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Space Network Users' Guide (SNUG)

August 3, 2012

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Preface

The Space Network Users' Guide (SNUG) is intended as a guide to the customer community for obtaining communication support from the National Aeronautics and Space Administration (NASA) Space Network (SN). The emphasis in the SNUG is on the interfaces between the customer and the SN.

This document is under the configuration management of the Goddard Space Flight Center (GSFC) Exploration and Space Communications (ESC) Projects Division, Code 450, Configuration Control Board (CCB).

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Section 1. Introduction

1.1 Purpose and Scope

1.1.1 Purpose

This document describes the customer services provided by the National Aeronautics and Space Administration (NASA) Space Network (SN) and guides the customer through the process of obtaining support from the SN.

1.1.2 Scope

The SN was established in the early 1980s to replace NASA's worldwide network of ground tracking stations. It consists of a constellation of geosynchronous satellites and associated ground systems and operates as a bent pipe relay system between customer platforms and customer ground facilities. For customer platforms operating in a low earth orbit (LEO) above 73 km in altitude, the SN is capable of providing tracking and data acquisition services over 100% of the customer platform's orbit. A more detailed description of the SN, its elements, support scenarios and coverage is provided in Section 2 of this guide.

The emphasis in this guide is on the interfaces between the customer and the SN. Topics covered include the following:

a. Ground interfaces between the customer Mission Operations Center (MOC) and the SN.

b. Radio Frequency (RF) interfaces between the customer platform and the SN.

c. Procedures for working with the Goddard Space Flight Center (GSFC) Exploration and Space Communications (ESC) Projects Division (Code 450), which has the management and operational responsibility for the SN, to establish customer interfaces.

d. The capabilities, service characteristics, and operational aspects of the SN.

e. Generalized capabilities and technical characteristics of non-SN elements that support the SN customer.

1.2 Additional Information

The SN is constantly evolving. Circumstances may exist in which SN customers need more information than is provided in this document and in the referenced documents. For services and capabilities not expressly defined within this user's guide, please contact GSFC Code 450. The GSFC Code 450 web page can be found at http://esc.gsfc.nasa.gov/.

1.3 Document Organization

This document is organized as shown in Table 1-1.

Table 1-1. Document Organization

Section/ Appendix	Title	Purpose
1	Introduction	Provides an introduction to the SN Users' Guide. Describes the purpose, scope, and organization of the document, and provides the list of reference documents.
2	SN Overview	Describes the SN and non-SN elements that provide support during SN operations, and describes the interfaces between the SN and the customer.
3	Service Available to Customers	Briefly describes the various services available to SN customers.
4	Obtaining SN Services	Describes the process for obtaining SN services.
5	MA Telecommunications Services	Describes the Multiple Access (MA) telecommunications services available to SN customers.
6	SSA Telecommunications Services	Describes the S-band Single Access (SSA) telecommunications services available to SN customers.
7	KuSA Telecommunications Services	Describes the Ku-band Single Access (KuSA) telecommunications services available to SN customers.
8	KaSA Telecommunications Services	Describes the Ka-band Single Access (KaSA) telecommunications services available to SN customers.
9	Tracking and Clock Calibration Services	Describes the tracking and clock calibration services available to customers for MA, SSA, and KuSA telecommunications services.

Table 1-1. Document Organization (cont'd)

Section/ Appendix	Title	Purpose
10	SN Operations for Tracking and Data Relay Satellite System (TDRSS) Services	Provides a general description of scheduling operations, real-time operations, and customer platform emergency operations.
A	Example Link Calculations	Contains example link calculations for SN telecommunications services.
B	Functional Configurations for TDRSS Forward and Return Services with Emphasis on Customers' Data Phase and Data Channel Ambiguity Resolution	Provides data communication functional configurations for TDRSS telecommunications services; and for these functional configurations, identifies the conditions under which either a data phase ambiguity or a data channel ambiguity may exist at the SN/customer data interface.
C	Operational Aspects of Signal and Autotrack Acquisition	Details the operational aspects associated with acquisition.
D	Spectrum Considerations	Describes some of the applicable treaty agreements on spectrum usage relevant to space missions utilizing the SN.
E	Customer Platform and Tracking and Data Relay Satellite (TDRS) Signal Parameters Definition	Contains the definitions of parameters applicable to the transmitted signal, where the forward definitions describe the signal characteristics from the TDRS spacecraft and the return definitions describe the signal characteristics from the customer platform.
F	Periodic Convolutional Interleaving with a Cover Sequence for Synchronization	Describes Periodic Convolutional Interleaving (PCI).
G	Predicted Performance Degradations Due to Radio Frequency Interference (RFI)	Describes the possible degradation to SN telecommunications services caused by RFI.
H	Demand Access System (DAS)	Describes the TDRSS MA Return (MAR) DAS capability.

Table 1-1. Document Organization (cont'd)

Section/ Appendix	Title	Purpose
I	NASA Integrated Services Network (NISN) Services	Describes the networked data services provided by the Communications Service Office's (CSO) NISN.
J	Expendable Launch Vehicle (ELV) Customer Constraints	Describes the customer constraint requirements for the S-band ELV class of SN customers.
K	Use of Reed-Solomon Coding in Conjunction with SN Customer Services	Describes the use of Reed-Solomon (R-S) coding in conjunction with the SN customer services.
L	McMurdo TDRSS Relay System (MTRS)	Describes the support available through the MTRS capability.
M	Deleted	Deleted.
N	Network Test Services	Summarizes the methodology, configurations, resources, responsibilities, and planning activities for SN testing services.
O	Self/Mutual Interference Considerations for New Customers at 2287.5 MHz	Provides an assessment of self-interference in the SN MA environment at 2287.5 MHz.
P	Space Network Access System (SNAS)	Describes the secure network-based graphical user interface (GUI) to the Network Control Center (NCC) Data System (NCCDS) and DAS to perform SN customer scheduling, real-time service monitoring and control, and state vector storage.
Q	White Sands Complex (WSC) Transmission Control Protocol (TCP)/Internet Protocol (IP) Data Interface Service Capability (WDISC) System	Describes the capabilities provided through the WDISC System for customer data interface.
R	WSC SN Gateway System	Describes the capabilities provided through the SN Gateway system for customer data interface.

S	SN Future Services	Describes future SN customer services introduced by the Space Network Ground Segment Sustainment (SGSS) Project expected to be completed by mid-2016.
T	User Spacecraft Clock Correlation System (USCCS)	Describes an overview of USCCS.
U	Recommended Customer Phase Noise Performance for Doppler Tracking Services	Provides recommended customer phase noise performance for Doppler tracking services.

1.4 Reference Documents

This section lists the specifications, standards, and other documents which serve as references. The most recent version of these documents should be referenced.

1. Requirements Specification for the White Sands Complex, Revision 2; 452-RSD-WSC
2. White Sands Complex (WSC) Ground Terminal Requirements for the TDRS H,I,J Era, 405-TDRS-RP-SY-011.
3. Space Network System Requirements Document, 452-SRD-SN.
4. User Spacecraft Clock Calibration System (USCCS) Users' Guide (UG), 452-UG-USCCS.
5. Near Earth Network Users' Guide (NENUG), 453-NENUG.
6. Space Network Radio Frequency Simulation Operation Control Test Systems Specifications, 450-SPEC-RFSOC.
7. Space and Near Earth Networks Compatibility Test Systems Specifications, 450-SPEC-CTA.
8. RF Compatibility Test Procedures Between Spacecraft and the Space Network and/or Near Earth Network Document, 450-PROC-CTP/SN/NEN.
9. Space Network Interoperable PN Code Libraries, 451-PN Code-SNIP.
10. Communications Link Analysis and Simulation System (CLASS) ACRS/TLAS Operator's Manual and Reference, NCC 98.
11. The Automated Conflict Resolution System and TDRSS Look Angle System, 452-PRES-ACRS/TLAS.
12. Interface Control Document Between the Space Network and Customers for Service Management, 452-ICD-SN/CSM. (formerly 451-ICD-NCCDS/MOC).

13. Interface Control Document (ICD) between the Network Control Center Data System (NCCDS) and the White Sands Complex (WSC), 452-ICD-NCCDS-WSC.
14. Interface Control Document (ICD) Between the Space Network and the Flight Dynamics Facility (FDF), 452-ICD-SN/FDF.
15. POCC Capabilities Document, Volume II, MCC/Remote POCC Interface Capabilities Description, JSC-14433.
16. NASCOM Interface Standard for Digital Data Transmission (NISDDT), 542-003.
17. Performance and Design Requirements and Specification for the Fourth Generation TDRSS User Transponder, 531-RSD-IVGXPDR.
18. NASA Integrated Services Network (NISN) Services Document, NISN/001-001.
19. Interface Control Document Between the Space Network (SN) and the NASA Integrated Services Network, 452-ICD-SN/NISN.
20. NASA Space Flight Program and Project Management Requirements, NPR 7120.5.
21. Network Requirements Document (NRD) Process, 450.1-WI-1310.1.8.
22. Networks Integration Process, 450-PG-1310.1.1.
23. Engineering Peer Reviews, GPR 8700.6.
24. White Sands Complex (WSC)/Data Services Management Center (DSMC) Operations Interface Procedure, 450-OIP-WSC/DSMC.
25. Space Network (SN) Access System (SNAS) MOC Client Software Users Guide, 452-UG-SNAS.
26. Interface Control Document Between Demand Access System (DAS) and the SN Access System (SNAS) ,452-ICD-DAS/SNAS.
27. Space Network Access System Operations Concept Document, 452-OCD-SNAS.DCN003.
28. Security of Information Technology, NPR 2810.1.
29. IONet Security Plan, 290-003.
30. TDRSS Constellation Management Plan, 452-PLAN-0002.
31. IP Operational Network (IONet) Access Protection Policy and Requirements, 290-004.

1.5 Reference Web Sites

Web sites that have been used as reference for these documents and throughout the SNUG are listed in Table 1-2.

Many of the links require access to the Next Generation Integrated Network (NGIN) website. The URL for NGIN is https://code450ngin.gsfc.nasa.gov/. Access to NGIN may be obtained by requesting an ID and password through IDMax / Network Advisory Messages (NAMs) https://idmax.nasa.gov/idm/user/login.jsp.

Table 1-2. Reference Web Sites

URL	Web Site Description
https://code450ngin.gsfc.nasa.gov/	Requirements Specification for the White Sands Complex, Revision 2, 452-RSD-WSC
https://code450ngin.gsfc.nasa.gov/	Space Network System Requirements Document, 452-SRD-SN
https://code450ngin.gsfc.nasa.gov/	The Automated Conflict Resolution System and TDRSS Look Angle System, 452-PRES-ACRS/TLAS
https://code450ngin.gsfc.nasa.gov/	Interface Control Document Between the Space Network and Customers for Service Management, 452-ICD-SN/CSM (formerly 451-ICD-NCCDS/MOC)
https://code450ngin.gsfc.nasa.gov/	Interface Control Document (ICD) between the Network Control Center Data System (NCCDS) and the White Sands Complex (WSC), 452-ICD-NCCDS- WSC
https://code450ngin.gsfc.nasa.gov/	Interface Control Document (ICD) Between the Space Network (SN) and the Flight Dynamics Facility (FDF), 452-ICD-SN/FDF
https://code450ngin.gsfc.nasa.gov/	Interface Control Document Between the Space Network (SN) and the NASA Integrated Services Network (NISN), 452-ICD-SN/NISN

https://code450ngin.gsfc.nasa.gov/	White Sands Complex (WSC)/Data Services Management Center (DSMC) Operations Interface Procedure, 450-OIP-WSC/DSMC
https://code450ngin.gsfc.nasa.gov/	Space Network Access System Operations Concept Document, 452-OCD-SNAS.DCN003
http://esc.gsfc.nasa.gov	“What’s New” web page from the Space Network Online Information Center Homepage
http://fdf.gsfc.nasa.gov/	Flight Dynamics Facility (FDF) Product Center web page
https://cds02.gsfc.nasa.gov/	Network Advisory Message Page
https://code450ngin.gsfc.nasa.gov/	User Spacecraft Clock Calibration System (USCCS) Users’ Guide
http://esc.gsfc.nasa.gov	Return Data Delay web page
http://classwww.gsfc.nasa.gov/GSAMS/	GSFC Spectrum Allocation and Management Site
http://www.ntia.doc.gov/osmhome/osmhome.html	National Telecommunications and Information Agency (NTIA) regulations
http://public.ccsds.org/publications/archive/401x0b09s.pdf	CCSDS 401.0-B Blue Handbook on RF Frequency and Modulation Systems, Part 1, Earth Stations
http://cnts.gsfc.nasa.gov/snas/pages/indexMain.jsp	Space Network Access System web page

http://www.nisn.nasa.gov/DOCUMENTS1/IONet_Access_Policy_Rev3.doc	Internet Protocol Operational Network (IONet) Access Protection Policy and Requirements
http://www.ccsds.org	Consultative Committee for Space Data Systems (CCSDS)
http://www.nisn.nasa.gov	CSO/NISN Homepage

Section 2. SN Overview

2.1 General

The purpose of this section is to provide a description of the interfaces between the customer and the SN, and an overview of the SN and non-SN elements that provide support during SN operations.

2.2 Customer Interfaces with the SN

There are three types of interfaces between the customer and the SN: the Customer Commitment Interface, the RF Interface, and the Operations Interface.

2.2.1 Customer Commitment Interface

The Customer Commitment Interface is the interface between the customer and the GSFC Networks Integration Management Office (NIMO) through which the customer requests SN services. The process for obtaining SN services is described in Section 4.

2.2.2 RF Interface

The RF Interface is the two-way interface between the customer platform and the SN, as shown in Figure 2-1. This interface provides for the transmission of RF signals between the customer platform and the SN. These signals are described in detail in Sections 5 through 8 for SN telecommunications services and in Section 9 for the SN tracking service.

2.2.3 Operations Interface

The Operations Interface is the two-way interface between the customer ground facilities and the SN, as shown in Figure 2-1. This interface provides for the scheduling of SN support and the conduct of real-time SN operations. All aspects of this interface, with the exception of tracking measurements, are described in Section 10. Details regarding tracking measurements are provided in Section 9.

2.3 Elements of the SN

The SN is operated under the control of GSFC Code 450 with the objective of providing tracking and data relay services to customer missions. The SN consists of a space segment and a ground segment. The space segment consists of a constellation of TDRSs. This TDRS constellation is divided as follows:

a. First generation TDRS: Flight 1 (F1) through Flight 7 (F7) – note that F1 and F4 have been retired from service and F2 was destroyed during launch.

b. Second generation TDRS: Flight 8 (F8) through Flight 10 (F10).

c. Third generation TDRS: TDRS K, TDRS L, and TDRS M to be launched as TDRS Flight 11 (F11), TDRS Flight 12 (F12), and TDRS Flight 13 (F13) in 2012, 2013, and 2016, respectively.

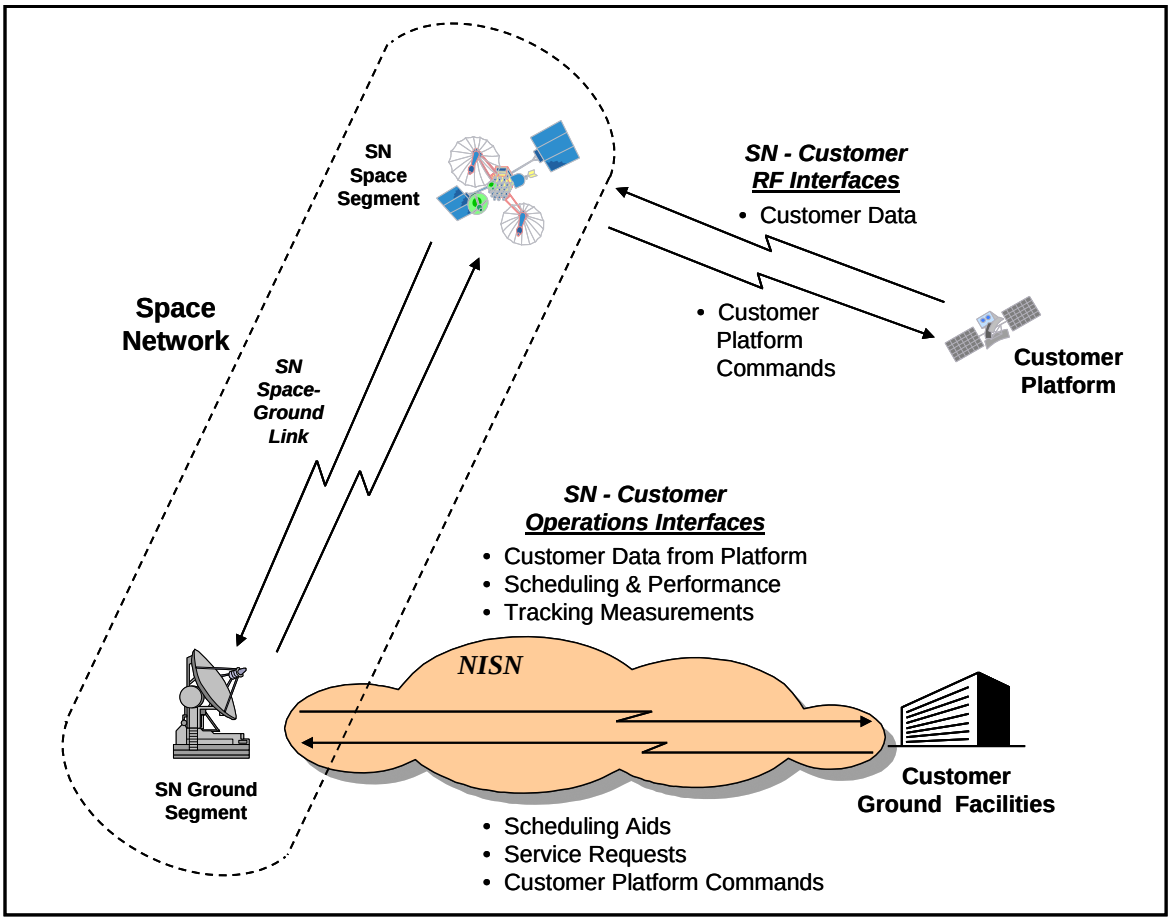


Figure 2-1. SN – Customer RF and Operations Interfaces

NOTE:

The F8 spacecraft is unavailable for normal customer scheduling.

The ground segment consists of WSC, the Guam Remote Ground Terminal (GRGT), the Bilateration Ranging Transponder System (BRTS), Contingency S-Band Tracking, Telemetry and Command (TT&C) sites (Australian TDRSS Facility (ATF) and Canberra), the NCCDS, and the Network Integration Center (NIC). WSC, GRGT, BRTS, and the NCCDS are dedicated to SN operations only, but the NIC is shared with another NASA element, the Near Earth Network (NEN).

The combination of the WSC, the GRGT and the TDRS constellation is also known as the Tracking and Data Relay Satellite System (TDRSS). The SN elements and interfaces are shown in Figure 2-2 and described in paragraphs 2.3.1 and 2.3.2 below.

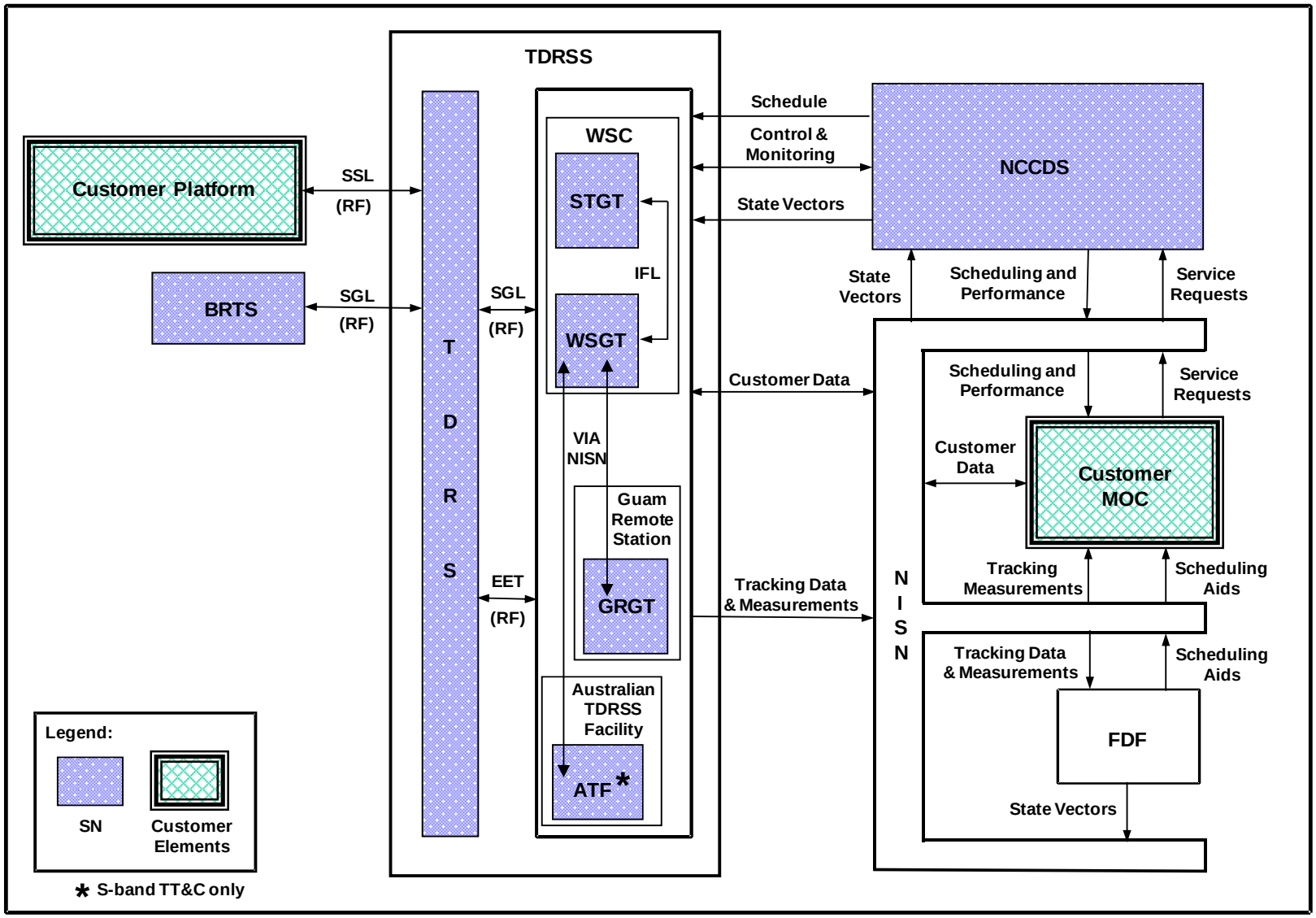


Figure 2-2. SN Elements and Interfaces

The procurement of TDRS-K, L, M spacecraft was initiated in August 2006 by letter from the Deputy Associate Administrator, Space Communications and Navigation Office, Office of Space Operations, to NASA GSFC. The TDRS K, L, M spacecraft (third generation TDRS) are to be the functional, performance, and operational equivalent of TDRS HIJ (F8-F10) for Single Access Services (S, Ku and Ka-bands) and better than first generation (TDRS 1-TDRS 7) for ground based beam-formed MA Return Services. The third generation TDRS MA Return antenna element specifications and MA ensemble return channel specifications are such that the MA Return formed beam G/T should be degraded by no more than 1 dB from second generation TDRS (TDRS HIJ) performance allowing for fewer return elements and ground beam-forming. The dual frequency TT&C for collocation of spacecraft is also retained.

The SN ground terminal upgrades for the TDRS K, L, M spacecraft include installation of Ka-band End-to-End Test (EET) terminals, new MA return service ground-based beamformers and retention of a compatible digital element interface to the DAS.

TDRS-K is scheduled to be launched in 2012, TDRS L is scheduled to be launched in 2013, and TDRS M is scheduled to be launched in 2016. Ground terminal upgrades are to be completed prior to TDRS K, L, M launch.

NOTE:

The SNUG reflects performance characteristics that may differ from those specified in TDRS Spacecraft and Ground Terminal Specifications. As TDRS K, L, M on-orbit performance data becomes available, the SNUG will be updated, if necessary, to reflect performance across the entire fleet.

2.3.1 Space Segment

The space segment of the SN consists of up to six operational TDRSs in geosynchronous orbit at allocated longitudes for relaying forward and return service signals to and from customers for data transfer and tracking. Additional spare TDRSs may be in geosynchronous orbit. All active first generation TDRSs (F3-F7) carry functionally identical payloads, all second generation TDRSs (F8-F10) carry functionally identical payloads, and all third generation TDRS (K, L, M) carry functionally identical payloads. Figure 2-3 and Figure 2-4 identify the pertinent communications components and associated parameters of the first generation (F1-F7) and second generation (F8-F10) TDRSs, respectively.

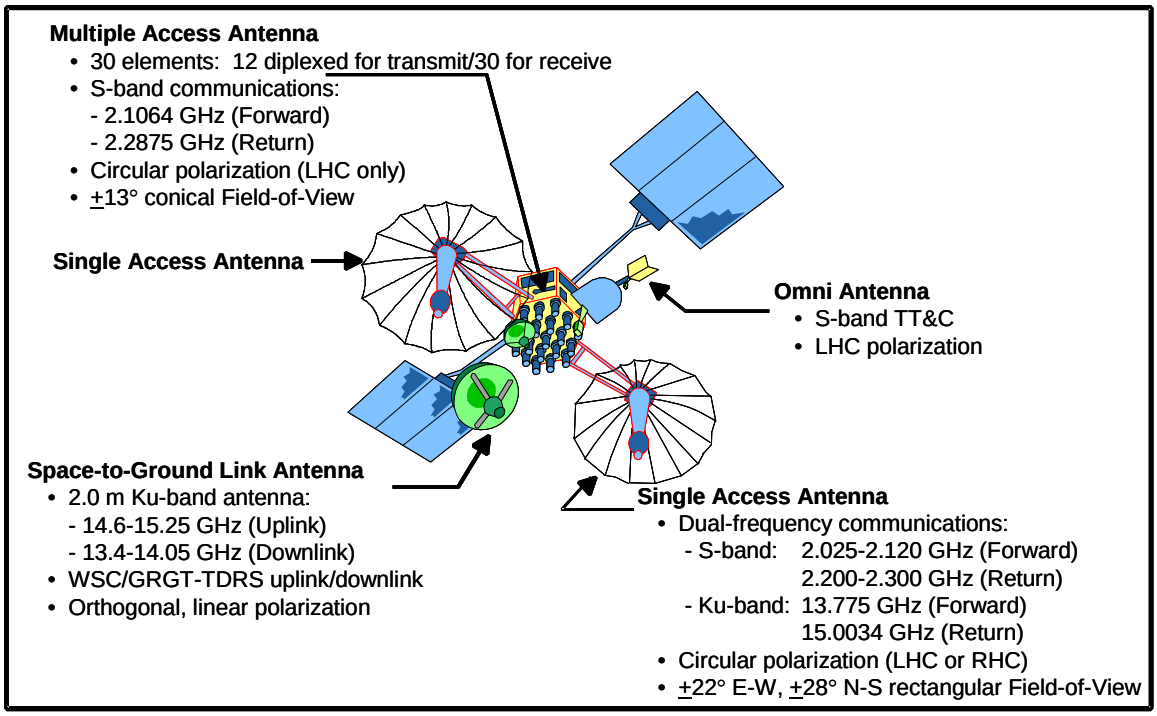


Figure 2-3. First Generation Tracking and Data Relay Satellite (F3-F7)

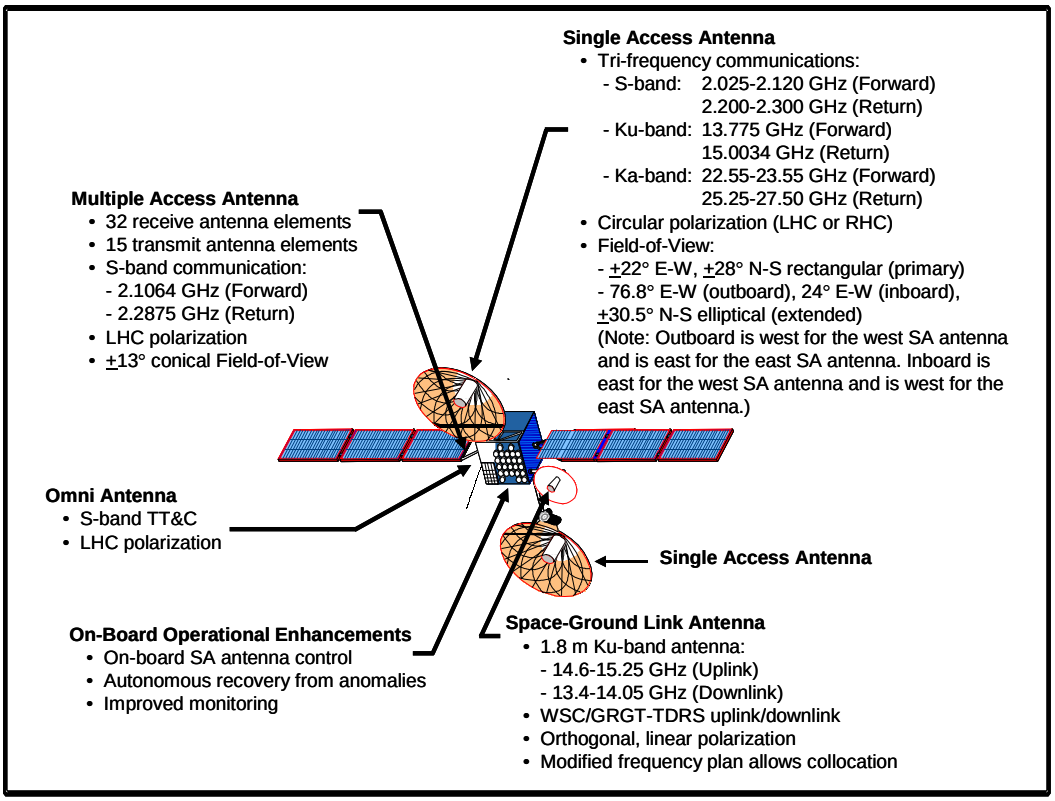


Figure 2-4. Second Generation Tracking and Data Relay Satellite (F8-F10)

2.3.1.1 Change of TDRS Location

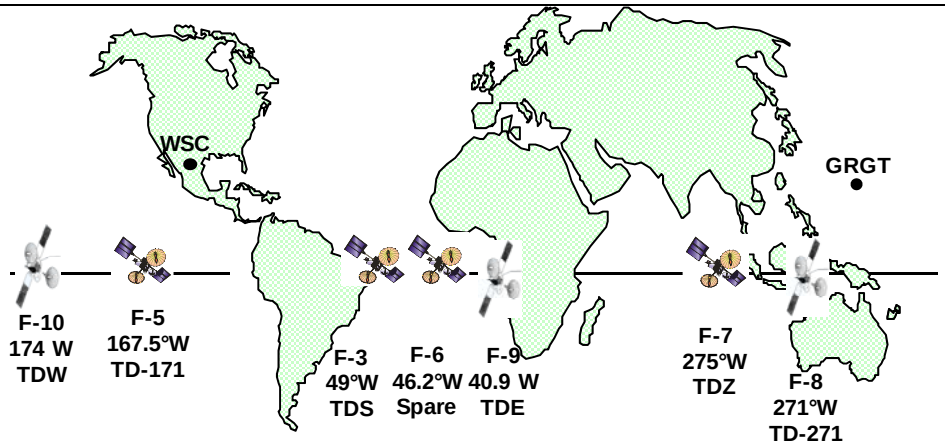
The GSFC Code 450 may change the geosynchronous location of any TDRS to any other geosynchronous location assigned to NASA. SN customers should contact NIMO or SN GSFC Code 452 for the current location of the TDRS spacecraft. Additionally, TDRS constellation information can be found in the TDRS Constellation Management Plan, 452-PLAN-0002.

Table 2-1 provides examples of TDRS constellation configurations. With second and third generation TDRS, up to two spacecraft can be collocated in one longitudinal location. These two spacecraft may be either two second or third-generation TDRSs or one first-generation TDRS and one second or third-generation TDRS. This feature allows the use of two partially failed spacecraft to be collocated in order to conserve orbital slots.

2.3.1.2 TDRS Line-of-Sight Coverage

TDRS line-of-sight coverage depends on customer platform altitude and inclination as well as TDRS geosynchronous longitude, inclination, and field-of-view (FOV). Assuming TDRS located at 41°W, 174°W, and 275°W with a 0° inclination, 100 percent line-of-sight (LOS) global coverage can be provided for:

Table 2-1. Example of TDRS Constellation Configuration



Example of TDRS Constellation – Spring 2012

Example Constellation Plan (note 1)	Geosynchronous Longitudes of First Generation Satellites (TDRSs F3-F7)	Geosynchronous Longitudes of Second Generation Satellites (TDRSs F8-F10) (note 2)
First Generation TDRSs and 3 Second Generation TDRSs	46.2°W (F6) (spare) 49°W (F3) 167.5°W (F5) 275°W (F7)	40.9°W (F9) 174°W (F10) 271°W (F8) (note 3)

Notes:

1. For exact TDRS orbital locations, please contact NIMO or SN GSFC Code 452 for the current location of the TDRS spacecraft. The TDRSS Constellation Management Plan, 452-Plan-002, also provides constellation location information. Additionally, the detailed TDRS spacecraft orbit (including inclination) can be found by referring to the element reports under the view mission products on the Flight Dynamics Facility (FDF) Product Center web page, which can be found at http://fdf.gsfc.nasa.gov/.
2. The TDRS F8-F10 spacecraft have the capability of supporting collocation on-orbit. When collocated, TDRS telecommunications services are provided from: 1) 2 TDRS F8-F10 in the same assigned orbital location (slot) with nodal crossings within 0.1 degrees of the assigned longitude, or 2) 1 TDRS F8-F10 and 1 TDRS F3-F7 in the same assigned orbital location (slot) with nodal crossings within $\pm$ 0.5 degrees of the assigned longitude. All services scheduled for a customer in a single event must be provided by a single TDRS; therefore, collocation may preclude scheduling of certain combinations of services.
3. The F8 spacecraft is unavailable for normal customer scheduling.

a. Customer altitudes between 73 km and 1000 km for the MA and Ku- and Ka-band Single Access (SA) LEO FOV (LEOFOV) limits of ±10.5° (conical) (refer to Figure 2-5 for an example average percent coverage and Sections 5, 7, and 8 for a description of MA, KuSA, and KaSA LEOFOV services)

b. Customer altitudes between approximately 73 km and 3000 km for the MA Primary FOV (PFOV) limits of ±13° (conical) (refer to Figure 2-6 for an example average percent coverage and Section 5 for a description of MA service).

c. Customer altitudes between approximately 73 km and 9000 km for the SA PFOV limits of ±22°E-W and ±28°N-S (refer to Figure 2-7 for an example average percent coverage and Sections 6 through 8 for a description of PFOV SA services). TDRS SA antenna pointing beyond ±13.5°E-W and ±13.5°N-S must be coordinated with GSFC Code 450 due to the potential to significantly impact TDRSS efficiency.

The second and third generation TDRS (F8-F10 and K,L, M) SA antennas have an Extended Elliptical FOV (EEFOV) of 76.8°E-W (outboard), 24°E-W (inboard), and ±30.5°N-S, which will allow for coverage to customers in geosynchronous orbit and above. TDRS SA antenna pointing beyond ±13.5°E-W and ±13.5°N-S must be coordinated with GSFC Code 450 due to the potential to significantly impact TDRSS efficiency.

NOTE:

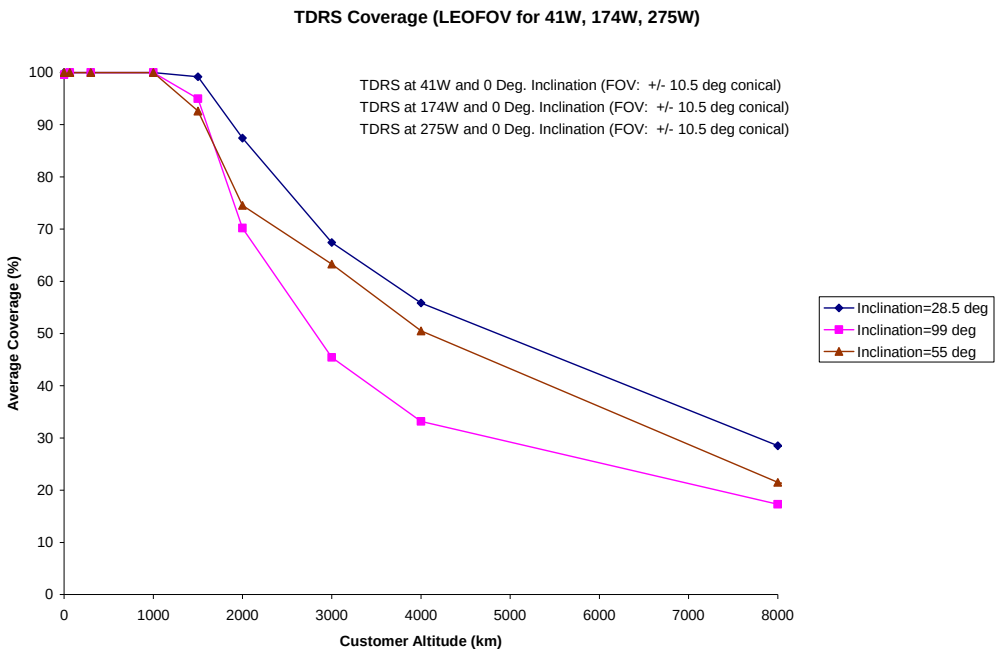
The SN is capable of supporting EEFOV of 76.8 degree E-W (outboard); however, its use must be coordinated with GSFC Code 450.

Figure 2-8 depicts the average percent coverage assuming the SA EEFOV for second and third generation TDRS located at 41°W and 174°W with 0° inclination and the SA PFOV for TDRSs F3-F7 located at 275°W with a 0° inclination. The average percent coverage figures consider only geometric line-of-sight coverage and do not consider other coverage constraints such as flux density restrictions, periods of RFI, customer platform constraints, fleet operation constraints and service limitations, including sun and weather interference, scheduling availability, or mutual interference. In this document, the percent coverage is provided for example and more detailed coverage analysis (refer to Section 3, paragraph 3.5.2) is available for a customer's specific conditions. Please contact the Code 450 Project office if additional coverage analysis is needed.

NOTE:

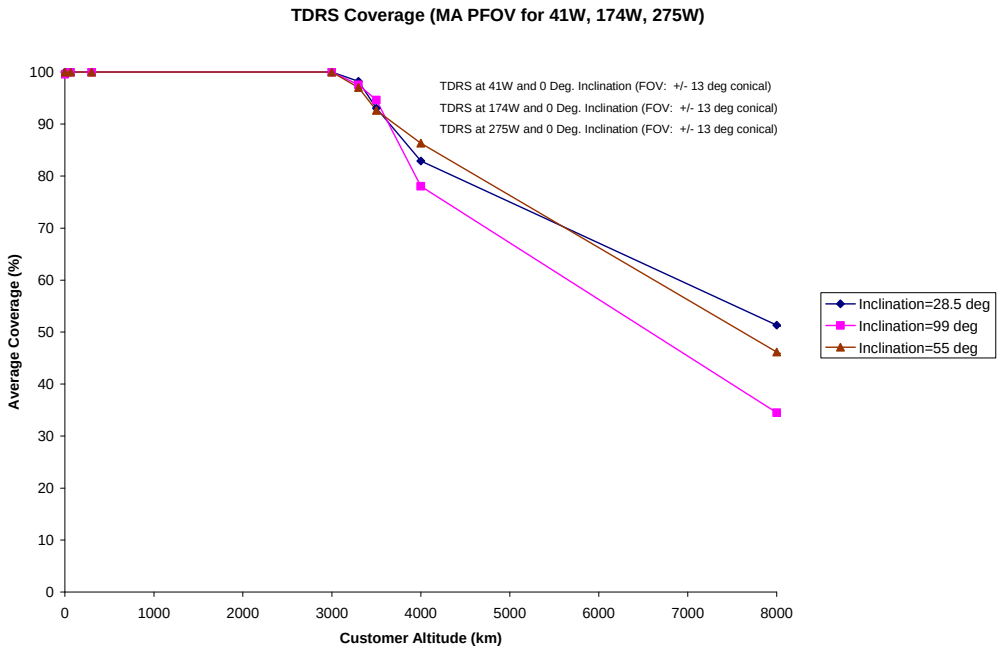
The TDRSs are geosynchronous satellites, which have the same orbit period as a geostationary satellite, but their orbit may be elliptical and inclined. A geosynchronous satellite in an inclined circular orbit moves in a figure-8 pattern as viewed from earth. The TDRSs F3-F7 and F8-F10 maintain nodal crossings to within ± 0.5° of the assigned longitude. In general, the SN does not require stringent north-south station keeping to maintain TDRSS

services. The detailed TDRS spacecraft orbit (including inclination) can be found by referring to the Element Reports under the View Mission Products on the Flight Dynamics Facility (FDF) Product Center web page, which can be found at http://fdf.gsfc.nasa.gov/.



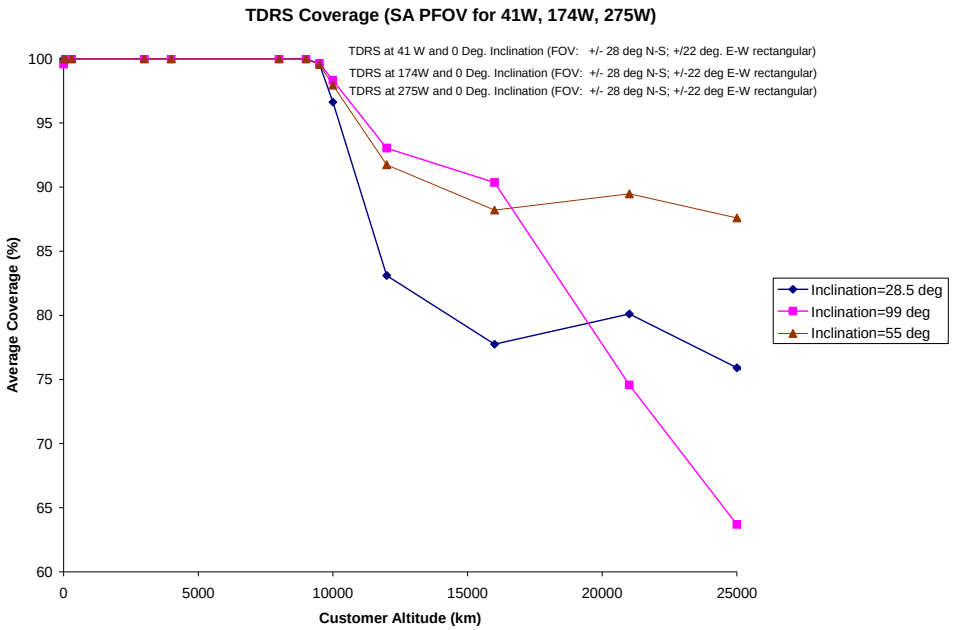
Note: The customer minimum altitude for 100% line-of-sight coverage is 73 km.

Figure 2-5. <u>Example</u> Average Line-of-Sight Coverage for LEOFOV



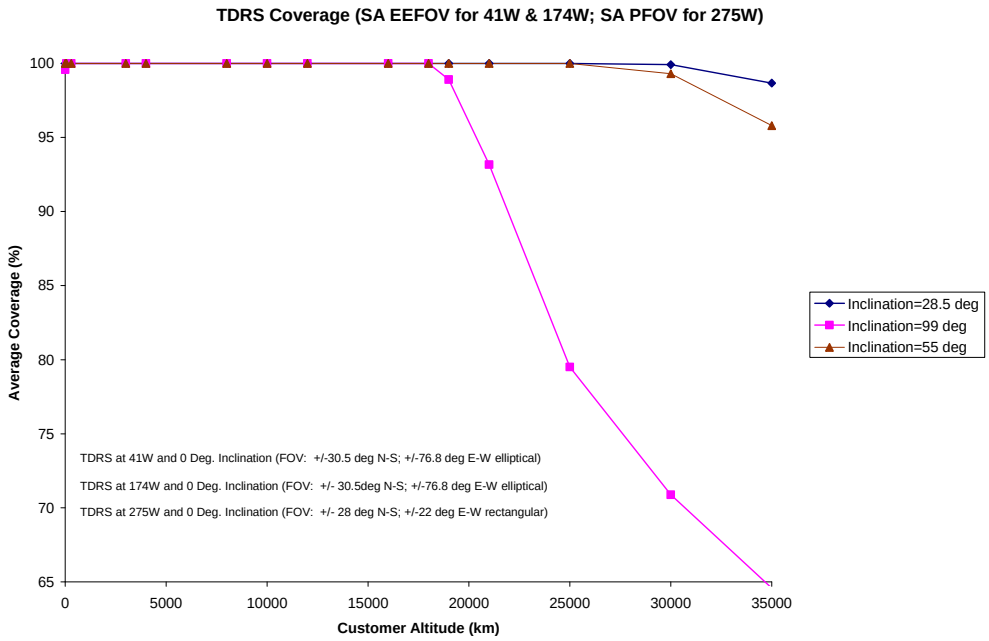
Note: The customer minimum altitude for 100% line-of-sight coverage is 73 km.

Figure 2-6. <u>Example</u> Average Line-of-Sight Coverage for MA PFOV



Note: The customer minimum altitude for 100% line-of-sight coverage is 73 km.

Figure 2-7. <u>Example</u> Average Line-of-Sight Coverage for SA PFOV



Note: The customer minimum altitude for 100% line-of-sight coverage is 73 km.

Figure 2-8. <u>Example</u> Average Line-of-Sight Coverage for SA EEFOV

2.3.2 Ground Segment

2.3.2.1 Dedicated Ground Elements

The majority of SN ground segment elements are dedicated to SN operations only. The SN dedicated ground elements are as follows:

a. Ground Terminals. WSC and GRGT provide the communications equipment necessary for transmitting and receiving data and tracking information relayed via each TDRS. The WSC consists of two ground terminals: the White Sands Ground Terminal (WSGT), and the Second TDRSS Ground Terminal (STGT). The WSGT, STGT, and GRGT are independent ground terminals (except for a consolidated operations control center located at STGT), each containing a number of autonomous Space-Ground Link (SGL) Terminals (SGLTs). WSGT contains two SGLTs, STGT contains three SGLTs, and GRGT contains two SGLTs. GRGT SGLT 7 is not available for SN Customer services. Each SGLT contains the hardware and software required to provide customer telecommunications and tracking services and TT&C functions for the assigned TDRS. SGLT operations are controlled and monitored through the TDRSS Operations Control Center (TOCC) located at STGT. A data link, known as the Interfacility Link (IFL), exists between the WSGT and the STGT for the exchange of operations data, customer data and tracking information. The interface between WSC and GRGT is accomplished by a commercial common carrier provided by the Communications Service Office's (CSO's) NASA Integrated Services Network (NISN). Equipment is available at all three sites to provide the customers with end-to-end system testing capabilities. Additional WSC and GRGT functions include data handling (refer to Section 3, paragraph 3.6).

b. Bilateration Ranging Transponder System (BRTS). The BRTS consists of unmanned and totally automated transponders and provides, in conjunction with the TDRSS and the FDF, metric tracking data for the accurate determination of the ephemerides for each TDRS available for SN Customers. The BRTS transponders are presently located at the WSC, Alice Springs, Ascension Island, and Guam.

c. Network Control Center Data System (NCCDS). Additional elements of the SN ground segment are the SNAS and the NCCDS. Collocated with WSC, the NCCDS schedules most SN elements for customer services. SNAS is a tool resident at WSC with clients at customer MOCs that provides the customer with an interface to the NCCDS for planning, acquisition, control, and status of the SN and their services. The customer obtains SN services by submitting specific schedule requests or establishes generic service requirements. The NCCDS translates customers' requirements into specific events. Upon customer request, the NCCDS provides operational performance information (such as data presence monitoring indicators and data quality monitoring messages) during actual events to determine if conditions exist that would affect data

quality. For further information on the MOC/NCCDS interface, please refer to Section 10 of this document.

