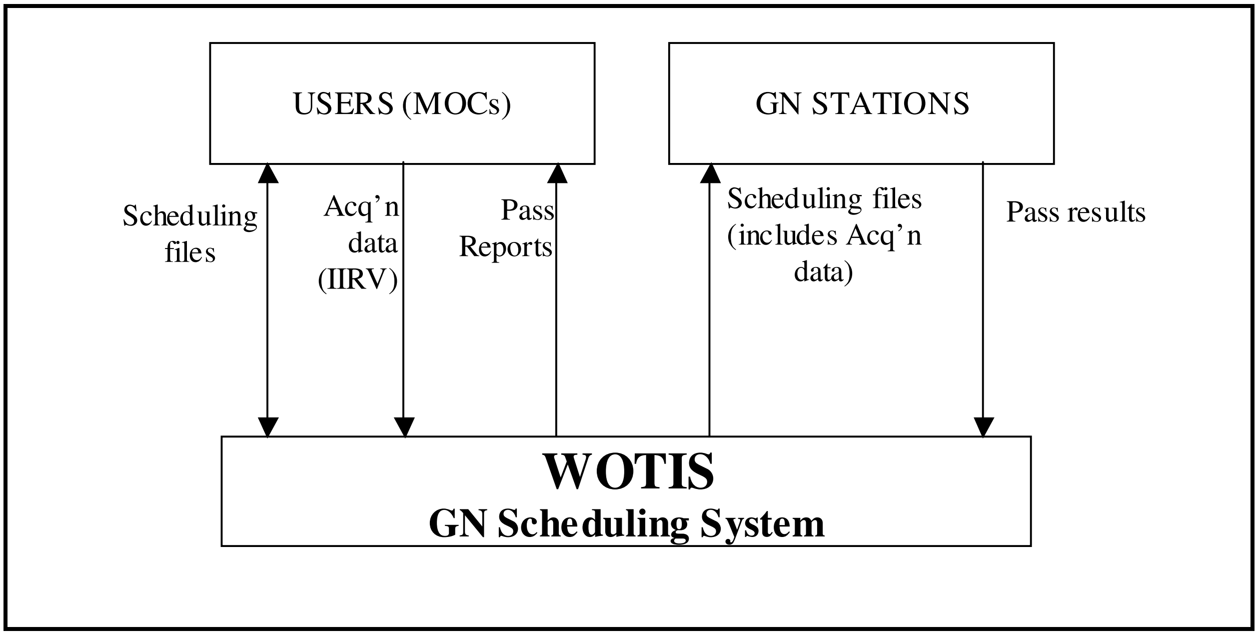


Figure 11-1. WOTIS Functional Interfaces

11.3.5 Scheduling During Emergency Situations

Emergency situations, such as evacuations at WSC, spacecraft emergencies, and changes in NEN resource (e.g., antenna) availability may impact scheduling. In emergency cases, NEN customers will be notified so that appropriate responses can be taken.

If an emergency evacuation or other unplanned event occurs at WSC and the WOTIS network is shut down, scheduling files will not be sent automatically. If such an event occurs, the scheduling office will notify the NEN Performance Analyst Office (NEN PAO) or the Wallops ground station controllers who will notify customer MOCs. Each MOC will need to directly communicate its scheduling requirements to the ground stations via telephone and/or e-mail. Spacecraft post-pass results files will not be sent to the MOC until the WOTIS network is restored. However, post-pass results files are not mission critical.

If a minor evacuation event causes NEN scheduling personnel to leave WOTIS unattended, but the WOTIS network is still running, automated scheduling files will still be processed and sent to the ground stations. However, if the customer MOC requires any additions, deletions, or other final changes to the schedule when NEN scheduling personnel are not available, the MOC will need to directly contact the ground station by telephone.

If a customer MOC declares a spacecraft emergency, the White Sands Complex Operations Supervisor (WSCOS) will send a "Spacecraft Emergency Notification" message to the Network Control Center Communications (NCC COMM) Center at GSFC, which will distribute the notification to all required customers and network elements. The WSCOS will send a "Spacecraft Emergency Termination" notice when the emergency is over.

If a NEN resource changes state or a contingency affects a site's ability to provide support, the WSCOS will send a "NENSTAT Report" to the NCC COMM Center at GSFC, which will distribute the notification to all required customers and network elements.

If a spacecraft or NEN emergency requires a change to the Real-time Schedule, NEN schedulers will immediately contact those customers whose schedules over the next 24 hours (48 hours during the weekend) will be impacted. NEN schedulers will then work interactively with impacted customers to best accommodate customer needs. For schedule impacts beyond the next 24 hours (or 48 on the weekends) NEN schedulers will work to reschedule mission customers to meet standing requirements.

11.3.6 Manual Scheduling

With manual scheduling, NENSO personnel perform the scheduling without automated support from WOTIS. The process for manual scheduling is as follows:

1. MOC and NEN scheduling personnel agree on the schedule via e-mail and telephone
2. NEN scheduling personnel e-mail the schedule to the NEN station operators
3. NEN station operators manually configure the equipment for the scheduled pass.

11.3.7 Scheduling Pre-Mission Test and Launch Services

NEN PAO schedules NEN resources for pre-mission test and launch services as follows:

a. <u>Scheduling Pre-Mission Test Services</u>

Depending on the type of pre-mission test that the user requests, the Network Operations Manager (NOM), STDN Mission Manager (SMM) and/or the Test Director (TD), in conjunction with the user, determine the pre-mission test technical details. Then the NOM, SMM, and/or TD provide NEN PAO with the relevant technical details, including schedule requirements, supporting stations, and support requirements. NEN

PAO identifies and resolves resource conflicts pre-mission tests may have with activities already on NEN schedules.

b. **Scheduling Launch Services**

When scheduling launch services, the Customer Service Representative and NOM, in conjunction with the customer, provide NEN PAO and NEN Scheduling with the following:

1. Launch schedule requirements
2. NEN stations required by the mission during launch
3. Launch and early orbit support requirements.

11.3.8 Schedule Format – Comma Delimited

All schedule requests and responses (Schedule Request, Strawman Schedule, Update Schedule, Confirmed Schedule, and Daily Schedule) are formatted in the same manner, as shown in Table 11-1.

Table 11-1. Request/Response Record Format

Item No.	Name	Format	Max Size (bytes)	Value(s)
1	Support Activity Tag	ASCII	15	Empty[1] (Initial Request File) or ID number assigned by WOTIS
2	Project	ASCII	3	Fixed alphanumeric assigned by WOTIS for each mission
3	Facility	ASCII	3	one of the following: • "SGS" • "WGS" • "MGS"
4	Beginning of Track	GMT Field[2]	13	station equipment "on" time

5	End of Track	GMT Field[2]	13	station equipment “off” time
6	Support Activity Code	ASCII	4	TR1 to TR99
7	Orbit	ASCII	10	Monotonically increasing orbit counter
8	Band	ASCII	2	one of the following: • “X0” = delete request[3] • “X1” to “Xn” (n possible X-band downlink frequencies • “S1” = S-Band downlink

1. This field is empty in the Initial Request File that the MOC sends to WOTIS. For all other schedule files, a WOTIS-generated identification number is used.
2. See Table 11-2 for format.
3. A value of “X0” in this field indicates that the particular X-band component of the contact should be deleted; this feature is only used in the Daily Schedule file.

Table 11-2. UTC (GMT) Field Definition

Field: yyyy/ddd:hh:mm:ss		**Format (Size): ASCII (17 bytes)**	**Range:**
yyyy	Year	ASCII (4 bytes)	1996 through 2100
ddd	Day of Year	ASCII (3 bytes)	001 through 366
hh	Hour	ASCII (2 bytes)	00 through 23
mm	Minute	ASCII (2 bytes)	00 through 59
ss	Second	ASCII (2 bytes)	00 through 59

11.3.9 Schedule File Descriptions & Names

The Schedule Request file is only employed in Specific Scheduling, and uses the Request/Response Format defined in Table 11-1. Records are included for each requested S-Band and X-Band contact. The key field in each record is set to zero by the MOC since this value is assigned by WOTIS later in the scheduling process. The period to be scheduled is Monday, 00:00:00z, through Sunday, 23:59:59z. However, the file may cover one week plus a day of overlap on each end to allow continuity from one scheduling period to the next. The following naming convention is used for the Schedule Request File:

iUbB1dD.C

where the definitions in Table 11-3 apply.

Table 11-3. Schedule Request File Name Definition

Filename Segment	Definition	Values
i	Initial Schedule designator	**I**
U	3 character Mission Identifier	Assigned by WOTIS (Ex. eo1)
b	Beginning period separator	**B**
B1	Year (YYYY) Day of Year (DoY) for first support in file	1999, 2000, etc. and 001 – 366
d	Duration separator	**D**
D	Duration in days (dd)	01 – 99
C	File Creation Time (hhmmss)	000000 – 235959

Note: All times in UTC

An example of a Schedule Request file name is: ***iam1b1999205d7.012345***

11.3.10 Strawman Schedule

The Strawman Schedule file is FTP'd from WOTIS to the MOC approximately 2.5 weeks before the first day of the week being scheduled. Like the Schedule Request File, the Strawman Schedule File covers one Monday-through-Sunday scheduling period. This file contains two Request/Response Format records for each available contact where both an X-Band and an S-Band downlink are requested, and one for an S-Band only downlink. The Strawman Schedule uses the Request/Response Format record as defined in Table 11-1.

The filename for the Strawman Schedule File follows this format:

sUbB1dD.C

where the definitions in Table 11-4 apply.

Table 11-4. Strawman Schedule File Name Definition

Filename Segment	Definition	Values
s	Strawman Schedule designator	**S**
U	3 character Mission Identifier	Assigned by WOTIS (Ex. eo1)
b	Beginning period separator	**B**
B1	Year (YYYY) Day of Year (DoY) for first support in file	1999, 2000, etc. and 001 – 366
d	Duration separator	**D**
D	Duration in days (dd)	01 – 99
C	File Creation Time (hhmmss)	000000 – 235959

Note: All times in UTC

An example of a Strawman Schedule file name is: ***sam1b1999205d7.012345***

11.3.11 Update Schedule

The Update Schedule file is FTP'd from the MOC to the WOTIS. Like the Schedule Request File, the Update Schedule File covers one Monday-through-Sunday scheduling period. The purpose of the Update Schedule is to allow the MOC to revise any parameters in any of the supports, to delete entire supports (by not returning them in the schedule), or to delete or add an X-Band component to an existing support. An add of an X-Band component will, of course, contain no Support Activity Tag; WOTIS will assign a tag upon ingestion of the Update Schedule File. The Update Schedule uses the Request/Response Format record as defined in Table 11-1.

The filename for the Update Schedule file follows this format:

uUbB1dD.C

where the definitions in Table 11-5 apply.

Table 11-5 Update Schedule File Name Definition

Filename Segment	Definition	Values
u	Update Schedule designator	**U**
U	3 character Mission Identifier	Assigned by WOTIS (Ex. eo1)
b	Beginning period separator	**B**
B1	Year (YYYY) Day of Year (DoY) for first support in file	1999, 2000, etc. and 001 – 366
d	Duration separator	**D**
D	Duration in days (dd)	01 – 99
C	File Creation Time (hhmmss)	000000 – 235959

Note: All times in UTC

An example of an Update Request file name is: **uam1b1999205d7.012345**

11.3.12 Confirmed Schedule

The Confirmed Schedule file, transmitted (if requested) from WOTIS, covers the same time period as the Strawman Schedule. That is, it runs from Monday through Sunday. It contains a data- and requirements-driven list of events that PROJECT requires of the NEN sites, and is a subset of the contacts in the Strawman Schedule. The Confirmed Schedule confirms the supports which the NEN has scheduled, and is a final verification of the ingestion and processing of the Update Schedule. In most all instances the Confirmed Schedule will match the Update Schedule. Each event, again, is formatted as a Request/Response record defined in Table 11-1.

The naming convention for the confirmed schedule is the same as the Strawman Schedule (Section 11.3.10), where the definitions in Table 11-4 apply.

Section 12. Baseband Data Interfaces and Storage

12.1 Introduction

This section describes the baseband data interface and storage equipment options at the NEN stations:

a. IONet Network

b. Serial Clock and Data

c. Mail Delivery of Recorded Data

d. Standard Autonomous File Server (SAFS)

Table 12-1 summarizes the baseband data interfaces available at each station; an "X" means that capability is offered. Figure 12-1 summarizes the IONet networks.

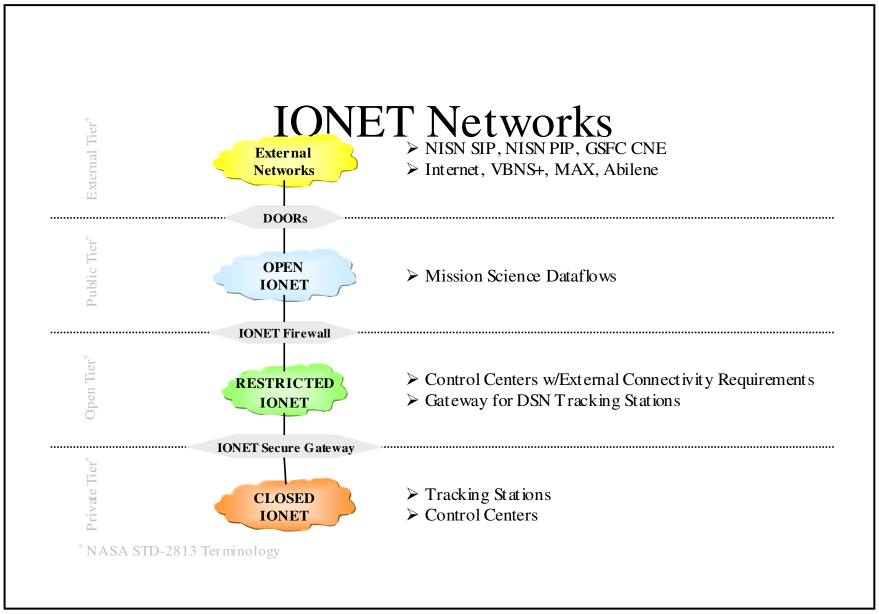


Figure 12-1. IONet Networks

12.2 IONet Network

The IONet Network can be used by MOCs to send commands to and receive telemetry data from a NEN station.

a. Open and Closed Networks

The IONet Network uses open, restricted and closed NASA IP networks. “Open” and “closed” are relative. The closed IONet is completely controlled while the open and restricted IONet has limited access. Although the closed network provides more security, the open network is still inaccessible to the public. A firewall (or “gateway”) is used when data crosses an open/closed boundary in either direction.

b. TCP/IP and UDP/IP

The IONet Network supports both Transmission Control Protocol/Internet Protocol (TCP/IP) and User Datagram Protocol/Internet Protocol (UDP/IP).

Figure 12-2 depicts the TCP/IP layer model. Each layer is encapsulated by the next lower level. “Encapsulation” is the addition of a control information header and/or trailer to a block of data. For example, in Figure 12-2, the Internet Protocol Data Unit (IPDU) packet encapsulates the Channel Access Data Unit (CADU) packet. For UDP/IP, the layering is identical to Figure 12-2, except the TCP layer is replaced by a UDP layer.

c. Packets and Layers

CADU and Command Link Transmission Unit (*CLTU*) packets are Consultative Committee for Space Data Systems (CCSDS)-compliant telemetry and command data unit protocols, respectively. (See Ref (u) for CLTU and Ref (n) for CADU in Section 1.3) For commands, the CADU layer in Figure 12-2 is replaced by a CLTU layer.

