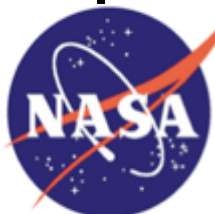**GSFC NEAR EARTH NETWORK CMO**

TBD

453-NENUG, Revision 5-
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Near Earth Network (NEN)
Users' Guide

Goddard Space Flight Center

Greenbelt, Maryland

National Aeronautics
and
Space Administration

Near Earth Network (NEN) Users' Guide
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This document supersedes all previous issues of the Near Earth Network Users' Guide, 453-NENUG (formerly 453-GNUG). Destroy all previously issued copies.

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Preface

As technology pushes the frontiers of science and discovery, the NEN is developing new capabilities to extend the reach of ground-based antenna systems beyond near earth orbit customers. The NEN anticipates that these missions will have multifarious telemetry, tracking, and commanding requirements, including high data rates and using complex waveforms, and so the NEN is developing capabilities to provide long duration contacts for medium earth orbit and earth/sun Lagrange point observatories. While the NEN currently supports high-rate S-band missions at L1, the NEN is also planning to provide Ka-band and X-band telemetry services for the L1 and L2 orbit regimes by 2024.

In addition to these new capabilities, the NEN is exploring technologies that will increase the NEN's service portfolio. Studies are under way that will make better use of existing antennas by implementing arraying technology and super-cooled low-noise amplifiers. These system enhancements will improve signal margins and allow much higher space to ground data transfer rates. To further enable low earth orbiters, the NEN is exploring the use of variable telemetry rate and energy efficient modulation and coding technology where the spacecraft and ground station synchronously vary the downlink rate to the highest rate that communications conditions permit.

An Antenna System (AS) includes the antennas, radomes, associated S-band, X-band, and Ka-band signal processing electronics, monitor and control components, timing components, and required facilities infrastructure. Historically, AS and ground stations have been used interchangeably, whereas, sometimes a ground station can also mean a group of AS on a site. In this document, Antenna Systems (AS) and sites are both referred to as stations.

As space-based earth sensing technology has increased, so has the demand for ground-based antenna services for low earth, polar orbiting missions. The NEN is developing new ground-based antenna systems, in new locations that will increase the availability of S- and X-band services and include new Ka-band services, as well. The Ka-band systems will support up to 4 Giga symbol per second, dual polarization telemetry services.

The NEN and NEN commercial partners continue to develop new capabilities that will provide cost effective methods for delivery of large volumes of data to satellite operators via the network of NASA and commercial antenna systems located around the world. NEN Management looks forward to feedback from the science community to ensure that the capabilities of the NEN keep pace with the needs of the missions. As the reader reviews this document, please be mindful that NEN capabilities are evolving faster than this document can be updated. Questions or comments regarding current or future capabilities should be directed to the Goddard Space Flight Center, Exploration and Space Communications Projects Division (ESC), Networks Integration Management Office (NIMO).

This Users' Guide for the NEN describes the current and near-term capabilities of the NEN ground stations and provides sufficient data for projects to begin interfacing with the NEN.

This document is controlled by the Code 453, Near Earth Network (NEN) Project Configuration Control Board (CCB). Proposed changes shall be submitted to the NEN Project Configuration Management (CM) Office (CMO) along with supportive material justifying the proposed change. Changes to this document will be made by Document Change Notice (DCN) or complete revision.

This document may be downloaded from the Exploration and Space Communications (ESC) Projects Division, Near Earth Network (NEN) library at https://ipdtdms.gsfc.nasa.gov/. If you do not have direct access to the library, you may obtain the document from the Code 453 Configuration Management Office (CMO).

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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.

NEN capabilities evolve based on user requirements and budget limitations. New projects can be assured of NEN capabilities agreed to in their Radio Frequency Interface Control Document (RFICD).

1.2 Scope

For the purpose of this document, the NEN consists of both the NASA-owned ground stations located in Alaska, Antarctica, Virginia, New Mexico, and Florida. In addition, the NEN consists of the contracted commercial stations run by the Swedish Space Corporation (SSC) [formerly the Universal Space Network (USN)] in Alaska, Australia, and Hawaii; SSC in Santiago, Chile, and Kiruna, Sweden, SSC/ South African National Space Agency (SANSA) in Hartebeesthoek, South Africa, and Kongsberg Satellite Services (KSAT) in Svalbard, Norway, Singapore, Punta Arenas, Chile and Troll, Antarctica. The NEN also includes support from the Network Integration Center (NIC) located at the GSFC.

For each NEN ground station, this document provides the following information:

   a. General characteristics, including geographic location, transmit/receive capabilities, and scheduling capabilities.

   b. Detailed performance characteristics.

   c. User tracking capabilities.

   d. Baseband data interfaces.

1.3 Reference Documents

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

   a. Consultative Committee for Space Data Systems (CCSDS) 401.0-B-17, *Radio Frequency and Modulation Systems, Part 1, Earth Stations, and Spacecraft,* Blue Book, Issue 25

   b. CCSDS 732.0-B-2 Cor. 1, *AOS Space Data Link Protocol*, Blue Book, Issue 2.

   c. CCSDS 412.0-G-1, *Radio Frequency and Modulation Systems-Spacecraft-Earth Station Compatibility Test Procedures*, Green Book, Issue 1. (Historical)

   d. CCSDS 413.0-G-2, *Bandwidth-Efficient Modulations: Summary of Definition, Implementation, and Performance*, Green Book. Issue 2.

e. NISN 001-001, *NISN Services Document (NSD)*

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

g. *NEN Compatibility Matrix.*

h. NASA Policy Directive (NPD) 2570.5, *NASA Electromagnetic Spectrum Management Manual*

i. NPD 8074.1, *Management and Utilization of NASA's Space Communication and Navigation Infrastructure.*

j. 450-PG-1310.1.1, *Networks Integration Process*

k. NASA Procedural Requirement (NPR) 2570.1, *NASA Radio Frequency (RF) Spectrum Management Manual*.

l. *NTIA Manual of Regulations & Procedures for Federal Radio Frequency Management (Redbook), May 2014 Revision of the May 2013 Edition*.

m. L7-ICD-40.1, *Interface Control Document between Landsat 7 Mission Operations Center (MOC) and the Landsat 7 Ground Network (LGN)*.

n. 5-1R5, *Space Frequency Coordination Group (SFCG) Recommendations regarding Efficient Spectrum Utilization for Space-To-Earth Links including SFCG Recommendations*: SFCG 5-1R5, SFCG 14-1R1, SFCG 14-3R9, SFCG 21-2R4, SFCG 21-3R1, and others as applicable.

o. 450-OIP-WSC, White Sands Complex (WSC) *Operations Interface Procedures (OIP)*.

p. CCSDS 912.1-B-3, *Space Link Extension – Forward CLTU Service Specification*, Blue Book, Issue 3.

q. CCSDS 131.0-B-2, *TM Synchronization and Channel Coding*, Blue Book, Issue 2.

r. 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

s. 700-DOC-007, *NASA Communications Operations Procedures (NASCOP),* Sanitized Version. (Historical – replaced by NISN-SOP)

t. NISN-SOP-0002, *NISN Standard Operating Procedures for Trouble Reporting, Activity Scheduling, Mission Freeze, and Major Outage Notifications*.

u. 450-CMFP-ESC, *Configuration Management Freeze Policy for the Integrated Networks and Supporting Elements*.

v. 450.1-TOOL-0008, *Customer Questionnaire* (new project questionnaire),

w. ITU-R Recommendations SA.1157, SA.1810 and P.618-8, *International Telecommunications Union Radio Regulations*.

x. 453-ICD-IRIS/NENG, *Near Earth Network (NEN) Interface Control Document (ICD) Between the NEN Gateway (NENG) and the Interface Region Imaging Spectrograph (IRIS) Mission Operations Center (MOC)*

y. *NASA Directory of Station Locations, (NDOSL)*,

z. SCNS-NEN-UG-0005, *Standard Autonomous File Server (SAFS) Users Guide*

1.4 **Related Internet Web Sites**

Alaska Satellite Facility	https://asf.alaska.edu/
FDF Home Page	http://fdf.gsfc.nasa.gov
GSFC Home Page	http://www.nasa.gov/goddard
Exploration and Space Communications Project (ESC) Website	http://ESC.gsfc.nasa.gov/
GSFC Online Library (NGIN)	https://code450ngin.gsfc.nasa.gov
Hartebeesthoek Tracking Station	www.sansa.org.za/spaceoperations/services/antennas
Large File Transfer	https://transfer.ndc.nasa.gov/
International Space Station	http://www.nasa.gov/mission_pages/station
Johnson Space Center	https://www.nasa.gov/centers/johnson
Kennedy Space Center	http://www.nasa.gov/centers/kennedy
Kiruna, SE – Esrange Satellite Station	http://www.sscspace.com/kiruna-satellite-station-4
Kongsberg Satellite Services	http://www.ksat.no/
Mission Set Database	http://msdb.gsfc.nasa.gov
MSFC Home Page	https://www.nasa.gov/centers/marshall
MSFC/Communications Service Office (CSO) Home Page	https://cso.nasa.gov/
NASA NEN Stations	https://esc.gsfc.nasa.gov/nen
NASA TV Schedule	http://www.nasa.gov/multimedia/nasatv http://www.nasa.gov/multimedia/nasatv/schedule.html
NEN Compatibility Matrix	https://esc.gsfc.nasa.gov/media/402
NEN Users' Guide	https://code450ngin.gsfc.nasa.gov/
Networks Integration Management Office (NIMO)	https://esc.gsfc.nasa.gov/nimo
Swedish Space Corporation (SSC)	https://www.sscspace.com/
SSC, Chile	http://www.sscspace.com/SSC-Chile
SSC, Santiago	https://www.sscspace.com/

Section 2. NEN Overview

2.1   **General**

This section provides an overview of the NEN, its ground stations, and customer services. The ground station overview provides general characteristics of NEN antenna tracking, telemetry, and command functions and capabilities. Further details on NEN ground station 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 NIMO (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. Please contact the Flight Dynamics Operations Director of the Flight Dynamics Facility (FDF) to determine tracking certification for specific antennas.

The information in this document describes the typical performance of the ground stations. Capabilities are often enhanced and potential users are encouraged to discuss the mission requirements with NIMO to ensure that requirements and capabilities are fully understood. Antenna gain-to-noise temperature (G/T) in Table 2-1 is an estimate for 5° antenna elevation for S-band and 10° for X-band and Ka-band.

The NASA NEN is a direct to earth network that provides 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. These NEN customers may have Low-Earth Orbits (LEO), Geosynchronous (GEO) orbits, 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 missions is listed in Figure 2-1.

Figure 2-2 represents Contractor/University Operated ground stations and currently contracted commercial stations. NEN consists of both the Contractor/University Operated ground stations (located in Alaska, Antarctica, Virginia, New Mexico, and Florida) and the contracted commercial stations. For support from commercial stations not yet shown on Figure 2-2, please contact NIMO.

NEN Customer Diversity Mission Examples and Bands	**Customers**	• NASA • Other Government • International • Commercial
	Phases	• On-orbit • Launch • Early Orbit • Disposal
	Orbits	• Sub-orbital LEO • GEO • Highly Elliptical • Launch • LEO – polar, mid latitude & equatorial • Lagrange
	Frequency	• X-band • S-Band • VHF • Ka-band

Figure 2-1. NEN Customers, Mission Examples and Bands
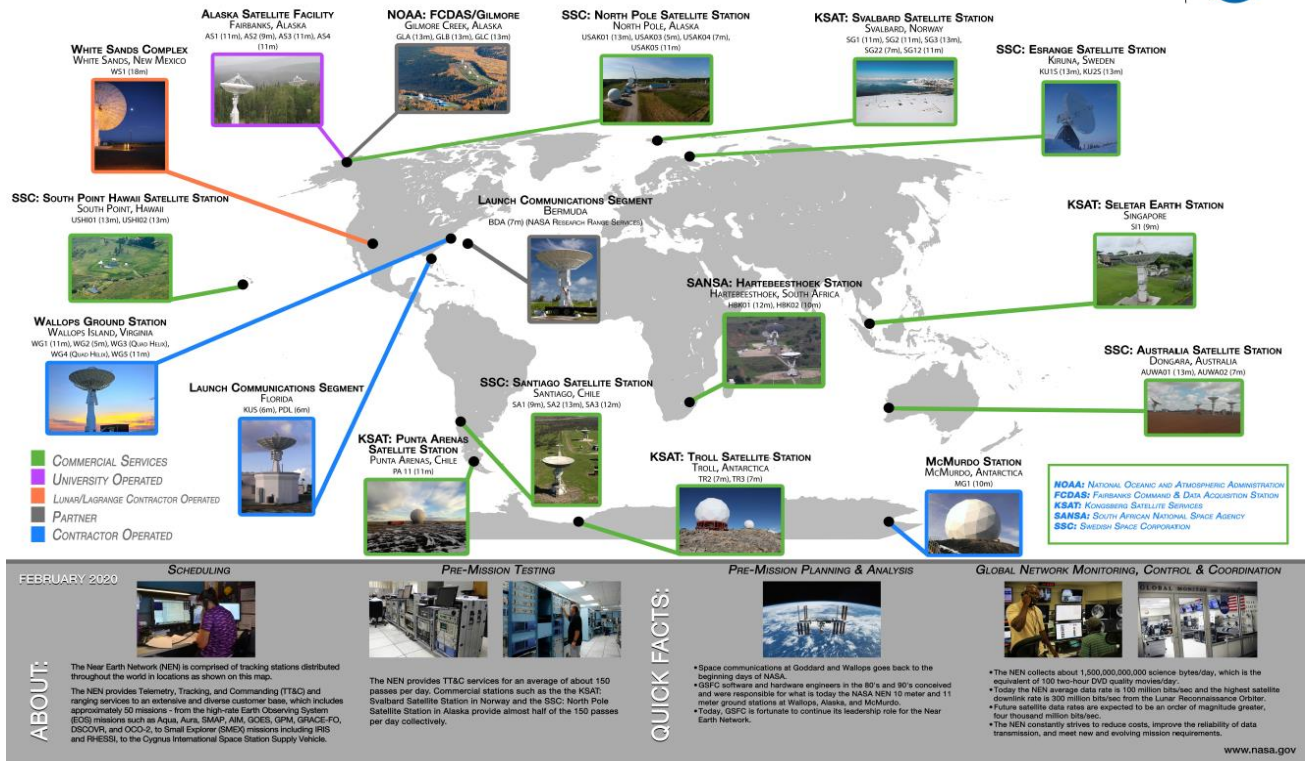
Figure 2-2. NEN Locations

Table 2-1. NEN Overview

Station Location	Antenna Name	Antenna Diameter (m)	Transmit Frequency (MHz)	Effective Isotropic Radiated Power (EIRP) (dBW)	Receive Frequency (MHz)	G/T (dB/K)	Location	Tracking
Fairbanks, Alaska (Alaska Satellite Facility (ASF))	AS1	11.3	2025-2120	64.6	2200-2300 8025-8500	22.0 35.2	64.8587°N 147.8576°W	A,D,R
	AS2	9.1	2025-2120	59	2200-2300 8025-8500	21.0 36.2	64.8597°N 147.8472°W	A,D,R
	AS3	11.0	2025-2120	65.7	2200-2300 8025-8500	22.9 35.2	64.8589°N 147.8541°W	A,D,R
	AS4 (Operational 6/2021)	11.3	2025-2120	56	2200-2300 8025-8500 25500-27000	21.4 35.0 41.5	64.7936° N 147.5381° W	A, D
North Pole, Alaska (SSC)	USAK01	13	1750-1850 2025-2120	69 68	2200-2400 8000-8500	23.5 37.7	64.8042° N 147.5002° W	A,D,R
	USAK03	5.4	2025-2120	55	2200-2400 8000-8500	16.0 31.50	64.8047° N 147.5042° W	A,D
	USAK04	7.3	2025-2120	58.4	2200-2400 8000-8500	19.6 31.0	64.8047° N 147.5042° W	A,D
	USAK05	11	2025-2120	65.4	2200-2300 8100-8400	23.2 34.0	64.8034° N 147.5006° W	A,D
Florida	KUS	6.1	2025-2120	57	2200-2400	17.2	28.542064 N 80.642953 W	A
	PDL	6.1	2025-2120	57	2200-2400	17.2	29.066647 N 80.913022 W	A

Station Location	Antenna Name	Antenna Diameter (m)	Transmit Frequency (MHz)	EIRP (dBW)	Receive Frequency (MHz)	G/T (dB/K)	Location	Tracking
Hartebeesthoek, South Africa (SSC/SANSA)	HBK01	12	2025-2150	69	2200-2400	22.4	25.8870°S 27.7120°E	A,D,R
	HBK02	10	2025-2100	65	2200-2400 8000-8400	19.1 30.5	25.8869°S 27.7067°E	A,D,R
South Point, Hawaii (SSC)	USHI01	13	2025-2120	78	2200-2400 8000-8500	23.5 37.7	19.0140° N 155.6633° W	A,D,R
	USHI02	13	2025-2120 7025-7200	68 86	2200-2400 8000-8500	23.5 37.7	19.0138° N 155.6629° W	A,D,R
Dongara Australia (SSC)	AUWA01	13	2025-2120	68	2200-2400 8000-8500	23.5 37.7	29.0457° S 115.3487° E	A,D,R
	AUWA02	7.3	7025-7200	85	-	-	29.0457° S 115.3487° E	Slave to AUWA01
Kiruna, Sweden (SSC)	KU1S	13	2025-2120	69	2200-2400 8000-8400	23.0 33.0	67.8896°N 21.0657°E	A,D,R
	KU2S	13	2025-2120	69	2200-2300 7600-8500	22.5 37.5	67.8791°N 21.0380°E	A,D
McMurdo, Antarctica	MG1	10	2025-2120	63	2200-2400 7700 – 8500	21.0 32.0	77.8391°S 166.6671°E	A,

Station Location	Antenna Name	Antenna Diameter (m)	Transmit Frequency (MHz)	EIRP (dBW)	Receive Frequency (MHz)	G/T (dB/K)	Location	Tracking
Troll, Antarctica (KSAT)	**TR2 (TrollSat)**	7.3	2025-2120	51	2200-2300 8025-8500 25500-27000	19.4 32 38	72.0022°S 2.0575°E	A,D
	TR3 (TrollSat)	7.3	2025-2120	51	2200-2400 7500-8500	19.4 32.0	72.00215° S 2.525012° E	A,D
Svalbard, Norway (KSAT)	**SG1**	11.3	2025-2120	63.5	2200-2400 7700-8500	22.1 36.8	78.231°N 15.389°E	A,D
	SG2	11.3	2025-2120	59	2200-2400 7500-8500	23.8 35.7	78.230°N 15.398°E	A,D
	SG3	13-	2025-2120	67	2200-2400 7500-8500	23.0 37.8	78.2297°N 15.4081°E	A,D
	SG12 (Operational 4/2021)	11.3	2025-2120	56	2200-2300 8025-8500 25500-27000	23 36 42	78.2° N 15.4° E	A,D,R
	SG22	7.3	2025-2120	51	2200-2300 25500-27000	19.4 38	78.2° N 15.4° E	A,D
Punta Arenas, Chile (KSAT) (Operational 5/2021)	**PA11**	11.3	2025-2120	56	2200-2300 8025-8500 25500-27000	23 36 42	52.9° S 70.9° W	A,D,R

Station Location	Antenna Name	Antenna Diameter (m)	Transmit Frequency (MHz)	EIRP (dBW)	Receive Frequency (MHz)	G/T (dB/K)	Location	Tracking
Santiago, Chile (SSC)	**SA1**	9-	2025-2120	75	2200-2300	23.0	33.1511° S 70.6664° W	A,D,R
	SA3	12	2025-2120	67.5	2200-2300	25.7	33.1515° S 70.6663 W	A,D,R
	SA2	13	2025-2120	70	2200-2300	24.4	33.1483° S 70.6676° W	A,D,R
Singapore (KSAT)	**SI1**	9.1	2025-2120	59	2200-2300 7985 8500	20.5 33.4	1.3962°N 103.8343°E	A,D
Wallops Island, Virginia	**WG1**	11.3	2025-2120	64.6	2200-2400 8000-8500	22.6 34.5	37.9249°N 75.4765°W	A,D,R
	WG2	4.7	2025-2120	59.2	2200-2300	17.0	37.9239°N 75.4761°W	Not Available
	WG3	N/A (Quad Yagi)	139.208	43.4	143.625	N/A	37.924°N 75.4764°W	Not Available
	WG4	N/A (Quad Yagi)	130.167	43.4	121.750	N/A	37.9236°N 75.4775°W	Not Available
	WG5 (Operational 9/2021)	11.3	2025-2120	56	2200-2300 8025-8500 25500-27000	21.4 35.0 41.5	37.92626° N 75.475561° W	A,D,R
White Sands, New Mexico	**WS1**	18.3	2025-2120	72 or 81	2200-2300, 25500-27000	29.6 46.98	32.5048°N 106.6108°W	A,D,R

Note – Tracking column capability- A=Angles, D=Doppler, R=Ranging

"Some listed commercial stations might require development and or testing and listed commercial stations might not include all asset capabilities."

2.2   NEN Ground Stations Overview

The NEN provides services from a diverse collection of ground station 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 LEO polar and low-inclination orbital missions, to Lunar and Lagrange orbits and to GEO spacecraft. 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 Wallops launch range, as well as to provide some coverage to launches from Kennedy Space Center. Stations are distributed around the globe to provide mission-critical event coverage to missions.

a. This NEN Users' Guide addresses the Contractor/University Operated/Maintained stations that are dedicated to NASA customer missions and commercially owned stations. Contractor/University Operated assets under the NEN are located at the following stations: Wallops Ground Station (WGS) in Virginia, operated by NASA.

b. McMurdo Ground Station (MGS) in Antarctica, operated by NASA.

c. Alaska Satellite Facility (ASF) in Alaska, operated by the University of Alaska, Fairbanks (UAF).

d. Florida Launch Communications Stations in Florida, operated by NASA.

e. White Sands Complex (WSC) ground station in New Mexico, operated by NASA.

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

a. KSAT station in Svalbard, Norway, Singapore, Chile and Antarctica.

b. SSC stations in Alaska, Hawaii, Australia, Santiago, Chile and Kiruna (Sweden).

c. SSC/SANSA station in Hartebeesthoek, South Africa.

These commercial service providers and their antenna assets are discussed in detail in this NEN Users Guide. Additional information about the commercial service providers may be acquired on the respective provider's web site in Section 1.4.

The NEN stations are summarized in Table 2-1 and detailed in chapters that follow. Additional information can be found at the following URL https://esc.gsfc.nasa.gov/NEN. The NEN Compatibility Matrix can be found at https://esc.gsfc.nasa.gov/media/402.

2.3   NEN Customer Services Overview

The 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, Radio Frequency (RF) link margins, geometric coverage analyses, and preliminary funding and staffing requirements. The *Customer Questionnaire*, 450.1-TOOL-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 and to obtain commitment of SCaN resources.

2.3.1 Obtaining NEN Services

For all NEN stations, flight projects request NEN support through NASA/GSFC, Code 450.1, 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 Networks Integration Manager 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 https://esc.gsfc.nasa.gov/nimo.

All customers planning on conducting defense-oriented activities with the intent of using the NASA Space Communications and Navigation (SCaN) Program Office's NEN assets at the MGS are responsible to be compliant with the Antarctic Treaty in order to obtain service from the SCaN and the antenna site.

2.3.2 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 concept development to assist in the definition of customer flight project needs for ESC services. Typical information needed for analyses includes the projected requirements for the communications timeline, such as, frequency, modulation, coding, data rate, number of data channels, spacecraft (S/C) antenna masking, and contact constraints.

2.3.3 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 is 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 RFICD is under NASA's control via the CCB but is a bi-lateral document signed by the mission and code 450. The Space Network (SN) has had issues providing service to customers who transmit pattern data or long strings of 1s or 0s. The SN worked with CCSDS) to develop a recommendation that customers use data randomization during all phases of the mission. The NEN recommends the same strategy for customers requiring NEN services.

2.3.4 Compatibility Testing

RF compatibility testing is performed after the flight radio is integrated into the spacecraft. Risk mitigation testing on the prototype model may be performed earlier to reduce risk, but final

compatibility is performed on the flight model. 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.

2.3.5 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 Interface Control Documents (ICD) 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.

2.3.6 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 NENS-GN-PRCD-0208, *NEN Directive Procedure,* 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 the management control of those sites.

2.5 NEN Outage and Service Loss Notification

2.5.1 Network Advisory Messages

Network Advisory Messages (NAM) are issued as a result of scheduled outage periods and allow the scheduling office and projects to mitigate impacts. The target date for submission is not later than 7 days prior to the event. However, shorter notice emergency notifications are issued as needed. The distribution is controlled via an email "list serve" collective and is controlled by NEN management. See Figure 2-3.

```
NAM ID : 0000788
        Network : NEN
        Expires: 4/21/2009
        Status: Open
NAM Title: Wallops Flight Facility Main Base Power Outage (April 18-19, 2011)
Advisory Message: This NAM is to notify the NEN customers that there will be a power outage at the Wallops
Flight Facility Main Base that will also affect the Wallops Ground Orbital Tracking Station (AWOTS).  AWOTS
will be down on April 18, 2011 from 1000 Universal Time Code (UTC) to 0100UTC April 19, 2011 and again on
April 19, 2011 from 1000UTC to 0100UTC on April 20, 2011.  This downtime is inclusive of the time to take the
equipment down and bring it back to operational status each day.
```

Figure 2-3. Example Network Advisory Message

2.5.2　　　**Status Messages**

Ground Network Status Messages (GNSTAT) are issued as a result of system or site failures and an e-mail is generated that details the anomaly (see example). The White Sands Operations Supervisor (OS) uses this information to contact management and ensure project personnel are informed of problems. The OS also assures that supports are moved to other sites via the scheduling office whenever possible. The email distribution is controlled by NEN management. A closure status message is e-mailed once the issue is resolved. See Figure 2-4.

```
TO: GNSTAT
A. SUBJECT: MG1 10M RED
B. START OF ANOMALY: 102/1646Z
C. ETRO: UNKNOWN
D. CHANGE OF STATUS: RED
E. EQUIPMENT AFFECTED: 10M
F. TYPE OF PROBLEM: Loss of communications with remote facility (i.e., Bldg 71 and 10M antenna)
G. COMMENTS:  Severe weather conditions in McMurdo prevent the crew from reaching the 10m antenna or
Bldg. 71 where the ACU, receivers, combiners, etc. are located.
Current winds at antenna are in excess of 85MPH
```

Figure 2-4. Example GNSTAT Message

2.5.3　　　**Significant Event Reporting**

The Significant Event Reporting System 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. A closure message is issued once the anomaly is resolved. See Figure 2-5.

2.5.4　　　**Comprehensive Discrepancy System**

The Comprehensive Discrepancy System is used for entering and managing operational, test and engineering discrepancies through disposition and resolution. The execution of this database system requires multiple levels and facets of responsibility in order to be efficient and effective. Discrepancy reporting and resolution is initiated and resolved at the respective sites. Discrepancy

closure however is administered through a focal point of administrative representatives in order to maintain control and consistency. A closure message is e-mailed once the issue is resolved.

Root Cause / Corrective Action (RCCA) is performed anytime there is a service loss during launch and early orbit phase of a mission and anytime there is a catastrophic system operational failure with regard to the performance of a NEN orbital system. RCCA will also be performed when Discrepancy Report review indicates a possible systemic operational issue, or when management deems it appropriate based on level or potential level of impact. Management serves as the ultimate authority in determining whether or not RCCA is required. See Figure 2-6.

2.6 **Status Server Overview**

The NEN Remote Status Server (RSS) exists on the Open Internet Protocol Operational Network (IONet) at WGS. The RSS currently receives status data from McMurdo Ground Station (MG1), White Sands Complex (WS1), Wallops Ground Station (WG1/WG2), and Alaska Satellite Facility (AS1/AS2/AS3).

Data comes in from stations in a fixed field status stream via Transmission Control Protocol/Internet Protocol (TCP/IP) to both servers, one serves as the prime for reporting purposes. Data is placed in a database for feeding a web page interface, custom reports, and a real time TCP/IP stream. Reports may be generated when the station goes from pre-pass into active track, or active track into post-pass. Reports can also be run on a time basis, such as a daily or weekly summary of operations. Reports may be distributed via email or SFTP to the customer.