NOTE:

The SN Scheduling Office issues Network Advisory Messages (NAM) to provide up-to-date information on network conditions and constraints. NAMs are used to notify affected customers of scheduled system outages so that MOCs can properly plan mission activities. These messages are accessible via the NCCDS active NAM web site at https://cds.gsfc.nasa.gov/. GSFC Code 450 uses the NAMs as a means of letting customers know of any performance constraints associated with the TDRS spacecraft. Additionally, TDRS constellation information can be found in the TDRS Constellation Management Plan, 452-PLAN-0002

d. Australian TDRSS Facility (ATF). The (ATF) provides contingency S-Band TT&C support of a TDRS within the GRGT zone of influence and a capability to drift a TDRS into (or out-of) that zone.

2.3.2.2 Shared Ground Elements

Network Integration Center (NIC). The NIC, which is located at GSFC, Building 13, provides the capability to monitor data, perform testing, and fault isolation services. The NIC provides critical monitoring and fault isolation support for ELV launch/early orbit activities.

2.4 External to the SN Ground Elements

NASA elements not part of the SN that complement and complete SN services are as follows:

a. NASA Integrated Services Network (NISN). NISN is a global system of communications transmission, switching, and terminal facilities that provide NASA with wide area network communications services. NISN services which support the SN include real-time and mission-critical IP routed data as well as high rate data and video services connecting the WSC to NASA Centers. Inter-center mission voice communications services are also provided for management of the network and for the customer's mission. For further information on NISN, refer to Appendix I.

b. Flight Dynamics Facility (FDF). Located at GSFC, the FDF provides services to the SN and NASA-approved customer platform missions for acquisition data generation, orbit determination, and orbit maneuvers. The FDF validates and calibrates the SN tracking data. The FDF also provides schedule guidelines for the BRTS for TDRS tracking and evaluates the BRTS tracking data.

c. RF Simulation Operations Center (RFSOC). The RFSOC, located at GSFC, provides facilities for conducting customer flight project mission simulations for SN customers. It can monitor SN performance during these mission simulations, simulate a mission-unique customer platform, verify SN/customer MOC interfaces, and simulate a customer MOC for fault isolation.

d. Compatibility Test Lab (CTL). Home-based at GSFC, CTL provides the means to test customer platforms at remote locations for RF compatibility with the SN, which may include an end-to-end test after compatibility testing is completed. The CTL can provide portable equipment representing the SN with cabled RF interfaces to a customer platform for local RF compatibility testing. The CTL also can provide a Compatibility Test Van (CTV) with a rooftop antenna or a portable tripod antenna system for TDRSS relay performance tests. Similarly, the GSFC-based CTL can provide RF interfaces to a customer platform for local RF testing and a rooftop antenna for SN performance tests. In this case, the customer brings the platform RF components to the GSFC CTL and these components are set up in an RF-shielded screen room for testing.

e. Near Earth Network (NEN). The NEN consists of NASA ground stations in McMurdo, Antarctica; Wallops Island, Virginia; Svalbard, Norway; the Alaska Satellite Facility (ASF) in Fairbanks; and White Sands, New Mexico. Under contract are commercial operators at Santiago, Chile; Poker Flat, Alaska; South Point, Hawaii; North Pole, Alaska; Dongara, Australia; Hartebeesthoek, South Africa; and Kongsberg Satellite Services at Svalbard, Norway. These stations provide orbital communications services for Near-Earth orbiting customer platforms. The NEN and SN combined were previously referred to as the Spaceflight Tracking and Data Network (STDN).

f. Deep Space Network (DSN). Managed by the Jet Propulsion Laboratory (JPL), Pasadena, CA, the DSN is comprised of ground tracking stations at Canberra, Australia; Goldstone, California; and Madrid, Spain. The DSN stations are used to support a standard mission set and provide emergency services in the event of customer contingency or degraded SN and/or NEN support.

g. McMurdo TDRSS Relay System 2 (MTRS2). The MTRS2 consists of two relay ground systems that are within the National Science Foundation's (NSF) McMurdo facilities in the Antarctic. MTRS2 has the capability to relay up to 300 Mbps to WSC via an assigned TDRS. MTRS2 Upgrade (MTRS2U) is in process to bring the equipment and system into an operational state in preparation for services to the Soil Moisture Active Passive (SMAP) decadal survey mission. For further information on the MTRS2, please refer to Appendix L.

Section 3. Services Available to Customers

3.1 General

The SN along with its supporting elements can provide various services to customers including: telecommunications, tracking, testing, analysis, and data distribution/ processing services.

3.2 Telecommunications Services

Several types of telecommunications services are simultaneously available to customers. The type of telecommunications service selected is determined by the data rate required, duration of service period, and customer platform telecommunications system design. The two primary telecommunications services are termed Multiple Access and Single Access. The MA services are available at S-band and the SA services are available at S-band, Ku-band, and Ka-band (F8-F10 and K, L, M only) frequencies.

The SN can provide any of the following services:

a. A forward service, defined as the communication path that generally originates at the customer control center and is routed through WSC or GRGT to the TDRS to the customer platform.

b. A return service, defined as the communication path that generally originates at the customer platform and is routed through the TDRS to WSC or GRGT back to the customer control center and/or data acquisition location.

c. Both forward and return services simultaneously.

The forward service is typically utilized for customer platform commanding and may include a separate ranging channel for use in tracking services. Forward service data rates are variable depending on the forward service type, which are S-band Multiple Access Forward (MAF) through TDRS F3 – F7, S-band Multiple Access Forward (SMAF) through TDRS F8 – F10 (and K, L, M once launched), S-band Single Access Forward (SSAF), Ku-band Single Access Forward (KuSAF), and Ka-band Single Access Forward (KaSAF) through TDRS F8 – F10 (and K, L, M once launched). Table 3-1 provides an overview of the TDRSS forward service characteristics.

The return service is typically utilized for the return of science data and customer platform status information. The return service consists of up to two channels, which may include a pseudorandom noise (PN) code for use in ranging services and to reduce power flux density. Similar to the forward service, return service data rates are variable depending on the return service type, which are S-band Multiple Access Return (SMAR) through TDRS F3-F7, SMAR through TDRS F8 – F10 (and K, L, M once launched), S-

band Single Access Return (SSAR), Ku-band Single Access Return (KuSAR), and Ka-band Single Access Return (KaSAR) through TDRS F8 – F10 (and K, L, M once launched). Return services are divided into two major groups, Data Group 1 (DG1) and Data Group 2 (DG2). DG1 services utilize spread spectrum modulation while DG2 services are non-spread.

Table 3-1. TDRSS Forward Service Characteristics

	MA (note 10)	SSA (note 10)	KuSA (note 10 and note 11)	KaSA (TDRS F8-F10 and TDRS K, L, M) (note 10)
Customer service links/satellite (note 2)	1	2	2	2/TDRS up to 8/WSC
Space-to-Space Freq. Bands	2106.4 MHz	2025.8-2117.9 MHz (note 6)	13.775 GHz	22.55-23.55 GHz (note 6)
Space-Space Polarization	LHCP only	LHCP and RHCP (selectable) (note 9)	LHCP and RHCP (selectable) (note 9)	LHCP and RHCP (selectable) (note 9)
RF Channel BW (3 dB, minimum)	6 MHz	20 MHz	50 MHz	50 MHz
Max Data Rate	300 kbps	7 Mbps (note 12)	25 Mbps (note 5)	7 Mbps (note 14)
Modulation(notes 1 and 4)	SS-UQPSK/SS-BPSK; data rates ≤300 kbps	SS-UQPSK/SS-BPSK for data rates ≤ 300 kbps BPSK: 300 kbps < dr < 7 Mbps (note 12) PCM/PM for data rates ≤ 1 Mbps PCM/PSK/PM for data rate ≤ 8 kbps	SS-UQPSK/SS-BPSK for data rates ≤300 kbps BPSK: 300 kbps < dr < 25 Mbps	SS-UQPSK/SS-BPSK for data rates ≤300 kbps BPSK: 300 kbps < dr < 25 Mbps
Field of View (max.) (note 3 and 13)	• PFOV: ± 13° conical • LEOFOV: ± 10.5° conical	• PFOV: ± 22° east-west ± 28° north-south • Extended Elliptical (EEFOV) (F8-F10 and K, L, M only): 76.8° east-west (outboard) 24° east-west (inboard) ± 30.5° north-south	• PFOV: ± 22° east-west ± 28° north-south • LEOFOV (F3-F10 and K, L, M): ± 10.5° conical • EEFOV (F8-F10 and K, L, M only): 76.8° east-west (outboard) 24° east-west (inboard) ± 30.5° north-south	• PFOV: ± 22° east-west ± 28° north-south • LEOFOV: ± 10.5° conical
Minimum Forward Link EIRP (note 3)	• PFOV: F3-F7: 34 dBW F8-F10 and K, L, M: 40 dBW • LEOFOV: F3-F7: 34 dBW F8-F10 and K, L, M: 42 dBW	• PFOV and EEFOV (F8-F10 and K, L, M only): Normal: 43.6 dBW High: 46.3 dBW (F3-F7)/ 48.5 dBW (F8-F10 and K, L, M) (note 7)	• PFOV and EEFOV (F8-F10 and K, L, M only): Normal/high autotrack mode: 46.5 dBW/48.5 dBW (notes 7,8) Normal/high program track mode: 40.5 dBW/42.5 dBW (note 7) • LEOFOV (F3-F10 and K, L, M): Normal/high autotrack mode: 46.5 dBW/48.5 dBW (note 7) Normal/high program track mode: 44.0 dBW/46 dBW (note 7)	• PFOV: Autotrack: 63.0 dBW Program track: 56.2 dBW • LEOFOV: Autotrack: 63.0 dBW Program track: 59.5 dBW

Table 3-1. TDRSS Forward Service Characteristics (cont'd)

Notes:

1. TDRSS spacecraft are capable of bent-pipe operation to support user defined (non-TDRSS) signal formats. Non-TDRSS signal formats may require the addition of ground terminal modulation/demodulation equipment. Precise performance will have to be handled on a case-by-case basis.
2. Ku and Ka-band forward services cannot be supported simultaneously through the same SA antenna. Ka-band services are not supported through GRGT.
3. For a thorough description of the service performance and additional constraints for the various FOVs, please see Sections 5 through 8 for MA, SSA, KuSA, and KaSA services.
4. Modulation:
    a. Spread Spectrum Unbalanced Quadriphase Shift Keying (SS-UQPSK) can be scheduled for data rates ≤ 300 kbps: the I channel contains the command data and is modulo-2 added to a 3 Mcps PN code and Q channel is a 3 Mcps PN code. I channel/Q channel power ratio is not balanced.
    b. Spread Spectrum Binary Phase Shift Keying (SS-BPSK) can be scheduled for data rates ≤ 300 kbps: Single channel contains the command data and is modulo-2 added to a 3 Mcps PN code.
    c. BPSK can be scheduled for data rates above 300 kbps: Single channel contains the command data.
    d. Phase Modulation (PM) can be scheduled, either direct carrier PM or subcarrier Phase Shift Keying (PSK).
5. Current GRGT SGLT-6 software limitations constrain the KuSAF data rate to 7 Mbps or less.
6. For specific center frequency assignments, please coordinate with GSFC Code 450 and your associated spectrum management office.
7. Use of the high power mode is restricted, and must be coordinated with GSFC Code 450 prior to use.
8. KuSAF EEFOV autotrack support shall be coordinated through GSFC Code 450.
9. The forward and return polarization for each band must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.
10. The F8 spacecraft is unavailable for normal customer scheduling.
11. NTIA and NASA policy does not permit use of the KuSAF service for customers other than ISS. If such support is essential, the SN should be notified and the NASA GSFC spectrum manager may request a waiver.
12. The NTIA will not grant TDRSS customers an S-band forward service frequency allocation greater than 6 MHz. If a frequency allocation greater than 6 MHz is required, the SN should be notified and the NASA GSFC spectrum manager may petition the NTIA for a temporary waiver.
13. TDRS SA antenna pointing beyond ±13.5°E-W and ±13.5°N-S must be coordinated with GSFC Code 450 due to the potential to significantly impact TDRSS efficiency.
14. Current WSC/GRGT is capable of 25 Mbps with changes.

Table 3-2 provides an overview of the TDRSS return service characteristics. Table 3-3 summarizes the differences between the SN data group and modes used for return service operations.

Each TDRS providing customer services is assigned a SGLT. The assigned SGLT performs both TT&C functions and customer telecommunications and tracking functions in support of TDRS operations. However, not all SGLTs possess the same telecommunications service capabilities. Figure 3-1 provides an overview of customer services available through each SGLT.

3.2.1 MA Service Overview

MA (also referred to as S-band Multiple Access (SMA) for TDRS F8 – F10 and K, L, M) forward and return services operate at fixed S-band frequencies (nominally 2106.4 MHz forward and 2287.5 MHz return) and polarization (Left-Hand Circular (LHC)). Forward service operations are time-shared among TDRS customers where one customer is supported per TDRS at a time. The TDRS F3 – F7 and K, L, M MA return service is provided by an on-board 30 element phased array antenna in conjunction with beamforming equipment located in the ground station. The TDRS F8 – F10 SMA return service is provided by an array of 32 elements in conjunction with TDRS on-board beamforming. The arrays on all generations of TDRSs allow for spatial discrimination due to the phase differential of the customer signal received at each spaced antenna element on the TDRS. The standard network MA services through all generations of TDRS are one forward and five return services per TDRS. The number of TDRS F3 – F7 and K, L, M MA return services supported by a SGLT is limited by the quantity of ground MA equipment and the level of self-interference among customers. The SN DAS allows expansion of the TDRSS F3 – F7 and K, L, M MAR DG1 mode 2 services well beyond the standard number of return services per TDRS/SGLT. For further information on DAS, refer to Appendix H.

NOTE:

> Unless denoted by the TDRS fleet, the term MA is used throughout this document to denote MA services through all generations of TDRS. If the term SMA is used, these capabilities are specific to TDRS F8 – F10 and K, L, M.

3.2.2 SA Service Overview

SA services available through each TDRS SA antenna are: SSAF, SSAR, KuSAF, KuSAR, KaSAF (F8-F10 and K, L, M only), and KaSAR (F8-F10 and K, L, M only). Each TDRS SA antenna has one polarizer (either Left-Hand Circular or Right-Hand Circular (RHC)) for each TDRS frequency band. The forward and return polarization for each band must be the same in order to obtain simultaneous forward and return services through the same SA antenna.

The SN can simultaneously support S-band and K-band (either Ku-band or Ka-band (F8-F10 and K, L, M only)) forward and/or return services through one SA antenna to the same ephemeris. Simultaneous Ku-band and Ka-band services through one SA antenna are not supported.

Table 3-2. TDRSS Return Service Characteristics

	MA (note 6) (note 13)	SSA (note 13)	KuSA (note 13)	KaSA (TDRS F8-F10 and TDRS K, L, M) (note 13)
Customer service links/satellite (notes 2 and 5)	5/TDRS up to 20/WSC 2/TDRS through GRGT	2	2	2/TDRS up to 8/WSC
Space-to-Space Freq. Bands	2287.5 MHz	2200-2300 MHz (note 7)	15.0034 GHz	25.25-27.5 GHz (note 7)
Space-Space Polarization	LHCP only	LHCP and RHCP (selectable) (note 10)	LHCP and RHCP (selectable) (note 10)	LHCP and RHCP (selectable) (note 10)
RF Channel BW (3 dB, minimum)	6 MHz	10 MHz (note 14)	225 MHz	225 or 650 MHz (note 4)
Max Total (I+Q) Data Rate	300 kbps (F3-F7) / 3 Mbps (F8-F10 and TDRS K, L, M) (rate ½ coded)	6 Mbps (rate ½ coded) (note 14)	300 Mbps (uncoded) (note 12)	300 Mbps (uncoded) (note 4)
Return FEC Scheme	Rate 1/2 convol. (F3-F7) / Rate 1/2 or 1/3 convol. (F8-F10 and TDRS K, L, M)	Rate 1/2 or 1/3 convol.	Rate 1/2 convol. or uncoded	Rate 1/2 convol. or uncoded
Return Data Group and Mode (note 1)	DG1 modes 1 and 2 (F3-F7) / DG1 and DG2 (F8-F10 and TDRS K, L, M)	DG1 and DG2	DG1 and DG2	DG2
Field of View (max.) (note 3 and 15)	• PFOV: ± 13° conical • LEOFOV: ± 10.5° conical	• PFOV: ± 22° east-west ± 28° north-south • EEFOV (F8-F10 and K, L, M only): 76.8° east-west (outboard) 24° east-west (inboard) ± 30.5° north-south	• PFOV: ± 22° east-west ± 28° north-south • LEOFOV (F3-F10 and K, L, M): ± 10.5° conical • EEFOV (F8-F10 and K, L, M only): 76.8° east-west (outboard) 24° east-west (inboard) ± 30.5° north-south	• PFOV: ± 22° east-west ± 28° north-south • LEOFOV: ± 10.5° conical • EEFOV: 76.8° east-west (outboard) 24° east-west (inboard) ± 30.5° north-south

TDRS G/T (Nadir, minimum) (note 3)	Formed Beam: • PFOV: F3-F7 and K, L, M: 2.2 dB/K F8 (cold)-F10: 3.2 dB/K F8 (hot): -0.2 dB/K (note 9) • LEOFOV: F3-F7 and K, L, M: 3.1 dB/K F8 (cold), F9-F10: 4.5 dB/K F8 (hot): 1.2 dB/K (note 9)	• PFOV: 9.5 dB/K • EEOFOV: F8-F10 and K, L, M: 9.5 dB/K	• PFOV and EEFOV (F8-F10 and K, L, M only): Autotrack: 24.4 dB/K (note 8) Program track: 18.4 dB/K • LEOFOV (F3-F10 and K, L, M): Autotrack: 24.4 dB/K Program Track: 21.9 dB/K	• PFOV and EEFOV: Autotrack: 26.5 dB (notes 8,11) Program track: 19.1 dB/K (PFOV only) • LEOFOV: Autotrack: 26.5 dB (notes 11) Program Track: 23.0 dB/K

Notes:

1. TDRSS spacecraft are capable of bent-pipe operations to support user defined (non-TDRSS) signal formats. Non-TDRSS signal formats may require the addition of ground terminal modulation/demodulation equipment. Precise performance will have to be handled on a case-by-case basis.
2. Ku and Ka-band return services cannot be supported simultaneously through the same SA antenna.
3. For a thorough description of the service performance and additional constraints for the various FOVs and antenna tracking modes, please see Sections 5 through 8 for MA, SSA, KuSA, and KaSA services. The TDRS G/T is a component of the P_{rec} equations provided in Sections 5 through 8. The required P_{rec} values should be used as a guide for determining SN performance.
4. Higher return link data rates are possible through the Ka-band 650 MHz bandwidth automated IF service, which requires customer receive equipment at WSC. Please see Section 8, paragraph 8.3.6 and contact GSFC Code 450 for further information.
5. Guam Remote Ground Terminal (GRGT) SGLT 6 does not currently support a TDRS F8-F10 or TDRS K, L, M spacecraft.
6. The Space Network Demand Access System (DAS) allows expansion of the TDRSS F3-F7 and K, L, M MAR DG1 mode 2 services well beyond the standard number of return services per TDRS/SGLT. For further information on DAS, refer to Appendix H.
7. For specific center frequency assignments, please coordinate with GSFC Code 450 and your associated spectrum management office.
8. KuSAR EEFOV autotrack support and KaSAR EEFOV autotrack support shall be coordinated through GSFC Code 450.
9. The F8 spacecraft has SMA return G/T performance variation due to an MA element array and sunshield proximity problem. The G/T varies based upon the normal daily TDRS diurnal cycle. The hot periods can be predicted and will occur at regular intervals with a total hot period of less than 12 hours/day. Note that F8 is unavailable for customer scheduling.
10. The forward and return polarization for each band must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.
11. Autotrack service is not available through the Ka-band 650 MHz bandwidth IF service.
12. GRGT support of KuSA return data rates in excess of 150 Mbps should be discussed with GSFC Code 450.
13. The F8 spacecraft is unavailable for normal customer scheduling.
14. The NTIA will not grant TDRSS customers an S-band return service frequency allocation greater than 6 MHz. If a frequency allocation greater than 6 MHz is required, the SN should be notified and the NASA GSFC spectrum manager may petition the NTIA for a temporary waiver.
15. TDRS SA antenna pointing beyond ±13.5°E-W and ±13.5°N-S must be coordinated with GSFC Code 450 due to the potential to significantly impact TDRSS efficiency.

Table 3-3. Return Link Data Group and Mode Description

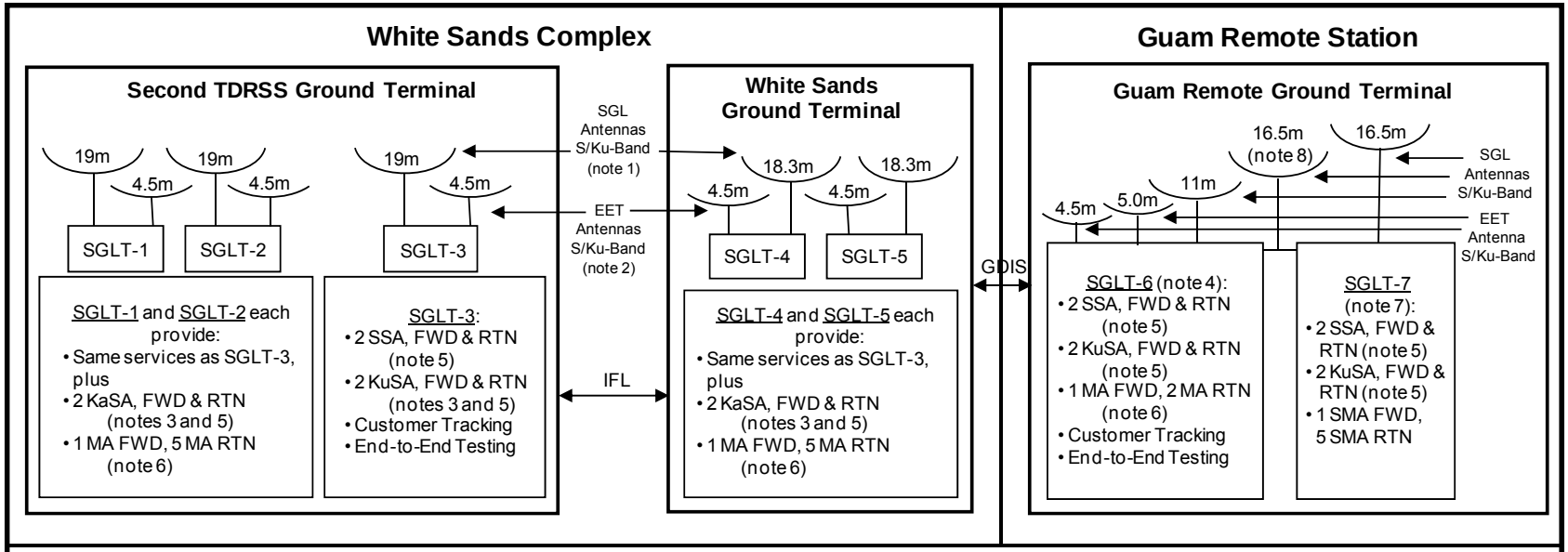
Data Group and Mode (note 4)	Doppler Measurements			Range and Time Transfer Measure-ments (note 2)	3 Mcps PN code added asynchronously to channel symbol stream	Baud Rate Transmission
	1-way Return	1-way Forward (note 5)	2-way (note 1)			
DG1 mode 1		✓	✓	✓	I and Q	I: Low rate (≤ 300 ksps MA, SSA, KuSA) Q: Low rate (≤ 300 ksps MA, SSA, KuSA)
DG1 mode 2	✓	✓			I and Q	I: Low rate (≤ 300 ksps MA, SSA, KuSA) Q: Low rate (≤ 300 ksps MA, SSA, KuSA)
DG1 mode 3		✓	✓	✓	I only	I: Low rate (≤ 300 ksps SMA F8-F10 and K, L, M, SSA) Q: up to High rate (≤ 3 Msps SMA F8-F10 and K, L, M; ≤ 6 Msps SSA (note 6))
DG2 coherent		✓	✓		None	I: up to High rate (≤ 3 Msps SMA F8-F10 and K, L, M; ≤ 6 Msps SSA (note 6); ≤ 300 Msps Ku/KaSA) Q: up to High rate (≤ 3 Msps SMA F8-F10 and K, L, M; ≤ 6 Msps SSA (note 6); ≤ 300 Msps Ku/KaSA (note 3)
DG2 noncoherent	✓	✓			None	

Notes:

1. Requires that the customer transponder coherently turns around the received forward service carrier.
2. Requires that the customer transponder coherently turns around the PN code epoch received in the forward service range channel.
3. TDRS F8-F10 and K, L, M support KaSA forward and return DG2 noncoherent services. Tracking services are not available through KaSA service. Higher KaSA return link symbol rates are possible through the Ka-band 650 MHz bandwidth automated IF service, which requires customer receive equipment at WSC.
4. Return channel time delay (RCTD) is available for all return link data groups and modes for 4800-bit block customers.
5. Requires customer receiver capability to measure Doppler on forward carrier. Additionally, Doppler compensation must be disabled.
6. The NTIA will not grant TDRSS customers an S-band return service frequency allocation greater than 6 MHz. If a frequency allocation greater than 6 MHz is required, the SN should be notified and the NASA GSFC spectrum manager may petition the NTIA for a temporary waiver.

3.2.2.1 Virtual Customer Platforms

It is normally impossible for two customer platforms to use the same SA antenna at the same time. However if a single customer MOC operates two platforms that dock while on-orbit or that otherwise maintain a close physical relationship while on-orbit, it may be possible for both of these platforms to use the same SA antenna at the same time. This can be done by defining a virtual customer platform with the S-band characteristics of one of the real platforms and the K-band (Ku or Ka) characteristics of the other. Data for this virtual platform can be entered into the NCCDS database in the same manner as is data for any other platform. After the database is established, the MOC's interaction with the SN for the virtual customer platform is the same as for a real platform and SN operations proceed normally. This approach allows both of these



Notes:

1. The WSGT SGL antennas support Ku-band operations only.
2. The TDRS K, L, M WSC upgrades will implement two Ka-band End-to-End (EET) terminals. The TDRS K, L, M WSC upgrades are expected to be completed by 2012.
3. Each TDRS F8-F10 and K, L, M supports either KuSA or KaSA services through each SA at a time.
4. There is no requirement to support TDRS F8-F10 or K, L, M through GRGT SGLT-6. The 5.0m EET antenna is provided for redundancy.
5. The SN can simultaneously support S-band and K-band (either Ku or Ka for F8-F10 and K, L, M) forward and/or return services through one SA antenna to the same ephemeris.
6. The SN DAS allows expansion of the TDRSS F3-F7 and K, L, M MAR DG1 mode 2 services well beyond the standard number of return services per TDRS/SGLT.
7. There is no requirement to support TDRS F3-F7 through GRGT SGLT-7. GRGT SGLT-7 is not available for SN Customer services (dedicated set of Customers only).
8. The 16.5m SGL antenna is provided for redundancy for both GRGT SGLT-6 and GRGT SGLT-7.

Figure 3-1. Telecommunications Services for each SGLT

platforms to have SA support on one of a TDRS's SA antennas while leaving the other SA antenna available for other users. Use of this approach is encouraged whenever feasible.

For the virtual customer platform concept to be viable, the differences between the vectors for the two real platforms should be small. Either the customer MOC or the FDF must provide the NCCDS with improved interrange vectors (IIRVs) for the virtual platforms. The IIRVs for the virtual platforms can be copies of the IIRVs for either of the two real platforms. Considering the differences in antenna beamwidth between S-band and Ku- or Ka-band, it is recommended that the IIRVs be provided based upon the Ku- or Ka-band real platform.

Two virtual customer platforms can be defined for a pair of real platforms. One of the virtual customer platforms is defined to have the S-band characteristics of the first real platform and the K-band characteristics of the second real platform. The other virtual customer platform complements the first, and is defined to have the K-band characteristics of the first real platform and the S-band characteristics of the second real platform.

3.2.3 Cross-Support Service Overview

Any customer platform that is compatible with MA service can use forward or return support from either the TDRSS MA or the TDRSS SSA services. When the forward and return services are supplied by different TDRSS telecommunications services (e.g., MA forward and SSA return), the configuration is called a cross-support service.

3.3 Tracking and Clock Calibration Services

The SN provides tracking and clock calibration measurements for MA, SSA, and KuSA customers, as well as SSA/MA cross-support customers. Note that the SN does not provide these services for KaSA customers. Table 3-3 describes the tracking and clock calibration services available for each return link data group and mode.

a. Range. Range measurements may be provided when the customer is configured to transmit a PN code on the return link with the epoch synchronized to the epoch of the PN code received on the forward link range channel.

b. Doppler. Two-way Doppler measurements may be provided when the customer is configured such that the return link carrier is coherently related to the received forward link carrier. One-way return Doppler measurements may be provided when the return link carrier is not coherently related to a forward link carrier.

c. Customer Time Transfer. The time transfer function requires that the customer transponder coherently turns around the PN code epoch received in the forward service range channel. The time transfer function provides a method to acquire the data necessary to update a customer platform clock. It gives the customer MOC the ability to determine the time difference between the on-board platform clock and Universal Time Coordinated (UTC). To facilitate the time transfer measurement, the customer must cause the platform to note and store the

platform clock reading at the time of arrival of the epoch portion of the PN range code. The clock reading must be included in the platform telemetry for processing by the MOC. It is the MOC's responsibility to make the necessary adjustment to the customer clock using the SN-supplied data.

d. Return Channel Time Delay (RCTD). RCTD measurements, in conjunction with other data delays, enable the customer MOC to calculate the time onboard the customer platform. RCTD measures the time delay from the SN ground station antenna input to the SN ground station baseband output (at the point of time tagging within the data transport) for each I and Q channel in the return link. Unlike time transfer, RCTD can be measured with either a coherent or noncoherent service.

3.4 Testing Services

The SN provides customer test services through the functional capabilities of the SN and its supporting elements. Mutually agreed upon end-to-end tests are conducted to validate all telecommunications system functions, as defined in the applicable Interface Control Documents (ICDs). In addition, operational exercises (i.e., simulations, data flows) are conducted to ensure that operations will satisfy requirements and timelines.

a. TDRSS End-to-End Test (EET) Services. The TDRSS EET services are provided within each SGLT at WSC. The EET provides customer projects the capability of testing the end-to-end SN data communications through a ground-based simulation of the customer platform to MOC link via TDRSS thus eliminating the need for the actual customer platform. Each EET system can simultaneously provide end-to-end testing of forward, return, and tracking services for one S-band (SSA or MA) and one Ku-band (KuSA) customer. Upon completion of the TDRS-K, -L, -M WSC upgrades in 2012, two Ka-band EET terminals will be located at WSC.

NOTE:

Since GRGT has no interface to support receiving and transmitting test data with the customer, end-to-end testing via GRGT is limited to local mode. Refer to Appendix N for further information on end-to-end testing.

b. TDRSS Compatibility and SN End-to-End Testing. Customers are provided a set of testing functions prior to and as part of the TDRSS services. This testing consists of the following customer platform compatibility testing and customer/SN simulation testing:

1. Compatibility Testing. The CTL is used to validate customer platform/TDRS RF interface compatibility prior to launch. The customer's Radio Frequency Interface Control Document (RFICD) with the SN is one of the primary documents used to develop the Compatibility Test Plan (CTP). The CTL emulates the TDRSS in data modulation/demodulation capabilities and provides an RF relay between the customer platform and

a TDRS. Compatibility testing is performed as early as possible but after the flight model radio is integrated into the spacecraft. 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 (CTR). Satisfactory completion of this testing (such as end-to-end Bit Error Rate (BER) tests) and certification is required to meet the SN readiness-for-launch criteria, specifically the statement of TDRSS RF compatibility.

2. SN Simulation Testing. Customer/SN simulation testing is performed before launch, using the customer ground facilities (customer MOC and/or data processing (DP) facility), TDRSS, and the RFSOC. The purpose of pre-launch simulation testing is to validate SN performance with the customer communications equipment. Validation includes operations checkout, end-to-end tests, and fault simulation tests. SN simulation testing is also provided during the customer's mission operations to validate support procedures.

3.5 Analysis Services

3.5.1 Network Loading Analysis Services

NASA's Networks Loading & Modeling (NLM) Team assesses the ability of the SN to provide service to new and changing missions in terms of resource capacity and resource allocation (scheduling). NLM analyses are also used to assess future workload and architecture changes as well as contingency situations. A geometric coverage and capacity analysis is performed for each new mission, as well as for operational missions with changing needs, before Code 450 commits to provide service. This NLM analysis capability is also used to aid the Project/Program in its telecommunications design/trade analyses as appropriate. Applicable analyses are performed any time in the Project/Program lifecycle but are required for all formal Code 450 customer commitment documents or requirements reviews.

3.5.2 Communications Link and Coverage Analysis Services

NASA's Communications Link Analysis and Simulation System provides the capability to perform space communications link evaluations for support via the SN. Information exchange for the RF communications link and coverage analysis begins during the early customer requirements phases and continues until firm coverage requirements and flight segment design are finalized. The CLASS analysis tool is used to help achieve a flight segment telecommunications design which is compatible with the TDRSS, and will achieve the desired level of performance. Design deficiencies (including non-compliance of customer transmit constraints and performance degradations) and possible trade-offs are defined during these analyses. The minimum required Power Received (P_{rec}) equations given in this document are customer guidelines to begin evaluation of SN support services. CLASS analysis will produce more accurate performance projections based upon the specific customer needs. The results of

CLASS are used to aid in the development of the RFICD, which is a controlling input to the flight segment telecommunications specifications. The performance parameters in the RFICD are defined for each RF link with a zero dB customer margin. Customer links that do not meet RF ICD requirements may potentially be supported; however, such support shall be coordinated through GSFC Code 450.

For SN support during launch and early orbit phase (LEOP) (or other mission times) where user spacecraft dynamics and non-stabilized attitudes are involved, a time-varying link analysis is mandatory to determine / define RF link closure. This requires knowledge of the trajectory and attitude of the user spacecraft and knowledge of the antenna pattern as mounted on the user spacecraft including where it is mounted and any blockage caused by user spacecraft structure. Formats for this data can be obtained from Code 450. Successful completion of this analysis will be the basis to allow Code 450 to provide a commitment to support.

3.5.3 Tracking Analysis Services

The FDF can perform tracking analysis services including customer platform trajectory computation and platform history of the on-board oscillator frequency based upon one-way return Doppler data. Pre-launch orbital error analyses may be performed to determine the frequency and interval of tracking data needed to provide the customer platform state vectors at the accuracies required by the customer project.

3.6 Data Distribution/Processing Services and Data Interfaces

3.6.1 Introduction

SN data distribution/processing services can be accommodated via a number of interfaces, as shown in Figure 3-2: the Multiplexer/Demultiplexer (MDM)/IP Operational Network (IONet), the Local Interface (LI), the WSC Transmission Control Protocol (TCP)/Internet Protocol (IP) Data Interface Service Capability (WDISC), the SN Gateway, the SN DAS, and on a case-by-case basis, Intermediate Frequency (IF) interfaces with the SGLTs. Table 3-4 provides an overview of the capabilities of these interfaces. All WSC return service baseband output is recorded to preserve data in the event of a downstream problem, with the exception of the LI output. For distribution/processing, data that is $\leq$ 7 Mbps (such as MDM data) goes through the Low Rate Switch (LRS) and data that is above 7 Mbps goes through the High Rate Switch (HRS). SN DAS data does not go through either switch, but instead interfaces directly with the SGLTs, the NISN IONet, and Local Interfaces at WSGT and GRGT.

Additional data interface services are available through the SN Gateway. Please refer to Appendix R for an overview of SN Gateway services.

3.6.2 MDM/IONet

The MDM system is a full-duplex data interface capable of supporting 75 channel outbound (return) and 30 channel inbound (forward) between the NISN IONet and each ground terminal at WSC. The Data Interface System (DIS) of STGT and WSGT each contain an MDM, as shown in Figure 3-2. The MDM blocks the outbound data in a

NASA-unique 4800 bit block and then encapsulates the block in a User Datagram Protocol (UDP) packet. Similarly, the MDM un-encapsulates and de-blocks inbound data. The IONet is a routed data network that connects the WSC to various customer locations (see Appendix I for additional information on the NISN IONet). Customer ground facilities are equipped with conversion devices to perform the inverse functions of the MDM. This legacy interface is targeted for End of Life in the near future and as such, it is not recommended that any new project interfaces be implemented on it.

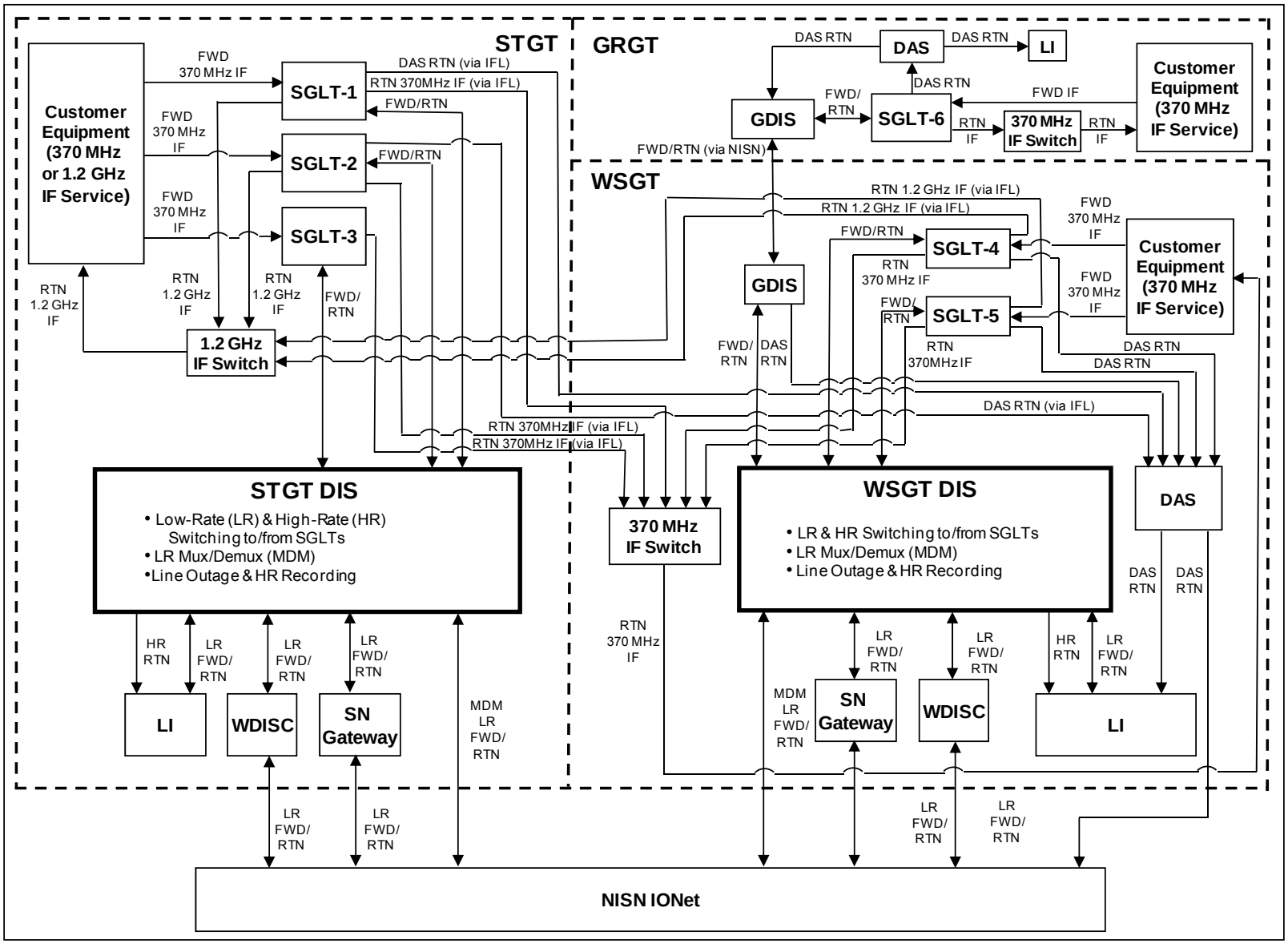


Figure 3-2. Data Distribution/Processing Services and Data Interfaces

Table 3-4. Data Distribution/Processing Interface Capabilities

	Forward Service (note 7)		**Return Service** (note 7)		
Interface	**Data Rate**	**Data Processing Function Provided**	**Data Rate**	**Data Processing Function Provided**	**Line Outage Recording**
MDM/IONet	≤ 7 Mbps per channel (note 1)	N/A	≤ 7 Mbps per channel (note 1)	N/A	Yes
LI	≤ 7 Mbps (note 2)	N/A	≤ 300 Mbps	N/A	Yes (note 4)
WDISC (note 10)	≤ 50 kbps per channel (note 5)	– Data format conversion from NRZ-L to NRZ-M, NRZ-S, BiΦ-L, BiΦ-M, or BiΦ-S – BCH encoding per CCSDS TC recommendation – Rate 1/2 convolutional encoding – De-encapsulation (LEO-T, IPDU, 4800-bit block)	≤ 512 kbps per channel (note 5)	– Grade 2 Reed-Solomon decoding (interleaves 1, 2, 3, 4, 5, and 8) – Encapsulation (LEO-T, IPDU, 4800-bit block)	Yes

Table 3-4. Data Distribution/Processing Interface Capabilities (cont'd)

	Forward Service (note 7)		**Return Service** (note 7)		
Interface	**Data Rate**	**Data Processing Function Provided**	**Data Rate**	**Data Processing Function Provided**	**Line Outage Recording**
SN Gateway (note 10)	100 bps to 6 Mbps per channel	– Data format conversion from NRZ-L to NRZ-M, NRZ-S, BiΦ-L, BiΦ-M, or BiΦ-S – BCH encoding per CCSDS TC recommendation – Rate ½ convolutional encoding – Grade 2 Reed-Solomon encoding (interleaves 1, 2, 3, 4, 5, and 8) – SLE Provider for FCLTU – De-encapsulation (LEO-T, IPDU, 4800-bit block)	1 kbps to 6 Mbps per channel	– Grade 2 Reed-Solomon decoding (interleaves 1, 2, 3, 4, 5, and 8) – SLE Provider for RAF,RCF services (Complete Online and Timely Online Delivery) – Encapsulation (LEO-T, IPDU, 4800-bit block)	Yes
DAS	N/A	N/A	≤ 7.5 Mbps aggregate (up to 50 simultaneous DAS Customer data streams with each DAS channel ≤ 150 kbps) (note 8)	– Grade 2 Reed-Solomon encoding (interleaves 1, 2, 3, 4, 5, and 8) – Encapsulation (LEO-T, IPDU, SFDU, VCDU, 4800-bit block)	Yes
IF Service	note 6	N/A	note 6	N/A	No

Table 3-4. Data Distribution/Processing Interface Capabilities (cont'd)

Notes:

1. The MDM/IONet is currently limited to 55 return channels and 30 forward channels. Although the MDM itself is capable of supporting data rates upto 7 Mbps, IONet interface hardware limits the data rates to 2 Mbps per channel return and 500 kbps per channel forward. Due to current loading of the 9 Mbps composite, IONet bandwidth and hardware would have to be augmented to accommodate new high-rate MDM customers.
2. Current GRGT SGLT-6 software limitations constrain the KuSAF data rate to 7 Mbps or less. Current WSC/GRGT software limitations constrain the KaSAF data rate to 7 Mbps or less.
3. Deleted.
4. For the High Data Rate Service, high rate recording is provided for data rates between 1.5 Mbps and 50 Mbps. Additionally, rate buffering is provided at playback rates $\leq$ 48 Mbps for any High Data Rate Service recorded data rate.
5. Higher single channel forward and return data rates may be possible; however, forward rates above 50 kbps and return rates above 512 kbps have the potential to cause overloading of the WDISC. If a customer has a higher data rate requirement, workload analysis and testing will be necessary to ensure that reliable operation is possible.
6. SN IF services are available to customers on a case-by-case basis. The SSA return, KSA return and KaSA return 650 MHz bandwidth IF services are automated. All other SN IF services require manual configuration and support must be negotiated through GSFC Code 450. All the IF services operate at 370 MHz, except for the KaSA return 650 MHz bandwidth IF service which operates at 1.2 GHz.
7. For SN customers using GRGT services: The GRGT – WSGT connection via NISN is currently limited in bandwidth to a 45 Mbps composite. New customers intending to use GRGT services should consult with GSFC Code 450 regarding GRGT to WSGT bandwidth utilization. In case of a break in communications between GRGT and WSGT during a customer return service, there is no provision to record data at GRGT.
8. The DAS aggregate data rate shown is the maximum capability of the DAS data distribution equipment. For SN customers that receive DAS MAR data via the NISN IONet, the operational bandwidth allocated to DAS is managed by NISN and subject to change depending on SN and NISN operational requirements.
9. Deleted.
10. WDISC will continue to support current missions. SN Gateway will provide these supports to future mission.

3.6.3 Deleted

3.6.4 Local Interface

Customers can provide interfaces at the ground terminals, as shown in Figure 3-2. Local interfaces are serial clock and data.

3.6.5 WDISC

The WDISC supports customers who require TCP/IP access to the WSC for telemetry and command processing. WDISC is located at both STGT and WSGT, as shown in Figure 3-2. WDISC supports up to six simultaneous forward data channels and six simultaneous return data channels at both STGT and WSGT. WDISC customers who make use of GRGT are supported by the WDISC located at WSGT. The SN customer MOC sends commands and data playback requests to WDISC via the NISN IONet. The WDISC sends real-time IP-encapsulated data and playback data files to the MOC, also via the NISN IONet. Refer to Appendix Q for more detailed WDISC information.

NOTE:

WDISC will continue to support current missions. SN Gateway will provide these supports to future mission.

3.6.6 SN Gateway

The SN Gateway, located at both STGT and WSGT, supports customers who require TCP/IP access to the WSC for telemetry and command processing above the data rates supported by WDISC as well as those data customers requiring Space Link Extension (SLE) service from WSC. The SN Gateway configuration can support up to four simultaneous forward data channels and four simultaneous return data channels per Terminal. SN Gateway customers who make use of GRGT are supported by the SN Gateway located at WSGT. The SN customer MOC sends commands to the SN Gateway via the NISN Restricted IONet. The SN Gateway sends real-time IP-encapsulated data to the MOC via the NISN Restricted IONet. The customer MOC may retrieve recorded return data from the SN Gateway via Secure Shell (SSH) File Transfer Protocol (SFTP). The SN Gateway can record up to 10 calendar days per user of return link data in the event of a network line outage from WSC to the user MOC. Refer to Appendix R for more detailed SN Gateway information.

NOTE:

The Space Network supports specific CCSDS protocol implementations. Protocol implementations not expressly specified herein should be discussed with the Space Network before any decision is made regarding

the Space Network's ability to support a particular customer Mission Operations Center or interface.

3.6.7 DAS

The SN DAS provides distribution of DAS MAR service data to customers via a TCP/IP interface to the NISN IONet and/or customer-provided LI equipment. DAS data distribution equipment is located at WSGT and GRGT, as shown in Figure 3-2. Refer to Appendix H for more detailed DAS information.

3.6.8 IF Services

SN SSA, KuSA, and KaSA forward and return IF services are available to customers on a case-by-case basis. The SSA and KSA return IF services have been automated and operate at 370 MHz. The KaSA return 650 MHz bandwidth IF service has also been automated; however, it operates at 1.2 GHz. The flow of the SSA, KuSA, and KaSA return IF service signals from the SGLTs through the appropriate IF switches to customer equipment is shown in Figure 3-2. MA/SMA forward and return services and SSA, KuSA, and KaSA forward services are not automated and require the use of the 370 MHz IF ports located in each of the SGLTs, as shown in Figure 3-2. Any special purpose customer equipment used for processing data at the return IF ports and the unmodulated IF forward ports will require manual configuration. Any Doppler compensation required for acquisition and tracking of the customer signal or the forward link will be provided by the customer equipment.