The *Network Access* Layer is a protocol format that provides physical access to NISN. For the NEN stations that support IP data transfer, the Network Access Layer is the Ethernet protocol that interfaces the NEN station to the Routers. The *IP Layer* allows data to traverse multiple networks between users and the NEN station. IP alone does not ensure that the data will be delivered, but when IP is used with *TCP*, all data is guaranteed to be delivered. TCP is a virtual connection protocol designed to work with IP. It provides reliable communication across a variety of both reliable and unreliable networks and internets.

Table 12-1. Baseband Data Interface Options

Station	NISN IP Network	Serial Clock and Data	Mail Delivery
AGO	X		
SG1	X	X	X
SG2	X	X	X
SG3	X	X	X
WGS	X	X	X
LEO-T – WFF	X	X	
PF1	X	X	X
PF2	X	X	X
USAK01	X		X
USAK02	X		X
USHI01	X		X
USHI02	X		X
AUWA01	X		X
AUWA02	X		X
MGS	X		X
MILA	X		
PDL	X		
ASF	X		X

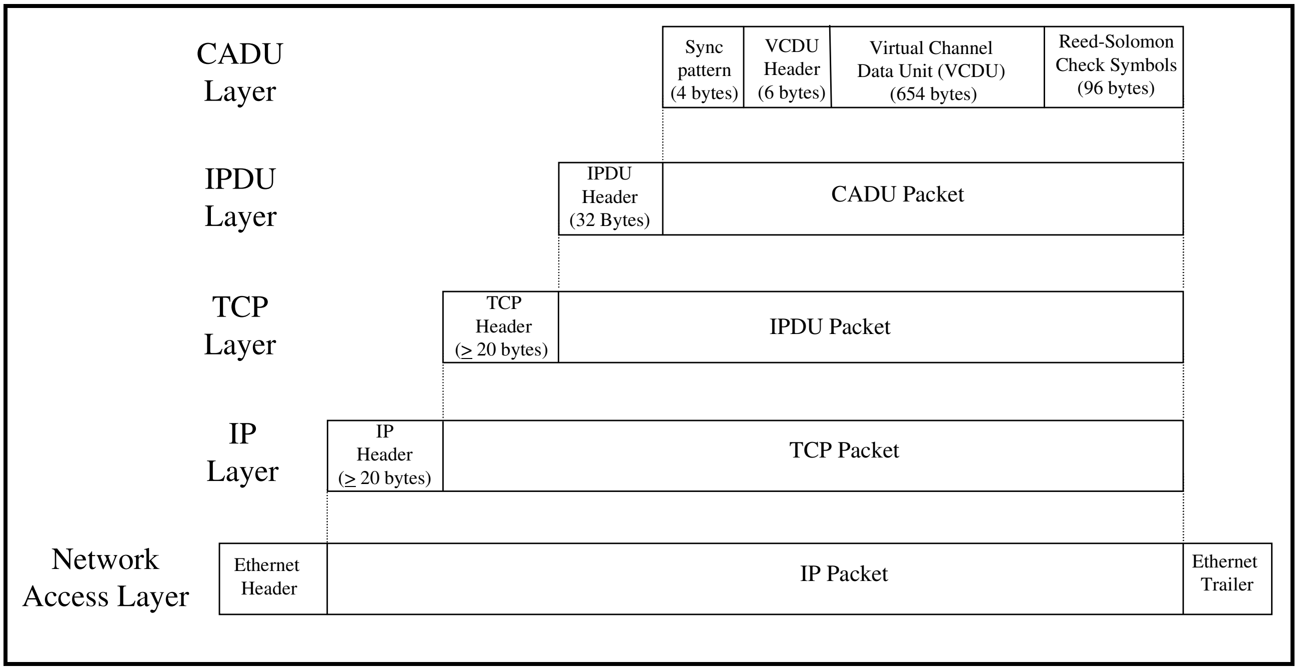


Figure 12-2. NISN IP Network Layers*

* <u>TCP</u>/IP layers are shown; <u>UDP</u>/IP is identical, except "TCP" is replaced by "UDP."

* <u>Telemetry</u> packets are shown; <u>command</u> packets are identical, except "CADU" is replaced by "CLTU."

d. UDP

UDP is available to users who want faster data transfers than TCP provides. UDP is unreliable, however, because – unlike TCP – it doesn't provide the handshaking protocols that guarantee delivery in order without duplicate or missing packets.

e. PTP Encapsulation

Except for the LEO-T station at Wallops, all NEN stations that support IP use Programmable Telemetry Processors (PTPs) to perform encapsulation and de-encapsulation. In addition to IPDU, the PTP supports several other packet formats for encapsulating CLTUs or CADUs prior to the TCP or UDP layers. PTPs offer the following packet format choices:

- IPDU
- Advanced X-ray Astrophysics Facility (AXAF) Standard Formatted Data Unit (SFDU)
- Deep Space-Terminal (DS-T) SFDU
- Advanced Composition Explorer (ACE) SFDU

- LEO-T Telemetry Frame Delivery Header (TFDH)
- LEO-T Command Delivery Header (CDH)
- NASCOM Real-time Transmission Protocol (RTP)
- No extra encapsulation between the CADU or CLTU layer and the TCP or UDP layer

Instead of a PTP, the LEO-T stations use a front-end processor that offers encapsulation and format choices that are a subset of the PTPs.

12.2.1 Command Data (Real-Time)

The MOC sends real-time command data to the NEN station via the IONet. Either TCP/IP or UDP/IP sockets may be used.

About fourteen minutes prior to each command service (assuming TCP/IP data transfer), the MOC initiates two TCP/IP socket connections with the NEN station: one socket for command data, the other for command echoes. If the user does not require command echo service, the MOC need not initiate the second socket.

12.2.2 S-Band Telemetry Data

About fourteen minutes prior to each S-band telemetry service (assuming TCP/IP data transfer), the MOC initiates two independent TCP/IP socket connections with the NEN station: one socket for telemetry data on the main carrier, the other for data on the subcarrier. The MOC needs to initiate only one socket if the user vehicle transmits only one stream of telemetry data.

12.3 Serial Clock and Data

The serial clock and data option is the transmission and/or reception of raw digital data streams with associated clock signals.

12.4 Mail Delivery of Recorded Data

When the telecommunication circuits at a NEN station cannot support the electronic transfer of high-rate science data (X-band or S-band), the NEN station will record the science data on magnetic, non-volatile media such as tape or disk. The station will then mail the recorded data to the user.

Operations agreements and support plans define the exact data-shipping criteria. Table 12-2 identifies the recording capabilities at each NEN station; an “X” means that capability is available. Table 12-3 lists the capabilities of each digital tape recorder.

Table 12-2. NEN Recording Capabilities

Station	Magnetic Disk Recording	Magnetic Tape Recording					
		Ampex DIS160	Ampex DIS260I	Ampex DCSRi 170	Metrum VLDS	Sony	LTO2
SGS	X		X		X		
SG2	X						
SG3	X						
WGS	X	X			X	X	
LEO-T – WFF	X						
PF1	X						
PF2	X						
USAK01	X						
USAK02	X						
USHI01	X						
USHI02	X						
AUWA01	X						
AUWA02	N/A						
MGS	X			X	X		X
MILA	X				X		
PDL	X				X		
ASF	X					X	

Table 12-3. Digital Tape Recorder Capabilities

Tape Recorder	Tape Format	Maximum Recording Speed	Playback Speed	Tape Storage Capacity
Ampex DIS260I	D2	160 Mbps	Any	160 GB
Ampex DCSRi 170	D2	105 Mbps	Any	160 GB
Ampex DIS160	D2	160 Mbps	Any	160 GB
Sony	D2	160 Mbps	Any	160 GB
Metrum VLDS	S-VHS	32 Mbps	Any	10 GB
Ultrium	LTO2	320 Mbps	Any	200GB

12.5 Standard Autonomous File Server

This section describes the Standard Autonomous File Server (SAFS). SAFS provides automated management of large data files without interfering with the assets involved in the acquisition of data. SAFS operates as a stand-alone solution, monitoring itself, and providing an automated level of fail-over processing to enhance reliability. By using an improved automated file transfer process, the SAFS system provides a quicker, more reliable file distribution for customers of near real-time data than has been realized by previous methods. More information is available via http://scp.gsfc.nasa.gov/websafs/.

12.5.1 SAFS Architecture and Operation

Initially, the SAFS was installed at some NASA GN sites for distributed acquisition of satellite data in support of QuikSCAT and ADEOS II missions. The SAFS has been installed at the following GN ground stations: ASF, MGS, MILA, SGS, and WGS. A SAFS also been installed at GSFC to provide for centralized customer data distribution. Figure 12-3 depicts the SAFS network architecture spanning both the Closed and Open IONets.

Note: *Due to IONet security protocols, data flows on the Closed IONet are restricted to Closed to Closed or Closed to Open. No data is allowed to flow from Open to Closed.*

The central SAFS provides a single point of contact for customers and isolates the GN ground stations from customer interactions. At each ground station, the telemetry processors accept raw satellite data and process the data into files (format for later customer consumption) that are sent to the station SAFS via a standard network protocol.

The station SAFS uses FASTCopy to automatically push the files to the central SAFS via a standard network protocol where the files are made available to the project customers. In addition each SAFS has the ability to send data to multiple recipients, and can provide automatic failover capabilities to send data to a secondary receiving server should the primary be unavailable. This failover capability is also extended to the Central SAFS (CSAFS) which consists of a primary and a backup server and Raid.

The factors determining SAFS send capability are network connectivity and the available protocols; FTP, SFTP, SCP, or FastCopy (SFTP, SCP, or FastCopy are preferred). Depending upon the network connectivity of the data recipient, if all connectivity is outside of NASA's Closed IONet then all data would be transferred from the CSAFS, however if a recipient is located on the Closed IONet, the data could be sent directly from a station SAFS (with limiting factors). The limiting factors on the Closed IONet deal with whether the station SAFS in question is a new SAFS or an old SAFS. The old SAFS; currently SGS and MILA; can only send data using the FastCopy protocol. Table 12-4 shows the data distribution capabilities of each SAFS.

Table 12-4. SAFS Network Distributions

Station	SAFS Type	Closed (FastCopy)	Closed (FTP, SFTP, or SCP)	Open (FastCopy)	Open (FTP, SFTP, or SCP)	Other (FTP, SFTP, SCP, or FastCopy)
ASF	new			X	O	O
MGS	new	X	X			
MILA	old	X				
SGS	old	X				
WGS	new	X	X			
Commercial	n/a			X	O	O
CSAFS	new			X	X	X

Notes:

- All station data flows to CSAFS at GSFC
- ASF includes the 10 and 11 meter antennas.
- WGS includes the Leot and 11 meter antennas.
- Commercial includes PF1, PF2, SG2, SG3, and USN.

Customers can "pull" their data files from the CSAFS system once they receive a data ready notification (DRN) of its availability, however due to email restrictions on the Closed IONet this function is not available from a station SAFS. Or if the customer chooses they may have the SAFS system automatically "push" their data files to them which would eliminate the delay inherent in the notification and reaction processes required for "pull" customers. Due to the added functionality FastCopy is the preferred transfer method from any SAFS, but FTP, SFTP, and SCP are also available transfer protocols, with FTP being the least desirable (These protocols are not available from the old SAFS servers, as shown in Table 12-4).

12.5.2 SAFS Hardware and Software

The SAFS system hardware is installed in a standard 19” rack and includes the following:

a. Redundant Array of Independent Disks (RAID) storage system
b. RAID monitoring/configuration system
c. SAFS server
d. Rack mounted keyboard, monitor, with touch pad

The SAFS software includes the following:

a. New SAFS: COTS RepliWeb Managed File Transfer (RMFT)
   Old SAFS: COTS FASTCopy file transfer software, with FEST automation software
b. Custom scripts for job control and monitoring

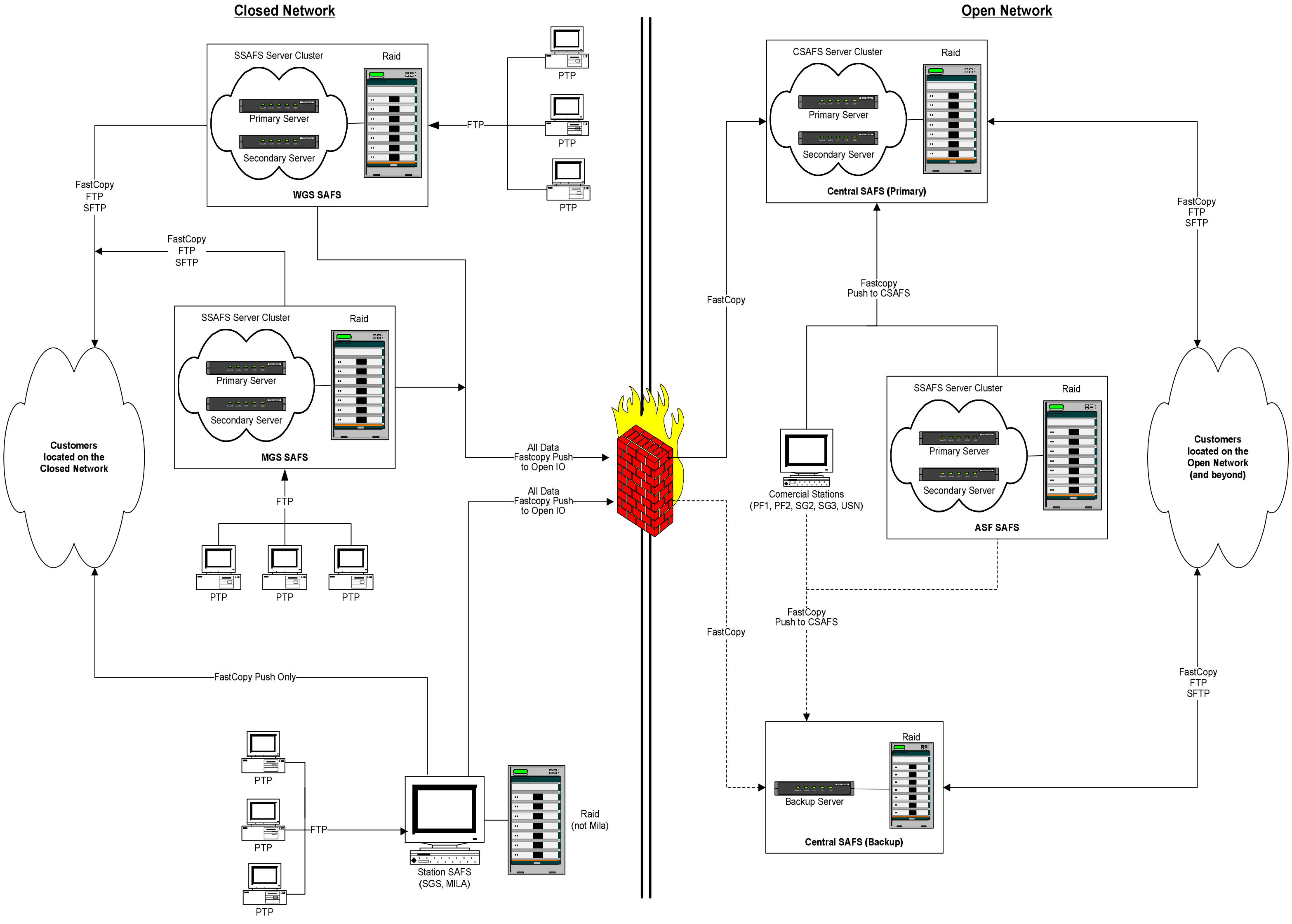


Figure 12-3. SAFS Architecture

Section 13. Frequency Management

13.1 Introduction

This section provides information to assist a flight project in determining its frequency spectrum requirements. It also describes the procedures for obtaining authorization for the required spectrum.