Customers may request and be granted access to the RSS web pages for real time monitoring of satellite tracks, as well as historical reports. When connecting into Status Server, the user is presented with an entrance page, see Figure 2-7. At any time, the user may return to the entrance page by clicking the NASA logo. The top list shows all supports that are currently active for each station. If a station does not have an active support, the next support scheduled is displayed. The drop down filters for spacecraft and station will affect the contents of the lower window. A user has permission to see only spacecraft with which they are involved.
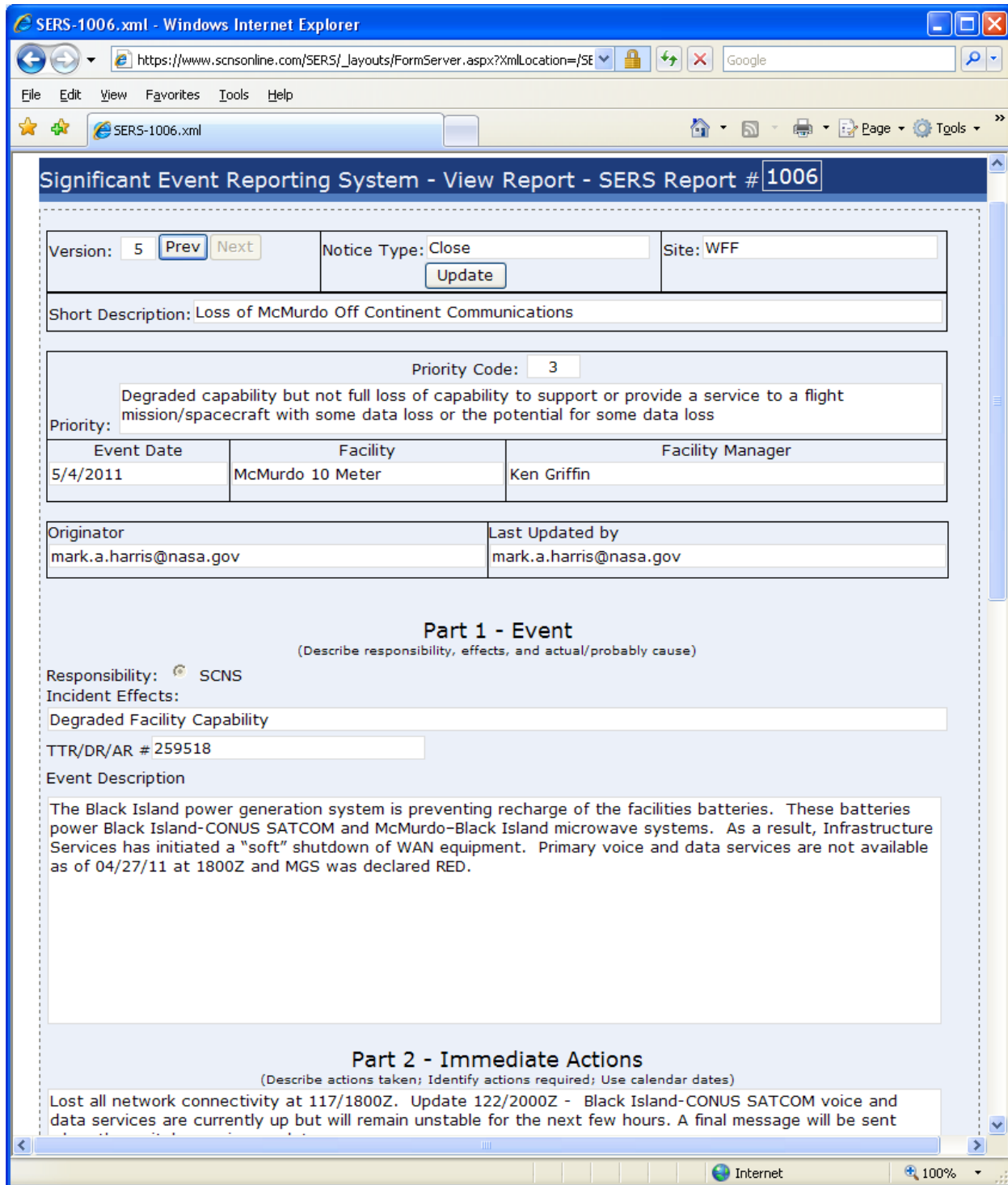
Figure 2-5. Significant Event Report Message

Figure 2-6. Example Discrepancy Report
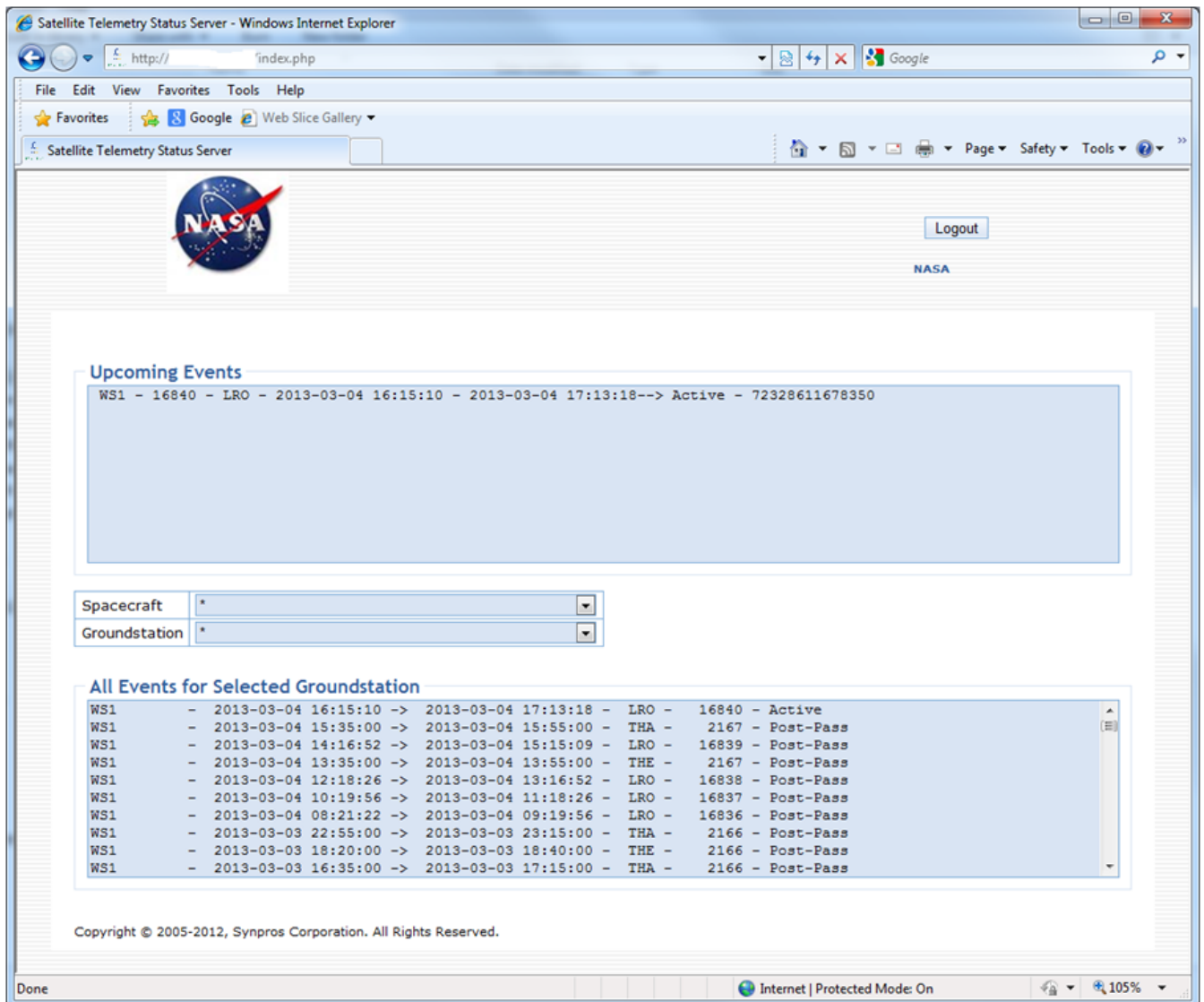
Figure 2-7. RSS Entrance Screen

2.6.1 Selection of an Active Track from the Entrance Page

Clicking on one of the entries in the lower entrance screen window moves the user to the data page. See Figure 2-8. If the pass is active, the data will change in near real time. If the pass is in the past, the data presented is the last data set received from the station during the support. The right side of the screen presents Boolean data points. The color and text is configurable according to station and spacecraft.
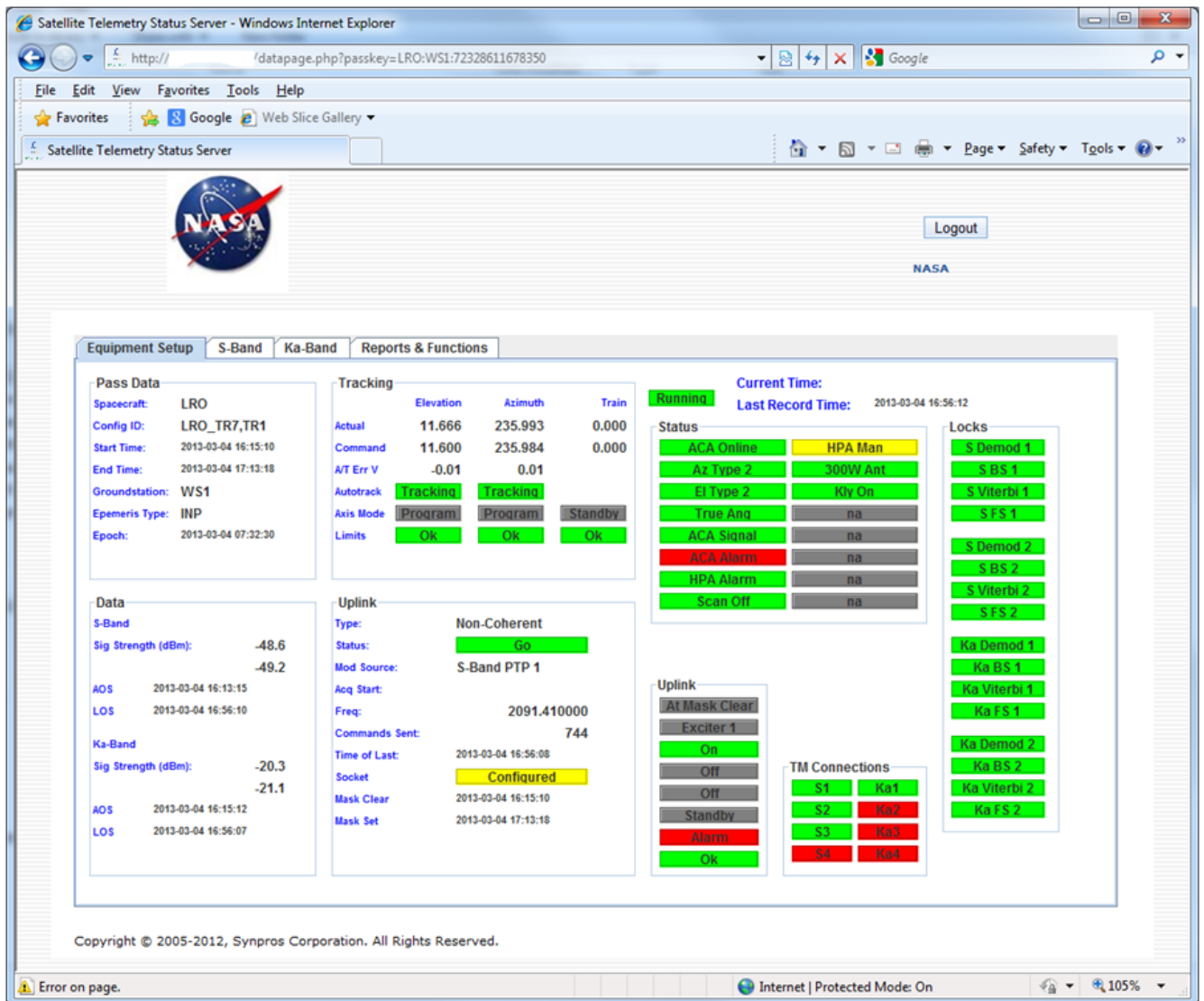
Figure 2-8. Active Track Details

2.6.2 **Selection of a VC Tab**

The user may select the Virtual Channel (VC) tabs, one for each band, to view VC and telemetry statistics of the respective links. See Figure 2-9.
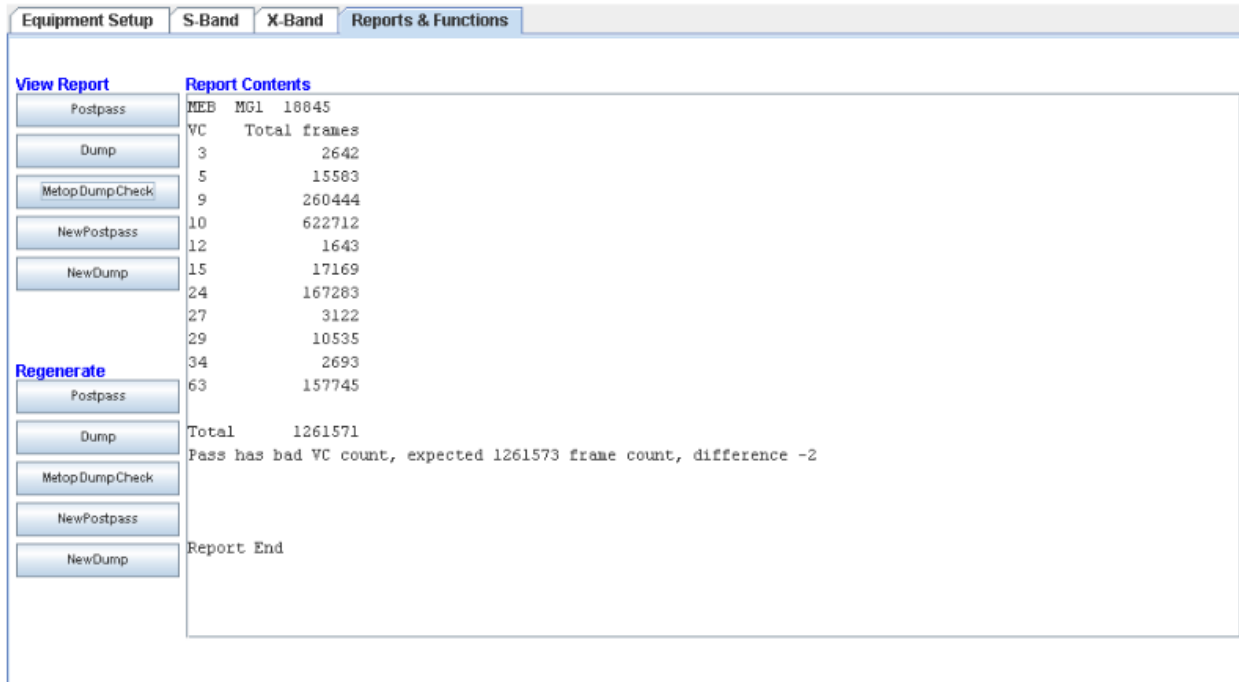
Figure 2-9. Active Track VC Statistics

2.6.3   **Selection of the Report Tab**

Reports are available from the Reports & Functions tab. See Figure 2-10. The reports are configurable by spacecraft and may be automatically generated at several status transition points in the event such as pre-pass to active, or active to post-pass. The reports may be regenerated at any time during the event, or after the event for several days. The user may also regenerate the report from the alternate status server. Both status servers receive the same data, but only one will automatically deliver the report. Regeneration will redeliver the report regardless of the server used.

Delivery of reports is via SFTP, email, or copy and paste from the web server. Delivery of the report may be conditional, as in the case of a failure to meet certain criteria. The examples below of the dump report show a good dump and a bad dump, where the VC count indicates missing frames. The report is created to email the report when the dump is bad.
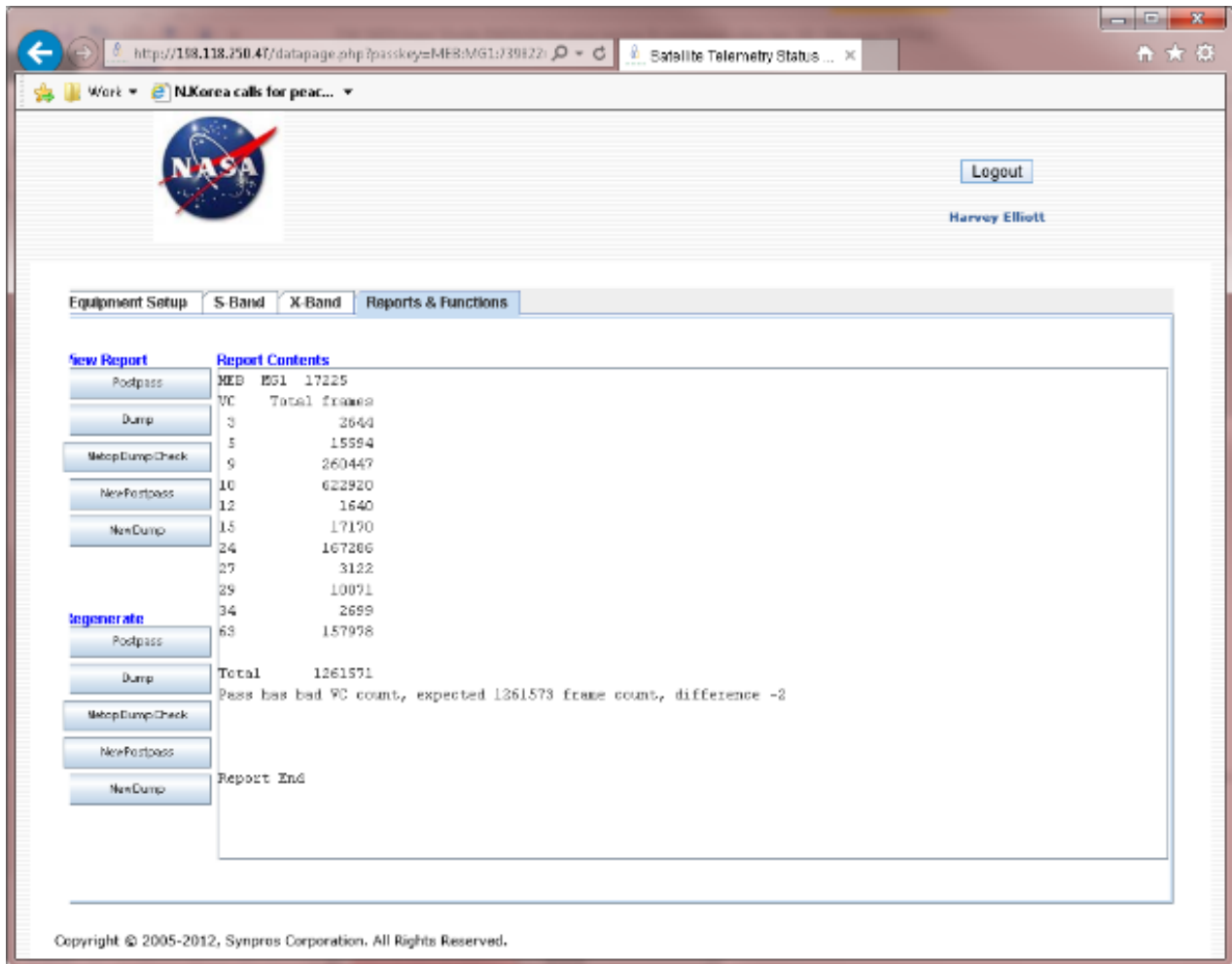
Figure 2-10. Reports Tab for Viewing and Regenerating

2.7   **Tracking Data Formats and Reduction Algorithms**

2.7.1   **General**

This section describes the tracking data formats transmitted by the NEN stations.   Applicable reduction algorithms are also given.

2.7.1.1   **Universal Tracking Data Format (UTDF)**

Universal Tracking Data Format (UTDF) data is transmitted post-pass or at a user specified time via SFTP, in files consisting of 75-byte UTDF frames. See Table 2-2 below.

Table 2-2. Universal Tracking Data Format

Byte	Format	Description
1	$0D_{(16)}$	Fixed
2	$0A_{(16)}$	Fixed
3	$01_{(16)}$	Fixed
4 to 5	ASCII	Tracking data router: 4141 = AA = GSFC 4444 = DD = GSFC 4646 = FF = GSFC/France (CNES) 4848 = HH = GSFC/Japan 4949 = II = GSFC/Germany (ESRO) 4A4A = JJ = GSFC/JSC
6	Binary	Last two digits of current year
7 to 8	Binary	SIC
9 to 10	Binary	VID
11 to 14	Binary	Seconds of year
15 to 18	Binary	Microseconds of second
19 to 22	FOC	Angle 1; X or az
23 to 26	FOC	Angle 2; Y or el (Angle 2 byte/bit format is the same as for bytes 19-22.)
		NOTE For bytes 19-22/23-26, convert angle data to decimal form. Angle data is given in fractions of a circle. To express raw angle in degrees, multiply decimal angle by 8.381903173 x 10^{-8} (360 degrees divided by 2^{32}). When the STPS is initialized as WPS S08 or S37, these bytes will read zero.
27 to 32	Binary	RTLT in 1/256 nsec (MSB = 524288 ns; LSB = 0.00390625 ns)
33 to 38	Binary	Bias Doppler, counts of: 240 MHz + 1000 $f_{d'}$ LSB = 1 count
39 to 40	Binary	AGC (an integer: $\dfrac{-150\,AGC}{8192} - 50 =$ dBm) Note: AGC field not used by systems with TDF
41 to 44	Binary	Transmit frequency information in 10's of Hz
45	Discrete	MSD = antenna size (xmit) as follows: $0_{(16)}$ = less than 1 m $1_{(16)}$ = 3.9 m $2_{(16)}$ = 4.3 m $3_{(16)}$ = 9 m $4_{(16)}$ = 12 m $5_{(16)}$ = 26 m $6_{(16)}$ = TDRSS ground antenna $7_{(16)}$ = 6 m $8_{(16)}$ = 7.3 m $9_{(16)}$ = 8.0 m $A_{(16)}$ through $F_{(16)}$ = spares

F

Table 2-3. Universal Tracking Data Format (continued)

Byte	Format	Description
45 (cont)		LSD = antenna geometry (xmit) as follows: $0_{(16)}$ = az-el $1_{(16)}$ = X-Y(+X-south) $2_{(16)}$ = X-Y(+X-east) $3_{(16)}$ = RA-DEC $4_{(16)}$ = HR-DEC $5_{(16)}$ through $F_{(16)}$ = spares
46	Binary	Pad ID (xmit) Link ID (refer to Appendix C)
		NOTE If S-band and 3 way, zeros are output. If S-band and 2 way, good data is output. If VHF and 3 way, zeros are output. If VHF and 2 way, byte 45 is 0 and 46 is pad ID.
47	Discrete	Antenna size (rcv; refer to byte 45)
48	Binary	Pad ID (rcv refer to byte 46)
		NOTE If VHF, byte 47 is 0 and 48 is pad ID. If S-band, good data is output.
49-50	Discrete	Mode-system unique (refer to Table 4-2)
51	Discrete	Data validity by bit: 8 = (MSB) sidelobe (1 = sidelobe) 7 = destruct $\dot{R}$ (1 = destruct) 6 = refraction correction to R, $\dot{R}$ (1 = corrected) 5 = refraction correction to angles (1 = corrected) 4 = angle data correction (1 = corrected) 3 = angle valid (1 = valid) 2 = $\dot{R}$ valid (1 = valid) 1 = (LSB) R valid (1 = valid)
52	Discrete	MSD= frequency band, as follows: $1_{(16)}$ = VHF $2_{(16)}$ = UHF $3_{(16)}$ = S-band $4_{(16)}$ = C-band $5_{(16)}$ = X-band $6_{(16)}$ = Ku-band $7_{(16)}$ = visible $8_{(16)}$ = S-band uplink/Ku-band downlink $9_{(16)}$ through $F_{(16)}$ = spares

Table 2-4. Universal Tracking Data Format (continued)

Byte	Format	Description
52 (cont)	Discrete	LSD = data transmission type, as follows: $0_{(16)}$ = test $1_{(16)}$ = spare $2_{(16)}$ = simulated $3_{(16)}$ = resubmit $4_{(16)}$ = RT (real time) $5_{(16)}$ = PB (playback) $6_{(16)}$ through $F_{(16)}$ = spares
53 to 54	Discrete	MSD = tracker type: Byte 53, bits 8 through 5: $0_{(16)}$ = C-band pulse track $1_{(16)}$ = SRE (S-band and VHF) or RER $2_{(16)}$ = X-Y angles only (data acquisition antenna) $3_{(16)}$ = Spare $4_{(16)}$ = SGLS (AFSCF S-band trackers) $5_{(16)}$ = Spare $6_{(16)}$ = TDRSS $7_{(16)}$ = STGT/WSGTU $8_{(16)}$ = TDRSS TT&C $9_{(16)}$ through $F_{(16)}$ = spares Byte 53, bit 4: 1 = last frame of data (not used by systems with TDF) Byte 53, bits 3 through 1 and eight bits of byte 54: 11 bits for transmission rate (positive indicates the binary seconds between samples up to a maximum of 1023; negative indicates the 2's complement of the number of samples per second).
55 to 72	Spare	
73	$04_{(16)}$	Fixed.
74	$0F_{(16)}$	Fixed.
75	$0F_{(16)}$	Fixed.

2.7.1.2 Data Reduction Algorithms

The following processes are used to convert UTDF to the decimal form of data.

a. Observed Angles. To process, convert angle data to decimal form. To express angle data in degrees, multiply by 8.381903173 x 10-8.

NOTE:

For X-Y angles only, subtract 360 degrees whenever the converted value exceeds 180 degrees.

b. Observed Range. The observed measurement is Round Trip Light Time (RTLT) in units of 1/256 nanoseconds and is time-tagged at receive time. To process, convert range data to decimal form. In units of length, the range is $R(T) = \left(\frac{c}{512}\right) 10^{-9} R_r (T)$ where: c = speed of light in units of length/sec and R_r = raw range value in decimal form.

c. Observed Range Rate. The Doppler measurement is the cumulative cycle count of the Doppler frequency plus a 240-MHz bias frequency. It is time tagged at the time of cycle counter reading. To process, convert Doppler data to decimal form. The observed average range rate is:

$$\dot{R}(T_0) = \frac{-c}{2f_T KM}\left[\frac{N(T_0)-N(T_{-1})}{T_0 - T_{-1}} - 2.4 \times 10^8\right] \text{ (units, same as "c")}$$

where: c = speed of light.

f_T = transmit frequency in Hertz.

K = 240/221 for S-band, or 1 for VHF, 880/749 for X-band.

M = 1000 for S-band and VHF, 250 for X-band.

N = cumulative Doppler-plus-bias counter reading

T_0, T_{-1} = time of present and previous Doppler count, respectively

2.8 4800-Bit Block Encapsulated in IP Packets

NASA is currently converting its remaining 4800-bit block point-to-point serial circuits to an IP-based network. The IONet however, will remain backward compatible with MOCs and other facilities that support only Communication Program's (CP's) 4800-bit-block serial clock and data transport. NEN stations will provide legacy support to users who require the 4800-bit block service by providing conversion devices that encapsulate 4800-bit blocks in UDP/IP datagrams. At GSFC, conversion devices will de-encapsulate the 4800-bit blocks and send them to the user over serial data circuits.

2.8.1 Network Header

The first 48 bits in the 4800-bit block contain the CP synchronization code, routing, and block-accounting information, as described below:

a. **Bits 1-24 (CP Synchronization Code)**

A fixed, 24-bit code (627627_{16}).

b. **Bits 25-32 (Source)**

An 8-bit, CP-assigned code that identifies the sender by geographic location.

c. **Bits 33-40 (Destination)**

An 8-bit, CP-assigned code that identifies the geographic destination (one or multiple destinations).

d. **Bits 41-43 (Block Sequence Number)**

A 3-bit code that identifies the block's location in a sequence of blocks. This enables the destination system to place each block in its proper order.

e. Bits 44-48 (Format Code)

A 5-bit code that identifies the type of data in the Data Field: telemetry, real-time commands, tracking data, or non-real-time commands.
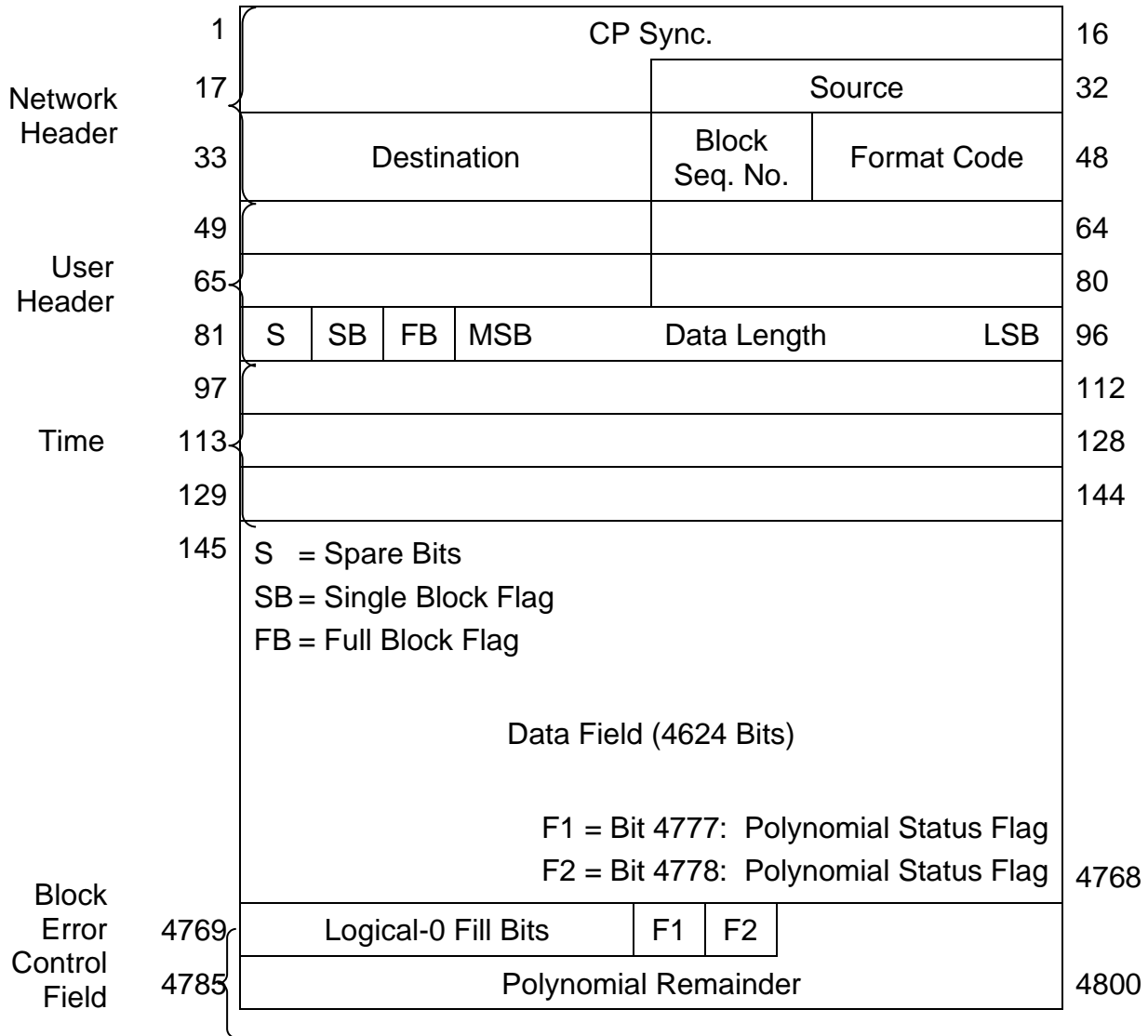
Figure 2-11 CP 4800-Bit Block Format

2.8.2 **User Header**

A 48-bit field that contains sender-supplied information that the destination system requires to route and process the data.

2.8.3 **Time**

A 48-bit code that provides the Universal Time Coordinated (UTC) in NASA Parallel Binary-4 (PB-4) format, with the parity bits set to logical 0.

2.8.4 **Data Field**

A 4624-bit field that contains the user data. If the user data is less than 4624 bits, fill bits are inserted after the real data.

2.8.5 **Block Error Control Field**

A 32-bit field that enables error detection, as described below:

a. **Bits 4769-4776 (Spares)**

The sender inserts logical 0 bits in this 8-bit field.

b. **Bit 4777 (Polynomial Status Flag)**

A 1-bit field that indicates whether the block passed (logical 0) or failed (logical 1) the sender's polynomial check.

c. **Bit 4778 (Polynomial Status Flag)**

A 1-bit field that indicates whether the block passed (logical 0) or failed (logical 1) the destination system's polynomial check.

d. **Bits 4779-4800 (Polynomial Remainder)**

The sender generates this 22-bit polynomial code.

Section 3. Kongsberg Satellite Services Ground Stations

3.1   General

This section describes the KSAT ground stations located in Svalbard, Norway, Antarctica and Singapore. Three apertures are available at Norway; SG1, SG2, SG3. A fourth and fifth, TR2 and TR3, are located in Antarctica and a sixth, SI1, at Singapore. These apertures are under 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.

3.2   Svalbard, 11.3-m, SG1

The general characteristics of the antenna are as follows:

<div align="center">

78° 13′ 51″ N

15° 23′ 22″ E

</div>

a. One 11.3-m antenna for simultaneously transmitting at S-band while receiving at S- and X-bands. Figure 3-1 is a photograph of the SG1 antenna.

b. Automatically scheduled by NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

c. Tracking services: 1- & 2-way Doppler and antenna autotracking angles.

d. Baseband data interfaces: Internet Protocol (IP), serial clock and data, 4800-bit blocks encapsulated in IP packets, and electronic file transfer and parcel shipping.

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

Figure 3-1. SG1 Antenna

3.2.1 **SG1 S-band Command**

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

3.2.2 **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	63.5 dBW
Polarization	RHC or LHC
Antenna 3dB beamwidth	0.8 deg typical
Antenna Gain	44.6 dBi
Command Modulation	FSK no bit blanking FSK+half-bit blanking. Duty cycle: 50/50 BPSK, BPSK+AM, PCM/PSK/PM Direct PCM/PM
Modulation Index	0-2.5 Radians
Carrier Data Rate	10 bps – 10 kbps (Low BW) 100 bps – 1 Mbps (Intermediate & High BW)
Subcarrier Frequency	5 kHz-2 MHz (Intermediate & High BW)
Subcarrier Modulation	PCM (Intermediate & High BW)
Subcarrier Data Rate	100 bps – 250 kbps
Data Format	CCSDS, Time Division Multiplexed (TDM) Non-Return-to-Zero Mark, Level, Space (NRZ-M, NRZ-L, S); or Biphase Level, Mark (Biϕ-L, M)

Note:

The command modulator capabilities listed in the table (e.g., data rates, modulation schemes, data formats, coding schemes) represent all possible modulator capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.

Table 3-2. SG1 S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T include radome	22.1 dB/K (clear sky & 5° elevation angle)
Polarization	RHC and LHC
Antenna 3 dB Beamwidth	0.8 deg typical
Antenna Gain	45.1 dBi
Carrier Modulation	PCM/PM
Modulation Index	0 to 2.5 Radians
Carrier Data Rate	100 b/s to 20 Mb/s (up to 40 Mb/s for QPSK demodulation + Viterbi decoding, up to 10 Mb/s in case of Bi-Phase decoding data format)
Carrier Data Format	CCSDS, TDM, NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	40 Hz – 128 kHz, 5 KHz – 2 MHz
Subcarrier Modulation	PCM/PSK/PM for high BW telemetry
Subcarrier Data Rate	10 bps – 25 kbps, (NRZ) for 40 Hz-128 kHz 1 kbps – 600 Kbps for 5kHz – 2 MHz
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi , Reed-Solomon, Turbo, LDPC 1/2

Note:

The telemetry receiver capabilities listed in the table (e.g., data rates, modulation schemes, data formats, decoding schemes) represent all possible receiver capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.

3.2.3 **SG1 X-band Telemetry**

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

Table 3-3. SG1 X-band Telemetry Characteristics

Characteristic	Value
Frequency	7700 – 8500 MHz
G/T include radome	36.8 dB/K (clear sky & 10° elevation angle)
Polarization	RHC and LHC
Antenna 3 dB beamwidth	0.2 deg typical
Antenna Gain	57.5 dBi
Modulation	BPSK, QPSK, SQPSK, UQPSK, or AQPSK*
Data Rate	2 – 320 Mbps; 160 Mbps per channel
Data Format	CCSDS, TDM NRZ-L or NRZ-M
Decoding	Derandomization, Viterbi and/or Reed-Solomon, 7/8 LDPC
* The AQPSK demodulation capability exists only for LANDSAT-7.	

3.2.4 **SG1 Tracking Services**

3.2.4.1 **SG1 Doppler Tracking**

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

Table 3-4. SG1 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 ($\Delta f/f$)	4×10^{-11} at 0.1 sec
Accuracy	0.01 Hz
Output Equation	$(f_{transmit} \times [240/221] - f_{received}) + f_{bias}$

3.2.4.2 **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 UTDF messages. (Refer to Table 4-1 of Reference h in Section 1.3)

3.2.5 **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. SG1 uses the site's fiber optic (155 Mbps) communication link to support command, telemetry, and ground station control and monitor.