3.6.9 Deleted

3.6.10 GRGT Constraints

The GRGT – WSGT interface is through a system called the Guam Data Interface System (GDIS), with the communications connection provided via NISN. While the GDIS is capable of transporting a total composite data rate of up to 45 Mbps, the GRGT to WSGT connection is currently limited in bandwidth to a 26 Mbps composite for all customer traffic. New customers intending to use GRGT services should consult with GSFC Code 450 regarding GRGT to WSGT bandwidth utilization. In case of a break in communications between GRGT and WSGT during a customer return service, there is no provision to record data at GRGT.

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Section 4. Obtaining SN Services

4.1 Overview

The information in this section describes the process for obtaining SN services, which is termed the Networks Integration Process. The process is described in the Code 450.1 Networks Integration Process, 450-PG-1310.1.1. The objective of the Networks Integration Process is to ensure that customer requirements are documented and that services are provided to meet customer objectives at the lowest life cycle cost. This process incorporates the following principles:

a. Establish contact between NIMO (Code 450.1) and potential customers as early in the planning phase as possible to assure mission concepts are developed with full information about Code 450 services.

b. Proactively assist customers in capturing requirements by progressively refining these requirements as their concepts evolve.

c. Maintain flexibility in working with potential customers to analyze alternative flight/ground system concepts, innovative approaches, and cost trades.

Code 450 is responsible for overall commitment of services and facilities for NASA and non-NASA customers. The Networks Integration Managers (NIMs) ensure that all requirements and commitments are integrated, and that RF, loading and coverage analyses are performed to ensure services are feasible.

4.2 Authorities and Responsibilities

Authority and responsibility for managing the SN, including the Networks Integration Process, is the responsibility of the Code 450 Division at GSFC.

The NIMO (Code 450.1) is responsible for coordinating and providing customer services. The SN Project (Code 452) is responsible for the management and operations of the TDRSS and the SN ground terminal. The Space Network Program Plan also describes these efforts.

4.3 Procedures for Obtaining SN Services

Initially, the customer must contact the NIMO and, using the NIMO questionnaire (450.1-FORM-0008), provide adequate information for RF engineering analyses, loading analyses, and coverage analyses. Then SN loading studies and preliminary analysis of the capability of the SN to provide services are completed. A determination is then made as to whether the customer requires any modifications to the SN in order to meet their requirements. Should modifications to the SN be required for customer

services, the SN will lead a process to determine how and when the new service will be implemented and how it will be funded.

4.4 System Reviews

NIMO conducts Network Requirements Reviews (NRRs) to confirm requirements and Mission Operations Readiness Reviews (MORRs) to confirm SN readiness to provide services. The MORR also includes FDF and NISN readiness, if they are providing customer services.

4.5 SN Services and Mission Support Documentation

4.5.1 General

The NASA documentation system for providing space communication services to customers recognizes basic required documents, as follows:

a. Project Service Level Agreement (PSLA): A formal agreement between NASA and the customer for services within a specific time frame.

b. Network Requirements Documents (NRD): Documents the customer's detailed SN requirements.

c. Radio Frequency Interface Control Document (RFICD): Describes the specific radio frequency interface details. The RFICD is a required document intended to be developed early in the design phase to drive the spacecraft RF telecommunications design. Example RFICDs can be found in the Code 450 Library on NGIN at https://code450ngin.gsfc.nasa.gov/.

d. Network Operations Support Plan (NOSP): Provides operational procedures and configurations information required by the SN.

e. Other documents include the Compatibility Test Plan and Test Report; the Customer Integration Test Pan and Test Report; and, the Lessons Learned Report.

4.5.2 Configuration Management

Configuration control over the SN service and customer services documentation is maintained through the Code 450.1 Configuration Control Board (CCB). The Configuration Change Request (CCR) form is obtained from the Code 450.1 Configuration Management Office (CMO).

Section 5. MA Telecommunications Services

5.1 General

5.1.1 Available Services

TDRSS MA services include forward and return telecommunications services, and tracking services. Tracking services are discussed in Section 9. This section focuses on the RF interface between the TDRS and the customer platform. This interface is characterized by the technical requirements imposed and the operational capabilities provided by the TDRSS. The operational interfaces are described in further detail in Section 10. Data interfaces between the customer MOC and the SN are described in paragraph 3.6. The SN DAS allows expansion of the TDRSS F3 – F7 and K, L, M MAR Data Group 1 (DG1) mode 2 services to be scheduled for extended duration or in a 'near real time' manner. This section will discuss the general MAR service capabilities; however, Appendix H should be referenced for any specific capabilities or limitations of DAS.

NOTE:

Unless denoted by the TDRS fleet, the term MA is used throughout this document to denote MA services through first, second and third generation TDRS (F3 – F7 and K, L, M). If the term SMA is used, these capabilities are specific to TDRS F8 – F10 and K, L, M.

NOTE:

The NCCDS issues NAMs to provide up-to-date information on network conditions and constraints. These messages are accessible via the NCCDS active NAM web site at https://cds.gsfc.nasa.gov/. GSFC Code 450 uses the NAM as a means of letting customers know of any performance constraints associated with the TDRS spacecraft. Additionally, TDRS constellation information can be found in the TDRS Constellation Management Plan, 452-PLAN-0002.

5.1.2 Interface Definition

The RF interface between the TDRS and a customer platform is defined in terms of signal parameters, RF characteristics, and field of view.

a. The RF interface for forward service represents the transmission by a TDRS of an appropriately modulated signal at or greater than a minimum specified signal Effective Isotropic Radiated Power (EIRP) in the direction of the desired customer platform. MAF service is discussed in paragraph 5.2.

b. The RF interface for return service defines a minimum received power (P_{rec}) at the TDRS antenna input for a specified data quality at the SN ground terminal receiver output. MAR service is discussed in paragraph 5.3.

5.1.3 Customer Acquisition Requirements

Acquisition and reacquisition by the customer platform of the TDRS transmitted signal requires prediction by the customer MOC of the customer platform receive frequency over various projected time periods. Similarly, acquisition and reacquisition by the SN ground terminal of the customer platform signal requires prediction by the customer MOC of the customer platform transmitter frequency over various projected time periods. The frequency predictions are ultimately incorporated in the Schedule Order (SHO) as customer platform frequencies for the specific service support periods. Refer to Section 9 for additional information on TDRSS tracking services that can assist customers in predicting their local oscillator frequencies.

5.1.4 TDRSS Acquisition Support to Customers

For each scheduled TDRSS service support period, the customer requirements for signal acquisition/reacquisition and the TDRSS capabilities to aid acquisition/ reacquisition are as follows:

a. Customer Epoch Uncertainty. The maximum epoch uncertainty of the customer platform ephemeris supplied to the TDRSS should be ±9 seconds for the MA LEO Field of View (LEOFOV) and the PFOV as defined in Table 5-2 for MAF and for MAR services.

b. Customer Frequency Uncertainty. The customer MOC must know the operating frequency of the customer platform to within ±700 Hz.

c. Forward Frequency Sweep. After the start of the forward link service, the TDRSS has a forward service frequency sweep capability of ±3 kHz.

d. Noncoherent Return Expanded Frequency Search. After the start of the noncoherent return link service, the TDRSS has a return service expanded frequency search capability to accommodate a customer platform's operating frequency uncertainty of up to ±3 kHz for MAR DG1, SMAR DG1, and SMAR SQPSK DG2 services. Similarly, the TDRSS has a return service expanded frequency search capability to accommodate a customer platform's operating frequency uncertainty of up to ±35 kHz for the SMAR binary phase shift key (BPSK) and non-staggered quadrature phase-shift keying (QPSK) DG2 services.

5.2 MA Forward Services

5.2.1 General

The characteristics of the data provided to the SN ground terminal interface and the RF signals provided by the TDRS to the customer platform during TDRSS MA forward services are outlined in paragraphs 5.2.2 through 5.2.5. This discussion assumes that

an appropriate forward service has been scheduled and a data signal is present at the SN ground terminal interface.

5.2.2 Signal Parameters

The TDRSS MA forward service signal parameters are defined in Table 5-1. The center frequency (f_o) of the customer platform receiver must be defined by the customer MOC in its service specification code for TDRSS MA forward service (refer to Section 10, paragraph 10.2.2). A description of the features inherent in the SS-UQPSK and BPSK signal parameters listed in Table 5-1 are discussed in paragraph 5.2.2.1.

5.2.2.1 QPSK Signal Parameters

a. Unbalanced QPSK Modulation (PN Modulation Enabled). The I channel is used to transmit the customer command data and is referred to as the command channel. The Q channel transmits a range signal and is referred to as the range channel. The command channel/range channel power ratio for SS-UQPSK forward service signals is +10 dB. This unbalanced QPSK modulation minimizes the power in the range channel to a level adequate for customer platform range channel acquisition and tracking. This feature increases the power in the command channel by 2.6 dB over that for balanced QPSK modulation without increasing customer platform receiver complexity, increasing customer platform command channel acquisition time, or decreasing TDRSS range tracking accuracy.

b. Spread Spectrum. TDRSS MA forward services with data rates equal to and below 300 kbps must incorporate spread spectrum modulation techniques to satisfy flux density restrictions imposed upon the TDRSS forward services by the NTIA. This modulation scheme includes separate but simultaneous command and range channels. The command channel includes a rapidly acquirable PN code and contains the forward service data. The range channel is acquired separately and contains a PN code which satisfies the range ambiguity resolution requirements. The length of the command channel PN code is 2^{10}-1, where the length of the range channel PN code is 256 times the command channel PN code length. The customer platform command channel acquisition can precede customer platform range channel acquisition; this feature permits rapid acquisition of the range channel by limiting the range channel PN code search to only 256 chip positions while the range channel PN code itself contains 261,888 chips. The PN code chip rate is coherently related to the TDRS transmit frequency in all cases. This feature permits the customer platform receiver to use the receiver PN code clock to predict the received carrier frequency, thereby minimizing receiver complexity and reducing acquisition time. 451-PN CODE-SNIP defines all the salient characteristics for the forward range and command channel PN code libraries. The Agency Spectrum Manager responsible for PN code assignments will allocate a customer platform-unique PN code assignment from these libraries. The GSFC Spectrum Manager is responsible for NASA PN code assignments.

Table 5-1. TDRSS MA Forward PSK Service Signal Parameters

Parameter	Definition
TDRS transmit carrier frequency (Hz)	F
Carrier frequency arriving at customer platform (Hz) (note 1)	F_R
Carrier frequency sweep (note 3)	$\pm$3 kHz
Carrier frequency sweep duration (note 3)	120 seconds
UQPSK (PN modulation enabled)	
$\frac{\text{Command channel radiated power}}{\text{Range channel radiated power}}$	+10 dB
SS-UQPSK Command Channel	
Carrier frequency (Hz)	Transmit carrier frequency (F)
PN code modulation	Phase Shift Key (PSK), $\pm$ π/2 radians
Carrier suppression	30 dB minimum
PN code length (chips)	$2^{10} - 1$
PN code epoch reference	Refer to 451-PN CODE-SNIP
PN code family	Gold codes
PN code chip rate (chips/sec)	$\frac{31}{221 \times 96} \times F$
Data modulation	Modulo-2 added asynchronously to PN code
Data format (note 2)	Not Applicable
Data rate restrictions (note 2)	0.1 - 300 kbps
SS-UQPSK Range Channel	
Carrier	Command channel carrier frequency delayed π/2 radians
PN code modulation	PSK, $\pm$ π/2 radians
Carrier suppression	30 dB minimum
PN code chip rate	Synchronized to command channel PN code chip rate
PN code length	$(2^{10} - 1) \times 256$
PN code epoch reference	All 1's condition synchronized to the command channel PN code epoch
PN code family	Truncated 18-stage shift register sequences

Table 5-1. TDRSS MA Forward PSK Service Signal Parameters (cont'd)

BPSK (PN modulation enabled; also referred to as Spread Spectrum BPSK (SS-BPSK)) (note 4)	
Carrier frequency (Hz)	Transmit carrier frequency (F)
PN code modulation	Phase Shift Key (PSK), $\pm\ \pi/2$ radians
Carrier suppression	30 dB minimum
PN code length (chips)	$2^{10} - 1$
PN code epoch reference	Refer to 451-PN CODE-SNIP
PN code family	Gold codes
PN code chip rate (chips/sec)	$\frac{31}{221 \times 96} \times F$
Data modulation	Modulo-2 added asynchronously to PN code
Data format (note 2)	Not Applicable
Data rate restrictions (note 2)	0.1 - 300 kbps

Notes:

1. The center frequency, f_o, of the customer platform receiver must be defined by the customer MOC in its service specification code to an integral multiple of 10 Hz. The SN ground terminal will round-off the customer receive frequency contained in the SHO to the nearest multiple of 221 Hz. Doppler compensation will be available for $\dot{R} \leq 12$ km/sec. During periods of Doppler compensation, $F_R = f_o \pm E$ Hz; where f_o = nominal center frequency of customer platform receiver as defined by the customer MOC and $E = |e \times f_o \times \ddot{R}/c| + C$; $e \leq \pm 9$ sec is the customer epoch uncertainty, $\ddot{R} \leq 15$ m/sec^2 (MA), $\ddot{R} \leq 50$ m/sec^2 (SMA), c is the free space speed of light in m/sec, and C = 400 Hz. If Doppler compensation is inhibited after the start of the forward service, a transition profile will be initiated to slowly change the frequency from the compensate profile to this integer multiple of 221 Hz.

   Forward service Doppler compensation will not increase the effective frequency rate of change seen at the customer receiver more than 28 Hz/sec relative to the frequency for a Doppler-free carrier.
2. The forward data rate in this table is the baud rate that will be transmitted by the TDRSS (includes all coding and symbol formatting). For non-WDISC customers, forward data conditioning is transparent to the SN. These transparent operations should be performed by the customer prior to transmission to the SN data interface. Refer to Section 3, paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities.
3. After the start of the MA forward service, if a customer MOC is unable to accurately define f_o (the nominal center frequency of the customer platform receiver), the forward service carrier frequency can be swept. The MA forward service frequency sweep will be initiated by the SN ground terminal at f_o-3 kHz and linearly swept to f_o+3 kHz in 120 seconds and held at f_o+3 kHz thereafter. The MA forward service frequency sweep does not impact simultaneous SN ground terminal Doppler compensation of the MA forward service carrier and PN code rate (if applicable).
4. Customers who operate in a SS-BPSK mode for one service cannot reconfigure any of their Forward Services (i.e., MAF, SMAF, SSAF, KuSAF, or KaSAF) to an SS-UQPSK mode. Contact Code 450 if additional flexibility is required.

c. Asynchronous Data Modulation. For data rates ≤ 300 kbps, the forward service data received at the SN ground terminal from the NISN data transport system is directly modulo-2 added by the SN ground terminal to the command channel PN code sequence. The forward service data will be asynchronous with the carrier and the PN code.

NOTE:

When the command channel does not contain any actual forward service data, the forward service command channel signal is the command channel PN code sequence with or without an idle pattern.

d. Functional Configurations: A further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in Appendix B, paragraph B.2.2.

e. Doppler Compensation. The TDRSS MA forward service carrier frequency (F) and the PN chip rate transmitted by a TDRS can optionally be compensated by the SN ground terminal for Doppler. When compensated, the carrier, F_R, arrives at the customer platform receiving system within a predictable tolerance (E) of f_o as defined in Table 5-1. This feature minimizes the Doppler resolution requirements of the customer platform receiver and is available continuously to facilitate reacquisition by the customer platform in the event of loss of lock of the TDRSS MA forward service signal. Doppler compensation may be inhibited and the TDRSS will transmit a fixed frequency MA forward service carrier and PN code chip rate.

5.2.2.2 BPSK Signal Parameters

a. BPSK Modulation (PN Modulation Enabled). The I channel is used to transmit the customer command data and is referred to as the command channel. TDRSS MA forward services with data rates equal to and below 300 kbps should incorporate spread spectrum modulation techniques to satisfy flux density restrictions imposed on the TDRSS forward services by the NTIA. The command channel includes a rapidly acquirable PN code and contains the forward service data. The PN code chip rate is coherently related to the TDRS transmit frequency in all cases. This feature permits the customer platform receiver to use the receiver PN code clock to predict the received carrier frequency, thereby minimizing receiver complexity and reducing acquisition time. 451-PN CODE-SNIP defines all the salient characteristics for the forward command channel PN code libraries. The Agency Spectrum Manager responsible for PN code assignments will allocate a customer platform-unique PN code assignment from these libraries. The GSFC Spectrum Manager is responsible for NASA PN code assignments.

NOTE:

Customers who operate in a SS-BPSK mode for one service cannot reconfigure any of their Forward Services (i.e., MAF, SMAF, SSAF, KuSAF, or KaSAF) to an SS-UQPSK mode. Contact Code 450 if additional flexibility is required.

b. Asynchronous Data Modulation. The forward service data will be asynchronous with the carrier.

c. Functional Configurations. A further description of the functional configurations and data polarity ambiguity is found in Appendix B, paragraph B.2.2.

d. Doppler Compensation. The TDRSS MA forward service carrier frequency (F) transmitted by a TDRS can optionally be compensated by the SN ground terminal for Doppler. When compensated, the carrier, F_R, arrives at the customer platform receiving system within a predictable tolerance (E) of f_O as defined in Table 5-1. This feature minimizes the Doppler resolution requirements of the customer platform receiver and is available continuously to facilitate reacquisition by the customer platform in the event of loss of lock of the TDRSS MA forward service signal. Customers are encouraged to utilize GT Doppler compensation unless the customer is relying on measuring the Doppler onboard for tracking data. Doppler compensation may be inhibited and the TDRSS will transmit a fixed frequency MA forward service carrier.

5.2.3 Communications Services

The TDRSS MA forward services available are listed in Table 5-2. Table 5-3 lists their salient characteristics. The definitions for the parameters listed in Table 5-3 are contained in Appendix E.

5.2.4 Real-Time Configuration Changes

Changes to the operating conditions or configuration of a TDRS MA forward service during a scheduled service support period are usually initiated by a Ground Control Message Request (GCMR) from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the GCMR at the SN ground terminal. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning SN ground terminal response times for the GCMRs is provided in Section 10. Table 5-4 lists the MA forward service real-time configuration changes and their effects on the forward service signal.

Table 5-2. TDRSS MA Forward Service

Parameter	Description	
Field of view (each TDRS)	PFOV ±13 degrees conical	LEOFOV ±10.5 degrees conical
Customer Ephemeris Uncertainty (note 3)	≤ ± 9 sec	≤ ± 9 sec
TDRS antenna polarization	Left-hand Circular (LHC)	
TDRS antenna axial ratio (maximum)	1.5 dB over 3-dB formed beamwidth	
TDRS signal EIRP (minimum)	PFOV	LEOFOV
SMAF via TDRS F8-F10 and K, L, M (note 2)	+40 dBW	+42 dBW
MAF via TDRS F3-F7	+34 dBW	+34 dBW
Transmit frequency (nominal) (refer to note 1)	$[2287.5 \pm 0.1] \times \frac{221}{240}$ MHz	
RF bandwidth (3 dB minimum)	6 MHz	
Duty factor	100 percent	

Notes:

1. The customer MOC must include the best estimate of the customer platform receiver center frequency at the start time of each scheduled service support period in its service specification code (refer to Section 10, paragraph 10.2.2). The TDRSS MA forward service carrier frequency is then implemented by the SN ground terminal to the accuracy of the SN ground terminal frequency standard except during Doppler compensation.
2. F8 is unavailable for normal customer scheduling.
3. User ephemeris uncertainty allowance is based upon the assumption of a low eccentricity LEO user orbit. User orbits with high eccentricity and large variations in velocity may need to comply with a more stringent user ephemeris uncertainty.

Table 5-3. Salient Characteristics for TDRSS MA Forward Services

Parameter (Note 1)	**Description** (Note 1)
$\frac{\text{Command channel radiated power}}{\text{Range channel radiated power}}$ (SS-UQPSK only)	+10 ± 0.5 dB
Modulator phase imbalance (peak)	±3 degrees (for each BPSK channel)
Modulator gain imbalance (peak)	±0.25 dB
Relative phase between command and range channels (SS-UQPSK only)	90 ±3 degrees
Data asymmetry (peak) (Note 2)	±3 percent
Phase nonlinearity (peak) (Note 3)	±0.12 radian over ±2.1 MHz
Gain flatness (peak) (Note 3)	±1.2 dB over ±2.1 MHz
Gain slope (peak) (Note 3)	±0.1 dB/MHz over ±2.1 MHz
AM/PM	≤13 degrees/dB
PN chip jitter (rms) (including effects of Doppler compensation)	≤1 degree
Data clock phase jitter (peak) (Note 2)	≤1 percent
Spurious PM (rms)	≤1 degree
In-band spurious outputs	≥27 dBc
Incidental AM (peak)	≤2 percent
Phase noise (rms): 1 Hz - 10 Hz 10 Hz - 32 Hz 32 Hz - 1 kHz 1 kHz - 3 MHz	 ≤1.5 degrees ≤1.5 degrees ≤4.0 degrees ≤2.0 degrees
Command/range channel PN chip skew (peak) (SS-UQPSK only)	≤0.01 chip
PN chip asymmetry (peak)	≤0.01 chip
PN chip rate (peak) relative to absolute coherence with carrier rate	≤0.01 chips/sec at PN code chip rate

Notes:

1. The definitions and descriptions of the salient characteristics are provided in Appendix E.
2. These values are the TDRSS contributions for data asymmetry and data clock phase jitter assuming perfect forward service data is provided to the SN ground terminal. The actual contributions by the NISN data transport system are negligible compared to those contributed by the TDRSS, since the SN ground terminal reclocks the data before it is processed by the SN ground terminal into the forward service signal.
3. Bandwidth limitation for gain flatness, phase nonlinearity and gain slope while maintaining consistency with NTIA spectral emission mask (Appendix D):70% of the signal main lobe width or 70 % of the necessary bandwidth whichever is smaller.

Table 5-4. MA Forward Service Real-Time Configuration Changes

Real-Time Configuration Changes	GCMR	OPM	Forward Service Signal Interruption
Customer Receiver Center Frequency	98/04	OPM 03	Yes
Doppler Compensation Inhibit	98/08	OPM 11	No
Doppler Compensation Reinitiation	98/04	OPM 03	No
Forward Service Reacquisition (note)	98/03	OPM 02	Yes
Forward Service Sweep Request (refer to Table 5-1 note 3)	98/05	OPM 04	Yes
Data Rate	98/04	OPM 03	No
Note: Forward service reacquisition is a TDRSS reinitiation of forward link service by applying a 1 MHz frequency offset for 3 seconds to the predicted customer receive frequency specified in the customer's service specification code (refer to Section 10, paragraph 10.2.2).			

5.2.5 Acquisition Scenarios

The following acquisition scenarios identify only the technical aspects of TDRSS MA forward service signal acquisition by the customer platform and do not include operational procedures related to acquisition:

a. The TDRSS MA forward service signal does not depend on a customer platform return service.

b. Prior to the start of the spatially formed TDRS MA forward service, the TDRSS MA antenna beam will be open-loop pointed in the direction of the customer platform.

c. At the start of the TDRSS MA forward service as defined by the SHO, the TDRS will radiate, in the direction of the customer platform, a signal compatible with the TDRSS MA forward service signal parameters listed in Table 5-1. The TDRS signal will be transmitted at the scheduled EIRP consistent with the values listed in Table 5-2. The signal transmitted towards the customer platform is dependent upon the customer providing an ephemeris uncertainty within the values defined in Table 5-2.

d. The customer platform receiving system will search for and acquire the command channel PN code and carrier. Normally, a customer MOC will not be transmitting forward service data to the NISN data transport system until the forward service signal has been acquired by the customer platform and the acquisition verified by the customer MOC from the customer platform return service telemetry. If the NASA fourth generation standard transponder is used, its design implementation requires that there be no data transitions during the signal acquisition process, while others may merely result in longer acquisition times.

e. The customer platform receiving system will search for and acquire the range channel PN code upon acquisition of the command channel PN code and carrier.

f. Depending upon customer platform receiving system design, upon completion of forward link acquisition and subsequent customer platform transition to signal tracking, the customer platform transmitting system may either switch to a coherent mode or remain in a noncoherent mode until commanded by the customer MOC to switch.

g. The SN ground terminal will continue Doppler compensation of the TDRSS MA forward service signal unless requested by the customer MOC to inhibit the Doppler compensation.

h. T_{acq} in the customer platform receiver is a function of the customer platform receiver design and signal-to-noise density ratio. For the purpose of an example, Table 5-5 provides the acquisition characteristics for the fourth generation transponder when receiving an MA SS-UQPSK signal. The T_{acq} values listed in Table 5-5 are contingent on the customer MOC defining the customer platform receiver center frequency, f_o, to an accuracy of $\pm$700 Hz in each service support schedule add request (SAR). The customer platform forward service acquisition time must be considered in determining the overall return service acquisition time for customer platform with a coherent mode of operation.

i. Appendix A provides example link calculations for the TDRSS MA forward service.

Table 5-5. MA Forward Service Example Acquisition Times for the Fourth Generation NASA Standard Transponder

S/N_0 (notes 1,3)	**Command Channel PN Code (note 2)**	**Carrier (note 2)**	**Range Channel PN Code (note 2)**	**Total (note 2)**
34 dB-Hz	$\leq$ 20 sec	$\leq$ 5 sec	$\leq$ 10 sec	$\leq$ 35 sec
$\geq$ 37 dB-Hz	$\leq$ 7 sec	$\leq$ 5 sec	$\leq$ 10 sec	$\leq$ 22 sec

Notes:

1. S/N_0 is the signal to noise density ratio (dB-Hz) at the customer platform transponder input.
2. With a probability $\geq$ 90%. Carrier acquisition starts after the command channel PN code has been acquired. Range channel PN code acquisition starts after the carrier has been acquired.
3. For further specific information on the Fourth Generation user transponder, reference should be made to 531-RSD-IVGXPDR.

5.3 MA Return Services

5.3.1 General

The RF signals provided by the customer platform to the TDRS and the characteristics of data provided at the SN ground terminal interface are defined in paragraphs 5.3.2 through 5.3.5. This discussion assumes that an appropriate return service has been scheduled and a data signal is present at the TDRS interface.

NOTE:

The F8 spacecraft has some SMA return G/T performance variations due to an MA element array and sunshield proximity problem. The F8 G/T varies based upon the normal daily TDRS diurnal cycle. This section documents the required P_{rec} values for both the F8 hot and cold conditions. The hot periods can be predicted and will occur at regular intervals with a total hot period of less than 12 hours/day. Note that F8 is unavailable for normal customer scheduling.

5.3.2 Signal Parameters

The TDRSS MA return service signal parameters are listed in Table 5-6. The services are divided into 2 major groups, Data Group 1 (DG1) and Data Group 2 (DG2). DG1 services utilize spread spectrum modulation while DG2 services are non-spread. A description of the features inherent in the DG1 and DG2 services is discussed in 5.3.2.2 and 5.3.2.3, respectively. Within each data group, there are several types of modulation. Additionally, both data groups support coherent and noncoherent modes. A description of these general characteristics is provided in 5.3.2.1.

Table 5-6. TDRSS MA Return Service Signal Parameters

Parameter (Note 6)	**Definition** (Note 6)
DG1 (note 1)	
Transmit carrier frequency (Hz) (note 5)	F_1
Carrier (F_1) reference (Hz)	
DG1 mode 1	$\frac{240}{221} \times FR$
DG1 mode 2	Customer platform transmitter oscillator
PN code modulation	
DG1 modes 1 and 2	SQPN, BPSK (refer to Appendix B and Table 5-7)
DG1 mode 3, I channel (SMA via F8-F10 and K, L, M)	PSK $\pm\pi/2$ radians
PN code chip rate (chips/sec)	$\frac{31}{[240 \times 96]} \times F1$
PN code length (chips)	
DG1 modes 1 and 3	$(2^{10} - 1) \times 256$
DG1 mode 2	$2^{11} - 1$
PN code epoch reference	
DG1 mode 1	
I channel	Epoch (all 1's condition) synchronized to epoch (all 1's condition) of received forward service range channel PN code
Q channel (note 3)	Epoch delayed x + 1/2 PN code chips relative to I channel PN code epoch
DG1 mode 2	Not Applicable
DG1 mode 3, I channel	Same as DG1 mode 1 (I channel)
PN code family	
DG1 mode 1	Truncated 18-stage shift register sequences
DG1 mode 2	Gold codes
Data modulation:	
DG1 modes 1 and 2	Modulo-2 added asynchronously to PN code
DG1 mode 3: (SMA via F8-F10 and K, L, M)	
I channel	Modulo-2 added asynchronously to PN code
Q channel	PSK $\pm\pi/2$ radians

Table 5-6. TDRSS MA Return Service Signal Parameters (cont'd)

Parameter (Note 6)	Definition (Note 6)
DG1 (note 1)	
Periodic convolutional interleaving (note 4)	Recommended for baud rates > 300 kbps
Data Format	NRZ-L, NRZ-M, NRZ-S
Symbol Format	NRZ
DG1 mode 1 data rate restrictions (rate 1/2 convolutional encoded)	
Total (note 1)	0.1 - 300 kbps
I channel	0.1 - 150 kbps
Q channel	0.1 - 150 kbps
DG1 mode 2 data rate restrictions (rate 1/2 convolutional encoded)	
Total (note 1)	1 - 300 kbps
I channel	1 - 150 kbps
Q channel	1 - 150 kbps
DG1 mode 3 data rate restrictions (rate 1/2 convolutional encoded) (SMA via F8-F10 and K, L, M)	
Total (note 1)	I (max) + Q (max)
I channel	0.1 - 150 kbps
Q channel	1 kbps – 1.5 Mbps
DG1 $\frac{\text{Q channel power}}{\text{I channel power}}$ restrictions (note 2)	
Single data source-alternate I/Q bits (SMA via F8-F10 and K, L, M)	1:1
Single data source-identical data	1:1 to 4:1
Single data source-single data channel	NA
Dual data sources	1:1 to 4:1
DG2 (SMAR via F8-F10 and K, L, M) (note 1)	
Transmit carrier frequency (note 5)	F_2
Carrier (F_2) reference (Hz)	
DG2 Coherent	$\frac{240}{221} \times F_R$
DG2 Noncoherent	Customer platform oscillator

Table 5-6. TDRSS MA Return Service Signal Parameters (cont'd)

Parameter (Note 6)	Definition (Note 6)
DG2 (SMAR via F8-F10 and K, L, M) (note 1)	
Data modulation (note 1)	BPSK, SQPSK, or QPSK (refer to Appendix B and Table 5-7)
Periodic convolutional interleaving (note 4)	Recommended for baud rates > 300 kbps
Symbol format	NRZ, Biϕ-L
Data format	NRZ-L, NRZ-M, NRZ-S
Data rate restrictions (rate 1/2 convolutional encoded)	
Total (note 1)	I (max) + Q (max)
I channel	1 kbps – 1.5 Mbps
Q channel	1 kbps – 1.5 Mbps
DG2 $\frac{\text{I channel power}}{\text{Q channel power}}$ restrictions	
Single data source-alternate I/Q bits	1:1
Single data source-alternate I/Q encoded symbols	1:1
Single data source-single data channel	NA
Dual data sources	1:1 or 4:1

Notes:

1. Customer platform data configurations, including specific data rate restrictions for coding and formatting, are defined in Table 5-7 for TDRSS MA return service (refer also to Appendix B). Unless otherwise stated, the data rate restrictions given in this table assume rate 1/2 convolutional encoding and NRZ formatting.
2. For DG1, the Q/I power parameter range can vary from 1:1 to 4:1 continuously during specification of applicable parameter values in the NCCDS scheduling database and during real-time service reconfiguration. However if this parameter is re-specified in schedule requests to the NCCDS (refer to paragraph 10.2.2), it is expressed as the ratio of two single-digit integers.
3. The Q channel PN code sequence must be identical to the I channel PN code sequence, but offset by x + 1/2 PN chips, where x >20,000. The value of x is defined by the PN code assignment for a particular customer platform (refer to 451-PN CODE-SNIP).
4. Periodic convolutional interleaving (PCI) is recommended on S-band return services for channel baud rates > 300 kbps. Biphase symbol formats are not allowed with PCI. When interleaving is not employed for channel baud rates > 300 kbps, S-band return performance may not be guaranteed.
5. The center frequency, f_O, of the customer platform transmitter must be defined by the customer MOC in its service specification code to an integral multiple of 10 Hz.
6. Unless otherwise noted, all data rate values are to be interpreted as data bit rates, and not as data symbol rates.

Table 5-7. MA/SMA Return Service Configurations

Return Service Configuration[10]				Source Data Rate Restrictions and Availability[9]					
				DG1 Mode				DG2 Mode (SMA only)	
				1[1] and 2[1,4,8]		3[2] (SMA only)		Coherent[3] and Noncoherent[3,4]	
				Data format	Data rate	Data format	Data rate	Data format	Data rate
Single Data Source	BPSK	Rate 1/2 coded		NRZ	≤150 kbps[1]	-	-	NRZ	1 kbps – 1.5 Mbps[5]
								NRZ with biphase symbols	1 kbps – 0.75 Mbps[5,6]
		Rate 1/3 coded		-	-	-	-	NRZ	1 kbps – 1 Mbps[5]
								NRZ with biphase symbols	1 kbps – 0.5 Mbps[5,6]
		Uncoded		[7]	[7]	-	-	[7]	[7]
	SQPN	Identical I & Q channel data	Rate 1/2 coded	NRZ	≤150 kbps	-	-	-	-
			Uncoded	[7]	[7]	-	-	-	-
	SQPSK	Rate 1/2 coded alternate I/Q encoded symbols		-	-	-	-	NRZ	1 – 300 kbps
	SQPN[1] or SQPSK[3]	Alternating I/Q data (SMA only)	Individually rate 1/2 coded	NRZ	≤300 kbps (SMA only)	-	-	NRZ	1 kbps – 3 Mbps[5]
			Individually rate 1/3 coded	-	-	-	-	NRZ	1 kbps – 2 Mbps[5]
			Uncoded	[7]	[7]	-	-	[7]	[7]
Dual Data Sources (data rates are for each source separately)	SQPN[1], QPSK[2,3] or SQPSK[3]	Rate 1/2 coded		NRZ	≤150 kbps	NRZ	I: 0.1-150 kbps Q: 1 kbps – 1.5 Mbps	NRZ	1 kbps – 1.5 Mbps[5,11]
								NRZ with biphase symbols	1 kbps – 0.75 Mbps[5,6,11]
		Rate 1/3 coded		-	-	NRZ	Q: 1 kbps – 1Mbps	NRZ	1 kbps – 1 Mbps[5,11]
								NRZ with biphase symbols	1 kbps – 0.5 Mbps[5,6,11]
		Uncoded		[7]	[7]	[7]	[7]	[7]	[7,11]

Table 5-7. MA/SMA Return Service Configurations (cont'd)

✓	Configuration supported
-	Configuration not supported

Notes:

1. For DG1 mode 1 and 2 configurations, where the minimum source data rates are 0.1 kbps for DG1 mode 1 and 1 kbps for DG1 mode 2:
   a. Data on a single I or Q channel, but not both channels: BPSK modulation is used where the data is modulo-2 added to the PN code.
   b. Data on both the I and Q channels: SQPN modulation is used and the SN supports I:Q power ratios of 1:1 to 1:4 for all the configurations, except the alternating I and Q data bit configuration, which requires a balanced I:Q power ratio.
   c. The alternating I/Q data bit configuration: the SN requires the I channel lead the Q channel by a half symbol. Similarly, the SN requires the I and Q channels be independently differentially formatted (-M,-S).
2. For DG1 mode 3 configurations:
   a. The modulation is QPSK, where the I channel data is modulo-2 added to the PN code, and the Q channel data directly modulates the carrier at $+\pi/2$ radians.
   b. The SN supports I:Q power ratios of 1:1 to 1:4.
   c. Rate 1/3 coding is supported for the Q channel only. (Rate 1/2 coding is supported on both the I and Q channels.)
3. For DG2 configurations:
   a. Single data source configurations with data on one channel: BPSK modulation is used.
   b. Single data source configurations with data on both channels: SQPSK modulation and an I:Q power ratio of 1:1 is used. For the alternate I/Q bit configuration, the SN requires the I and Q channels be independently differentially formatted (-M,-S).
   c. Dual data source configurations: SQPSK must be used when there are identical baud rates on the I and Q channels (see paragraph 5.3.2.1.b); QPSK is used for all other configurations; for both SQPSK and QPSK, either an I:Q power ratio of 1:1 or 4:1 is supported. For unbalanced QPSK, the I channel must contain the higher data rate and when the data rate on the I channel exceeds 70 percent of the maximum allowable data rate, the Q channel data rate must not exceed 40 percent of the maximum allowable data rate on that Q channel.
4. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of $\pm$ 700 Hz. If a customer cannot accurately define their transmit frequency to within $\pm$ 700 Hz, a customer can request a reconfiguration which would expand the oscillator frequency search to $\pm$ 3 kHz for DG1 and SQPSK DG2 configurations and $\pm$ 35 kHz for BPSK and QPSK DG2 configurations after the start of service.
5. Periodic convolutional interleaving (PCI) is recommended on S-band return service for channel baud rates > 300 kbps. When interleaving is not employed for channel baud rates > 300 kbps, S-band performance may not be guaranteed.
6. Biphase symbol formats are not allowed with PCI. Use of biphase symbol formats on S-band services at baud rates > 300 kbps should be coordinated with GSFC Code 450.
7. For all configurations and modes, the SN is capable of providing SMA support of uncoded links; however, performance is not guaranteed in RFI and must be coordinated with GSFC Code 450.
8. The SN DAS allows expansion of the TDRS F3-F7 and K, L, M MAR Data Group 1 (DG1) mode 2 services to be scheduled for extended duration or in a 'near real time' manner. Refer to Appendix H for further information.
9. Unless otherwise noted, all data rates are to be interpreted as data bit rates, and not as data symbol rates. Refer to Section 3, paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities.
10. Appendix B describes the functional configurations and associated I-Q channel and data polarity ambiguities. Additionally, Figure B-10 depicts the SN supported convolutional coding schemes.
11. For S-band DG2, dual data channel, balanced power configurations, the minimum total (I+Q) data rate must be 60 kbps or greater.

5.3.2.1 General Modulation and Coherent/Noncoherent Description

a. SQPN Modulation. SQPN modulation is used to prevent simultaneous transitions of the I and Q PN sequences. For SQPN modulation, the PN chips of the I and Q channels are staggered by a 1/2 chip. For data configurations that use two PN spread channels, SQPN modulation must be used.

b. SQPSK Modulation. SQPSK modulation staggers one channel with respect to the other to prevent synchronous transitions. For non-spread signal configurations with identical I and Q symbol rates that are NRZ symbol formatted, SQPSK modulation should be used. The symbols of the Q channel are delayed 1/2 symbol relative to the I channel. For non-spread signal configurations that use biphase symbol formatting on either channel and the baud rate of the two channels are identical, SQPSK modulation should be used and the transitions of one channel occur at the mid-point of adjacent transitions of the other channel.

c. QPSK Modulation. QPSK modulation is available when there is no relation between the I and Q channel transitions. For dual data source configurations, in which one or both channels are not spread and SQPSK is not required, QPSK modulation is used.

d. BPSK Modulation. BPSK modulation is available for single data source configurations that use only one channel of the link.

NOTE:

For SQPN and SQPSK modulation, the spectral characteristics of a customer platform saturated power amplifier will, to a great degree, retain the spectral characteristics of the band-limited input signal to that amplifier. This should result in better control of out-of-band emissions, which, in turn, provides more efficient communications and less interference to the customer platform using adjacent frequency channels on the TDRS links.

e. Coherent Mode. For coherent modes, the customer platform transmitted return link carrier frequency and PN code clock frequency (if applicable) are derived from the customer platform received forward link carrier frequency. For coherent PN spread return links, the return PN code length is identical to the length of the received forward service range channel PN code. The customer return I channel PN code epoch is synchronized with the epoch of the received forward service range channel PN code. Two-way Doppler measurements and range measurements (if PN spread) are available.

f. Noncoherent Mode. For noncoherent modes, the customer platform transmitted return link carrier frequency and PN code clock frequency (if applicable) are derived from an on-board local oscillator. The customer

platform transmit frequency for noncoherent service must be defined by the customer MOC to an accuracy of ±700 Hz in its configuration code when requesting TDRSS MA return service (refer to Section 10, paragraph 10.2.2). For customers whose frequency uncertainty is greater than ±700 Hz, an expanded frequency search capability is available after service start.

g. Asynchronous Data Modulation. The data modulation is asynchronous to the carrier and the channel PN code (if applicable). This prevents Doppler variations of the forward service carrier and PN code frequencies from affecting the return service data rate.

5.3.2.2 DG1 Signal Parameters.

DG1 signal parameters are subdivided into three modes of operation, DG1 modes 1, 2, and 3. For all DG1 modes, the PN code clock must be coherently related to the transmitted carrier frequency. This feature permits the customer platform transmitter to use a common source for generating the carrier and the PN code clock frequencies. 451-PN CODE-SNIP defines all the salient characteristics for the DG1 PN code libraries. The Agency Spectrum Manager responsible for PN code assignments will allocate a customer platform-unique PN code assignment from these libraries. The GSFC Spectrum Manager is responsible for NASA PN code assignments. The three DG1 modes are distinguished as follows:

a. DG1 Mode 1. DG1 mode 1 must be used when range and two-way Doppler measurements (coherent transponder operations) are required concurrently with return service low-rate data transmission. Return service signal acquisition by the SN ground terminal for DG1 mode 1 is possible only when the scheduled TDRSS (MA or SSA) forward service signal is acquired by the customer platform and the PN code and carrier transmitted by the customer platform are coherently related to the forward service signal from the TDRS. If the TDRSS forward service signal becomes unavailable to the customer platform (the forward service is time-shared with other customer platforms), the customer platform transmitter must switch to noncoherent transmitter operation (DG1 mode 2) (refer to paragraph 5.3.5.c.2). In order to reacquire the DG1 mode 2 signal, the return service must be reconfigured. The I and Q channel PN codes are generated from a single code generator. For DG1 mode 1 operation, the I and Q channel PN codes are identical but are offset by at least 20,000 chips. This separation is adequate for TDRSS to identify each data channel unambiguously without requiring a unique PN code for each channel.

b. DG1 Mode 2. DG1 mode 2 will be used when SN ground terminal return service signal acquisition is necessary without the requirement for prior customer platform signal acquisition of the TDRSS (MA or SSA) forward service (noncoherent transponder operation). The customer platform transmit frequency for DG1 mode 2 service must be defined by the customer MOC to an accuracy of ±700 Hz in its configuration code when requesting TDRSS MA return service (refer to Section 10, paragraph 10.2.2). For customers whose frequency uncertainty is greater than ±700 Hz, an expanded frequency search

capability of ±3 kHz is available. For DG1 mode 2, the I and Q channel PN codes are unique 2^{11}-1 Gold Codes.

NOTE:

The SN DAS allows expansion of the TDRSS F3 – F7 and K, L, M MAR DG1 mode 2 services to be scheduled for extended duration or in a 'near real time' manner. Refer to Appendix H for further information.

c. DG1 Mode 3 (SMA via F8 – F10 or K, L, M). DG1 mode 3 can be used when range and two-way Doppler measurements (coherent transponder operations) are required concurrently with return service high-rate data transmission. Restrictions on DG1 mode 3 signal acquisition are identical to those for DG1 mode 1. In DG1 mode 3, the Q channel must contain only data and no PN code.

d. Functional Configurations. Table 5-7 lists the DG1 MA return service functional configurations and a further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in Appendix B, paragraph B.3.2.

5.3.2.3 DG2 Signal Parameters

DG2 signal parameters are subdivided into two modes of operation, DG2 coherent and noncoherent. DG2 must be used when the return service data rate equipment exceeds the capability of DG1 operations. DG2 operations cannot provide TDRSS range tracking because PN code modulation is not used. The two DG2 modes are distinguished as follows:

a. DG2 Coherent (SMA via F8 – F10 or K, L, M). Return service signal acquisition by the SN ground terminal for DG2 coherent is possible only when the scheduled TDRSS (SSA or MA) forward service signal is acquired by the customer platform and the carrier transmitted by the customer platform are coherently related to the forward service signal from the TDRS. TDRSS two-way Doppler tracking can be provided when the DG2 carrier is coherently related to the TDRSS (SSA or MA) forward service carrier frequency.

b. DG2 Noncoherent (SMA via F8 – F10 or K, L, M). The DG2 carrier is independent of the TDRSS (SSA or MA) forward service carrier frequency. The customer platform transmit frequency for DG2 noncoherent service must be defined by the customer MOC to an accuracy of ±700 Hz in its service specification code when requesting TDRSS SMA return service (refer to Section 10, paragraph 10.2.2). For customers whose frequency uncertainty is greater than ±700 Hz, an expanded frequency search capability of ±3 kHz for SQPSK DG2 services and ±35 kHz for BPSK and QPSK DG2 services is available after start of the return service.

c. Functional Configurations. Table 5-7 lists the DG2 SMA return service functional configurations and a further description of the functional

configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in paragraph B.3.3.

5.3.3 Communication Services

To obtain TDRSS MA return service performance defined in this paragraph, the customer platform transmitted signal must meet the requirements found in Table 5-8 and signal characteristics specified in Table 5-11. The TDRSS MA return service performance defined in this paragraph also assumes return service operation in an Additive White Gaussian Noise (AWGN) environment. Appendix G discusses performance degradations to the TDRSS MA return service due to RFI. Example link calculations are provided in Appendix A. TDRSS MAR supports customers with an ephemeris uncertainty as defined in Table 5-8 and dynamics, described as non-powered flight and powered flight (SMAR only), as defined in Table 5-9.

5.3.3.1 Acquisition

The MAR service supports acquisition for customer platforms operating under non-powered flight dynamics as defined in Table 5-9. MAR acquisition will be protected against false SN ground terminal lock to: interfering customer platform PN codes, customer platform PN code sidelobes, and carrier recovery. The MAR total channel acquisition times (T_{acq}) are given in Table 5-8 and are the sum of the following:

a. PN (DG1 only) and carrier acquisition time
b. Symbol/Decoder synchronization time or Symbol/Deinterleaver/Decoder synchronization time (if deinterleaving is applicable).

T_{acq} assumes that the customer platform return service signal is present at the SN ground terminal at the start time of the scheduled return service support period and the process is described below.

a. PN code (if applicable) and carrier acquisition will commence upon the start of the scheduled return service support period.
b. After PN code (if applicable) and carrier acquisition is achieved, TDRSS tracking services data is available.
c. Symbol/Decoder and Symbol/Deinterleaver/Decoder synchronization times will be measured from the time when the carrier acquisition is achieved to the time when the decoder synchronization is achieved. Decoder synchronization is achieved when the Viterbi decoder has selected and implemented the correct blocking of the input symbols (into groups of (G1,G2) symbol pairs for rate 1/2 codes, or (G1,G2,G3) symbol triplets for rate 1/3 codes).