13.2 Determining Frequency Spectrum Requirements

13.2.1 International Frequency Spectrum Allocations

International frequency spectrum allocations are prepared by World Radiocommunication Conferences (WRCs) convened under the auspices of the International Telecommunications Union (ITU). These allocations become part of the ITU International Radio Regulations, a treaty that requires ratification by the United States (US). In most cases, these allocations also become part of the National Allocation Table.

Management of the radio frequency spectrum within the US is divided between government and non-government uses: the National Telecommunications and Information Administration (NTIA) administers government allocations (including NASA), and the Federal Communications Commission (FCC) manages non-government allocations.

NASA is a member of the NTIA's Interdepartment Radio Advisory Committee (IRAC), which coordinates US spectrum allocation issues. US allocations relevant to the NEN are consistent with the international allocations.

Table 13-1 identifies the bands in which the NEN is "primary" or "secondary" with respect to other services. Within these bands, NEN operations with a primary status are protected from unacceptable interference from other services, but NEN operations with a secondary status shall be operated on a non-interference basis.

Table 13-1. NEN Primary Frequency Allocations

Band	Frequency	Link	Allocated Services
S-band	2025-2110 MHz	Uplink	Primary: Space Operation, Earth Exploration-Satellite, Space Research
	2110-2120 MHz	Uplink	Primary: Space Research (deep space only)
	2200-2290 MHz	Downlink:	Primary: Space Operation, Earth Exploration-Satellite, Space Research
	2290-2300 MHz	Downlink:	Primary: Space Research (deep space only)

X-Band	8025-8400 MHz;	Downlink:	Primary: Earth Exploration-Satellite
	8400-8450 MHz	Downlink:	Primary: Space Research (deep space only)
	8450-8500 MHz	Downlink:	Primary: Space Research
Ku-band	13.4-14.2 GHz	Downlink:	Secondary: Space Research (Note)
	14.5-15.35 GHz	Uplink	Secondary: Space Research
Ka-band	25.5-27.0 GHz	Downlink	Primary: Earth Exploration-Satellite, Space Research
Note: In the band 13.75 –14.0 GHz geostationary space stations in the space research service, for which information for advance publication has been received by the IFRB prior to 31 January 1992, shall operate on an equal basis with stations in the fixed satellite service; new geostationary space stations in the space research service advanced published after that date will operate on a secondary basis.			

13.2.2 DSN Protection

As stated above, the DSN has primary allocations in the 2290 – 2300 MHz, and 8400 – 8450 MHz bands. Each of these bands is adjacent to a NEN allocation. NEN sites are responsible for protecting DSN stations from unacceptable interference.

The ITU recommended interference protection criteria in the DSN band for interference from non-DSN transmitters are summarized in Table 13-2

Table 13-2. Interference Protection Criteria for DSN

Frequency (MHz)	Protection Criteria for DSN Earth Stations(dBW/Hz)
2290 – 2300	-222.0
8400 – 8450	-221.0

TDRSS S-band links operating in the upper portion of the 2200 – 2290 MHz band have the potential to cause unacceptable interference to deep space missions operating in the 2290 – 2300 MHz band. Recommendation ITU-R SA.1157 defines protection criteria for deep space operations in the 2 GHz band. This recommendation indicates that the protection criterion for deep space Earth stations operating near 2 GHz is that the interference at the input to the deep space earth station receiver should not exceed -222 dBW/Hz and current NASA policy is that this criterion must be met 100% of the time. This protection criterion is measured at the deep space Earth station after accounting for the receiving antenna gain. Platforms operating in the upper portion of the 2200 – 2290 MHz band need very stringent filtering to meet the deep space protection criteria. In particular, a platform using the 2287.5 MHz TDRSS return links with a necessary bandwidth of 5 MHz or higher will easily violate the deep space protection criteria when it transmits sufficiently close to the beam of a DSN 70 meter or 34 meter antenna. Mitigation techniques such as filtering out sideband emissions have been very successful to meet the deep space protection criterion. In particular, the “NASA/GSFC Recommended Filtering Referenced to the Output of the Power Amplifier” minimizes the interference in the DSN band with a reasonable implementation loss. Figure 13.1 shows the output spectral plot of the “NASA/GSFC Recommended Filtering Referenced to the Output of the Power Amplifier”. Figure 13.2 shows an example of the spectral output of an unfiltered BPSK signal vs. a signal filtered by the “NASA/GSFC Recommended Filtering Referenced to the Output of the Power Amplifier” and compares them to the DSN protection criterion.TDRSS X-band links operating in the upper portion of the 8025-8400 MHz band also have the potential to cause unacceptable interference to deep space missions operating in the 8400-8450 MHz band, and current NASA policy is that this criterion must be met 100% of the time, so appropriate mitigation techniques must be employed.

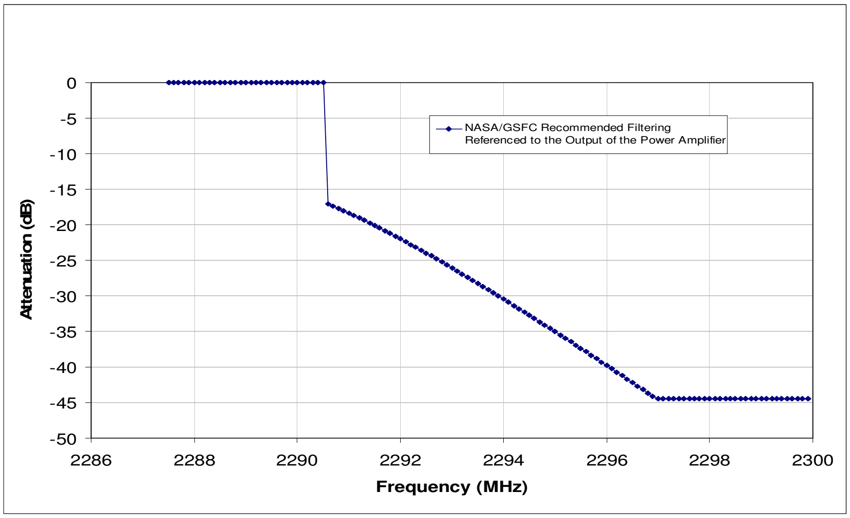


Figure 13-1. Spectral Output for NASA/GSFC Recommended Filtering Referenced to the Output of the Power Amplifier

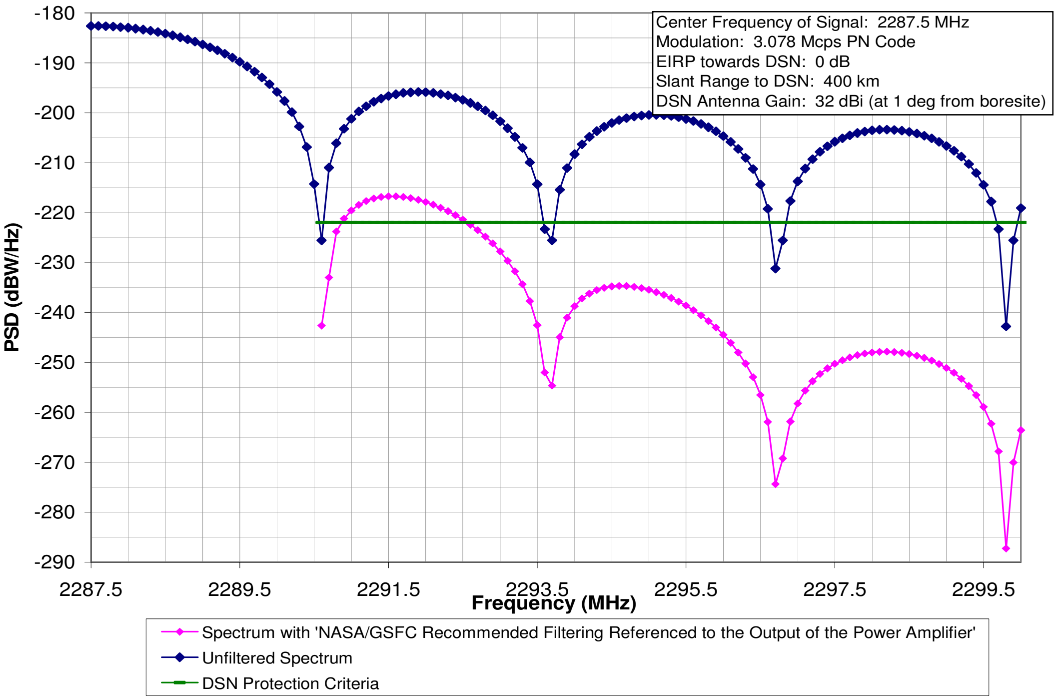


Figure 13-2. Example of Unfiltered and Filtered 3 Mcps Code with DSN Protection Criteria

13.2.3 In-Band Power Flux Density Restrictions

NEN users share most of their receive bands with terrestrial services. Terrestrial services are protected by limiting the spacecraft power-flux density at the surface of the earth from space-based transmitters. Power Flux Density limits are imposed on national missions by both the NTIA and the ITU limits whose values can be found in the ITU-R Radio Regulations Article 21, Table 21-4. Although largely similar, there are a few differences. Table 13-3 summarizes the national power flux density limits applicable to TDRS space to space links.

The national PFD limits were extracted from NTIA manual Table 8.2.36. The PFD limit is defined at the Earth's surface as a function of the angle of arrival above the local horizontal plane, **θ**, for all conditions and for all methods of modulation. The limits relate to the PFD that would be obtained under assumed free-space propagation conditions.

Table 13-3. National PFD Limits applicable to NEN Operations

Frequency (MHz)	Power-Flux Density Limit for Angles of Arrival (θ) Above the Horizontal Plane (dBW/m^2)			Reference Bandwidth
	$0^\circ \le \theta \le 5^\circ$	$5^\circ < \theta < 25^\circ$	$25^\circ \le \theta \le 90^\circ$	
2025 – 2110	-154 -130	-154 + 0.5 (θ - 5) -130 + 0.5 (θ - 5)	-144 -120	4 kHz (Note 1) 1 MHz (Note 2)
2200 – 2290	-154 -130	-154 + 0.5 (θ - 5) -130 + 0.5 (θ - 5)	-144 -120	4 kHz (Note 1) 1 MHz (Note 2)
8025 – 8400	-150	-150 + 0.5 (θ - 5)	-140	4 kHz
13400 -14050	-152	-152	-152	4 kHz
14050 – 14200	No Limit	No Limit	No Limit	Not applicable
14500 -15350	-124	-124 + 0.5 (θ - 5)	-114	1 MHz
25500-27000	-115	-115 + 0.5 (θ - 5)	-105	1 MHz

Note 1: As per Section 2 in NTIA Report 84-152, these PFD levels can be relaxed by 10 dB for GSO satellite transmissions and 16 dB for LEO satellite transmissions.

Note 2: As per IRAC 31015, these PFD levels can be calculated in a 1 MHz bandwidth in determining compliance.

13.3 Obtaining Frequency Spectrum Authorization

13.3.1 Regulations, Policies, and Instructions

NASA missions must comply with all US and international frequency spectrum requirements. Reference [l] in Section 1.3 states these requirements and other legal obligations mandated by NTIA. Reference [k] provides detailed instructions for obtaining frequency spectrum authorization in compliance with Reference [i].

13.3.2 GSFC Spectrum Management Office

The GSFC Spectrum Management Office is responsible for all spectrum-related activities associated with the NEN. The Office is part of the Exploration and Space Communications (ESC) Projects Division, Code 450.0. The responsibilities of the Spectrum Management Office include:

1. Coordinate RF spectrum requirements pertaining to GSFC and NEN resources, in accordance with Chapter 3 of Reference [k] in Section 1.3.
2. Ensure interference-free operations between user vehicles and the NEN, in accordance with Chapter 4 of Reference [k].
3. Assist the flight project in determining frequency requirements, including performing interference analyses.
4. Provide guidance in completing the Frequency Authorization Request Package to be sent to the NTIA. Chapter 10 of Reference [l] provides instructions for filling out the forms in the Package.
5. Coordinate with the NTIA's Spectrum Planning Subcommittee and Space Systems Subcommittee, which conduct the frequency spectrum allocation review, and the review of international spectrum paperwork. Appendix F of Reference [l] describes the four-stage review process for the national process.

13.3.3 Flight Project Responsibilities

Flight projects that would like to use the NEN should contact the GSFC Spectrum Management Office to begin the allocation request process prior to any contractual decisions that would commit the project to a specific design (see Section 13.3.2 above). Each project must designate a point-of-contact for working with the Spectrum Management Office as given in Reference NPR-2570.1B NASA Radio Frequency (RF) Spectrum Management Manual.

13.4 Bandwidth Requirements

In order to more efficiently utilize the limited spectrum allocated for space-to-Earth data transmissions, the Space Frequency Coordination Group (SFCG) and NTIA have recommendations for bandwidth utilization in S and X bands as discussed below. NEN bands not listed do not have such restrictions.:

13.4.1 BW requirements in the 2200-2290 MHz Band

Considering that most space-to Earth systems and space-to-space systems currently operating in the band use bandwidths no more than 6 MHz and that larger bandwidths than the above do not promote homogeneity and tend to increase future congestion in the band, SFCG RES 24-1R1 recommends that systems using this band be designed to minimize their bandwidths to reduce the potential interference to other systems in the band and that, whenever practical, bandwidths should not exceed 6 MHz.

However, NTIA recommends the following in section 8.2.41 of the NTIA manual:

In the band 2200-2290 MHz, space-to-Earth and space-to-space operations should make use of transmissions that have necessary bandwidths constrained to no more than 5 MHz. For transmissions that require necessary bandwidths of greater than 5 MHz, the requesting agency shall submit justification on why a bandwidth exceeding 5 MHz is necessary; furthermore agencies are to explain why the radio communications requirement cannot be satisfied through use of transmissions using less bandwidth, i.e., 5 MHz or less, e.g., through use of more spectrally efficient modulation. Spread spectrum missions (e.g., space-to-Tracking and Data Relay Satellite communications, lunar downlinks, and lunar data relay satellite communications) that enable multiple users on the same channel and require a necessary bandwidth of approximately 6.16 MHz are exempt from this policy.

13.4.2 BW requirements in the 8450-8500 MHz Band

SFCG RES 5-1R5 recommends that the 8450 - 8500 MHz band be used for Category A (near-Earth) missions requiring an occupied bandwidth of up to 10 MHz per mission and having technical requirements that are best satisfied in the band.

13.5 NTIA Emission Mask

Figure 13-3 shows the unwanted emission mask given in Section 5.6 of the NTIA Manual. This emission mask is applicable for all Earth and space stations operating above 470 MHz. The NTIA emission mask applies to the continuous spectrum and all discrete spectral lines, including spurious outputs and harmonics.

The NTIA mask is interpreted as follows:

- dBsd is dB attenuation in a 4 kHz bandwidth, relative to the maximum power in any 4 kHz band within the necessary bandwidth.
- For frequencies offset from the assigned frequency less than the 50% of the necessary bandwidth (B_n), no attenuation is required.
- At a frequency offset equal to 50% of the necessary bandwidth, an attenuation of at least 8 dB is required.
- Frequencies offset more than 50% of the necessary bandwidth should be attenuated by the following mask:

$$40 \cdot \log\left(\frac{2 \cdot | f_d |}{B_n}\right) \quad + \quad 8 \quad (\text{dBsd})$$

  where f_d is the frequency displaced from the center of the emission bandwidth.