3.3 **Svalbard, 11.3-m, SG2**

The general characteristics of SG2 are as follows:

$$78° 13′ 49″ \text{ N}$$

$$15° 23′ 53″ \text{ E}$$

a. One 11.3-m antenna for simultaneously transmitting at S-band while receiving at S- and X-bands. Figure 3-2 is a photograph of the SG2 antenna.

b. Automatically scheduled by NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

c. Tracking services: 1- and 2-way Doppler and antenna autotracking angle.

d. Baseband data interfaces: 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 3-2. SG2 Antenna

3.3.1 **SG2 S-band Command**

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

3.3.2 **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 dBW
Polarization	RHC or LHC
Antenna Beamwidth	0.91 deg
Antenna Gain	44.4 dBi
Command Modulation	FSK no bit blanking FSK+ hbb. Duty cycle: 50/50 BPSK, BPSK+AM, PCM/PSK/PM Direct PCM/PM
Modulation Index	0-2.5 Radians
Carrier Data Rate	10 bps – 10 kbps (Low BW) 100 bps – 1 Mbps (Intermediate & High BW)
Subcarrier Frequency	5 kHz – 2 MHz (Intermediate & High BW)
Subcarrier Modulation	PCM (Intermediate & High BW)
Subcarrier Data Rate	100 bps-250 kbps
Data Format	CCSDS, TDM NRZ-M, NRZ-L, S Biφ-L, M, S

Note:

The command modulator capabilities listed in the table (e.g., data rates, modulation schemes, data formats, coding schemes) represent all possible modulator capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.

Table 3-6. SG2 S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T include radome	22.6 dB/K (clear sky & 5° elevation angle)
Polarization	RHC or LHC
Antenna Beamwidth	0.84 deg
Antenna Gain	45.1 dBi
Carrier Modulation	FM, PM, BPSK, QPSK, OQPSK, AQPSK
Modulation Index	0 to 2.5 Radians
Carrier Data Rate	100 bps to 20 Mbps (up to 40 Mbps for QPSK demodulation + Viterbi decoding, up to 10 Mbps in case of Bi-Phase data format)
Carrier Data Format	CCSDS, TDM, NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	40 Hz – 128 kHz, 5 kHz – 2 MHz
Subcarrier Modulation	PSK,BPSK , PCM/PM for high BW telemetry
Subcarrier Data Rate	10 bps-25 kbps, (NRZ) for 40 Hz-128 kHz 1 kbps – 600 Kbps for 5 kHz – 2 MHz
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Derandomization, Viterbi and/or Reed-Solomon, 7/8 LDPC

Note:

The telemetry receiver capabilities listed in the table (e.g., data rates, modulation schemes, data formats, decoding schemes) represent all possible receiver capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.

3.3.3 SG2 X-band Telemetry

Table 3-3 identifies the X-band telemetry characteristics of the SG2 antenna, because they are identical to those of SG1.

3.3.4 SG2 Tracking Services

3.3.4.1 SG2 Doppler Tracking

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 3-7.

Table 3-7. SG2 X-band Telemetry Characteristics

Characteristic	Value
Frequency	7500-8500 MHz (Extends down to 7500 for testing)
G/T include radome	35.7 dB/K (clear sky & 10° elevation angle)
Polarization	RHC or LHC
Antenna Beamwidth	0.23 deg
Antenna Gain	57 dBi
Modulation	BPSK, QPSK, UQPSK, SQPSK
Data Rate	1 Mbps – 150 Mbps; Capable of 320 Mbps with upgrade)
Data Format	CCSDS, TDM NRZ-L, or NRZ-M
Decoding	Viterbi and/or Reed-Solomon 7/8 LDPCV

Table 3-8. SG2 Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	10 Samples Pr 1 Sec / 1 Samples Pr 1 Sec / 1 Sample Pr 10 Sec 0.004 cycles
Doppler Frequency Shift	≤ 0.23 MHz
Doppler Bias Frequency	0.24 MHz
Drift (Δf/f)	4×10^{-11} at 0.1 sec
Accuracy	0.01 Hz
Output Equation	$(f_{transmit} \times [240/221] - f_{received}) + f_{bias}$

3.3.4.2   **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 UTDF messages. (Refer to Table 4-1 of Reference h in Section 1.3)

3.3.5   **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. SG2 uses the site's fiber optic communication link to support command, telemetry, and ground station control and monitor.

3.4   **Svalbard, 13.0-m, SG3**

The general characteristics of SG3 are as follows:

78° 13′ 47″ N

15° 24′ 29″ E

a.   One 13.0-m antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 3-3 is a photograph of the SG3 antenna.

b.   Scheduled by KSAT scheduling office per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling.*

c.   Tracking services: 1- & 2-way Doppler and antenna autotracking angle.

d.   Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.

Sections 3.4.1 through 3.4.3 describe S- and X-band performance characteristics. Sections 3.4.4 and 3.4.5 describe the tracking services and baseband data interfaces, respectively.

Figure 3-3. SG3 Antenna

3.4.1   **SG3 S-band Command**

Table 3-8 identifies the S-band command characteristics of the SG3 antenna.

3.4.2   **SG3 S-band Telemetry**

Table 3-9 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	67 dBW
Polarization	RHC or LHC
Antenna Beamwidth	0. 77 deg
Antenna Gain	45.9 dBi
Command Modulation	FSK no bit blanking FSK+hbb Duty cycle: 50/50 BPSK, BPSK+AM, PCM/PSK/PM Direct PCM/PM
Modulation Index	0-2.5 Radians
Carrier Data Rate	10 bps – 10 kbps (Low BW) 100 bps – 1 Mbps (Intermediate & High BW)
Subcarrier Frequency	5 kHz – 2 MHz (Intermediate & High BW)
Subcarrier Modulation	PCM (Intermediate & High BW)
Subcarrier Data Rate	100 bps – 250 kbps
Data Format	CCSDS, TDM NRZ-M,S Biφ-L, M
Note:	
The command modulator capabilities listed in the table (e.g., data rates, modulation schemes, data formats, coding schemes) represent all possible modulator capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.	

Table 3-10. SG3 S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T include radome	23.0 dB/K (clear sky & 5° elevation angle)
Polarization	RHC or LHC
Antenna Beamwidth	≈ 0.71 deg @ 2200 MHz
Antenna Gain	≈ 46.9 dBi
Carrier Modulation	PM, FM, BPSK, QPSK, OQPSK
Modulation Index	0-2.5 Radians
Carrier Data Rate	100 bps to 20 Mbps (up to 40 Mbps for QPSK demodulation + Viterbi decoding, up to 10 Mbps in case of Bi-Phase data format)
Carrier Data Format	CCSDS, TDM, NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	40 Hz – 128 kHz, 5 kHz – 2 MHz
Subcarrier Modulation	PSK, BPSK, PCM/PM for high BW telemetry
Subcarrier Data Rate	10 bps- 25 kbps ,(NRZ) for 40 Hz-128 kHz 1 kbps – 600 kbps for 5 kHz – 2 MHz
Subcarrier Data Format	CCSDS, TDM
Decoding	Viterbi and/or Reed-Solomon

Note:

The telemetry receiver capabilities listed in the table (e.g., data rates, modulation schemes, data formats, decoding schemes) represent all possible receiver capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.

3.4.3 SG3 X-band Telemetry

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

3.4.4 SG3 Tracking Services

3.4.4.1 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 3-11.

Table 3-11. SG3 X-band Telemetry Characteristics

Characteristic	Value
Frequency	7500 – 8500 MHz (Extends down to 7500 for testing)
G/T include radome	37.8 dB/K (clear sky & 10° elevation angle)
Polarization	RHC or LHC
Antenna Beamwidth	0.19 deg @8025 MHz
Antenna Gain	≈ 59 dBi
Modulation	BPSK, QPSK, OQPSK (SQPSK), UQPSK (AQPSK)
Data Rate	BPSK & UQPSK (AQPSK): 1 Mbps – 235 Mbps QPSK, OQPSK (SQPSK): 2 Mbps – 470 Mbps
Data Format	CCSDS, TDM, NRZ-L/M/S DNRZ for QPSK
Decoding	Viterbi and/or Reed-Solomon, 7/8 LDPC

Table 3-12. SG3 Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	10 Samples Pr 1 Sec / 1 Sample Pr 1 Sec / 1 Sample Pr 10 Sec 0.004 cycles
Doppler Frequency Shift	$\leq$ 0.23 MHz
Doppler Bias Frequency	0.24 MHz
Drift (Δf/f)	4×10^{-11} at 0.1 sec
Accuracy	0.01 Hz
Output Equation	1000 (ftransmit $\times$ [240/221] – freceived) + fbias

3.4.4.2 **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 UTDF messages. (Refer to Table 4-1 of Reference h in Section 1.3)

3.4.5 **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. SG3 uses the site's fiber optic (155 Mbps) communication link to support command, telemetry, and ground station monitor and control.

3.5 **Svalbard, Norway, 11m, S-, X-, and Ka-band, SG12**

This section will be populated in the next revision.

3.6   **TrollSat, Antarctica, 7.3m, TR2**

The general characteristics of TR2 ground station at Antarctica are as follows:

-72° 00' 08" S, 02° 31' 27" E

a   One 7.3-m antenna for simultaneously transmitting at S-band while receiving at S- and X-band. This aperture currently has Ka-Band capability which NEN does not currently access. Figure 3-4 is a photograph of the TR2 antenna.

b   Scheduled by KSAT scheduling office per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

c   Tracking services: 1- and 2-way Doppler and antenna autotracking angles.

d   Baseband data interfaces: Video and/or telemetry.

Sections 3.5.1 through 3.5.3 describe S- and X-band performance characteristics. Sections 3.5.4 and 3.5.5 describe the tracking services and baseband data interfaces, respectively.

Figure 3-4. TR2 Antenna

3.6.1   **TR2 S-band Command**

Table 3-12 identifies the S-band command characteristics of the TR2 antenna.

3.6.2   **TR2 S-band Telemetry**

Table 3-13 identifies the S-band telemetry characteristics of the TR2 antenna.

Table 3-13. TR2 S-band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	51 dBW
Polarization	RHC or LHC
Antenna Beamwidth	1.32 deg
Antenna Gain	41.2 dBi
Command Modulation	FSK no bit blanking FSK+ hbb BPSK, BPSK+AM, PCM/PSK/PM Direct PCM/PM
Modulation Index	0-2.5 Radians
Carrier Data Rate	10 bps – 10 kbps(Low BW) 100 bps-1 Mbps (Intermediate & High BW)
Subcarrier Frequency	5 kHz – 2 MHz (Intermediate & High BW)
Subcarrier Modulation	PCM (Intermediate & High BW)
Subcarrier Data Rate	100 bps – 250 kbps
Data Format	CCSDS, TDM NRZ-M, NRZ-L, S; or Biφ-L, M

Note:

The command modulator capabilities listed in the table (e.g., data rates, modulation schemes, data formats, coding schemes) represent all possible modulator capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.

Table 3-14. TR2 S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	19.4 dB/K (clear sky & 5° elevation angle)
Polarization	RHC or LHC or Diversity Combining
Antenna Beamwidth	≈ 1.16 deg @ 2200 MHz
Antenna Gain	≈ 41.8 dBi
Carrier Modulation	PM, FM, BPSK, QPSK, OQPSK
Modulation Index	0-2.5 Radians
Carrier Data Rate	100 b/s to 20 Mb/s (up to 40 Mb/s for QPSK demodulation + Viterbi decoding, up to 10 Mb/s in case of Bi-Phase decoding data format)
Carrier Data Format	CCSDS, TDM, NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	40 Hz-128 kHz, 5 kHz-2 MHz
Subcarrier Modulation	PSK,BPSK, PCM/PM for high BW telemetry
Subcarrier Data Rate	10 bps- 25 kbps, (NRZ) for 40 Hz-128 kHz 1 kbps – 600 kbps for 5 kHz – 2 MHz
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon

Note:

The telemetry receiver capabilities listed in the table (e.g., data rates, modulation schemes, data formats, decoding schemes) represent all possible receiver capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.

3.6.3   TR2 X-band Telemetry

Table 3-14 identifies the X-band telemetry characteristics of the TR2 antenna.

3.6.4   TR2 Tracking Services

3.6.4.1   TR2 Doppler Tracking

The TR2 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 TR2 S-band uplink signal with a frequency ratio of 240/221.

Table 3-15. TR2 X-band Telemetry Characteristics

Characteristic	Value
Frequency	8000 – 8500 MHz (Extends down to 7500 for testing)
G/T include radome	32 dB/K (clear sky at 10° elevation)[1]
Polarization	RHC or LHC
Antenna Beamwidth	0.32 deg @8025 MHz
Antenna Gain	≈ 54 dBi
Modulation	BPSK, QPSK, OQPSK (SQPSK), UQPSK (AQPSK),
Data Rate	BPSK & UQPSK (AQPSK): 1 Mbps – 235 Mbps QPSK, OQPSK (SQPSK): 2 Mbps – 470 Mbps
Data Format	CCSDS, TDM, NRZ-L/M/S DNRZ for QPSK
Decoding	Viterbi and/or Reed-Solomon, 7/8 LDPC
[1] Actually measured at 60° elevation but the difference is considered negligible.	

3.6.4.2 TR2 Antenna Autotracking Angle Data

The TR2 antenna can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (Refer to Table 4-1 of Reference h in Section 1.3)

3.6.5 TR2 Baseband Data Interfaces

The TR2 antenna can send and receive baseband data in any of the following formats: Video and telemetry.

3.7 TrollSat, Antarctica, 7.3m TR3

The general characteristics of TR3 are as follows:

72° 00' 7.72948" S

02° 31' 30.04227"

a. Height: 1416.350m
b. Pad ID = 137

3.7.1 TR3 S-band Command

Table 3-13 identifies the S-band command characteristics of the TR3 antenna except TR2 has a 50W HPA and TR3 has 100W.

3.7.2 TR3 S-band Telemetry

Table 3-14 identifies the S-band telemetry characteristics of the TR3 antenna.

3.7.3 **TR3 X-band Telemetry**

Table 3-15 identifies the X-band telemetry characteristics of the TR3 antenna.

3.7.4 **TR3 Tracking Services**

3.7.4.1 **TR3 Doppler Tracking**

The TR3 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 TR3 S-band uplink signal with a frequency ratio of 240/221.

3.7.4.2 **TR3 Antenna Autotracking Angle Data**

The TR3 antenna can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (Refer to Table 4-1 of Reference h in Section 1.3)

3.7.5 **TR3 Baseband Data Interfaces**

The TR3 antenna can send and receive baseband data in any of the following formats: Video and telemetry.

3.8 **Singapore, 9-m S- and X-band Antenna, SI1**

The general characteristics of the Singapore ground station are as follows:

1° 23' 46" N, 103° 50' 03"E.

a. One 9.1-m antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 3-5 is a photograph of the Singapore antenna.

b. Scheduled by KSAT scheduling office per 453-UG-NEN Scheduling, Users' Guide for Near Earth Network Scheduling.

c. Tracking services: 1- and 2-way Doppler and antenna autotracking angles.

d. Baseband data interfaces: Video and/or telemetry.

Sections 3.6.1 through 3.6.3 describe S- and X-band performance characteristics. Sections 3.6.4 and 3.6.5 describe the tracking services and baseband data interfaces, respectively.

Figure 3 5. Singapore 9.1-m S- and X-band Antenna

3.8.1 **Singapore S-band Command**

Table 3-15 identifies the S-band command characteristics of the Singapore antenna.

Table 3-16. Singapore S-band Command Characteristics

Characteristic	Value
Frequency	2025 -2120 MHz
EIRP	57 dBW
Polarization	RHC or LHC
Antenna Beamwidth	1.07°
Antenna Gain	41.6 dBi
Command Modulation	FSK no bit blanking FSK+half-bit blanking. Duty cycle: 50/50 BPSK, BPSK+AM,PCM/PSK/PM Direct PCM/PM
Modulation Index	0-2.5 Radians
Carrier Data Rate	10 bps – 10 kbps (Low BW) 100 bps – 1 Mbps (Intermediate & High BW)
Subcarrier Frequency	5 kHz-2 MHz (Intermediate & High BW)
Subcarrier Modulation	PCM (Intermediate & High BW)
Subcarrier Data Rate	100 bps – 250 kbps
Data Format	CCSDS, TDM NRZ-M, NRZ-L, S; or Bi□-L, M
Note: The command modulator capabilities listed in the table (e.g., data rates, modulation schemes, data formats, coding schemes) represent all possible modulator capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.	

3.8.2 **Singapore S-band Telemetry**

Table 3-16 identifies the S-band telemetry characteristics of the Singapore antenna.

Table 3-17. Singapore S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	20.5 dB/K (clear sky & 5° elevation angle)
Polarization	RHC and LHC
Antenna Beamwidth	0.98°
Antenna Gain	43.13 dBi
Carrier Modulation	FM, PM, BPSK, QPSK, OQPSK, AQPSK
Modulation Index	0 to 2.5 Radians
Carrier Data Rate	100 b/s to 20 Mb/s (up to 40 Mb/s for QPSK demodulation + Viterbi decoding, up to 10 Mb/s in case of Bi-Phase decoding data format)
Carrier Data Format	CCSDS, TDM, NRZ-L, M, or S; or Bi□-L, M, or S
Subcarrier Frequency	40 Hz – 128 kHz, 5 KHz – 2 MHz
Subcarrier Modulation	PSK,BPSK, PCM/PM for high BW telemetry
Subcarrier Data Rate	10 bps – 25 kbps, (NRZ) for 40 Hz-128 kHz 1 kbps – 600 Kbps for 5kHz – 2 MHz
Subcarrier Data Format	NRZ-L, M, or S; or Bi□-L, M, or S
Decoding	Viterbi and/or Reed-Solomon

Note:

The telemetry receiver capabilities listed in the table (e.g., data rates, modulation schemes, data formats, decoding schemes) represent all possible receiver capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.

3.8.3 **Singapore X-band Telemetry**

Table 3-17 identifies the X-band telemetry characteristics of the Singapore antenna.

Table 3-18. Singapore X-band Telemetry Characteristics

Characteristic	Value
Frequency	7985 – 8500 MHz
G/T	35.4 dB/K (clear sky & 10° elevation angle)
Polarization	RHC or LHC
Antenna Beamwidth	0.24°
Antenna Gain	55.42 dBi
Modulation	BPSK, QPSK, OQPSK (SQPSK), UQPSK
Data Rate	BPSK & UQPSK: 1 Mbps – 235 Mbps QPSK, OQPSK (SQPSK): 2 Mbps – 470 Mbps
Data Format	CCSDS, TDM, NRZ-L/M/S DNRZ for QPSK
Decoding	Viterbi and/or Reed-Solomon, 7/8 LDPC

3.8.4 **Singapore Tracking Services**

3.8.4.1 **Singapore Doppler Tracking**

The Singapore 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 Singapore S-band uplink signal with a frequency ratio of 240/221.

3.8.4.2 **Singapore Antenna Autotracking Angle Data**

The Singapore antenna can record the angle of the ground antenna as it autotracks the user in UTDF format.

3.8.5 **Singapore Baseband Data Interfaces**

The Singapore 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.

3.9 **Punta Arenas 11-m S-, X- and Ka-band, SG12**

Details will be added in the next revision.

Section 4. Wallops Flight Facility Ground Station

4.1　General

This section describes the NEN station located at the Wallops Flight Facility (WFF).

This satellite ground station consists of the following assets:

    a. WG1 11.28-m (Section 4.2).

    b. WG2 Low Earth Orbiter-Terminal (Section 4.3).

    c. WG3/WG4 Two VHF Ground Stations (Section 4.4).

    d. WG5 11.28-m (Section 4.5)

    e. Remote Operations Status and Execution Service (ROSES) computers for remote monitoring of the McMurdo MG1 and White Sands WS1 antennas.

4.2　Wallops 11.28-m, S- and X-band, WG1

The general characteristics of the WG1 ground station at WFF are as follows:

<div align="center">

37º 55′ 28″ N

75º 28′ 35″ W

</div>

a. One 11.3-m antenna for simultaneously transmitting at S-band while receiving at S-and/or X-bands. Figure 4-1 is a photograph of the WG1 antenna.

    b. Automatically scheduled by NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

    c. Remote monitoring of the McMurdo 10-m system and the White Sands 18-m system.

    d. Tracking services: 1- & 2-way Doppler, Tone ranging and antenna autotracking angles.

    e. Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.

Sections 4.2.1 and 4.2.2 describe S-band and X-band performance characteristics. Sections 4.2.3 and 4.2.4 describe the tracking services and baseband data interfaces, respectively.

4.2.1　S-band Command

Table 4-1 identifies the S-band command characteristics of the WG1.

4.2.2　S-band Telemetry

Table 4-2 identifies the S-band telemetry characteristics of the WG1.

Figure 4-1. WG1 Antenna

Table 4-1. WG1 S-band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	$\geq$ 66dBW
Polarization	RHC or LHC
Antenna Beamwidth	0.95 deg
Antenna Gain	44.8 dBi
Command Modulation	FSK no bit blanking FSK+half-bit blanking. Duty cycle: 50/50 BPSK, BPSK+AM,PCM/PSK/PM/FM/QPSK Direct PCM/PM
Modulation Index	FM: 1-KHz – 50 KHz deviation PM: 0.01-2.50 Radians BPSK
Carrier Data Rate	1 Kbps – 1 Mbps
Subcarrier Frequency	5 KHz – 2 MHz
Subcarrier Modulation	FSK and BPSK
Subcarrier Data Rate	100 bps – 250 Kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 4-2. WG1 S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	23.6 dB/K (clear sky & 5° elevation angle)
Polarization	RHC or LHC
Antenna Beamwidth	0.85 deg
Antenna Gain	45.8 dBi
Carrier Modulation	PM/PCM, FM/PCM, BPSK, or QPSK / OQPSK
Modulation Index	PM: 0.2 – 2.8 Radians (peak)
Carrier Data Rate (High Rate Telemetry Channel)	1 Kbps – 10 Mbps (FM/PCM) 100 bps – 20 Mbps (PM/PCM, BPSK, OQPSK) 1 Kbps – 40 Mbps (QPSK) [$\leq$ 20 Mbps per channel]
Carrier Data Format	NRZ-L, M or S, Biϕ-L, M or S; DM-M or S; DBP-M or S; RNRZ
Subcarrier Frequency	5 kHz – 2 MHz
Subcarrier Modulation	PSK, BPSK, PCM/PM for high BW telemetry
Subcarrier Data Rate	100 bps – 600 Kbps
Subcarrier Data Format	Passes all NRZ or Biϕ or DM
Decoding	Derandomization, Viterbi and/or Reed-Solomon (Ref Para 1.3 s)

4.2.3 **X-band Telemetry**

Table 4-3 identifies the X-band telemetry characteristics of the WG1.

4.2.4 **Tracking Services**

4.2.4.1 **Doppler Tracking**

WG1 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 WG1 S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 4-4.

Table 4-3. WG1 X-band Telemetry Characteristics

Characteristic	Value
Frequency	8000-8500 MHz
G/T	34.5 dB/K (clear sky & 10° elevation angle)
Polarization	RHC or LHC
Antenna Beamwidth	0.23 deg
Antenna Gain	56.8 dBi
Modulation	BPSK, QPSK, OQPSK, UQPSK, 8PSK, GMSK, (16,32,64 APSK)
Demodulator Data Rate Dual Channel	500 Kbps – 240 Mbps (BPSK) per channel 1 Mbps – 350 Mbps (QPSK, OQPSK) per channel 1 Mbps – 2X240 Mbps (UQPSK) per channel 1 Mbps – 350 Mbps (8PSK) per channel
Data Format	NRZ-L, M, S. Biϕ-L, M, S, DNRZ
Decoding	Derandomization, Viterbi, and or Reed-Solomon (Section 1.3, ref o), 7/8 LDPC

Table 4-4. WG1 Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.00054 cycles
Doppler Frequency Shift	$\leq$ 0.25 MHz
Doppler Bias Frequency (fbias)	0.24 MHz
Drift (Δf/f)	3×10^{-11} at 0.1 sec
Accuracy	0.0031 Hz
Output Equation	$(f_{transmit} \times [240/221] - f_{received}) + f_{bias}$

4.2.4.2   **Antenna Autotracking Angle Data**

The WG1 can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages.

4.2.4.3   **Range Tracking**

Ranging capability has been successfully implemented at WG1. Tracking characteristics are shown in Table 4-5.

4.2.5   **Baseband Data Interfaces**

The WG1 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. WG1 currently has a T-1 (1.544 Mbps) communications link with GSFC to support command, low-rate telemetry, and ground station control and monitor.

Table 4-5. WG1 Ranging Characteristics

Characteristic	Value
Modulation	PM
Supported standards	ESA standard ESA like standard (includes USB) ESA code standard Continuous Tone standard
Major Tone	500 KHz (Tone Ranging) or 450 KHz (Code Ranging)
Minor Tones	Minor Tones are each a programmable ratio of the major tone. Up to 6 minor tones for ESA standard or up to 8 minor tones for ESA like standard. ESA code and Continuous Tone standards do not use minor tones.
Modulation Index	0.1 – 2.5 Radians
Resolution	30.0 cm

4.3   **Wallops WG2 – 5-m, S-band**

4.3.1   **General**

The general characteristics of the WG2 (low Earth orbit) antenna at WFF are as follows:

37º 55′ 25″ N (see NDOSL "LE2S" for details)

75º 28′ 34″ W

a. One 5-m antenna for simultaneously transmitting and receiving at S-band. Figure 4-2 is a photograph of the WG2 antenna.

b. Automatically scheduled by NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

c. Tracking services: None.

d. Baseband data interfaces: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets.

Sections 4.3.1 and 4.3.2 describe S-band performance characteristics, and Section 4.3.3 describes the baseband data interfaces.

4.3.2   **S-band Command**

Table 4-6 identifies the S-band command characteristics of the WG2 – WFF antenna system.

4.3.3   **S-band Telemetry**

Table 4-7 identifies the S-band telemetry characteristics of the WG2 – WFF antenna system station.

Figure 4-2. WG2 WFF Antenna

Table 4-6. WG2 – S-band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
Maximum EIRP	$\geq$ 59.0 dBW
Polarization	RHC or LHC
Antenna Beamwidth	1.8 deg
Antenna Gain	38.6 dBi
Command Modulation	FSK no bit blanking FSK+half-bit blanking. Duty cycle: 50/50 BPSK, BPSK+AM,PCM/PSK/PM/FM/QPSK Direct PCM/PM
Modulation Index	PM: 0.2 – 1.5 Radians (peak)
Carrier Data Rate	N/A
Subcarrier Frequency	$\leq$ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	10 bps – 1 Mbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 4-7. WG2 – S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	17.0 dB/K (clear sky & 5° elevation angle)
Polarization	RHC or LHC
Antenna Beamwidth	1.83 deg
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: 10 bps – 8 Mbps Rate-½ coded: 10 bps – 4 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 4 MHz
Subcarrier Modulation	PSK, BPSK, PCM/PM for high BW telemetry
Subcarrier Data Rate	N/A
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Version 1 & 2, Ref Para 1.3 v)

4.3.4   **Baseband Data Interfaces**

The WG2 antenna system 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. 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.

4.4   **Wallops WG3/WG4 VHF Air/Ground Antenna Systems**

The two VHF Air/Ground (A/G) antenna systems 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:

37 ° N (see NDOSL "WP2Z for VHF-1 and "WP3Z" for VHF-2)

75 º W

a.   Two Quad Yagi antennas (WG3 VHF-1 and WG4 VHF-2) for simultaneously transmitting voice at VHF while receiving voice at VHF.

b.   Manually scheduled by Wallops via NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*. Only Johnson Space Center – Mission Control Center (JSC-MCC) is allowed to request support.

c.   Tracking services: None.

d   Baseband interfaces: Dedicated NASA Communications (NASCOM) communications voice loops.

Sections 4.4.1 and 4.4.2 describe the VHF-1 and VHF-2 voice A/G characteristics, respectively. Section 4.4.3 describes the baseband voice interfaces.

4.4.1   **VHF-1 A/G Voice Antenna Systems, WG3**

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	$\geq$ 43.4 dBW
Polarization	N/A
Antenna Beamwidth	20 deg
Antenna Gain	18.0 dBi
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
Polarization	RHC
Antenna Beamwidth	20 deg
Antenna Gain	18.0 dBi
Carrier Modulation	FM
FM Deviation	± 10 kHz
Carrier Data Rate	N/A (Voice only on downlink)

4.4.2   **VHF-2 A/G Voice Antenna Systems, WG4**

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	43.4 dBW
Polarization	N/A
Antenna Beamwidth	20 deg
Antenna Gain	18.0 dBi
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
Polarization	RHC
Antenna Beamwidth	20 deg
Antenna Gain	18.0 dBi
Carrier Modulation	FM
FM Deviation	± 10 kHz
Carrier Data Rate	N/A (Voice only on downlink)

4.4.3   **Baseband Voice Interfaces**

The WFF VHF-1 and WFF VHF-2 A/G antennas can send and receive baseband voice and receive packet data from only the JSC-MCC via dedicated NASCOM communications voice loops.

4.5 Wallops WG5, 11-m, S-, X- and Ka-band

This section will be populated in the next revision.

Section 5. McMurdo Ground Station (10m)

5.1   General

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

77° 50′ 21″ S   (for details see NDOSL "MC1S")

166° 40′ 01″ E

a. One 10-m antenna (MG1) for simultaneously transmitting at S-band while receiving at S-and X-bands. Figure 5-1 is a photograph of the MG1 antenna.

b. Future upgrade to McMurdo TDRS Relay System Upgrade (MTRSU) for high speed data transfers.

c. Automatically scheduled by NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

d. Remotely monitored via Wallops (24x7).

e. Tracking services: No tracking data capability but the antenna does have "auto track" capability.

f. Baseband data interfaces: IP, 4800-bit blocks encapsulated in IP packets, and mail.

g. MG1 cannot be considered a launch MANDATORY project-required site.

Sections 5.2 through 5.4 describe the current S- and X-band performance characteristics. Section 5.5 describes the baseband data interfaces.

Figure 5-1. McMurdo 10-m, MG1 Antenna

5.2 **S-band Command**

Table 5-1 identifies the S-band command characteristics of the MG1.

Table 5-1. MG1 S-band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
Maximum EIRP	≥ 63 dBW
Polarization	RHC or LHC
Antenna Beamwidth	1.05 deg
Antenna Gain	44 dBi
Command Modulation	FSK no bit blanking FSK+half-bit blanking. Duty cycle: 50/50 BPSK, BPSK+AM,PCM/PSK/PM/FM/QPSK Direct PCM/PM
Modulation Index	FM: 1 kHz – 5.0 MHz deviation PM 0.01 – 2.50 Radians
Carrier Data Rate	1 Kbps – 1 Mbps
Subcarrier Frequency	5 KHz – 2 MHz
Subcarrier Modulation	FSK and BPSK
Subcarrier Data Rate	100 bps – 250 Kbps
Data Format	NRZ-L, M, or S; or Biφ-L, M, or S

5.3 **S-band Telemetry**

Table 5-2 identifies the S-band telemetry characteristics of the MG1.

Table 5-2. McMurdo 10-m MG1 S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T include radome	21 dB/K (clear sky & 5° elevation angle)
Polarization	RHC, LHC or Diversity Combining
Antenna Beamwidth	0.91 deg
Antenna Gain	45 dBi
Carrier Modulation	PM/PCM, FM/PCM, BPSK, QPSK, or OQPSK
Modulation Index	PM: 0.2 – 2.8 Radians (peak)
Carrier Data Rate	1 kbps – 10 Mbps (FM/PCM) 100 bps – 20 Mbps (PM/PCM, BPSK, OQPSK) 1 kbps – 40 Mbps (QPSK) [<20 Mbps per channel]
Carrier Data Format	NRZ-L, M, or S; Biφ-L, M, or S; DM-M or S; DBP-M or S; RNRZ-L
Subcarrier Frequency	5 kHz – 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	100 bps – 600 kbps
Subcarrier Data Format	NRZ, Biφ, or DM
Decoding	Derandomization, Viterbi and/or Reed-Solomon (Section 1.3 ref s.)

5.4 **X-band Telemetry**

Table 5-3 identifies the X-band telemetry characteristics of the MG1.

Table 5-3. MG1 X-band Telemetry Characteristics

Characteristic	Value
Frequency	7700 – 8500 MHz
G/T include radome	32.0 dB/K (clear sky & 10° elevation angle)
Polarization	RHC or LHC
Antenna Beamwidth	0.26 deg
Antenna Gain	56 dBi
Modulation Type	BPSK, QPSK, OQPSK, UQPSK, 8PSK, GMSK, (16,32,64 APSK)
Demodulator Data Rate – Mono Channel	500 Kbps – 240 Mbps (BPSK) per channel 1 Mbps – 350 Mbps (QPSK, OQPSK) per channel 1 Mbps – 2X240 Mbps (UQPSK) per channel 1 Mbps – 350 Mbps (8PSK) per channel
Data Format	NRZ-L, M, S, Biφ-L, M, S, DNRZ
Decoding	Derandomization, Viterbi and/or Reed-Solomon (Para 1.3 ref s.)