Table 5-8. TDRSS MA Return Service

Parameter (Note 7)	**Description** (Note 7)	
Field of view F(OV) (each TDRS)	PFOV ±13 degrees conical	LEOFOV ±10.5 degrees conical
Customer Ephemeris Uncertainty (along the customer orbital track) (note 8)	≤ ± 9 sec	≤ ± 9 sec
TDRS antenna polarization	LHC	
TDRS antenna axial ratio (maximum)	1.5 dB over 3-dB formed beamwidth	
Receive frequency (nominal) (see paragraph 5.3.3.5.b)	2287.5 ±0.1 MHz	
RF bandwidth (3dB, minimum)	6 MHz	
10^{-5} Bit Error Rate (notes 1, 2, 7)		
Orbital Dynamics	Powered (SMAR only) and non-powered flight dynamics (defined in Table 5-9)	
Minimum Required P_{rec} for Rate 1/2 convolutional coding:	All P_{rec} values are in dBW; dr is data rate in bps	
	PFOV	LEOFOV
DG1 modes 1 and 2:		
F3-F7 and K, L, M	$-220.9 + 10\log_{10}(dr)$	$-221.8 + 10\log_{10}(dr)$
F8 (cold), F9, F10 (note 6)	$-222.4 + 10\log_{10}(dr)$	$-223.7 + 10\log_{10}(dr)$
F8 (hot) (note 6)	$-219.0 + 10\log_{10}(dr)$	$-220.4 + 10\log_{10}(dr)$
DG1 mode 3 (SMAR only via F8 – F10 and K, L, M) (note 6)		
I channel (F8 cold, F9, F10, and K, L, M)	$-222.4 + 10\log_{10}(dr)$	$-223.7 + 10\log_{10}(dr)$
I channel (F8 hot)	$-219.0 + 10\log_{10}(dr)$	$-220.4 + 10\log_{10}(dr)$
Q channel (F8 cold, F9, F10, and K, L, M)		
Data rate ≤ 1 Mbps	$-222.8 + 10\log_{10}(dr)$	$-224.1 + 10\log_{10}(dr)$
Data rate > 1 Mbps	$-222.1 + 10\log_{10}(dr)$	$-223.4 + 10\log_{10}(dr)$
Q channel (F8 hot)		
Data rate ≤ 1 Mbps	$-219.4 + 10\log_{10}(dr)$	$-220.8 + 10\log_{10}(dr)$
Data rate > 1 Mbps	$-218.7 + 10\log_{10}(dr)$	$-220.1 + 10\log_{10}(dr)$
DG2 (SMAR only via F8 cold, F9, F10 and K, L, M) (note 6)		
Data rate ≤ 1 Mbps	$-222.8 + 10\log_{10}(dr)$	$-224.1 + 10\log_{10}(dr)$
Data rate > 1 Mbps	$-222.1 + 10\log_{10}(dr)$	$-223.4 + 10\log_{10}(dr)$

Table 5-8. TDRSS MA Return Service (cont'd)

Parameter (Note 7)	**Description** (Note 7)	
10^{-5} Bit Error Rate (notes 1, 2, 7) (cont'd)		
Minimum Required P_{rec} for Rate 1/2 convolutional coding (cont'd):	All P_{rec} values are in dBW; dr is data rate in bps	
DG2 (SMAR only via F8 hot) (note 6)		
Data rate $\leq$ 1 Mbps	$-219.4 + 10\log_{10}(dr)$	$-220.8 + 10\log_{10}(dr)$
Data rate > 1 Mbps	$-218.7 + 10\log_{10}(dr)$	$-220.1 + 10\log_{10}(dr)$
Minimum Required P_{rec} for Rate 1/3 convolutional coding:	All P_{rec} values are in dBW; dr is data rate in bps	
DG1 mode 3, Q channel (SMAR only via F8 cold, F9, F10 and K, L, M) (note 6)	PFOV	LEOFOV
Data rate $\leq$ 1 Mbps	$-223.1 + 10\log_{10}(dr)$	$-224.4 + 10\log_{10}(dr)$
Data rate > 1 Mbps	$-222.5 + 10\log_{10}(dr)$	$-223.8 + 10\log_{10}(dr)$
DG1 mode 3, Q channel (SMAR only via F8 hot) (note 6)		
Data rate $\leq$ 1 Mbps	$-219.7 + 10\log_{10}(dr)$	$-222.1 + 10\log_{10}(dr)$
Data rate > 1 Mbps	$-219.1 + 10\log_{10}(dr)$	$-220.5 + 10\log_{10}(dr)$
DG2 (SMAR only via F8 cold, F9, F10, and K, L, M) (note 6)		
Data rate $\leq$ 1 Mbps	$-223.1 + 10\log_{10}(dr)$	$-224.4 + 10\log_{10}(dr)$
Data rate > 1 Mbps	$-222.5 + 10\log_{10}(dr)$	$-223.8 + 10\log_{10}(dr)$
DG2 (SMAR only via F8 hot) (note 6)		
Data rate $\leq$ 1 Mbps	$-219.7 + 10\log_{10}(dr)$	$-222.1 + 10\log_{10}(dr)$
Data rate > 1 Mbps	$-219.1 + 10\log_{10}(dr)$	$-220.5 + 10\log_{10}(dr)$
Acquisition (note 3):		
Orbital dynamics	free-flight dynamics only (defined in Table 5-9)	
Total Channel Acquisition Time (assumes the customer return service signal is present at the SN ground terminal at the start time of the return service support period)	Sum of the following: 1. PN (DG1 only) and carrier acquisition time 2. Symbol/Decoder synchronization time or Symbol/Deinterleaver/Decoder synchronization time (if deinterleaving is applicable)	

Table 5-8. TDRSS MA Return Service (cont'd)

Parameter (Note 7)	**Description** (Note 7)	
Acquisition (note 3) (cont'd):		
PN Code (if applicable) and Carrier Acquisition		
P_{rec}	PFOV	LEOFOV
F3-F7 and K, L, M	≥-192.2 dBW or consistent with the P_{rec} for BER, whichever is greater	≥-193.1 dBW or consistent with the P_{rec} for BER, whichever is greater
F8 cold, F9, F10 (note 6)	≥-193.7 dBW or consistent with the P_{rec} for BER, whichever is greater	≥-195.0 dBW or consistent with the P_{rec} for BER, whichever is greater
F8 hot (note 6)	≥-190.3 dBW or consistent with the P_{rec} for BER, whichever is greater	≥-191.7 dBW or consistent with the P_{rec} for BER, whichever is greater
Acquisition Time (P_{acq} ≥ 90%)		
Coherent operations	≤ 1 sec	
Noncoherent operations with frequency uncertainty (note 4):		
≤ ± 700 Hz	≤ 1 sec	
≤ ± 3 kHz	≤ 3 sec	
≤ ± 35 kHz	≤ 3 sec	
Channel Decoder/Symbol Synchronization Acquisition (note 5):		
Minimum data bit transition density	≥ 64 randomly distributed data bit transitions within any sequence of 512 data bits	
Number of consecutive data bits without a transition	≤ 64	
P_{rec} (dBW)	consistent with the P_{rec} for BER	
Acquisition time (in seconds) with > 99% probability:		
Biphase	≤ 1100/(Channel Data Rate in bps)	
NRZ	≤ 6500/(Channel Data Rate in bps)	

Table 5-8. TDRSS MA Return Service (cont'd)

Parameter (Note 7)	**Description** (note 7)
Acquisition (note 3) (cont'd):	
Channel Symbol/Deinterleaver(PCI)/Decoder Synchronization Acquisition (note 5):	
Minimum data bit transition density	$\geq$ 64 randomly distributed data bit transitions within any sequence of 512 data bits
Number of consecutive data bits without a transition	$\leq$ 64
P_{rec} (dBW)	consistent with the P_{rec} for BER
Acquisition time (in seconds) with >99% probability:	
Rate 1/2 coding	Average: $\leq$ 36000/(Channel Data Rate in bps) Maximum: $\leq$ 66000/(Channel Data Rate in bps)
Rate 1/3 coding	Average: $\leq$ 26000/(Channel Data Rate in bps) Maximum: $\leq$ 46000/(Channel Data Rate in bps)
Signal Tracking	
Orbital dynamics	During Free Flight refer to paragraph 5.3.3.3 a During Powered Flight (SMAR only) refer to paragraph 5.3.3.3.b
Reacquisition (powered (SMAR only) and non-powered flight)	refer to paragraph 5.3.3.4
Duty factor	100 percent

Notes:

1. The BER is for a customer platform transmitting a signal on an AWGN channel which complies with the constraints defined in Table 5-11. Refer to Appendix G for a discussion of the additional degradation potentially applicable to TDRSS MA return performance service due to S-band RFI.
2. The required customer P_{rec} must meet the P_{rec} for BER or signal acquisition, whichever is greater. Paragraph 5.3.3.2.b provides the required P_{rec} description for each possible MAR data configuration. Refer to Appendix A, paragraph A.4, for a definition of P_{rec}. The minimum required P_{rec} equations for BER produce the minimum P_{rec} for a given data rate for all possible signal characteristics. CLASS analysis will produce a more accurate performance projection based upon desired customer signal characteristics, such as data rate, data type, and jitter values. The P_{rec} equations for BER include 2 dB for self and mutual interference degradation. Appendix O provides an assessment of self and mutual interference in the TDRSS MA environment at 2287.5 MHz. The amount of self and mutual interference included in a customer's MAR/SMAR link budget should be negotiated with GSFC Code 450. SN support may be possible for customers whose P_{rec} is less than the required P_{rec} for 10^{-5} BER performance; however, such support shall be coordinated through GSFC Code 450. In general, customer platforms should be designed to the most limiting TDRS to ensure SN support can be provided.

Table 5-8. TDRSS MA Return Service (cont'd)

Notes (Cont'd):

3. For PN code (if applicable) and carrier acquisition, the minimum P_{rec} value listed applies to the total $(I+Q)P_{rec}$. For carrier acquisition of SMAR SQPSK DG2 and noncoherent ±35 kHz expanded frequency uncertainty DG2 configurations, the total $(I+Q)P_{rec}$ must be ≥ -183.0 dBW for LEOFOV or ≥ -181.7 dBW for Primary FOV when operating with F8(cold), F9, F10. Similarly, when operating with F8 (hot) the total $(I+Q)P_{rec}$ must be ≥ -179.7 dBW for LEOFOV or ≥ -178.3 dBW for Primary FOV during carrier acquisition of SMAR SQPSK DG2 and noncoherent ±35 kHz expanded frequency uncertainty DG2 configurations. In all cases, acquisition requires the P_{rec} to also be consistent with the P_{rec} required for BER.
4. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of ± 700 Hz. If a customer cannot accurately define their transmit frequency to within ± 700 Hz, a customer can request a reconfiguration which would expand the oscillator frequency search to ± 3 kHz for DG1 and SQPSK DG2 configurations and ± 35 kHz for BPSK and non-staggered QPSK DG2 configurations after the start of service.
5. For symbol/decoder synchronization and symbol/deinterleaver/decoder synchronization, the minimum symbol transition density and consecutive symbols without a transition must meet the specifications defined in Table 5-11. It is recommended that customers use G_2 inversion to increase symbol transition density. Additionally, biphase symbol formatting increases symbol transition density.
6. The F8 spacecraft has some SMA return G/T performance variations due to an MA element array and sunshield proximity problem. The G/T varies based upon the normal daily TDRS diurnal cycle. The hot periods can be predicted and will occur at regular intervals with a total hot period of less than 12 hours/day. Note that F8 is unavailable for normal customer scheduling.
7. All data rate values (and notes which modify these values, based upon specific signal format and encoding restrictions) are to be interpreted as data bit rates, and not as data symbol rates.
8. User ephemeris uncertainty allowance is based upon the assumption of a low eccentricity LEO user orbit. User orbits with high eccentricity and large variations in velocity may need to comply with a more stringent user ephemeris uncertainty.

Table 5-9. Customer Dynamics Supported through TDRSS MAR Service

Parameter	Non-powered Flight Dynamics (MAR and SMAR)	Powered Flight Dynamics (SMAR only)
$\dot{R}$	≤ 12 km/sec	≤ 15 km/sec
$\ddot{R}$	≤ 15 m/sec^2	≤ 50 m/sec^2
$\dddot{R}$	≤ 0.02 m/sec^3	≤ 2 m/sec^3

d. After symbol/decoder and symbol/deinterleaver/decoder synchronization is achieved, MA return service channel data is available at the SN ground terminal interface.

e. To minimize return data loss, it is recommended that the customer platform transmit idle pattern on its data channels until after it has observed (via the user performance data (UPD) data) that the SN ground terminal has completed all of its data channel signal acquisition processes.

f. Requirements for bit error probability and symbol slipping take effect at the time decoder synchronization is achieved.

NOTE:

Acquisition times will be reduced when data and symbol transition density values are higher than the minimum required.

5.3.3.2 Bit Error Rate (BER)

Table 5-8 provides P_{rec} equations that will result in a customer achieving a BER of 10^{-5} for TDRSS compatible signals. The BER P_{rec} equations are applicable for either powered (SMAR only) or non-powered flight dynamics and the following conditions:

a. Data Encoding. Convolutional encoding (rate 1/2 or rate 1/3 (SMAR only)) should be used for all customer platform MA transmissions both to minimize P_{rec} and as an RFI mitigation technique. Detailed coding design is described in Appendix B. Reed-Solomon decoding is available to WDISC customers; typical performance is given in Appendix K.

NOTE:

For all configurations and modes, the SN is capable of providing SMAR support of uncoded links; however, performance is not guaranteed in RFI and must be coordinated with GSFC Code 450.

b. Received Power. P_{rec} is in units of dBW. The customer project, in determining its design requirements for minimum customer spacecraft EIRP, must take into account customer platform transmit antenna pointing losses, the space loss between the customer platform and the TDRS, and the polarization loss incurred between the customer platform transmit antenna and the TDRS receive antenna. The maximum TDRS receive antenna axial ratio is given in Table 5-8 (also refer to Appendix A). For DG1 and DG2 services, the following conditions apply:

1. Balanced Power Single Data Source-Identical Data on the I and Q Channels (DG1 mode 1 and 2 only). For a customer platform synchronously transmitting identical data on the I and Q channels (single data source – identical data) with a balanced I and Q channel power

division, the total (I+Q) P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 5-8, where dr is the single data source data rate. Refer to Appendix B for further information on this data configuration.

2. Balanced Power Single Data Source-Alternate I/Q Bits (SMAR DG1 mode 1 and 2 and DG2). For a customer platform transmitting alternate I and Q data bits from a data source (single data source-alternate I/Q bits), the total (I+Q) P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 5-8, where dr is the single data source data rate prior to separation into the I and Q channels. The Q/I (power) must be equal to 1:1. Refer to Appendix B for further information on this data configuration.

3. Balanced Power Single Data Source-Alternate I/Q Encoded Symbols (SMAR DG2 only). For a customer platform transmitting alternate I and Q encoded symbols from a data source (single data source-alternate I/Q encoded symbols), the total (I+Q) P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 5-8, where dr is the single data source data rate prior to the rate 1/2 encoder. The Q/I (power) must be equal to 1:1. Refer to Appendix B for further information on this data configuration.

4. Unbalanced Power Single Data Source-Identical Data on the I and Q Channels (DG1 mode 1 and 2). For a customer platform synchronously transmitting identical data on the I and Q channels (single data source-identical data) having unbalanced I and Q channel power division, the stronger power channel P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 5-8, where dr is the single data source data rate. The weaker power channel P_{rec} need not be consistent with the P_{rec} for a 10^{-5} BER listed in Table 5-8. The Q/I (power) must not exceed 4:1. Refer to Appendix B for further information on this data configuration.

5. Dual Data Sources (DG1 and SMAR DG2). For a customer platform transmitting independent data on the I and Q channels (dual data sources), each channel's P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 5-8, where dr is that channel's data rate. Refer to Appendix B for further information on this data configuration.

6. Single Data Source with Single Data Channel (DG1 modes 1 and 2 and SMAR DG2). For a customer platform transmitting one channel, the P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 5-8, where dr is the channel data rate. Refer to Appendix B for further information on this data configuration.

c. Customer Degradations. Further reductions in the TDRSS MA return service performance identified in Table 5-8 can occur. The TDRSS MA return service will also be degraded due to RFI (refer to Appendix G). The TDRSS MA return services and tracking services will be provided without degradation for user customer platform transmitted signal characteristics within the constraints specified in Table 5-11. Customer platform parameters exceeding these constraints can also degrade TDRSS MA return service performance. Refer to

Section 3, paragraph 3.5 for guidelines if the constraints in this paragraph cannot be met. Definitions of user customer platform constraints are given in Appendix E.

d. Multipath. The SN ground terminal will provide lockup and interference protection from multipath signals reflected from the Earth.

e. Periodic Convolutional Interleaving. At baud rates above 300 kbps, symbol interleaving of the customer platform transmission is recommended for DG1 mode 3 and DG2 signals. Biphase symbol formats are not allowed with PCI. When interleaving is not employed at baud rates above 300 kbps, S-band performance may not be guaranteed. Deinterleaving is not supported for baud rates $\leq$ 300 kbps. The functional description of the (30,116) periodic convolutional interleaving of either rate 1/2 or rate 1/3 convolutional encoder symbols, which will be used when identified in the SHO, is defined in Appendix F.

5.3.3.3 Signal Tracking

TDRSS provides MA return signal tracking (carrier, PN, symbol synchronization, convolutional deinterleaver synchronization, Viterbi decoder synchronization) for both powered (SMAR only) and non-powered flight dynamics. During a customer MA return service support period, loss-of-lock (carrier, symbol synchronization, and Viterbi decoder) indications appear in the periodically updated UPD (every 5 seconds).

a. Non-powered Flight Dynamics. For all valid return service signals operating under non-powered flight dynamics, the MA return service shall maintain signal tracking for the following conditions:

1. Cycle Slips. The mean-time-between-cycle slip in the SN ground terminal carrier tracking loop for each TDRSS MA return service is 90 minutes, minimum. This value applies at carrier tracking threshold, which is 3 dB less than the minimum P_{rec} required for BER, and increases exponentially as a function of linear dB increases in P_{rec}. Cycle slips may result in channel and/or data polarity reversal. The SN ground terminal can correct for these reversals under the same conditions as the SN ground terminal can resolve channel and/or data polarity ambiguity as discussed in Appendix B. The time for the SN ground terminal to recover from a cycle slip will be consistent with the time required for the SN ground terminal receiver to detect and automatically reacquire the signal.

2. Bit Slippage. For each TDRSS MA return service operating with a minimum P_{rec} required consistent with the P_{rec} for BER and data transition densities greater than 40% for NRZ symbols or any transition density for biphase symbols, the minimum mean time between slips caused by a cycle slip in the SN ground terminal symbol clock recovery loop is either 90 minutes or 10^{10} symbol periods, whichever is greater. For an MA return service operating with 1 dB more than the minimum P_{rec} required for BER, and NRZ symbol transition densities between 25% and 40%, the

minimum mean time between slips is either 90 minutes or 10^{10} symbol periods, whichever is greater.

3. Loss of Symbol Synchronization. For each TDRSS MA return service with data transition densities greater than 40% for NRZ symbols and any transition density for biphase symbols, the SN ground terminal symbol synchronization loop will not unlock for a P_{rec} that is 3 dB less than the minimum P_{rec} required for BER. For NRZ symbol transition densities between 25% and 40%, the SN ground terminal symbol synchronizer loop will not unlock for a P_{rec} that is 2 dB less than the minimum P_{rec} required for BER. In both cases, BER performance will be degraded when the P_{rec} is less than the minimum P_{rec} required for BER.

b. Powered Flight Dynamics (SMAR only). TDRSS will provide signal tracking with a probability of more than 0.99 over 90 minutes for a customer with powered flight dynamics and an ephemeris uncertainty as defined in Table 5-8. This value applies at the carrier tracking threshold. For F8 (cold), F9, F10, the carrier tracking threshold for DG1 signals is a minimum P_{rec} of –193.5 dBW for LEOFOV, –192.2 dBW for PFOV, or the minimum P_{rec} for BER, whichever is greater. For F8 (hot), the carrier tracking threshold for DG1 signals is a minimum P_{rec} of –190.2 dBW for LEOFOV, –188.8 dBW for PFOV, or the minimum P_{rec} for BER, whichever is greater. For F8 (cold), F9, F10, the carrier tracking threshold for DG2 signals is a minimum P_{rec} of –187.4 dBW for LEOFOV, –186.1 dBW for PFOV, or the minimum P_{rec} for BER, whichever is greater. For F8 (hot), the carrier tracking threshold for DG2 signals is a minimum P_{rec} of –184.1 dBW for LEOFOV, –182.7 dBW for PFOV, or the minimum P_{rec} for BER, whichever is greater.

NOTE:

The F8 spacecraft has some SMA return G/T performance variations due to an MA element array and sunshield proximity problem. The G/T varies based upon the normal daily TDRS diurnal cycle. The hot periods can be predicted and will occur at regular intervals with a total hot period of less than 12 hours/day. Note that F8 is unavailable for normal customer scheduling.

5.3.3.4 Reacquisition

While in the PN/carrier tracking state, a loss of lock condition induced by a cycle slip will be automatically detected and a reacquisition will be automatically initiated. For a customer platform that continues to transmit the minimum P_{rec} for acquisition and maintains an ephemeris uncertainty as defined in Table 5-8, the normal total channel reacquisition time for either powered or non-powered flight dynamics will be less than or equal to that for the initial total channel acquisition for non-powered flight dynamics, with a probability of at least 0.99. If lock is not achieved within 10 seconds of loss of lock, an acquisition failure notification will be sent to the MOC and the SN ground terminal will reinitiate the initial service acquisition process. TDRSS MA return service does not support acquisition of customers with powered flight dynamics. Upon receipt of the loss-of-lock indications in the UPD, the customer MOC may request a TDRSS MA return service reacquisition GCMR (refer to Section 10). It is recommended that the customer MOC delay initiation of the GCMR for at least 35 seconds after initial receipt of the loss-of-lock indications in the UPD.

5.3.3.5 Additional Service Restrictions

a. Sun Interference. The TDRSS MA return service performance will not be guaranteed when the center of the sun is within 3 degrees (MAR) or 4 degrees (SMAR) of the TDRS MA receiving antenna boresight; however, this sun interference checking is a customer MOC responsibility. Additionally, the TDRSS MA return service performance will not be guaranteed when the center of the sun is within 1 degree of the boresight of the SN ground terminal receiving antenna supporting the TDRS.

b. Frequency and Polarization. The TDRSS MA return service requires a customer platform to transmit at 2287.5 MHz with LHC polarization (refer to Appendix D for power level restrictions into the 2290-2300 MHz band and NASA/GSFC Recommended Filtering).

5.3.4 Real-Time Configuration Changes

Changes to the operating conditions or configuration of a TDRSS MA return service during a scheduled service support period are initiated by a GCMR from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the GCMR at the SN ground terminal. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning the SN ground terminal response times for GCMRs is provided in Section 10. Table 5-10 lists the MA return service real-time configuration changes and their effects on the return service.

Table 5-10. MA Return Service Real-Time Configuration Changes

Real-Time Configuration Changes	GCMR	OPM	Return Service Interruption
Return Service Reacquisition	98/03	OPM 03	Yes
Noncoherent Expanded User Spacecraft Frequency Uncertainty	98/07	OPM 07	No
Channel Data Rate	98/04	OPM 03	No
Noncoherent Transmit Frequency	98/04	OPM 03	Yes
Redefinition of minimum customer EIRP	98/04	OPM 03	Yes
Redefinition of maximum customer EIRP	98/04	OPM 03	No
I/Q Power Ratio	98/04	OPM 03	Yes
Channel Data Format	98/04	OPM 03	No
Channel Data Bit Jitter	98/04	OPM 03	No
DG1 Mode	98/04	OPM 03	Yes
Data Group (SMAR only)	98/04	OPM 03	Yes
DG2 Coherency (coherent or noncoherent) (SMAR only)	98/04	OPM 03	Yes
Periodic Convolutional Interleaving (SMAR only)	98/04	OPM 03	No
DG2 Carrier Modulation (SMAR only)	98/04	OPM 03	Yes
Data Source/Channel Configuration	98/04	OPM 03	Yes
G_2 inversion	98/04	OPM 03	No
Frame Length	98/04	OPM 03	No
Frame Sync Word Length	98/04	OPM 03	No
Frame Sync Word Bit Pattern	98/04	OPM 03	No
Sync Strategy Parameters	98/04	OPM 03	No

Note:
Items that are indicated to cause return service interruption will cause the SN ground terminal receiver to discontinue signal tracking and attempt to reacquire the return service signal after the appropriate reconfiguration. Additionally, any reconfigurations to the forward service that cause forward link interruption will also cause return interruption for coherent return links. Any other reconfigurations of the SN ground terminals may momentarily affect signal tracking.

5.3.5 Acquisition Scenarios

The following acquisition scenarios identify only the technical aspects of TDRSS MA return service signal acquisition by the SN ground terminal and do not include operational procedures related to acquisition. Acquisition is dependent upon the customer providing an ephemeris with a maximum uncertainty as defined in Table 5-8.

a. Coherent Modes (DG1 Mode 1, DG1 Mode 3 (SMAR only), and DG2 Coherent (SMAR only))

   1. For optimal TDRSS performance, all coherent services should have the TDRSS forward and return services starting at the same time. If operational considerations require starting the TDRSS forward service before the return service, no reconfigurations of the forward service can be sent within 30 seconds of the start of the return service. A forward link sweep request operations message (OPM) cannot be sent within 150 seconds of the start of the return service.
   2. The customer platform P_{rec} must be compatible with the minimum P_{rec} required for BER and the other TDRSS MA return service signal parameters listed in Table 5-8.
   3. The SN ground terminal will adaptively point the spatially formed TDRSS MA antenna beam in the direction of the customer platform.
   4. At the service start time specified by the SHO, the SN ground terminal will begin the search for the customer platform signal based upon predicted range and Doppler. The SN ground terminal corrects the received customer platform signal for Doppler to allow for SN ground terminal implementation of receivers with narrow acquisition and tracking bandwidths. The Doppler correction used by SN ground terminals is either one-way return (Forward Doppler compensation enabled) or two-way (Forward Doppler compensation inhibited). For coherent operation, the Doppler correction is based upon the forward service frequency.
   5. After the forward service has been acquired, the SN ground terminal will acquire the customer platform signal (PN code (applicable to DG1 only) and carrier) within the time listed in Table 5-8. Return service will be achieved at the SN ground terminal receiver output within the total channel acquisition time limits listed in Table 5-8, which includes the SN ground terminal symbol, deinterleaver (if applicable), and Viterbi decoder synchronization.

b. Noncoherent (DG1 Mode 2 and DG2 Noncoherent (SMAR only))

   1. This mode of customer platform operation does not require that a TDRSS (MA or SSA) forward service signal be received by the customer platform. However, the customer platform transmitter must be commanded to turn on when noncoherent transmissions are desired, either by stored commands, on-board configuration settings, or direct commands from its customer MOC.

2. The customer platform P_{rec} must be compatible with the minimum P_{rec} required for BER and the other TDRSS MA return service signal parameters listed in Table 5-8.
3. The SN ground terminal will adaptively point the spatially formed TDRS MA antenna beam in the direction of the customer platform.
4. At the service start time specified by the SHO, the SN ground terminal will begin the search for the customer platform signal based upon predicted Doppler. The SN ground terminal corrects the received customer platform signal for Doppler to allow for SN ground terminal implementation of receivers with narrow acquisition and tracking bandwidths. The Doppler correction used by SN ground terminals is one-way return and based on the customer platform transmission frequency stated in the SHO and any subsequent OPMs.
5. The SN ground terminal will acquire the customer platform signal (PN code (applicable to DG1 only) and carrier) within the time limits listed in Table 5-8. Return service will be achieved at the SN ground terminals receiver output within the total acquisition time limits listed in Table 5-8, which includes the SN ground terminal symbol and Viterbi decoder synchronization.

c. DG1 Mode Transitions.

1. DG1 Mode 2 to DG1 Mode 1 Transition. A TDRSS (MA or SSA) forward service must be scheduled to be established prior to customer MOC transmission of the GCMR to reconfigure the TDRSS for DG1 mode 1 operations (refer to paragraph 5.3.5.a (1)).
2. DG1 Mode 1 to DG1 Mode 2 Transitions. When the customer platform switches to the noncoherent mode (DG1 mode 2), customer platform return service signal parameters (e.g., carrier and channel PN codes) are changed causing the SN ground terminal to drop TDRSS MA return service signal lock. Customer platform transponders designed to automatically switch from a coherent transponder mode to a noncoherent mode when the TDRSS SSA/MA forward service signal is lost will result in SN ground terminal loss of MA return service signal lock. Reconfiguration and reacquisition by the SN ground terminal is required and must be initiated by a GCMR from the customer MOC.

NOTE:

Failure to observe these conventions may result in the SN ground terminal rejection of reconfiguration messages, excessive acquisition times, and unnecessary loss of customer platform return service data.

d. DG2 Mode Transitions.

1. DG2 noncoherent to DG2 coherent Transitions. A TDRSS (MA or SSA) forward service must be scheduled to be established prior to customer MOC transmission of the GCMR to reconfigure the TDRSS for DG2 coherent operations (refer to paragraph 5.3.5.a (1)).

2. DG2 coherent to DG2 noncoherent Transitions. When the customer platform switches to the noncoherent mode, the resulting customer transmit frequency offset will probably cause the SN ground terminal to drop TDRSS MA return service signal lock when the switch is made. If return service signal lock is lost, reconfiguration and reacquisition by the SN ground terminal is required and must be initiated by a GCMR from the customer MOC.

NOTE:

Failure to observe these conventions may result in the SN ground terminal rejection of reconfiguration messages, excessive acquisition times, and unnecessary loss of customer platform return service data.

Table 5-11. TDRSS MA Return Service Customer Platform Signal Constraints

Parameters (Notes 1, 2, and 13)	**Description** (Notes 1, 2, and 13)
Minimum channel data bit transition density (required for acquisition/reacquisition)	≥ 64 randomly distributed data bit transitions within any sequence of 512 data bits
Consecutive channel data bits without a bit transition (required for acquisition/reacquisition)	≤ 64
Minimum channel symbol transition density (Note 3)	≥128 randomly distributed symbol transitions within any sequence of 512 symbols
Consecutive channel symbols without a symbol transition	≤ 64 symbols
Symbol asymmetry (peak)	≤ ± 3 percent
Symbol jitter and jitter rate	≤ 0.1 percent
Phase imbalance	
DG1 modes 1 and 2	≤ ± 5 degrees
DG1 mode 3 (applicable to SMA only)	
Q channel baud rate ≤ 1.024 Msps	≤ ± 5 degrees
Q channel baud rate > 1.024 Msps	≤ ± 3 degrees
DG2 (applicable to SMA only)	
BPSK	
Baud rate ≤ 1.024 Msps	≤ ± 9 degrees
Baud rate > 1.024 Msps	≤ ± 3 degrees
QPSK	
Baud rate per channel ≤ 1.024 Msps	≤ ± 5 degrees
Baud rate per channel > 1.024 Msps	≤ ± 3 degrees
Gain imbalance	
DG1 modes 1 and 2	≤ ± 0.50 dB
DG1 mode 3 (applicable to SMA only)	
Q channel baud rate ≤ 1.024 Msps	≤ ± 0.50 dB
Q channel baud rate > 1.024 Msps	≤ ± 0.25 dB
DG2 (applicable to SMA only)	
BPSK	
Baud rate ≤ 1.024 Msps	≤ ± 1.0 dB
Baud rate > 1.024 Msps	≤ ± 0.25 dB
QPSK	
Baud rate per channel ≤ 1.024 Msps	≤ ± 0.50 dB
Baud rate per channel > 1.024 Msps	≤ ± 0.25 dB

Table 5-11. TDRSS MA Return Service Customer Platform Signal Constraints (cont'd)

Parameters (Notes 1, 2, and 13)	**Description** (Notes 1, 2, and 13)
Phase nonlinearity (applies for all types of phase nonlinearities) (peak) (Note 11)	
DG1 modes 1 and 2	≤ 4 degrees over ±2.1 MHz
DG1 mode 3 (applicable to SMA only)	
Q channel baud rate ≤ 1.024 Msps	≤ 4 degrees over ±2.1 MHz
Q channel baud rate > 1.024 Msps	≤ 3 degrees over ±2.1 MHz
DG2 (applicable to SMA only)	
Baud rate per channel ≤ 1.024 Msps	≤ 4 degrees over ±1.0 MHz
Baud rate per channel > 1.024 Msps	≤ 3 degrees over ±2.1 MHz
Gain flatness (peak) (Note 11)	
DG1 modes 1 and 2	≤ 0.4 dB over ±2.1 MHz
DG1 mode 3 (applicable to SMA only)	
Q channel baud rate ≤ 1.024 Msps	≤ 0.4 dB over ±2.1 MHz
Q channel baud rate > 1.024 Msps	≤ 0.3 dB over ±2.1 MHz
DG2 (applicable to SMA only)	
Baud rate per channel ≤ 1.024 Msps	≤ 0.4 dB over ±1.0 MHz
Baud rate per channel > 1.024 Msps	≤ 0.3 dB over ±2.1 MHz
Gain slope (peak) (Note 11)	
DG1 modes 1 and 2	Not specified
DG1 mode 3 (applicable to SMA only)	
Q channel baud rate ≤ 1.024 Msps	Not specified
Q channel baud rate > 1.024 Msps	≤ 0.1 dB/MHz over ±2.1 MHz
DG2 (applicable to SMA only)	
Baud rate per channel ≤ 1.024 Msps	Not specified
Baud rate per channel > 1.024 Msps	≤ 0.1 dB/MHz over ±2.1 MHz
AM/PM	
DG1 modes 1 and 2	≤ 15 degrees/dB
DG1 mode 3 (applicable to SMA only)	
Q channel baud rate ≤ 1.024 Msps	≤ 15 degrees/dB
Q channel baud rate > 1.024 Msps	≤ 12 degrees/dB

Table 5-11. TDRSS MA Return Service Customer Platform Signal Constraints (cont'd)

Parameters (Notes 1, 2, and 13)	**Description** (Notes 1, 2, and 13)
AM/PM (cont'd):	
DG2 (applicable to SMA only)	
Baud rate per channel ≤ 1.024 Msps	≤ 15 degrees/dB
Baud rate per channel > 1.024 Msps	≤ 12 degrees/dB
Noncoherent frequency stability (peak) (Notes 4, 5, 10)	
±700 Hz customer oscillator frequency uncertainty	
1-sec average time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 1 \times 10^{-7}$
48-hr observation time	$\leq 3 \times 10^{-7}$
± 3 kHz customer oscillator frequency uncertainty	
1-sec average time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 4.3 \times 10^{-7}$
48-hr observation time	$\leq 1.29 \times 10^{-6}$
± 35 kHz customer oscillator frequency uncertainty	
1-sec average time	
Baud rate per channel ≤ 12.5 ksps	$\leq 7.37 \times 10^{-9}$
Baud rate per channel > 12.5 ksps	$\leq 26 \times 10^{-9}$
5-hr observation time	$\leq 3.77 \times 10^{-6}$
48-hr observation time	$\leq 11.3 \times 10^{-6}$
Incidental AM (peak):	
At frequencies ≥10 Hz for data rates <1 kbps; at frequencies >100 Hz for data rates ≥1 kbps	≤ 5 percent
Spurious PM (rms)	
DG1	≤ 2 degrees
DG2 (applicable to SMA only)	
BPSK	≤ 2 degrees
QPSK	
I/Q = 4:1	≤ 2 degrees
I/Q = 1:1	≤ 1 degree

Table 5-11. TDRSS MA Return Service Customer Platform Signal Constraints (cont'd)

Parameters (Notes 1, 2, and 13)	**Description** (Notes 1, 2, and 13)
Minimum 3-dB bandwidth prior to power amplifier	
DG1	≥ 4.5 MHz or two times maximum baud rate, whichever is larger
DG2 (applicable to SMA only)	≥ 2 times maximum channel baud rate
Phase noise (rms) (Note 6 and 7)	
DG1 Mode 1 (Note 12)	
Channel baud rate < 18 ksps	
1 Hz – 10 Hz	≤1.8° rms
10 Hz – 1 kHz	≤1.5° rms
1 kHz – 3 MHz	≤1.5° rms
Channel baud rate ≥ 18 ksps	
1 Hz – 10 Hz	≤ 25.0° rms
10 Hz – 1 kHz	≤ 2.5° rms
1 kHz – 3 MHz	≤ 2.0° rms
DG1 Mode 2	
Channel baud rate < 18.5 ksps	
1 Hz – 10 Hz	≤ 3.8° rms
10 Hz – 100 Hz	≤ 1.8° rms
100 Hz – 1 kHz	≤ 1.4° rms
1 kHz – 3 MHz	≤ 1.4° rms
Channel baud rate ≥ 18.5 ksps	
1 Hz – 10 Hz	≤ 22.0° rms
10 Hz – 100 Hz	≤ 2.2° rms
100 Hz – 1 kHz	≤ 1.4° rms
1 kHz – 3 MHz	≤ 1.4° rms

Table 5-11. TDRSS MA Return Service Customer Platform Signal Constraints (cont'd)

Parameters (Notes 1, 2, and 13)	**Description** (Notes 1, 2, and 13)
Phase noise (rms) (Note 6 and 7) (cont'd)	
DG1 Mode 3 (applicable to SMA only) (Note 12)	
Channel baud rate < 222.5 ksps	
1 Hz – 10 Hz	≤ 4.0° rms
10 Hz – 1 kHz	≤ 2.8° rms
1 kHz – 6 MHz	≤ 1.4° rms
Channel baud rate ≥ 222.5 ksps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 1 kHz	≤ 5.5° rms
1 kHz – 6 MHz	≤ 1.8° rms
DG2 Coherent (applicable to SMA only) (Note 12)	
Channel baud rate < 18 ksps	
1 Hz – 10 Hz	≤3.8° rms
10 Hz – 1 kHz	≤2.3° rms
1 kHz – 3 MHz	≤2.0° rms
18 kbps ≤ Channel baud rate ≤ 1.024 Msps	
1 Hz – 10 Hz	≤25.0° rms
10 Hz – 1 kHz	≤2.5° rms
1 kHz – 3 MHz	≤2.0° rms
Channel baud rate > 1.024 Msps	
1 Hz – 10 Hz	≤5.0° rms
10 Hz – 1 kHz	≤1.0° rms
1 kHz – 3 MHz	≤0.5° rms
DG2 Noncoherent (applicable to SMA only)	
Channel baud rate < 12.5 ksps	
1 Hz – 10 Hz	≤ 5.0° rms
10 Hz – 100 Hz	≤ 1.0° rms
100 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 3 MHz	≤ 2.0° rms

Table 5-11. TDRSS MA Return Service Customer Platform Signal Constraints (cont'd)

Parameters (Notes 1, 2, and 13)	**Description** (Notes 1, 2, and 13)
Phase noise (rms) (Note 6 and 7) (cont'd)	
DG2 Noncoherent (applicable to SMA only) (cont'd)	
12.5 ksps ≤ Channel baud rate ≤ 1.024 Msps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 100 Hz	≤ 5.5° rms
100 Hz – 1 kHz	≤ 2.4° rms
1 kHz – 3 MHz	≤ 2.4° rms
Channel baud rate > 1.024 Msps	
1 Hz – 10 Hz	≤ 10.0° rms
10 Hz – 100 Hz	≤ 1.5° rms
100 Hz – 1 kHz	≤ 0.5° rms
1 kHz – 3 MHz	≤ 0.5° rms
In-band spurious outputs, where in-band is twice the maximum channel baud rate	
DG1 modes 1 and 2	≥ 23 dBc
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≥ 23 dBc
Q channel baud rate > 1.024 Msps	≥ 30 dBc
DG2	
Baud rate per channel ≤ 1.024 Msps	≥ 23 dBc
Baud rate per channel > 1.024 Msps	≥ 30 dBc
Out-of-band emissions	See Appendix D for NASA/GSFC Recommended Filtering in the 2290-2300 MHz band and allowable limits on out-of-band emissions, including spurs
I/Q symbol skew (relative to requirements of I/Q data synchronization where appropriate) (peak)	≤ 3 percent
I/Q PN chip skew (relative to 0.5 chip)	≤ 0.01 chip
PN chip rate (peak), DG1 mode 2 (relative to absolute coherence with carrier rate)	≤ 0.01 chips/sec at PN code chip rate
Customer-induced PN correlation loss (noncoherent and coherent)	≤ 0.3 dB
Customer Antenna-Induced PM	≤ 10 degrees
Data rate tolerance	≤ ±0.1 percent
I/Q power ratio tolerance	≤ ±0.4 dB
Permissible P_{rec} variation without reconfiguration GCMR from customer MOC) (Note 8)	≤12 dB
Permissible rate of P_{rec} variation	≤10 dB/sec

Table 5-11. TDRSS MA Return Service Customer Platform Signal Constraints (cont'd)

Parameters (Notes 1, 2, and 13)	**Description** (Notes 1, 2, and 13)
Maximum P_{rec}	
For support through F3-F7 and K, L, M	-161.2 dBW
For support through F8-F10	-149 dBW

Notes:

1. The definitions and descriptions of the customer constraints are provided in Appendix E.
2. When a constraint value is listed for a baud rate range and data is transmitted on both channels, the maximum baud rate of the 2 channels should be used to determine the constraint value applicable.
3. It is recommended that customers use G_2 inversion to increase symbol transition density. Additionally, biphase symbol formatting increases symbol transition density. CCSDS randomization is recommended to aid in compliance with the data randomness requirements.
4. The frequency stability requirements are valid at any constant temperature (±0.5° C) in the range expected during the mission. At a minimum, a temperature range of -10° C to +55° C shall be considered.
5. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of ± 700 Hz. If a customer cannot accurately define their transmit frequency to within ± 700 Hz, a customer can request a reconfiguration which would expand the oscillator frequency search to ± 3 kHz for DG1 and SQPSK DG2 configurations and ± 35 kHz for BPSK and QPSK DG2 configurations after the start of service.
6. Derivation of the phase noise requirements involved making assumptions about the distribution of the phase noise power in each frequency region. Since no phase noise PSD will exactly match the phase noise power distribution assumed for this derivation, phase noise PSDs which are close to violating the phase noise limits or phase noise PSDs which violate the phase noise limits should be evaluated on a case-by-case basis to determine their acceptability.
7. For customers receiving Doppler tracking services, more stringent phase noise constraints should be considered by the customer. It is the responsibility of the customer to ensure customer transponder / transmitter phase noise performance enables achievement of the desired total Doppler tracking error performance. Appendix U provides recommended customer phase noise performance constraints which ensure a total Doppler tracking error (system + customer) ≤ 0.2 rad/sec (1σ, channel data rate > 1 kbps) or ≤ 0.4 rad/sec (1σ, channel data rate ≤ 1 kbps) assuming an averaging time of 1 second.
8. The minimum SHO EIRP should reflect the minimum P_{rec} expected over the service period, where the P_{rec} can exceed this minimum by no more than 12 dB. An actual customer P_{rec} value that is 12 dB greater than the minimum may cause false PN lock or nonacquisition.
9. Deleted.
10. Deleted.
11. Bandwidth limitation for gain flatness, phase nonlinearity and gain slope while maintaining consistency with NTIA spectral emission mask (Appendix D):70% of the signal main lobe width or 70 % of the necessary bandwidth whichever is smaller.
12. Coherent return link phase noise user constraint assumes a forward service signal with no phase noise on it. Phase noise created in the user receiver carrier tracking loop by thermal noise on the forward link is a component which must be considered as a contributor to the user coherent return service phase noise.
13. Customers are recommended to provide to the SN a transmitter EVM measurement for each of their service modes.

Section 6. SSA Telecommunications Services

6.1 General

6.1.1 Available Services

TDRSS SSA services include forward and return telecommunications services, and tracking services. SSA return service includes service through the SN receive equipment and an automated IF service, where SN IF services are available to customers on a case-by-case basis, IF service requires the customer to provide the receiver equipment and the SN only provides the signal at the IF. Tracking services are discussed in Section 9. This section focuses on the RF interface between the TDRS and the customer platform. This interface is characterized by the technical requirements imposed and the operational capabilities provided by the TDRSS. The operational interfaces are described in further detail in Section 10. Data interfaces between the customer MOC and the SN are described in Section 3, paragraph 3.6.

NOTE:

The NCCDS issues NAMs to provide up-to-date information on network conditions and constraints. These messages are accessible via the NCCDS active NAM web site at https://cds.gsfc.nasa.gov/. The GSFC Code 450 uses the NAMs as a means of letting customers know of any performance constraints associated with the TDRS spacecraft. Additionally, TDRS constellation information can be found in the TDRS Constellation Management Plan, 452-PLAN-0002.

6.1.2 Interface Definition

The RF interface between the TDRS and a customer platform is defined in terms of signal parameters, RF characteristics, and field of view.

a. The RF interface for forward service represents the transmission by a TDRS of an appropriately modulated signal at or greater than a minimum signal EIRP in the direction of the desired customer platform. SSA forward (SSAF) service is discussed in paragraph 6.2.

b. The RF interface for return service defines a minimum received power (P_{rec}) at the TDRS antenna input for a specified data quality at the SN ground terminal receiver output. SSAR service is discussed in paragraph 6.3.

NOTE:

The SSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.

6.1.3 Customer Acquisition Requirements

Acquisition and reacquisition by the customer platform of the TDRS transmitted signal requires prediction by the customer MOC of the customer platform receive frequency over various projected time periods. Similarly, acquisition and reacquisition by the SN ground terminal of the customer platform signal requires prediction by the customer MOC of the customer platform transmitter frequency over various projected time periods. The frequency predictions are ultimately incorporated in the SHO as customer platform frequencies for the specific service support periods. Refer to Section 9 for additional information on TDRSS tracking services that can assist customers in predicting their local oscillator frequencies.

6.1.4 TDRSS Acquisition Support to Customers

For each scheduled TDRSS service support period, the customer requirements for signal acquisition/reacquisition and the TDRSS capabilities to aid acquisition/reacquisition are as follows:

a. Customer Epoch Uncertainty. The maximum epoch uncertainty of the customer platform ephemeris supplied to the TDRSS should be ±9 seconds for the SSA PFOV and ±7.8 seconds for the SSA F8 – F10 and K, L, M extended EEFOV as defined in Table 6-2 for SSAF and Table 6-9 for SSAR services.

b. Customer Frequency Uncertainty. The customer MOC must know the operating frequency of the customer platform to within ±700 Hz.

c. Forward Frequency Sweep. After the start of the forward link service, the TDRSS has a forward service frequency sweep capability of ±3 kHz for the phase-shift key (PSK) modulation services and a sweep capability of up to ±600 kHz for the phase modulation (PM) services.

d. Noncoherent Return Expanded Frequency Search. After the start of the noncoherent return link service, the TDRSS has a return service expanded frequency search capability to accommodate a customer platform's operating frequency uncertainty of up to ±3 kHz for the DG1 and SQPSK DG2 services and up to ±35 kHz for the BPSK and non-staggered QPSK DG2 services.

6.2 SSA Forward Services

6.2.1 General

The characteristics of the data provided to the SN ground terminal interface and the RF signals provided by the TDRS to the customer platform during TDRSS SSA forward services are described in paragraphs 6.2.2 through 6.2.6. This discussion assumes that an appropriate forward service has been scheduled and a data signal is present at the SN ground terminal interface.

For SSA, this document refers to two general modulation categories as follows:

a. PSK modulation: refer to paragraph 6.2.2 for specific signal parameters

b. Phase modulation (PM): refer to paragraph 6.2.3 for specific signal parameters

6.2.2 PSK Signal Parameters

The TDRSS SSA forward PSK signal parameters are defined in Table 6-1. The center frequency, f_O, of the customer platform receiver must be defined by the customer MOC in its service specification code for TDRSS SSA forward service (refer to Section 10, paragraph 10.2.2). A description of the features inherent in the QPSK and BPSK signal parameters listed in Table 6-1 are discussed in paragraphs 6.2.2.1 and 6.2.2.2, respectively.

6.2.2.1 QPSK Signal Parameters

a. Unbalanced QPSK Modulation (PN Modulation Enabled). The I channel is used to transmit the customer command data and is referred to as the command channel. The Q channel transmits a range signal and is referred to as the range channel. The command channel/range channel power ratio for SS-UQPSK forward service signals is +10 dB. This unbalanced QPSK modulation minimizes the power in the range channel to a level adequate for customer platform range channel acquisition and tracking. This feature increases the power in the command channel by 2.6 dB over that for balanced QPSK modulation without increasing customer platform receiver complexity, increasing customer platform command channel acquisition time, or decreasing TDRSS range tracking accuracy.

b. Spread Spectrum. TDRSS SSA forward services with data rates equal to and below 300 kbps should incorporate spread spectrum modulation techniques to satisfy flux density restrictions imposed on the TDRSS forward services by the NTIA. This modulation scheme includes separate but simultaneous command and range channels. The command channel includes a rapidly acquirable PN code and contains the forward service data. The range channel is acquired separately and contains a PN code which satisfies the range ambiguity resolution requirements. The length of the command channel PN code is 2^{10}-1, where the length of the range channel PN code is 256 times the command channel PN code length. The customer platform command channel acquisition can precede customer platform range channel acquisition; this feature permits rapid acquisition of the range channel by limiting the range channel PN code search to only 256 chip positions while the range channel PN code itself contains 261,888 chips. The PN code chip rate is coherently related to the TDRS transmit frequency in all cases. This feature permits the customer platform receiver to use the receiver PN code clock to predict the received carrier frequency, thereby minimizing receiver complexity and reducing acquisition time. 451-PN CODE-SNIP defines all the salient characteristics for the forward range and command channel PN code libraries. The Agency Spectrum Manager responsible for PN code assignments will allocate a customer platform-unique PN code assignment from these libraries. The GSFC Spectrum Manager is responsible for NASA PN code assignments.