- For cases of very narrow-band emissions where the necessary bandwidth is less than the minimum bandwidth (B_L) given in Figure 13.3, B_L shall be used in place of B_n.

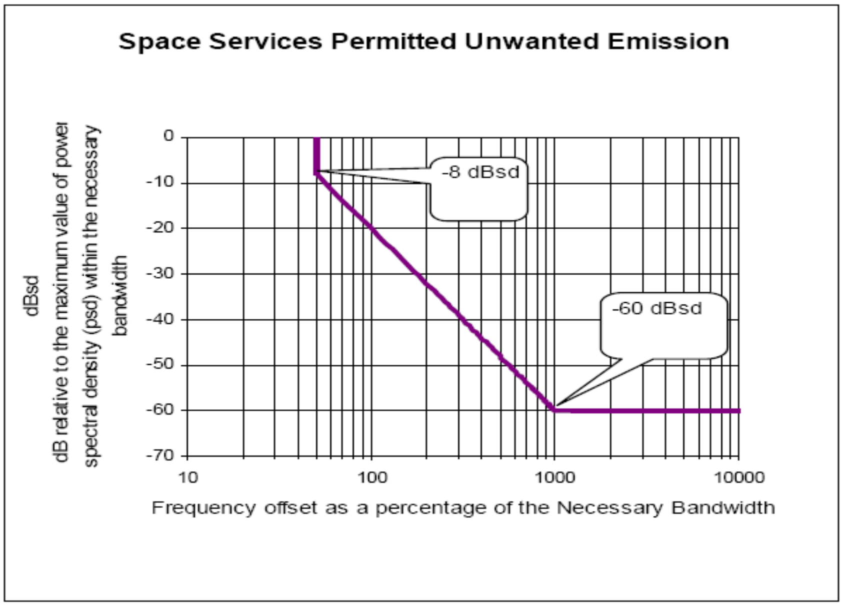


Figure 13-3. NTIA OOB Emission Mask for Earth and Space Stations

Table 13-4. United States and ITU Table of Frequency Allocations

International Table			United States Table	
Region 1 Table	Region 2 Table	Region 3 Table	Federal Table	Non-Federal Table
2025-2110 SPACE OPERATION (Earth-to-space) (space-to-space) EARTH EXPLORATION-SATELLITE (Earth-to-space) (space-to-space) FIXED MOBILE 5.391 SPACE RESEARCH (Earth-to-space) (space-to-space) 5.392			2025-2110 SPACE OPERATION (Earth-to-space) (space-to-space) EARTH EXPLORATION-SATELLITE (Earth-to-space) (space-to-space) SPACE RESEARCH (Earth-to-space) (space-to-space) 5.391 5.392 US90 US222 US346 US347 US393	2025-2110 FIXED NG118 MOBILE 5.391 5.392 US90 US222 US346 US347 US393
2110-2120 FIXED MOBILE 5.388A 5.388B SPACE RESEARCH (deep space) (Earth-to-space) 5.388			2110-2120 US252	2110-2120 FIXED MOBILE US252

International Table			United States Table	
Region 1 Table	Region 2 Table	Region 3 Table	Federal Table	Non-Federal Table
2200-2290 SPACE OPERATION (space-to-Earth) (space-to-space) EARTH EXPLORATION-SATELLITE (space-to-Earth) (space-to-space) FIXED MOBILE 5.391 SPACE RESEARCH (space-to-Earth) (space-to-space) 5.392			2200-2290 SPACE OPERATION (space-to-Earth) (space-to-space) EARTH EXPLORATION-SATELLITE (space-to-Earth) (space-to-space) FIXED (line-of-sight only) MOBILE (line-of-sight only including aeronautical telemetry, but excluding flight testing of manned aircraft) 5.391 SPACE RESEARCH (space-to-Earth) (space-to-space) 5.392 US303	2200-2290 US303
2290-2300 FIXED MOBILE except aeronautical mobile SPACE RESEARCH (deep space) (space-to-Earth)			2290-2300 FIXED MOBILE except aeronautical mobile SPACE RESEARCH (deep space) (space-to-Earth)	2290-2300 SPACE RESEARCH (deep space) (space-to-Earth)

International Table			United States Table	
Region 1 Table	Region 2 Table	Region 3 Table	Federal Table	Non-Federal Table
8025-8175 EARTH EXPLORATION-SATELLITE (space-to-Earth) FIXED FIXED-SATELLITE (Earth-to-space) MOBILE 5.463 5.462A			8025-8175 EARTH EXPLORATION-SATELLITE (space-to-Earth) FIXED FIXED-SATELLITE (Earth-to-space) Mobile-satellite (Earth-to-space) (no airborne transmissions) US258 G117	8025-8400 US258
8175-8215 EARTH EXPLORATION-SATELLITE (space-to-Earth) FIXED FIXED-SATELLITE (Earth-to-space) METEOROLOGICAL-SATELLITE (Earth-to-space) MOBILE 5.463 5.462A			8175-8215 EARTH EXPLORATION-SATELLITE (space-to-Earth) FIXED FIXED-SATELLITE (Earth-to-space) METEOROLOGICAL-SATELLITE (Earth-to-space) Mobile-satellite (Earth-to-space) (no airborne transmissions) US258 G104 G117	
8215-8400 EARTH EXPLORATION-SATELLITE (space-to-Earth) FIXED FIXED-SATELLITE (Earth-to-space) MOBILE 5.463 5.462A			8215-8400 EARTH EXPLORATION-SATELLITE (space-to-Earth) FIXED FIXED-SATELLITE (Earth-to-space) Mobile-satellite (Earth-to-space) (no airborne transmissions) US258 G117	
8400-8500 FIXED MOBILE except aeronautical mobile SPACE RESEARCH (space-to-Earth) 5.465 5.466			8400-8450 FIXED SPACE RESEARCH (space-to-Earth) (deep space only)	8400-8450 Space research (space-to-Earth) (deep space only)
			8450-8500 FIXED SPACE RESEARCH (space-to-Earth)	8450-8500 SPACE RESEARCH (space-to-Earth)

International Table			United States Table	
Region 1 Table	Region 2 Table	Region 3 Table	Federal Table	Non-Federal Table
13.25-13.4 EARTH EXPLORATION-SATELLITE (active) AERONAUTICAL RADIONAVIGATION 5.497 SPACE RESEARCH (active) 5.498A 5.499			13.25-13.4 EARTH EXPLORATION-SATELLITE (active) AERONAUTICAL RADIONAVIGATION 5.497 SPACE RESEARCH (active) 5.498A	13.25-13.4 AERONAUTICAL RADIONAVIGATION 5.497 Earth exploration-satellite (active) Space research (active)
13.4-13.75 EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION SPACE RESEARCH 5.501A Standard frequency and time signal-satellite (Earth-to-space) 5.499 5.500 5.501 5.501B			13.4-13.75 EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION G59 SPACE RESEARCH 5.501A Standard frequency and time signal-satellite (Earth-to-space) 5.501B	13.4-13.75 Earth exploration-satellite (active) Radiolocation Space research Standard frequency and time signal-satellite (Earth-to-space)
13.75-14 FIXED-SATELLITE (Earth-to-space) 5.484A RADIOLOCATION Earth exploration-satellite Standard frequency and time signal-satellite (Earth-to-space) Space research 5.499 5.500 5.501 5.502 5.503			13.75-14 RADIOLOCATION G59 Standard frequency and time signal-satellite (Earth-to-space) Space research US337 US356 US357	13.75-14 FIXED-SATELLITE (Earth-to-space) US337 Radiolocation Standard frequency and time signal-satellite (Earth-to-space) Space research US356 US357
14-14.25 FIXED-SATELLITE (Earth-to-space) 5.457A 5.457B 5.484A 5.506 5.506B RADIONAVIGATION 5.504 Mobile-satellite (Earth-to-space) 5.504C 5.506A Space research 5.504A 5.505			14-14.2 Space research	14-14.2 FIXED-SATELLITE (Earth-to-space) NG183 Mobile-satellite (Earth-to-space) Space research

International Table			United States Table	
Region 1 Table	Region 2 Table	Region 3 Table	Federal Table	Non-Federal Table
14.5-14.8 FIXED FIXED-SATELLITE (Earth-to-space) 5.510 MOBILE Space research			14.5-14.7145 FIXED Mobile Space research	14.5-14.8
			14.7145-14.8 MOBILE Fixed Space research	
14.8-15.35 FIXED MOBILE Space research 5.339			14.8-15.1365 MOBILE SPACE RESEARCH Fixed US310	14.8-15.1365 US310
			15.1365-15.35 FIXED SPACE RESEARCH Mobile 5.339 US211	15.1365-15.35 5.339 US211

International Table			United States Table	
Region 1 Table	Region 2 Table	Region 3 Table	Federal Table	Non-Federal Table
25.5-27 EARTH EXPLORATION-SATELLITE (space-to-Earth) 5.536B FIXED INTER-SATELLITE 5.536 MOBILE SPACE RESEARCH (space-to-Earth) 5.536C Standard frequency and time signal-satellite (Earth-to-space) 5.536A			25.5-27 EARTH EXPLORATION-SATELLITE (space-to-Earth) FIXED INTER-SATELLITE 5.536 MOBILE SPACE RESEARCH (space-to-Earth) Standard frequency and time signal-satellite (Earth-to-space) 5.536A US258	25.5-27 Inter-satellite 5.536 Standard frequency and time signal-satellite (Earth-to-space) 5.536A US258

Section 14. Link Budget Parameters

This section provides S-band and X-band link parameters that will assist flight projects with link budget calculations. The link budget parameters provided in this section are estimated values for example purposes only. For specific link budget calculations, contact the Exploration and Space Communications (ESC) Projects Division Program Office. This section provides the following information:

- S-band atmospheric and rain attenuation constants.
- X-band atmospheric and rain attenuation constants.
- Ka-band atmospheric and rain attenuation constants.
- Example user spacecraft constraint losses and ground terminal losses for telemetry links.
- X-band G/T measurement data.
- Ground station line-of-sight coverage for spacecraft altitudes between 500 km and 1000 km.

14.1 S-band Atmospheric and Rain Attenuation Constants

Atmospheric and rain attenuation constants were developed for S-band (2200 MHz – 2400 MHz) NEN stations based on ITU recommendation ITU-R P.618-8. Table 14-1 lists the S-band rain attenuation constants for the NEN stations that have S-band capabilities. There are other propagation effects such as scintillation, cloud, site diversity etc… Contact Code 450 CLASS for further detail analysis.

14.2 X-band Atmospheric and Rain Attenuation Constants

Atmospheric and rain attenuation constants were developed for the X-band (8000 MHz – 8500 MHz) NEN based on ITU recommendation ITU-R P.618-8.. Table 14-2 lists the X-band rain attenuation constants for the NEN stations that have X-band capabilities. There are other propagation effects such as scintillation, cloud, site diversity etc… Contact Code 450 CLASS for further detail analysis

14.3 Ka-band Atmospheric and Rain Attenuation Constants

Atmospheric and rain attenuation constants were developed for the Ka-band (25500 MHz – 27000 MHz) NEN based on ITU recommendation ITU-R P.618-8.. For Table 14-3 lists the Ka-band rain attenuation constants for the NEN stations that have Ka-band capabilities. There are other propagation effects such as scintillation, cloud, site diversity etc… Contact Code 450 CLASS for further detail analysis

14.4 Implementation Losses, Constraint Losses, and Ground Terminal Losses

Constraint loss is the link degradation due to linear and non-linear spacecraft transmitter distortions. Ground terminal loss is the link degradation due to ground terminal receive system distortions. The sum of the constraint loss and the ground terminal loss is typically stated as the implementation loss in NEN link budgets.

Constraint losses and ground terminal losses vary with spacecraft and ground station design, and are usually analyzed on a case-by-case basis. There is no fixed constraint loss value for all spacecraft and no fixed ground terminal loss value for all NEN stations. Variations in a spacecraft's transmitter signal characteristics from mission to mission can significantly impact the amount of constraint loss. Likewise, variations in the ground terminal's receive performance characteristics and operational data rate can significantly impact the amount of ground terminal loss. The Exploration and Space Communications (ESC) Projects Division Program Office typically performs analytical modeling and simulation as required for specific flight project communications hardware and NEN receivers to estimate the overall implementation loss for a mission link budget.

Paragraphs 14.4.1 and 14.4.2 provide example implementation losses, constraint losses, ground terminal losses, and distortion characteristics for X-band and S-band links, respectively.

The loss values and parameters discussed below in paragraphs 14.4.1 and 14.4.2 are intended to only provide the user an example of the expected link performances under specific scenarios. As previously stated, implementation loss for NEN links should be analyzed on a case-by-case basis. The implementation loss assessment will determine the additional user spacecraft EIRP required to provide acceptable performance throughout the lifetime of the mission.

In addition to the distortion characteristics stated in paragraphs 14.4.1 and 14.4.2, the Consultative Committee for Space Data Systems (CCSDS) and Space Frequency Coordination Group (SFCG) provide recommended X-band and S-band spacecraft characteristics and distortion limits for space-to-Earth data transmissions. This information can be found in references [b and o].

14.4.1 X-Band Implementation Loss Examples

Table 14-4 lists the signal characteristics specified for the ICESat X-band transmitter. Simulation for the ICESat project resulted in an estimated constraint loss of 3.0 dB. The constraint loss is greatly dependent on the shape of the transmitter signal magnitude and phase response over the 3 dB bandwidth. Because the actual (measured) response was not available for the simulation, a response shape was assumed for the simulation. As test data becomes available for the flight hardware, the simulations can be repeated using measured distortion values to improve the accuracy of the constraint loss estimate.

The ground terminal loss for ICESat was estimated by performing characterization tests at the Wallops Ground Station using similar equipment to that implemented for ICESat. The test results indicated an estimated ground terminal loss of 2.0 dB. Thus, the resulting X-band implementation loss for the ICESat link budget was estimated at 5.0 dB.

Similar analyses for the PM-1 mission resulted in an estimated spacecraft constraint loss of 1.9 dB and a ground terminal loss of 2.5 dB for a total implementation loss of 4.4 dB. The difference in implementation loss between PM-1 and ICESat can be attributed to a number of factors including required BER (10E-3 for PM-1 versus 10E-5 for ICESat), the use of measured transmitter gain flatness and phase non-linearity values rather than specified values, and differences in other signal parameters such as data rate, phase noise, and AM/PM distortion.

14.4.2 S-Band Implementation Loss Examples

Table 14-5 lists the signal characteristics for a typical LEO spacecraft's S-Band transmitter for the following two scenarios:

1. Suppressed carrier modulation, but no convolutional coding
2. Phase Modulation (PM) with a residual carrier, but no convolution coding.

Table 14-6 lists the signal characteristics for a typical LEO spacecraft's S-Band transmitter for the following two scenarios:

1. Suppressed carrier modulation with rate ½ convolutional coding
2. PM with a residual carrier with rate ½ convolution coding

Simulations were conducted to determine the implementation loss for S-Band using suppressed carrier modulation schemes and PM with a residual carrier. The simulations were conducted with and without ½ rate convolution. Ground station characteristics were included in the simulations. The ground station characteristics were assumed, but the fidelity scenarios assumed were a conservative representation for existing (or future) NEN ground terminals.