5.5 **Baseband Data Interfaces**

MG1 can send and receive baseband data in either of the following formats: IP or 4800-bit blocks encapsulated in IP packets (see Section 14). MG1 currently has a 1 Mbps outbound and 500 kbps inbound 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. MG1 also has a MTRSU system for high speed data transfers. It is currently being used by the Soil Moisture Active Passive (SMAP) mission. Please contact the NEN for potential use of MTRSU.

The MTRSU is a Tracking and Data Relay Satellite (TDRS) ground system, owned and operated by the NEN, located at McMurdo Station, Antarctica. High speed data can be sent from MGS to the MTRSU via fiber to provide delivery of near real time or stored high rate scientific data. The data is sent through the SN to White Sands Complex (WSC) for delivery to end users. The MTRSU can be used to relay data at rates of up to 300 - 600 Mbps. In 2017, the MTRSU system received a significant upgrade at MGS that improved the reliability of the overall system and added new capabilities (higher modulations and Forward Error Correction (FEC)). The MTRSU system uses 8-Phase Shift Keying (PSK) modulation and a Forward Error Correction of Low Density Parity Check Code for Rate 7/8 (LDPC 7/8). This is a similar modulation and FEC scheme to what the International Space Station (ISS) uses for their high speed communications. In addition to its current operational use, the system can be used as a testbed for future capability testing for the Space Network.

Figure 5-2 depicts an overview of the MTRSU data flow from orbiting missions to the WSC. The components of the MTRSU are split between McMurdo and the WSC. The McMurdo subsystem

is located on Ross Island approximately 1.5 miles from the MGS and provides on average 10 hours of daily SN visibility for data relay.

The MTRSU subsystem transmits the data via the SN Ku-band Single Access (SA) return service at total data rates up to 300 Mbps (capable of up to 600 Mbps awaiting upgrades at WSC). The data is received at the WSC and processed by the MTRSU subsystem located there. The data is then transferred to the customer via an Internet Protocol (IP) network. The MTRSU supports various data transfer protocols to allow for a fully reliable file transfer system to the end users of the system. An added benefit of the system is its ability to provide an emergency/backup link to offload data and provide limited network connectivity from McMurdo in the event that the low rate connection fails. Enabling SN Ku-band SA forward service would add uplink capability.

High-rate X-band telemetry data recorded by MG1 may also be transferred to media then shipped (limited flights during the austral winter) to the end user via international carrier from Christchurch, New Zealand.
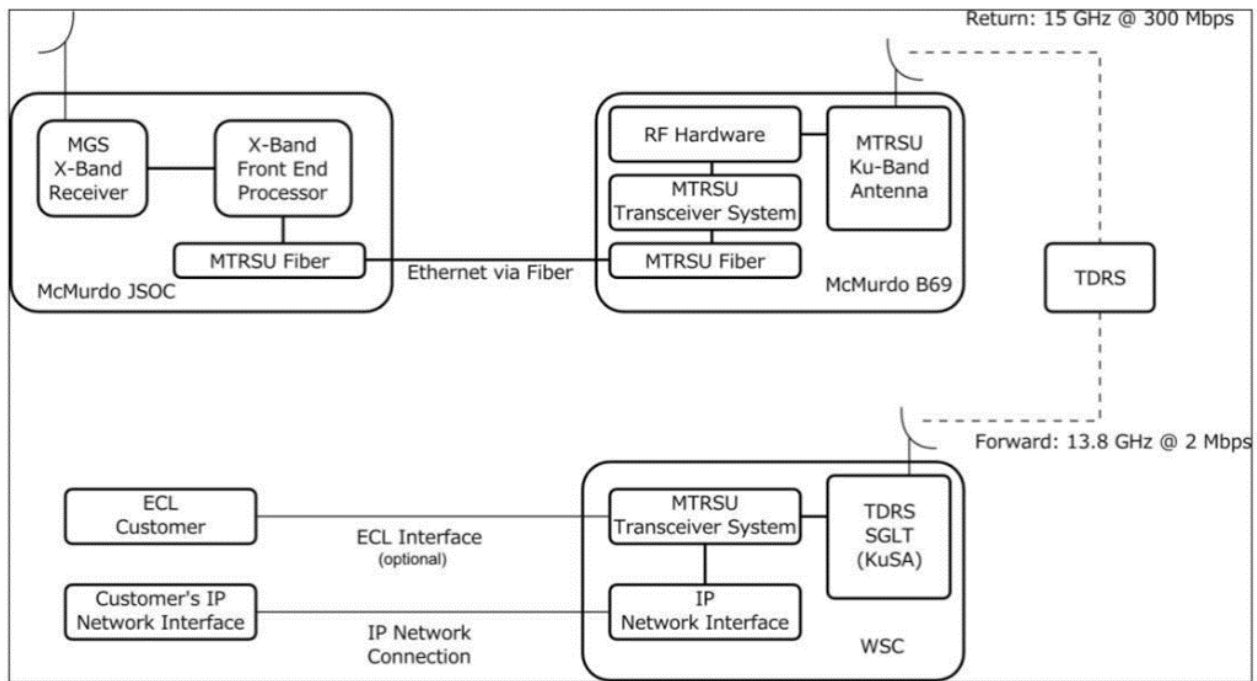
Figure 5-2. Overview of the MTRSU data flow from orbiting missions to the WSC

Section 6. Swedish Space Corporation (SSC) Ground Stations

6.1   **General**

Swedish Space Corporation is a commercial service provider with three primary stations; North Pole in Alaska, Hawaii, and Western Australia. SSC also has collaborative agreements for access to other stations located at various sites around the world. Further details concerning these sites are available at URL: http://www.sscspace.com.

This section describes the NEN stations at North Pole, Hawaii, and Australia. The antennas at Poker Flat were moved to North Pole, Alaska.

6.1.1   **North Pole, Alaska 13m, USAK01**

This section describes the North Pole (a suburb of Fairbanks), Alaska, 13-m system referred to as USAK01.

The general characteristics of the USAK01 aperture are as follows:

<div align="center">

64° 48′ 15″ N (for details see NDOSL "USAS")

147° 30′ 01″ W

</div>

a.   13-m antenna for simultaneously transmitting at L-band or S-band while receiving at S- and X-band. Figure 6-1 is a photograph of the USAK01 antenna.

b   Supports S-band and X-band CCSDS services. Supports L-band Space-to-Ground Link Subsystem and United States Air Force services.

c   Manually scheduled by SSC via NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

d   Tracking services: 1- & 2-way Doppler, ranging, and antenna auto tracking angles.

e   Baseband data interfaces: TCP/IP, 4800-bit blocks encapsulated in IP packets, and mail.

f.   Site Power: Commercial power. UPS power to RF and baseband equipment only. 200-KW back-up power generator.

Figure 6-1 USAK01 13-meter Antenna

6.1.2 **USAK01 L/S-band Command**

Table 6-1 identifies the L/S-band command characteristics of the USAK01 aperture.

6.1.3 **USAK01 S-band Telemetry**

Table 6-2 identifies the S-band telemetry characteristics of the USAK01 aperture.

Table 6-1. USAK01 L/S-band Command Characteristics

Characteristic	Value
Frequency	L-band: 1750-1850 MHz S-band: 2025 – 2120 MHz
Maximum 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
Command Modulation	PCM,PSK, PM, FM, QPSK or BPSK Direct PCM/PM
Modulation Index	PM: 1.5 Radians (peak) BPSK
Carrier Data Rate	10 bps – 10 Mbps
Subcarrier Frequency	$\leq$ 5 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	32 bps - 1 Mbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 6-2. USAK01 S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	23.5 dB/K (clear sky & 5° elevation angle)
Polarization	RHC and LHC
Antenna Beam-width	0.70 deg
Antenna Gain	48.0 dBi
Carrier Modulation	PM, FM, BPSK, QPSK, or OQPSK
Modulation Index	PM: 0.2 – 2.8 Radians (peak)
Carrier Data Rate	100 bps – 20 Mbps Uncoded
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	$\leq$ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	100 bps – 256 kbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi (Rate-1/2) and/or Reed-Solomon

6.1.4 **USAK01 X-band Telemetry**

Table 6-3 identifies the X-band telemetry characteristics of the USAK01 aperture.

Table 6-3. USAK01 X-band Telemetry Characteristics

Characteristic	Value
Frequency	8000 – 8500 MHz
G/T	37.7 dB/K (clear sky & 10° elevation angle)
Polarization	RHC or LHC
Antenna Beam-width	0.17 deg
Antenna Gain	59.1 dBi
Modulation	BPSK,QPSK,SQPSK or AQPSK
Data Rate	1 Mbps – 150 Mbps Uncoded
Data Format	NRZ-L or M
Decoding	Viterbi (Rate-½), 7/8 LDPC

6.1.5   USAK01 Tracking Services

The USAK01 aperture can provide Doppler, ranging, and angular tracking measurements. The measurement message format can be delivered in the native SSC format or in customer-defined formats such as UTDF format.

6.1.5.1   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.

6.1.5.2   USAK01 Ranging

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

6.1.5.3   USAK01 Antenna Autotrack Angle Data

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

6.1.6   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 SSC Network Management Center (NMC) in 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.

6.2   North Pole, Alaska, UASK03

This section describes the North Pole, Alaska, 5.4-m system referred to as USAK03. The general characteristics of the antenna system:

64° 48′ 17″ N (for details see NDOSL "U3AS")

147° 30′ 15″ W

a   One 5.4-m antenna for simultaneously transmitting at S-band while receiving at S- and X-bands. Figure 6-2 is a photograph of the USAK03 antenna.

b.   Automatically scheduled by NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

c.   Tracking services: 1- & 2-way Doppler and antenna auto tracking angles.

d.   Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.

e.   Site Power: Commercial power. Uninterruptable Power Source (UPS) power to RF and baseband equipment only. Backup (500 KVA) Generator.

6.2.1   **USAK03 S-band Command**

Table 6-4 identifies the S-band command characteristics of the USAK03 aperture.

6.2.2   **USAK03 S-band Telemetry**

Table 6-5 identifies the S-band telemetry characteristics of the USAK03 aperture.

6.2.3   **USAK03 X-band Telemetry**

Table 6-6 identifies the X-band telemetry characteristics of the USAK03 aperture.

Figure 6-2. North Pole, Alaska 5.4 Antenna (USAK03)

Table 6-4. USAK03 S-Band Command Characteristics

Characteristic	Value
Frequency	S-Band: 2025 – 2120 MHz
Maximum EIRP	S-Band: $\geq$ 56.1 dBW
Polarization	RHC or LHC
Antenna Beam-width	1.7 deg
Antenna Gain	40.3 dBi
Command Modulation	PCM, PSK, PM, FM, QPSK or BPSK Direct PCM/PM
Modulation Index	PM: 1.5 radians (peak) BPSK
Carrier Data Rate	100 bps – 250kbps
Subcarrier Frequency	$\leq$ 1.2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	$\leq$ 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 6-5. USAK03 S-Band Telemetry characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	17.2 dB/K (clear sky & 5° elevation angle)
Polarization	RHC or LHC
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	$\leq$ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	100 bps - 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 6-6. USAK03 X-band Telemetry Characteristics

Characteristic	Value
Frequency	8000 – 8500 MHz
G/T	31.5 dB/K (clear sky & 5° elevation angle)
Polarization	RHC or LHC
Antenna Beam-width	0.45 deg
Antenna Gain	48.45 dBi
Modulation	BPSK, QPSK, SQPSK, or AQPSK
Data Rate	40 Mbps – 400 Mbps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon, 7/8 LDPC

6.2.4 USAK03 Tracking Services

The USAK03 aperture can provide Doppler and ranging measurements to the FDF. The measurement message format can be delivered in the native SSC format or in customer-defined formats such as UTDF format.

6.2.4.1 USAK03 Doppler Tracking

The USAK03 aperture can collect 1-way and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier.

6.2.4.2 USAK03 Ranging

The USAK03 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.

6.2.4.3 USAK03 Antenna Autotrack Angle Data

The USAK03 aperture records the angle of the ground antenna as it autotracks.

6.2.4.4 USAK03 Baseband Data Interfaces

The USAK03 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 MPLS service for transporting the TCP/IP data to the SSC NMC in 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 USAK03 site as required. Services available in the area include open Internet, MPLS, and private line via fiber and copper media.

6.3 North Pole, Alaska, 7.3-m S- and X-band Antenna System, USAK04 (5.4m)

This section describes the North Pole, Alaska 7.3-m system referred to as USAK04.

The general characteristics of the station are as follows:

64° 48′ 17″ N (for more detail, see NDOSL "U4AS")

147° 30′ 15″ W

a.   One 7.3-m antenna for simultaneously transmitting at S-band while receiving at S- and X-bands. Figure 6-3 is a photograph of the USAK04 antenna.

b.   Automatically scheduled by NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

c.   Tracking services: 1- & 2-way Doppler and antenna auto tracking angles.

d.   Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.

e.   Site Power: Commercial power. Uninterruptable Power Source (UPS) power to RF and baseband equipment only. Backup (500 KVA) Generator.

Figure 6-3. USAK04 Antenna (old photo)

6.3.1   **USAK04 S-band Command**

Table 6-7 identifies the S-band command characteristics of the USAK04 aperture.

6.3.2   **USAK04 S-band Telemetry**

Table 6-8 identifies the S-band telemetry characteristics of the USAK04 aperture.

Table 6-7. USAK04 S-band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
Maximum EIRP	58.4 dBW
Polarization	RHC or LHC
Antenna Beam-width	1.39 deg
Antenna Gain	42.1 dBi
Command Modulation	PCM, PSK, PM, FM, QPSK or BPSK Direct PCM/PM
Modulation Index	PM: 1.5 Radians (peak) FM: 50 kHz – 50 MHz deviation BPSK
Carrier Data Rate	100 bps – 1 Mbps
Subcarrier Frequency	$\leq$ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	100 bps – 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 6-8. USAK04 S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	19.6 dB/K (clear sky & 5° elevation angle)
Polarization	RHC and LHC
Antenna Beam-width	1.25 deg
Antenna Gain	42.4 dBi
Carrier Modulation	PM, FM, BPSK, QPSK, or OQPSK
Modulation Index	PM: 0.2 – 2.8 Radians (peak)
Carrier Data Rate	100 bps – 20 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	$\leq$ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	100 bps – 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon

6.3.3 **USAK04 X-band Telemetry**

Table 6-9 identifies the X-band telemetry characteristics of the USAK04 aperture.

Table 6-9. USAK04 X-band Telemetry Characteristics

Characteristic	Value
Frequency	8000 – 8500 MHz
G/T	31.0 dB/K (clear sky & 10° elevation angle)[1]
Polarization	RHC or LHC
Antenna Beam-width	0.29 deg
Antenna Gain	54.2 dBi
Modulation	BPSK, QPSK, SQPSK or PM
Data Rate	10 Mbps – 150 Mbps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon, 7/8 LDPC
[1] Actually measured at 60° elevation but the difference is considered negligible.	

6.3.4 **USAK04 Tracking Services**

6.3.4.1 **USAK04 Doppler Tracking**

The USAK04 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 USAK04 S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 6-10.

Table 6-10. USAK04 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 sec
Accuracy	0.01 Hz
Output Equation	1000 ($f_{transmit} \times [240/221] - f_{received}$) + f_{bias}

6.3.4.2 **USAK04 Antenna Autotracking Angle Data**

The USAK04 records the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages.

6.3.5 **USAK04 Baseband Data Interfaces**

The USAK04 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. USAK04 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. USAK04 will also mail high-rate, recorded X-band telemetry data to the user as required. Data is recorded on Universal Serial Bus (USB) Flash drives.

6.4 North Pole, Alaska, 11.0-m S- and X-band Antenna System, USAK05

This section describes the North Pole, Alaska, 11.0-m system referred to as USAK05.

The general characteristics of the station are as follows:

<div align="center">

65° 7′ 4″ N

147° 26′ 01″ W

</div>

a. One 11-m antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 6-4 is a photograph of the USAK05 antenna with the Radome installed.

b. Automatically scheduled by NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

c. Tracking services: 1- & 2-way Doppler and antenna auto tracking angles.

d. Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.

e. Site Power: Commercial power. UPS power to RF and baseband equipment only. No back-up power generator.

Figure 6-4. USAK05 Antenna Radome

6.4.1 USAK05 S-band Command

Table 6-11 identifies the S-band command characteristics of the USAK05.

6.4.2 **USAK05 S-band Telemetry**

Table 6-12 identifies the S-band telemetry characteristics of the USAK05 aperture.

Table 6-11. USAK05 S-band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
Maximum EIRP	65.4 dBW
Polarization	RHC or LHC
Antenna Beam-width	0.92 deg
Antenna Gain	45.7 dBi
Carrier Modulation	PM, FM, or BPSK
Modulation Index	PM: 1.5 Radians (peak) FM: 50 kHz – 50 MHz deviation BPSK
Carrier Data Rate	100 bps – 1 Mbps
Subcarrier Frequency	$\leq$ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	100 bps –250kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 6-12. USAK05 S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T include Radome	23.2 dB/K (clear sky & 5° elevation angle)
Polarization	RHC and LHC
Antenna Beam-width	0.85 deg
Antenna Gain	46.0 dBi
Command Modulation	PCM, PSK, PM, FM, BPSK, or QPSK Direct PCM/PM
Modulation Index	PM: 0.2 – 2.8 Radians (peak)
Carrier Data Rate	100 bps – 36 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	$\leq$ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	100 bps – 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon

6.4.3 USAK05 X-band Telemetry

Table 6-13 identifies the X-band telemetry characteristics of the USAK05 aperture.

Table 6-13. USAK05 X-band Telemetry Characteristics

Characteristic	Value
Frequency	7000 – 9000 MHz Receive 8100 – 8400 MHz Autotrack
G/T include Radome	34.0 dB/K (clear sky & 10° elevation angle)
Polarization	RHC or LHC
Antenna Beam-width	0.20 deg
Antenna Gain	56.86 dBi
Modulation	BPSK,QPSK,SQPSK or AQPSK
Data Rate	10 Mbps – 150 Mbps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon, 7/8 LDPC

6.4.4 USAK05 Tracking Services

6.4.4.1 USAK05 Doppler Tracking

The USAK05 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 USAK05 S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 6-14.

Table 6-14. USAK05 UTDF Doppler Tracking Characteristics

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

6.4.4.2 USAK05 Antenna Autotrack Angle Data

The USAK05 records the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages.

6.4.5 USAK05 Baseband Data Interfaces

The USAK05 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. USAK05 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. USAK05 will also mail

high-rate, recorded X-band telemetry data to the user as required. Data is recorded on USB Flash drives.

6.5   **South Point, Hawaii, 13-m, S- and X-band Antenna System, USHI01**

This section describes the South Point, Hawaii, 13-m system referred to as USHI01.

The general characteristics of the USHI01 aperture are as follows:

19° 00′ 50″ N

155° 39′ 47″ W

a.   13-m antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 6-5 is a photograph of the USHI01 antenna.

b.   High Power S-band uplink (2500-W Transmitter).

c.   Manually scheduled by SSC via NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

d.   Tracking services: 1- and 2-way Doppler, ranging, and antenna auto tracking angles.

e.   Baseband data interfaces: TCP/IP, 4800-bit blocks encapsulated in IP packets, and mail.

f.   Site Power: Commercial power. UPS power to RF and baseband equipment only. 350-KW back-up power generator.

Figure 6-5. USHI01 Antenna

6.5.1 **USHI01 S-band Command**

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

6.5.2 **USHI01 S-band Telemetry**

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

Table 6-15. USHI01 S-band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
Maximum EIRP	78 dBW
Polarization	RHC or LHC
Antenna Beam-width	0.78 deg
Antenna Gain	47.1 dBi
Command Modulation	PCM, PSK, PM, FM, or BPSK Direct PCM/PM
Modulation Index	PM: 1.5 Radians (peak) BPSK
Carrier Data Rate	10 bps – 10 Mbps
Subcarrier Frequency	≤ 5 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	32 bps – 1 Mbps
Data Format	NRZ-L, M, or S; or Biφ-L, M, or S

Table 6-16. USHI01 S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	23.5 dB/K (clear sky & 5° elevation angle)
Polarization	RHC and LHC
Antenna Beam-width	0.70 deg
Antenna Gain	48.0 dBi
Carrier Modulation	PM, FM, BPSK, QPSK, or OQPSK
Modulation Index	PM: 0.2 – 2.8 Radians (peak)
Carrier Data Rate	100 bps – 20 Mbps Uncoded
Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Demodulation	BPSK
Subcarrier Data Rate	10 bps – 256 kbps
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi (Rate-1/2) and/or Reed-Solomon, Rate-½ Turbo

6.5.3 USHI01 X-band Telemetry

Table 6-17 identifies the X-band telemetry characteristics of the USHI01 aperture.

Table 6-17. USHI01 X-band Telemetry Characteristics

Characteristic	Value
Frequency	8000 – 8500 MHz
G/T	37.7 dB/K (clear sky & 10° elevation angle)
Polarization	RHC or LHC
Antenna Beam-width	0.17 deg
Antenna Gain	59.1 dBi
Modulation	BPSK,QPSK,SQPSK or AQPSK
Data Rate	1 Mbps – 150 Mbps, Uncoded
Data Format	NRZ-L or M
Decoding	Viterbi (Rate-1/2) and/or Reed-Solomon, 7/8 LDPC

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 SSC format or in customer-defined formats such as 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 (see Table 4-5). 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 MPLS service for transporting the TCP/IP data to the SSC NMC in Pennsylvania.

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

CCSDS Space Link Extension is available at this station.

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 128-Kbps Integrated Services Digital Network (ISDN) lines.

6.6 South Point, Hawaii, 13-m S- and X-band Antenna System, USHI02

This section describes the South Point, Hawaii, 13-m system referred to as USHI02.

The general characteristics of the USHI02 aperture are as follows:

19° 00′ 50″ N

155° 39′ 47″ W

a. 13-m antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 6-6 is a photograph of the USHI02 antenna.

b. High Power X-band uplink (3000-W Transmitter). X-band transmit – or – X-band receive.

c. Manually scheduled by SSC via NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

d. Tracking services: 1- and 2-way Doppler, ranging, and antenna auto tracking angles.

e. Baseband data interfaces: TCP/IP, 4800-bit blocks encapsulated in IP packets, and mail.

f. Site Power: Commercial power. UPS power to RF and baseband equipment only. 350-KW back-up power generator.

Figure 6-6. USHI02 Antenna

6.6.1 **USHI02 S-band Command**

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

6.6.2 **USHI02 X-band Command**

Table 6-19 identifies the X-band command characteristics of the USHI02 aperture.

Table 6-18. USHI02 S-band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
Maximum EIRP	68 dBW
Polarization	RHC or LHC
Antenna Beam-width	0.78 deg
Antenna Gain	47.1 dBi
Command Modulation	PCM, PSK, PM, FM, or BPSK Direct PCM/PM
Modulation Index	PM: 1.5 Radians (peak) BPSK
Carrier Data Rate	10 bps – 10 Mbps
Subcarrier Frequency	$\leq$ 5 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	32 bps – 1 Mbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 6-19. 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
Carrier Modulation	PM, FM, or BPSK
Modulation Index	PM: 1.5 radians (peak) BPSK
Carrier Data Rate	10 bps – 32 Kbps
Subcarrier Frequency	$\leq$ 1.2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	32 bps – 1 Mbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

6.6.3 USHI02 S-band Telemetry

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

Table 6-20. USHI02 S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	23.5 dB/K (clear sky & 5° elevation angle)
Polarization	RHC and LHC
Antenna Beam-width	0.70 deg
Antenna Gain	48.0 dBi
Carrier Modulation	PM, FM, BPSK, QPSK, or OQPSK
Modulation Index	PM: 0.2 – 2.8 Radians (peak)
Carrier Data Rate	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	10 bps – 256 bps
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi (Rate-1/2) and/or Reed-Solomon, Rate-½ Turbo, 7/8 LDPC

6.6.4 USHI02 X-band Telemetry

Table 6-21 identifies the X-band telemetry characteristics of the USHI02 aperture.

Table 6-21. USHI02 X-band Telemetry Characteristics

Characteristic	Value
Frequency	8000 – 8500 MHz
G/T	37.7 dB/K (clear sky & 10° elevation angle)
Polarization	RHC or LHC
Antenna Beam-width	0.17 deg
Antenna Gain	59.1 dBi
Modulation	BPSK,QPSK,SQPSK or AQPSK
Data Rate	1 Mbps – 150 Mbps, Uncoded
Data Format	NRZ-L or M
Decoding	Viterbi (Rate-1/2) 7/8 LDPC

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 SSC format or in customer-defined formats such as UTDF format.

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 (see Table 4-5). 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 MPLS service for transporting the TCP/IP data to the SSC NMC in Pennsylvania.

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

CCSDS Space Link Extension is available at this station.

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 128-Kbps ISDN lines.

6.7 **Dongara, Australia, 13-m S- and X-band Antenna System, AUWA01**

This section describes the Dongara, Western Australia, 13-m system referred to as AUWA01.

The general characteristics of the AUWA01 aperture are as follows:

<div align="center">

29° 02′ 44.780″ S

115° 20′ 55.240″ E

</div>

a. 13-m antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 6-7 is a photograph of the AUWA01 antenna.

b. Manually scheduled by SSC via NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

c. Tracking services: 1- and 2-way Doppler, ranging, and antenna auto tracking angles.

d. Baseband data interfaces: TCP/IP, 4800-bit blocks encapsulated in IP packets, and mail.

e. Site Power: Commercial power. UPS power to RF and baseband equipment only. 100-KW back-up power generator.

Figure 6-7. AUWA01 Antenna

6.7.1   **AUWA01 S-band Command**

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

6.7.2   **AUWA01 S-band Telemetry**

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

Table 6-22. AUWA01 S-band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
Maximum EIRP	68 dBW
Polarization	RHC or LHC
Antenna Beam-width	0.78 deg
Antenna Gain	47.1 dBi
Carrier Modulation	PCM, PSK, PM, FM, or BPSK Direct PCM/PM
Modulation Index	PM: 1.5 Radians (peak) BPSK
Carrier Data Rate	10 bps – 10 Mbps
Subcarrier Frequency	$\leq$ 5 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	32 bps – 1 Mbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 6-23. AUWA01 S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	23.5 dB/K (clear sky & 5° elevation angle)
Polarization	RHC and LHC
Antenna Beam-width	0.70 deg
Antenna Gain	48.0 dBi
Carrier Modulation	PM, FM, BPSK, QPSK, or OQPSK
Modulation Index	PM: 0.2 – 2.8 Radians (peak)
Carrier Data Rate	100 bps – 20 Mbps Uncoded
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	$\leq$ 2 MHz
Subcarrier Demodulation	BPSK
Subcarrier Data Rate	10 bps – 256 kbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi (Rate-½) and/or Reed-Solomon, Rate-½ Turbo

6.7.3 AUWA01 X-band Telemetry

Table 6-24 identifies the X-band telemetry characteristics of the AUWA01 aperture.

Table 6-24. AUWA01 X-band Telemetry Characteristics

Characteristic	Value
Frequency	8000 – 8500 MHz
G/T	37.7 dB/K (clear sky & 10° elevation angle)
Polarization	RHC or LHC
Antenna Beam-width	0.17 deg
Antenna Gain	59.1 dBi
Modulation	BPSK,QPSK,SQPSK or AQPSK
Data Rate	1 Mbps – 150 Mbps, Uncoded
Data Format	NRZ-L or M
Decoding	Viterbi (Rate-½) , 7/8 LDPC

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 SSC format or in customer-defined formats such as 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 (see Table 4-5). 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 Virtual Private Network (VPN)/Internet service for transporting the TCP/IP data to the SSC NMC in Pennsylvania.

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

CCSDS Space Link Extension is available at this station.

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 128-Kbps ISDN lines.

6.8 Dongara, Australia, 7.3-m X-band Antenna System, AUWA02

This section describes the Dongara, Western Australia, 7.3-m system referred to as AUWA02.

The general characteristics of the AUWA02 aperture are as follows:

29° 02′ 44.5″ S

115° 20′ 56.5″ E

a. 7.3-m antenna X-band uplink only. Figure 6-8 is a photograph of the AUWA02 antenna.

b. Manually scheduled by SSC via NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

c. High Power X-band uplink (3000-W Transmitter).

d. Program track or slaved to AUWA01 13-m for tracking satellites services.

e. Baseband data interfaces: TCP/IP, 4800-bit blocks encapsulated in IP packets.

f. Site Power: Commercial power. UPS power to RF and baseband equipment only. 100-KW back-up power generator.

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

6.8.1 **AUWA02 X-band Command**

Table 6-25 identifies the X-band command characteristics of the AUWA02 aperture.

Table 6-25. AUWA02 X-band Command Characteristics

Characteristic	Value
Frequency	7025 – 7200 MHz
Maximum EIRP	85 dBW
Polarization	RHC or LHC
Antenna Beam-width	0.34 deg
Antenna Gain	52.8 dBi
Command Modulation	PCM, PSK, PM, FM, or BPSK Direct PCM/PM
Modulation Index	PM: 1.5 Radians (peak) BPSK
Carrier Data Rate	10 bps – 10 Mbps
Subcarrier Frequency	$\leq$ 5 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	1 Mbps – 150 Mbps Uncoded
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 SSC NMC in Pennsylvania.

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

CCSDS Space Link Extension is available at this station.

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 128-Kbps ISDN lines.

Section 7. Alaska Satellite Facility

7.1   General

This section describes the University of Alaska Ground Station in Fairbanks, Alaska. The station is operated by the University and consists of three University Operated antenna systems. The University Operated systems at ASF include:

    a. AS1, AS2, AS3 and AS4 – (Section 7.2, 7.3, 7.4, 7.5 respectively) additional information available at https://www.asf.alaska.edu/ground-station/antennas/

7.2   ASF 11.28-meter – AS1

This section describes the Alaska Satellite Facility 11.28-m system referred to as AS1.

The general characteristics of the system are as follows:

        64º 51′ 31″ N (for more detail see NDOSL, "ASFS")

            147º 51′ 27″ W

    a. The 11.3-m antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 7-1 is a photograph of the AS1 antenna.

    b. Automatically scheduled by NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

    c. Tracking services: 1- & 2-way Doppler and antenna auto tracking Angles.

    d. Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets.

Sections 7.3.1 through 7.3.3 describe S- and X-band performance characteristics. Sections 7.3.4 and 7.3.5 describe the tracking services and baseband data interfaces, respectively.

7.2.1   S-band Command

Table 7-1 identifies the S-band command characteristics of the AS1.

7.2.2   S-band Telemetry

Table 7-2 identifies the S-band telemetry characteristics of the AS1.

7.2.3   X-band Telemetry

Table 7-3 identifies the X-band telemetry characteristics of the AS1.

Figure 7-1. AS1 Antenna

Table 7-1. AS1 S-band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
Maximum EIRP	≥ 64.0 dBW
Polarization	RHC or LHC
Antenna Beamwidth	0.95 deg
Antenna Gain	44.6 dBi
Command Modulation	PCM, PSK, PM, FM, BPSK, QPSK or QPSK Direct PCM/PM
Modulation Index	PM: 0.01 – 2.5 Radians FM: 1 kHz – 50 kHz deviation BPSK
Carrier Data Rate	1 kbps – 1 Mbps
Subcarrier Frequency	5 kHz- 2 MHz
Subcarrier Modulation	FSK and BPSK
Subcarrier Data Rate	100 bps – 250 kbps
Data Format	NRZ-L, M, or S; or Biφ-L, M, or S

Table 7-2. AS1 S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	22 dB/K (clear sky & 5° elevation angle)
Polarization	RHC or LHC
Antenna Beamwidth	0.85 deg
Antenna Gain	45.8 dBi
Carrier Modulation	PM/PCM, FM/PCM, BPSK, or QPSK / OQPSK
Modulation Index	PM: 0.2 – 2.8 Radians (peak)
Carrier Data Rate (High Rate Telemetry Channel)	1 Kbps – 10 Mbps (FM/PCM) 100 bps – 20 Mbps (PM/PCM, BPSK, OQPSK) 1 Kbps – 40 Mbps (QPSK) [≤ 20 Mbps per channel]
Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S; DM-M or S; DBP-M or S; RNRZ
Subcarrier Frequency	5 kHz – 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	100 bps – 600 Kbps
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. AS1 X-band Telemetry Characteristics

Characteristic	Value
Frequency	8025 – 8500 MHz
G/T	37.2 dB/K (clear sky & 10° elevation angle)
Polarization	RHC or LHC
Antenna Beamwidth	0.23 deg
Antenna Gain	56.8 dBi
Modulation	BPSK, QPSK, OQPSK, UQPSK, 8PSK, GMSK, (16,32,64 APSK)
Demodulator Data Rate Dual Channel	500 Kbps – 240 Mbps (BPSK) per channel 1 Mbps – 350 Mbps (QPSK, OQPSK) per channel 1 Mbps – 2X240 Mbps (UQPSK) per channel 1 Mbps – 350 Mbps (8PSK) per channel
Data Format	NRZ-L, M, S. Biφ-L, M, S, DNRZ
Decoding	Derandomization, Viterbi (R-½) or Reed-Solomon, Rate 7/8 LDPC
Note:	
Current data rates intentionally omitted. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.	