Table 6-1. TDRSS SSA Forward PSK Service Signal Parameters

Parameter	Description
TDRS transmit carrier frequency (Hz)	F
Carrier frequency arriving at customer platform (Hz) (note 1)	F_R
Carrier frequency sweep (note 4)	$\pm$3 kHz
Carrier frequency sweep duration (note 4)	120 seconds
UQPSK (PN modulation enabled)	
$\frac{\text{Command channel radiated power}}{\text{Range channel radiated power}}$	+10 dB
SS-UQPSK Command Channel	
Carrier frequency (Hz)	Transmit carrier frequency (F)
PN code modulation	PSK, $\pm\pi/2$ radians
Carrier suppression	30 dB minimum
PN code length (chips)	$2^{10} - 1$
PN code epoch reference	Refer to 451-PN CODE-SNIP
PN code family	Gold codes
PN code chip rate (chips/sec)	$\frac{31}{221 \times 96} \times F$
Data modulation	Modulo-2 added asynchronously to PN code
Data format (note 2)	Not Applicable
Data rate restrictions (note 2)	0.1 - 300 kbps
SS-UQPSK Range Channel	
Carrier	Command channel carrier frequency delayed $\pi/2$ radians
PN code modulation	PSK $\pm$ $\pi/2$ radians
Carrier suppression	30 dB minimum
PN code chip rate	Synchronized to command channel PN code chip rate
PN code length (chips)	$(2^{10} - 1) \times 256$
PN code epoch reference	All 1's condition synchronized to the command channel PN code epoch.
PN code family	Truncated 18-state shift register sequences

Table 6-1. TDRSS SSA Forward PSK Service Signal Parameters (cont'd)

Parameter	Description
BPSK (PN modulation enabled; also referred to as Spread Spectrum BPSK (SS-BPSK)) (note 5)	
Carrier frequency (Hz)	Transmit carrier frequency (F)
PN code modulation	PSK, $\pm\pi/2$ radians
Carrier suppression	30 dB minimum
PN code length (chips)	$2^{10} - 1$
PN code epoch reference	Refer to 451-PN CODE-SNIP
PN code family	Gold codes
PN code chip rate (chips/sec)	$\frac{31}{221 \times 96} \times F$
Data modulation	Modulo-2 added asynchronously to PN code
Data format (note 2)	Not Applicable
Data rate restrictions (note 2)	0.1 - 300 kbps
BPSK (PN modulation disabled)	
Carrier frequency (Hz)	Transmit carrier frequency (F)
Data modulation	PSK, $\pm\pi/2$ radians
Carrier suppression	30 dB minimum
Data format (note 2)	Not Applicable
Data rate restrictions (notes 2, 3, 6)	300 kbps - 7 Mbps

Notes:

1. The center frequency, f_O, of the customer platform receiver must be defined by the customer MOC in its service specification code to an integral multiple of 10 Hz. The SN ground terminal will round-off the customer receive frequency contained in the SHO to the nearest multiple of 221 Hz. Doppler compensation will be available for $\dot{R} \leq 12$ km/sec. During periods of Doppler compensation, $F_R = f_O \pm E$ Hz, where f_O = nominal center frequency of customer platform receiver as defined by the customer MOC and $E = |e \times f_O \times \ddot{R}/c| + C$; $e \leq \pm 9$ sec is the customer epoch uncertainty, $\ddot{R} \leq 50$ m/sec^2, c is the free space speed of light in m/sec, and C = 400 Hz. If Doppler compensation is inhibited after the start of the forward service, a transition profile will be initiated to slowly change the frequency from the compensate profile to this integer multiple of 221 Hz.

   Forward service Doppler compensation will not increase the effective frequency rate of change seen at the customer receiver more than 28 Hz/sec relative to the frequency for a Doppler-free carrier.
2. For PSK customers, the forward data rate in this table is the baud rate that will be transmitted by the TDRSS (includes all coding and symbol formatting). For non-WDISC customers, forward data conditioning is transparent to the SN. These transparent operations should be performed by the customer prior to transmission to the SN data interface. Refer to Section 3, paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities.

Table 6-1. TDRSS SSA Forward PSK Service Signal Parameters (cont'd)

Notes (cont'd):

3. The SN is capable of supporting BPSK signals at data rates less than 300 kbps; however, its use will be controlled and must be coordinated with GSFC Code 450.
4. After the start of the SSA forward PSK service, if a customer MOC is unable to accurately define f_O (the nominal center frequency of the customer platform receiver), the forward service carrier frequency can be swept. The SSA forward service frequency sweep will be initiated by the SN ground terminal at f_O -3 kHz and linearly swept to f_O +3 kHz in 120 seconds and held at f_O +3 kHz thereafter. The SSA forward service frequency sweep does not impact simultaneous SN ground terminal Doppler compensation of the SSA forward service carrier and PN code rate (if applicable).
5. Customers who operate in a SS-BPSK mode for one service cannot reconfigure any of their Forward Services (i.e., MAF, SMAF, SSAF, KuSAF, or KaSAF) to an SS-UQPSK mode. Contact Code 450 if additional flexibility is required.
6. The NTIA will not grant TDRSS customers an S-band forward service frequency allocation greater than 6 MHz. If a frequency allocation greater than 6 MHz is required, the SN should be notified and the NASA GSFC spectrum manager may petition the NTIA for a temporary waiver.

c. Asynchronous Data Modulation. For data rates ≤ 300 kbps, the forward service data received at the SN ground terminal from the NISN data transport system is directly modulo-2 added by the SN ground terminal to the command channel PN code sequence. The forward service data will be asynchronous with the carrier and the PN code.

NOTE:

When the command channel does not contain any actual forward service data, the forward service command channel signal is the command channel PN code sequence with or without an idle pattern.

d. Functional Configurations. A further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in Appendix B, paragraph B.2.2.

e. Doppler Compensation. The TDRSS SSA forward service carrier frequency (F) and the PN chip rate transmitted by a TDRS can optionally be compensated by the SN ground terminal for Doppler. When compensated, the carrier, F_R, arrives at the customer platform receiving system within a predictable tolerance (E) of f_O as defined in Table 6-1. This feature minimizes the Doppler resolution requirements of the customer platform receiver and is available continuously to facilitate reacquisition by the customer platform in the event of loss of lock of the TDRSS SSA forward service signal. Doppler compensation may be inhibited and the TDRSS will transmit a fixed frequency SSA forward service carrier and PN code chip rate.

6.2.2.2 BPSK Signal Parameters

a. BPSK Modulation (PN Modulation Enabled). The I channel is used to transmit the customer command data and is referred to as the command channel. TDRSS SSA forward services with data rates equal to and below 300 kbps should incorporate spread spectrum modulation techniques to satisfy flux density restrictions imposed on the TDRSS forward services by the NTIA. The command channel includes a rapidly acquirable PN code and contains the forward service data. The PN code chip rate is coherently related to the TDRS transmit frequency in all cases. This feature permits the customer platform receiver to use the receiver PN code clock to predict the received carrier frequency, thereby minimizing receiver complexity and reducing acquisition time. 451-PN CODE-SNIP defines all the salient characteristics for the forward command channel PN code libraries. The Agency Spectrum Manager responsible for PN code assignments will allocate a customer platform-unique PN code assignment from these libraries. The GSFC Spectrum Manager is responsible for NASA PN code assignments.

NOTE:

Customers who operate in a SS-BPSK mode for one service cannot reconfigure any of their Forward Services (i.e., MAF, SMAF, SSAF, KuSAF, or KaSAF) to an SS-UQPSK mode. Contact Code 450 if additional flexibility is required.

b. BPSK Modulation (PN Modulation Disabled). For data rates greater than 300 kbps, there is no PN code modulation and the customer data directly BPSK modulates the carrier by $+\pi/2$ radians.

NOTE:

The SN is capable of supporting non-spread BPSK signals at data rates less than 300 kbps; however, its use will be controlled and must be coordinated with GSFC Code 450.

c. Asynchronous Data Modulation. The forward service data will be asynchronous with the carrier.

NOTE:

When the command channel does not contain any actual forward service data, the forward service command channel signal is carrier only.

d. Functional Configurations. A further description of the functional configurations and data polarity ambiguity is found in Appendix B, paragraph B.2.2.

e. Doppler Compensation. The TDRSS SSA forward service carrier frequency (F) transmitted by a TDRS can optionally be compensated by the SN ground terminal for Doppler. When compensated, the carrier, FR, arrives at the customer platform receiving system within a predictable tolerance (E) of f_O as defined in Table 6-1. This feature minimizes the Doppler resolution requirements of the customer platform receiver and is available continuously to facilitate reacquisition by the customer platform in the event of loss of lock of the TDRSS SSA forward service signal. Doppler compensation may be inhibited and the TDRSS will transmit a fixed frequency SSA forward service carrier.

6.2.3 Phase Modulation (PM) Signal Parameters

The SN is capable of supporting SSA forward phase modulated signals; however, its use will be controlled and must be coordinated with GSFC Code 450. The TDRSS SSA forward residual carrier phase modulation signal parameters are defined in Table 6-2. The center frequency, f_O, of the customer platform receiver must be defined by the customer MOC in its service specification code for TDRSS SSA forward service (refer to Section 10, paragraph 10.2.2). The features inherent in the signal parameters listed in Table 6-2 are as follows:

a. Direct Phase Modulation. The forward service data received at the SN ground terminal from the NISN data transport system directly phase modulates the carrier. The forward service data is asynchronous with the carrier.

NOTE:

For the direct data phase modulation scheme, the modulation index can be $\pi/2$ radians.

When the command channel does not contain any actual forward service data, the forward service command channel signal is carrier only unless the customer is utilizing the SN ground terminal idle pattern feature.

b. PSK Subcarrier Phase Modulation. The forward service data received at the SN ground terminal from the NISN data transport system PSK modulates either a sinewave or squarewave subcarrier, which, in turn, phase modulates the carrier. The forward service data rate is synchronous with the subcarrier frequency.

NOTE:

When the command channel does not contain any actual forward service data, the forward service command channel signal is an unmodulated subcarrier and residual carrier

unless the customer is utilizing the SN ground terminal idle pattern feature.

c. Functional Configurations. A further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in Appendix B, paragraph B.2.3.

Table 6-2. TDRSS SSA Forward Phase Modulation Service Signal Parameters

Parameter	Description	
TDRS transmit carrier frequency (Hz)	F	
Carrier frequency arriving at customer platform (Hz) (note 1)	F_R	
Carrier Frequency Sweep (note 5)	$\pm$10 Hz to $\pm$600 kHz	
Carrier Frequency Sweep Duration (note 5)	1 to 120 seconds	
Direct Phase Modulation (note 3)		
Carrier frequency (Hz)	Transmit carrier frequency (F)	
Modulation index	0.2 to 1.5 radians, or $\pi/2$ radians	
Data modulation (note 4)	Data directly phase modulates the carrier	
Data format (note 2)	NRZ-L, -M, -S	Biphase-L, -M, -S
Data rate restrictions (note 2)	0.125 kbps - 1 Mbps	0.125 kbps - 500 kbps
PSK Subcarrier Phase Modulation (note 3)		
Carrier frequency (Hz)	Transmit carrier frequency (F)	
Data modulation (note 4)	Data PSK modulates a subcarrier	
Subcarrier Type	Squarewave or Sinusoidal	
Subcarrier Frequency	2, 4, 8, or 16 kHz	
Carrier modulation	Linearly phase modulated by the subcarrier	
Carrier Modulation index	0.2 to 1.8 radians	
Data format (note 2)	NRZ-L, -M, -S	Biphase-L, -M, -S
Data rate restrictions (note 2 and subject to subcarrier to data rate ratio restrictions below)	0.125 kbps - 8 kbps	0.125 kbps - 4 kbps
Subcarrier to Data Rate Ratio (R)	$R=2^n$, where n=1, …7	$R=2^n$, where n=2, …7

Notes:

1. The center frequency, f_O, of the customer platform receiver must be defined by the customer MOC in its service specification code to an integral multiple of 10 Hz. The SN ground terminal will round-off the customer receive frequency contained in the SHO to the nearest multiple of 221 Hz. Doppler compensation will be available for $\dot{R} \leq 12$ km/sec. During periods of Doppler compensation, $F_R = f_O \pm E$ Hz, where f_O = nominal center frequency of customer platform receiver as defined by the customer MOC and $E = |e \times f_O \times \ddot{R}/c| + C$; $e \leq \pm 9$ sec is the customer epoch uncertainty, $\ddot{R} \leq 50$ m/sec^2, c is the free space speed of light in m/sec, and C = 400 Hz. Forward service Doppler compensation will not increase the effective frequency rate of change seen at the customer receiver more than 28 Hz/sec relative to the frequency for a Doppler-free carrier.

Table 6-2. TDRSS SSA Forward Phase Modulation Service Signal Parameters (cont'd)

Notes (cont'd):

2. For PM customers, the forward data rate in this table is the uncoded data rate that will be transmitted by the TDRSS, where the baud rate transmitted by TDRSS is equal to the data rate for uncoded NRZ formatted signals and two times the data rate for uncoded Biphase formatted signals. The SN supports data conditioning for WDISC and forward link PM customers; these customer signal characteristics should be discussed with GSFC Code 450 prior to service to determine if the data conditioning will be done at the user MOC or at the SN. Refer to Section 3, paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities.
3. The SN is capable of supporting SSA forward PM signals; however, its use will be controlled and must be coordinated with GSFC Code 450.
4. The SN ground terminal can optionally provide idle pattern.
5. After the start of an SSAF PM service, the carrier frequency will sweep plus and minus the Sweep Range (SR) around the center frequency (CF) in a triangle-wave pattern, sweeping from CF to either extreme in Sweep Duration (SD). At sweep start, all modulation (including subcarrier, when applicable) will be removed. The carrier will sweep from CF to (CF – SR) in SD seconds. The sweep will reverse, sweeping from (CF – SR) to CF in SD seconds; then continue sweeping from CF to (CF + SR), again in SD seconds. The sweep will continue in alternating directions (triangle-wave pattern) until a termination request is received. Upon receipt of the termination request, the sweep will continue until its next arrival at CF and the frequency profile will continue to follow the Doppler compensated frequency profile (if enabled). At sweep termination, modulation will be applied. The SSAF PM service frequency sweep does not impact simultaneous SN ground terminal Doppler compensation of the SSAF service carrier. Figure 6-1 depicts an example PM frequency sweep.

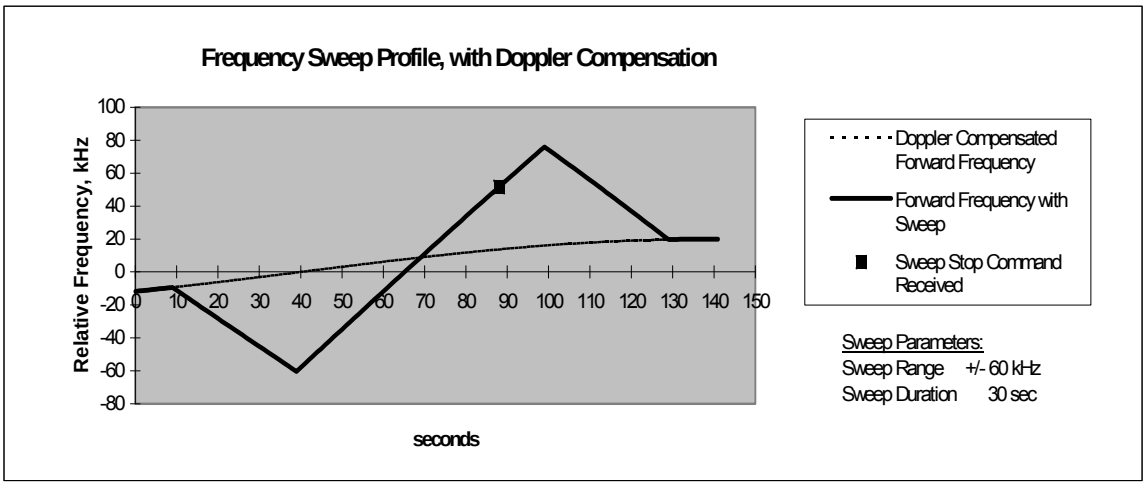

Figure 6-1. Example SSA Forward Phase Modulation Service Frequency Sweep Profile

d. Doppler Compensation. The TDRSS SSA forward service carrier frequency (F) transmitted by a TDRS can optionally be compensated by the SN ground terminal for Doppler. When compensated, the carrier, F_R, arrives at the customer platform receiving system within a predictable tolerance (E) of f_o as defined in Table 6-2. This feature minimizes the Doppler resolution requirements of the customer platform receiver and is available continuously to facilitate reacquisition by the customer platform in the event of loss of lock of the TDRSS SSA forward service signal. Doppler compensation may be inhibited and the TDRSS will transmit a fixed frequency SSA forward service carrier.

6.2.4 Communications Services

The TDRSS SSA forward service parameters are listed in Table 6-3. Table 6-4 lists their salient characteristics. The definitions for the parameters listed in Table 6-4 are contained in Appendix E.

6.2.5 Real-Time Configuration Changes

Changes to the operating conditions or configuration of a TDRSS SSA forward service during a scheduled service support period are usually initiated by a GCMR from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the request at the SN ground terminal. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning SN ground terminal response times for the GCMRs is provided in Section 10. Table 6-5 lists the SSA forward service real-time configuration changes and their effects on the forward service signal.

6.2.6 Acquisition Scenarios

The following acquisition scenarios identify only the technical aspects of TDRSS SSA forward service signal acquisition by the customer platform and do not include operational procedures related to acquisition:

a. The TDRSS SSA forward service signal does not depend on a customer platform return service.

b. Prior to the start of the TDRSS SSA forward service, the TDRSS SSA antenna will be open-loop pointed in the direction of the customer platform.

c. At the start of the TDRSS SSA forward service as defined by the SHO, the TDRS will radiate, in the direction of the customer platform, a signal compatible with the TDRSS SSA forward service signal parameters listed in Table 6-1 (PSK) or Table 6-2 (PM) whichever is applicable. The signal will be transmitted at the scheduled EIRP consistent with the values listed in Table 6-3. The EIRP directed towards the customer platform is dependent upon the customer providing an ephemeris uncertainty within the values defined in Table 6-3. The use of TDRSS SSA forward service high-power operation is restricted and must be coordinated with GSFC Code 450.

Table 6-3. TDRSS SSA Forward Service

Parameter	Description	
Field of view (FOV) (each TDRS) (note 4)	Primary ±22 degrees east-west ±28 degrees north-south	Extended Elliptical (F8-F10 and K, L, M) 24.0 degrees inboard east-west 76.8 degrees outboard east-west ±30.5 degrees north-south
Customer Ephemeris Uncertainty (along the customer orbital track) (note 5)	≤ ± 9 sec	≤ ± 7.8 sec
TDRS antenna polarization (note 1)	Selectable RHC or LHC	
TDRS antenna axial ratio (maximum)		
Normal or high-power mode	1.5 dB over 3 dB beamwidth	
TDRS signal EIRP (minimum)		
Normal power mode	+43.6 dBW	
High power mode (note 3)	+46.3 dBW (F3-F7) +48.5 dBW (F8-F10 and K, L, M)	
Transmit frequency (nominal) (note 2)	Selectable receiver frequency 2025.8 MHz to 2117.9 MHz $[\text{based on } \frac{221}{240} \times (2200 \text{ to } 2300)\text{MHz}]$	
RF bandwidth (3 dB, minimum)	20 MHz	
Duty factor	100 percent	

Notes:

1. Operational considerations may limit choice of TDRS antenna polarization. The SSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.
2. The customer MOC must include the best estimate of the customer platform receiver center frequency at the start time of each scheduled service support period in its service specification code (refer to Section 10, paragraph 10.2.2). The TDRSS SSA forward service carrier frequency is then implemented by the SN ground terminal to the accuracy of the SN ground terminal frequency standard except during Doppler compensation.
3. The SSAF high power mode can be requested via coordination with GSFC Code 450. TDRS F3-F7 may have SSAF EIRP capabilities in excess of 46.3 dBW, but those values may not be guaranteed. The available F3-F7 SSAF EIRP is TDRS-specific and is subject to change.
4. TDRS SA antenna pointing beyond ±13.5°E-W and ±13.5°N-S must be coordinated with GSFC Code 450 due to the potential to significantly impact TDRSS efficiency.
5. User ephemeris uncertainty allowance is based upon the assumption of a low eccentricity LEO user orbit. User orbits with high eccentricity and large variations in velocity may need to comply with a more stringent user ephemeris uncertainty.

Table 6-4. Salient Characteristics for TDRSS SSA Forward Service

Parameter (Note 1)	**PSK Modulation** (Note 1)		**PM Modulation** (Note 1)	
Command channel radiated power / Range channel radiated power	QPSK +10 ±0.5 dB	BPSK NA	NA	
Modulation index accuracy	NA		±10% of the modulation index	
			Direct Data	PSK Subcarrier
Subcarrier frequency accuracy	NA		NA	±0.5 Hz
Data transition and subcarrier coherency	NA		NA	Transitions occur at subcarrier zero crossings within ±1 degree
Modulator phase imbalance (peak)	±3 degrees (for each BPSK channel)		NA	NA
Modulator gain imbalance (peak)	±0.25 dB		±0.25 dB	
Relative phase between command and range channels	QPSK 90 ±3 degrees	BPSK NA	NA	
Data asymmetry (peak) (Note 2)	±3 percent		±3 percent	
			Direct Data	PSK Subcarrier
Phase nonlinearity (peak) (Note 3)				
For baud rates ≤ 128 kbps	±0.15 radian over ±7 MHz		±0.05 radians over ±90 kHz	±0.05 radians over ±90 kHz
For baud rates > 128 kbps	±0.15 radian over ±7 MHz		±0.25 radians over ±1.5 MHz	NA

Table 6-4. Salient Characteristics for TDRSS SSA Forward Service (cont'd)

Parameter (Note 1)	**PSK Modulation** (Note 1)		**PM Modulation** (Note 1)	
Gain flatness (peak) (Note 3)				
For baud rates ≤ 128 kbps	±0.8 dB over ±7 MHz		±0.8 dB over ±90 kHz	±0.8 dB over ±90 kHz
For baud rates > 128 kbps	±0.8 dB over ±7 MHz		±0.8 dB over ±1.5 MHz	NA
Gain slope (peak) (Note 3)				
For baud rates ≤ 128 kbps	±0.1 dB/MHz		±0.005 dB/kHz over ±90 kHz	±0.005 dB/kHz over ±90 kHz
For baud rates > 128 kbps	±0.1 dB/MHz		±0.75 dB/MHz over ±1.5 MHz	NA
AM/PM	≤10 degrees/dB		≤10 degrees/dB	
PN chip jitter (rms) (including effects of Doppler compensation)	QPSK/SS-BPSK ≤1 degree	BPSK NA	NA	
Data clock phase jitter (peak) (Note 2)	≤1 percent		≤1 percent	
Spurious PM (rms)	≤1 degree		≤1 degree	
In-band spurious outputs	≥27 dBc		≥27 dBc	
Incidental AM (peak)	≤2 percent		≤2 percent	
Phase Noise (rms)				
1 Hz - 10 Hz	≤1.5 degrees		≤1.5 degrees	
10 Hz - 32 Hz	≤1.5 degrees		≤1.5 degrees	
32 Hz - 1 kHz	≤4 degrees		≤4 degrees	
1 kHz - 6 MHz	≤2 degrees		≤2 degrees	
	QPSK/SS-BPSK	BPSK		
Command/range channel PN chip skew (peak)	≤0.01 chip / NA	NA	NA	
PN chip asymmetry (peak)	≤0.01 chip	NA	NA	

Table 6-4. Salient Characteristics for TDRSS SSA Forward Service (cont'd)

Parameter (Note 1)	**PSK Modulation** (Note 1)		**PM Modulation** (Note 1)
	QPSK/SS-BPSK	BPSK	
PN chip rate (peak) relative to absolute coherent with carrier rate	≤0.01 chips/sec at PN code chip rate	NA	NA

Notes:

1. The definitions and descriptions of the salient characteristics are provided in Appendix E.
2. These values are the TDRSS contributions for data asymmetry and data clock phase jitter assuming perfect forward service data is provided to the SN ground terminal. The actual contributions by the NISN data transport system are negligible compared to those contributed by the TDRSS, since the SN ground terminal reclocks the data before it is processed by the SN ground terminal into the forward service signal.
3. Bandwidth limitation for gain flatness, phase nonlinearity and gain slope while maintaining consistency with NTIA spectral emission mask (Appendix D): 70% of the signal main lobe width or 70 % of the necessary bandwidth whichever is smaller.

Table 6-5. SSA Forward Service Real-Time Configuration Changes

Real-Time Configuration Changes	**GCMR**	**OPM**	**Forward Service Signal Interruption**
Customer Receiver Center Frequency	98/04	OPM 03	Yes
Doppler Compensation Inhibit	98/08	OPM 11	No
Doppler Compensation Reinitiation	98/04	OPM 03	No
Forward Service Reacquisition (note 1)	98/03	OPM 02	Yes
Forward PSK Service Sweep Request (refer to Table 6-1 note 4)	98/05	OPM 04	Yes
Forward PM Service Sweep Request (refer to Table 6-2 note 5)	98/05	OPM 04	No
Data Rate	98/04	OPM 03	No
Polarization	98/04	OPM 03	Yes
Initiation or termination of the command channel PN code (note 2)	98/04	OPM 03	No
Forward Service Normal/High Power Mode EIRP Change	98/06	OPM 06	No

Notes:

1. Forward service reacquisition is a TDRSS reinitiation of forward link service by applying a 1 MHz frequency offset for 3 seconds to the predicted customer receive frequency specified in the customer's service specification code (refer to Section 10, paragraph 10.2.2).
2. Initiation or termination of the command channel PN code enables or disables all forward link PN modulation (including the command and range channel, if applicable), respectively.

d. The customer platform receiving system will search for and acquire the command channel PN code (if applicable) and carrier. Normally, a customer MOC will not be transmitting forward service data to the NISN data transport system until the forward service signal has been acquired by the customer platform and the acquisition verified by the customer MOC from customer platform return service telemetry. If the NASA fourth generation standard transponder is used, its design implementation requires that there be no data transitions during the signal acquisition process, while others may merely result in longer acquisition times. Data transmission is inhibited by the SN ground terminal during PM carrier frequency sweep.

e. For QPSK modulation, the customer platform receiving system will search for and acquire the range channel PN code upon acquisition of the command channel PN code and carrier.

f. Depending upon the customer platform receiving system design, upon completion of forward link acquisition and subsequent customer platform transition to signal tracking, the customer platform transmitting system may either switch to a coherent mode or remain in a noncoherent mode until commanded by the customer MOC to switch.

g. The SN ground terminal will continue Doppler compensation of the TDRSS SSA forward service signal unless requested by the customer MOC to inhibit the Doppler compensation.

h. T_{acq} in the customer platform receiver is a function of the customer platform receiver design and signal-to-noise density ratio. For the purpose of an example, Table 6-6 provides the acquisition characteristics for the fourth generation transponder when receiving an SSA QPSK signal. The T_{acq} values listed in Table 6-6 are contingent on the customer MOC defining the customer platform receiver center frequency, f_o, to an accuracy of $\pm$700 Hz in each service support schedule add request (SAR). The customer platform forward service acquisition time must be considered in determining the overall return service acquisition time for customer platform with a coherent mode of operation.

i. Appendix A provides example link calculations for the TDRSS SSA forward service.

6.3 SSA Return Services

6.3.1 General

The RF signals provided by the customer platform to the TDRS and the characteristics of data provided at the SN ground terminal interface are defined in paragraphs 6.3.2 through 6.3.6. This discussion assumes that an appropriate return service has been scheduled and a data signal is present at the TDRS interface. The SSA return service supports data services using the SN ground terminal receivers and an automated IF service.

Table 6-6. SSA Forward Service Example Acquisition Times for the Fourth Generation NASA Standard Transponder

S/N_0 (notes 1, 3)	Command Channel PN Code (note 2)	Carrier (note 2)	Range Channel PN Code (note 2)	Total (note 2)
34 dB-Hz	≤ 20 sec	≤ 5 sec	≤ 10 sec	≤ 35 sec
≥ 37 dB-Hz	≤ 7 sec	≤ 5 sec	≤ 10 sec	≤ 22 sec

Notes:

1. S/N_0 is the signal to noise density ratio (dB-Hz) at the customer platform transponder input.
2. With a probability ≥ 90%. Carrier acquisition starts after the command channel PN code has been acquired. Range channel PN code acquisition starts after the carrier has been acquired.
3. For further specific information on the Fourth Generation user transponder, reference should be made to 531-RSD-IVGXPDR.

6.3.2 Signal Parameters

The TDRSS SSA return service signal parameters are listed in Table 6-7. Refer to 6.3.6 for SSA return IF service signal parameter characteristics and recommendations. The services are divided into 2 major groups, DG1 and DG2. DG1 services utilize spread spectrum modulation while DG2 services are non-spread. A description of the features inherent in the DG1 and DG2 services is discussed in paragraphs 6.3.2.2 and 6.3.2.3, respectively. Within each data group, there are several types of modulation. Additionally, both data groups support coherent and noncoherent modes. A description of these general characteristics is provided in paragraph 6.3.2.1.

6.3.2.1 General Modulation and Coherent/Noncoherent Description

a. SQPN Modulation. SQPN modulation is used to prevent simultaneous transitions of the I and Q PN sequences. For SQPN modulation, the PN chips of the I and Q channel are staggered by a 1/2 chip. For data configurations that use two PN spread channels, SQPN modulation must be used.

b. SQPSK Modulation. SQPSK modulation staggers one channel with respect to the other to prevent synchronous transitions. For non-spread signal configurations with identical I and Q symbol rates that are NRZ symbol formatted, SQPSK modulation must be used. The symbols of the Q channel are delayed 1/2 symbol relative to the I channel. For non-spread signal configurations that use biphase symbol formatting on either channel and the baud rate of the two channels are identical, SQPSK modulation is used and the transitions of one channel occur at the mid-point of adjacent transitions of the other channel.

Table 6-7. TDRSS SSA Return Service Signal Parameters

Parameter (Note 6)	**Description** (Note 6)
DG1 (note 1)	
Transmit carrier frequency (Hz) (note 5)	F_1
Carrier (F_1) reference (Hz)	
DG1 modes 1 and 3	$\frac{240}{221} \times FR$
DG1 mode 2	Customer platform transmitter oscillator
PN code modulation	
DG1 modes 1 and 2	SQPN, BPSK (see Appendix B and Table 6-8)
DG1 mode 3, I channel	PSK $\pm\pi/2$ radians
PN code chip rate (chips/sec)	$\frac{31}{[240 \times 96]} \times F_1$
PN code length (chips)	
DG1 modes 1 and 3	$(2^{10} - 1) \times 256$
DG1 mode 2	$2^{11} - 1$
PN code epoch reference	
DG1 mode 1	
I channel	Epoch (all 1's condition) synchronized to epoch (all 1's condition) of received forward service range channel PN code
Q channel (note 3)	Epoch delayed x + 1/2 PN code chips relative to I channel PN code epoch
DG1 mode 2	Not Applicable
DG1 mode 3, I channel	Same as DG1 mode 1 (I channel)
PN code family	
DG1 modes 1 and 3	Truncated 18-stage shift register sequences
DG1 mode 2	Gold codes
Data modulation:	
DG1 modes 1 and 2	Modulo-2 added asynchronously to PN code
DG1 mode 3:	
I channel	Modulo-2 added asynchronously to PN code
Q channel	PSK $\pm\pi/2$ radians

Table 6-7. TDRSS SSA Return Service Signal Parameters (cont'd)

Parameter (Note 6)	**Description** (Note 6)
DG1 (note 1) (Cont'd)	
Periodic convolutional interleaving (note 4)	Recommended for baud rates > 300 kbps
Data format	NRZ-L, NRZ-M, NRZ-S
Symbol format	NRZ
DG1 mode 1 data rate restrictions	
Total (note 1)	0.1 - 300 kbps
I channel	0.1 - 150 kbps
Q channel	0.1 - 150 kbps
DG1 mode 2 data rate restrictions	
Total (note 1)	1 - 300 kbps
I channel	1 - 150 kbps
Q channel	1 - 150 kbps
DG1 mode 3 data rate restrictions	
Total (note 1)	I (max) + Q (max)
I channel	0.1 - 150 kbps
Q channel	1 kbps - 3 Mbps
DG1 $\frac{\text{Q channel power}}{\text{I channel power}}$ restrictions (note 2)	
Single data source-alternate I/Q bits	1:1
Single data source-identical data	1:1 to 4:1
Single data source-single data channel	NA
Dual data sources	1:1 to 4:1
DG2 (note 1)	
Transmit carrier frequency (note 5)	F_2
Carrier (F_2) reference (Hz)	
DG2 Coherent	$\frac{240}{221} \times F_R$
DG2 Noncoherent	Customer platform oscillator
Data modulation (note 1)	BPSK SQPSK, or QPSK (refer to Appendix B and Table 6-8)

Table 6-7. TDRSS SSA Return Service Signal Parameters (cont'd)

Parameter (Note 6)	**Description** (Note 6)
DG2 (note 1) (cont'd)	
Periodic convolutional interleaving (note 4)	Recommended for baud rates > 300 kbps
Symbol format	NRZ, Bi∅-L
Data format	NRZ-L, NRZ-M, NRZ-S
Data rate restrictions	
Total (note 1)	I (max) + Q (max)
I channel	1 kbps - 3 Mbps
Q channel	1 kbps - 3 Mbps
DG2 $\frac{\text{I channel power}}{\text{Q channel power}}$ restrictions	
Single data source-alternate I/Q bits	1:1
Single data source-alternate I/Q encoded symbols	1:1
Single data source-single data channel	NA
Dual data sources	1:1 or 4:1

Notes:

1. Customer platform data configurations, including specific data rate restrictions for coding and formatting, are defined in Table 6-8 for TDRSS SSA return service (refer also to Appendix B). Unless otherwise stated, the data rate restrictions given in this table assume rate 1/2 convolutional encoding and NRZ formatting.
2. For DG1, the Q/I power parameter range can vary from 1:1 to 4:1 continuously during specification of applicable parameter values in the NCCDS scheduling database and during real-time service reconfiguration. However if this parameter is re-specified in schedule requests to the NCCDS (refer to Section 10, paragraph 10.2.2), it is expressed as the ratio of two single-digit integers.
3. The Q channel PN code sequence must be identical to the I channel PN code sequence, but offset by x + 1/2 PN code chips, where $x \geq 20{,}000$. The value of x is defined by the PN code assignment for a particular customer platform (refer to 451-PN CODE-SNIP).
4. Periodic convolutional interleaving (PCI) recommended on S-band return services for channel baud rates > 300 kbps. Biphase symbol formats are not allowed with PCI. When interleaving is not employed for channel baud rates > 300 kbps, S-band return performance may not be guaranteed.
5. The center frequency, f_O, of the customer platform transmitter must be defined by the customer MOC in its service specification code to an integral multiple of 10 Hz.
6. Unless otherwise noted, all data rate values are to be interpreted as data bit rates, and not as data symbol rates. Data rates and modulation schemes are based upon support through the SSAR SN ground terminal receivers. Other data rates and modulation schemes are possible through the SSA return automated IF service, which is available on a case-by-case basis. Please refer to paragraph 6.3.6 and contact GSFC Code 450 for further information.

c. QPSK Modulation. QPSK modulation is available when there is no relation between the I and Q channel transitions. For dual data source configurations, in which one or both channels are not spread and SQPSK is not required, QPSK modulation is used.

d. BPSK Modulation. BPSK modulation is available for single data source configurations that use only one channel of the link.

NOTES:

For SQPN and SQPSK modulation, the spectral characteristics of a customer platform saturated power amplifier will, to a great degree, retain the spectral characteristics of the band-limited input signal to that amplifier. This should result in better control of out-of-band emissions, which, in turn, provides more efficient communications and less interference to the customer platform using adjacent frequency channels on the TDRS links.

For non-spread SSA services, PSK subcarrier phase modulation (PCM/PSK/PM) and direct phase modulation (PCM/PM) may also be supported by the SN. However, its use and customer specific supporting characteristics must be coordinated with GSFC Code 450.

e. Coherent Mode. For coherent modes, the customer platform transmitted return link carrier frequency and PN code clock frequency (if applicable) are derived from the customer platform received forward link carrier frequency. For coherent PN spread return links, the return PN code length is identical to the length of the received forward service range channel PN code. The customer return I channel PN code epoch is synchronized with the epoch of the received forward service range channel PN code. Two-way Doppler measurements and range measurements (if PN spread) are available.

f. Noncoherent Mode. For noncoherent modes, the customer platform transmitted return link carrier frequency and PN code clock frequency (if applicable) are derived from an on-board local oscillator. The customer platform transmit frequency for noncoherent service must be defined by the customer MOC to an accuracy of ±700 Hz in its service specification code when requesting TDRSS SSA return service (refer to Section 10, paragraph 10.2.2). For customers whose frequency uncertainty is greater than ±700 Hz, an expanded frequency search capability is available after service start.

g. Asynchronous Data Modulation. The data modulation is asynchronous to the carrier and the channel PN code (if applicable). This prevents Doppler variations of the forward service carrier and PN code frequencies from affecting the return service data rate.

6.3.2.2 DG1 Signal Parameters

DG1 signal parameters are subdivided into three modes of operation, DG1 modes 1, 2, and 3. For all DG1 modes, the PN code clock must be coherently related to the transmitted carrier frequency. This feature permits the customer platform transmitter to use a common source for generating the carrier and the PN code clock frequencies. 451-PN CODE-SNIP defines all the salient characteristics for the DG1 PN code libraries. The Agency Spectrum Manager responsible for PN code assignments will allocate a customer platform-unique PN code assignment from these libraries. The GSFC Spectrum Manager is responsible for NASA PN code assignments. The three DG1 modes are distinguished as follows:

a. DG1 Mode 1. DG1 mode 1 must be used when range and two-way Doppler measurement (coherent transponder operations) are required concurrently with return service low-rate data transmission. Return service signal acquisition by the SN ground terminal for DG1 mode 1 is possible only when the scheduled TDRSS (SSA or MA) forward service signal is acquired by the customer platform and the PN code and carrier transmitted by the customer platform are coherently related to the forward service signal from the TDRS. If the TDRSS forward service signal becomes unavailable to the customer platform, the platform transmitter must switch to noncoherent transmitter operation (DG1 mode 2) (refer to paragraph 6.3.5.c.2). In order to reacquire the DG1 mode 2 signal, the return service must be reconfigured. The I and Q channel PN codes are generated from a single code generator. For DG1 mode 1 operation, the I and Q channel PN codes are identical but are offset by at least 20,000 chips. This separation is adequate for TDRSS to identify each data channel unambiguously without requiring a unique PN code for each channel.

b. DG1 Mode 2. DG1 mode 2 can be used when SN ground terminal return service signal acquisition is necessary without the requirement for prior customer platform signal acquisition of the TDRSS (SSA or MA) forward service (noncoherent transponder operation). The customer platform transmit frequency for DG1 mode 2 service must be defined by the customer MOC to an accuracy of $\pm$700 Hz in its service specification code when requesting TDRSS SSA return service (refer to Section 10, paragraph 10.2.2). For customers whose frequency uncertainty is greater than $\pm$700 Hz, an expanded frequency search capability of $\pm$3 kHz is available after the start of the return service. For DG1 mode 2, the I and Q channel PN codes are unique 2^{11}-1 Gold Codes.

c. DG1 Mode 3. DG1 mode 3 can be used when range and two-way Doppler measurements (coherent transponder operations) are required concurrently with return service high-rate data transmission. Restrictions on DG1 mode 3 signal acquisition are identical to those for DG1 mode 1. In DG1 mode 3, the Q channel must contain only data and no PN code.

d. Functional Configurations. Table 6-8 lists the DG1 SSA return service functional configurations and a further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in Appendix B, paragraph B.3.2.

Table 6-8. SSA Return Service Configurations

Return Service Configuration[10]				Source Data Rate Restrictions and Availability[8,9,12]					
				DG1 Mode				DG2 Mode	
				1[1] and 2[1,4]		3[2]		Coherent[3] and Noncoherent[3,4]	
				Data format	Data rate	Data format	Data rate[13]	Data format	Data rate[13]
Single Data Source	BPSK	Rate 1/2 coded		NRZ	≤150 kbps[1]	-	-	NRZ	1 kbps – 3 Mbps[5]
								NRZ with biphase symbols	1 kbps – 1.5 Mbps[5,6]
		Rate 1/3 coded		-	-	-	-	NRZ	1 kbps – 2 Mbps[5]
								NRZ with biphase symbols	1 kbps – 1 Mbps[5,6]
		Uncoded		7	7	-	-	7	7
	SQPN	Identical I & Q channel data	Rate 1/2 coded	NRZ	≤150 kbps	-	-	-	-
			Uncoded	7	7	-	-	-	-
	SQPSK	Rate 1/2 coded alternate I/Q encoded symbols		-	-	-	-	NRZ	1 – 300 kbps
	SQPN[1] or SQPSK[3]	Alternating I/Q data	Individually rate 1/2 coded	NRZ	≤300 kbps	-	-	NRZ	1 kbps – 6 Mbps[5]
			Individually rate 1/3 coded	-	-	-	-	NRZ	1 kbps – 4 Mbps[5]
			Uncoded	7	7	-	-	7	7
Dual Data Sources (data rates are for each source separately)	SQPN[1], QPSK[2,3] or SQPSK[3]	Rate 1/2 coded		NRZ	≤150 kbps	NRZ	I: 0.1-150 kbps Q: 1 kbps – 3 Mbps	NRZ	1 kbps – 3 Mbps[5,11]
								NRZ with biphase symbols	1 kbps – 1.5 Mbps[5,6,11]
		Rate 1/3 coded		-	-	NRZ	Q: 1 kbps – 2 Mbps	NRZ	1 kbps – 2 Mbps[5,11]
								NRZ with biphase symbols	1 kbps – 1 Mbps[5,6,11]
		Uncoded		7	7	7	7	7	7,11

Table 6-8. SSA Return Service Configurations (cont'd)

✓	Configuration supported
-	Configuration not supported

Notes:

1. For DG1 mode 1 and 2 configurations, where the minimum source data rates are 0.1 kbps for DG1 mode 1 and 1 kbps for DG1 mode 2:
   a. Data on a single I or Q channel, but not both channels: BPSK modulation is used where the data is modulo-2 added to the PN code.
   b. Data on both the I and Q channels: SQPN modulation is used and the SN supports I:Q power ratios of 1:1 to 1:4 for all the configurations, except the alternating I and Q data bit configuration, which requires a balanced I:Q power ratio.
   c. The alternating I/Q data bit configuration: the SN requires the I channel lead the Q channel by a half symbol. Similarly, the SN requires the I and Q channels be independently differentially formatted (-M,-S).
2. For DG1 mode 3 configurations:
   a. The modulation is QPSK, where the I channel data is modulo-2 added to the PN code, and the Q channel data directly modulates the carrier at $+\pi/2$ radians.
   b. The SN supports I:Q power ratios of 1:1 to 1:4.
   c. Rate 1/3 coding is supported for the Q channel only. (Rate 1/2 coding is supported on both the I and Q channels.)
3. For DG2 configurations:
   a. Single data source configurations with data on one channel: BPSK modulation is used.
   b. Single data source configurations with data on both channels: SQPSK modulation and an I:Q power ratio of 1:1 is used. For the alternate I/Q bit configuration, the SN requires the I and Q channels be independently differentially formatted (-M,-S).
   Dual data source configurations: SQPSK must be used when there are identical baud rates on the I and Q channels (see paragraph 6.3.2.1.b); QPSK is used for all other configurations; for both SQPSK and QPSK, either an I:Q power ratio of 1:1 or 4:1 is supported. For unbalanced QPSK, the I channel must contain the higher data rate and when the data rate on the I channel exceeds 70 percent of the maximum allowable data rate, the Q channel data rate must not exceed 40 percent of the maximum allowable data rate on that Q channel.
4. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of ± 700 Hz. If a customer cannot accurately define their transmit frequency to within ± 700 Hz, a customer can request a reconfiguration which would expand the oscillator frequency search to ± 3 kHz for DG1 and SQPSK DG2 configurations and ± 35 kHz for BPSK and QPSK DG2 configurations after the start of service.
5. Periodic convolutional interleaving (PCI) recommended on S-band return service for channel baud rates > 300 kbps. When interleaving is not employed for channel baud rates > 300 kbps, S-band performance may not be guaranteed.
6. Biphase symbol formats are not allowed with PCI. Use of biphase symbol formats on S-band services at baud rates > 300 kbps should be coordinated with GSFC Code 450.
7. For all configurations and modes, the SN is capable of providing SSA support of uncoded links; however, performance is not guaranteed in RFI and must be coordinated with GSFC Code 450.
8. TDRSS may be capable of supporting other return signal configurations, such as residual carrier Phase Modulation signals; however, performance will have to be handled on a case-by-case basis with GSFC Code 450.
9. Unless otherwise noted, all data rates are to be interpreted as data bit rates, and not as data symbol rates. Refer to Section 3, paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities.
10. Appendix B describes the functional configurations and associated I-Q channel and data polarity ambiguities. Additionally, Figure B-10 depicts the SN supported convolutional coding schemes.
11. For S-band DG2, dual data channel, balanced power configurations, the minimum total (I+Q) data rate must be 60 kbps or greater.
12. Data rates and modulation schemes are based upon support through the SSAR SN ground terminal receivers. Other data rates and modulation schemes are possible through the SSA return automated IF services, which is available on a case-by-case basis. Please refer to paragraph 6.3.6 and contact GSFC Code 450 for further information.
13. The NTIA will not grant TDRSS customers an S-band return service frequency allocation greater than 6 MHz. If a frequency allocation greater than 6 MHz is required, the SN should be notified and the NASA GSFC Spectrum Manager may petition the NTIA for a temporary waiver.

6.3.2.3 DG2 Signal Parameters

DG2 signal parameters are subdivided into two modes of operation, DG2 coherent and noncoherent. DG2 must be used when the return service data rate equipment exceeds the capability of DG1 operations. DG2 operations cannot provide TDRSS range tracking because PN code modulation is not used. The two DG2 modes are distinguished as follows:

a. DG2 Coherent. Return service signal acquisition by the SN ground terminal for DG2 coherent is possible only when the scheduled TDRSS (SSA or MA) forward service signal is acquired by the customer platform and the carrier transmitted by the customer platform is coherently related to the forward service signal from the TDRS. TDRSS two-way Doppler tracking can be provided when the DG2 carrier is coherently related to the TDRSS (SSA or MA) forward service carrier frequency.

b. DG2 Noncoherent. The DG2 carrier is independent of the TDRSS (SSA or MA) forward service carrier frequency. The customer platform transmit frequency for DG2 noncoherent service must be defined by the customer MOC to an accuracy of ±700 Hz in its service specification code when requesting TDRSS SSA return service (refer to Section 10, paragraph 10.2.2). For customers whose frequency uncertainty is greater than ±700 Hz, an expanded frequency search capability of ±3 kHz for SQPSK DG2 services and ±35 kHz for BPSK and QPSK DG2 services is available after the start of the return service.