Simulations using the Table 14-5 and Table 14-6 characteristics yielded the implementation losses listed in Table 14-7:

As an example of implementation loss for S-Band links with subcarriers, reference [n] states an implementation loss for the ICESat S-band subcarrier telemetry link (PCM, BPSK, PM) as 2.0 dB.

14.5 Ground Station Line-Of-Sight Coverage

Figures 14-1 through 14-13 depict each ground station's line-of-sight coverage for spacecraft altitudes of 500 km, 750 km, and 1000 km. All line-of-sight coverages are based on the local terrain. Line-of-sight coverage analyses for specific mission orbit parameters can be performed by the Exploration and Space Communications (ESC) Projects Division Program Office.

Table 14-1. S-Band Rain Attenuation Constants (5° Elevation Angle) [2.3 GHz]

Ground Station	Rain Attenuation for 99% Availability (dB)	Rain Attenuation for 99.9% Availability (dB)
SGS (Norway)	0.0	0.0
WGS (WFF)	0.01	0.04
LEO-T (WFF)	0.01	0.04
MGTAS (WFF)	0.01	0.04
MGS (Antarctica)	0.0	0.0
LEO-T (Alaska)	0.0	0.01
AGS (Alaska)	0.0	0.01
MILA (Florida)	0.02	0.15
PDL (Florida)	0.02	0.15
WS1 (White Sands)	0.01	0.04
HWGS (USN South Point, Hawaii)	0.01	0.1
AUWS (USN Dongara, Australia)	0.0	0.03
HBK (Hartebeesthoek, South Africa)	0.01	0.08
KIR (Kiruna, Sweden)	0.0	0.01
AGO (Santiago, Chile)	0.0	0.02
WEIL (Weilheim, Germany)	0.0	0.02

Table 14-2. X-Band Rain Attenuation Constants (5° and 10° Elevation Angle) [8.5 GHz]

Ground Station	Elevation Angle	Rain Attenuation for 99% Availability (dB)	Rain Attenuation for 99.9% Availability (dB)
SGS (Norway)	5°	0.08	0.39
	10°	0.04	0.19
WGS (WFF)	5°	0.94	3.93
	10°	0.54	2.36
MGS (Antarctica)	5°	0.01	0.04
	10°	0.0	0.02
AGS (Alaska)	5°	0.25	1.15
	10°	0.13	0.66
HWGS (USN South Point, Hawaii)	5°	1.38	7.33
	10°	0.74	4.77
AUWS (USN Dongara, Australia)	5°	0.42	2.43
	10°	0.21	1.51
HBK (Hartebeesthoek, South Africa)	5°	1.33	7.06
	10°	0.69	4.44

Table 14-3. Ka-Band Rain Attenuation Constants (5° and 10° Elevation Angle) [27GHz]

Ground Station	Elevation Angle	Rain Attenuation (dB)			
		90% Availability	95% Availability	99% Availability	99.9% Availability
WS1 (White Sands)	5°	1.95	3.25	9.47	42.12
	10°	1.14	1.92	5.77	30.41

Table 14-4. ICESat X-Band Transmitter Characteristics

Parameter	Value
Frequency	8100 MHz
Data Format	NRZ-M
Data Rate (I/Q Bit Rate)	20 Mbps on each channel (40 Mbps total)
Data Modulation	Staggered QPSK
Data Asymmetry (1)	≤ 3 percent
Data Rise Time (1)	≤ 2.5 nsec
Data Bit Jitter (1)	≤ 1 percent
I/Q Power Ratio	1:1
I/Q Data Skew (1)	0.5 ± 0.1 symbol period
QPSK Gain Imbalance	≤ 1.2 dB peak to peak
QPSK Phase Imbalance	≤ 5.0 degrees
AM/AM	≤ 1.0 dB/dB
AM/PM	≤ 10.0 degrees/dB
3 dB Bandwidth	60.0 MHz
Roll-off	0.62 dB/MHz
Gain Flatness	≤ 2.0 dB peak to peak
Gain Slope	≤ 0.4 dB/MHz
Phase Nonlinearity	≤ 5.0 dB peak to peak
Phase Noise (1) 100 Hz – 40 MHz offset from carrier	≤ 2.0 degrees RMS
Spurious Phase Modulation (1)	≤ 2.0 degrees RMS
Out-of-Band Spurious Output (1)	≤ -40 dBc
Incidental AM (1)	≤ 5 percent

(1) Parameter not simulated for ICESat constraint loss estimate

Table 14-5. USAT S-Band Transmitter Characteristics (Uncoded)

Parameter	Value
Frequency	2200-2400 MHz
Data Format	NRZ-L
Data Rate (I/Q Bit Rate)	4 Mb/sec (BPSK), 8 Mb/sec (QPSK)
Data Modulation	BPSK, QPSK
Data Asymmetry	3 percent
Data Rise Time	5 percent
Data Bit Jitter (1)	$\leq$ 0.1 percent
I/Q Power Ratio	1:1
I/Q Data Skew	2.5 percent
Gain Imbalance	0.25 dB
Phase Imbalance	3.0 degrees
AM/AM	0 dB/dB (full saturation)
AM/PM	12 degrees/dB
3 dB Bandwidth	8.0 MHz
Roll-off	25 dB/MHz
Gain Flatness (peak-to-peak)	0.3 dB over ± 3.5 MHz
Gain Slope	0.1 dB/MHz
Phase Nonlinearity (peak-to-peak)	3.0 degrees over ± 3.5 MHz
Phase Noise (1)	1 Hz – 10 Hz: $\leq$ 50.0 degrees RMS 10 Hz – 100 Hz: $\leq$ 6.0 degrees RMS 100 Hz – 1 kHz: $\leq$ 2.5 degrees RMS 1 kHz – 6 MHz: $\leq$ 2.5 degrees RMS
Spurious Phase Modulation	2 degrees RMS @ 15.63 kHz (BPSK) 1 degree RMS @ 15.63 kHz (QPSK)
Spurious Outputs	-23 dBc @ 47.0 kHz -15 dBc @ 12.0 MHz
Incidental AM	5 percent @ 7.48 kHz

(1) Parameter not simulated, but impact on implementation loss determined via analysis techniques

Table 14-6. USAT S-Band Transmitter Characteristics (rate ½ convolutional coding)

Parameter	Value
Frequency	2200 – 2400 MHz
Data Format	NRZ-L
Data Rate (I/Q Bit Rate)	2 Mb/sec (BPSK), 4 Mb/sec (QPSK)
Data Modulation	BPSK, QPSK
Data Asymmetry	3 percent
Data Rise Time	5 percent
Data Bit Jitter(1)	0.1 percent
I/Q Power Ratio	1:1
I/Q Data Skew	2.5 percent
Gain Imbalance	1.0 dB (BPSK); 0.5 dB (QPSK)
Phase Imbalance	9.0 degrees (BPSK); 5.0 degrees (QPSK)
AM/AM	0 dB/dB (full saturation)
AM/PM	15 degrees/dB
3 dB Bandwidth	8.0 MHz
Roll-off	25 dB/MHz (BPSK), 50 dB/MHz (QPSK)
Gain Flatness (peak-to-peak)	0.4 dB over ± 3.5 MHz
Gain Slope	0.1 dB/MHz
Phase Nonlinearity (peak-to-peak)	4.0 degrees over ± 3.5 MHz
Phase Noise (1)	1 Hz – 10 Hz: $\leq$ 50.0 degrees RMS 10 Hz – 100 Hz: $\leq$ 6.0 degrees RMS 100 Hz – 1 kHz: $\leq$ 2.5 degrees RMS 1 kHz – 6 MHz: $\leq$ 2.5 degrees RMS
Spurious Phase Modulation	2 degrees RMS @15.6 kHz (BPSK) 1 degree RMS @ 15.6 kHz (QPSK)
Spurious Outputs	-23 dBc @ 23.5 kHz -15 dBc @ 12.0 MHz
Incidental AM	5 percent @ 3.74 kHz

(1) Parameter not simulated, but impact on implementation loss determined via analysis

Table 14-7. S-Band Implementation Losses

Modulation Scheme	Implementation Loss
PM, Residual Carrier	1.7 dB
BPSK	1.7 dB
QPSK	4.2 dB
PM, Residual Carrier (rate ½ coding)	1.9 dB
BPSK (rate ½ coding)	1.9 dB
QPSK (rate ½ coding)	2.3 dB