7.2.4   Tracking Services

7.2.4.1   Doppler Tracking

AS1 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 AS1 S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 7-4.

7.2.4.2   Antenna Autotrack Angle Data

The AS1 can record the angle of the ground antenna as it autotracks. This data is provided to the user as UTDF messages.

7.2.5   Baseband Data Interfaces

AS1 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. AS1 currently has a T-1 (1.544 Mbps) communications link with GSFC to support command, telemetry, and ground station control and monitor.

Table 7-4. AS1 Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.004 cycles
Doppler Frequency Shift	$\leq$ 0.23 MHz
Doppler Bias Frequency	0.24 MHz
Drift (Δf/f)	4×10^{-11} at 0.1 sec
Accuracy	0.01 Hz

Output Equation	$1000 \; (f_{transmit} \times [240/221] - f_{received}) + f_{bias}$

7.3 **ASF 9.1- meter – AS2**

The ASF 9.1-m antenna is described below:

<div align="center">64º 51' 35" N for more detail see NDOSL, "ASFS"</div>

<div align="center">147º 50' 50" W</div>

a. The 9.1-m antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 7-3 is a photograph of the AS2 antenna.

b. Automatically scheduled by NEN schedulers per 453-UG-NEN Scheduling, Users' Guide for Near Earth Network Scheduling.

c. Tracking services: 1- & 2-way Doppler and antenna auto tracking Angles.

d. Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets.

Sections 7.5.1 through 7.5.3 describe S- and X-band performance characteristics. Sections 7.5.4 and 7.5.5 describe the tracking services and baseband data interfaces, respectively. *Until the system is delivered in 2017, the AS2 capabilities identified in this section are notional.*

7.3.1 **S-band Command**

Table 7-5 identifies the S-band command characteristics of the AS2.

7.3.2 **S-band Telemetry**

Table 7-6 identifies the S-band telemetry characteristics of the AS2.

7.3.3 **X-band Telemetry**

Table 7-7 identified the X-band telemetry characteristics of the AS2.
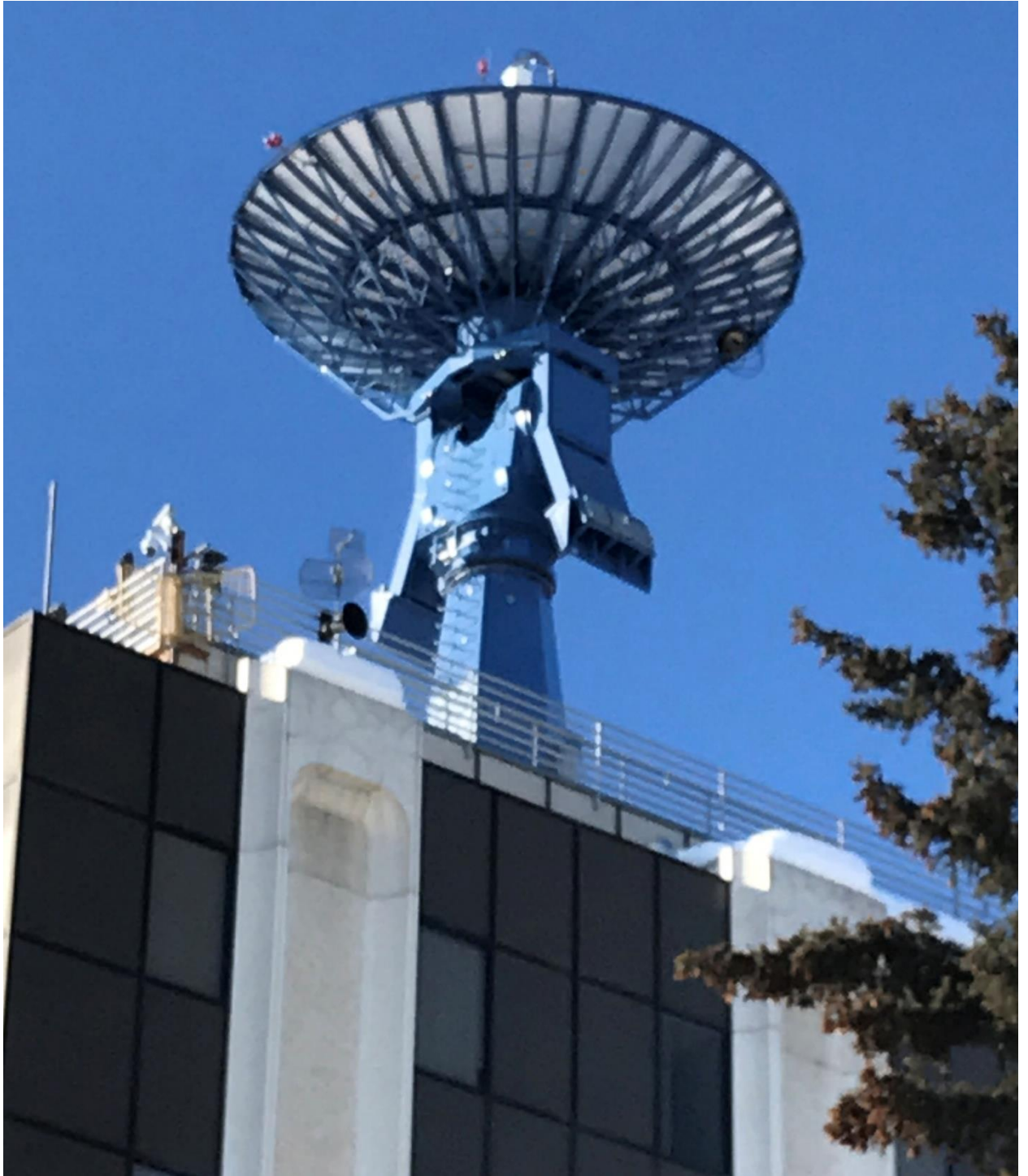
Figure 7-2. AS2 Antenna

Table 7-5. AS2 - S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
Maximum EIRP	$\geq$ 56.9 dBW
Polarization	RHC or LHC
Antenna Beamwidth	1.07 deg
Antenna Gain	41.6 dBi
Command Modulation	PCM, PSK, PM, FM, BPSK, QPSK or QPSK Direct PCM/PM
Modulation Index	PM: 0.01 – 2.5 Radians FM: 1 kHz – 50 kHz deviation BPSK
Carrier Data Rate	1 kbps – 1 Mbps
Subcarrier Frequency	5 kHz- 2 MHz
Subcarrier Modulation	FSK and BPSK
Subcarrier Data Rate	100 bps – 250 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 7-6. AS2 – Alaska S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	21.0 dB/K (clear sky and 5° elevation)
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 7-7. AS2 X-band Telemetry Characteristics

Characteristic	Value
Frequency	8025 – 8500 MHz
G/T	36.2 dB/K (clear sky & 10° elevation angle)
Polarization	RHC or LHC
Antenna Beamwidth	0.23 deg
Antenna Gain	56.8 dBi
Modulation	BPSK, QPSK, OQPSK, UQPSK, 8PSK, GMSK, (16,32,64 APSK)
Demodulator Data Rate Dual Channel	500 Kbps – 240 Mbps (BPSK) per channel 1 Mbps – 350 Mbps (QPSK, OQPSK) per channel 1 Mbps – 2X240 Mbps (UQPSK) per channel 1 Mbps – 350 Mbps (8PSK) per channel
Data Format	NRZ-L, M, S. Biϕ-L, M, S, DNRZ
Decoding	Derandomization, Viterbi (R-½) or Reed-Solomon, Rate 7/8 LDPC
Note:	
Current data rates intentionally omitted. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.	

7.3.4   Tracking Services

7.3.4.1   Doppler Tracking

AS2 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 AS2 S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 7-8.

Table 7-8. AS2 Doppler Tracking Characteristics

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

7.3.4.2   Antenna Autotrack Angle Data

The AS3 can record the angle of the ground antenna as it autotracks. This data is provided to the user as UTDF messages.

7.3.5 **Baseband Data Interfaces**

AS2 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. AS2 currently has a T-1 (1.544 Mbps) communications link with GSFC to support command, telemetry, and ground station control and monitor.

7.4   **ASF 11.0-meter – AS3**

This section describes the Alaska Satellite Facility 11.0-m system referred to as AS3.
The general characteristics of the system are as follows:

64º 51' 32'' N

147º 51' 15'' W

a. The 11-m antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 7-3 is a photograph of the AS3 antenna.
b. Automatically scheduled by NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.
c. Tracking services: 1- & 2-way Doppler and antenna auto tracking Angles.
d. Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets.

7.4.1 **S-band Command**

Table 7-9 identifies the S-band command characteristics of the AS3.

7.4.2 **S-band Telemetry**

Table 7-10 identifies the S-band telemetry characteristics of the AS3.

7.4.3 **X-band Telemetry**

Table 7-11 identified the X-band telemetry characteristics of the AS3.

Figure 7-3. AS3 Antenna and Foundation (foreground)
Existing AS1 (background)

Table 7-9. AS3 S-band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
Maximum EIRP	$\geq$ 65.7 dBW
Polarization	RHC or LHC
Antenna Beamwidth	0.95 deg
Antenna Gain	40.6 dBi
Command Modulation	PCM, PSK, PM, FM, BPSK or QPSK Direct PCM/PM
Modulation Index	PM: 0.01 – 2.5 Radians FM: 1 kHz – 50 kHz deviation BPSK
Carrier Data Rate	1 kbps – 1 Mbps
Subcarrier Frequency	5 kHz- 2 MHz
Subcarrier Modulation	FSK and BPSK
Subcarrier Data Rate	100 bps – 250 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 7-10. AS3 S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	22.9 dB/K (clear sky & 5° elevation angle)
Polarization	RHC or LHC
Antenna Beamwidth	0.85 deg
Antenna Gain	45.8 dBi
Carrier Modulation	PM/PCM, FM/PCM, BPSK, or QPSK / OQPSK
Modulation Index	PM: 0.2 – 2.8 Radians (peak)
Carrier Data Rate (High Rate Telemetry Channel)	1 Kbps – 10 Mbps (FM/PCM) 100 bps – 20 Mbps (PM/PCM, BPSK, OQPSK) 1 Kbps – 40 Mbps (QPSK) [$\leq$ 20 Mbps per channel]
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S; DM-M or S; DBP-M or S; RNRZ
Subcarrier Frequency	5 kHz – 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	100 bps – 600 Kbps
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 7-11. AS3 X-band Telemetry Characteristics

Characteristic	Value
Frequency	8025 – 8500 MHz
G/T	36.2 dB/K (clear sky & 10° elevation angle)
Polarization	RHC or LHC
Antenna Beamwidth	0.23 deg
Antenna Gain	56.8 dBi
Modulation	BPSK, QPSK, OQPSK, UQPSK, 8PSK, GMSK, (16,32,64 APSK)
Demodulator Data Rate Dual Channel	500 Kbps – 240 Mbps (BPSK) per channel 1 Mbps – 350 Mbps (QPSK, OQPSK) per channel 1 Mbps – 2X240 Mbps (UQPSK) per channel 1 Mbps – 350 Mbps (8PSK) per channel
Data Format	NRZ-L, M, S. Biφ-L, M, S, DNRZ
Decoding	Derandomization, Viterbi (R-½) or Reed-Solomon, Rate 7/8 LDPC

7.4.4   **Tracking Services**

7.4.4.1   **Doppler Tracking**

AS3 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 AS3 S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 7-12.

Table 7-12. AS3 Doppler Tracking Characteristics

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

7.4.4.2   **Antenna Autotrack Angle Data**

The AS3 can record the angle of the ground antenna as it autotracks. This data is provided to the user as UTDF messages.

7.4.5   **Baseband Data Interfaces**

AS3 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. AS3 currently has a T-1 (1.544 Mbps) communications link with GSFC to support command, telemetry, and ground station control and monitor.

7.5 **ASF 11m – AS4This section will be populated in the next revision.**

Section 8. Launch Communications Stations (LCS) (6.1m)

8.1 General

The NEN operates two permanent launch communications stations. Their primary purpose is to support human space flight missions launching from the Kennedy Space Center (KSC), but they can also provide S-band communications services to orbital satellites. The stations, Kennedy Uplink Station (KUS) and Ponce de Leon (PDL), provide unique S-band uplink services to communicate with astronauts and state-of-the art telemetry signal processing and data handling services. The stations are a key enabler of KSC's transformation into a 21st century multi-user spaceport, and were driven by the technical requirements of NASA's next generation human exploration Orion crew capsule and Space Launch System (SLS) heavy-lift rocket. The stations are equipped to handle all known and anticipated human and robotic launch communications requirements for spacecraft and launch vehicles departing from (or returning to) KSC/Cape Canaveral Air Force Station (CCAFS) launch complexes. They are compliant with both CCSDS and Inter-Range Instrumentation Group (IRIG) 106 signal and data standards. Operational costs have been vastly reduced compared to the Space Shuttle-era stations through the implementation of remote station monitor and control technologies for routine events.

The following sections provide an overview of the characteristics and capabilities of KUS and PDL. Note that the command and telemetry tables highlight the current capabilities, but due to the use of software defined radios, additional modulations, coding, etc. could be an inherent capability of the radios and could be enabled.

8.2 Kennedy Uplink Station (KUS)

This section describes the KUS, located at KSC on the east coast of Florida. KUS is one of two permanent NEN launch communications stations.

The general characteristics of the station are as follows:

<div align="center">

28° 32' 31.43'' N

80° 38' 34.63'' W

</div>

a. One 6.1-meter antenna capable of simultaneously transmitting and receiving at S-band. A future upgrade will add C-band telemetry [Available in the EM-2 timeframe]. Figure 8-1 is a photograph of the KUS Ground Station.

b. Automatically scheduled by the NEN schedulers at WSC using NEN Scheduling System.

c. Tracking services: Antenna autotracking angles.

> Note: Doppler and Ranging capabilities could be made available if required.

d. Baseband data interfaces: IP (CCSDS SLE)

e. Best Frame Select Capability

Sections 8.2.1 and 8.2.2 describe the S-band performance characteristics. Sections 8.2.3, 8.2.4, 8.2.5, 8.2.6 describe the tracking services, baseband data interfaces, best frame select, and station status capability, respectively.

Figure 8-1. Kennedy Uplink Station

8.2.1   **S-Band Command**

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

Table 8-1. KUS S-Band Command Characteristics

Characteristic	Value
Frequency	2025-2120 MHz
EIRP	57 dBW (maximum)
Polarization	RHC or LHC
Command Modulation	PM, FM, PCM/PSK/PM, PCM/PM, PCM/FM, BPSK, QPSK, OQPSK (SQPSK), SS-UQPSK
PM Modulation Index	1 – 2.5 radians
FM Deviation	<= +/- 5 MHz
Carrier Data Rate	7 bps to 10 kbps (Low Bandwidth Command Mode) 100 bps to 600 kbps (High Bandwidth Subcarrier Command Mode) 100 bps to 1 Mbps (High Bandwidth PCM Command Mode)
Carrier Data Format	NRZ: L,M,S BiΦ: L, M, S R-NRZ
Subcarrier Frequency	40 Hz to 100 kHz (Low Bandwidth Command Mode) 5 kHz to 2 MHz (High Bandwidth Subcarrier Command Mode)
Subcarrier Data Rate	7 bps to 10 kbps (Low Rate Command Mode) 100 bps to 600 kbps (High Rate Command Mode)
Subcarrier Data Format	NRZ: L,M,S BiΦ: L, M, S R-NRZ
Coding	Convolutional ½, LDPC ½

8.2.2 **S-Band Telemetry**

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

Table 8-2. KUS S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200-2400 MHz
G/T	17.2 dB/K *(Assumes transmitter is up, clear sky conditions, and a 5 degree elevation angle. Accounts for the following losses: radome loss, con-scan/auto-track loss, tracking error loss for velocity <= 5 deg/sec and acceleration <= 5 deg/sec², and antenna to back end electronics loss)*
Polarization [1]	RHC or LHC Diversity combination of RHCP/LHCP (pre/post detection)
Telemetry Demodulation	PM, FM, PCM/PSK/PM, PCM/PM, PCM/FM, BPSK, QPSK, OQPSK (SQPSK), SOQPSK, SQPN, AQPSK
PM Modulation Index	0 to 2.5 radians
FM Deviation	<= +/- 500 kHz
Carrier Information Rate	100 bps to 40 Mbps **Maximum rate is modulation and coding dependent*
Carrier Line Coding	NRZ: L,M,S BiΦ: L, M, S DBP: M, S DM: M, S R-NRZ V35
Subcarrier Frequency	40 Hz to 128 kHz (Low Bandwidth Telemetry Mode) 5 kHz to 2 MHz (High Bandwidth Telemetry Mode)
Subcarrier Information Rate	7 bps to 25 kbps (Low Bandwidth Telemetry Mode) 100 bps to 600 kbps (High Bandwidth Telemetry Mode) **Modulation and coding dependent*
Subcarrier Line Coding	NRZ: L,M,S (Low or High Bandwidth Telemetry Mode) BiΦ: L, M, S (Low or High Bandwidth Telemetry Mode) DBP: M, S (High Bandwidth Telemetry Mode) DM: M, S (High Bandwidth Telemetry Mode) R-NRZ (High Bandwidth Telemetry Mode)
Decoding	Viterbi ½ Reed-Solomon (255, 223) i = 1 to 5 Concatenated (Reed-Solomon/Convolutional) LDPC ½ LDPC 7/8, (8160, 7136) Turbo Code 1/2
Supported Data Formats	CCSDS and IRIG-106

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[1] Post Detection Diversity Combining is available for the following modulations schemes: Video Mode (PM), PCM Mode (PCM/PM, PCM/BPSK, PCM/QPSK, or PCM/OQPSK). Pre Detection Diversity Combining is available for the following modulations schemes: Video Mode (PM, FM, Coherent/Non-Coherent FM), PCM Mode (PCM/PM, PCM/BPSK, PCM/QPSK, or PCM/OQPSK).

8.2.3   Tracking Services

8.2.3.1 Antenna Autotracking Angle Data

KUS can record the angle of the ground antenna as it autotracks the user. This data is provided to the FDF as UTDF files or CCSDS Tracking Data Messages (TDM) [TDMs available in the EM-2 timeframe, or sooner if required].

8.2.4   Baseband Data Interfaces

KUS has an internal IP interface, through a fiber connection, with the Communication Distribution & Switching Center (CD&SC) located at KSC that supports the sending and reception of baseband data in IP formats. The NEN presence at the CD&SC includes a Space Link Extension (SLE) Gateway that acts as the external interface to user mission ground systems. Real-time data and commands are transferred using the CCSDS SLE format. Post-pass playbacks will be made available for post-support retrieval using the SLE offline mode. The SLE services adhere to the following CCSDS Blue and Orange books; CCSDS 910.4-B-2 SLE, CCDSD 911.1-B-3 RAF, CCSDS 911.2-B-2 RCF, CCSDS 912.11-O-1 EFCLTU, and CCSDS 912.1-B-3 FCLTU.

8.2.5   Best Frame Select Capability

KUS is capable of utilizing the centralized Best Frame Selector (BFS) within the SLE Gateway (located at the KSC CD&SC facility). The BFS, in conjunction with the PDL and Bermuda (BDA) stations, can mitigate frame errors generated by plume effects (e.g., attenuation and diffraction model fades and scintillation), multipath, antenna pointing errors, and Radio Frequency Interference. The Best Frame Select Capability provides the launch customer with a complete set of Virtual Channel data received by all of the connected ground stations (i.e., KUS, PDL, and BDA). The Best Frame Select Capability could also be used from KUS alone to mitigate single string failure when bandwidth allows for the transmission of redundant streams of data from KUS to the CD&SC.

8.2.6   Station Status

Via a status server, KUS has the ability to collect and deliver remote ground station data at a rate of once per second to users missions connected to the terrestrial communications backbone. Status data will be made available to user missions by three delivery methods: NEN Standard Socket Interface, GSFC Mission Services Evolution Center (GMSEC), and Web Client. For the NEN Standard Socket Interface, the status server provides a continuous stream via a TCP/IP data socket. This method requires user missions to create an interface/application to ingest data for processing by their systems. The GMSEC method utilizes 3rd party messaging software to facilitate communications with the user missions. The final method for delivering station status is through the NEN Web Client. This method is user mission configurable and includes ground station selection, customized alarm threshold, and drill down capability.

8.3   Ponce deLeon (PDL) (6.1m)

This section describes the Ponce de Leon (PDL) ground station, located approximately 40 miles north of KSC in New Smyrna, Florida. PDL serves as a wing site to KUS, providing an off-axis view of a launch vehicle to avoid potential solid rocket motor plume induced communications outages at KUS.

The general characteristics of the station are as follows:

29° 3' 59.93" N

80° 54' 46.88" W

a. One 6.1-meter antenna capable of simultaneously transmitting and receiving at S-band. A future upgrade will add C-band telemetry [Available in the EM-2 timeframe]. Figure 8-2 is a photograph of the PDL Ground Station.

b. Automatically scheduled by the NEN schedulers at WSC using NEN Scheduling System.

c. Tracking services: Antenna autotracking angles.

Note: Doppler and Ranging capabilities could be made available if required

d. Baseband data interfaces: IP (CCSDS SLE).

e. Best Frame Select Capability

Sections 8.3.1 and 8.3.2 describe the S-band performance characteristics. Sections 8.3.3, 8.3.4, 8.3.5, and 8.3.6 describe the tracking services, baseband data interfaces, best frame select, and station status capability, respectively.

Figure 8-2. PDL Ground Station

8.3.1   **S-band Command**

Table 8-3 identifies the S-band command characteristics of PDL.

Table 8-3. PDL S-band Command Characteristics

Characteristic	Value
Frequency	2025-2120 MHz
EIRP	57 dBW (maximum)
Polarization	RHC or LHC
Command Modulation	PM, FM, PCM/PSK/PM, PCM/PM, PCM/FM, BPSK, QPSK, OQPSK (SQPSK), SS-UQPSK
PM Modulation Index	1 – 2.5 radians
FM Deviation	<= +/- 5 MHz
Carrier Data Rate	7 bps to 10 kbps (Low Bandwidth Command Mode) 100 bps to 600 kbps (High Bandwidth Subcarrier Command Mode) 100 bps to 1 Mbps (High Bandwidth PCM Command Mode)
Carrier Data Format	NRZ: L,M,S BiΦ: L, M, S R-NRZ
Subcarrier Frequency	40 Hz to 100 kHz (Low Bandwidth Command Mode) 5 kHz to 2 MHz (High Bandwidth Subcarrier Command Mode)
Subcarrier Data Rate	7 bps to 10 kbps (Low Rate Command Mode) 100 bps to 600 kbps (High Rate Command Mode)
Subcarrier Data Format	NRZ: L,M,S BiΦ: L, M, S R-NRZ
Coding	Convolutional ½, LDPC ½

8.3.2   **S-band Telemetry**

Table 8-4 identifies the S-band telemetry characteristics of PDL.

Table 8-4. PDL S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200-2400 MHz
G/T	17.2 dB/K *(Assumes transmitter is up, clear sky conditions, and a 5 degree elevation angle. Accounts for the following losses: radome loss, con-scan/auto-track loss, tracking error loss for velocity <= 5 deg/sec and acceleration <= 5 deg/sec², and antenna to back end electronics loss)*
Polarization [2]	RHC or LHC Diversity combination of RHCP/LHCP (pre/post detection)
Telemetry Demodulation	PM, FM, PCM/PSK/PM, PCM/PM, PCM/FM, BPSK, QPSK, OQPSK (SQPSK), SOQPSK, SQPN, AQPSK
PM Modulation Index	0 to 2.5 radians
FM Deviation	<= +/- 500 kHz
Carrier Information Rate	100 bps to 40 Mbps *Modulation and coding dependent*
Carrier Line Coding	NRZ: L,M,S BiΦ: L, M, S DBP: M, S DM: M, S R-NRZ V35
Subcarrier Frequency	40 Hz to 128 kHz (Low Bandwidth Telemetry Mode) 5 kHz to 2 MHz (High Bandwidth Telemetry Mode)
Subcarrier Information Rate	7 bps to 25 kbps (Low Bandwidth Telemetry Mode) 100 bps to 600 kbps (High Bandwidth Telemetry Mode) *Modulation and coding dependent*
Subcarrier Line Coding	NRZ: L,M,S (Low or High Bandwidth Telemetry Mode) BiΦ: L, M, S (Low or High Bandwidth Telemetry Mode) DBP: M, S (High Bandwidth Telemetry Mode) DM: M, S (High Bandwidth Telemetry Mode) R-NRZ (High Bandwidth Telemetry Mode)
Decoding	Viterbi ½ Reed-Solomon (255, 223) i = 1 to 5 Concatenated (Reed-Solomon/Convolutional) LDPC ½ LDPC 7/8, (8160, 7136) Turbo Code ½
Supported Data Formats	CCSDS and IRIG-106

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[2] Post Detection Diversity Combining is available for the following modulations schemes: Video Mode (PM), PCM Mode (PCM/PM, PCM/BPSK, PCM/QPSK, or PCM/OQPSK). Pre Detection Diversity Combining is available for the following modulations schemes: Video Mode (PM, FM, Coherent/Non-Coherent FM), PCM Mode (PCM/PM, PCM/BPSK, PCM/QPSK, or PCM/OQPSK).

8.3.3   **Tracking Services**

8.3.3.1Antenna Autotracking Angle Data

PDL can record the angle of the ground antenna as it autotracks the user. This data is provided to the FDF as UTDF files.

8.3.4   **Baseband Data Interfaces**

PDL has an internal IP interface, through a fiber connection, with the CD&SC located at KSC that supports the sending and reception of baseband data in IP formats. The NEN presence at the CD&SC includes an SLE Gateway that acts as the external interface to user mission ground systems. Real-time data and commands are transferred using the CCSDS SLE format. Post-pass playbacks will be made available for post-support retrieval using the SLE offline mode. The SLE services adhere to the following CCSDS Blue and Orange books; CCSDS 910.4-B-2 SLE, CCDSD 911.1-B-3 RAF, CCSDS 911.2-B-2 RCF, CCSDS 912.11-O-1 EFCLTU, and CCSDS 912.1-B-3 FCLTU.

8.3.5   **Best Frame Select Capability**

PDL is capable of utilizing the centralized BFS within the SLE Gateway (located at the KSC CD&SC facility). The BFS, in conjunction with the KUS and BDA stations, can mitigate frame errors generated by plume effects (e.g., attenuation and diffraction model fades and scintillation), multipath, antenna pointing errors, and Radio Frequency Interference. The Best Frame Select Capability provides the launch customer with a complete set of Virtual Channel data received by all of the connected ground stations (i.e., KUS, PDL, and BDA). The Best Frame Select Capability could also be used from PDL alone to mitigate single string failure when bandwidth allows for the transmission of redundant streams of data from PDL to the CD&SC.

8.3.6   **Station Status**

Via a status server, PDL has the ability to collect and deliver remote ground station data at a rate of once per second to users missions connected to the terrestrial communications backbone. Status data will be made available to user missions by three delivery methods: NEN Standard Socket Interface, GSFC Mission Services Evolution Center (GMSEC), and Web Client. For the NEN Standard Socket Interface, the status server provides a continuous stream via a TCP/IP data socket. This method requires user missions to create an interface/application to ingest data for processing by their systems. The GMSEC method utilizes 3rd party messaging software to facilitate communications with the user missions. The final method for delivering station status is through the NEN Web Client. This method is user mission configurable and includes ground station selection, customized alarm threshold, and drill down capability.

Section 9. White Sands Complex Ground Stations

9.1   General

This section describes the Ground Stations located at WSC, White Sands, New Mexico. The stations available at WSC include the 18-m system referred to as WS1, and the VHF A/G stations used for International Space Station support.

9.2   WS1 (18.3)

WS1 is an 18-m 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 is S-band multi-mission capable, with supports limited between LRO views or when the Moon is not in view until after the LRO mission is complete.

The general characteristics of the station are as follows:

<div align="center">

32 ° 32′ 27″ N

106 ° 36′ 44″ W   (see NDOSL "WS1S" for details)

</div>

    a. 18.3-m azimuth/elevation antenna for simultaneously transmitting at S-band while receiving at S- and Ka-bands. Figure 9-1 is a photograph of the WS1 antenna.

    b. Automatically scheduled by NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

    c. Tracking services: 1 & 2-way Doppler, Range, and antenna auto tracking angles.

<div align="center">(Note: Ka is non-coherent).</div>

    d. Baseband data interfaces: IP (Small Explorer/WG2 and Internet Protocol Data Unit [IPDU]).

    e. WS1 is a dual axis (azimuth/elevation) antenna with a maximum axis velocity of 2 degrees per second. Due to the rate limitation, the antenna will lag the spacecraft in azimuth at high antenna elevations. The actual elevation at which this drive limitation keyhole will impact support is dependent on the spacecraft altitude. (For most near earth orbiting satellites this will be above 75 degrees).

    f. There is also an RF interference keyhole around 180 degrees azimuth on the horizon due to the White Sands Ground Terminal SN Multiple Access Calibration which radiates at 2287.5 MHz. This will impact supports from 2280 MHz to 2295 MHz. The size on this radio frequency interface Keyhole varies with the spacecraft depending on downlink frequency; spacecraft (S/C) transmit power and S/C modulation type. Tests will be performed to determine potential impact for each new S/C. Generally, a spacecraft at 2280 MHz will encounter impacting interference within 10 degrees of south; at 2287.5 MHz, this could increase to 40 degrees.

Sections 9.2.1 through 9.2.3 describe WS1 S-band and Ka-band performance characteristics. Sections 9.2.4 and 9.2.5 describe WS1 tracking services and baseband data interfaces, respectively.

Figure 9-1. WS1 Antenna

9.2.1   **WS1 S-band Command**

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

9.2.2   **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
Maximum EIRP	81 dBW (with 2 KW HPA) 72 dBW (with 300 Watts SSPA)
Polarization	RHC or LHC
Antenna Beamwidth	0.56 Deg.
Antenna Gain	49 dBi
Command Modulation	PCM Encoding FM or PM[1] FSK, BPSK[2] CCDS Recommendations Direct PCM/PM
Modulation Index	FM: 50 kHz – 50 MHz deviation PM: 0.1 – 2.5 Radians BPSK
Carrier Data Rate	100 bps – 1 Mbps
Subcarrier Frequency	5 kHz – 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	100 bps – 250 kbps
Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Notes: 1. IF Modulation 2. Modulation at baseband	

Table 9-2. WS1 S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	29.6 dB/K (minimum at 5° elevation, clear sky)
Polarization	RHC or LHC
Antenna Beamwidth	0.5 deg
Antenna Gain	50 dBi
Carrier Modulation	PM, FM, BPSK, or QPSK/OQSPK
Modulation Index	PM: 0.2 – 2.8 Radians (peak)
Carrier Data Rate	100 bps – 20 Mbps (up to 40 Mbps for QPSK demodulation + Viterbi decoding, up to 10 Mbps in the case of Bi-phase decoding)
Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	5 kHz – 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	100 bps to 256 kbps (128 kbps max if Bi-Phase)
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver. 1 & 2)

9.2.3 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, 10° elevation, clear sky
Polarization	RHC or LHC
Antenna Beamwidth	0.04 deg
Antenna Gain	70.5 dBi
Demodulation	BPSK, QPSK, OQPSK, (SQPSK), AQPSK, UQPSK, (AUQPSK, AUSQPSK, AUSQPSK
Data Rate	235 Mbps single decoder mode 470 Mbps dual decoder (I&Q)
Data Format	NRZ-L, M, S, DNRZ
Decoding	CCSDS Compliant Viterbi Convolutional Decoding

9.2.4   WS1 Tracking Services

9.2.4.1   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
Counter Resolution	0.001 cycles
Doppler Frequency Shift	≤ 0.25 MHz
Doppler Bias Frequency (fbias)	.240 MHz
Drift (Δf/f)	5×10^{-11} at 1 day
Accuracy	Function of CNR, IF Receiver PLL BW & Reference Clock Accuracy Typical: 0.0017 Hz @ 30 Hz PLL BW, 65 dB-Hz 0.0051 Hz @ 100 Hz PLL BW, 65 dB-Hz 0.046 Hz @ 300 Hz PLL BW, 65 dB-Hz
Output Equation	$(f_{transmit} \times [240/221] - f_{received}) + f_{bias}$
Auto Track Threshold	-87 dB

9.2.4.2   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.

9.2.4.3   Range Tracking

Range tracking characteristics are shown in Table 9-5.