NOTE:

For non-spread SSA services, PSK subcarrier phase modulation (PCM/PSK/PM) and direct phase modulation (PCM/PM) may also be supported by the SN. For PCM/PSK/PM, the SN will acquire and demodulate data on either the upper or lower subcarrier. For this scenario, the minimum required P_{rec} is the minimum required channel P_{rec} and should be compared against the predicted channel P_{rec} after data loss due to the modulation index and a 3 dB loss due to demodulating only the upper or lower subcarrier. The use of these modulation schemes and customer specific supporting characteristics must be coordinated with GSFC Code 450.

c. Functional Configurations. Table 6-8 lists the DG2 SSA return service functional configurations through the SN ground terminal receiver and a further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in Appendix B, paragraph B.3.3. Refer to paragraph 6.3.6 for the SSAR IF service functional configurations.

6.3.3 Communications Services

To obtain TDRSS SSA return service performance defined in this paragraph, the customer platform transmitted signal must meet the requirements found in Table 6-9

and signal characteristics specified in Table 6-12. The TDRSS SSA return service performance defined in this paragraph also assumes return service operation in an AWGN environment. Appendix G discusses performance degradations to the TDRSS SSA return service due to RFI. Example link calculations are provided in Appendix A. TDRSS SSAR supports customers with an ephemeris uncertainty as defined in Table 6-9 and dynamics, described as non-powered flight and powered flight, as defined in Table 6-10.

6.3.3.1 Acquisition

The SSAR service supports acquisition for customer platforms operating under non-powered flight dynamics as defined in Table 6-10. SSAR acquisition will be protected against false SN ground terminal lock to: interfering customer platform PN codes, customer platform PN code sidelobes, and carrier recovery. The SSAR total channel acquisition times (T_{acq}) are given in Table 6-9 and are the sum of the following:

a. PN (DG1 only) and carrier acquisition time
b. Symbol/Decoder synchronization time or Symbol/Deinterleaver/Decoder synchronization time (if deinterleaving is applicable).

T_{acq} assumes that the customer platform return service signal is present at the SN ground terminal at the start time of the scheduled return service support period and the process is described below.

a. PN code (if applicable) and carrier acquisition will commence upon the start of the scheduled return service support period.
b. After PN code (if applicable) and carrier acquisition is achieved, TDRSS tracking services data is available.
c. Symbol/Decoder and Symbol/Deinterleaver/Decoder synchronization times will be measured from the time when the carrier acquisition is achieved to the time when the decoder synchronization is achieved. Decoder synchronization is achieved when the Viterbi decoder has selected and implemented the correct blocking of the input symbols (into groups of (G1,G2) symbol pairs for rate 1/2 codes, or (G1,G2,G3) symbol triplets for rate 1/3 codes).
d. After symbol/decoder and symbol/deinterleaver/decoder synchronization is achieved, SSA return service channel data is available at the SN ground terminal interface.
e. To minimize return data loss, it is recommended that the customer platform transmit idle pattern on its data channels until after it has observed (via the UPD data) that the SN ground terminal has completed all of its data channel signal acquisition processes.
f. Requirements for bit error probability and symbol slipping take effect at the time decoder synchronization is achieved.

Table 6-9. TDRSS SSA Return Service

Parameter (Note 7)	Description (Note 7)	
Field of View (FOV) (each TDRS) (note 9)	Primary ±22 degrees east-west ±28 degrees north-south	Extended Elliptical (F8-F10 and K, L, M) 24.0 degrees inboard east-west 76.8 degrees outboard east-west ±30.5 degrees north-south
Customer Ephemeris Uncertainty (along the customer orbital track) (note 10)	≤ ± 9 sec	≤ ± 7.8 sec
TDRS antenna polarization (note 4)	RHC or LHC selectable	
TDRS antenna axial ratio (maximum)	1.5 dB over 3 dB beamwidth	
Receive frequency band (see paragraph 6.3.3.5.b)	2200 MHz to 2300 MHz	
RF bandwidth (3dB, minimum)	10 MHz	
10^{-5} Bit Error Rate (notes 1, 2, 3, 8):		
Orbital Dynamics	Powered and non-powered flight dynamics (defined in Table 6-10)	
Minimum Required P_{rec} for Rate 1/2 convolutional coding:	All P_{rec} values are in dBW	
DG1 modes 1 and 2	$-231.6 + 10\log_{10}$(data rate in bps)	
DG1 mode 3		
I channel	$-231.6 + 10\log_{10}$(data rate in bps)	
Q channel		
Data rate ≤ 1 Mbps	$-232.1 + 10\log_{10}$(data rate in bps)	
Data rate > 1 Mbps	$-231.2 + 10\log_{10}$(data rate in bps)	
DG2		
Data rate ≤ 1 Mbps	$-232.1 + 10\log_{10}$(data rate in bps)	
Data rate > 1 Mbps	$-231.2 + 10\log_{10}$(data rate in bps)	
Minimum Required P_{rec} for Rate 1/3 convolutional coding:	All P_{rec} values are in dBW	
DG1 mode 3, Q channel		
Data rate ≤ 1 Mbps	$-232.4 + 10\log_{10}$(data rate in bps)	
Data rate > 1 Mbps	$-231.6 + 10\log_{10}$(data rate in bps)	

Table 6-9. TDRSS SSA Return Service (cont'd)

Parameter (Note 7)	Description (Note 7)
10^{-5} Bit Error Rate (notes 1, 2, 3, 8) (cont'd):	
Minimum Required P_{rec} for Rate 1/3 convolutional coding (cont'd):	
DG2	
Data rate $\leq$ 1 Mbps	-232.4 + $10\log_{10}$(data rate in bps)
Data rate > 1 Mbps	-231.6 + $10\log_{10}$(data rate in bps)
Acquisition (notes 3, 8):	
Orbital dynamics	Free-flight dynamics only (defined in Table 6-10)
Total Channel Acquisition Time (assumes the customer return service signal is present at the SN ground terminal at the start time of the return service support period)	Sum of the following: 1. PN (DG1 only) and carrier acquisition time 2. Symbol/Decoder synchronization time or Symbol/Deinterleaver/Decoder synchronization time (if deinterleaving is applicable)
PN Code (if applicable) and Carrier Acquisition:	
P_{rec}	$\geq$ -202.9 dBW or consistent with the P_{rec} for BER, whichever is greater
Acquisition Time ($P_{acq} \geq$ 90%):	
Coherent operations	$\leq$ 1 sec
Noncoherent operations with frequency uncertainty (note 5):	
$\leq \pm$ 700 Hz	$\leq$ 1 sec
$\leq \pm$ 3 kHz	$\leq$ 3 sec
$\leq \pm$ 35 kHz	$\leq$ 3 sec
Channel Decoder/Symbol Synchronization Acquisition (note 6):	
Minimum data bit transition density	$\geq$ 64 randomly distributed data bit transitions within any sequence of 512 data bits
Number of consecutive data bits without a transition	$\leq$ 64
P_{rec} (dBW)	consistent with the P_{rec} for BER

Table 6-9. TDRSS SSA Return Service (cont'd)

Parameter (Note 7)	Description (Note 7)
Acquisition (notes 3, 8) (cont'd):	
Channel Decoder/Symbol Synchronization Acquisition (note 6) (cont'd):	
Acquisition time (in seconds) with >99% probability:	
Biphase	< 1100/(Channel Data Rate in bps)
NRZ	< 6500/(Channel Data Rate in bps)
Channel Symbol/Deinterleaver (PCI)/ Decoder Synchronization Acquisition (note 6):	
Minimum data bit transition density	≥ 64 randomly distributed data bit transitions within any sequence of 512 data bits
Number of consecutive data bits without a transition	≤ 64
P_{rec} (dBW)	consistent with the P_{rec} for BER
Acquisition time (in seconds) with >99% probability:	
Rate 1/2 coding	Average: ≤ 36000/(Channel Data Rate in bps) Maximum: ≤ 66000/(Channel Data Rate in bps)
Rate 1/3 coding	Average: ≤ 26000/(Channel Data Rate in bps) Maximum: ≤ 46000/(Channel Data Rate in bps)
Signal Tracking	
Orbital dynamics	During Free Flight refer to paragraph 6.3.3.3.a During Powered Flight refer to paragraph 6.3.3.3.b
Reacquisition (powered and non-powered flight)	refer to paragraph 6.3.3.4
Duty Factor	100%

Notes:

1. The BER is for a customer platform transmitting a signal on an AWGN channel which complies with the constraints defined in Table 6-12. Refer to Appendix G for a discussion of the additional degradation applicable to TDRSS SSA return service performance due to S-band RFI.

Table 6-9. TDRSS SSA Return Service (cont'd)

Notes (cont'd):

2. The required customer P_{rec} must meet the P_{rec} for BER or signal acquisition, whichever is greater. Paragraph 6.3.3.2.b provides the required P_{rec} description for each possible SSAR data configuration. Refer to Appendix A, paragraph A.4, for a definition of P_{rec}. The minimum required P_{rec} equations for BER produce the minimum P_{rec} for a given data rate for all possible signal characteristics. CLASS analysis will produce a more accurate performance projection based upon desired customer signal characteristics, such as data rate, data type, and jitter values. SN support may be possible for customers whose P_{rec} is less than the required P_{rec} for 10^{-5} BER performance; however, such support shall be coordinated through GSFC Code 450.
3. For PN code (if applicable) and carrier acquisition, the total $(I+Q)P_{rec}$ must be $\geq$ -202.9 dBW for all configurations, except SQPSK DG2 and noncoherent $\pm$35 kHz expanded frequency uncertainty DG2 configurations which require the total $(I+Q)P_{rec}$ to be $\geq$ -190.9 dBW. However, acquisition requires the P_{rec} to also be consistent with the P_{rec} required for BER.
4. Operational considerations may limit the choice of TDRS antenna polarization. The SSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.
5. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of $\pm$ 700 Hz. If a customer cannot accurately define their transmit frequency to within $\pm$ 700 Hz, a customer can request a reconfiguration which would expand the oscillator frequency search to $\pm$ 3 kHz for DG1 and SQPSK DG2 configurations and $\pm$ 35 kHz for BPSK and non-staggered QPSK DG2 configurations after the start of service.
6. For symbol/decoder synchronization and symbol/deinterleaver/decoder synchronization, the minimum symbol transition density and consecutive symbols without a transition must meet the specifications defined in Table 6-12. It is recommended that customers use G_2 inversion to increase symbol transition density. Additionally, biphase symbol formatting increases symbol transition density.
7. All data rate values (and notes which modify these values, based upon specific signal format and encoding restrictions) are to be interpreted as data bit rates, and not as data symbol rates.
8. SSAR performance characteristics are through the SN ground terminal receivers. An automated SSAR IF service is available on a case-by-case basis. Please refer to paragraph 6.3.6 and contact GSFC Code 450 for further information.
9. TDRS SA antenna pointing beyond ±13.5°E-W and ±13.5°N-S must be coordinated with GSFC Code 450 due to the potential to significantly impact TDRSS efficiency.
10. User ephemeris uncertainty allowance is based upon the assumption of a low eccentricity LEO user orbit. User orbits with high eccentricity and large variations in velocity may need to comply with a more stringent user ephemeris uncertainty.

Table 6-10. Customer Dynamics Supported through TDRSS SSAR Service

Parameter	Non-powered Flight Dynamics	Powered Flight Dynamics
$\dot{R}$	$\leq$ 12 km/sec	$\leq$ 15 km/sec
$\ddot{R}$	$\leq$ 15 m/sec^2	$\leq$ 50 m/sec^2
$\dddot{R}$	$\leq$ 0.02 m/sec^3	$\leq$ 2 m/sec^3

NOTE:

Data and symbol transition density values higher than the minimums required will reduce these acquisition times.

6.3.3.2 Bit Error Rate (BER)

Table 6-9 provides P_{rec} equations that will result in a customer achieving a BER of 10^{-5} for TDRSS compatible signals. The IF service BER depends on the customer receiver characteristics. Refer to paragraph 6.3.6 for more information on the IF service. The BER P_{rec} equations are applicable for either powered or non-powered flight dynamics and the following conditions:

a. Data Encoding. Convolutional encoding (rate 1/2 or rate 1/3) should be used for all customer platform SSA transmissions both to minimize P_{rec} and as an RFI mitigation technique. Detailed coding design is described in Appendix B. Reed-Solomon decoding is available to WDISC customers; typical performance is given in Appendix K.

NOTE:

For all configurations and modes, the SN is capable of providing SSAR support of uncoded links; however, performance is not guaranteed in RFI and must be coordinated with GSFC Code 450.

b. Received Power. P_{rec} is in units of dBW. The customer project, in determining its design requirements for minimum customer platform EIRP, must take into account customer platform transmit antenna pointing losses, the space loss between the customer platform and the TDRS, and the polarization loss incurred between the customer platform transmit antenna and the TDRS receive antenna. The maximum TDRS receive antenna axial ratio is given in Table 6-9 (also refer to Appendix A). For DG1 and DG2 services, the following conditions apply:

1. Balanced Power Single Data Source-Identical Data on the I and Q Channels (DG1 mode 1 and 2 only). For a customer platform synchronously transmitting identical data on the I and Q channels (single data source-identical data) with a balanced I and Q channel power division, the total (I+Q) P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 6-9, where data rate is the single data source data rate. Refer to Appendix B for further information on this data configuration.

2. Balanced Power Single Data Source-Alternate I/Q Bits (DG1 mode 1 and 2 and DG2). For a customer platform transmitting alternate I and Q data bits from a data source (single data source-alternate I/Q bits), the total (I+Q) P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 6-9, where data rate is the single data source data rate prior to separation into the I and Q channels. The Q/I (power) must be equal to 1:1. Refer to Appendix B for further information on this data configuration.

3. Balanced Power Single Data Source-Alternate I/Q Encoded Symbols (DG2 only). For a customer platform transmitting alternate I and Q encoded symbols from a data source (single data source-alternate I/Q encoded symbols), the total (I+Q) P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed Table 6-9, where data rate is the single data source data rate prior to the rate 1/2 encoder. The Q/I (power) must be equal to 1:1. Refer to Appendix B for further information on this data configuration.

4. Unbalanced Power Single Data Source-Identical Data on the I and Q Channels (DG1 mode 1 and 2). For a customer platform synchronously transmitting identical data on the I and Q channels (single data source-identical data) having unbalanced I and Q channel power division, the stronger power channel P_{rec} must be consistent with P_{rec} for a 10^{-5} BER listed in Table 6-9, where data rate is the single data source data rate. The weaker power channel P_{rec} need not be consistent with the P_{rec} for a 10^{-5} BER listed in Table 6-9. The Q/I (power) must not exceed 4:1. Refer to Appendix B for further information on this data configuration.

5. Dual Data Sources (DG1 and DG2). For a customer platform transmitting independent data on the I and Q channels (dual data sources), each channel's P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 6-9, where data rate is that channel's data rate. Refer to Appendix B for further information on this data configuration.

6. Single Data Source with Single Data Channel (DG1 modes 1 and 2 and DG2). For a customer platform transmitting one channel, the channel's P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 6-9, where data rate is the channel data rate. Refer to Appendix B for further information on this data configuration.

c. Customer Degradations. Further reductions in the TDRSS SSA return service performance identified in Table 6-9 can occur. The TDRSS SSA return service will also be degraded due to RFI (refer to Appendix G). The TDRSS SSA return services and tracking services will be provided without degradation for user customer platform transmitted signal characteristics within the constraints specified in Table 6-12. Customer platform parameters exceeding these constraints can also degrade TDRSS SSA return service performance. Refer to Section 3, paragraph 3.5 for guidelines if the constraints in this paragraph cannot be met. Definitions of user customer platform constraints are given in Appendix E.

d. Multipath. The SN ground terminal will provide lockup and interference protection from multipath signals reflected from the Earth.

e. Periodic Convolutional Interleaving. At baud rates above 300 kbps, symbol interleaving of the customer platform transmission is recommended for DG1 mode 3 and DG2 signals. Biphase symbol formats are not allowed with PCI. When interleaving is not employed at baud rates above 300 kbps, S-band performance may not be guaranteed. Deinterleaving is not supported for baud rates $\leq$ 300 kbps. The functional description of the (30,116) periodic

convolutional interleaving of either rate 1/2 or rate 1/3 convolutional encoder symbols is defined in Appendix F.

6.3.3.3 Signal Tracking

TDRSS provides SSA return signal tracking (carrier, PN, symbol synchronization, convolutional deinterleaver synchronization, Viterbi decoder synchronization) for both powered and non-powered flight dynamics. During a customer SSA return service support period, loss-of-lock (carrier, symbol synchronization, and Viterbi decoder) indications appear in the periodically updated User Performance Data (UPD) (every 5 seconds).

a. Non-powered Flight Dynamics. For all valid return service signals operating under non-powered flight dynamics, the SSA return service shall maintain signal tracking for the following conditions:

   1. Cycle Slips. The mean time-between-cycle slip in the SN ground terminal carrier tracking loop for each TDRSS SSA return service will be 90 minutes minimum. This value applies at the carrier tracking threshold, which is 3 dB less than the minimum P_{rec} for BER, and increases exponentially as a function of linear dB increases in P_{rec}. Cycle slips may result in channel and/or data polarity reversal. The SN ground terminal can correct for these reversals under the same conditions as the SN ground terminal can resolve channel and/or data polarity ambiguity as discussed in Appendix B. The time for the SN ground terminal to recover from a cycle slip will be consistent with the time required for the SN ground terminal receiver to detect and automatically reacquire the signal.

   2. Bit Slippage. For each TDRSS SSA return service operating with a minimum P_{rec} required consistent with the P_{rec} for BER and data transition densities greater than 40% for NRZ symbols or any transition density for biphase symbols, the minimum mean time between slips caused by a cycle slip in the SN ground terminal symbol clock recovery loop is either 90 minutes or 10^{10} symbol periods, whichever is greater. For an SSA return service operating with 1 dB more than the minimum P_{rec} required for BER, and NRZ symbol transition densities between 25% and 40%, the minimum mean time between slips is either 90 minutes or 10^{10} symbol periods, whichever is greater.

   3. Loss of Symbol Synchronization. For each TDRSS SSA return service with either rate 1/2 or rate 1/3 convolutional encoding and data transition densities greater than 40% for NRZ symbols and any transition density for biphase symbols, the SN ground terminal symbol synchronization loop will not unlock for a P_{rec} that is 3 dB less than the minimum P_{rec} required for BER. For NRZ symbol transition densities between 25% and 40%, the SN ground terminal symbol synchronizer loop will not unlock for a P_{rec} that is 2 dB less than the minimum P_{rec} required for BER. In both cases, the BER performance will be degraded when the P_{rec} is less than the minimum required for BER.

b. Powered Flight Dynamics. TDRSS will provide signal tracking with a probability of more than 0.99 over 90 minutes for a customer with powered flight dynamics

and an ephemeris uncertainty as defined in Table 6-9. This value applies at the carrier tracking threshold. The carrier tracking threshold for DG1 signals is a minimum P_{rec} of -201.4 dBW or the minimum P_{rec} for BER, whichever is greater. The carrier tracking threshold for DG2 signals is a minimum P_{rec} of -195.3 dBW or the minimum P_{rec} for BER, whichever is greater.

6.3.3.4 Reacquisition

While in the PN/carrier tracking state, a loss of lock condition induced by a cycle slip will be automatically detected and a reacquisition will be automatically initiated. For a customer platform that continues to transmit the minimum P_{rec} for acquisition and maintains with an ephemeris uncertainty as defined in Table 6-9, the normal total channel reacquisition time for either powered or non-powered flight dynamics will be less than or equal to that for the initial total channel acquisition for non-powered flight dynamics, with a probability of at least 0.99. If lock is not achieved within 10 seconds of loss of lock, an acquisition failure notification will be sent to the MOC and the SN ground terminal will reinitiate the initial service acquisition process. TDRSS SSA return service does not support acquisition of customers with powered flight dynamics. Upon receipt of the loss-of-lock indications in the UPD, the customer MOC may request a TDRSS SSA return service reacquisition GCMR (refer to Section 10). It is recommended that the customer MOC delay initiation of the GCMR for at least 35 seconds after initial receipt of the loss-of-lock indications in the UPD.

6.3.3.5 Additional Service Restrictions

a. Sun Interference. The TDRSS SSA return service performance will not be guaranteed when the center of the sun is within 4 degrees of the TDRS SSA receiving antenna boresight; however, this sun interference checking is a customer MOC responsibility. Additionally, the TDRSS SSA return service performance will not be guaranteed when the center of the sun is within 1 degree of the boresight of the SN ground terminal receiving antenna supporting the TDRS.

b. Frequency and Polarization. The TDRSS SSA return service can support the customer platform with assigned frequencies anywhere within the 2200 to 2300 MHz band with either RHC or LHC polarization. The following restrictions apply:

   1. The BER relationships of Table 6-9 are satisfied for center frequencies from 2205 to 2295 MHz (refer to Appendix D for power level restrictions into the 2290-2300 MHz band and NASA/GSFC Recommended Filtering). For customer center frequencies below 2205 MHz or center frequencies above 2295 MHz, acceptable data service may be achieved when the customer's spectrum does not spill over the edges of the 2200 to 2300 MHz band.
   2. The customer platform spectrum should be constrained so that the first null of the spectrum falls within the 2200 to 2300 MHz band.
   3. In addition, the customer platform should consider employing selectable polarization capability.

4. To avoid interference with MA return customers, the SN may restrict support to SSA only customers that operate LHC polarization at frequencies above 2280 MHz.
5. The SSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.

c. Mutual Interference. It is possible for the mutual interference between SSA customer platforms operating on the same polarization to become significant. The SN can provide tools to assist customers in interference prediction and interference mitigation.

NOTE:

Frequency assignment and polarization selection for TDRSS SSA return service customers is performed during the mission planning phase.

6.3.4 Real-Time Configuration Changes

Changes to the operating conditions or configuration of a TDRSS SSA return service during a scheduled service support period are initiated by a GCMR from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the GCMR at the SN ground terminal. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning SN ground terminal response times for GCMRs is provided in Section 10. Table 6-11 lists the SSA return service real-time configuration changes and their effects on the return service.

6.3.5 Acquisition Scenarios

The following acquisition scenarios identify only the technical aspects of TDRSS SSA return service signal acquisition by the SN ground terminal and do not include operational procedures related to acquisition. Acquisition is dependent upon the customer providing an ephemeris with a maximum uncertainty as defined in Table 6-9:

a. Coherent Modes (DG1 Modes 1 or 3 and DG2 Coherent)

1. For optimal TDRSS performance, all coherent services should have the TDRSS forward and return services starting at the same time. If operational considerations require starting the TDRSS forward service before the return service, no reconfigurations of the forward service can be sent within 30 seconds of the start of the return service. A forward link sweep request OPM cannot be sent within 150 seconds of the start of the return service.

Table 6-11. SSA Return Service Real-Time Configuration Changes

Real-Time Configuration Changes	GCMR	OPM	Return Service Interruption
Return Service Reacquisition	98/03	OPM 03	Yes
Noncoherent Expanded User Spacecraft Frequency Uncertainty	98/07	OPM 07	No
Channel Data Rate	98/04	OPM 03	No
Noncoherent Transmit Frequency	98/04	OPM 03	Yes
Redefinition of customer minimum EIRP	98/04	OPM 03	Yes
Redefinition of customer maximum EIRP	98/04	OPM 03	No
I/Q Power Ratio	98/04	OPM 03	Yes
Channel Data Format	98/04	OPM 03	No
Channel Data Bit Jitter	98/04	OPM 03	No
DG1 Mode	98/04	OPM 03	Yes
Polarization	98/04	OPM 03	No
Data Group	98/04	OPM 03	Yes
DG2 Coherency (coherent or noncoherent)	98/04	OPM 03	Yes
Periodic Convolutional Interleaving	98/04	OPM 03	No
DG2 Carrier Modulation	98/04	OPM 03	Yes
Data Source/Channel Configuration	98/04	OPM 03	Yes
G_2 inversion	98/04	OPM 03	No
Frame Length	98/04	OPM 03	No
Frame Sync Word Length	98/04	OPM 03	No
Frame Sync Word Bit Pattern	98/04	OPM 03	No
Sync Strategy Parameters	98/04	OPM 03	No

Note:
Items that are indicated to cause return service interruption will cause the SN ground terminal receiver to discontinue signal tracking and attempt to reacquire the return service signal after the appropriate reconfiguration. Additionally, any reconfigurations to the forward service that cause forward link interruption will also cause return interruption for coherent return links. Any other reconfigurations of the SN ground terminals may momentarily affect signal tracking.

2. The customer platform P_{rec} must be compatible with the minimum P_{rec} required for BER and the other TDRSS SSA return service signal parameters listed in Table 6-9.
3. The SN ground terminal will open-loop point the TDRS SSA antenna in the direction of the customer platform.
4. At the service start time specified by the SHO, the SN ground terminal will begin the search for the customer platform signal based upon predicted range and Doppler. The SN ground terminal corrects the received

customer platform signal for Doppler to allow for SN ground terminal implementation of receivers with narrow acquisition and tracking bandwidths. The Doppler correction used by the SN ground terminal is either one-way return (Forward Doppler compensation enabled) or two-way (Forward Doppler compensation inhibited). For coherent operation, the Doppler correction is based upon the forward service frequency.

5. After the forward service has been acquired, the SN ground terminal will acquire the customer platform signal (PN code (applicable to DG1 only) and carrier) within the time limits listed in Table 6-9. Return service will be achieved at the SN ground terminal receiver output within the total channel acquisition time limits listed in Table 6-9, which includes SN ground terminal symbol, deinterleaver (if applicable), and Viterbi decoder synchronization.

b. Noncoherent (DG1 Mode 2 and DG2 Noncoherent)

1. This mode of customer platform operation does not require a TDRSS (MA or SSA) forward service signal to be received by the customer platform. However, the customer platform transmitter must be commanded to turn on when noncoherent transmissions are desired, either by stored commands, on-board configuration settings, or direct commands from its customer MOC.
2. The customer platform P_{rec} must be compatible with the minimum P_{rec} required for BER and the other TDRSS SSA return service signal parameters listed in Table 6-9.
3. The SN ground terminal will open-loop point the TDRSS SSA antenna in the direction of the customer platform.
4. At the service start time specified by the SHO, the SN ground terminal will begin the search for the customer platform signal based upon predicted Doppler. The SN ground terminal corrects the received customer platform signal for Doppler to allow for SN ground terminal implementation of receivers with narrow acquisition and tracking bandwidths. The Doppler correction used by the SN ground terminal is one-way return and based on the customer platform transmission frequency stated in the SHO and any subsequent OPMs.
5. The SN ground terminal will acquire the customer platform signal (PN code (applicable to DG1 only) and carrier) within the time limits listed in Table 6-9. Return service will be achieved at the SN ground terminal receiver output within the total acquisition time limits listed in Table 6-9, which includes SN ground terminal symbol and Viterbi decoder synchronization.

c. DG1 Mode Transitions

1. DG1 Mode 2 to DG1 Mode 1 (or 3) Transitions. A TDRSS (MA or SSA) forward service must be scheduled to be established prior to customer MOC transmission of the GCMR to reconfigure the TDRSS for DG1 mode 1 (or 3) operations (refer to paragraph 6.3.5.a.(1)).

2. DG1 Mode 1 (or 3) to DG1 Mode 2 Transitions. When the customer platform switches to the noncoherent mode (DG1 mode 2), customer platform return service signal parameters (e.g., carrier and channel PN codes) are changed causing the SN ground terminal to drop TDRSS SSA return service signal lock. Customer platform transponders designed to automatically switch from a coherent transponder mode to a noncoherent mode when the TDRSS SSA/MA forward service signal is lost will result in SN ground terminal loss of SSA return service signal lock. Reconfiguration and reacquisition by the SN ground terminal is required and must be initiated by a GCMR from the customer MOC.

NOTE:

Failure to observe these conventions may result in SN ground terminal rejection of reconfiguration messages, excessive acquisition times, and unnecessary loss of customer platform return service data.

d. DG2 Mode Transitions

1. DG2 noncoherent to DG2 coherent Transitions. A TDRSS (MA or SSA) forward service must be scheduled to be established prior to customer MOC transmission of the GCMR to reconfigure the TDRSS for DG2 coherent operations (refer to paragraph 6.3.5.a.(1)).

2. DG2 coherent to DG2 noncoherent Transitions. When the customer platform switches to the noncoherent mode, the resulting customer transmit frequency offset will probably cause the SN ground terminal to drop TDRSS SSA return service signal lock when the switch is made. If return service signal lock is lost, reconfiguration and reacquisition by the SN ground terminal is required and must be initiated by a GCMR from the customer MOC.

NOTE:

Failure to observe these conventions may result in SN ground terminal rejection of reconfiguration messages, excessive acquisition times, and unnecessary loss of customer platform return service data.

Table 6-12. TDRSS SSA Return Service Customer Platform Signal Constraints

Parameter (Notes 1, 2, and 14)	**Description** (Notes 1, 2, and 14)
Minimum channel data bit transition density (required for acquisition/reacquisition)	≥ 64 randomly distributed data bit transitions within any sequence of 512 data bits
Consecutive channel data bits without a bit transition (required for acquisition/reacquisition)	≤ 64
Minimum channel symbol transition density (Note 3)	≥128 randomly distributed symbol transitions within any sequence of 512 symbols
Consecutive channel symbols without a symbol transition	≤64 symbols
Symbol asymmetry (peak)	≤ ±3 percent
Symbol jitter and jitter rate (note 4)	≤ 0.1 percent
Phase imbalance	
DG1 modes 1 and 2	≤ ± 5 degrees
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≤ ± 5 degrees
Q channel baud rate > 1.024 Msps	≤ ± 3 degrees
DG2	
BPSK	
Baud rate ≤ 1.024 Msps	≤ ± 9 degrees
Baud rate > 1.024 Msps	≤ ± 3 degrees
QPSK	
Baud rate per channel ≤ 1.024 Msps	≤ ± 5 degrees
Baud rate per channel > 1.024 Msps	≤ ± 3 degrees
Gain Imbalance	
DG1 modes 1 and 2	≤ ± 0.50 dB
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≤ ± 0.50 dB
Q channel baud rate > 1.024 Msps	≤ ± 0.25 dB
DG2	
BPSK	
Baud rate ≤ 1.024 Msps	≤ ± 1.0 dB
Baud rate > 1.024 Msps	≤ ± 0.25 dB
QPSK	
Baud rate per channel ≤ 1.024 Msps	≤ ± 0.50 dB
Baud rate per channel > 1.024 Msps	≤ ± 0.25 dB

Table 6-12. TDRSS SSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1, 2, and 14)	**Description** (Notes 1, 2, and 14)
Phase nonlinearity (applies for all types of phase nonlinearities) (peak) (Note 12)	
DG1 modes 1 and 2	≤ 4 degrees over ±2.1 MHz
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≤ 4 degrees over ±2.1 MHz
Q channel baud rate > 1.024 Msps	≤ 3 degrees over ±3.5 MHz
DG2	
Baud rate per channel ≤ 1.024 Msps	≤ 4 degrees over ±1.0 MHz
Baud rate per channel > 1.024 Msps	≤ 3 degrees over ±3.5 MHz
Gain flatness (peak) (Note 12)	
DG1 modes 1 and 2	≤ 0.4 dB over ±2.1 MHz
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≤ 0.4 dB over ±2.1 MHz
Q channel baud rate > 1.024 Msps	≤ 0.3 dB over ±3.5 MHz
DG2	
Baud rate per channel ≤ 1.024 Msps	≤ 0.4 dB over ±1.0 MHz
Baud rate per channel > 1.024 Msps	≤ 0.3 dB over ±3.5 MHz
Gain slope (peak) (Note 12)	
DG1 modes 1 and 2	Not specified
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	Not specified
Q channel baud rate > 1.024 Msps	≤ 0.1 dB/MHz over ±3.5 MHz
DG2	
Baud rate per channel ≤ 1.024 Msps	Not specified
Baud rate per channel > 1.024 Msps	≤ 0.1 dB/MHz over ±3.5 MHz
AM/PM	
DG1 modes 1 and 2	≤ 15 degrees/dB
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≤ 15 degrees/dB
Q channel baud rate > 1.024 Msps	≤ 12 degrees/dB

Table 6-12. TDRSS SSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1, 2, and 14)	**Description** (Notes 1, 2, and 14)
AM/PM (cont'd)	
DG2	
Baud rate per channel ≤ 1.024 Msps	≤ 15 degrees/dB
Baud rate per channel > 1.024 Msps	≤ 12 degrees/dB
Noncoherent frequency stability (peak) (Notes 5, 6, 11)	
±700 Hz customer oscillator frequency uncertainty	
1-sec average time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 1 \times 10^{-7}$
48-hr observation time	$\leq 3 \times 10^{-7}$
± 3 kHz customer oscillator frequency uncertainty	
1-sec average time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 4.3 \times 10^{-7}$
48-hr observation time	$\leq 1.29 \times 10^{-6}$
± 35 kHz customer oscillator frequency uncertainty	
1-sec average time	
Baud rate per channel ≤ 12.5 ksps	$\leq 7.37 \times 10^{-9}$
Baud rate per channel > 12.5 ksps	$\leq 26 \times 10^{-9}$
5-hr observation time	$\leq 3.77 \times 10^{-6}$
48-hr observation time	$\leq 11.3 \times 10^{-6}$
Incidental AM (peak)	
At frequencies >10 Hz for data rates <1 kbps;	
At frequencies >100 Hz for data rates ≥1 kbps	≤5 percent
Spurious PM (rms)	
DG1	≤ 2 degrees
DG2	
BPSK	≤ 2 degrees
QPSK	
I/Q = 4:1	≤ 2 degrees
I/Q = 1:1	≤ 1 degree

Table 6-12. TDRSS SSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1, 2, and 14)	**Description** (Notes 1, 2, and 14)
Minimum 3-dB bandwidth prior to power amplifier	
DG1	≥4.5 MHz or two times maximum baud rate, whichever is larger
DG2	≥2 times maximum channel baud rate
Phase noise (rms) (Note 7 and 8)	
DG1 Mode 1 (Note 13)	
Channel baud rate < 18 ksps	
1 Hz – 10 Hz	≤1.0° rms
10 Hz – 1 kHz	≤1.0° rms
1 kHz – 6 MHz	≤1.5° rms
Channel baud rate ≥ 18 ksps	
1 Hz – 10 Hz	≤ 25.0° rms
10 Hz – 1 kHz	≤ 2.2° rms
1 kHz – 6 MHz	≤ 2.0° rms
DG1 Mode 2	
Channel baud rate < 40 ksps	
1 Hz – 10 Hz	≤ 7.5° rms
10 Hz – 100 Hz	≤ 2.0° rms
100 Hz – 1 kHz	≤ 1.5° rms
1 kHz – 6 MHz	≤ 1.5° rms
Channel baud rate ≥ 40 ksps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 100 Hz	≤ 5.5° rms
100 Hz – 1 kHz	≤ 2.5° rms
1 kHz – 6 MHz	≤ 2.5° rms
DG1 Mode 3 (Note 13)	
Channel baud rate < 222.5 ksps	
1 Hz – 10 Hz	≤ 4.0° rms
10 Hz – 1 kHz	≤ 2.8° rms
1 kHz – 6 MHz	≤ 1.4° rms

Table 6-12. TDRSS SSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1, 2, and 14)	**Description** (Notes 1, 2, and 14)
Phase noise (rms) (Note 7 and 8) (cont'd)	
DG1 Mode 3 (Note 13) (cont'd)	
Channel baud rate ≥ 222.5 ksps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 1 kHz	≤ 5.5° rms
1 kHz – 6 MHz	≤ 1.8° rms
DG2 Coherent (Note 13)	
Channel baud rate < 18 ksps	
1 Hz – 10 Hz	≤3.8° rms
10 Hz – 1 kHz	≤2.3° rms
1 kHz – 6 MHz	≤2.0° rms
18 ksps ≤ Channel baud rate ≤ 1.024 Msps	
1 Hz – 10 Hz	≤25.0° rms
10 Hz – 1 kHz	≤2.5° rms
1 kHz – 6 MHz	≤2.0° rms
Channel baud rate > 1.024 Msps	
1 Hz – 10 Hz	≤5.0° rms
10 Hz – 1 kHz	≤1.0° rms
1 kHz – 6 MHz	≤0.5° rms
DG2 Noncoherent	
Channel baud rate < 12.5 ksps	
1 Hz – 10 Hz	≤ 5.0° rms
10 Hz – 100 Hz	≤ 1.0° rms
100 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 6 MHz	≤ 2.0° rms
12.5 ksps ≤ Channel baud rate ≤ 1.024 Msps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 100 Hz	≤ 5.5° rms
100 Hz – 1 kHz	≤ 2.4° rms
1 kHz – 6 MHz	≤ 2.4° rms

Table 6-12. TDRSS SSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1, 2, and 14)	**Description** (Notes 1, 2, and 14)
Phase noise (rms) (Note 7 and 8) (cont'd)	
DG2 Noncoherent (cont'd)	
Channel baud rate > 1.024 Msps	
1 Hz – 10 Hz	≤ 10.0° rms
10 Hz – 100 Hz	≤ 1.5° rms
100 Hz – 1 kHz	≤ 0.5° rms
1 kHz – 6 MHz	≤ 0.5° rms
In-band spurious outputs, where in-band is twice the maximum channel baud rate	
DG1 modes 1 and 2	≥ 23 dBc
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≥ 23 dBc
Q channel baud rate > 1.024 Msps	≥ 30 dBc
DG2	
Baud rate per channel ≤ 1.024 Msps	≥ 23 dBc
Baud rate per channel > 1.024 Msps	≥ 30 dBc
Out-of-band emissions	See Appendix D for NASA/GSFC Recommended Filtering in the 2290-2300 MHz band and allowable limits on out-of-band emissions, including spurs
I/Q symbol skew (relative to requirements for I/Q data synchronization where appropriate) (peak)	≤3 percent
I/Q PN chip skew (relative to 0.5 chip)	≤0.01 chip
PN chip rate (peak), DG1 mode 2 (relative to absolute coherence with carrier rate)	≤0.01 chips/sec at PN code chip rate
Customer-induced PN correlation loss (noncoherent and coherent)	≤0.3 dB
Customer Antenna-Induced PM	≤10 degrees
Data rate tolerance	≤+0.1 percent
I/Q power ratio tolerance	≤+0.4 dB
Permissible P_{rec} variation (without reconfiguration GCMR from customer MOC) (Note 9)	≤12 dB
Permissible rate of P_{rec} variation	≤10 dB/sec
Maximum P_{rec}	-149.7 dBW -157.7 dBW (SSA cross-support: DG1 mode 3)

Table 6-12. TDRSS SSA Return Service Customer Platform Signal Constraints (cont'd)

Notes:

1. The definitions and descriptions of the customer constraints are provided in Appendix E.
2. When a constraint value is listed for a baud rate range and data is transmitted on both channels, the maximum baud rate of the 2 channels should be used to determine the constraint value applicable.
3. It is recommended that customers use G2 inversion to increase symbol transition density. Additionally, biphase symbol formatting increases symbol transition density. CCSDS randomization is recommended to aid in compliance with the data randomness requirements.
4. The symbol jitter and jitter rate are defined as the customer transmitted signal peak clock frequency jitter and peak clock jitter rate (sinusoidal or 3σ random) as a percent of the symbol clock rate.
5. The frequency stability requirements are valid at any constant temperature ($\pm 0.5°$ C) in the range expected during the mission. At a minimum, a temperature range of -10° C to +55° C shall be considered.
6. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of $\pm$ 700 Hz. If a customer cannot accurately define their transmit frequency to within $\pm$ 700 Hz, a customer can request a reconfiguration which would expand the oscillator frequency search to $\pm$ 3 kHz for DG1 and SQPSK DG2 configurations and $\pm$ 35 kHz for BPSK and QPSK DG2 configurations after the start of service.
7. Derivation of the phase noise requirements involved making assumptions about the distribution of the phase noise power in each frequency region. Since no phase noise PSD will exactly match the phase noise power distribution assumed for this derivation, phase noise PSDs which are close to violating the phase noise limits or phase noise PSDs which violate the phase noise limits should be evaluated on a case-by-case basis to determine their acceptability.
8. For customers receiving Doppler tracking services, more stringent phase noise constraints should be considered by the customer. It is the responsibility of the customer to ensure customer transponder / transmitter phase noise performance enables achievement of the desired total Doppler tracking error performance. Appendix U provides recommended customer phase noise performance constraints which ensure a total Doppler tracking error (system + customer) ≤ 0.2 rad/sec (1σ, channel data rate > 1 kbps) or ≤ 0.4 rad/sec (1σ, channel data rate ≤ 1 kbps) assuming an averaging time of 1 second.
9. The minimum SHO EIRP should reflect the minimum P_{rec} expected over the service period, where the P_{rec} can exceed this minimum by no more than 12 dB. An actual customer P_{rec} value that is 12 dB greater than the minimum may cause false PN lock or nonacquisition.
10. Deleted.
11. Deleted.
12. Bandwidth limitation for gain flatness, phase nonlinearity and gain slope while maintaining consistency with NTIA spectral emission mask (Appendix D):70% of the signal main lobe width or 70 % of the necessary bandwidth whichever is smaller.
13. Coherent return link phase noise user constraint assumes a forward service signal with no phase noise on it. Phase noise created in the user receiver carrier tracking loop by thermal noise on the forward link is a component which must be considered as a contributor to the user coherent return service phase noise.
14. Customers are recommended to provide to the SN a transmitter EVM measurement for each of their service modes.

6.3.6 Automated IF Service

This section specifies characteristics and recommendations for the SSAR automated IF service. SN IF services are available to customers on a case-by-case basis. The IF

service is supported through TDRS F3 – F7, TDRS F8 – F10 and K, L, M via the SN ground terminal infrastructure, where the customer provides the receiver equipment and the SN only provides the signal at the IF with the characteristics described in this section. Paragraph 6.3.6.1 describes the aggregate channel characteristics of the TDRS spacecraft and SN ground segment for understanding the IF interface.

The performance of the customer link greatly depends on the customer signal characteristics and the receiver used. Paragraph 6.3.6.2 describes potential signal characteristics and expected performance through the TDRS spacecraft and SN ground segment. The expected performance is based upon simulation results only and has not been verified by testing. Data rates and coding techniques should be carefully considered and coordinated with Code 450 to achieve desired performance.

Changes to the operating conditions or configuration of a TDRSS SSAR IF service during a scheduled service support period are initiated by a GCMR from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the GCMR at the SN ground terminal. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning SN ground terminal response times for GCMRs is provided in Section 10. Table 6-13 lists the SSA IF return service real-time configuration changes and their effects on the return service.

Table 6-13. SSA Return IF Service Real-Time Configuration Changes

Real-Time Configuration Changes	GCMR	OPM	Return Service Interruption
Polarization	98/04	OPM 03	Yes
Note: Items that are indicated to cause return service interruption will cause the SN ground terminal receiver to discontinue signal tracking and attempt to reacquire the return service signal after the appropriate reconfiguration. Any other reconfigurations of the SN ground terminal may momentarily affect signal tracking.			

6.3.6.1 Channel Characteristics

As discussed above, this is not an end-to-end service so a set of customer platform signal constraints is not available due to the dependencies on the exact customer signal characteristics as well as receiver capabilities. The IF service provides a SSAR signal through the TDRS spacecraft and SN ground segment, including IF output channel characteristics as specified in Table 6-14. This will allow customers to be able to understand the signal distortions that are outside of their control. For additional characteristics applicable to the SSAR IF service, refer to Table 6-9.

Table 6-14. TDRS SSAR IF Service Spacecraft and Ground Segment Channel Characteristics

Parameter	Description
TDRS S-band Receive Center Frequencies (note 1)	2200 MHz to 2300 MHz
3-dB RF bandwidth (note 3)	≥ 17 MHz
Gain Flatness (peak) (note 2)	≤ 0.74 dB over ±3.5 MHz
Gain Slope (note 2)	≤ 0.14 dB/MHz over ± 3.5 MHz
Phase nonlinearity (applies for all types of phase nonlinearities) (peak) (note 2)	≤ 16.1° over ± 3.5 MHz
AM/AM (note 2)	> 0.57 dB/dB
AM/PM (note 2)	≤ 6.5°/dB
Spurious PM (note 2)	≤ 2.24° rms
In-band spurious outputs (note 2)	
Total	≥ 27 dBc
Individual	≥ 40 dBc
Incidental AM (peak) (note 2)	≤ 1% (within 3-dB RF bandwidth)
Phase noise (note 2)	
1 Hz to 10 Hz	≤ 2.3° rms
10 Hz to 100 Hz	≤ 2.9° rms
100 Hz to 1 kHz	≤ 4.6° rms
1 kHz to 6 MHz	≤ 2.0 ° rms
Additional TDRS Ground Segment IF Characteristics:	
IF center frequency	370 MHz
Output level	-15 dBm ±3 dB
Output VSWR	≤ 1.3:1 into 50Ω load, ± 3 MHz from center frequency

Table 6-14. TDRS SSAR IF Service Spacecraft and Ground Segment Channel Characteristics (cont'd)

Notes:

1. The customer receive center frequency that is scheduled for SN support will be translated to the center of the IF bandwidth. The signal and carrier frequency will be constrained such that the first null of the spectrum falls between 2200 and 2300 MHz. The SSAR IF service only supports non-coherent frequencies. The SSAR IF service supports only one S-band frequency through 1 TDRS at a time. These frequencies do not include the effects of Doppler shift. The SSAR IF service is not required to provide a Doppler-corrected IF output signal. The customer provided receiver needs to handle Doppler.
2. Constraint parameters are contributions from the TDRS spacecraft and the SN ground segment to the IF interface. Not included in these aggregate distortion amounts are TDRS spacecraft gain flatness linear and parabolic allowances and phase nonlinearity parabolic and cubic allowances as described in 405-TDRS-RP-SY-001, WU-02-01, and SY1-89E. Customer and receiver signal characteristics need to be considered to determine the end-to-end performance. Please contact GSFC Code 450 for further information.
3. The 3 dB RF bandwidth is larger than the specified 10 MHz bandwidth value specified in Table 6-9. This value has validated through spacecraft and ground terminal measurements, but may not be applicable to future TDRS.

6.3.6.2 Potential Signal Parameters and Signal Performance for IF Service

As discussed earlier, this is not an end-to-end service so a set of well defined customer signal parameters is not available. This section describes example signal characteristics and expected performance through the TDRS spacecraft and SN ground segment. SN IF services are available to customers on a case-by-case basis. Customers should contact Code 450 if they are interested in this service to determine expected performance for their specific signal characteristics and receiver.

The performance of the IF link is greatly dependent on the customer provided receiver. Typically, the SNUG specifies performance at BER of 10^{-5}; BERs better than 10^{-5} may be possible for the automated IF service.

NOTE:

The expected performance is based upon simulation results only and has not been verified by testing. Data rates and coding techniques should be carefully considered and coordinated with GSFC Code 450 to achieve desired BER.

All values in this section assume using a receiver with reasonable implementation loss. Table 6-15 provides expected required Eb/No values for example data rates and modulation schemes for a 10^{-5} BER. Additionally, Table 6-15 also provides the theoretical Eb/No and implementation loss values for those modulation and coding schemes at 10^{-5} BER over a simple AWGN channel. Table 6-15 also provides a potential minimum required P_{rec} (dBW) equation for the example data rates, coding and modulation schemes through the IF service assuming these expected required Eb/No values, which were based upon simulation results and have not been verified by testing.

Table 6-15. Example SSAR IF Service Implementation Loss Amounts and Required P_{rec} Equations for Various Data Rates Using Different Modulation and Coding Techniques

Return IF Service Configuration (note 2)		Data Rates	Required Eb/No at input to receiver for 10^{-5} BER (notes 1, 2)	Theoretical Required Eb/No (note 1)	Implementation Loss Amounts (notes 1, 2)	Required P_{rec} (K) at TDRS (dBW) for a 10^{-5} BER (LEO Program Track) (note 2)
BPSK/QPSK/ SQPSK (unspread)	(2048, 1024) AR4JA LDPCC	$\leq$ 1 Mbps	2.9 dB	1.7 dB	1.2 dB	-236.0 + 10 log (dr)

Notes:

1. Unless otherwise noted, all values are based upon a customer transmitter power amplifier operating point of 1 dB OBO, i.e., AM/PM = 12°/dB and AM/AM = 0.47 dB/dB. Values assume baseband equalization used. Values do not include margin. All values are given for a receiver with reasonable loss. Better performance may be achievable with better power amplifier and/or filters, etc.
2. These service configurations and data rates were based upon simulation results only and have not been verified by testing. Other data rates and modulation schemes may be possible. Please contact GSFC Code 450 for further information.