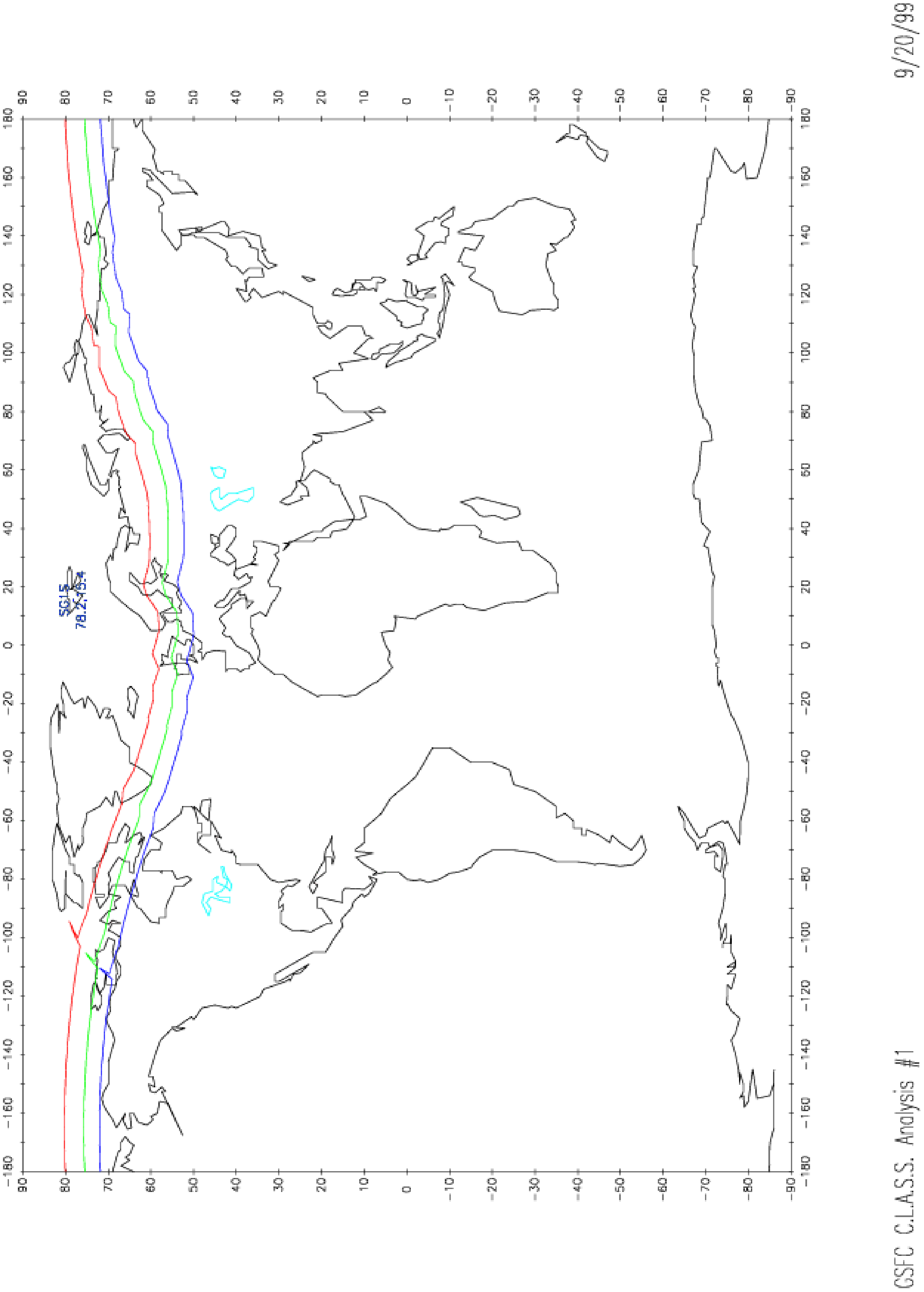


Figure 14-1. Norway Line-Of-Sight Coverage

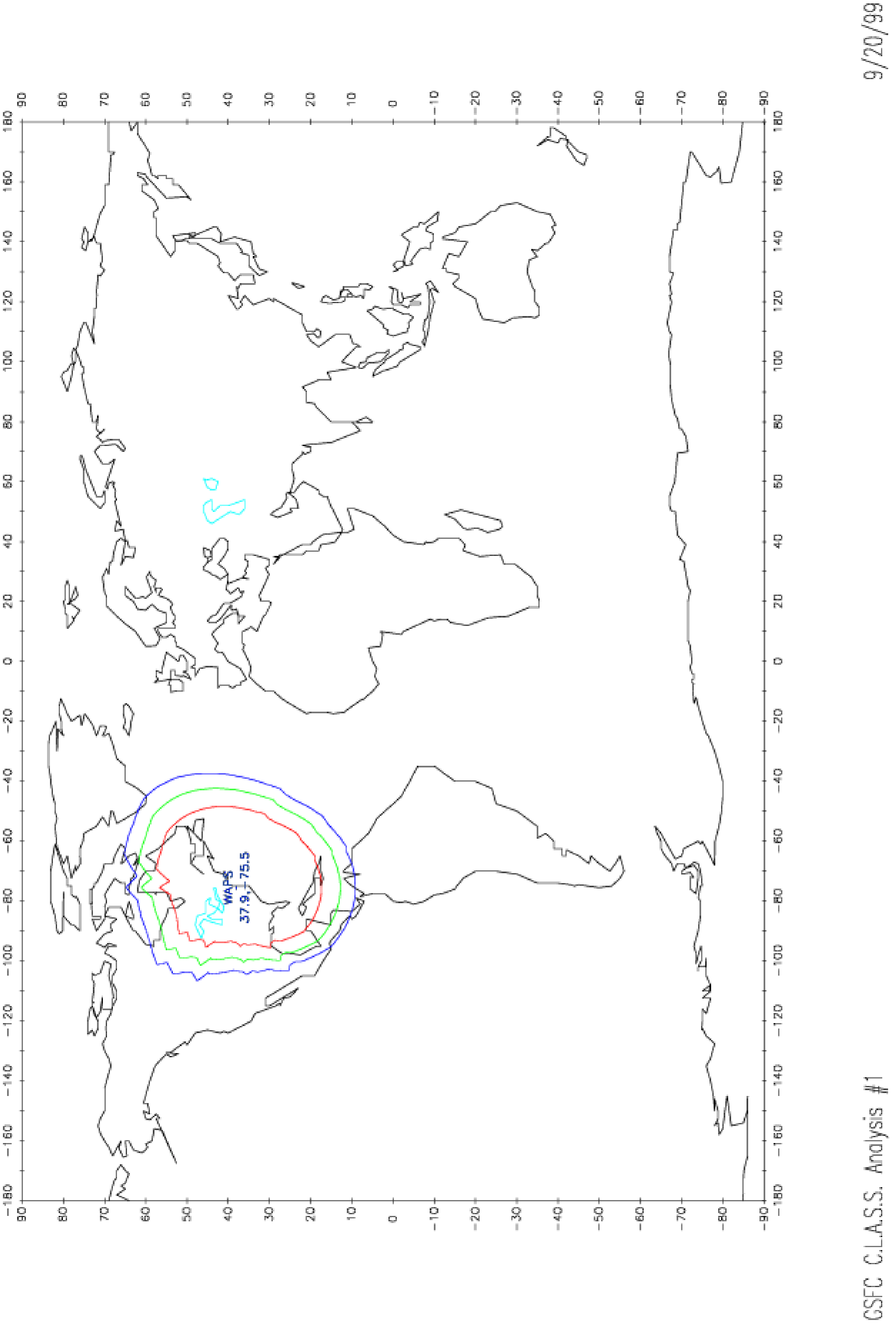


Figure 14-2. Wallops Line-Of-Sight Coverage

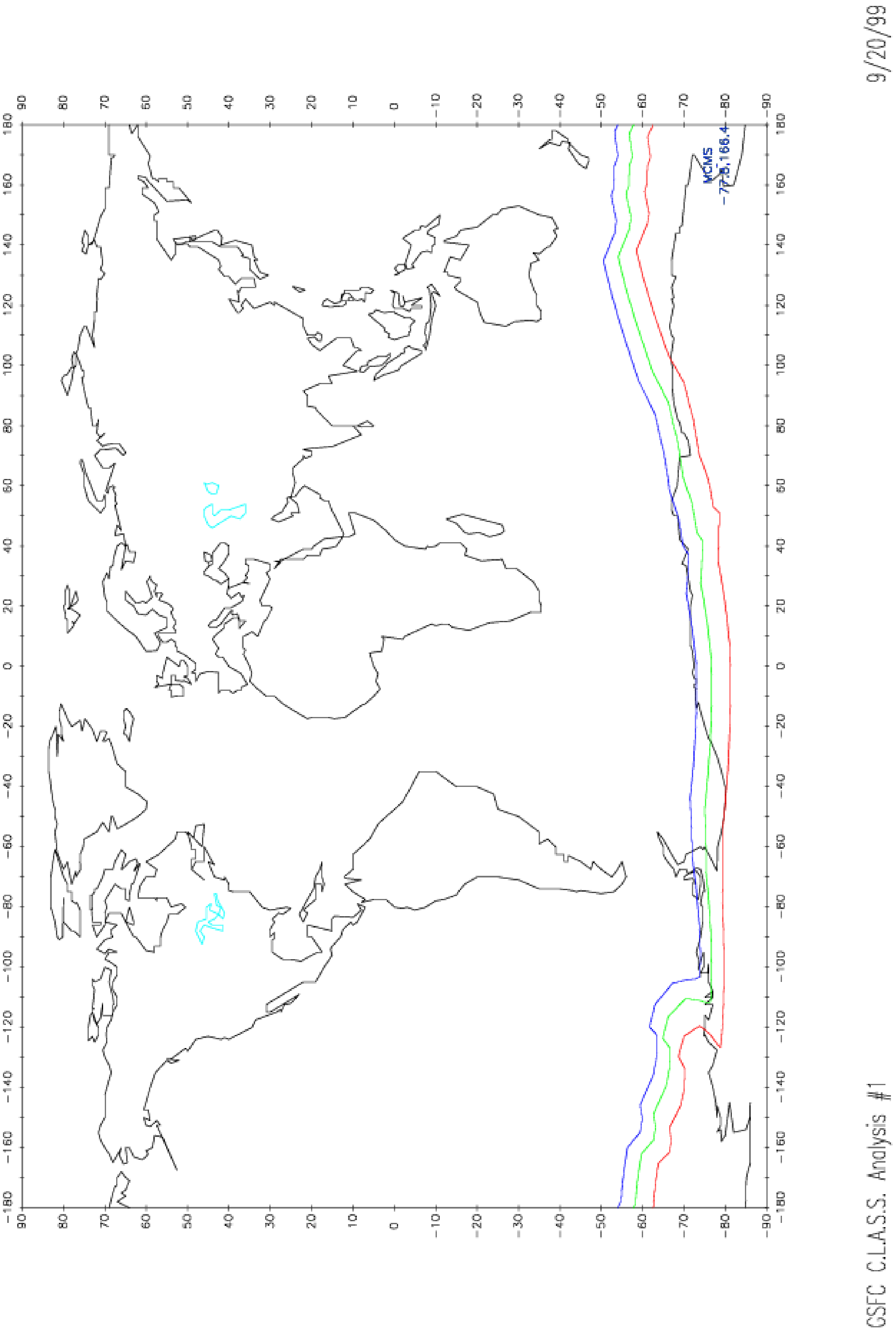


Figure 14-3. McMurdo Line-Of-Sight Coverage

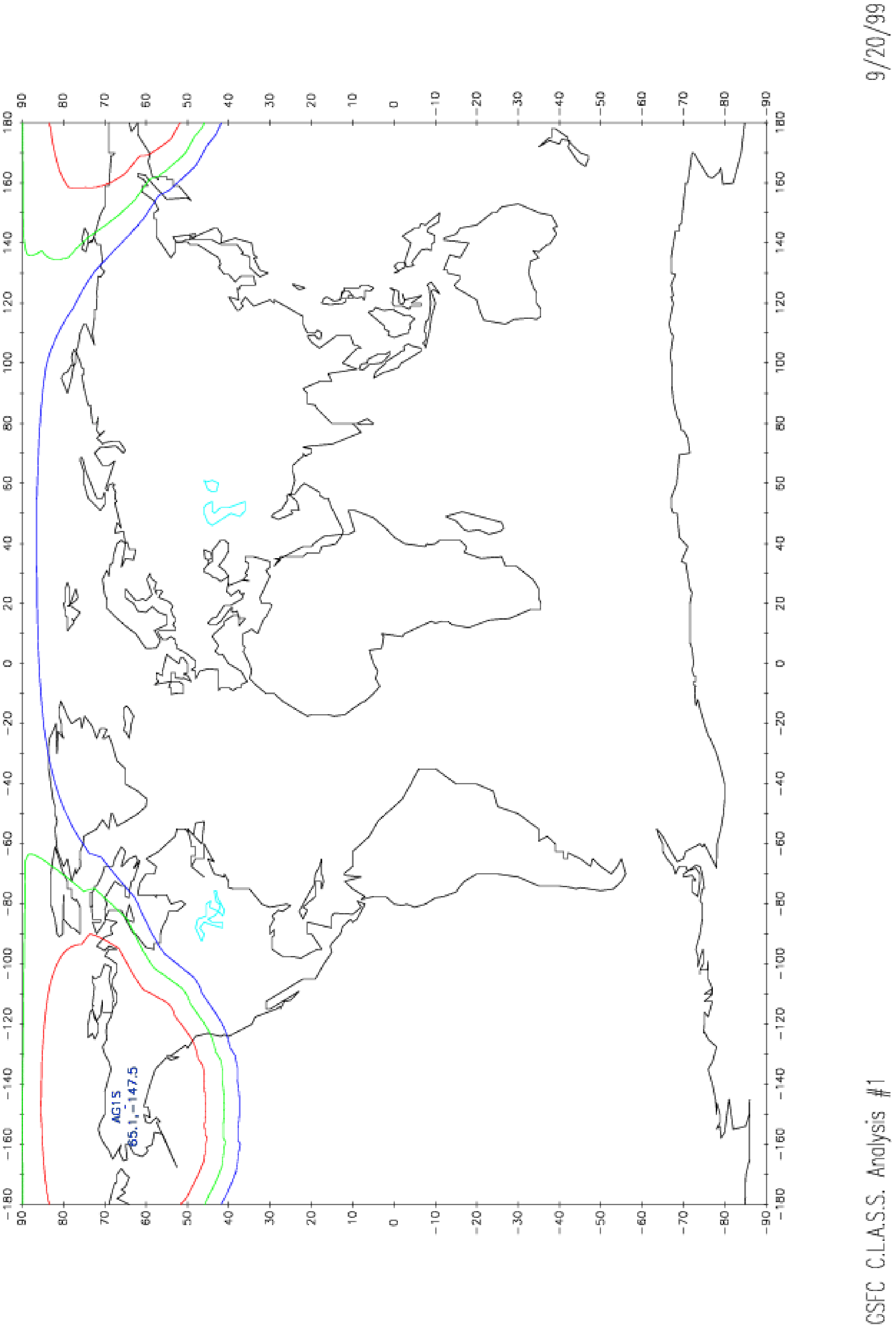
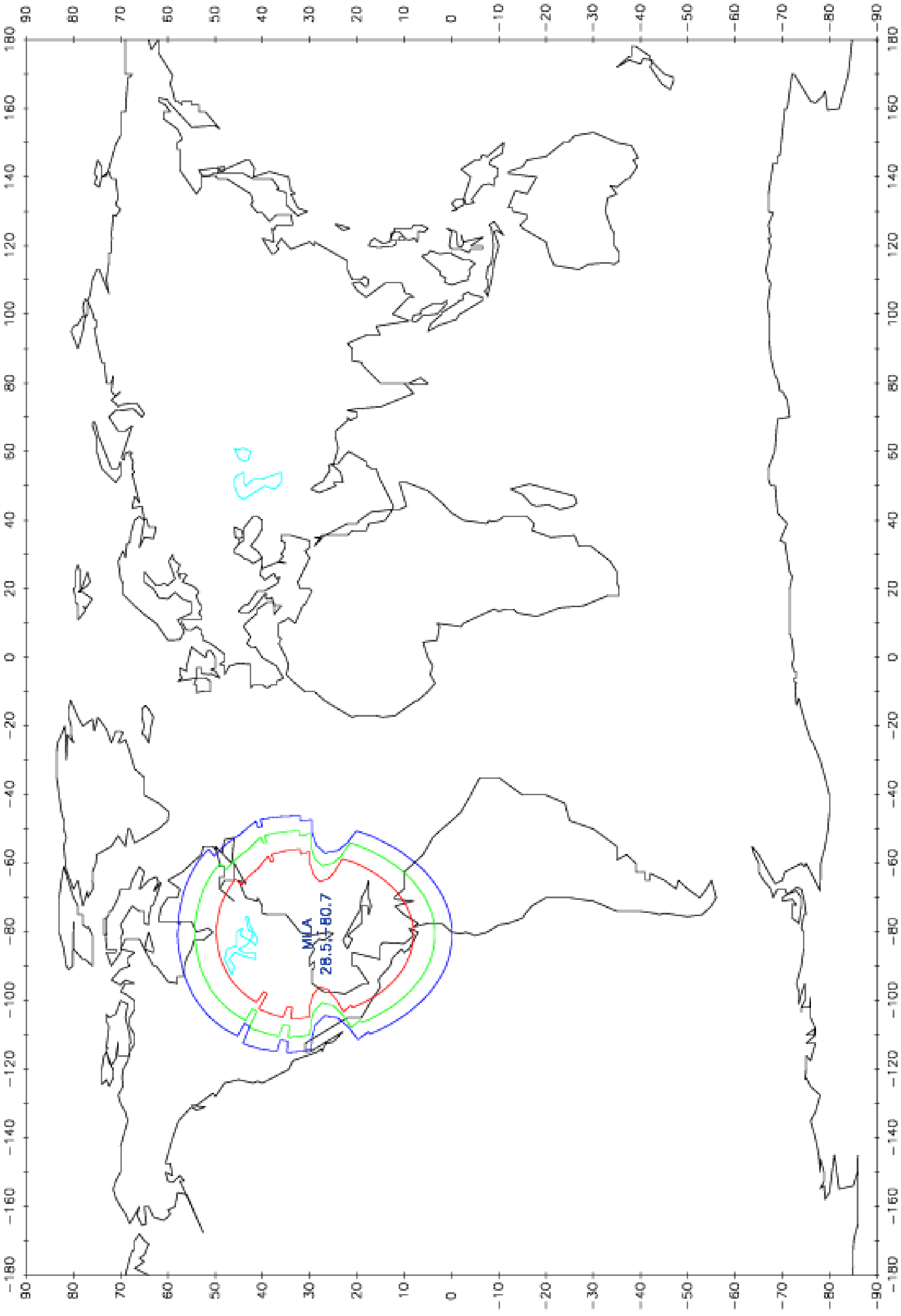