Table 9-5. WS1 Range Tracking Characteristics

Characteristic	Value
Modulation	PM, FM
Supported standards	ESA Standard, ESA Like Standard (includes USB) ESA Code Continuous Tone Standard
Major Tone	500 KHz 100 KHz (Tone Ranging) or 450 KHz (Code Ranging)
Minor Tones	Minor tones are each a programmable ratio of the major tone. Up to 6 minor tones for ESA standard or up To 8 minor tones for ESA like standard. ESA code and continuous tone standards do not use minor tones.
Modulation Index	0.1 – 2.5 Radians
Resolution	1 NS, ≈ 0.3 Meters

9.2.5   **WS1 Baseband Data Interfaces**

The WS1 sends and receives baseband data IP formats. Post-pass playbacks are via Secure Copy Protocol (SCP) or Secure File Transfer Protocol (SFTP).

Section 10. Santiago Satellite Station

10.1 General

This section describes the Santiago, Chile Satellite Station, fully owned and operated by SSC Chile S.A., a part of the SSC Group. The following URL can be used to link to further information regarding the Swedish Space Corporation's assets: http://www.sscspace.com/ssc-chile. Future developments may include the station at Punto Arenas, Chile.

10.2 AGO, 9-meter, SA1

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

<div align="center">

33º 09′ 04″ S

70º 39 ′59″ W

733 meters above sea level (MASL)

</div>

 a. One 9-m antenna for simultaneously transmitting at S-band while receiving at S-band. Figure 10-1 is a photograph of the 9-m antenna.

 b. Routine supports are automatically scheduled by NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

 c. Real-time tracking services include: 1- & 2-way Doppler tracking, tone ranging (see Table 4-5), and antenna autotracking angles.

 d. Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets.

Sections 10.5 and 10.6 describe S-band performance characteristics. Sections 10.7.1 and 10.7.2 describe the tracking services and baseband data interfaces, respectively.

10.3 AGO, 12-meter, SA3

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

<div align="center">

33º 09′ 05′ S

70º 40′ 05′ W

731 MASL

</div>

 a. One 12-m antenna for simultaneously transmitting at S-band while receiving at S-band. Figure 10-2 is a photograph of the 12-m ground station. (New feed allowing uplink installed and being tested.)

 b. Automatically scheduled by NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

 c. Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets.

Sections 10.5 and 10.6 describe S-band performance characteristics. Sections 10.7.1 and 10.7.2 describe the tracking services and baseband data interfaces, respectively.

Figure 10-1. AGO 9-m S-band Antenna

Figure 10-2. AGO 12-m S-band Antenna

10.4   **AGO, 13-meter, SA2**

The general characteristics of the 13-m ground station at AGO are as follows:

<div align="center">

33º 08′ 54′ S

70º 40′ 03″ W

732 MASL

</div>

a. One 13-m antenna for simultaneously transmitting at S-band while receiving at S-band. Figure 10-3 is a photograph of the 13-m antenna.

b. Routine supports are automatically scheduled by NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

c. Real-time tracking services include 1- & 2-way Doppler tracking, tone ranging (see Table 4-5), and antenna autotracking angles.

d. Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets.

Optional X-band receiving upgrade and/or optional Ku-band transmit/receive upgrades are possible, while maintaining S-band capability.

Sections 10.5 and 10.6 describe S-band performance characteristics. Sections 10.7.1 and 10.7.2 describe the tracking services and baseband data interfaces, respectively.

Figure 10-3. AGO 13-m S-band Antenna

10.5 **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 12-m antenna.

Table 10-3 identifies the S-band command characteristics of the AGO 13-m antenna.

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

Characteristic	Value
Frequency	2025 – 2120 MHz
Maximum EIRP	75 dBW
Polarization	RHC or LHC
Antenna Beamwidth	1.12 deg
Antenna Gain	43.8 dBi
Command Modulation	FSK, BPSK, BPSK+AM, BPSK Square (Low BW) BPSK, Direct PCM/PM (Intermediate & High BW)
Modulation Index	PM: 3.0 Radians (peak) BPSK
Carrier Data Rate	10 – 10,000 bps (Low BW) 100 bps – 1 Mbps (Intermediate & High BW)
Subcarrier Frequency	5 kHz – 2 MHz (Intermediate & High BW)
Subcarrier Modulation	PCM (Intermediate & High BW)
Subcarrier Data Rate	100 bps – 250 kbps
Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Note: The command modulator capabilities listed in the table (e.g., data rates, modulation schemes, data formats, coding schemes) represent all possible modulator capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.	

Table 10-2. AGO 12-m S-band Command Characteristics

Characteristic	Value
Frequency	2025-2120 MHz
Maximum EIRP	67.5 dBW
Polarization	RHCP or LHCP
Antenna Beamwidth	0.75 deg
Antenna Gain	46.5 dBi
Command Modulation	FM, PM, PCM, PSK BPSK, QPSK, OQPSK, AQPSK Direct PCM/PM
Modulation Index	0 to 2.5 rad
Carrier Data Rate	100 bps to 1 Mbps
Subcarrier Frequency	5 kHz to 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	100 bps – 250 kbps
Data Format	NRZ-L, M, or S; or Bi□-L, M, or S

Note:

The command modulator capabilities listed in the table (e.g., data rates, modulation schemes, data formats, coding schemes) represent all possible modulator capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.

Table 10-3. AGO 13-m S-band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
Maximum EIRP	70 dBW
Polarization	RHC or LHC
Antenna Beamwidth	0.75 deg
Antenna Gain	46 dBi
Command Modulation	FSK, PCM, PSK PM BPSK, BPSK+AM, BPSK Square (Low BW) BPSK, Direct PCM/PM (Intermediate & High BW)
Modulation Index	PM: 2.5 Radians (peak) BPSK
Carrier Data Rate	10 bps – 10,000 bps (Low BW) 100 bps – 1 Mbps (Direct PCM on Carrier; Intermediate & High BW)
Subcarrier Frequency	5 kHz to 2 MHz (Intermediate & High BW)
Subcarrier Modulation	PCM (Intermediate & High BW)
Subcarrier Data Rate	100 bps to 250 kbps
Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Note:	
The command modulator capabilities listed in the table (e.g., data rates, modulation schemes, data formats, coding schemes) represent all possible modulator capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.	

10.6   AGO S-band Telemetry

Table 10-4 identifies the S-band telemetry characteristics of the AGO 9-m antenna.

Table 10-5 identifies the S-band telemetry characteristics of the AGO 12-m antenna.

Table 10-6 identifies the S-band telemetry characteristics of the AGO 13-m antenna.

Table 10-4. AGO 9-m S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	23.0 dB/K (clear sky & 5° elevation angle)
Polarization	RHC or LHC
Antenna Beamwidth	1.0 deg
Antenna Gain	44.0 dBi
Carrier Modulation	BPSK, QPSK, OQPSK, PM/NRZ
Modulation Index	PM: 0.2 – 1.4 Radians (peak)
Carrier Data Rate	2 kbps – 10 Mbps (High BW Telemetry)
Carrier Data Format	NRZ-L, M, or S; Biϕ-L, M, or S; DM-M or S; M2M, RZ, and PN Randomized
Subcarrier Frequency	40 Hz – 128 kHz (Low BW) 5 kHz – 2 MHz (Intermediate & High BW)
Subcarrier Modulation	BPSK,
Subcarrier Data Rate	10 bps– 25 kbps, (NRZ) for 40 Hz-128 kHz 1 kbps – 250 Kbps for 5kHz – 2 MHz 1 kbps – 256 kbps (up to 128 kbps w/ Biϕ-L) for 5kHz – 2 MHz 1 kbps – 600 kbps (up to 128 kbps w/ Biϕ-L) for 5kHz – 2 MHz
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)

Note:

The telemetry receiver capabilities listed in the table (e.g., data rates, modulation schemes, data formats, decoding schemes) represent all possible receiver capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.

Table 10-5. AGO 12-m S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	25.7 dB/K (clear sky & 5° elevation angle)
Polarization	RHC or LHC
Antenna Beamwidth	0.75 deg
Antenna Gain	46.5 dBi
Carrier Modulation	BPSK, QPSK, OQPSK, PM/NRZ
Modulation Index	PM: 0.2 – 1.4 Radians (peak)
Carrier Data Rate	2 kbps – 10 Mbps (High BW Telemetry)
Carrier Data Format	NRZ-L, M, or S; Biφ-L, M, or S; DM-M or S; M2M, RZ, and PN Randomized
Subcarrier Frequency	40 Hz – 128 kHz (Low BW) 5 kHz – 2 MHz (Intermediate & High BW)
Subcarrier Modulation	BPSK, PCM/PM
Subcarrier Data Rate	10 bps– 25 kbps, (NRZ) for 40 Hz-128 kHz 1 kbps – 250 Kbps for 5kHz – 2 MHz 1 kbps – 256 kbps (up to 128 kbps w/ Biφ-L) for 5kHz – 2 MHz 1 kbps – 600 kbps (up to 300 kbps w/ Biφ-L) for 5kHz – 2 MHz 1 kbps – 5 Mbps PM/PCM for 5kHz – 2 MHz
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)

Note:

The telemetry receiver capabilities listed in the table (e.g., data rates, modulation schemes, data formats, decoding schemes) represent all possible receiver capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.

Table 10-6. AGO 13-m S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	24.4 dB/deg K (clear sky & 5° elevation angle)
Polarization	RHC or LHC
Antenna Beamwidth	0.69 deg
Antenna Gain	47 dBi
Carrier Modulation	PCM/PM, BPSK, QPSK, OQPSK, SOQPSK, AQPSK, PCM/FM
Modulation Index	PM: 0.2 – 1.4 Radians (peak)
Carrier Data Rate	2 kbps – 10 Mbps (High BW Telemetry)
Carrier Data Format	NRZ-L, M, or S; Biφ-L, M, or S; DM-M or S; R-NRZ
Subcarrier Frequency	10 bps – 25 kbps, (NRZ) for 40 Hz-128 kHz 1 kbps – 250 Kbps for 5kHz – 2 MHz 1 kbps – 256 kbps (up to 128 kbps w/ Biφ-L) for 5kHz – 2 MHz 1 kbps – 600 kbps (up to 300 kbps w/ Biφ-L) for 5kHz – 2 MHz 1 kbps – 5 Mbps PM/PCM for 5kHz – 2 MHz
Subcarrier Modulation	BPSK, PM/PCM
Subcarrier Data Rate	40 Hz – 128 kHz (Low BW) 5 kHz – 2 MHz (Intermediate & High BW)
Subcarrier Data Format	NRZ-L, M, or S; Biφ-L, M, or S; DM-M or S, RZ
Decoding	Viterbi and/or Reed-Solomon (CCSDS)
Note:	
The telemetry receiver capabilities listed in the table (e.g., data rates, modulation schemes, data formats, decoding schemes) represent all possible receiver capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.	

10.7 Tracking Services

10.7.1 Doppler Tracking

The 9-m and 13-m ground stations generate 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 and 13-m S-band uplink signals with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 10-7.

10.7.2 Range Tracking

Range tracking characteristics are shown in Table 4-5.

Table 10-7. AGO 9-m and 13-m Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.001 cycles
Doppler Frequency Shift	≤ 0.25 MHz
Doppler Bias Frequency	0.24 MHz
Drift ($\Delta f/f$)	4×10^{-11} at 0.1 sec
Accuracy	0.01 Hz
Output Equation	$1000 \, (f_{transmit} \times [240/221] - f_{received}) + f_{bias}$

10.7.3 Antenna Autotracking Angle Data

The 9-m and 13-m ground stations can record the angle of the ground antenna as they autotrack the satellite. This data is provided to the FDF as UTDF messages.

10.7.4 Baseband Data Interfaces

The 9-m and 13-m ground stations 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.

Section 11. Hartebeesthoek Satellite Station

For Information only. Check with GSFC 453/NEN for further support capabilities (or with GSFC 450.1/NIMO for future support possibilities). This station belongs to the SANSA. www.sansa.org.za/

11.1 HBK01: S-(and Ext C)-band antenna)

Slew rate: 10°/sec
Dish diameter: **12m**
Tracking mode: Program and Autotrack
Polarization: LCP and RCP

Transmit 2
Frequency range: **2.025 - 2.15 GHz**
Receive
Frequency range: **2.2 - 2.4 GHz**
G/T: **22.4 dB/K**
Acquisition Aid ant: 1.07m 2.2 - 2.3 GHz only
EIRP**: 69dBW** (Maximum)

HBK01

11.2 HBK02: S, X-band antenna
Slew rate: 10°/sec
Dish diameter: **10m**
Tracking mode: Program and Autotrack
Polarization: LCP and RCP

Receive
Frequency range:
Rx1: **2.2 - 2.4 GHz [G/T: 21.4 dB/K]**
Rx2: **8.0 - 8.5 GHz [G/T: 31.0 dB/K]**

Transmit
Frequency range: **2.025 - 2.10 GHz**
EIRP: **65dBW** (Maximum)

HBK02

Section 12. Kiruna, Sweden, Esrange Station

12.1 **General**

This section describes the Esrange Satellite Station located near Kiruna, Sweden, north of the Arctic Circle. Two 13-m antenna systems are described here. The Esrange Satellite Station includes six independent Telemetry Tracking & Command (TT&C) systems in S-Band (one with receive capability also in the UHF-Band), six multi-frequency receive antenna systems in S/X-Band and an operational building (manned 24x7) which houses reception system electronics and data processing equipment.

12.2 **Kiruna, 13.0-m, KU2S**

The general characteristics of the KU2S antenna are as follows:

$$67° \ 52' \ 44.655'' \ N$$

$$21° \ 02' \ 16.800'' \ E$$

a. One 13.0-m 3-axis antenna for simultaneously transmitting at S-band while receiving at S- and X-bands.

b. Automatically scheduled by NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

c. Tracking services: Tone ranging, Doppler and antenna autotracking angles.

d. Baseband data interfaces: Internet Protocol (IP), serial clock and data, 4800-bit blocks encapsulated in IP packets, and electronic file transfer and parcel shipping.

Sections 12.2.1 through 12.2.3 describe S-band and X-band performance characteristics.

12.2.1 **KU2S S-band Command**

Table 12-1 identifies the S-band command characteristics of the KU2S antenna.

12.2.2 **KU2S S-band X-band Telemetry**

Table 12-2 identifies the S-band and X-band telemetry characteristics of the KU2S antenna.

Table 12-1. KU2S S-band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
Maximum EIRP	≥ 69.0 dBW
Polarization	RHC or LHC
Antenna 3dB beamwidth	0.8 deg typical
Antenna Gain	46.5 dBi
Transmit Modulation	PM,FM, BPSK, QPSK, OQPSK, AQPSK
Transmit Subcarrier	BPSK <= 2 MHz (up to 10 MHz with limitations) FSK tones < 100 Hz
Metric Tracking	Tone ranging, Doppler tracking and Antenna angles

Note:

The command modulator capabilities listed in the table (e.g., data rates, modulation schemes, data formats, coding schemes) represent all possible modulator capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.

Table 12-2. KU2S S-band & X-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz 7600 – 8500 MHz
G/T include radome	≥ 22.5 dB/K (S-band) (clear sky and 5° elevation) ≥ 37.5 dB/K (X-band) (clear sky and 10° elevation)
Polarization	RHC & LHC diversity (S) RHC & LHC simultaneously (X)
Antenna 3 dB Beamwidth	0.7 deg typical S-band 0.2 deg typical X-band
Receive Modulation	FM, PM, BPSK, QPSK, OQPSK, SOQPSK, GMSK, AQPSK (S-Band). BPSK, QPSK, UQPSK,SQPSK, 8-PSK, Double Polarization (X-Band)
Receive Subcarrier (S-band)	BPSK <= 2 MHz (up to 10 MHz with limitations)
Receive Data Rate	<= 20 Mb/s no subcarrier <= 600kbps with subcarrier (S-band) Mission Specific (X-band)
Receive Link Coding	Viterbi, Reed-Solomon, Descrambling, Turbo

Note:

The telemetry receiver capabilities listed in the table (e.g., data rates, modulation schemes, data formats, decoding schemes) represent all possible receiver capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.

12.3 **Kiruna, 13.0-m, KU1S**

The general characteristics of the KU1S antenna are as follows:

67° 53′ 22.410″ N

21° 03′ 56.357″ E

a. One 13.0-m Az-El antenna for simultaneously transmitting at S-band while receiving at S- and X-bands.

b. Automatically scheduled by NEN schedulers per 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling*.

c. Tracking services: Tone ranging, Doppler tracking and antenna autotracking angles.

d. Baseband data interfaces: Call to verify.

Sections 12.3.1 through 12.3.3 describe S-band and X-band performance characteristics.

12.3.1 **KU1S S-band Command**

Table 12-3 identifies the S-band command characteristics of the KU1S antenna.

12.3.2 **KU1S S-band X-band Telemetry**

Table 12-4 identifies the S-band and X-band telemetry characteristics of the KU1S antenna.

Table 12-3. KU1S S-band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
Maximum EIRP	≥ 69.0 dBW
Polarization	RHC or LHC
Antenna 3dB beamwidth	0.8 deg typical
Antenna Gain	46.5 dBi
Transmit Modulation	PM,FM, BPSK, QPSK, OQPSK, AQPSK
Transmit Subcarrier	BPSK <= 2 MHz (up to 10 MHz with limitations) FSK tones < 100 Hz
Metric Tracking	Tone ranging, Doppler tracking and Antenna angles
Note:	
The command modulator capabilities listed in the table (e.g., data rates, modulation schemes, data formats, coding schemes) represent all possible modulator capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.	

Table 12-4. KU1S S-band & X-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz 7600 – 8500 MHz
G/T include radome	$\geq$ 23 dB/K (S-band) (clear sky and 5° elevation) $\geq$ 37.5 dB/K (X-band) (clear sky and 10° elevation)
Polarization	RHC & LHC diversity (S) RHC & LHC simultaneously (X)
Antenna 3 dB Beamwidth	0.7 deg typical S-band 0.2 deg typical X-band
Receive Modulation	FM, PM, BPSK, QPSK, OQPSK, SOQPSK, GMSK, AQPSK (S-Band). BPSK, QPSK, UQPSK, SQPSK, 8-PSK, Double Polarization (X-Band)
Receive Subcarrier (S-band)	BPSK <= 2 MHz (up to 10 MHz with limitations)
Receive Data Rate	<= 20 Mb/s no subcarrier <= 600kbps with subcarrier (S-band) Mission Specific (X-band)
Receive Link Coding	Viterbi, Reed-Solomon, Descrambling, Turbo

Note:

The telemetry receiver capabilities listed in the table (e.g., data rates, modulation schemes, data formats, decoding schemes) represent all possible receiver capabilities, but may not reflect the actual ground station capabilities implemented by the NEN. Potential NEN users are encouraged to discuss the mission requirements and NEN capabilities with the NIMO to ensure that requirements and capabilities are fully understood and represented in the RFICD.

Section 13. National Oceanic and Atmospheric Administration (NOAA) Fairbanks Command and Data Acquisition Station (FDCAS), Gilmore Creek, Alaska, GLC

TBD

Section 14. Scheduling

This section superseded by the standalone documents 453-UG-NEN Scheduling, *Users' Guide for Near Earth Network Scheduling* and 450-OIP-WSC, *White Sands Complex (WSC) Operations Interface Procedure (OIP).*

Section 15. Baseband Data Interfaces and Storage

15.1   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.   Parcel Shipment of Recorded Data.

   d.   Standard Autonomous File Server (SAFS).

   e.   NEN Gateway (Available only at the Wallops and Alaska Satellite Facility stations)

Table 15-1 summarizes the baseband data interfaces available at each station. An "X" means that capability is offered.

15.2   IONet Network

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

15.2.1   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.

15.2.2   TCP/IP and UDP/IP

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

Figure 15-1 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 15-1, the IPDU packet encapsulates the Channel Access Data Unit (CADU) packet. For UDP/IP, the layering is identical to Figure 15-1, except the TCP layer is replaced by a UDP layer.

15.2.3   Packets and Layers

CADU and Command Link Transmission Unit (CLTU) packets are CCSDS-compliant telemetry and command data unit protocols, respectively. (See reference u in Section 1.3. for CLTU and reference n in Section 1.3 for CADU in Section 1.3.) For commands, the CADU layer in Figure 15-1 is replaced by a CLTU layer.

The Network Access Layer is a protocol format that provides physical access to NASCOM. 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 15-1. Baseband Data Interface Options

Station	NASCOM IP Network	Serial Clock and Data	Parcel Shipping	SAFS	Gateway
AGO	X			X	
ASF	X		X	X	X
SG1	X	X	X	X	
SG2	X	X	X	X	
SG3	X	X	X	X	
TR2	X				
TR3	X				
WS1	X	X	X	X	
WG1	X	X	X	X	X
WG2	X	X		X	
MG1[1]	X		X	X	
USAK04	X	X	X	X	
USAK05	X	X	X	X	
USAK01	X		X	X	
USAK03	X		X	X	
USHI01	X		X	X	
USHI02	X		X	X	
AUWA01	X		X	X	
AUWA02	X		X	X	
SI1 (Singapore)	X			X	
PDL	No Service	No Service	No Service	No Service	
KUS	No service	No Service	No Service	No Service	
Note: An "X" indicates the capability is offered at the station.					
1 – MG1 data delivery is not available by parcel shipping for ½ of the year. Contact the NEN for potential use of the MTRS.					

| CADU Layer | | | | Sync pattern (4 bytes) | VCDU Header (6 bytes) | Virtual Channel Data Unit (VCDU) (654 bytes) | Reed-Solomon Check Symbols (96 bytes) |
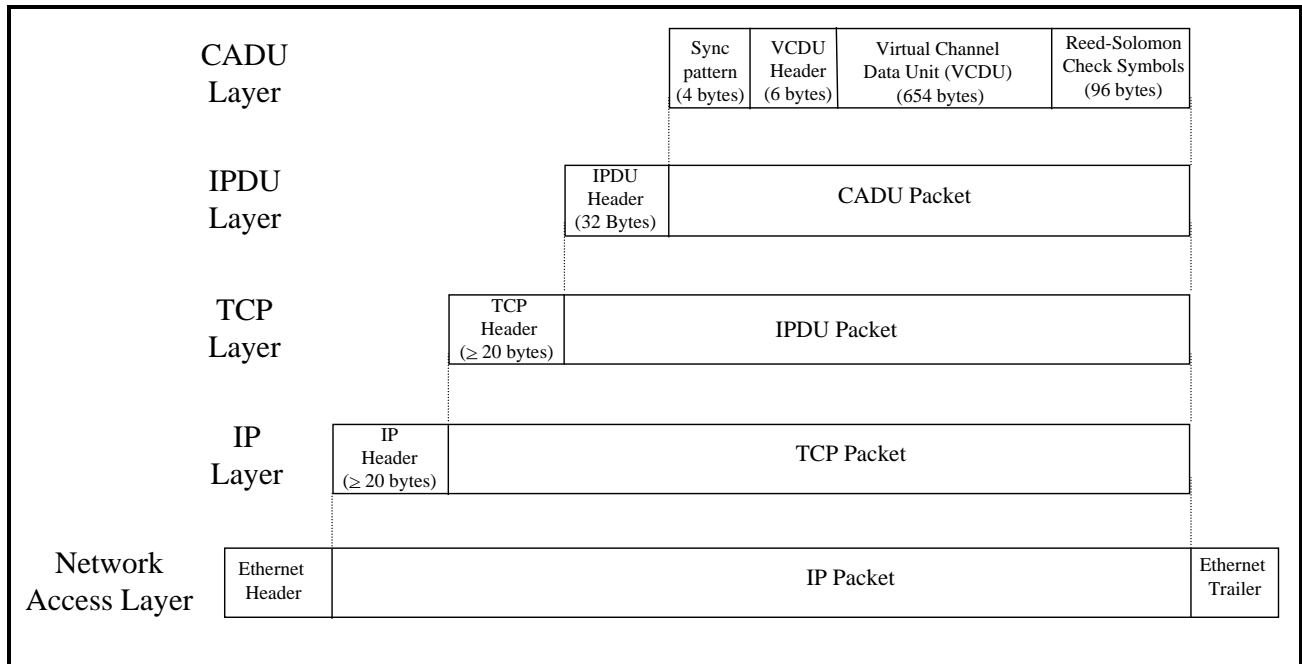
Figure 15-1. NASCOM IP Network Layers

Notes

1. TCP/IP layers are shown; UDP/IP is identical, except "TCP" is replaced by "UDP."

2. Telemetry packets are shown; command packets are identical, except "CADU" is replaced by "CLTU."

15.2.4   **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.

15.2.5   **PTP Encapsulation**

All NEN stations that support IP use Programmable Telemetry Processors (PTP) 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:

a. IPDU.

b. Advanced X-ray Astrophysics Facility (AXAF) Standard Formatted Data Unit (SFDU).

c. Deep Space-Terminal SFDU.

d. Advanced Composition Explorer (ACE) SFDU.

e. WG2 Telemetry Frame Delivery Header.

f. WG2 Command Delivery Header (CDH).

g. NASA Communications Real-time Transmission Protocol.

h. No extra encapsulation between the CADU or CLTU layer and the TCP or UDP layer.

Instead of a PTP, the WG2 stations use a front-end processor that offers encapsulation and format choices that are a subset of the PTPs.

15.2.6 **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.

A few 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.

15.2.7 **S-band Telemetry Data**

A few 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.

15.3 **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.

15.4 **Parcel Shipping 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 non-volatile media such as a disk. The station will then parcel ship the recorded data to the user.

Operations agreements and support plans define the exact data-shipping criteria. Table 15-2 identifies the recording capabilities at each NEN station; an "X" means that capability is available.

Table 15-2. Digital Data Recording

Station	Solid State Recording
SG1	X
SG2	X
SG3	X
SI1	X
WG1	X
WG2 – WFF	X
USAK04	X
USAK05	X
USAK01	X
USAK03	X
USHI01	X
USHI02	X
AUWA01	X
AUWA02	N/A
MG1	X
PDL	No Service
KUS	No Service
ASF	X
WS1	X

15.5   **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.

15.5.1 **SAFS Architecture and Operation**

Initially, the SAFS was installed at some NASA NEN sites for distributed acquisition of satellite data in support of QuikSCAT and ADEOS II missions. The SAFS have now been installed at the following NEN ground stations: ASF, MG1, SGS, WGS, and WS1. A SAFS also been installed at GSFC to provide for centralized customer data distribution. Figure 15-3 depicts the SAFS network architecture spanning the Closed, Restricted and Open IONet.

Note
Due to IONet security protocols, data flows are restricted to transfers within the same network or from a higher security network to a lower security network (i.e. Closed to Restricted, Closed to Open, or Restricted to Open). No data is allowed to flow from Open to the Restricted or Closed.

The central SAFS provides a single point-of-contact for customers and isolates the NEN 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 mission 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 backup servers and Raids.

Depending upon the network connectivity of the data recipient, if all connectivity is outside of NASA's Closed or Restricted IONet then all data would be transferred from the CSAFS, however, if a recipient is located on the Closed or Restricted IONet, the data could be sent directly from a station SAFS. Table 15-3 shows the data distribution capabilities of each SAFS.

Table 15-3. SAFS Network Distributions using FastCopy, SFTP, SCP

Station	Closed Push	Closed Pull	Restricted Push	Restricted Pull	Open Push	Open Pull	Other Push	Other Pull
AGO			X					
ASF					X			
MG1	X							
SG1 (SGS)	X							
WGS	X							
WS1			X					
Commercial					X			
CSAFS					X	X	X	X

Notes:

- X = existing capability
- ALL station data flows to CSAFS at GSFC.
- AGO includes the SA1 and SA2 antennas.
- ASF includes the AS1, AS2, and AS3 antennas.
- WGS includes the WG1 (11 meter) and WG2 (LEOT) antennas.
- Commercial includes SSC antennas and KSAT antennas (SG2, SG3, SI1, & TR2).

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 local station 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.

15.5.2 **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. Windows servers

c. Rack mounted keyboard, monitor, with touch pad

The SAFS software includes the following:

a. COTS RepliWeb Managed File Transfer

b. Custom scripts for job control and monitoring

Closed Network

SSAFS Server Cluster   Raid

Primary Server

Secondary Server

MGS & WGS SAFS

PTP

PTP

PTP

FTP

FastCopy
FTP
SFTP

FastCopy
FTP
SFTP

Customers
located on the
Closed Network

Raid

SAFS Server

SGS SAFS

FTP

PTP   PTP   PTP

Customers
located on the
Restricted Network

Restricted Network

SSAFS Server Cluster   Raid

Primary Server

Secondary Server

WS1 SAFS

PTP

PTP

PTP

FTP

FastCopy
FTP
SFTP

FastCopy

All Data
Fastcopy Push
Closed to Open IO

All Data
Fastcopy Push
Restricted to Open IO

FastCopy

Open Network

CSAFS Server Cluster   Raid

Primary Server

Secondary Server

Central SAFS (Primary)

FastCopy
FTP
SFTP

Fastcopy
Push to CSAFS

Comercial Stations
(KSAT, SSC)

Raid

SAFS Server

ASF SAFS

FTP

Customers
located on the
Open Network
(and beyond)

PTP   PTP   PTP

FastCopy
FTP
SFTP

FastCopy
Push to CSAFS

Raid

Backup Server

Central SAFS (Backup)

Figure 15-2. SAFS Architecture

15.5.3 **SAFS Distribution Methods**

There are four defined types of interactions possible between the TM Processors (TMP), Station SAFS (SSAFS), CSAFS, and customers. These types are dependent on the project and station SAFS used.

<div align="center">Note</div>

> Direct distribution from a Station SAFS (Type 3 or Type 4) can only be done if the customer MOC is located on the same network as the Station SAFS, and is only available as a push transfer.

Type 1: Uses SAFS file naming convention, with distribution from the CSAFS:

   a. TMP pushes file to SSAFS using *safsFileName*.

   b. SSAFS pushes file to CSAFS using *safsFileName*.

   c. CSAFS transfers file to customer using *safsFileName* (this can be CSAFS pushes to the customer or the customer pulls from CSAFS).

   d. Events logged using *safsFileName,* and files archived using *safsFileName*.

Type 2: Uses Project file naming convention, with distribution from the CSAFS:

   a. TMP pushes file to SSAFS using *projectFileName***.**

   b. SSAFS pushes file to CSAFS using *projectFileName***.**

   c. CSAFS transfers file to customer using *projectFileName* (this can be CSAFS pushes to the customer or the customer pulls from CSAFS).

   d. Events logged using *projectFileName*, and files archived using *projectFileName*.

Type 3: Uses SAFS file naming convention, with distribution from the SSAFS:

   a. TMP pushes file to SSAFS using *safsFileName*.

   b. SSAFS pushes file to CSAFS using *safsFileName*. (This is to provide added availability/contingency and archive for the customer to pull data if needed.)

   c. SSAFS transfers file to customer using *safsFileName* (this is a push function only).

   d. Events logged using *safsFileName,* and files archived using *safsFileName*.

Type 4: Uses Project file naming convention, with distribution from the SSAFS:

   a. TMP pushes file to SSAFS using *projectFileName*.

   b. SSAFS pushes file to CSAFS using *projectFileName*. (This is to provide added availability/contingency and archive for the customer to pull data if needed.)

   c. SSAFS transfers file to customer using *projectFileName* (**P**ush function only).

   d. Events logged using *projectFileName,* and files archived using *projectFileName*.