Section 7. KuSA Telecommunications Services

7.1 General

7.1.1 Available Services

TDRSS KuSA services include forward and return telecommunications services, and tracking services. KuSA return service includes service through the SN receive equipment and an automated IF service, where SN IF services are available to customers on a case-by-case basis. IF service requires the customer to provide the receiver equipment and the SN only provides the signal at the IF interface. Tracking services are discussed in Section 9. This section focuses on the RF interface between the TDRS and the customer platform. This interface is characterized by the technical requirements imposed and the operational capabilities provided by the TDRSS. The operational interfaces are described in further detail in Section 10. Data interfaces between the customer MOC and the SN are described in Section 3, paragraph 3.6.

NOTE:

The NCCDS issues NAMs to provide up-to-date information on network conditions and constraints. These messages are accessible via the NCCDS active NAM web site at https://cds.gsfc.nasa.gov/. The GSFC Code 450 uses the NAM as a means of letting customers know of any performance constraints associated with the TDRS spacecraft. Additionally, TDRS constellation information can be found in the TDRS Constellation Management Plan, 452-PLAN-0002.

7.1.2 Interface Definition

The RF interface between the TDRS and a customer platform is defined in terms of signal parameters, RF characteristics, and field of view.

a. The RF interface for forward service represents the transmission by a TDRS of an appropriately modulated signal at or greater than a minimum specified signal EIRP in the direction of the desired customer platform. KuSA forward (KuSAF) service is discussed in paragraph 7.2.

b. The RF interface for return service defines a minimum received power (P_{rec}) at the TDRS antenna input for a specified data quality at the SN ground terminal receiver output. KuSA return (KuSAR) service is discussed in paragraph 7.3.

NOTE:

The KuSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.

7.1.3 Customer Acquisition Requirements

Acquisition and reacquisition by the customer platform of the TDRS transmitted signal requires prediction by the customer MOC of the customer platform receive frequency over various projected time periods. Similarly, acquisition and reacquisition by the SN ground terminal of the customer platform signal requires prediction by the customer MOC of the customer platform transmitter frequency over various projected time periods. The frequency predictions are ultimately incorporated in the SHO as customer platform frequencies for the specific service support periods. Refer to Section 9 for additional information on TDRSS tracking services that can assist customers in predicting their local oscillator frequencies.

7.1.4 TDRSS Acquisition Support to Customers

For each scheduled TDRSS service support period, the customer requirements for signal acquisition/reacquisition, and the TDRSS capabilities to aid acquisition/ reacquisition, are as follows:

a. Customer Epoch Uncertainty

1. Autotrack. The maximum epoch time uncertainty of the applicable customer platform ephemeris supplied to the TDRSS shall be ±4.5 seconds and ±3.2 seconds for customer platform operations requiring the TDRSS KuSA return service autotrack process within the TDRSS Primary FOV and EEFOV, respectively. Similarly, the maximum epoch time uncertainty of the customer platform ephemeris shall be ±4.5 seconds for the TDRSS KuSA return service autotrack process within the TDRSS LEOFOV.

NOTE:

KuSAF EEFOV autotrack support and KuSAR EEFOV autotrack support shall be coordinated through GSFC Code 450. Autotrack service is not available through the Ku-band return IF service.

2. Program track. The maximum epoch time uncertainty of the applicable customer platform ephemeris supplied to the TDRSS shall be ±4.5 seconds and ±3.2 seconds for customer platform operations using TDRSS KuSA open-loop pointing within the TDRSS Primary FOV and EEFOV, respectively.

3. LEO Program track. The maximum epoch time uncertainty of the applicable customer platform ephemeris supplied to the TDRSS shall be ±1.5 seconds for customer platform operations requiring the TDRSS KuSA open-loop pointing for customers within the TDRSS LEOFOV.

b. Customer Frequency Uncertainty. The customer MOC must know the operating frequency of the customer platform to within ±5 kHz.

c. Frequency Sweep on the Forward Link. After the start of the forward link service, the TDRSS has a forward service frequency sweep capability of ±30 kHz.

d. Noncoherent Return Expanded Frequency Search. After the start of the return link service, the TDRSS has a return service expanded frequency search capability of ±20 kHz.

7.2 KuSA Forward Services

7.2.1 General

The characteristics of the data provided to the SN ground terminal interface and the RF signals provided by the TDRS to the customer platform during TDRSS KuSA forward services are described in paragraphs 7.2.2 through 7.2.5. This discussion assumes that an appropriate forward service has been scheduled and a data signal is present at the SN ground terminal interface.

NOTE:

NTIA and NASA policy does not permit use of the KuSAF service for customers other than ISS. If such support is essential, the SN should be notified and the NASA GSFC spectrum manager may request a waiver.

7.2.2 Signal Parameters

The TDRSS KuSA forward service signal parameters are defined in Table 7-1. The center frequency, f_o, of the customer platform receiver must be defined by the customer MOC in its service specification code for TDRSS KuSA forward service (refer to Section 10, paragraph 10.2.2). A description of the features inherent in the QPSK and BPSK signal parameters listed in Table 7-1 are discussed in paragraphs 7.2.2.1 and 7.2.2.2, respectively.

7.2.2.1 QPSK Signal Parameters

a. Unbalanced QPSK Modulation (PN Modulation Enabled). The I channel is used to transmit the customer command data and is referred to as the command channel. The Q channel transmits a range signal and is referred to as the range channel. The command channel/range channel power ratio for SS-UQPSK forward service signals is +10 dB. This unbalanced QPSK modulation minimizes the power in the range channel to a level adequate for customer platform range channel acquisition and tracking. This feature increases the power in the command channel by 2.6 dB over that for balanced QPSK modulation without increasing customer platform receiver complexity, increasing customer platform command channel acquisition time, or decreasing TDRSS range tracking accuracy.

b. Spread Spectrum. All TDRSS KuSA forward services with data rates ≤300 kbps should incorporate spread spectrum modulation techniques to satisfy flux density restrictions imposed upon TDRSS forward services by the NTIA. This modulation scheme includes separate but simultaneous command and range channels. The command channel includes a rapidly acquirable PN code and contains the forward service data. The range channel is acquired separately and contains a PN code which satisfies the range ambiguity resolution requirements. The length of the command channel PN code is 2^{10}-1, where the length of the range channel PN code is 256 times the command channel PN code length. The customer platform command channel acquisition can precede customer platform range channel acquisition; this feature permits rapid acquisition of the range channel by limiting the range channel PN code search to only 256 chip positions while the range channel PN code itself contains 261,888 chips. The PN code chip rate is coherently related to the TDRS transmit frequency in all cases. This feature permits the customer platform receiver to use the receiver PN code clock to predict the received carrier frequency, thereby minimizing receiver complexity and reducing acquisition time. 451-PN CODE-SNIP defines all the salient characteristics for the forward range and command channel PN code libraries. The Agency Spectrum Manager responsible for PN code assignments will allocate a customer platform-unique PN code assignment from these libraries. The GSFC Spectrum Manager is responsible for NASA PN code assignments.

c. Asynchronous Data Modulation. For data rates ≤ 300 kbps, the forward service data received at the SN ground terminal from the NISN data transport system is directly modulo-2 added by the SN ground terminal to the command channel PN code sequence. The forward service data will be asynchronous with the carrier and the PN code.

NOTE:

When the command channel does not contain any actual forward service data, the forward service command channel signal is the command channel PN code sequence with or without an idle pattern.

d. Functional Configurations. A further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in section B.2.2.

e. Doppler Compensation. The TDRSS KuSA forward service carrier frequency (F) and the PN chip rate transmitted by a TDRS can optionally be compensated by the SN ground terminal for Doppler. When compensated, the carrier, F_R, arrives at the customer platform receiving system within a predictable tolerance (E) of f_o as defined in Table 7-1. This feature minimizes the Doppler resolution requirements of the customer platform receiver and is available continuously to facilitate reacquisition by the customer platform in the event of loss of lock of the TDRSS KuSA forward service signal. Doppler compensation may be inhibited and the TDRSS will transmit a fixed frequency KuSA forward service carrier and PN code chip rate.

Table 7-1. TDRSS KuSA Forward Service Signal Parameters

Parameter	Description
TDRS transmit carrier frequency (Hz)	F
Carrier frequency arriving at customer platform (note 1)	F_R
Carrier frequency sweep (note 4)	$\pm$30 kHz
Carrier frequency sweep duration (note 4)	120 seconds
UQPSK (PN modulation enabled)	
$\frac{\text{Command channel radiated power}}{\text{Range channel radiated power}}$	+10 dB
SS-UQPSK Command Channel	
Carrier frequency (Hz)	Transmit carrier frequency (F)
PN code modulation	PSK, $\pm$ π/2 radians
Carrier suppression	30 dB minimum
PN code length (chips)	2^{10} - 1
PN code epoch reference	Refer to 451-PN CODE-SNIP
PN code family	Gold codes
PN code chip rate (chips/sec)	$\frac{31}{1469 \times 96} \times F$
Data modulation	Modulo-2 added asynchronously to PN code
Data format (note 2)	Not applicable
Data rate restrictions (note 2)	1 kbps - 300 kbps
SS-UQPSK Range Channel	
Carrier	Command channel carrier frequency delayed π/2 radians
PN code modulation	PSK, $\pm$ π/2 radians
Carrier suppression	30 dB minimum
PN code chip rate	Synchronized to command channel PN code chip rate
PN code length (chips)	(2^{10} - 1) x 256
PN code epoch reference	All 1's condition synchronized to the command channel PN code epoch.
PN code family	Truncated 18-stage shift register sequences

Table 7-1. TDRSS KuSA Forward Service Signal Parameters (cont'd)

Parameter	Description
BPSK (PN modulation enabled; also referred to as Spread Spectrum BPSK (SS-BPSK)) (note 5)	
Carrier frequency (Hz)	Transmit carrier frequency (F)
PN code modulation	PSK, $\pm \pi/2$ radians
Carrier suppression	30 dB minimum
PN code length (chips)	$2^{10} - 1$
PN code epoch reference	Refer to 451-PN CODE-SNIP
PN code family	Gold codes
PN code chip rate (chips/sec)	$\frac{31}{1469 \times 96} \times F$
Data modulation	Modulo-2 added asynchronously to PN code
Data format (note 2)	Not applicable
Data rate restrictions (note 2)	1 kbps - 300 kbps
BPSK (PN modulation disabled)	
Carrier frequency (Hz)	Transmit carrier frequency (F)
Data modulation	PSK, $\pm\pi/2$ radians
Carrier suppression	30 dB minimum
Data format (note 2)	Not Applicable
Data rate restrictions (notes 2, 3)	300 kbps - 25 Mbps

Notes:

1. The center frequency, f_O, of the customer platform receiver must be defined by the customer MOC in its service specification code to an integral multiple of 10 Hz. The SN ground terminal will round-off the customer receive frequency contained in the SHO to the nearest multiple of 1469 Hz. Doppler compensation will be available for $\dot{R} \leq 12$ km/sec. During periods of Doppler compensation, $F_R = f_O \pm E$ Hz, where f_O = nominal center frequency of customer platform receiver as defined by the customer MOC and $E = |e \times f_O \times \ddot{R}/c| + C$; $e \leq \pm 4.5$ sec is the customer epoch uncertainty, $\ddot{R} \leq 15$ m/sec^2, c is the free space speed of light in m/sec, and C = 1900 Hz. If Doppler compensation is inhibited after the start of the forward service, a transition profile will be initiated to slowly change the frequency from the compensate profile to this integer multiple of 1469 Hz.

   Forward service Doppler compensation will not increase the effective frequency rate of change seen at the customer receiver more than 330 Hz/sec relative to the frequency for a Doppler free carrier.
2. The forward data rate in this table is the baud rate that will be transmitted by the TDRSS (includes all coding and symbol formatting). For non-WDISC customers, forward data conditioning is transparent to the SN. These transparent operations should be performed by the customer prior to transmission to the SN data interface. Refer to Section 3, paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities. Current GRGT SGLT-6 software limitations constrain the KuSAF data rate to 7 Mbps or less.

Table 7-1. TDRSS KuSA Forward Service Signal Parameters (cont'd)

Notes (cont'd):

3. The SN is capable of supporting BPSK signals at data rates less than 300 kbps; however, its use will be controlled and must be coordinated with GSFC Code 450.
4. After the start of the KuSA forward service, if a customer MOC is unable to accurately define f_o (the nominal center frequency of the customer platform receiver), the forward service carrier frequency can be swept. The KuSA forward service frequency sweep will be initiated by the SN ground terminal at f_o-30 kHz and linearly swept to f_o+30 kHz in 120 seconds and held at f_o+30 kHz thereafter. The KuSA forward service frequency sweep does not impact simultaneous SN ground terminal Doppler compensation of the KuSA forward service carrier and PN code rate (if applicable).
5. Customers who operate in a SS-BPSK mode for one service cannot reconfigure any of their Forward Services (i.e., MAF, SMAF, SSAF, KuSAF, or KaSAF) to an SS-UQPSK mode. Contact Code 450 if additional flexibility is required.

7.2.2.2 BPSK Signal Parameters

a. BPSK Modulation (PN Modulation Enabled). The I channel is used to transmit the customer command data and is referred to as the command channel. TDRSS KuSA forward services with data rates equal to and below 300 kbps should incorporate spread spectrum modulation techniques to satisfy flux density restrictions imposed on the TDRSS forward services by the NTIA. The command channel includes a rapidly acquirable PN code and contains the forward service data. The PN code chip rate is coherently related to the TDRS transmit frequency in all cases. This feature permits the customer platform receiver to use the receiver PN code clock to predict the received carrier frequency, thereby minimizing receiver complexity and reducing acquisition time. 451-PN CODE-SNIP defines all the salient characteristics for the forward command channel PN code libraries. The Agency Spectrum Manager responsible for PN code assignments will allocate a customer platform-unique PN code assignment from these libraries. The GSFC Spectrum Manager is responsible for NASA PN code assignments.

NOTE:

Customers who operate in a SS-BPSK mode for one service cannot reconfigure any of their Forward Services (i.e., MAF, SMAF, SSAF, KuSAF, or KaSAF) to a SS-UQPSK mode. Contact Code 450 if additional flexibility is required.

b. BPSK Modulation (PN Modulation Disabled). For data rates greater than 300 kbps, there is no PN code modulation and the customer data directly BPSK modulates the carrier by $\pm\pi/2$ radians.

NOTE:

The SN is capable of supporting non-spread BPSK signals at data rates less than 300 kbps; however, its use will be controlled and must be coordinated with GSFC Code 450.

c. Asynchronous Data Modulation. The forward service data will be asynchronous with the carrier.

NOTE:

When the command channel does not contain any actual forward service data, the forward service command channel signal is carrier only.

d. Functional Configurations. A further description of the functional configurations and data polarity ambiguity is found in section B.2.2.

e. Doppler Compensation. The TDRSS KuSA forward service carrier frequency (F) transmitted by a TDRS can optionally be compensated by the SN ground terminal for Doppler. When compensated, the carrier, F_R, arrives at the customer platform receiving system within a predictable tolerance (E) of f_o as defined in Table 7-1. This feature minimizes the Doppler resolution requirements of the customer platform receiver and is available continuously to facilitate reacquisition by the customer platform in the event of loss of lock of the TDRSS KuSA forward service signal. Doppler compensation may be inhibited and the TDRSS will transmit a fixed frequency KuSA forward service carrier.

7.2.3 Communications Services

The TDRSS KuSA forward services available are listed in Table 7-2. Table 7-3 lists their salient characteristics. The definitions for the parameters listed in Table 7-3 are contained in Appendix E.

7.2.4 Real-Time Configuration Changes

Changes to the operating conditions or configuration of a TDRSS KuSA forward service during a scheduled service support period are usually initiated by a GCMR from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the GCMR at the SN ground terminal. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning SN ground terminal response times for the GCMRs is provided in Section 10. Table 7-4 lists the KuSA forward service real-time configuration changes and their effects on the forward service signal.

7.2.5 Acquisition Scenarios

The following acquisition scenarios identify only the technical aspects of TDRSS KuSA forward service signal acquisition by the customer platform and do not include operational procedures related to acquisition:

a. KuSAF Program Track and LEO Program Track Scenarios:

1. The TDRSS KuSA forward service signal does not depend on a customer platform return service.
2. Prior to the start of the TDRSS KuSA forward service, the TDRSS KuSA antenna will be open-loop pointed in the direction of the customer platform.
3. At the start of the TDRSS KuSA forward service as defined by the SHO, the TDRS will radiate, in the direction of the customer platform, a signal compatible with the TDRSS KuSA forward service signal parameters listed in Table 7-1. The EIRP directed towards the customer platform is dependent upon the customer providing an ephemeris uncertainty within the values defined in Table 7-2.
4. The customer platform receiving system will search for and acquire the command channel PN code (if applicable) and carrier. Normally, a customer MOC will not be transmitting forward service data to the NISN data transport system until the forward service signal has been acquired by the customer platform and the acquisition verified by the customer MOC from customer platform return service telemetry. Some customer platforms may require that there be no data transitions during the signal acquisition process, while others may merely result in longer acquisition times.
5. For QPSK modulation, the customer platform receiving system will search for and acquire the range channel PN code upon acquisition of the command channel PN code and carrier.
6. Depending upon the customer platform receiving system design, upon completion of forward link acquisition and subsequent customer platform transition to signal tracking, the customer platform transmitting system may either switch to a coherent mode or remain in a noncoherent mode until commanded by the customer MOC to switch.
7. The SN ground terminal will continue Doppler compensation of the TDRSS KuSA forward service signal unless requested by the customer MOC to inhibit the Doppler compensation.
8. Acquisition times (T_{acq}) in the customer platform receiver is a function of the customer platform receiver design and signal-to-noise density ratio. The customer platform forward service acquisition time must be considered in determining the overall return service acquisition time for customer platform with a coherent mode of operation.

9. Appendix A provides example link calculations for the TDRSS KuSA forward service.

b. KuSAF Acquisition Scenario with Return Autotrack Services:

1. Prior to return autotrack acquisition, the TDRSS forward service EIRP will be the program or LEO program track high-power values, whichever is applicable based upon customer characteristics (see paragraph 7.2.5.a for a description of the program and LEO program track acquisition scenarios). The EIRP directed towards the customer platform is dependent upon the customer providing an ephemeris uncertainty within the values defined in Table 7-2. The appropriate TDRS KuSA autotrack normal-power or high-power mode signal EIRP listed in Table 7-2 will be provided after return service autotrack acquisition is achieved.

Table 7-2. TDRSS KuSA Forward Service

Parameter	Description (Note 6)		
Field of view (FOV) (each TDRS) (note 7)	PFOV	LEOFOV	Extended Elliptical (EEFOV) (F8-F10 and K, L, M)
	±22 degrees east-west ±28 degrees north-south	±10.5 degree conical	24.0 degrees inboard east-west 76.8 degrees outboard east-west ±30.5 degrees north-south
Customer Ephemeris Uncertainty (along the customer orbital track) (note 8)	≤ ± 4.5 sec	≤ ± 1.5 sec	≤ ± 3.2 sec
TDRS antenna polarization (note 1)	RHC or LHC selectable		
	Autotrack (PFOV, and EEFOV) (notes 3, 5)	LEO Program Track (LEOFOV)	Program Track (PFOV and EEFOV)
TDRS antenna axial ratio (maximum)			
Normal or high-power mode	1 dB over 3-dB beamwidth	1 dB over 3-dB beamwidth	1.5 dB
TDRS signal EIRP (minimum) (note 4)			
Normal power mode	+46.5 dBW	44 dBW	40.5 dBW
High power mode	+48.5 dBW	46 dBW	42.5 dBW
Transmit frequency (nominal) (note 2)	13.775 GHz ±0.7 MHz		
RF bandwidth (3dB, minimum)	50 MHz		
Duty factor	100 percent (normal and high power)		

Table 7-2. TDRSS KuSA Forward Service (cont'd)

Notes:

1. Operational considerations may limit choice of TDRS antenna polarization. The KuSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.
2. The customer MOC must include the best estimate of the customer platform receiver center frequency at the time of startup of each scheduled service support period in its service specification code (refer to Section 10, paragraph 10.2.2). The TDRSS KuSA forward service carrier frequency is then implemented by the SN ground terminals to the accuracy of the SN ground terminal frequency standard except during Doppler compensation.
3. EIRP values are for a TDRSS forward service with a TDRSS return autotrack service acquired. Forward service EIRP will default to high power program track values when: 1) a simultaneous return service with autotrack enabled is ongoing AND 2) TDRSS is in the autotrack acquisition process. Return service autotrack acquisition will be achieved within 10 seconds of KuSA return service P_{rec} consistent with the BER or autotrack acquisition, whichever is larger. Following return autotrack acquisition, the forward EIRP power mode reverts to the normal or high power mode specified in the SHO. Autotrack service is not available through the Ku-band return IF service.
4. The autotrack EIRP will be transmitted towards a customer meeting the required ephemeris uncertainties for the Primary FOV, or the EEFOV. The program track EIRP will be transmitted towards a customer meeting the required ephemeris uncertainties for the Primary FOV or the EEFOV. The LEO program track EIRP will be transmitted towards a customer meeting the required LEO ephemeris uncertainties for the LEOFOV. Customers may experience better performance through the KuSA program track and LEO program track services than listed in this document. Performance improvements particular to each customer should be discussed with GSFC Code 450.
5. KuSAF EEFOV autotrack support shall be coordinated through GSFC Code 450.
6. NTIA and NASA policy does not permit use of the KuSAF service for customers other than ISS. If such support is essential, the SN should be notified and the NASA GSFC spectrum manager may request a waiver.
7. TDRS SA antenna pointing beyond ±13.5°E-W and ±13.5°N-S must be coordinated with GSFC Code 450 due to the potential to significantly impact TDRSS efficiency.
8. User ephemeris uncertainty allowance is based upon the assumption of a low eccentricity LEO user orbit. User orbits with high eccentricity and large variations in velocity may need to comply with a more stringent user ephemeris uncertainty.

Table 7-3. Salient Characteristics for TDRSS KuSA Forward Services

Parameter (Note 1)	**Value** (Note 1)	
Command channel radiated power	QPSK	BPSK
Range channel radiated power	+10 ±0.5 dB	NA
Modulator phase imbalance (peak)	±3 degrees (for each BPSK channel)	
Modulator gain imbalance (peak)	±0.25 dB	
Relative phase between command and range channels	QPSK	BPSK
	90 ±3 degrees	NA
Data asymmetry (peak) (Note 2)	±3 percent	
Phase nonlinearity (peak) (Note 3)	±0.15 radian over ±17.5 MHz	
Gain flatness (peak) (Note 3)	±0.8 dB over ±17.5 MHz	
Gain slope (peak) (Note 3)	±0.1 dB/MHz	
AM/PM	≤7 degrees/dB	
PN chip jitter (rms) (including effects of Doppler compensation)	QPSK/SS-BPSK	BPSK
	≤1 degree	NA
Data clock phase jitter (peak) (Note 2)	≤1 percent	
Spurious PM (rms)	≤1 degree	
In-band spurious outputs	≥27 dBc	
Incidental AM (peak)	≤2 percent	
Phase noise (rms)		
1 Hz - 10 Hz	≤1.5 degrees	
10 Hz - 32 Hz	≤1.5 degrees	
32 Hz - 1 kHz	≤4 degrees	
1 kHz - 25 MHz	≤2 degrees	
	QPSK/SS-BPSK	BPSK
Command/range channel PN chip skew (peak)	≤0.01 chip / NA	NA
PN chip asymmetry (peak)	≤0.01 chip	NA
PN chip rate (peak) (relative to absolute coherence with carrier rate)	≤0.01 chips/sec at PN code chip rate	NA

Notes:

1. The definitions and descriptions of the salient characteristics are provided in Appendix E.
2. These values are the TDRSS contributions for data asymmetry and data clock phase jitter assuming perfect forward service data is provided to the SN ground terminal. The actual contributions by the NISN data transport system are negligible compared to those contributed by the TDRSS, since the SN ground terminal reclocks the data before it is processed by the SN ground terminal into the forward service signal.
3. Bandwidth limitation for gain flatness, phase nonlinearity and gain slope while maintaining consistency with NTIA spectral emission mask (Appendix D):70% of the signal main lobe width or 70 % of the necessary bandwidth whichever is smaller.

Table 7-4. KuSA Forward Service Real-Time Configuration Changes

Real-Time Configuration Changes	GCMR	OPM	Forward Service Signal Interruption
Customer Receiver Center Frequency	98/04	OPM 03	Yes
Doppler Compensation Inhibit	98/08	OPM 11	No
Doppler Compensation Reinitiation	98/04	OPM 03	No
Forward Service Reacquisition (note 1)	98/03	OPM 02	Yes
Forward Service Sweep Request (refer to Table 7-1)	98/05	OPM 04	Yes
Data Rate	98/04	OPM 03	No
Polarization	98/04	OPM 03	Yes
Initiation or termination of the command channel PN code (note 2)	98/04	OPM 03	No
Forward Service Normal/High Power Mode EIRP Change	98/06	OPM 06	No

Notes:

1. Forward service reacquisition is a TDRSS reinitiation of forward link service by applying a 1 MHz frequency offset for 3 seconds to the predicted customer receive frequency specified in the customer's service specification code (refer to Section 10, paragraph 10.2.2).
2. Initiation or termination of the command channel PN code enables or disables all forward link PN modulation (including the command and range channel, if applicable), respectively.

7.3 KuSA Return Services

7.3.1 General

The RF signals provided by the customer platform to the TDRS and the characteristics of data provided at the SN ground terminal interface are defined in paragraphs 7.3.2 through 7.3.6. This discussion assumes that an appropriate return service has been scheduled and a data signal is present at the TDRS interface. The KuSA return service supports data services using the SN ground terminal receivers and an IF service, where automation of this service is currently being considered for implementation. Contact Code 450 for availability.

7.3.2 Signal Parameters

The TDRSS KuSA return service signal parameters are listed in Table 7-5. Refer to paragraph 7.3.6 for KuSA return IF service signal parameter characteristics and recommendations. The services are divided into 2 major groups, Data Group 1 (DG1) and Data Group 2 (DG2). DG1 services utilize spread spectrum modulation while DG2 services are non-spread. A description of the features inherent in the DG1 and DG2 services is discussed in paragraphs 7.3.2.2 and 7.3.2.3, respectively. Within each data group, there are several types of modulation. Additionally, both data groups support coherent and noncoherent modes. A description of these general characteristics is provided in paragraph 7.3.2.1.

Table 7-5. TDRSS KuSA Return Service Signal Parameters

Parameter (Note 5)	**Description** (Note 5)
DG1 (Notes 1, 6)	
Transmit carrier frequency (Hz) (Note 4)	F_1
Carrier (F1) reference (Hz)	
DG1 mode 1	$\left(\frac{1600}{1469}\right) \times F_R$
DG1 mode 2	Customer platform transmitter oscillator
PN code modulation	
DG1 modes 1 and 2	SQPN, or BPSK (see Appendix B and Table 7-6)
PN code chip rate (chips/sec)	$\left[\frac{31}{1600 \text{ x } 96}\right] \times F_1$
PN code length (chips)	
DG1 mode 1	$(2^{10}-1) \text{ x } 256$
DG1 mode 2	$2^{11}-1$
PN code epoch reference	
DG1 mode 1	
I channel	Epoch (all 1's condition) synchronized to epoch (all 1's condition) of received forward service range channel PN code
Q channel (Note 3)	Epoch delayed x + 1/2 PN code chips relative to I channel PN code epoch
DG1 mode 2	Not Applicable

Table 7-5. TDRSS KuSA Return Service Signal Parameters (cont'd)

Parameter (Note 5)	**Description** (Note 5)
DG1 (Notes 1, 6)(cont)	
PN code family	
DG1 mode 1	Truncated 18-stage shift register sequences
DG1 mode 2	Gold codes
Data modulation (Notes 1, 6)	
DG1 modes 1 and 2	Modulo-2 added asynchronously to PN code
Data format	NRZ-L, NRZ-M, NRZ-S
DG1 mode 1 data rate restrictions (uncoded)	
Total	1 - 600 kbps
I channel	1 - 300 kbps
Q channel	1 - 300 kbps
DG1 mode 2 data rate restrictions (uncoded)	
Total	1 - 600 kbps
I channel	1 - 300 kbps
Q channel	1 - 300 kbps
DG1 $\frac{\text{Q channel power}}{\text{I channel power}}$ restrictions (Note 2)	
Single data source-identical data	1:1 to 4:1
Single data source-single data channel	NA
Dual data sources	1:1

Table 7-5. TDRSS KuSA Return Service Signal Parameters (cont'd)

Parameter (Note 5)	**Description** (Note 5)
DG2 (Notes 1, 6)	
Transmit carrier frequency (Hz) (Note 4)	F_2
Carrier (F_2) reference (Hz)	
DG2 Coherent	$\left(\frac{1600}{1469}\right) x F_R$
DG2 Noncoherent	Customer platform oscillator
Data modulation (Notes 1, 6)	BPSK, SQPSK, or QPSK (refer to Appendix B and Table 7-6)
Data format	NRZ-L, NRZ-M, NRZ-S
Data rate restrictions (uncoded)	
Total (Note 1)	1 kbps - 300 Mbps
I channel	1 kbps - 150 Mbps
Q channel	1 kbps - 150 Mbps
DG2 $\frac{\text{I channel power}}{\text{Q channel power}}$ restrictions	
Single data source-alternate I/Q bits	1:1
Single data source-alternate I/Q encoded symbols	1:1
Single data source-single data channel	NA
Dual data sources	1:1

Notes:

1. Customer platform data configurations, including specific data rate restrictions for coding and formatting, are defined in Table 7-6 for TDRSS KuSA return service (refer also to Appendix B). Unless otherwise stated, the data rate restrictions given in this table assume uncoded and NRZ formatted signals.
2. For DG1, the Q/I power parameter range can vary from 1:1 to 4:1 continuously during specification of applicable parameter values in the NCCDS scheduling database and during real-time service reconfiguration. However if this parameter is re-specified in schedule requests to the NCCDS (refer to paragraph 10.2.2), it is expressed as the ratio of two single-digit integers.
3. The Q channel PN code sequence must be identical to the I channel PN code sequence, but offset by x + 1/2 PN code chips, where x $\geq$20,000. The value of x is defined by the PN code assignment for a particular customer platform (refer to 451-PN CODE-SNIP).
4. The center frequency, f_O, of the customer platform transmitter must be defined by the customer MOC in its service specification code to an integral multiple of 10 Hz.
5. Unless otherwise noted, all data rate values are to be interpreted as data bit rates, and not as data symbol rates.
6. Data rates and modulation schemes are based upon support through the KuSAR 225 MHz SN ground terminal receivers. Other data rates and modulation schemes are possible through the Ku-band return IF service. Please refer to paragraph 7.3.6 and contact GSFC Code 450 for further information.

7.3.2.1 General Modulation and Coherent/Noncoherent Description

a. SQPN Modulation. SQPN modulation is used to prevent simultaneous transitions of the I and Q PN sequences. For SQPN modulation, the PN chips of the I and Q channel are staggered by a 1/2 chip. For data configurations that use two PN spread channels, SQPN modulation must be used.

b. SQPSK Modulation. SQPSK modulation staggers one channel with respect to the other to prevent synchronous transitions. For non-spread signal configurations with identical I and Q symbol rates that are NRZ symbol formatted, SQPSK modulation must be used. The symbols of the Q channel are delayed 1/2 symbol relative to the I channel.

c. QPSK Modulation. QPSK modulation is available when there is no relation between the I and Q channel transitions. For dual data source configurations, in which one or both channels are not spread and SQPSK is not required, QPSK modulation is used.

d. BPSK Modulation. BPSK modulation is available for single data source configurations that use only one channel of the link.

NOTE:

For SQPN and SQPSK modulation, the spectral characteristics of a customer platform saturated power amplifier will, to a great degree, retain the spectral characteristics of the band-limited input signal to that amplifier. This should result in better control of out-of-band emissions, which, in turn, provides more efficient communications and less interference to the customer platform using adjacent frequency channels on the TDRS links.

e. Coherent Mode. For coherent modes, the customer platform transmitted return link carrier frequency and PN code clock frequency (if applicable) are derived from the customer platform received forward link carrier frequency. For coherent PN spread return links, the customer return PN code length is identical to the length of the received forward service range channel PN code. The customer return I channel PN code epoch is synchronized with the epoch of the received forward service range channel PN code. For coherent operations, two-way Doppler measurements and range measurements (if PN spread) are available.

f. Noncoherent Mode. For noncoherent modes, the customer platform transmit return link carrier frequency and PN code clock frequency (if applicable) are derived from an on-board local oscillator. The customer platform transmit frequency for noncoherent service must be defined by the customer MOC to an accuracy of ±5 kHz in its service specification code when requesting TDRSS KuSA return service. For customers whose frequency uncertainty is greater than ±5 kHz, an expanded frequency search capability is available.

g. Asynchronous Data Modulation. The data modulation is asynchronous to the carrier and the channel PN code (if applicable). This prevents Doppler variations of the forward service frequency from affecting the return service data rate.

7.3.2.2 DG1 Signal Parameters

KuSA DG1 signal parameters are discussed for DG1 mode 1 and mode 2 operations only. For all DG1 modes, the PN code clock must be coherently related to the transmitted carrier frequency. This feature permits the customer platform transmitter to use a common source for generating the carrier and the PN code clock frequencies. 451-PN CODE-SNIP defines all the salient characteristics for the DG1 PN code libraries. The Agency Spectrum Manager responsible for PN code assignments will allocate a customer platform-unique PN code assignment from these libraries. The GSFC Spectrum Manager is responsible for NASA PN code assignments. These three DG1 modes which are distinguished as follows:

a. DG1 Mode 1. DG1 mode 1 must be used when TDRSS range and two-way Doppler measurements (coherent transponder operations) are required concurrently with return service low-rate data transmission. Return service signal acquisition by the SN ground terminal for DG1 mode 1 is possible only when the scheduled TDRSS KuSA forward service signal is acquired by the customer platform and the PN code and carrier transmitted by the customer platform are coherently related to the forward service signal from the TDRS. If the TDRSS forward service signal becomes unavailable to the customer platform, the customer platform transmitter must switch to noncoherent transmitter operation (DG1 mode 2) (refer to paragraph 7.3.5.d.(2)). In order to reacquire the DG1 mode 2 signal, the return service must be reconfigured. The I and Q channel PN codes are generated from a single code generator. For DG1 mode 1 operation, the I and Q channel PN codes are identical but are offset by at least 20,000 chips. This separation is adequate for TDRSS to identify each data channel unambiguously without requiring a unique PN code for each channel.

b. DG1 Mode 2. DG1 mode 2 can be used when the SN ground terminal return service signal acquisition is necessary without the requirement for prior customer platform signal acquisition of the TDRSS KuSA forward service (noncoherent transponder operation). The customer platform transmit frequency for DG1 mode 2 service must be defined by the customer MOC to an accuracy of $\pm$5 kHz in its service specification code when requesting TDRSS KuSA return service. For customers whose frequency uncertainty is greater than $\pm$5 kHz, an expanded frequency search capability of $\pm$20 kHz is available after start of the return service. For DG1 mode 2, the I and Q channel PN codes are unique 2^{11}-1 Gold Codes.

c. Functional Configurations. Table 7-6 lists the DG1 KuSA return service functional configurations and a further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in section B.3.2.

7.3.2.3 DG2 Signal Parameters

DG2 signal parameters are subdivided into two modes of operation, DG2 coherent and noncoherent. DG2 must be used when the return service data rate equipment exceeds the capability of DG1 operations. DG2 operations cannot provide TDRSS range tracking because PN code modulation is not used. The two DG2 modes are distinguished as follows:

a. DG2 Coherent. Return service signal acquisition by the SN ground terminal for DG2 coherent is possible only when the scheduled KuSA TDRSS forward service signal is acquired by the customer platform and the carrier transmitted by the customer platform are coherently related to the forward service signal from the TDRS. TDRSS two-way Doppler tracking can be provided when the DG2 carrier is coherently related to the TDRSS KuSA forward service carrier frequency.

b. DG2 Noncoherent. The DG2 carrier is independent of the TDRSS KuSA forward service carrier frequency. The customer platform transmit frequency for DG2 noncoherent service must be defined by the customer MOC to an accuracy of ±5 kHz in its service specification code when requesting TDRSS KuSA return service. For customers whose frequency uncertainty is greater than ±5 kHz, an expanded frequency search capability of ±20 kHz is available after start of the return service.

c. Functional Configurations. Table 7-6 lists the DG2 KuSA return service functional configurations through the SN ground terminal receiver and a further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in Appendix B, paragraph B.3.3. Refer to paragraph 7.3.6 for the KuSAR IF service functional configurations.

Table 7-6. KuSA Return Service Configurations

Return Service Configuration[6]				Source Data Rate Restrictions and Availability[5]					
				DG1 Mode				DG2 Mode	
				1[1] and 2[1,4]		3		Coherent[3] and Noncoherent[3,4]	
				Data format	Data rate	Data format	Data rate	Data format	Data rate
Single Data Source	BPSK	Rate 1/2 coded		NRZ	1 - 150 kbps[1]	-	-	NRZ	1 kbps – 75 Mbps
		Rate 1/3 coded		-	-	-	-	-	-
		Uncoded		NRZ	1 - 300 kbps[1]	-	-	NRZ	1 kbps – 150 Mbps
	SQPN	Identical I & Q channel data	Rate 1/2 coded	NRZ	1 - 150 kbps[1]	-	-	-	-
			Uncoded	NRZ	1 - 300 kbps[1]	-	-	-	-
	SQPSK	Rate 1/2 coded alternate I/Q encoded symbols		-	-	-	-	NRZ	1 kbps – 10 Mbps
	SQPSK[3]	Alternating I/Q data	Individually rate 1/2 coded	-	-	-	-	NRZ	>10 – 150 Mbps
			Individually rate 1/3 coded	-	-	-	-	-	-
			Uncoded	-	-	-	-	NRZ	1 kbps – 300 Mbps

Table 7-6. KuSA Return Service Configurations (cont'd)

Return Service Configuration[6]			Source Data Rate Restrictions and Availability[5,6]					
			DG1 Mode				DG2 Mode	
			1[1] and 2[1,4]		3[2]		Coherent[3] and Noncoherent[3,4]	
			Data format	Data rate	Data format	Data rate	Data format	Data rate
Dual Data Sources (data rates are for each source separately)	SQPN[1], QPSK[2,3] or SQPSK[3]	Rate 1/2 coded	NRZ	1 - 150 kbps	-	-	NRZ	1 kbps – 75 Mbps
		Rate 1/3 coded	-	-	-	-	-	-
		Uncoded	NRZ	1 - 300 kbps	-	-	NRZ	1 kbps – 150 Mbps

✓ Configuration supported
- Configuration not supported

Notes:

1. For DG1 mode 1 and 2 configurations:
   a. Single data source configurations with data on a single I or Q channel, but not both channels: BPSK modulation is used where the data is modulo-2 added to the PN code.
   b. Single data source configurations with data on both the I and Q channels: SQPN modulation is used and the SN supports I:Q power ratios of 1:1 to 1:4.
   c. Dual data source configurations: SQPN modulation is used and the SN supports I:Q power ratios of 1:1 only
2. Deleted.
3. For DG2 configurations:
   a. Single data source configurations with data on one channel: BPSK modulation is used.
   b. Single data source configurations with data on both channels: SQPSK modulation and an I:Q power ratio of 1:1 is used. For the alternate I/Q bit configuration, the SN requires the I and Q channels be independently differentially formatted (-M,-S).
   c. Dual data source configurations: SQPSK must be used when there are identical baud rates on the I and Q channels (see paragraph 7.3.2.1.b); QPSK is used for all other configurations; for both SQPSK and QPSK, an I:Q power ratio of 1:1 is supported.
4. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of ± 5 kHz. If a customer cannot accurately define their transmit frequency to within ± 5 kHz, a customer can request a reconfiguration which would expand the oscillator frequency search to ± 20 kHz after the start of service.
5. Unless otherwise noted, all data rates are to be interpreted as data bit rates, and not as data symbol rates. Refer to Section 3, paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities.
6. Appendix B describes the functional configurations and associated I-Q channel and data polarity ambiguities. Additionally, Figure B-10 depicts the SN supported convolutional coding schemes. For a channel with rate 1/2 coding and data rates greater than 10 Mbps, the customer transmitter must be configured to use an N-parallel encoder, where N is the number of branch rate 1/2 encoders for the channel. N = channel data rate in bps/1×10^7, where N is rounded to the next higher integer if N is not an integer.
7. Data rates and modulation schemes are based upon support through the KuSAR SN ground terminal receivers. Other data rates and modulation schemes are possible through the Ku-band IF services. Please refer to paragraph 7.3.6 and contact GSFC code 450 for further information.

7.3.3 Communications Services

To obtain TDRSS KuSA return service performance defined in this paragraph, the customer platform transmitted signal must meet the requirements found in Table 7-7 and signal characteristics specified in Table 7-9. The TDRSS KuSA return service performance defined in this paragraph also assumes return service operation in an AWGN environment. Appendix G discusses performance degradations to the TDRSS KuSA return service due to RFI. Example link calculations are provided in Appendix A. TDRSS KuSAR supports only non-powered flight customer dynamics ($\dot{R} \leq 12$ km/sec, $\ddot{R} \leq 15$ m/sec^2, and $\dddot{R} \leq 0.02$ m/sec^3).

7.3.3.1 Acquisition

The KuSAR service supports acquisition for customer platforms operating under non-powered flight dynamics as defined in paragraph 7.3.3. KuSAR acquisition will be protected against false SN ground terminal lock due to: interfering customer platform PN codes, customer platform PN code sidelobes, and carrier recovery. The KuSAR service total channel T_{acq} will be less than or equal to the sum of the following, which are given in Table 7-7:

a. Autotrack acquisition time (when the TDRSS KuSA return service autotrack mode is enabled)

b. PN (DG1 only) and carrier acquisition time

c. Symbol/Decoder synchronization time (for coded data) or Symbol synchronization time (for uncoded data).

T_{acq} assumes that the customer platform return service signal is present at the SN ground terminal at the start time of the scheduled return service support period. The total acquisition process consists of the following acquisition sub-processes:

a. If autotrack is enabled, autotrack acquisition will commence upon the start of the scheduled return service support period or at the instant at which user signal energy is present at the KuSAR autotrack signal processing input, whichever occurs last, and will occur within the time given in Table 7-7 for P_{rec} greater than or equal to the values in Table 7-7.

b. PN code (if applicable) and carrier acquisition will occur within the time given in Table 7-7. The PN code and carrier acquisition may not commence until the P_{rec} is greater than or equal to the value commensurate with the applicable minimum Program Track P_{rec} under the applicable Program Track scenario. If autotrack is disabled, the time allowed for PN code and carrier acquisition will commence at the start of scheduled return service support period or when the minimum P_{rec} is achieved, whichever occurs last. If autotrack is enabled, PN code and carrier acquisition may commence at any time after the start of scheduled return service support period, but the time allowed will not commence until the minimum P_{rec} is achieved. If autotrack is enabled and required to achieve this minimum P_{rec}, the total time allowed to achieve PN

code and carrier acquisition will be the sum of the time allowed for autotrack acquisition and PN code and carrier acquisition.

c. After PN code (if applicable) and carrier acquisition is achieved, TDRSS tracking services data is available.

d. Symbol/Decoder and Symbol synchronization times will be measured from the time carrier acquisition is achieved to the time either symbol synchronization is achieved for uncoded channels or decoder synchronization is achieved for rate 1/2 coded channels. Decoder synchronization is achieved when the Viterbi decoder has selected and implemented the correct blocking of the input symbols (into groups of (G1, G2) symbol pairs) for rate 1/2 codes.

e. After symbol/decoder and symbol synchronization is achieved, KuSA return service channel data is available at the SN ground terminal interface.

f. To minimize return data loss, it is recommended that the customer platform transmit idle pattern on its data channels until after it has observed (via the UPD data) that the SN ground terminal has completed all of its data channel signal acquisition processes.

g. Requirements for bit error probability and symbol slipping take effect at the time decoder synchronization is achieved for convolutional encoded data and at the time symbol synchronization is achieved for uncoded data.

NOTE:

Data and symbol transition density values higher than the minimums required will reduce these acquisition times.