Figure 14-4. Poker/North Pole/ASF Line-Of-Sight Coverage



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GSFC C.L.A.S.S. Analysis #1

Figure 14-5. MILA Line-Of-Sight Coverage

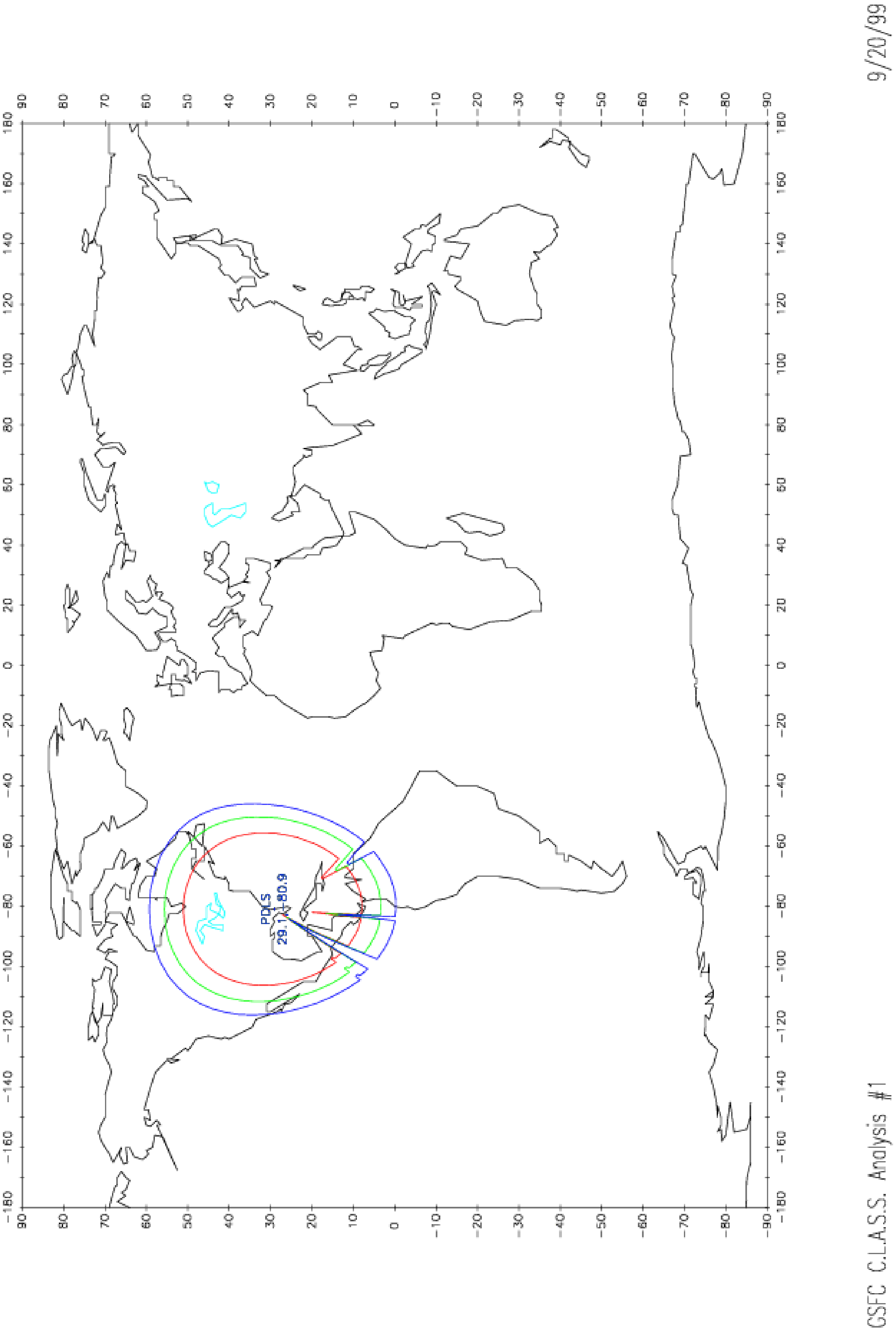

Figure 14-6. PDL Line-Of-Sight Coverage

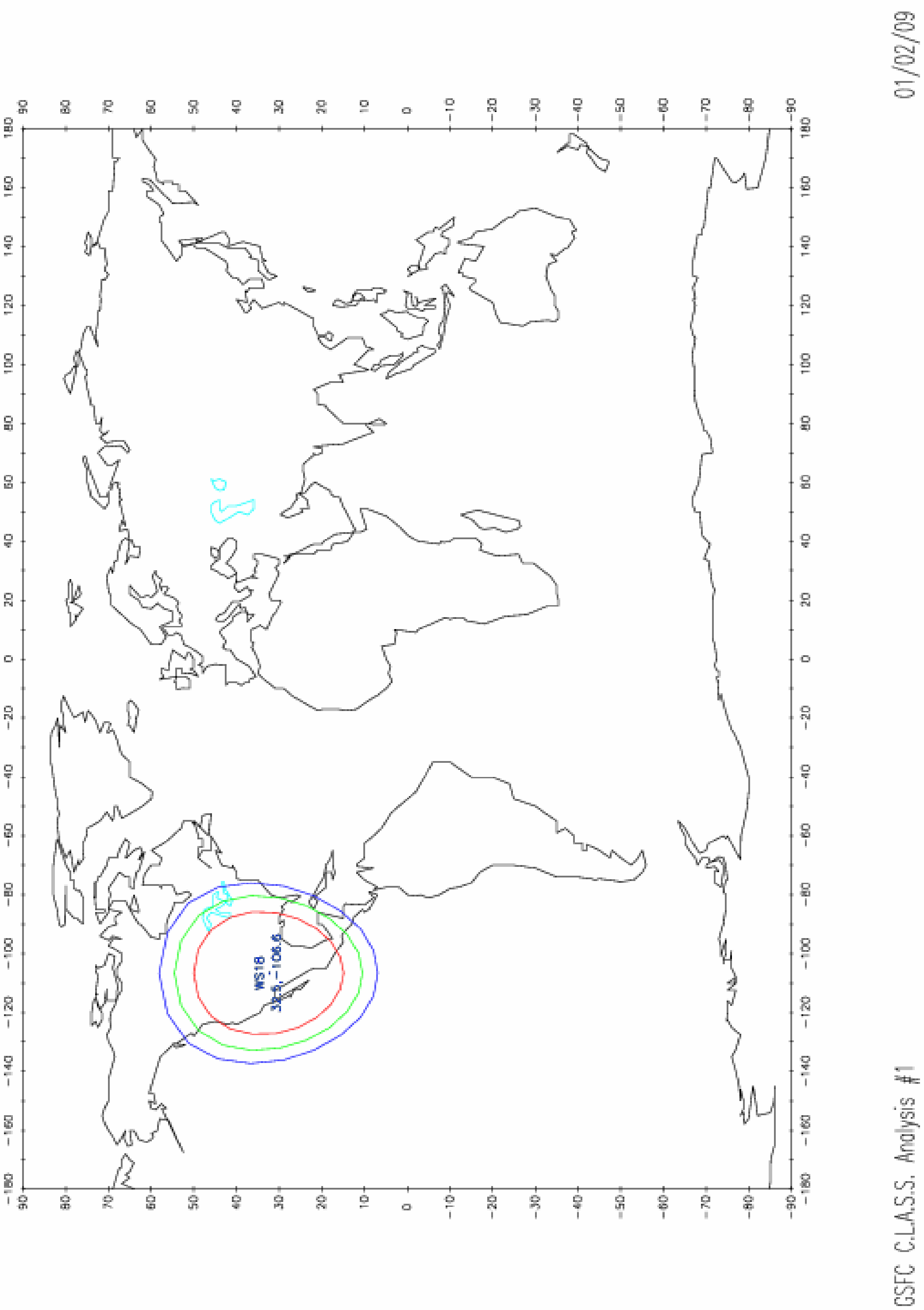

Figure 14-7. WS1 Line-Of-Sight Coverage

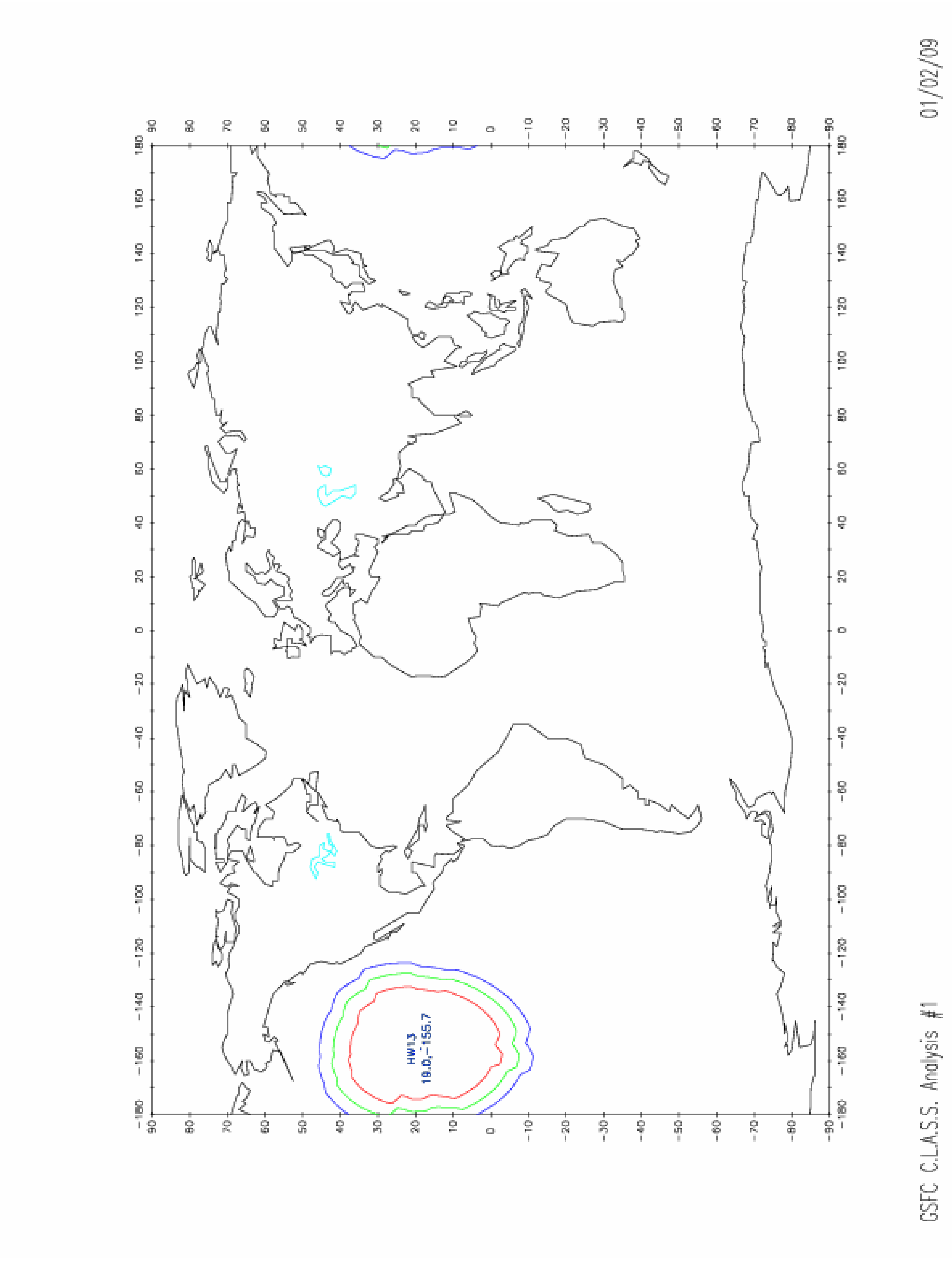

Figure 14-8. USN South Point Hawaii Line-Of-Sight Coverage

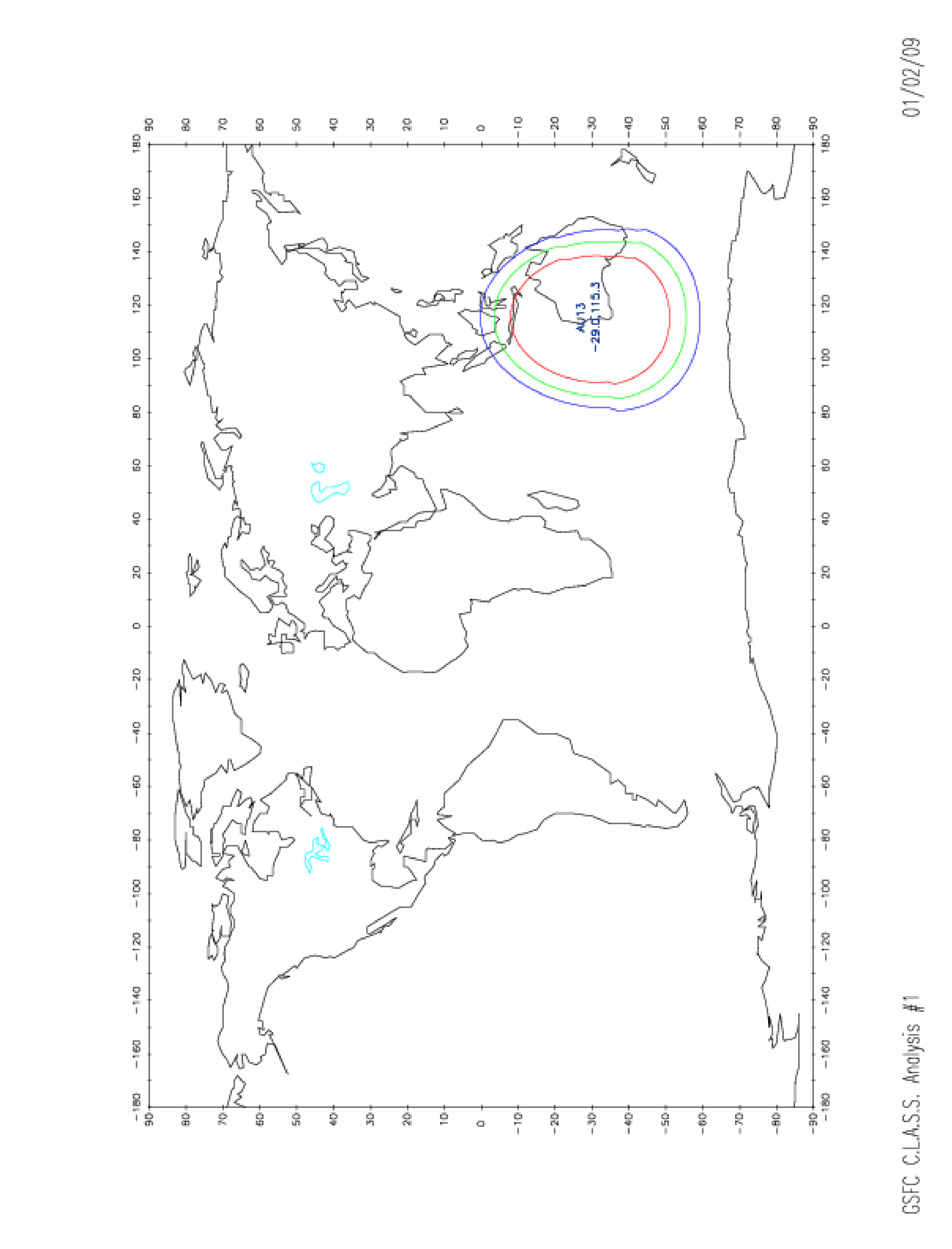

Figure 14-9. USN Dongara Western Australia Line-Of-Sight Coverage

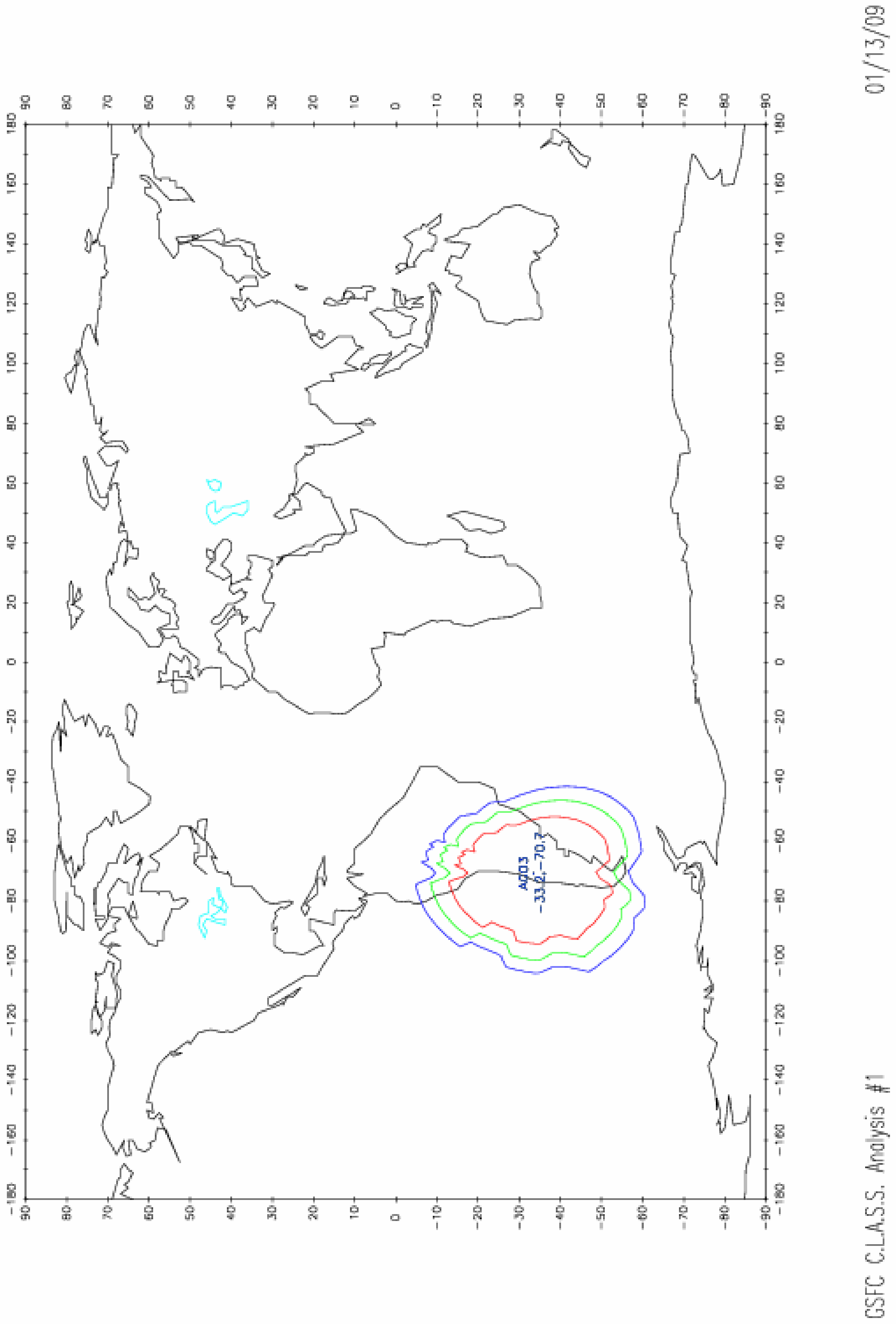

Figure 14-10. AGO Line-Of-Sight Coverage

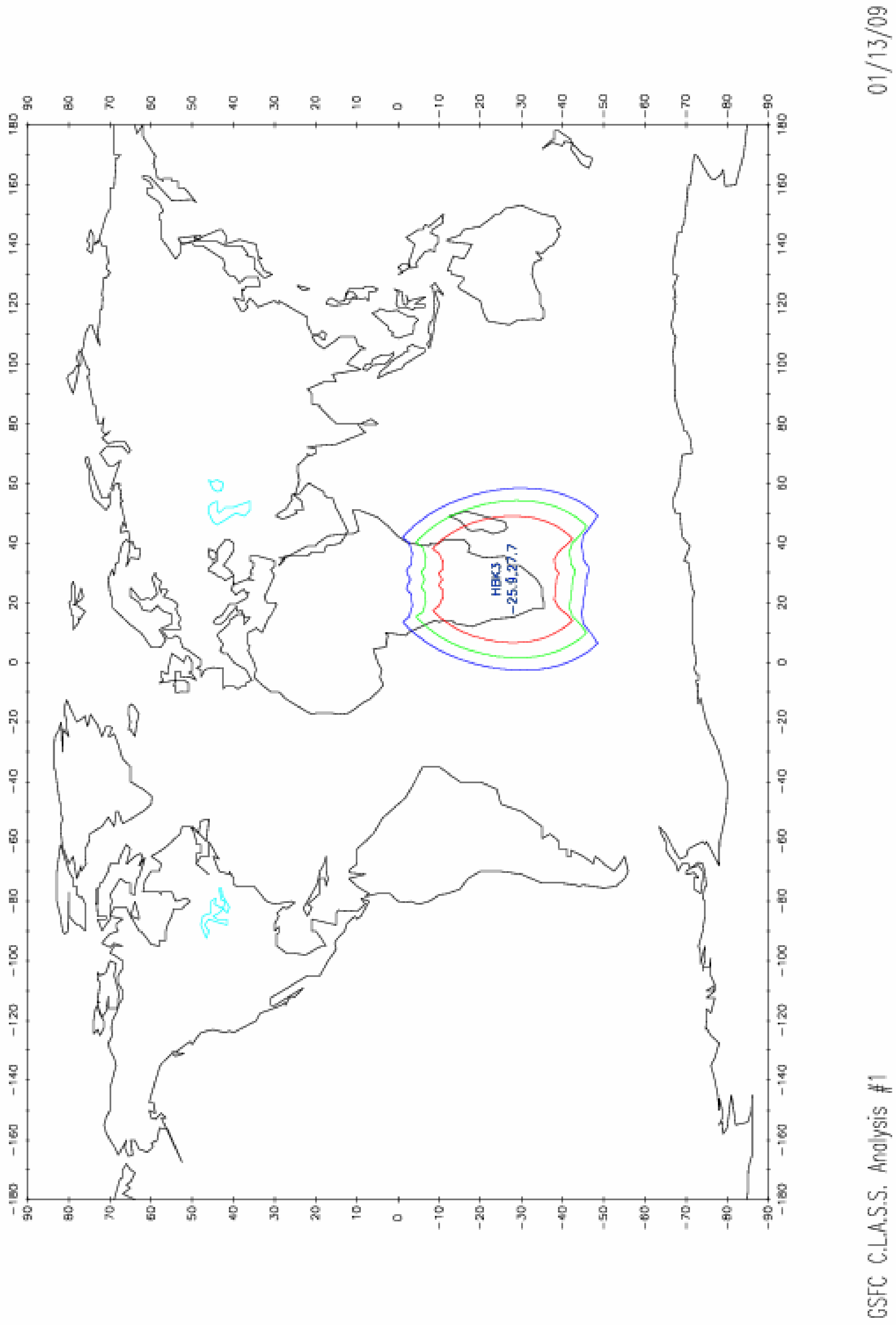

Figure 14-11. Hartebeesthoek Line-Of-Sight Coverage

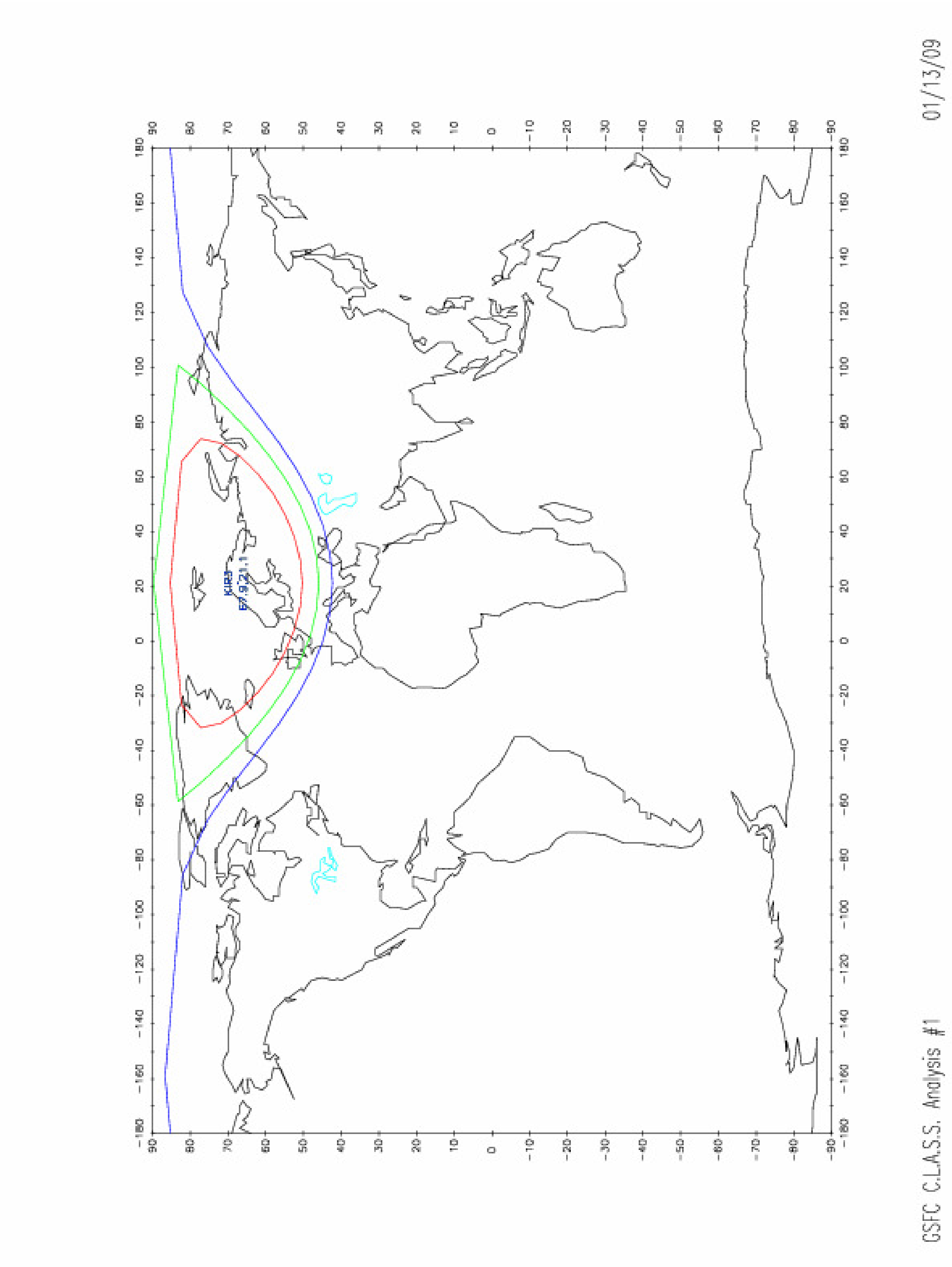

Figure 14-12. Kiruna Line-Of-Sight Coverage

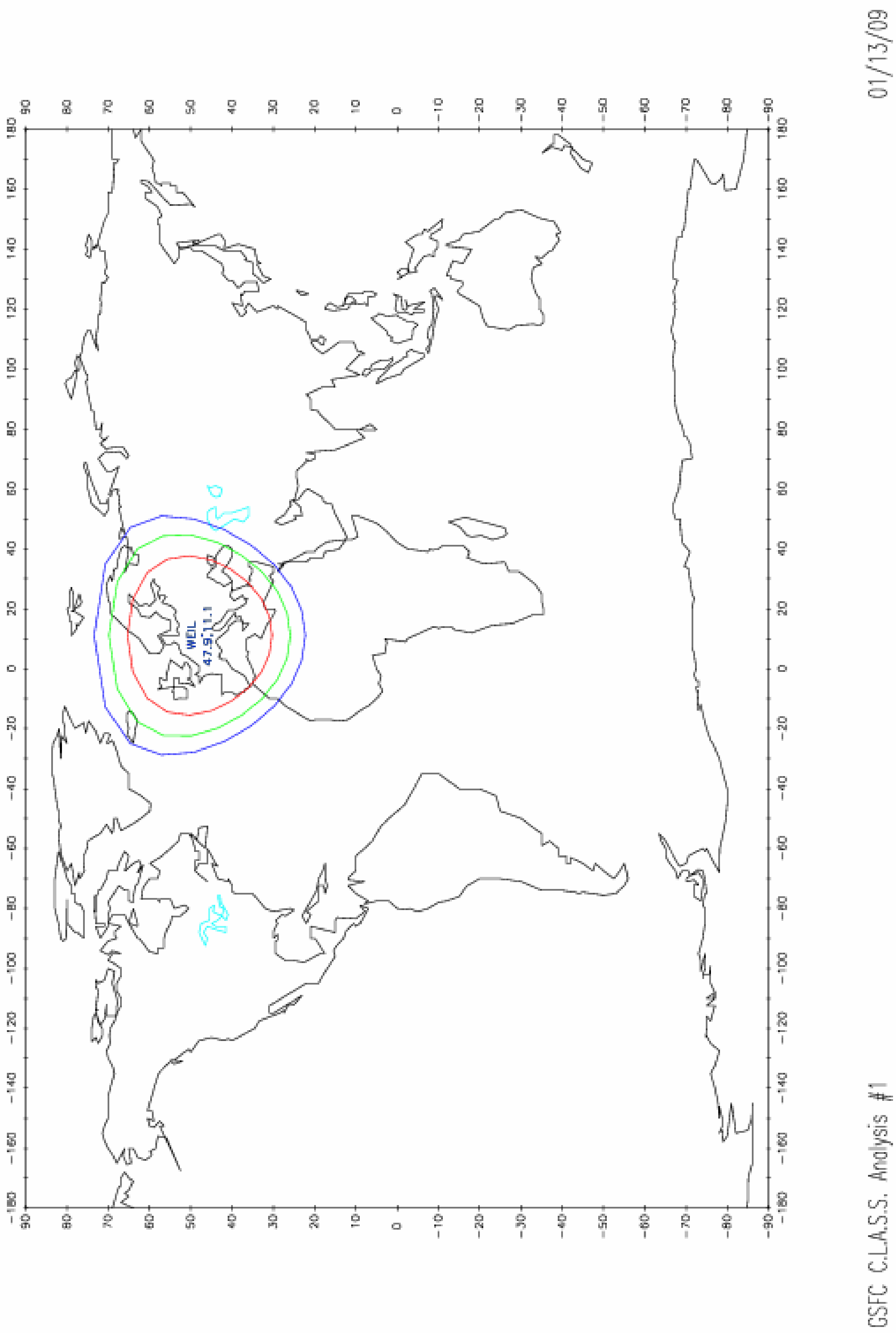

Figure 14-13. Weilheim Line-Of-Sight Coverage

Appendix A. Acronyms

ACE	Advanced Composition Explorer
ASF	Alaska Satellite Facility
AWOTS	Automated Wallops Orbital Tracking Station Project
AXAF	Chandra Advanced X-ray Astrophysics Facility
CADU	Channel Access Data Unit
CCB	Configuration Control Board
CCSDS	Consultative Committee for Space Data Systems
CDH	Command Delivery Header
CLASS	Communications Link Analysis and Simulation System
CLTU	Command Link Transmission Unit
CSR	Customer Service Representative
DCN	Document Change Notice
Dop	Doppler
DSN	Deep Space Network
DS-T	Deep Space Terminal
EIRP	Effective Isotropic Radiated Power
EOS	Earth Observing System
EPGS	EOS Polar Ground Stations
ESC	Exploration and Space Communications Projects Division
FCC	Federal Communications Commission
GB	Gigabytes
GN	Ground Network
GNPAO	Ground Network Performance Analyst Office
NENPO	Near Earth Network Networks Project Office
GNSO	Ground Network Scheduling Operator
GSFC	Goddard Space Flight Center
ICD	Interface Control Document
IP	Internet Protocol
IPDU	Internet Protocol Data Unit
IRAC	Interdepartment Radio Advisory Committee