15.5.4 SAFS Project Parameters (Current Mission Set)

Project	SAFS Id*	SAFS Type	SAFS GS	Data File(s)		SAFS Name	Meta Data	File Trans	Archive (Default 7)
AIM	aim	1	ASF SG1 SKS# SSC# WGS	Housekeeping1 Housekeeping2 Real Time Science	hk1 hk2 rt sci	Y	Y	FC Push CSAFS	7 Days
COSMIC	cos	1	ASF MG1	VC 00 VC 01 VC 02	vc0 vc1 vc2	Y	N	SFTP Pull CSAFS	15 Days
RHESSI	hes	1	AGO# WGS WS1	VC 00 VC 01 VC 02 VC 03	vc0 vc1 vc2 vc3	Y	N	SFTP Pull CSAFS	7 Days
ICESAT-2	ice2	1	ASF SG1 SG2 WGS	VC 00 VC 01 VC 02 VC 05	vc0 vc1 vc2 vc5	Y	N	SFTP Push CSAFS	7 Days
CYGNUS	orb	1	WGS	VC ALL	vca	Y	N	SFTP Pull CSAFS	7 Days
QUIKSCAT	qst	1	ASF SG1 SKS# SSC# MG1 WGS	Housekeeping1 Housekeeping2 Science	hk1 hk2 sci	Y	Y	FC Push CSAFS	7 Days
SCAN (Testbed)	sca	1	WGS	VC ALL	vca	Y	N	SFTP Pull CSAFS	7 Days
SCISAT-1	sci	1	ASF	RAW	raw	Y	N	SFTP Push CSAFS	14 Days
SMAP	smp	1	ASF MG1 SG1 SG2 TR2 WGS	VC 00 VC 01	vc0 vc1	Y	N	SFTP Pull CSAFS	14 Days
SOLAR-B	sol		MG1 WGS	RAW	raw	Y	N	SFTP Pull CSAFS	7 Days
SORCE	sor	1	AGO# WGS	HRT PBK SCI	hrt pbk sci	Y	N	FC Push CSAFS	7 Days

Project	SAFS Id*	SAFS Type	SAFS GS	Data File(s)		SAFS Name	Meta Data	File Trans	Archive (Default 7)
SWIFT	swi	2	AGO# WGS SSC#	VC 00 VC 01 VC 02 VC 03 VC 04 VC 06 VC 07	vc0 vc1 vc2 vc3 vc4 vc6 vc7	N	N	SFTP Push SSAFS	7 Days
THEMIS	thm	1	AGO# WGS WS1 SSC#	VC 00 VC 01 VC 02 VC 03 VC 04 VC 06	vc0 vc1 vc2 vc3 vc4 vc6	Y	N	SFTP Pull CSAFS	30 Days

* Defined by NEN Scheduling

Utilizes a SAFS like interface to send data to CSAFS

15.5.5   **SAFS File Naming Convention**

The SAFS file naming convention is defined as follows:

ProjectID YYYYMMDDHHMMSS TMprocessorID Type . Ext

Pass Recording Start Time

Where:

ProjectID	3 character project Identifier as defined by NEN Scheduling. (Example: qst, cos, eo1)
Pass Recording Start Time	YYYYMMDDHHMMSS
YYYY	Year
MM	Month
DD	Day of Month
HH	Hour (24 hour clock)
MM	Minutes
SS	Seconds
TMprocessorID	P [PTP sequence – 2 digit number]
	D [Data stripper sequence – 2 digit number]
Type	Data type (Example: for QuikSCAT: sci/hk1/hk2)
Ext	Extension (3 characters)
	dat (data)
	mta (metadata)
	flg (flag file – see section IV below)

Example 1:

SAFS file name for QuikSCAT:	qst20121125132245p01sci.dat
ProjectID	qst

Pass Recording StartTime:
    Year
    Month
    Day of Month
    Hour (24 hour clock)
    Minutes
    Seconds
	
	2012
	11
	25
	13
	22
	45

TMprocessorID	p01
Type	sci
Ext	dat

Example 2:

SAFS file name for ADEOS II:	sol20121201081532p01raw.dat
ProjectID	sol

Pass Recording StartTime:
    Year
    Month
    Day of Month
    Hour (24 hour clock)
    Minutes
    Seconds
	
	2012
	12
	01
	08
	15
	32

TMprocessorID	p01
Type	raw
Ext	dat

15.5.6 **Telemetry Processor to SAFS Interface Requirements**

The requirements for the interface between the Standard Autonomous File Server (SAFS) and the Telemetry Processor (TMP) are as follows:

1. The TMP will transfer files to specific SAFS directories by project and file types, using project parameters from section II above. The SAFS file destination path structure will be: /raid1/safs/**ProjectID** with one or more data type subdirectories as needed.

Example 3: /raid1/safs/qst/sci/
/raid1/safs/cosmic/vcdat/

2. If a metadata file is associated with a data file, it will be sent to the same directory as its corresponding data file.

Example 4: The QuikSCAT files qst20121201081532p02hk2.dat and qst20121201081532p02hk2.mta would both be sent to the SAFS directory /raid1/safs/qst/hk2.

3. If the TMP is **not** using FASTCopy to transfer files to the SAFS, then **after** the data and metadata files are transferred to a SAFS directory, a flag file must be sent to the same SAFS directory to indicate completion of the data/metadata transfers. The flag file will have the same

file name, but with an extension of **.flg**. This flag file will contain the names of the data and metadata files.

Example 5:   After the QuikSCAT files **qst20120213134522p01sci.dat** and **qst20120213134522p01sci.mta** are sent to the SAFS, the file **qst20120213134522p01sci.flg** will be sent as the flag file for the pair and will contain the following:

      qst20120213134522p01sci.dat
      qst20120213134522p01sci.mta

Example 6:   After the SOLARB file **sol20121022011657p01raw.dat** is sent to the SAFS, the file **sol20121022011657p01raw.flg** will be sent as the flag file and will contain the following: sol20121022011657p01raw.dat

NOTE

If the TMP is using FASTCopy to transfer files to the SAFS, flag files are not required, but may be used.

15.5.6.1   **SAFS Data Exchange and Email Formats**

TYPE	DIRECTION	PROTOCOL	DESCRIPTION
DRN	Customer "pulls"	E-mail	Server sends an E-mail message to inform "pull" customers that data is ready at server for transfer.
RCN	All Customers	E-mail	All customers send an E-mail message to inform the server when data is received, and the status of the transfer.
FDN	Server "pushes"	E-mail	Server sends an E-mail message to inform "push" customers that their data has been delivered, and the status of the transfer.

The E-mail message consists of a subject and message area.

a) The subject area has the same format for all message types:

SUBJECT:

Fixed Value
NR - normal mail

I - Data Ready Notification (DRN)
R - Receipt Confirmation Notification (RCN)
D - File Delivery Notification (FDN)

Station/customer ID – Ex: GSFC,WGS, QPAC, MOC

nn - Spacecraft

mm - Data Type

F - BB - C - DDDD_DDDD - EEEE_EEEE

Sending ID   Receiving ID
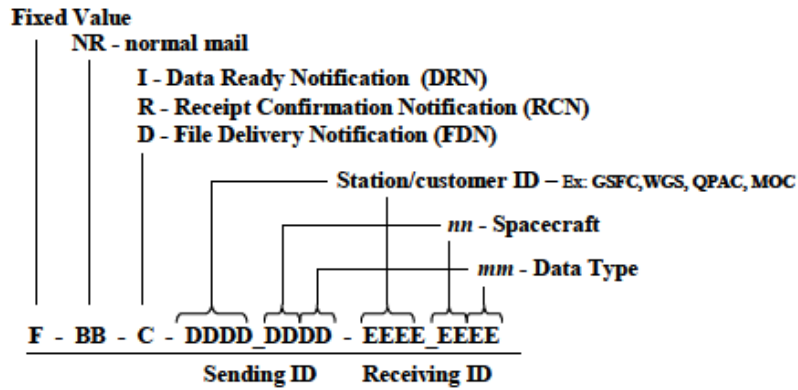
Example data message subject lines:

DRN: F-NR-I-ASF_1021-GSFC_1021
FDN: F-NR-D-ASF_1021-GSFC_1021
RCN: F-NR-R-ASF_1021-GSFC_1021

b) The message area for DRN and RCN (Receipt Confirmation Notice) message
    types is as follows, and has a single content line:

Message Content:

<BOM>

Fixed Value

File Name to retrieve with absolute path

File Size (in bytes)

Station/customer ID – Ex.: GSFC, SGS, MOC

nn - Spacecraft

mm - Data Type

CON> B> C> DDDD_DDDD > E>

Receiving ID

Status of data retrieval - only used for RCN
0 - Successful Retrieval
1 - Duplicate file
2 - Error

<EOM>
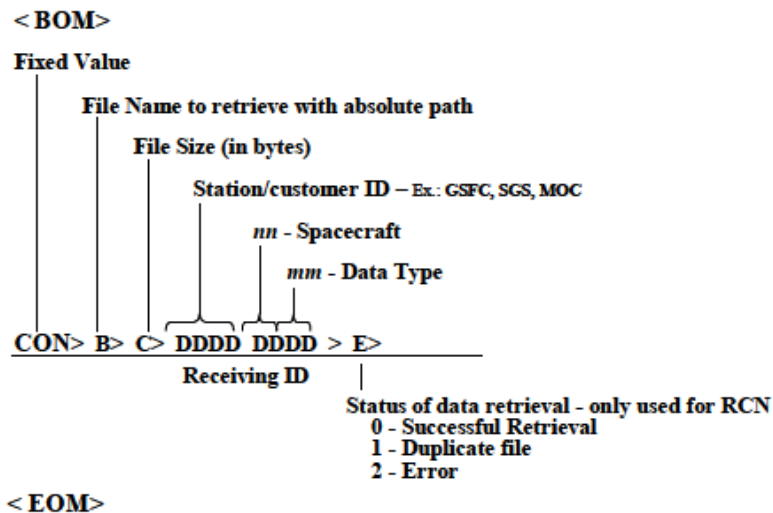
Example DRN message content:

<BOM>
CON>/raid1/safsarchive/sam/12185173627_vc0>866636>SAMPEX_7784>

>

<EOM>

   c) the message area for the FDN (File Delivered Notification) message type is as follows, and has two content lines:

Message Content:
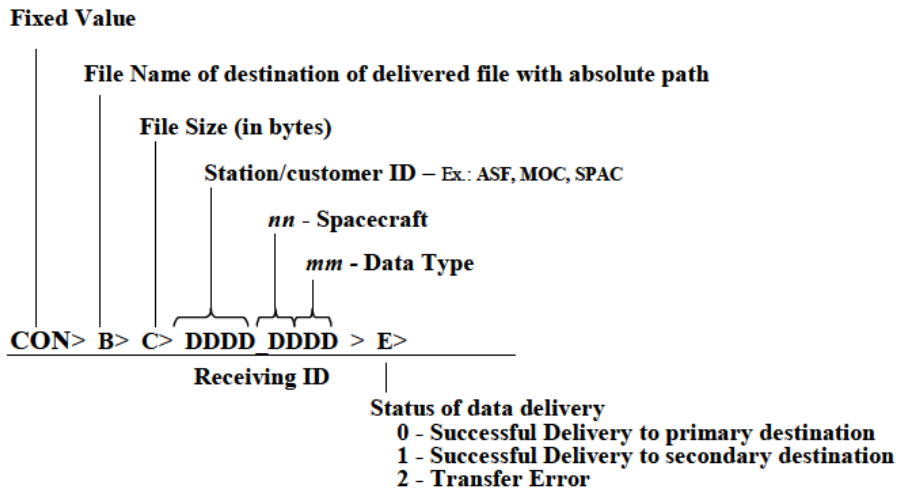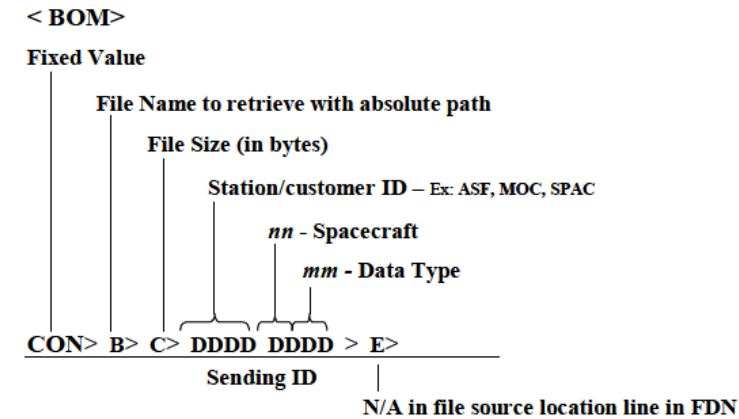
Example FDN message content:

<BOM>
CON>/raid1/safsarchive/qst/qst20120703170202p62hk1.dat>7803936>ASF
_1021>>
CON>/raid1/safs/qst/hk1/qst20120703170202p62hk1.dat>7803936>GSFC_
1021>0>
<EOM>

15.5.7 SAFS Transfer Protocols

DATA DIRECTION	PROTOCOL	PROCEDURES
Customer "pulls"	, SFTP, SCP or COTS *(CSAFS only)*	1) Server sends DRN to customer before transfer. 2) Customer "pulls" file and sends RCN to server after transfer.

Server "pushes"	, SFTP, SCP or COTS *(FDN and Failover COTS only)*	1) Server sends FDN to customer after file transfer:
		  a) If transfer not successful to customer's primary destination after *n* tries, then
		    • Server sends FDN to customer's primary destination with failure status.
		    • File is transferred to customer's secondary destination
		  b) If transfer not successful to customer's secondary destination after *n* tries, then
		    • Server sends FDN to customer's secondary destination with failure status.
		    • Server sends FDN to customer's tertiary destination with failure status and info for customer "pull" of file.
		2) Customer sends RCN to server after transfer.

15.5.8 SAFS Data Archive

Upon being processed by the SAFS (Station and Central) data files are archived for a configurable period of time (NASA requires a minimum of 3 days) to allow for customer retrieval or station resend on a contingency basis. By default the archive period is typically 7 days, but can be shorter or longer depending upon storage requirements and customer needs.

15.6 NEN Gateway

The NEN Gateway (NENG) separates X-band Virtual Channel data, packages it into manageable sized files and delivers them to the project. The NENG uses standard Transmission Control Protocol/Internet Protocol (TCP/IP) and file-based transmission protocols. The NENG is a computer system connected to the NEN station Cortex XXL, X-band receiver that handles file construction from an incoming Consultative Committee for Space Data Standards (CCSDS) Advanced Orbiting Systems (AOS) stream. Presently, the NENG is located at the WGS and the ASF and supports downlink data processing for the IRIS and Seahawk missions. The current maximum data rate is 600Mbps. NENG service to other customers can be implemented.

15.6.1 Operational Description

The NEN station Cortex HDR XXL – High Data Rate Receiver performs demodulation, decoding and frame synchronization on the customer X-band data stream. Each virtual channel in the AOS frame that is received by the station X-band receiving system will be written into separate files. Files are separated into small one-minute file sizes for a single VCID that allow for faster turn-

around time on the data and smaller transmission cycles in case of NENG to user transfer problems. The NENG stores the file-based data in a 7-day temporary circular buffer used for retransmissions and failure recovery when necessary. At the end of a pass the NENG will perform an automatic secure file transfer protocol (SFTP)/secure copy protocol (SCP) push to the customer. If the customer wants to "replay" a data set they may use the self-service /SFTP/SCP interface on the system to pull their data to their site. Alternatively, the customer may choose to manually retrieve files and not select automatic file transfer. The NENG will store customer data sets for at least 7 days, allowing for delayed retrieval.

Figure 15-3 shows the data flow from the NEN station antenna to the NEN Gateway and then, the customer interface.
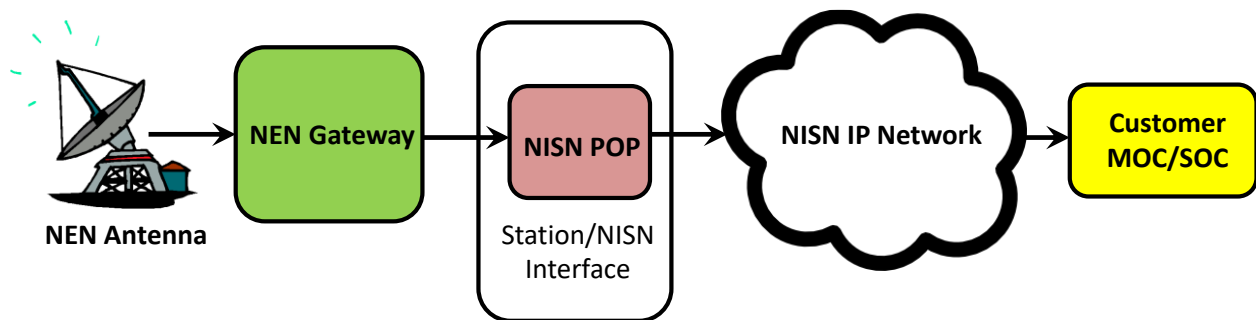
Figure 15-3. NEN Antenna to NEN Gateway to Customer Data flow

15.6.2   Gateway Design

The NEN Gateway storage system is a single fault tolerant RAID disk system, with a capacity of about 10 terabytes. The software and hardware traces its legacy to the SDO, LRO, and WS1 implementations. The NEN Gateway uses Commercial off the Shelf (COTS) hardware exclusively. NEN customers schedule services via the NEN and receive return data packetized for transport via an Open Systems Interface (OSI) Level 4 (L4) protocol. Multiple missions and/or science centers can schedule services from the NEN Gateway, to the extent resources permit.

Section 16. Frequency Management

16.1 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.

16.2 Determining Frequency Spectrum Requirements

16.2.1 International Frequency Spectrum Allocations

International frequency spectrum allocations are prepared by World Radio Communication Conferences convened under the auspices of the International Telecommunications Union (ITU). These allocations become part of the ITU-R 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. Refer Table 16-1.

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 manages non-government allocations.

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

Table 16-2 identifies the bands in which the space science services are "primary" or "secondary" with respect to other services. Within these bands, 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.

It is important to note that all spacecraft communication links with the NEN and other ground networks must be coordinated, licensed, and internationally registered prior to operation.

Table 16-1. United States and ITU-R 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)

Table 16-1. United States and ITU-R Table of Frequency Allocations (continued)

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

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
				US258

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)

Table 16-1. United States and ITU-R Table of Frequency Allocations (continued)

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

Table 16-1. United States and ITU-R Table of Frequency Allocations (continued)

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			14.8-15.1365 MOBILE SPACE RESEARCH Fixed	14.8-15.1365
			US310	US310
			15.1365-15.35 FIXED SPACE RESEARCH Mobile	15.1365-15.35
5.339			5.339 US211	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)
			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)
				25.5-27
				Inter-satellite 5.536
				Standard frequency and time
				  signal-satellite (Earth-to-space)

5.536A			5.536A US258	5.536A US258

Table 16-2. 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 Internal Frequency Registration Board 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.

16.2.2   DSN Protection

As stated above, the Deep Space Network (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-R recommended interference protection criteria in the DSN band for interference from non-DSN transmitters are summarized in Table 16-3.

Table 16-3. Interference Protection Criteria for DSN

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

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. For example, a platform using a 2287.5 MHz return/down link with a necessary bandwidth of 5 MHz or higher could easily violate the deep space protection criteria when it transmits within the view of a DSN ground 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 16-1 shows the output spectral plot of the "NASA/GSFC Recommended Filtering Referenced to the Output of the Power Amplifier". Figure 16-2 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. Such a filter could reduce or eliminate the need for operational coordination of down/return links.

X-band links operating in the upper portion of the 8025-8400 MHz and the 8450-8500 MHz bands also have the potential to cause unacceptable interference to deep space missions operating in the 8400-8450 MHz band. Current NASA policy is that this criterion must be met 100% of the time, so appropriate mitigation techniques must be employed to ensure that ITU-R SA.1157 protection criteria are met above 8400 MHz.
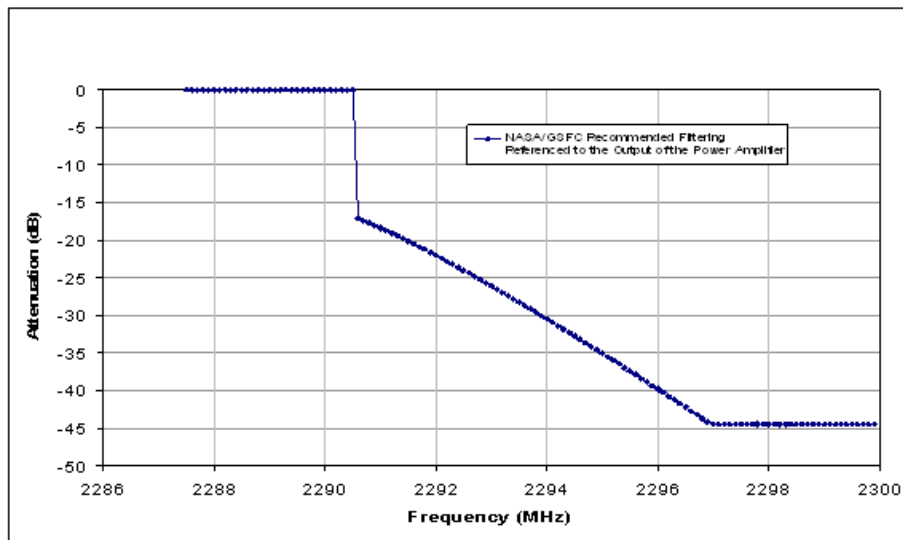
Figure 16-1. Spectral Output for NASA/GSFC Recommended S-band Filtering Referenced to the Output of the Power Amplifier

The chart contains the following annotation box:

Center Frequency of Signal: 2287.5 MHz
Modulation: 3.078 Mcps PN Code
EIRP towards DSN: 0 dB
Slant Range to DSN: 400 km
DSN Antenna Gain: 32 dBi (at 1 deg from boresite)

Legend:
- Spectrum with 'NASA/GSFC Recommended Filtering Referenced to the Output of the Power Amplifier'
- Unfiltered Spectrum
- DSN Protection Criteria
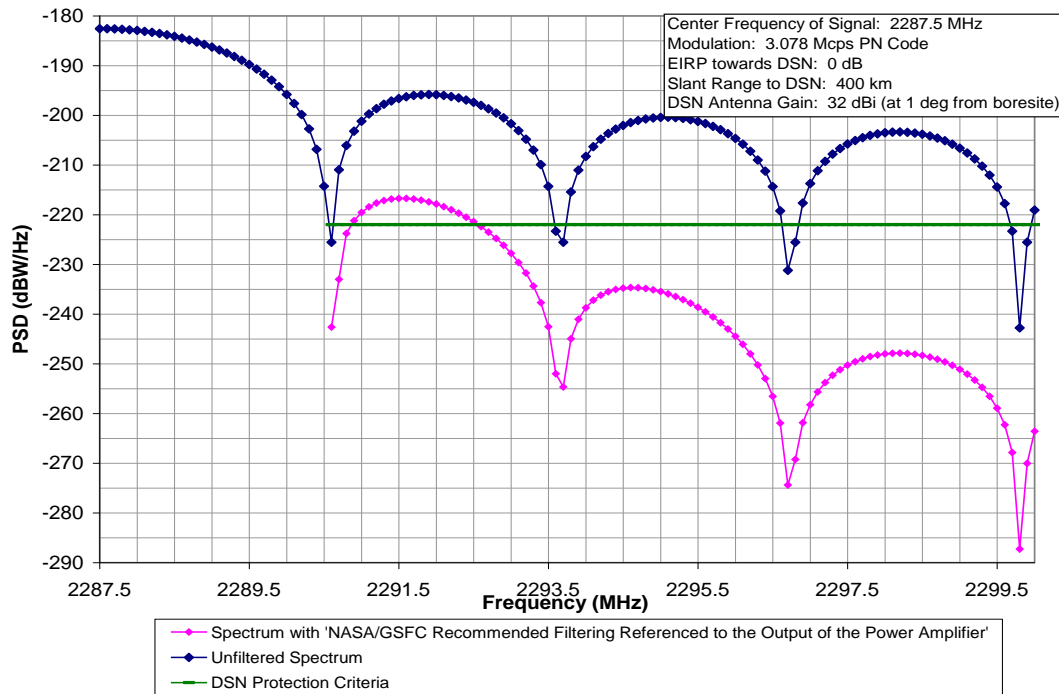
Figure 16-2. Example of Unfiltered and Filtered 3 Mcps Code with DSN Protection Criteria for S-band

16.2.1   **Protection of Terrestrial Operations and Ground Receivers**

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 missions by both the NTIA and the ITU-R. Those limit values can be found in the ITU-R Radio Regulations Article 21, Table 21-4. Although largely similar, there are a few differences between the ITU-R and the NTIA National Power Flux Density limits also imposed upon US missions. In some cases, the NTIA limits may be more constraining or there may be NTIA limitations for spectrum where there are no ITU-R limitations. Additional limitations apply for EESS operation in the 8025-8400 MHz spectrum.

The Power Flux Density (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 16-4. PFD Limits Applicable to TypicalNEN Bands

Frequency (MHz)	Power-Flux Density Limit for Angles of Arrival (θ) Above the Horizontal Plane (dBWi/m²)			Reference Bandwidth
	$0° \leq θ \leq 5°$	$5° < θ < 25°$	$25° \leq θ \leq 90°$	
460 – 470	-152	-152	-152	4 kHz
2200 – 2290	-154 -130	-154 + 0.5 (θ - 5) -130 + 0.5 (θ - 5)	-144 -120	4 kHz
8025 – 8500	-150	-150 + 0.5 (θ - 5)	-140	4 kHz
25500 – 27000	-115	-115 + 0.5 (θ - 5)	-105	1 MHz

16.2.1 ITU-R and SFCG Limits on PFD in X-band for EESS Downlinks

SFCG Recommendation 14-3R9 and ITU-R Recommendation SA.1810 provide system design guidelines for Earth-exploration satellites operating in the band 8025-8400 MHz and they define the following specific PFD limit for EESS transmissions in the 8025-8400 MHz band. This limit is more constraining than the normal ITU-R (and NTIA) limitation.

16.3 Obtaining Frequency Spectrum Authorization

16.3.1 Regulations, Policies, and Instructions

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

16.3.2 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 ESC Projects Division, Code 450. The responsibilities of the Spectrum Management Office include:

a. Coordinate RF spectrum requirements pertaining to GSFC and NEN resources, in accordance with Chapters 2 and 3 of reference 'i' in Section 1.3.

b. Ensure interference-free operations between user vehicles and the NEN, in accordance with Chapter 4 of reference 'i' in Section 1.3.

c. Assist the flight project in determining frequency requirements, including performing interference analyses and specifying the frequencies to be used after obtaining all required domestic and international coordination agreements..

d. Provide guidance in providing the information required to complete the Frequency Authorization Request to be sent to the NTIA. Chapter 10 of reference 'j' in Section 1.3 provides instructions for information required for filing the requests.

e. 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 'j' in Section 1.3 describes the four-stage review process for the national process.

16.3.3 **Flight Project Responsibilities**

Flight projects must 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). Each project must designate a point-of-contact for working with the Spectrum Management Office as given in Reference NPD 2570.1, *NASA Radio Frequency (RF) Spectrum Management Manual*.

16.4 **Bandwidth (BW) Requirements**

In order to more efficiently utilize the limited spectrum allocated for space-to-Earth data transmissions, the 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.

The SN has had issues providing service to customers who transmit pattern data or long strings of 1s or 0s. The SN worked with Consultative Committee for Space Data Systems (CCSDS) to develop a recommendation that customers use data randomization during all phases of the mission. The NEN recommends the same strategy for customers requiring NEN services.

16.4.1 **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, the SFCG recommends that systems using this band be designed to minimize their bandwidths to reduce the potential interference to other systems in the band.

NTIA requires the following limits in Section 8.2.41 of the NTIA manual for all US licensed operations:

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.

16.4.2 **BW Requirements in the 8450-8500 MHz Band**

SFCG Recommendation SFCG 05-1R5 recommends that the 8450 – 8500 MHz band is 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.

16.5   **Unwanted Emission Masks**

Figure 16-3 shows the unwanted emission mask given in Section 5.6 of the NTIA Manual. This emission mask is applicable for all US authorized 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:

   a.   dBsd is dB attenuation in a 4 kHz bandwidth, relative to the maximum power in any 4 kHz band within the necessary bandwidth.

   b.   For frequencies offset from the assigned frequency less than the 50% of the necessary bandwidth (B_n), no attenuation is required.

   c.   At a frequency offset equal to 50% of the necessary bandwidth, an attenuation of at least 8 dB is required.

   d.   Frequencies offset more than 50% of the necessary bandwidth should be attenuated by the following mask:

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

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

   a.   For cases of very narrow-band emissions where the necessary bandwidth is less than the minimum bandwidth (B_L) given in Figure 15-3, B_L shall be used in place of B_n.
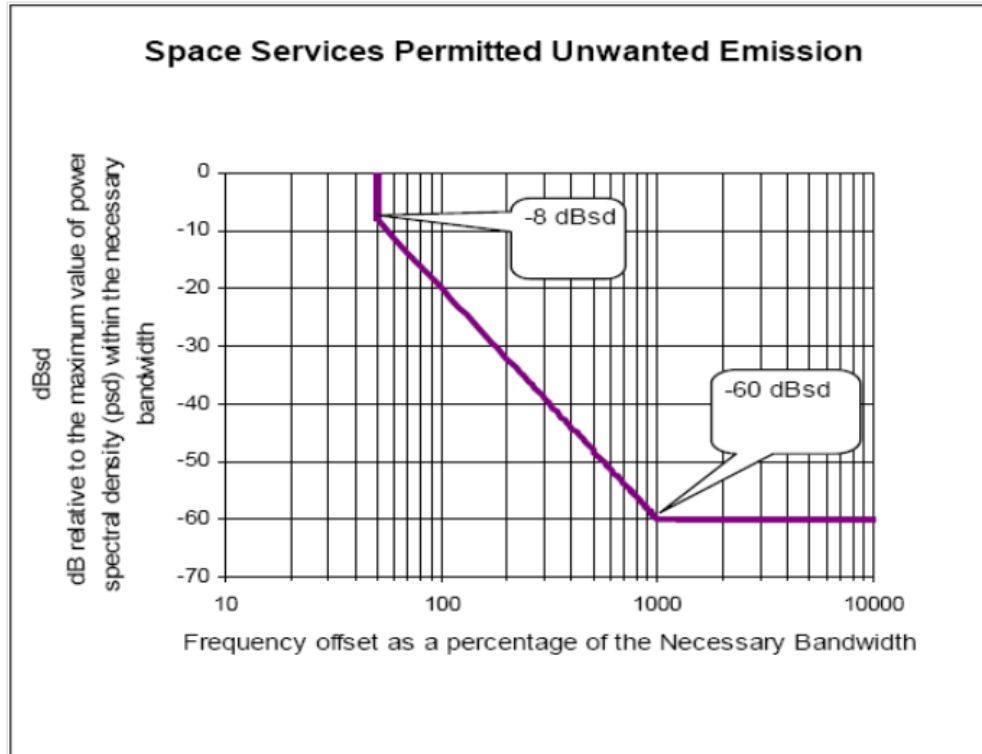
Figure 16-3. NTIA OOB Emission Mask for Earth and Space Stations

16.5.1 **SFCG Emission Mask**

Figure 16-4 shows the unwanted emission mask specified by SFCG Recommendation SFCG 21-2R4. That Recommendation contains the following recommendations for all operations:

1) that space agencies use the most bandwidth efficient modulation schemes practicable for their missions;

2) that, PCM/PM/Bi-phase or PCM/PM/NRZ modulation only be used when a carrier component is technically necessary and for symbol rates below 2 Ms/s;

3) that the emitted spectrum[3,4] for all Space Science Services projects that will utilize space-to-Earth link frequency assignments in the bands 2200–2290 MHz, 8025–8400 MHz and 8450–8500 MHz, adhere to the low rate spectral emission mask of Figure 16-4 for symbol rates below 2 Ms/s and to the high rate spectral emission mask of Figure 16-4 for symbol rates equal or above 2 Ms/s;

4) that the emitted spectrum[3] for all Space Science Services projects designed for launch after 2020 that will utilize space-to-Earth link frequency assignments in the 25.5-27.0 GHz band and for channel symbol rates[5] equal or above 10 Ms/s, adhere to the high rate spectral emission mask of Figure 16-4;

5) that transmissions that include a ranging signal be exempt from the spectrum masks in Fig 16-4;

6) that PCM/PSK/PM transmissions in accordance with REC SFCG 21-3 be exempt from the spectrum masks in Fig 16-4.
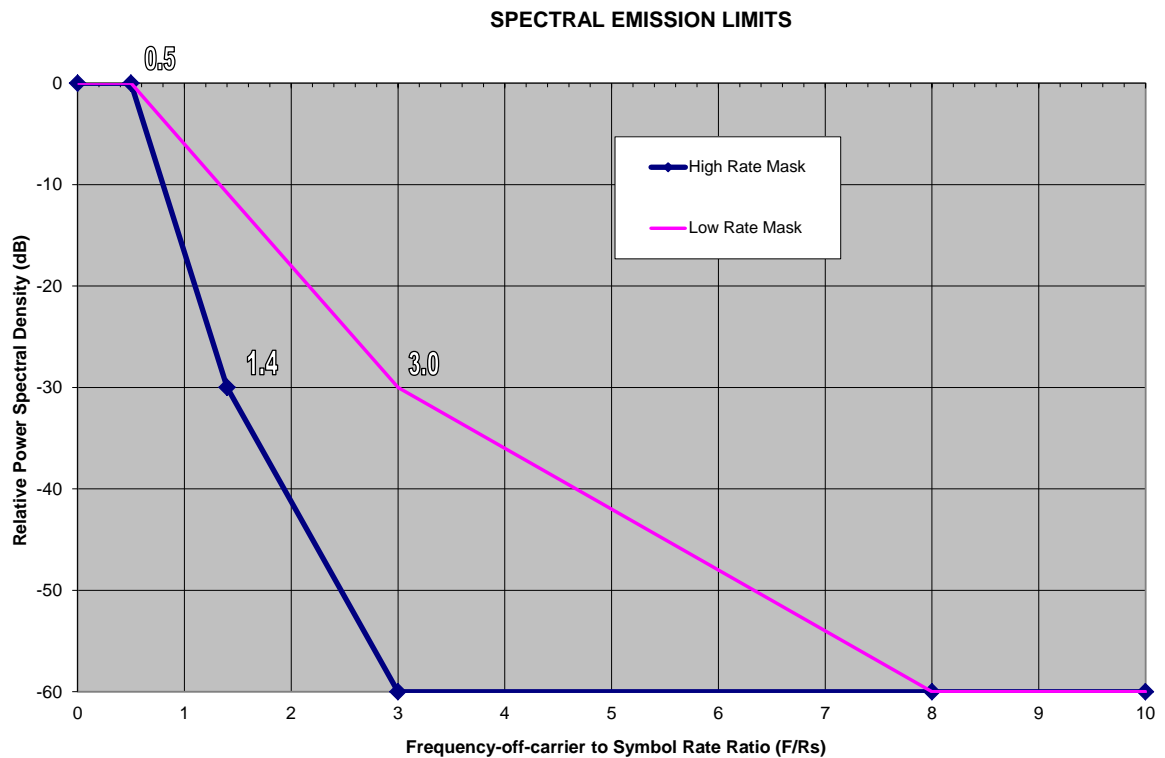
Figure 16-4. SFCG OOB Emission Mask for Space Stations in S/X/Ka-Bands

Refer to Recommendation SFCG 21-2R4for full details on the requirements as the document is subject to revisions and updates and the information included her is just a summary.