ITU	International Telecommunications Union
KSAT	Kongsberg Satellite Services

KSC	Kennedy Space Center
LEO-T	Low Earth Orbiter-Terminal
Mbps	Megabits per second
MBps	Megabytes per second
METEOSAT	Meteorological Satellite
MGS	McMurdo Ground Station
MGTAS	Medium Gain Telemetry Antenna System
MILA	Merritt Island Launch Annex
MOC	Mission Operations Center
MSP	Mission Services Program (former GSFC Code 450 title)
MTRS	McMurdo TDRS Relay System
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications Network
NCC COMM	Network Control Center Communications
NCCDS	Network Control Center Data System (at WSC)
NEN	Near Earth Network
NISN	NASA Integrated Services Network
NOM	Network Operations Manager
NPD	NASA Policy Directive
NSF	National Science Foundation
NTIA	National Telecommunications and Information Agency
PAO	Performance Analyst Office
PDL	Ponce De Leon
POC	Point of Contact
PTP	Programmable Telemetry Processor
RCC	Range Control Center
RF	Radio Frequency
RF/ICD	Radio Frequency/Interface Control Document
R-S	Reed-Solomon
RSM	Range Support Manager
RSO	Range Safety Officer
RTP	Real-time Transmission Protocol
SAFS	Standard Autonomous File Server
SFCG	Space Frequency Coordination Group

SFDU	Standard Formatted Data Unit
SGS	Svalbard Ground Station
SMM	STDN Mission Manager
STDN	Spaceflight Tracking and Data Network
TCP	Transmission Control Protocol
TD	Test Director
TDMA	Time Division Multiple Access
TDRS	Tracking and Data Relay Satellite
TFDH	Telemetry Frame Delivery Header
TOTS	Transportable Orbital Tracking System
UDP	User Datagram Protocol
US	United States
USN	Universal Space Network
UTC	Universal Time, Coordinated
UTDF	Universal Tracking Data Format
WFF	Wallops Flight Facility
WGS	Wallops Ground Station
WISAC	Wallops Information System Access
WISDB	Wallops Information System Database
WOTIS	Wallops Orbital Tracking Information System
WOTRS	Wallops Orbital Tracking Resource Scheduler
WRC	World Radiocommunication Conferences
WSC	White Sands Complex
WSCOS	White Sands Complex Operations Supervisor