Section 17. Link Budget Parameters

17.1   General

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 ESC Projects Division Program Office. This section provides the following information:

   a.   S-band atmospheric and rain attenuation constants.

   b.   X-band atmospheric and rain attenuation constants.

   c.   Ka-band atmospheric and rain attenuation constants.

17.2   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.618-10. Table 17-1 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. Refer to the Code 450 CLASS Group for further detail analysis.

17.3   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.618-10. Table 17-2 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. Refer to the Code 450 CLASS Group for further detail analysis.

17.4   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.618-10. For Table 17-3 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. Refer to the Code 450 CLASS Group for further detail analysis.

Table 17-1. S-band Rain Attenuation Constants (5° Elevation Angle) [2.3 GHz]

Ground Station	Rain Attenuation (dB)		
	99% Availability	99.9% Availability	99.99% Availability
SGS (Norway)	0.0	0.0	0.02
WGS (WFF)	0.01	0.04	0.16
MG1 (Antarctica)	0.0	0.0	0.0
ASF (Alaska)	0.0	0.01	0.06
PDL (Florida)	0.02	0.12	0.40
WS1 (White Sands, New Mexico))	0.00	0.03	0.12
USHI (SSC South Point, Hawaii)	0.02	0.15	0.48
AUWA (SSC Dongara, Australia)	0.0	0.03	0.13
HBK (Hartebeesthoek, South Africa)	0.01	0.07	0.25
KIR (Kiruna, Sweden)	0.0	0.01	0.05
AGO (Santiago, Chile)	0.0	0.02	0.06
TR (Troll, Antarctica)	0.0	0.0	0.0

Table 17-2. X-band Rain Attenuation Constants (5° and 10° Elevation Angle) [8.5 GHz]

Ground Station	Elevation Angle	Rain Attenuation (dB)	
		99% Availability	99.9% Availability
SGS (Norway)	5°	0.12	0.62
	10°	0.06	0.32
WGS (WFF)	5°	1.04	4.30
	10°	0.60	2.60
MG1 (Antarctica)	5°	0.01	0.05
	10°	0.0	0.02
ASF (Alaska)	5°	0.36	1.63
	10°	0.20	0.95
USHI (SSC South Point, Hawaii)	5°	2.74	13.71
	10°	1.46	8.87
AUWA (SSC Dongara, Australia)	5°	0.77	4.28
	10°	0.40	2.66
TR (Troll, Antarctica)	5°	5°	0.01
	10°	10°	0.0
HBK (Hartebeesthoek, South Africa)	5°	1.53	8.02

	10°	0.80	5.03

Table 17-3. Ka-band Rain Attenuation Constants (5° and 10° Elevation Angle) [27 GHz]

Ground Station	Elevation Angle	Rain Attenuation (dB)			
		90% Availability	95% Availability	99% Availability	99.9% Availability
WS1 (White Sands)	5°	1.84	3.08	8.98	40.15
	10°	1.07	1.82	5.47	28.94

17.5   **Ground Station Line-Of-Sight Coverage**

NEN masking data is controlled and stored in the GSFC Online Library (NGIN) at: https://code450ngin.gsfc.nasa.gov. Document numbering is 453-SPEC-<antenna>.

The Networks Integration Manager (NIM) or Mission Commitment Engineer (MCE) can provide the masking data upon request.

The NEN does not guarantee X-band data quality transmissions below 10 degrees.

Appendix A. 8PSK Strategy

CCSDS 401.0-B-25 section 2.4.18, is a recommendation for the EESS 8 GHz band that contains several bit to modulation symbol mappings. Included is a recommendation for 8PSK modulation that specifies the bit-to-symbol mapping found in the Appendix, A 2.3.2 Case 2, Figure 2.4.18-17. For the purposes of the NEN and SN, this specification of 2.4.18 will be used as the bit-to-symbol mapping for 8PSK. *CCSDS 131.3-B-1 DVB-S2 March 2013* is a subset of the DVB-S2 standard that has the same 8 PSK constellation mapping.

8-PSK
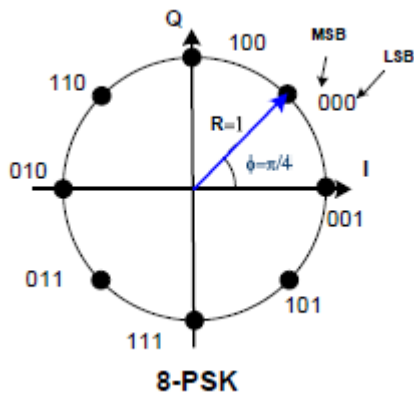
Appendix B. Downlink OQPSK Configuration Examples

This Appendix provides several recommended downlink configuration examples with various encoding schemes for missions using OQPSK that are NEN compatible. It highly recommends employing CCSDS compliance. For detailed discussion, please contact GSFC Code 450.
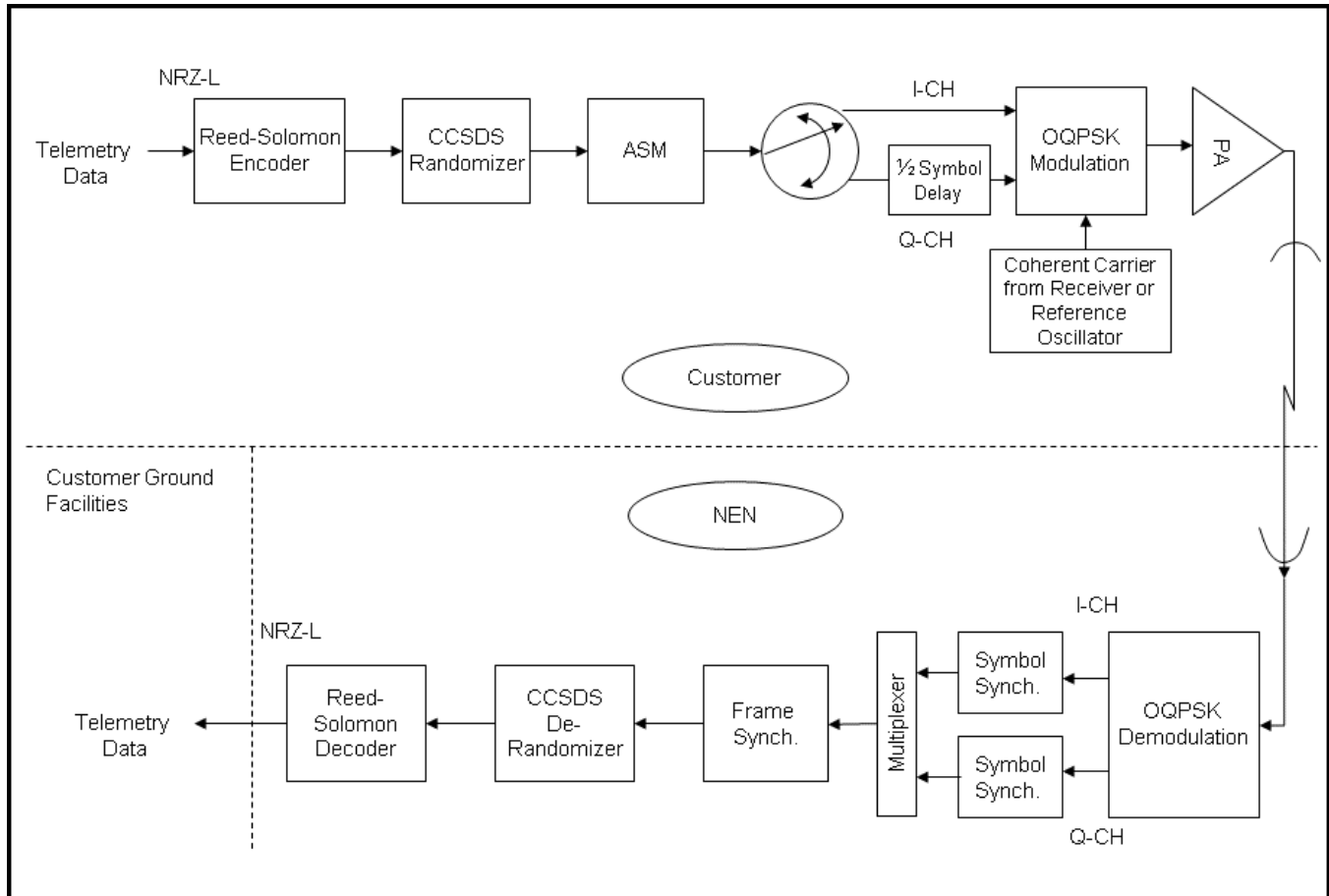
Figure B-1. Reed-Solomon OQPSK Downlink Configuration
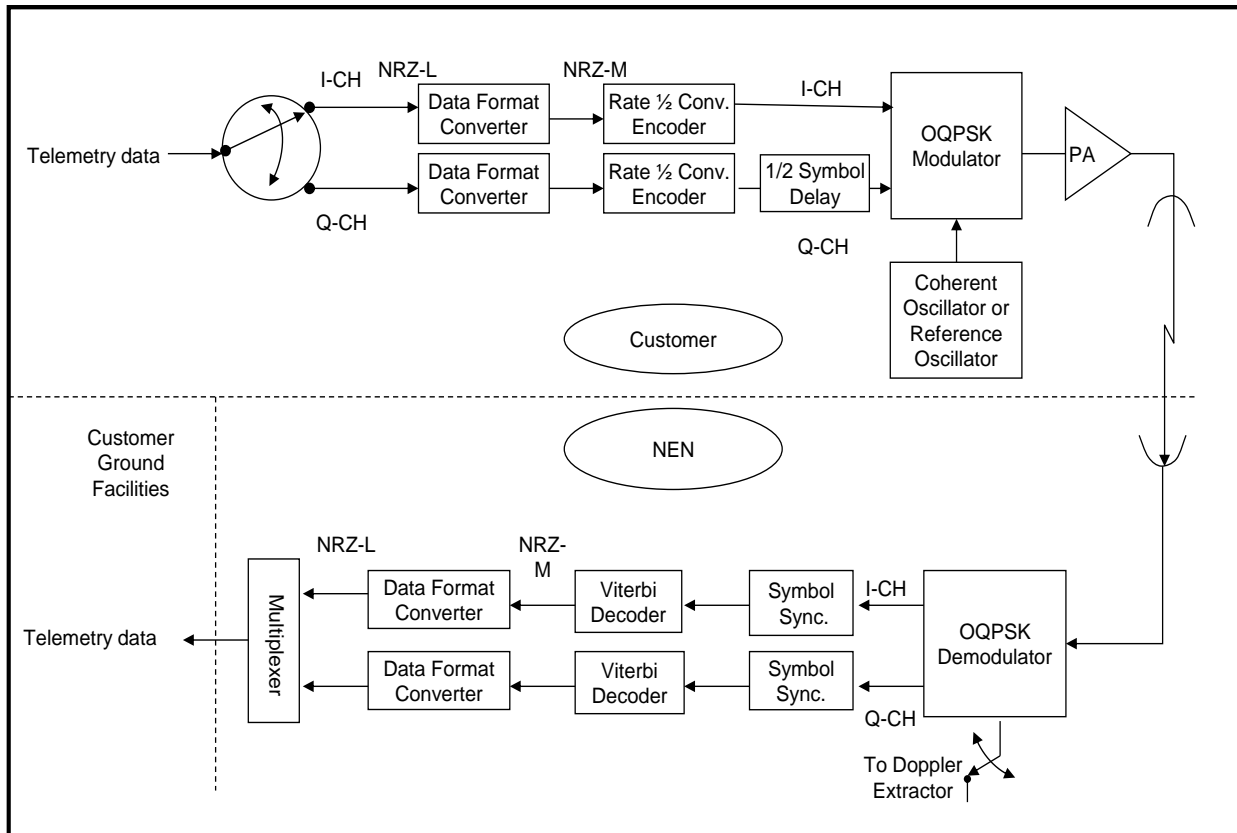
Figure B-2. Rate ½ Convolutional OQPSK Downlink Configuration
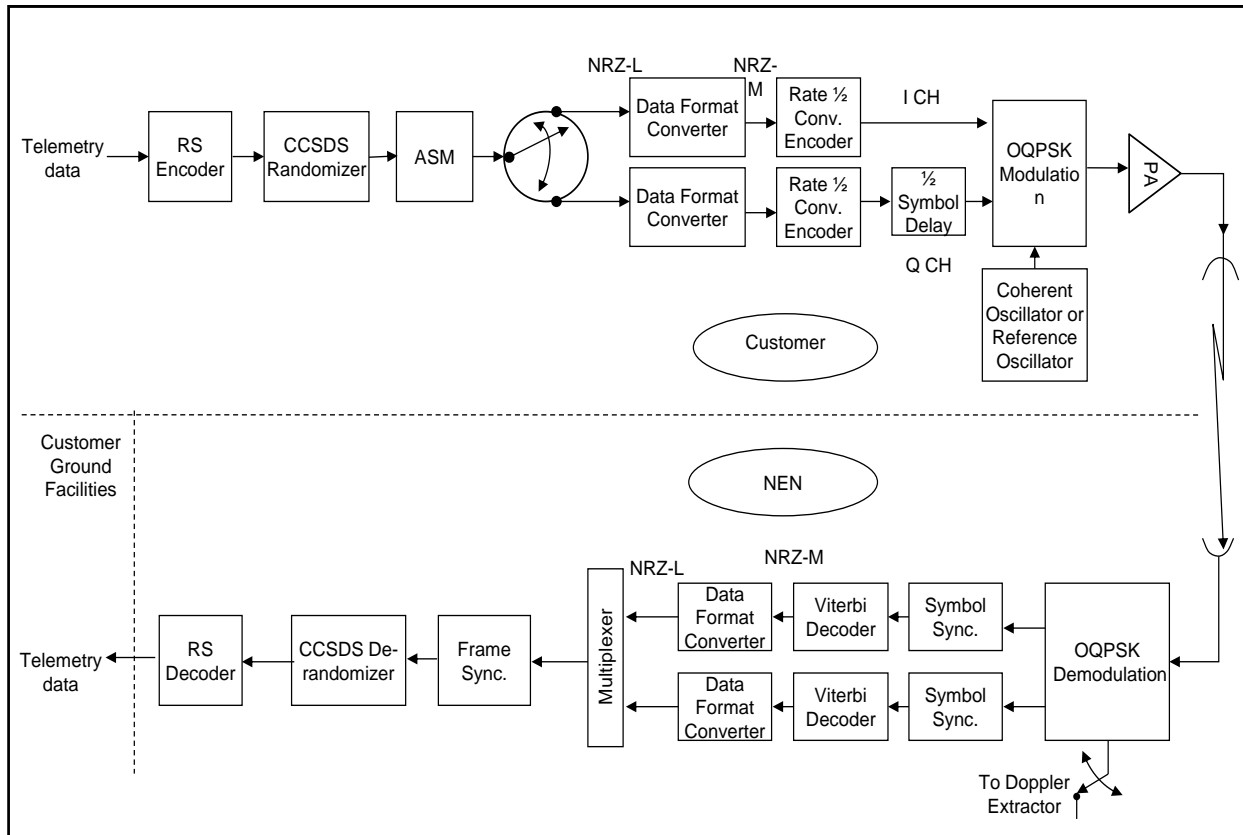
Figure B-3. Rate ½ Convolutional and Reed-Solomon OQPSK Downlink Configuration
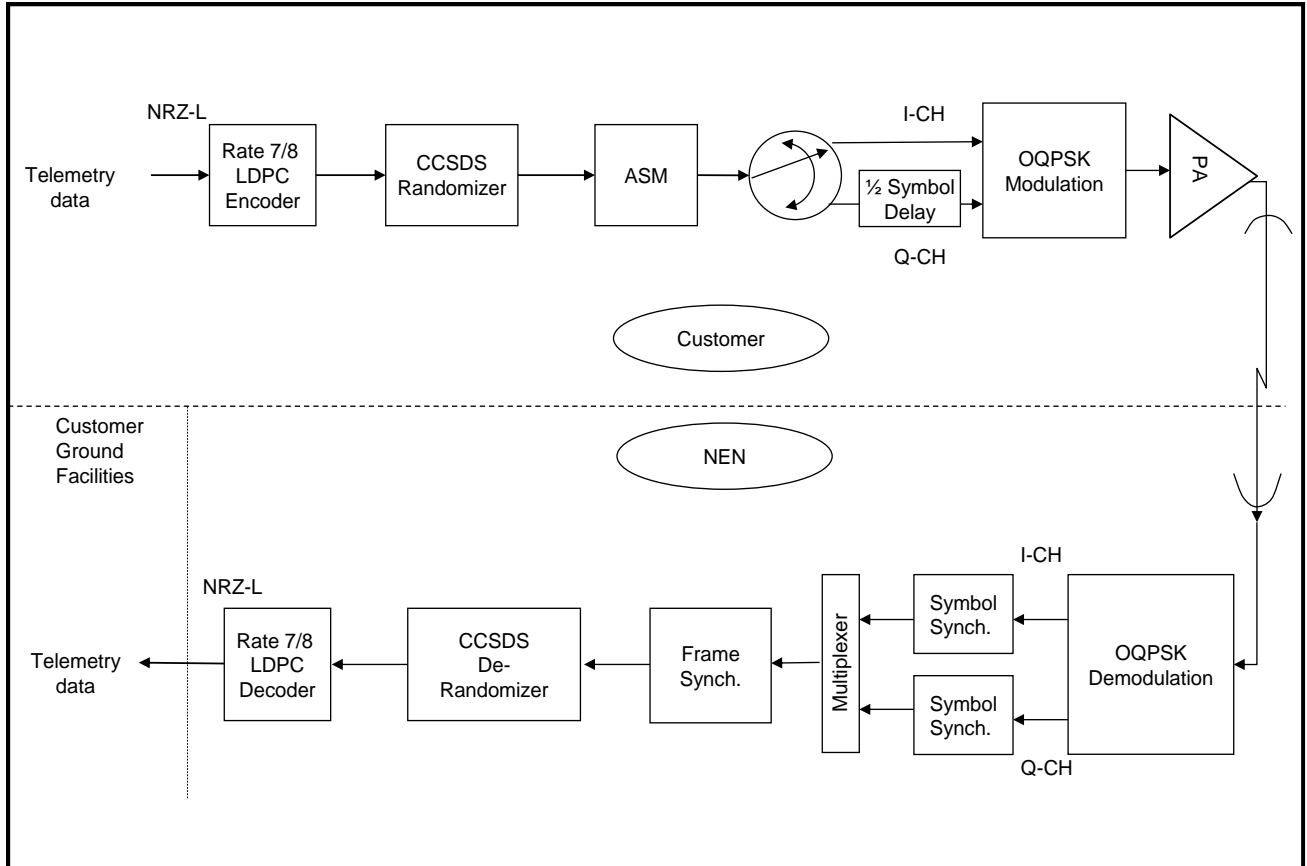
Figure B-4. Synchronous Data Frame Rate 7/8 LDPC OQPSK Downlink Configuration

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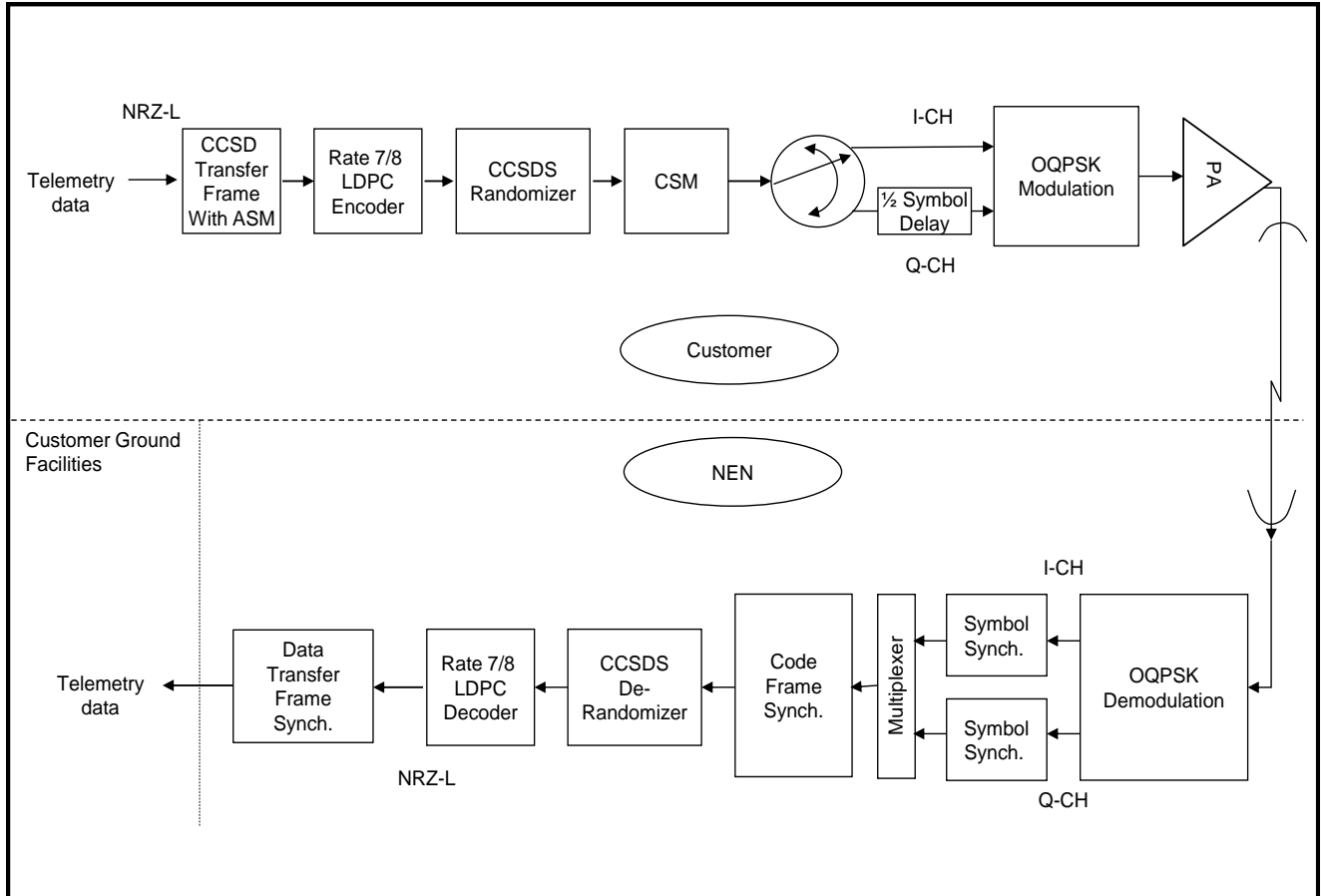
Figure B-5. Sliced (Asynchronous) Data Frame Rate 7/8 LDPC OQPSK Downlink Configuration

Appendix C. Units of Measurement

This appendix contains abbreviations and symbols for commonly used units of measurement. As a general rule, these short forms should be used only in tables or charts, or in text when used with numerals.

|			
A	atto- (prefix 10^{-18})	dBm	decibel referred to 1 milliwatt
A	ampere	dBV	decibel referred to 1 volt
Å	Angstrom	dBWi	decibel referred to 1 watt
ata	atmosphere absolute	deg	degree
b/b	bit per block	deg/sec	degree per second
b/f	bit per frame	dg	decigram
b/in.	bit per inch	dr	dram
bps	bit per second	eV	electron volt
Btu	British thermal unit	f	femto- (prefix 10^{-15})
c	centi- (prefix 10^{-2})	F	farad
^{o}C	degree Celsius	F_{o}	frequency of resonance (center frequency)
C	coulomb	^{o}F	degree Fahrenheit
cal	calorie	frm/sec	frame per second
cc	cubic centimeter	ft	foot
cg	centigram	ft/min	foot per minute
cgs	centimeter-gram-second	ft/sec	foot per second
cm	centimeter	G	gauss; giga- (prefix 10^{9})
d	deci- (prefix 10^{-1})	g	unit of gravitational force; gram
da	deka- (prefix 10^{1})	gal	gallon
dB	decibel	gal/min	gallon per minute
dBi	decibel referred to an isotropic radiation source	gal/sec	gallon per second
GHz	gigahertz (1000 MHz)	lb	pound

		lb/sq in.	pound per square inch	

Abbrev	Definition	Abbrev	Definition
h:m:s	hours:minutes:seconds	lin ft	linear foot
hp	horsepower	lm	lumen
hr	hour	M	mega- (prefix 106)
Hz	hertz (cycles per second)	m	meter; milli- (prefix 10^{-3})
in.	inch	mA	milliampere
in.-lb	inch-pound	mb	millibar
in./sec	inch per second	Mbps	megabit per second
k	kilo- (prefix 103)	mG	milligauss
kΩ	kilohm	mg	milligram
K	kelvin	mi/hr	mile per hour
kb	kilobit	MHz	megahertz
kbps	kilobit per second	μ	micro- (prefix 10^{-6})
keV	kiloelectron volt	μA	microampere (microamp)
kg	kilogram	μsec	microsecond
kHz	kilohertz	μV	microvolt
km	kilometer	μW	microwatt
km/hr	kilometer per hour	mi	statute mile
kp/sec	kilopulse per second	min	minute
kV	kilovolt	ml	milliliter
kVA	kilovoltampere	mm	millimeter
kW	kilowatt	mm/sec	millimeter per second
kWh	kilowatthour	mμ	millimicron
kw	kiloword	mo	month
kw/sec	kiloword per second	MΩ	megohm
kyd	kiloyard	msec	Millisecond
kyd/sec	kiloyard per second	MV	megavolt
mV	millivolt	T	tera- (prefix 1012)
MW	megawatt	V	volt
mW	milliwatt	VA	voltampere

n	nano- (prefix 10^{-9})	Vac	volt, alternating current
nm	nanometer	Vdc	volt, direct current
nmi	nautical mile	V/mil	volt per mil
nsec	nanosecond	Vpp	volt peak to peak
Ω	ohm	Vrms	volt root mean square
oz	ounce	W	watt
p	pico- (prefix 10^{-12})	w/frm	word per frame
pF	picofarad	w/min	word per minute
p/min	pulse per minute	w/sec	word per second
psec	picosecond	wk	week
p/sec	pulse per second	yd	yard
q	dynamic pressure	yr	year
rad	radian		
Re	earth radius		
rev	revolution		
rev/min	revolution per minute		
rev/sec	revolution per second		
rms	root mean square		
sec	second		
smp	sample		
smp/sec	sample per second		
Sq	square		

Abbreviations and Acronyms

Acronym	Definition
ACE	Advanced Composition Explorer
A/G	Air-to-Ground
AGO	Santiago Satellite Station, Santiago, Chile (SSC)
AM	Amplitude Modulation
AOS	Advanced Orbiting Systems
AQPSK	Asynchronous Quadrature Phase Shift Keying
ASF	Alaska Satellite Facility, Fairbanks, AK
AXAF	Chandra Advanced X-ray Astrophysics Facility
BER	Bit Error Rate
Biφ	Bi-phase
BP	Bi-phase
BPSK	Biphase Shift Keyed
BW	Bandwidth
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 (tool)
CLTU	Command Link Transmission Unit
CNR	Carrier to Noise Ratio
COTS	Commercial-off-the-Shelf
CSAFS	Central SAFS
CSO	Communications Service Office
DBP	Differential B-Phase
DLM	Depot Level Maintenance
DM	Delta Modulation
DRN	Data Ready Notification
DSMC	Data Services Management Center
DSN	Deep Space Network

Acronym	Definition
EIRP	Effective Isotropic Radiated Power
EOM	End of Mission
EOS	Earth Observing System
ESA	European Space Agency
ESC	Exploration and Space Communications Projects Division, GSFC
FDF	Flight Dynamics Facility, GSFC
FDN	File Delivered Notification
FM	Frequency Modulation
FSK	Frequency Shift Keyed
GEO	Geosynchronous
GN	Ground Network
GNSTAT	Ground Network Status Message
GSFC	Goddard Space Flight Center, Greenbelt, MD
G/T	Gain to Noise (antenna gain/noise temp in deg Kelvin)
HBK	Hartebeesthoek Tracking Station, Hartebeesthoek, South Africa
HPA	High Power Amplifier
ICD	Interface Control Document
ICESat	Ice Cloud, and Land Elevation Satellite
ID	Identification
IF	Intermediate Frequency
INP	Internet Predicts
INPv2	INP version 2
IONet	Internet Protocol Operational Network
I	In-phase Data Channel
IP	Internet Protocol
IPDU	Internet Protocol Data Unit
IRIG	Inter-Range Instrumentation Group
ISDN	Integrated Services Digital Network
ITU-R	International Telecommunications Union – Radiocommunication Sector
JSC	Johnson Space Center, Houston, TX
KIR	Kiruna Satellite Station, Kiruna, Sweden (SSC)

Acronym	Definition
KSAT	Kongsberg Satellite Services, Svalbard, Norway
LEO	Low Earth Orbit
LHC	Left Hand Circular (polarization)
LRO	Lunar Reconnaissance Orbiter
MASL	Meters Above Sea Level
MCC	Mission Control Center (JSC)
Mcps	Mega cycles per second
MGS	McMurdo Ground Station, McMurdo, Antarctica
MG1	McMurdo 10-m Antenna system, Antarctica
MOC	Mission Operations Center
MPLS	Multiprotocol Label Switching
MTRS	McMurdo TDRS Relay System
N/A	Not Applicable
NAM	Network Advisory Message
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications
NDOSL	*NASA Directory of Station Locations*
NEN	Near Earth Network
NENG	Near Earth Network Gateway
NENUG	Near Earth Network Users' Guide
NGIN	Next Generation Integrated Network
NIMO	Networks Integration Management Office, GSFC
NISN	NASA Integrated Services Network
NMC	Network Management Center, SSC
NPD	NASA Policy Directive
NRZ	Non Return to Zero; level (-L), Mark (-M), Space (-S)
NTIA	National Telecommunications and Information Agency
OOB	Out-of-Band
OQPSK	Offset Quadriphase Shift Keyed
OS	Operations Supervisor
PCM	Pulse Code Modulation
PDL	Ponce De Leon, NEN station, New Smyrna Beach, FL

Acronym	Definition
PFD	Power Flux Density
PLL	Phase Locked Loop
PM	Phase Modulation
PN	Pseudorandom Noise
PTP	Programmable Telemetry Processor
Q	Quadrature Phase Data Channel
QPSK	Quadriphase Shift Keyed
RAID	Redundant Array of Independent Discs
RCCA	Root Cause/Corrective Action
RCN	Receipt Confirmation Notice
RF	Radio Frequency
RFICD	Radio Frequency Interface Control Document
RHC	Right Hand Circular (polarization)
RMS	Root Mean Square
RNRZ	Randomized Non-Return-to-Zero
RNRZ-L	Randomized Non-Return-to-Zero-Level
RSS	Remote Status Server
SAFS	Standard Autonomous File Server
SANSA	South African National Space Agency
S/C	spacecraft
SCaN	NASA Space Communications and Navigation (Program)
SCP	Space Communications Processor; secure copy protocol
SFCG	Space Frequency Coordination Group
SFDU	Standard Formatted Data Unit
SFTP	secure file transport protocol
SGS	Svalbard Ground Station, Svalbard, Norway
SLE	Space Link Extension
SN	Space Network
SQPSK	Staggered QPSK
SSAFS	Station SAFS
SSC	Swedish Space Corporation
SSPA	Solid State Power Amplifier

Acronym	Definition
TBD	To Be Determined
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TDM	Time Division Multiplexed
TDRS	Tracking and Data Relay Satellite
TM	Telemetry
TMP	Telemetry Processor
TR2	TrollSat Antenna No.2, KSAT, TrollSat, Antarctica
UDP	User Datagram Protocol
UG	Users' Guide
UPS	Uninterruptible Power Source
UQPSK	Unbalanced Quadriphase Shift Keyed
URL	Universal Resource Location (Internet)
US	United States
USB	Universal Serial Bus
UTDF	Universal Tracking Data Format
VC	Virtual Channel
VHF	Very High Frequency
VPN	Virtual Private Network
WFF	Wallops Flight Facility
WGS	Wallops Ground Station, Wallops Island, VA
WS1	White Sands One Ground Station
WSC	White Sands Complex, White Sands, NM
Z	Zulu