Table 7-7. TDRSS KuSA Return Service

Parameter (Note 4)	**Description** (Note 4)		
Field of view (FOV) (each TDRS) (note 13)	PFOV ± 22 degrees east-west ± 28 degrees north-south	LEOFOV ±10.5 degree conical	Extended Elliptical (EEFOV) (F8-F10 and K, L, M) (note 10) 24.0 degrees inboard east-west 76.8 degrees outboard east-west ±30.5 degrees north-south
Customer Ephemeris Uncertainty (along the customer orbital track) (note 14)	≤ ± 4.5 sec	≤ ± 1.5 sec	≤ ± 3.2 sec
TDRS antenna polarization (note 1)	RHC or LHC selectable		
TDRS antenna axial ratio (maximum)	After Autotrack Acquisition (PFOV, and EEFOV) (notes 10, 12) 1 dB over 3 dB beamwidth	LEO Program Track (LEOFOV) 1 dB over 3-dB beamwidth	Program Track (PFOV and EEFOV) 1.5 dB
Receive frequency (nominal)	$\left(\frac{1600}{1469}\right) \times 13.775\,\text{GHz} \pm 0.7\,\text{MHz}$		
RF bandwidth (3dB, minimum)	225 MHz		
10^{-5} Bit Error Rate (notes 2, 3, 4, 8, 12)	All P_{rec} values are in dBW; dr=data rate in bps		
Orbital Dynamics (free flight)	$\dot{R} \leq 12$ km/sec, $\ddot{R} \leq 15$ m/sec^2, jerk $\leq .02$ m/sec^3		
Minimum Required P_{rec} (dBW) for uncoded channels (note 9):	Autotrack (PFOV, and EEFOV) (note 10)	LEO Program Track (LEOFOV)	Program Track (PFOV and EEFOV)
DG1, modes 1 and 2	-240.0. + $10\log_{10}$(dr)	-237.5 + $10\log_{10}$(dr)	-234.0 + $10\log_{10}$(dr)

Table 7-7. TDRSS KuSA Return Service (cont'd)

Parameter (Note 4)	**Description** (Note 4)		
10^{-5} Bit Error Rate (notes 2, 3, 4, 8, 12) (cont'd):			
Minimum Required P_{rec} (dBW) for uncoded channels (cont'd) (note 9):	Autotrack (PFOV, and EEFOV) (note 10)	LEO Program Track (LEOFOV)	Program Track (PFOV and EEFOV)
DG2			
Data rate $\leq$ 25 Mbps	$-240.0 + 10\log_{10}(dr)$	$-237.5 + 10\log_{10}(dr)$	$-234.0 + 10\log_{10}(dr)$
Data rate > 25 Mbps (F3-F7) (note 11)	$-237.9 + 10\log_{10}(dr)$	$-235.4 + 10\log_{10}(dr)$	$-231.9 + 10\log_{10}(dr)$
Data rate > 25 Mbps (F8-F10 and K, L, M)	$-239.0 + 10\log_{10}(dr)$	$-236.5 + 10\log_{10}(dr)$	$-233.0 + 10\log_{10}(dr)$
Minimum Required P_{rec} (dBW) for Rate 1/2 convolutional encoded channels (note 9):			
DG1, modes 1 and 2	$\geq$ -183.3 dBW (note 3)	$\geq$ -180.8 dBW (note 3)	$\geq$ -177.3 dBW (note 3)

Table 7-7. TDRSS KuSA Return Service (cont'd)

Parameter (Note 4)	**Description** (Note 4)		
10^{-5} Bit Error Rate (notes 2, 3, 4, 8, 12) (cont'd):			
Minimum Required P_{rec} (dBW) for Rate 1/2 convolutional encoded channels (note 9) (cont'd):	Autotrack (PFOV, and EEFOV) (note 10)	LEO Program Track (LEOFOV)	Program Track (PFOV and EEFOV)
DG2			
Data rate ≤ 10 Mbps	$-246.4 + 10\log_{10}(dr)$	$-243.9 + 10\log_{10}(dr)$	$-240.4 + 10\log_{10}(dr)$
Data rate > 10 Mbps	$-245.2 + 10\log_{10}(dr)$	$-242.7 + 10\log_{10}(dr)$	$-239.2 + 10\log_{10}(dr)$
Acquisition (notes 5, 8, 12):			
Orbital dynamics (free flight)	$\dot{R} \leq 12$ km/sec, $\ddot{R} \leq 15$ m/sec ^{2}, jerk $\leq .02$ m/sec ^{3}		
Total Channel Acquisition Time (assumes the customer return service signal is present at the SN ground terminal at the start time of the return service support period)	Sum of the following: 1. Autotrack acquisition time (when the TDRSS KuSA return service autotrack mode is enabled) 2. PN (DG1 only) and carrier acquisition time 3. Symbol/Decoder synchronization time (coded channel) or Symbol synchronization time (uncoded channel)		
Autotrack Acquisition (if applicable):			
Minimum Required P_{rec} with probability > 99% (note 9)	PFOV	LEOFOV	EEFOV (note 10)
	≥-183.3 dBW or consistent with the P_{rec} for BER, whichever is greater	≥-186.8 dBW or consistent with the P_{rec} for BER, whichever is greater	≥-183.3 dBW or consistent with the P_{rec} for BER, whichever is greater
Acquisition Time:	≤ 10 seconds		

Table 7-7. TDRSS KuSA Return Service (cont'd)

Parameter (Note 4)	**Description** (Note 4)		
Acquisition (notes 5, 8, 12) (cont'd):			
PN Code (if applicable) and Carrier Acquisition:			
Minimum Required P_{rec} (note 9)	Autotrack (PFOV, and EEFOV) (note 10) ≥ -183.3 dBW or consistent with the P_{rec} for BER, whichever is greater	LEO Program Track (LEOFOV) ≥ -180.8 dBW or consistent with the P_{rec} for BER, whichever is greater	Program Track (PFOV and EEFOV) ≥ -177.3 dBW or consistent with the P_{rec} for BER, whichever is greater
Acquisition Time (P_{acq} ≥ 90%)			
Coherent operations	≤ 1 sec		
Noncoherent operations with frequency uncertainty (note 6):			
≤ ± 5 kHz	≤ 1 sec		
≤ ± 20 kHz	≤ 3 sec		
Channel Decoder/Symbol Synchronization Acquisition (coded data) (note 7):			
Minimum data bit transition density	≥ 64 randomly distributed data bit transitions within any sequence of 512 data bits		
Number of consecutive data bits without a transition	≤ 64		
P_{rec} (dBW)	consistent with the P_{rec} for BER		
Acquisition time (in seconds) with >99% probability:			
NRZ	< 6500/(Channel Data Rate in bps)		

Table 7-7. TDRSS KuSA Return Service (cont'd)

Parameter (Note 4)	**Description** (Note 4)
Acquisition (notes 5, 8, 12) (cont'd):	
Channel Symbol Synchronization Acquisition (uncoded data) (note 7):	
P_{rec} (dBW)	consistent with the P_{rec} for BER
Synchronization	Achieved when error rate for next 1000 bits is $\leq 10^{-5}$
Acquisition time (in seconds) with >99% probability:	
NRZ	< 3000/(Channel Data Rate in bps)
Signal Tracking	refer to paragraph 7.3.3.3
Orbital dynamics (free flight)	$\dot{R} \leq 12$ km/sec, $\ddot{R} \leq 15$ m/sec^2, jerk $\leq .02$ m/sec^3
Reacquisition	refer to paragraph 7.3.3.4
Orbital dynamics (free flight)	$\dot{R} \leq 12$ km/sec, $\ddot{R} \leq 15$ m/sec^2, jerk $\leq .02$ m/sec^3
Duty Factor	100 percent

Notes:

1. Operational considerations may limit choice of TDRS antenna polarization. The KuSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.
2. The BER is for a customer platform transmitting a signal on an AWGN channel which complies with the constraints defined in Table 7-9. Refer to Appendix G for a discussion of the additional degradation applicable to the TDRSS KuSA return service performance due to K-band RFI.

Table 7-7. TDRSS KuSA Return Service (cont'd)

Notes (cont'd):

3. The required customer P_{rec} must meet the P_{rec} for BER, autotrack acquisition, or signal acquisition, whichever is greatest. Paragraph 7.3.3.2.b provides the required P_{rec} description for each possible KuSAR data configuration. Refer to Appendix A, paragraph A.4, for a definition of P_{rec}. The minimum required P_{rec} equations for BER produce the minimum P_{rec} for a given data rate for all possible signal characteristics. CLASS analysis will produce a more accurate performance projection based upon desired customer signal characteristics, such as data rate, data type, and jitter values. SN support may be possible for customers whose P_{rec} is less than the required P_{rec} for 10^{-5} BER performance; however, such support shall be coordinated through GSFC Code 450. In general, customer platforms should be designed to the most limiting TDRS to ensure SN support can be provided.
4. All data rate values (and notes which modify these values, based upon specific signal format and encoding restrictions) are to be interpreted as data bit rates, and not as data symbol rates.
5. For acquisition, the minimum P_{rec} value listed applies to the total (I+Q)P_{rec}. Acquisition requires the P_{rec} to also be consistent with the P_{rec} required for BER, whichever is greater. Failure to provide the minimum P_{rec} for autotrack acquisition at the start of service may preclude successful TDRSS autotrack pull-in.
6. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of $\pm$ 5 kHz. If a customer cannot accurately define their transmit frequency to within $\pm$ 5 kHz, a customer can request a reconfiguration which would expand the oscillator frequency search to $\pm$ 20 kHz after the start of service.
7. For symbol synchronization and symbol/decoder synchronization, the minimum symbol transition density and consecutive symbols without a transition must meet the specifications defined in Table 7-9. For encoded channels, it is recommended that customers use G_2 inversion to increase symbol transition density.
8. All minimum P_{rec} values include atmospheric and rain attenuation on the link from TDRS to the SN ground terminal; however, service outages may be experienced during periods of heavy rain.
9. The required P_{rec} for autotrack performance is based upon a customer meeting the required ephemeris uncertainties for the Primary FOV, or the EEFOV. The required P_{rec} for program track performance is based upon a customer meeting the required ephemeris uncertainties for the Primary FOV or the EEFOV. The required P_{rec} for LEO program track performance is based upon a customer meeting the required LEO ephemeris uncertainties for the LEOFOV. Customers may experience better performance through the KuSA program track and LEO program track services than listed in this document. Performance improvements particular to each customer should be discussed with GSFC Code 450.
10. KuSAR EEFOV autotrack support shall be coordinated through GSFC Code 450.
11. For KuSA DG2 uncoded service, the required P_{rec} values for support through GRGT are only valid up to a total (I+Q) data rate of 150 Mbps. If higher data rates are required through GRGT, contact GSFC Code 450 for detailed calculations and use of dedicated service.
12. KuSAR performance characteristics are through the SN ground terminal receivers. Please refer to paragraph 7.3.6 and contact GSFC Code 450 for further information. Autotrack service is not available through the IF service.
13. TDRS SA antenna pointing beyond ±13.5°E-W and ±13.5°N-S must be coordinated with GSFC Code 450 due to the potential to significantly impact TDRSS efficiency.
14. User ephemeris uncertainty allowance is based upon the assumption of a low eccentricity LEO user orbit. User orbits with high eccentricity and large variations in velocity may need to comply with a more stringent user ephemeris uncertainty.

7.3.3.2 Bit Error Rate (BER)

Table 7-7 provides P_{rec} equations that will result in a customer achieving a BER of 10^{-5} for TDRSS compatible signals. The IF service BER depends on the customer receiver characteristics. Refer to paragraph 7.3.6 for more information on the IF service. The BER P_{rec} equations are applicable for non-powered flight dynamics and the following conditions:

a. Data encoding. Customer platform transmission of Rate 1/2 convolutional encoded or uncoded signals are supported for KuSA return services. Detailed rate 1/2 coding design is described in Appendix B. Reed-Solomon decoding is available to WDISC customers; typical performance is given in Appendix K.

b. Received Power. P_{rec} is in units of dBW. The customer project, in determining its design requirements for minimum customer platform EIRP, must take into account customer platform transmit antenna pointing losses, the space loss between the customer platform and the TDRS, and the polarization loss incurred between the customer platform transmit antenna and the TDRS receive antenna. The maximum TDRS receive antenna axial ratio is given in Table 7-7 (also refer to Appendix A). For DG1 and DG2 services, the following conditions apply:

   1. Balanced Power Single Data Source-Identical Data on the I and Q Channels (DG1 mode 1 and 2 only). For a customer platform synchronously transmitting identical data on the I and Q channels (single data source-identical data) with a balanced I and Q channel power division, the total (I+Q) P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 7-7, where dr is the single data source data rate. Refer to Appendix B for further information on this data configuration.

   2. Balanced Power Single Data Source-Alternate I/Q Bits (DG2). For a customer platform transmitting alternate I and Q data bits from a data source (single data source-alternate I/Q bits), the total (I+Q) P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 7-7, where dr is the single data source data rate prior to separation into the I and Q channels. The Q/I (power) must be equal to 1:1. Refer to Appendix B for further information on this data configuration.

   3. Balanced Power Single Data Source-Alternate I/Q Encoded Symbols (DG2 only). For a customer platform transmitting alternate I and Q encoded symbols from a data source (single data source-alternate I/Q encoded symbols), the total (I+Q) P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 7-7, where dr is the single data source data rate prior to the rate 1/2 encoder. The Q/I (power) must be equal to 1:1. Refer to Appendix B for further information on this data configuration.

   4. Unbalanced Power Single Data Source-Identical Data on the I and Q Channels (DG1 mode 1 and 2). For a customer platform synchronously transmitting identical data on the I and Q channels (single data source-

identical data) having unbalanced I and Q channel power division, the stronger power channel P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 7-7, where dr is the single data source data rate. The weak channel P_{rec} need not be consistent with the P_{rec} for a 10^{-5} BER listed in Table 7-7. The Q/I (power) must not exceed 4:1. Refer to Appendix B for further information on this data configuration.

5. Dual Data Sources (DG1 and DG2). For a customer platform transmitting independent data on the I and Q channels (dual data sources), each channel's P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 7-7, where dr is that channel's data rate. Refer to Appendix B for further information on this data configuration.

6. Single Data Source with Single Data Channel (DG1 modes 1 and 2 and DG2). For a customer platform transmitting one channel, the channel's P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 7-7Table 7-7, where dr is the channel data rate. Refer to Appendix B for further information on this data configuration.

c. Customer Degradations. Further reductions in the TDRSS KuSA return service performance identified in Table 7-7 can occur. The TDRSS KuSA return services and tracking services will be provided without degradation for customer platform transmitted signal characteristics within the constraints specified in Table 7-9. Customer platform parameters exceeding these constraints can also degrade TDRSS KuSA return service performance. Refer to Section 3, paragraph 3.5 for guidelines if the constraints in this paragraph cannot be met. Definitions of customer platform constraints are given in Appendix E.

d. Multipath. The SN ground terminal will provide lockup and interference protection from multipath signals reflected from the Earth.

7.3.3.3 Signal Tracking

TDRSS provides KuSA return signal tracking (carrier, PN, symbol synchronization, Viterbi decoder synchronization) for non-powered flight dynamics. During a customer KuSA return service support period, loss-of-lock (carrier, symbol synchronization, and Viterbi decoder) indications appear in the periodically updated User Performance Data (UPD) (every 5 seconds). The KuSA return service shall maintain signal tracking for the following conditions:

a. Cycle Slips. The mean time-between-cycle slip in the SN ground terminal carrier tracking loop for each TDRSS KuSA return service will be 90 minutes minimum. This value applies at carrier tracking threshold, which is 3 dB less than the minimum P_{rec} for BER listed in Table 7-7, and increases exponentially as a function of linear dB increases in P_{rec}. Cycle slips may result in channel and/or data polarity reversal. The SN ground terminal can correct for these reversals under the same conditions as the SN ground terminal can resolve channel and/or data polarity ambiguity as discussed in Appendix B. The time for the SN ground terminal to recover from a cycle slip will be consistent with

the time required for the SN ground terminal receiver to detect and automatically reacquire the signal.

b. Bit Slippage. For each TDRSS KuSA return service operating with a minimum P_{rec} required consistent with the P_{rec} for BER of Table 7-7 and data transition densities greater than 40% for NRZ symbols, the minimum mean time between slips caused by a cycle slip in the SN ground terminal symbol clock recovery loop is either 90 minutes or 10^{10} symbol periods, whichever is greater. For a KuSA return service operating with 1 dB more than the minimum P_{rec} required for the BER, and NRZ symbol transition densities between 25% and 40%, the minimum mean time between slips is either 90 minutes or 10^{10} symbol periods, whichever is greater.

c. Loss of Symbol Synchronization. For each TDRSS KuSA return service with data transition densities greater than 40% for NRZ symbols, the SN ground terminal symbol synchronization loop will not unlock for a P_{rec} that is 3 dB less than the minimum P_{rec} required for BER in Table 7-7 (refer also to note 3 of Table 7-7). For NRZ symbol transition densities between 25% and 40%, the SN ground terminal symbol synchronizer loop will not unlock for a P_{rec} that is 2 dB less than the minimum P_{rec} required for BER. In both cases, the BER performance will be degraded when the P_{rec} is less than the minimum required for BER.

d. Loss of Autotrack. Loss of autotrack is detected by the SN ground terminal when either:

1. The autotrack SA antenna azimuth/elevation angles diverge from the program track SA antenna azimuth/elevation angles. The check on angle divergence protects the autotrack system from false tracking an interfering signal. When loss of autotrack is detected due to angle divergence, the SN ground terminal will automatically begin the reautotrack acquisition process.

2. There is a drop in received power that causes the receiver to drop carrier lock. The receiver will maintain carrier lock for a P_{rec} that is 3 dB less than the minimum P_{rec} for BER.

   (a) When loss of autotrack is detected due to signal fades during TDRS F3 – F7 KuSAR support, the SN ground terminal will revert to return program track, transmit a forward link signal towards a customer platform using the high power program track EIRP values listed in Table 7-2 (if forward service is scheduled), and automatically begin the return autotrack reacquisition process.

   (b) For a maximum of 60 seconds after the first loss of autotrack is detected due to signal fades during TDRS F8 – F10 and K, L, M KuSAR support, the TDRS SA antenna will continue to move at the calculated customer platform angular rate. If, within that 60 seconds, the KuSA return service P_{rec} has increased back to or above the minimum level required by the TDRSS KuSA return PN code/carrier

acquisition, the process should transfer almost immediately to its fine-track mode as the TDRS SA antenna boresight should still be pointed fairly close to the actual direction of the customer platform position. However, if after 60 seconds the KuSA return service P_{rec} has not increased back to or above the minimum level required by the TDRSS KuSA return service PN code/carrier acquisition, the SN ground terminal reverts to open-loop pointing (program track) the TDRS SA antenna in the calculated direction of the customer platform position. When the SN ground terminal reverts to program track, the TDRSS will transmit a forward link signal towards a customer platform using the high power program track EIRP values listed in Table 7-2 (if forward service is scheduled). The TDRSS KuSA return service autotrack process will not restart until the KuSA return service P_{rec} has increased back to or above the minimum level required by that process.

7.3.3.4 Reacquisition

For return service autotrack reacquisition process, refer to paragraph 7.3.3.3.d. While in the PN/carrier tracking state, a loss of lock condition induced by a cycle slip will be automatically detected and a reacquisition will be automatically initiated. For a customer platform that continues to transmit the minimum P_{rec} for acquisition and maintains an ephemeris uncertainty as defined in Table 7-7, the normal total channel reacquisition time for non-powered flight dynamics will be less than or equal to that for the initial total channel acquisition, with a probability of at least 0.99. If lock is not achieved within 10 seconds of loss of lock, an acquisition failure notification message will be sent to the MOC and the SN ground terminal will reinitiate the initial service acquisition process. Upon receipt of the loss-of-lock indications in the UPD, the customer MOC may request a TDRSS KuSA return service reacquisition GCMR (refer to Section 10). It is recommended that the customer MOC delay initiation of the GCMR for at least 35 seconds after initial receipt of the loss-of-lock indications in the UPD.

7.3.3.5 Additional Service Restrictions

a. Sun Interference. The TDRSS KuSA return service performance will not be guaranteed when the center of the sun is within 1 degree of the TDRS KuSA receiving antenna boresight. Additionally, the TDRSS KuSA return service performance will not be guaranteed when the center of the sun is within 1 degree of the boresight of the SN ground terminal receiving antenna supporting the TDRS.

b. Mutual Interference. It is possible for mutual interference to exist between KuSA customer platforms operating with the same polarization. The SN can provide tools to assist customers in interference prediction and interference mitigation.

7.3.4 Real-Time Configuration Changes

Changes to the operating conditions or configuration of a TDRSS KuSA return service during a scheduled service support period are initiated by a GCMR from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the GCMR at the SN ground terminal. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning SN ground terminal response times for GCMRs is provided in Section 10. Table 7-8 lists the KuSA return service real-time configuration changes and their effects on the return service.

7.3.5 Autotrack/Signal Acquisition Scenarios

The following acquisition scenario identifies only the technical aspects of TDRSS KuSA return service autotrack (if enabled) and signal acquisition by the SN ground terminal and does not include operational procedures related to acquisition. Acquisition is dependent upon the customer providing an ephemeris with a maximum epoch uncertainty as defined in Table 7-7:

a. TDRS SA Antenna Pointing:

   1. KuSA Autotrack Description. The TDRSS KuSA return service autotrack process (if enabled) will acquire and track a customer platform KuSA return service signal providing an improved pointing of the TDRS SA antenna in the direction of the customer platform. This decreases the required P_{rec} at the input to the TDRS antenna. TDRSS KuSA return autotrack service is independent of whether the return signal is coherent or noncoherent relative to a TDRSS KuSA forward service signal or whether a TDRS forward service signal is concurrently scheduled.

Table 7-8. KuSA Return Service Real-Time Configuration Changes

Real-Time Configuration Changes	GCMR	OPM	Return Service Interruption
Return Service Reacquisition	98/03	OPM 03	Yes
Noncoherent Expanded Customer Spacecraft Frequency Uncertainty	98/07	OPM 07	No
Channel Data Rate	98/04	OPM 03	No
Noncoherent Transmit Frequency	98/04	OPM 03	Yes
Redefinition of minimum customer EIRP	98/04	OPM 03	Yes
Redefinition of maximum customer EIRP	98/04	OPM 03	No
I/Q Power Ratio	98/04	OPM 03	Yes
Channel Data Format	98/04	OPM 03	No
Channel Data Bit Jitter	98/04	OPM 03	No
DG1 Mode	98/04	OPM 03	Yes
Polarization	98/04	OPM 03	No
Data Group	98/04	OPM 03	Yes
DG2 Coherency	98/04	OPM 03	Yes
DG2 Carrier Modulation	98/04	OPM 03	Yes
TDRSS Autotrack Mode	98/04	OPM 03	No
Data Source/Channel Configuration	98/04	OPM 03	Yes
G_2 inversion	98/04	OPM 03	No
Frame Length	98/04	OPM 03	No
Frame Sync Word Length	98/04	OPM 03	No
Frame Sync Word Bit Pattern	98/04	OPM 03	No
Sync Strategy Parameters	98/04	OPM 03	No

Note:

1. Items that are indicated to cause return service interruption will cause the SN ground terminal receiver to discontinue signal tracking and attempt to reacquire the return service signal after the appropriate reconfiguration. Additionally, any reconfigurations to the forward service that cause forward link interruption will also cause return interruption for coherent return links. Any other reconfigurations of the SN ground terminal may momentarily affect signal tracking.

2. Autotrack Power Requirement. For the TDRSS KuSA return service autotrack process to acquire a customer platform signal, the KuSA return service P_{rec} must be consistent with either the P_{rec} required for autotrack acquisition or the P_{rec} required for BER, whichever is greater (refer to Table 7-7).
3. Program track Operational Process. The SN ground terminal open-loop points the TDRS SA antenna in the calculated direction of the customer platform. The acquisition process begins with PN/carrier acquisition as described below for coherent or noncoherent operations as applicable.
4. Autotrack Operational Process. The SN ground terminal initially open-loop points the TDRS SA antenna in the calculated direction of the customer platform. If the TDRSS KuSA return service autotrack process is initiated (or reinitiated), the SN ground terminal then processes error signals derived from the received customer platform KuSA return service signal to correct for small error build-ups in moving the TDRS antenna at the calculated angular rate of the customer platform. After the time when the signal is first present at the TDRS with adequate KuSA return service P_{rec} [see paragraph 2 above], autotrack acquisition will be achieved within the autotrack acquisition time listed in Table 7-7. The acquisition process continues with PN/carrier acquisition as described below for coherent or noncoherent operations as applicable.
5. TDRS Forward EIRP Level. If the TDRSS KuSA return service autotrack process is enabled, the forward service EIRP will default to the high power program track values listed in Table 7-2 during autotrack acquisition. Following the completion of return autotrack acquisition, the forward EIRP will be consistent with the autotrack normal or high power values listed in Table 7-2. If the return autotrack service experiences a reacquisition, the forward EIRP values may decrease to the high power program track values. If the TDRSS KuSA return service autotrack process is inhibited, the forward EIRP will be consistent with the normal power or high power program track values listed in Table 7-2, where either LEO program track or program track values depend upon customer platform orbital characteristics.
6. Interference Mitigation to S-band Customers. An instantaneous P_{rec} increase in the TDRSS KuSA return service channel being supported via the TDRS composite downlink Traveling Wave Tube Amplifier (TWTA) can potentially cause BER degradations to TDRSS SSA return services being concurrently supported via that same TDRS. For a customer platform KuSA return service signal that results in a P_{rec} greater than -159.2 dBW, it is recommended that the customer MOC plan to use the following operational procedure to minimize return service performance degradations to other ongoing customer platform missions due to an instantaneous increase in Ku-band P_{rec} level caused either by its customer platform signal being present at, or prior to, T_R (the time the return service

begins) or by its customer platform turning on its transmitting system at, or subsequent to, T_R:

(a) Prior to T_R: The P_{rec} (resulting from the customer platform KuSA return service signal level) must be less than -159.2 dBW. The instantaneous rate of change of P_{rec} need not be less than or equal to 10 dB/sec.

(b) At, or subsequent to T_R: During the time period from T_R to the time that the P_{rec} (resulting from the customer platform KuSA return service signal level) reaches its scheduled initial value, the instantaneous rate of change of P_{rec} from T_R to that time should be less than or equal to 10 dB/sec (e.g., by initially causing the customer platform KuSA antenna to be off-pointed from the calculated direction of the TDRS at T_R and then slewing it at an appropriate rate, starting at T_R, to where it is pointing in the calculated direction of the TDRS).

b. Coherent Signal Acquisition Scenarios (DG1 Mode 1 and DG2 Coherent):

1. For optimal TDRSS performance, all coherent services should have the TDRSS forward and return services starting at the same time. If operational considerations require starting the TDRSS forward service before the return service, no reconfigurations of the forward service can be sent within 30 seconds of the start of the return service. A forward link sweep request OPM cannot be sent within 150 seconds of the start of the return service.

2. The customer platform P_{rec} must be compatible with the minimum P_{rec} required for BER and the other TDRSS KuSA return service signal parameters listed in Table 7-5.

3. At the service start time specified by the SHO, the SN ground terminal will begin the search for the customer platform signal based upon predicted range and Doppler. The SN ground terminal corrects the received customer platform signal for Doppler to allow for the SN ground terminal implementation of receivers with narrow acquisition and tracking bandwidths. The Doppler correction used by the SN ground terminal is either one-way return (Forward Doppler compensation enabled) or two-way (Forward Doppler compensation inhibited). For coherent operation, the Doppler correction is based upon the forward service frequency.

4. After the forward service has been acquired and the P_{rec} is consistent with minimum P_{rec} required for BER, the SN ground terminal will begin PN/carrier acquisition. PN/carrier acquisition may occur prior to completion of autotrack acquisition (if enabled). The SN ground terminal will acquire the customer platform signal (PN code (applicable to DG1 only) and carrier) within the time limits listed in Table 7-7. Return service will be achieved at the SN ground terminal receiver output within the total

channel acquisition time limits listed in Table 7-7, which includes SN ground terminal symbol and Viterbi decoder (if applicable) synchronization.

c. Noncoherent (DG1 Mode 2 and DG2 Noncoherent):

1. This mode of customer platform operation does not require a TDRSS forward service signal to be received by the customer platform. However, the customer platform transmitter must be commanded to turn on when noncoherent transmissions are desired, either by stored commands, on-board configuration settings, or direct commands from its customer MOC.

2. The customer platform P_{rec} must be compatible with the minimum P_{rec} required for BER and the other TDRSS KuSA return service signal parameters listed in Table 7-5.

3. At the service start time specified by the SHO, the SN ground terminal will begin the search for the customer platform signal based upon predicted Doppler. The SN ground terminal corrects the received customer platform signal for Doppler to allow for SN ground terminal implementation of receivers with narrow acquisition and tracking bandwidths. The Doppler correction used by the SN ground terminal is one-way return and based on the customer platform transmission frequency stated in the SHO and any subsequent OPMs.

4. The SN ground terminal will begin PN/carrier acquisition when the P_{rec} meets the minimum required value for this acquisition process. PN/carrier acquisition may occur prior to completion of autotrack acquisition (if enabled). The SN ground terminal will complete acquisition of the customer platform signal (PN code (applicable to DG1 only) and carrier) within the time limits listed in Table 7-7. Return service will be achieved at the SN ground terminal receiver output within the total acquisition time limits listed in Table 7-7, which includes SN ground terminal symbol and Viterbi decoder synchronization.

d. DG1 Mode Transitions:

1. <u>DG1 Mode 2 to DG1 Mode 1 Transitions</u>. A TDRSS KuSA forward service must be scheduled to be established prior to customer MOC transmission of the GCMR to reconfigure the TDRSS for DG1 mode 1 (or 3) operations (refer to paragraph 7.3.5.b.(1)).

2. <u>DG1 Mode 1 to DG1 Mode 2 Transitions</u>. When the customer platform switches to the noncoherent mode (DG1 mode 2), customer platform return service signal parameters (e.g., carrier and channel PN codes) are changed causing the SN ground terminal to drop TDRSS KuSA return service signal lock. Customer platform transponders designed to automatically switch from a coherent transponder mode to a noncoherent mode when the TDRSS KuSA forward service signal is lost will result in SN ground terminal loss of KuSA return service signal lock.

Reconfiguration and reacquisition by the SN ground terminal is required and must be initiated by a GCMR from the customer MOC.

NOTE:

Failure to observe these conventions may result in SN ground terminal rejection of reconfiguration messages, excessive acquisition times, and unnecessary loss of customer platform return service data.

e. DG2 Mode Transitions:

1. DG2 noncoherent to DG2 coherent Transitions. A TDRSS KuSA forward service must be scheduled to be established prior to customer MOC transmission of the GCMR to reconfigure the TDRSS for DG2 coherent operations (refer to paragraph 7.3.5.b.(1)).

2. DG2 coherent to DG2 noncoherent Transitions. When the customer platform switches to the noncoherent mode, the resulting customer transmit frequency offset will probably cause the SN ground terminal to drop TDRSS KuSA return service signal lock when the switch is made. If return service signal lock is lost, reconfiguration and reacquisition by the SN ground terminal is required and must be initiated by a GCMR from the customer MOC.

NOTE:

Failure to observe these conventions may result in SN ground terminal rejection of reconfiguration messages, excessive acquisition times, and unnecessary loss of customer platform return service data.

Table 7-9. TDRSS KuSA Return Service Customer Platform Signal Constraints

Parameter (Notes 1, 2, and 14)	**Description** (Notes 1, 2, and 14)
Minimum channel data bit transition density (required for acquisition/reacquisition)	≥ 64 randomly distributed data bit transitions within any sequence of 512 data bits
Consecutive channel data bits without a bit transition (required for acquisition/reacquisition)	≤ 64
Minimum channel symbol (bit) transition density (Note 3)	≥128 randomly distributed symbols (bit) transitions within any sequence of 512 symbols (bits)
Consecutive channel symbols (data bits) without a symbol (data bit) transition (Note 3)	≤64 symbols (data bits)
Data asymmetry (peak) (Note 3)	≤ ± 3 percent
Symbol (data) bit jitter and jitter rate (Note 3)	≤ 0.1 percent (see Appendix E)
Phase imbalance	
DG1 modes 1 and 2	≤ ± 5 degrees
DG2	≤ ± 3 degrees
Gain imbalance	
DG1 modes 1 and 2	≤ ± 0.50 dB
DG2	≤ ± 0.25 dB
Phase nonlinearity (applies for all types of phase nonlinearities) (peak) (Note 12)	
DG1 modes 1 and 2	≤ 4 degrees over ±2.1 MHz
DG2	≤ 3 degrees over ±80 MHz
Gain flatness (peak) (Note 12)	
DG1 modes 1 and 2	≤0.4 dB over ±2.1 MHz
DG2	≤0.3 dB over ±80 MHz
Gain slope (Note 12)	
DG1 modes 1 and 2	Not Specified
DG2	≤0.1 dB/MHz over ±80 MHz
AM/PM	
DG1 modes 1 and 2	≤15 deg/dB
DG2	≤12 deg/dB

Table 7-9. TDRSS KuSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1, 2, and 14)	**Description** (Notes 1, 2, and 14)
Noncoherent frequency stability (peak) (Notes 4, 5, 11)	
±5 kHz customer oscillator frequency uncertainty	
1-sec average time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 1 \times 10^{-7}$
48-hr observation time	$\leq 3 \times 10^{-7}$
±20 kHz customer oscillator frequency uncertainty	
1-sec average time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 4 \times 10^{-7}$
48-hr observation time	$\leq 1.2 \times 10^{-6}$
Incidental AM (peak)	
For open-loop pointing	
At frequencies ≥100 Hz	≤5 percent
For autotrack performance	
At frequencies: 10 Hz-10 kHz	≤3 percent
At frequencies: 10 Hz-2 kHz	≤0.6 percent (Note 6)
Spurious PM	≤2 degrees
Minimum 3-dB bandwidth prior to power amplifier	
DG1	≥4.5 MHz or two times maximum baud rate, whichever is larger
DG2	≥2 times maximum channel baud rate
Phase noise (rms) (Note 7 and 8)	
DG1 Mode 1 (Note 13)	
Channel baud rate < 16 ksps	
1 Hz – 10 Hz	≤4.0° rms
10 Hz – 1 kHz	≤3.0° rms
1 kHz – 150 MHz	≤1.4° rms

Table 7-9. TDRSS KuSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1, 2, and 14)	**Description** (Notes 1, 2, and 14)
Phase noise (rms) (Note 7 and 8) (cont'd)	
DG1 Mode 1 (Note 13) (cont'd)	
Channel baud rate ≥ 16 ksps	
1 Hz – 10 Hz	≤ 25.0° rms
10 Hz – 1 kHz	≤ 3.0° rms
1 kHz – 150 MHz	≤ 2.0° rms
DG1 Mode 2	
Channel baud rate < 16 ksps	
1 Hz – 10 Hz	≤ 4.0° rms
10 Hz – 100 Hz	≤ 3.0 ° rms
100 Hz – 1 kHz	≤ 1.8° rms
1 kHz – 150 MHz	≤ 1.4° rms
Channel baud rate ≥ 16 ksps	
1 Hz – 10 Hz	≤ 25.0° rms
10 Hz – 100 Hz	≤ 4.0° rms
100 Hz – 1 kHz	≤ 2.0° rms
1 kHz – 150 MHz	≤ 2.0° rms
DG2 Coherent (Note 13)	
Channel baud rate < 434 ksps	
1 Hz – 10 Hz	≤3.6° rms
10 Hz – 1 kHz	≤1.8° rms
1 kHz – 150 MHz	≤1.0° rms
434 ksps ≤ Channel baud rate ≤ 6 Msps	
1 Hz – 10 Hz	≤50.0° rms
10 Hz – 1 kHz	≤6.0° rms
1 kHz – 150 MHz	≤2.4° rms
Channel baud rate > 6 Msps	
1 Hz – 10 Hz	≤50.0° rms
10 Hz – 1 kHz	≤5.5° rms
1 kHz – 150 MHz	≤1.1° rms

Table 7-9. TDRSS KuSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1, 2, and 14)	**Description** (Notes 1, 2, and 14)
Phase noise (rms) (Note 7 and 8) (cont'd)	
DG2 Noncoherent	
Channel baud rate < 108.5 ksps	
1 Hz – 10 Hz	≤ 4.0° rms
10 Hz – 100 Hz	≤ 2.5° rms
100 Hz – 1 kHz	≤ 1.4° rms
1 kHz – 150 MHz	≤ 1.4° rms
108.5 ksps ≤ Channel baud rate ≤ 6 Msps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 100 Hz	≤ 5.5° rms
100 Hz – 1 kHz	≤ 2.4° rms
1 kHz – 150 MHz	≤ 2.4° rms
Channel baud rate > 6 Msps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 100 Hz	≤ 10.0° rms
100 Hz – 1 kHz	≤ 2.0° rms
1 kHz – 150 MHz	≤ 2.0° rms
In-band spurious outputs, where in-band is twice the maximum channel baud rate	
DG1 modes 1 and 2	≥ 23 dBc
DG2	≥ 30 dBc
Out-of-band emissions	See Appendix D for allowable limits on out-of-band emissions, including spurs
I/Q data skew (relative to requirements for I/Q data synchronization where appropriate) (peak) (Note 3)	≤3 percent
I/Q PN chip skew (relative to 0.5 chip)	≤0.01 chip
PN chip rate (peak) DG1 mode 2 (relative to absolute coherence with carrier rate)	≤0.01 chips/sec at PN code chip rate
Customer-induced PN correlation loss (noncoherent and coherent)	≤0.3 dB
Axial ratio for autotrack	≤3 dB
Data rate tolerance	≤+0.1 percent
I/Q power ratio tolerance	≤+0.4 dB
Permissible P_{rec} variation (without reconfiguration GCMR from customer MOC) (Note 9)	≤12 dB
Permissible rate of P_{rec} Variation	≤10 dB/sec

Table 7-9. TDRSS KuSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1, 2, and 14)	**Description** (Notes 1, 2, and 14)
Maximum P_{rec}	-149.2 dBW

Notes:

1. The definitions and descriptions of the customer constraints are provided in Appendix E.
2. When a constraint value is listed for a baud rate range and data is transmitted on both channels, the maximum baud rate of the 2 channels should be used to determine the constraint value applicable.
3. When the data is Rate 1/2 convolutionally encoded, these data bit parameters should be interpreted as symbol parameters. For encoded channels, it is recommended that customers use G2 inversion to increase symbol transition density. CCSDS randomization is recommended to aid in compliance with the data randomness requirements.
4. The frequency stability requirements are valid at any constant temperature (±0.5° C) in the range expected during the mission. At a minimum, a temperature range of -10° C to +55° C shall be considered.
5. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of ± 5 kHz. If a customer cannot accurately define their transmit frequency to within ± 5 kHz, a customer can request a reconfiguration which would expand the oscillator frequency search to ± 20 kHz after the start of service.
6. The TDRSS design implementation may not provide the stated TDRSS KuSA return service autotrack performance when P_{rec} = P_{rec} (minimum) and the Incidental AM (peak), at frequencies ≤2 kHz, is close to or at 0.6 percent. For TDRSS KuSA return service autotrack performance, either P_{rec} must be increased above P_{rec} (minimum), or the Incidental AM (peak), at frequencies ≤2 kHz, must be more tightly controlled.
7. Derivation of the phase noise requirements involved making assumptions about the distribution of the phase noise power in each frequency region. Since no phase noise PSD will exactly match the phase noise power distribution assumed for this derivation, phase noise PSDs which are close to violating the phase noise limits or phase noise PSDs which do violate the phase noise limits should be evaluated on a case-by-case basis to determine their acceptability.
8. For customers receiving Doppler tracking services, more stringent phase noise constraints should be considered by the customer. It is the responsibility of the customer to ensure customer transponder / transmitter phase noise performance enables achievement of the desired total Doppler tracking error performance. Appendix U provides recommended customer phase noise performance constraints which ensure a total Doppler tracking error (system + customer) ≤ 0.2 rad/sec (1σ) assuming an averaging time of 1 second.
9. The minimum SHO EIRP should reflect the minimum P_{rec} expected over the service period, where the P_{rec} can exceed this minimum by no more than 12 dB. An actual customer P_{rec} value that is 12 dB greater than the minimum may cause false PN lock or nonacquisition.
10. Deleted.
11. Deleted.
12. Bandwidth limitation for gain flatness, phase nonlinearity and gain slope while maintaining consistency with NTIA spectral emission mask (Appendix D):70% of the signal main lobe width or 70 % of the necessary bandwidth whichever is smaller.
13. Coherent return link phase noise user constraint assumes a forward service signal with no phase noise on it. Phase noise created in the user receiver carrier tracking loop by thermal noise on the forward link is a component which must be considered as a contributor to the user coherent return service phase noise.
14. Customers are recommended to provide to the SN a transmitter EVM measurement for each of their service modes.

7.3.6 225 MHz IF Service

This section specifies characteristics and recommendations for the KuSAR IF service. SN IF services are available to customers on a case-by-case basis. The IF service is supported through TDRS F3 – F7 and TDRS F8 – F10 and K, L, M via the SN ground terminal infrastructure, where the customer provides the receiver equipment and the SN only provides the signal at the IF with the characteristics described in this section. Paragraph 7.3.6.1 describes the aggregate channel characteristics of the TDRS spacecraft and SN ground segment for understanding the IF interface.

The performance of the customer link greatly depends on the customer signal characteristics and the receiver used. Paragraph 7.3.6.2 describes potential signal characteristics and expected performance through the TDRS spacecraft and SN ground segment. The expected performance is based upon simulation results only and has not been verified by testing. Data rates and coding techniques should be carefully considered and coordinated with Code 450 to achieve desired performance.

NOTE:

Autotracking is not provided for the IF service.

Changes to the operating conditions or configuration of a TDRSS KuSAR IF service during a scheduled service support period are initiated by a GCMR from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the GCMR at the SN ground terminal. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning SN ground terminal response times for GCMRs is provided in Section 10. Table 7-10 lists the KuSA IF return service real-time configuration changes and their effects on the return service.

Table 7-10. KuSA Return IF Service Real-Time Configuration Changes

Real-Time Configuration Changes	GCMR	OPM	Return Service Interruption
Polarization	98/04	OPM 03	Yes
Note: Items that are indicated to cause return service interruption will cause the SN ground terminal receiver to discontinue signal tracking and attempt to reacquire the return service signal after the appropriate reconfiguration. Any other reconfigurations of the SN ground terminal may momentarily affect signal tracking.			

7.3.6.1 Channel Characteristics

As discussed above, this is not an end-to-end service so a set of customer platform signal constraints is not available due to the dependencies on the exact customer signal characteristics as well as receiver capabilities. The IF service provides a KuSAR signal through the TDRS spacecraft and SN ground segment, including IF output channel characteristics as specified in Table 7-11. This will allow customers to be able to

understand the signal distortions that are outside of their control. For additional characteristics applicable to the KuSAR IF service, refer to Table 7-7.

7.3.6.2 Potential Signal Parameters for IF Service

As discussed earlier, this is not an end-to-end service so a set of well defined customer signal parameters is not available. This section describes potential signal characteristics and expected performance through the TDRS spacecraft and SN ground segment. The KuSA return IF service is not currently automated; however, automation of this service is being considered for implementation. SN IF services are available to customers on a case-by-case basis. Customers should contact Code 450 if they are interested in this service to determine expected performance for their specific signal characteristics and receiver. Potential TDRS KuSA return service signal configurations are provided in Table 7-12.

Table 7-11. TDRS KuSAR IF Service Spacecraft and Ground Segment Channel Characteristics

Parameter	Description
TDRS Ku-band Receive Center Frequencies (note 1)	15.0034 GHz
3-dB RF bandwidth (note 3)	≥ 240 MHz
Gain Flatness (peak) (note 2)	≤ 0.8 dB over ±80 MHz
Gain Slope (note 2)	≤ 0.14 dB/MHz over ± 80 MHz
Phase nonlinearity (applies for all types of phase nonlinearities) (peak) (note 2)	≤ 16.5° over ± 80 MHz
AM/AM (note 2)	> 0.57 dB/dB
AM/PM (note 2)	≤ 7°/dB
Spurious PM (note 2)	≤ 2.24° rms
In-band spurious outputs (note 2)	
Total	≥ 27 dBc
Individual	≥ 40 dBc
Incidental AM (peak) (note 2)	≤ 1% (within 3-dB RF bandwidth)
Phase noise (note 2)	
1 Hz to 10 Hz	≤ 3.8° rms
10 Hz to 100 Hz	≤ 3.6° rms
100 Hz to 1 kHz	≤ 4.3° rms
1 kHz to 150 MHz	≤ 2.7 ° rms
1 kHz to 400 MHz	NA
Additional TDRS Ground Segment IF Characteristics:	
IF center frequency	370 MHz
Output level	-15 dBm ±3 dB
Output VSWR	≤ 1.3:1 into 50Ω load, ± 80 MHz from center frequency

Table 7-11. TDRS KuSAR IF Service Spacecraft and Ground Segment Channel Characteristics (cont'd)

Notes:

1. The customer should schedule the TDRS receive center frequency to the KuSAR TDRS receive center frequency, where the TDRS receive center frequency will be translated to the center of the IF bandwidth. The signal and carrier frequency will be constrained such that the first null of the spectrum falls between 14.8834 and 15.1234 GHz. The KuSAR IF service only supports non-coherent frequencies. The KuSAR IF service supports only one Ku frequency through one TDRS at a time. These frequencies do not include the effects of Doppler shift. The KuSAR IF service is not required to provide a Doppler-corrected IF output signal. The customer provided receiver needs to handle Doppler.
2. Constraint parameters are contributions from the TDRS spacecraft and the SN ground segment to the IF interface. Not included in these aggregate distortion amounts are TDRS spacecraft gain flatness, linear and parabolic allowances, and phase nonlinearity parabolic and cubic allowances as described in 405-TDRS-RP-SY-001, WU-02-01, and SY1-89E. Customer and receiver signal characteristics need to be considered to determine the end-to-end performance. Please contact GSFC Code 450 for further information.
3. The 3 dB RF bandwidth is larger than the specified 225 MHz bandwidth value specified in Table 7-7. This value has validated through spacecraft and ground terminal measurements, but may not be applicable to future TDRS.

Table 7-12. Potential TDRSS KuSA IF Return Service Configurations (Customer interfaces with the SN at a 370 MHz IF and Customer provides the Receiver)

Return IF Service Configuration (notes 1, 2)		Potential Maximum Data Rates (IF Service)
BPSK	Rate 1/2 convolutional coded	See Table 7-6
	Uncoded	See Table 7-6
QPSK / SQPSK	Rate 1/2 convolutional coded	See Table 7-6
	Uncoded	See Table 7-6
	(128,120)x(128,120) TPC (note 3)	400 Mbps
	(8176,7136) LDPCC (notes 3, 4)	400 Mbps
	(2048, 1024) AR4JA LDPCC	200 Mbps
8PSK	(128,120)x(128,120) TPC (note 3)	600 Mbps
	(8176,7136) LDPCC (notes 3, 4)	600 Mbps
	Uncoded	450 Mbps

Notes:

1. All data rates assume NRZ data format.
2. These service configurations and maximum data rates were based upon simulation results only and have not been verified by testing. Other data rates and modulation schemes may be possible. Please contact GSFC Code 450 for further information.
3. For the IF service, data rates up to 410 Mbps may be possible for QPSK/SQPSK modulation with either TPC or (8176, 7136) LDPCC. For the 225 MHz IF service, data rates up to 625 Mbps may be possible for 8PSK with either TPC or (8176,7136) LDPCC. Please contact GSFC Code 450 for further information.
4. The code being supported is the (8160, 7136), the shortened version of the (8176, 7136) code.

7.3.6.3 Potential Signal Performance for IF Service

The performance of the IF link is greatly dependent on the customer provided receiver. Typically, the SNUG specifies performance at BER of 10^{-5}; BERs better than 10^{-5} may be possible for the IF service.

NOTE:

The expected performance is based upon simulation results only and has not been verified by testing. Data rates and coding techniques should be carefully considered and coordinated with GSFC Code 450 to achieve desired BER.

All values in this section assume using a receiver with reasonable implementation loss. Table 7-13 provides expected, required Eb/No values for various data rates and modulation schemes for a 10^{-5} BER. Additionally, Table 7-13 also provides the theoretical Eb/No and implementation loss values for those modulation and coding schemes at 10^{-5} BER over a simple AWGN channel. Table 7-13 also provides a potential minimum required P_{rec} (dBW) equation for various data rates, coding and modulation schemes through the IF service assuming these expected required Eb/No values, which were based upon simulation results and have not been verified by testing.

NOTE:

Autotracking is not provided for the IF service.

Table 7-13. Potential KuSAR IF Service Implementation Loss Amounts and LEO Program Track Required Prec Equations for Various Data Rates Using Different Modulation and Coding Techniques

Return IF Service Configuration (notes 2, 3)		Data Rates	Required Eb/No at input to receiver for 10^{-5} BER (notes 1, 2)	Theoretical Required Eb/No (note 1)	Implementation Loss Amounts (notes 1, 2)	Required Prec (K) at TDRS (dBW) for a 10^{-5} BER (LEO Program Track) (note 2)
QPSK/SQPSK (note 5)	(128,120)x(128, 120) TPC (note 4)	400 Mbps	7.9 dB	3.9 dB	4.0 dB	-241.5 + 10 log (dr)
		300 Mbps	6.6 dB		2.7 dB	-243.5 + 10 log (dr)
		≤ 200 Mbps	6.1 dB		2.2 dB	-244.3 + 10 log (dr)
	(8176,7136) LDPCC (note 4, 6)	400 Mbps	8.4 dB	4.4 dB	4.0 dB	-240.7 + 10 log (dr)
		300 Mbps	7.3 dB		2.9 dB	-242.6 + 10 log (dr)
		≤ 200 Mbps	6.4 dB		2.0 dB	-244.0 + 10 log (dr)
	(2048, 1024) AR4JA LDPCC	200 Mbps	4.0 dB	1.7 dB	2.3 dB	-246.6 + 10 log (dr)
		≤ 150 Mbps	3.6 dB		1.9 dB	-247.1 + 10 log (dr)

Table 7-13. Potential KuSAR IF Service Implementation Loss Amounts and LEO Program Track Required Prec Equations for Various Data Rates Using Different Modulation and Coding Techniques (cont'd)

Return IF Service Configuration (notes 2, 3)		Data Rates	Required Eb/No at input to receiver for 10^{-5} BER (notes 1, 2)	Theoretical Required Eb/No (note 1)	Implementation Loss Amounts (notes 1, 2)	Required Prec (K) at TDRS (dBW) for a 10^{-5} BER (LEO Program Track) (note 2)
8PSK (note 5)	(128,120)x(128,120) TPC (note 4)	600 Mbps	10.5 dB	6.9 dB	3.6 dB	-238.4 + 10 log (dr
		500 Mbps	9.4 dB		2.5 dB	-240.3 + 10 log (dr)
		≤ 400 Mbps	8.8 dB		1.9 dB	-241.3 + 10 log (dr)
	(8176,7136) LDPCC (note 4, 6)	600 Mbps	11.5 dB	7.3 dB	4.2 dB	-236.7 + 10 log (dr)
		500 Mbps	10 dB		2.7 dB	-239.5 + 10 log (dr)
		≤ 400 Mbps	9.5 dB		2.2 dB	-240.5 + 10 log (dr)
	Uncoded	≤ 450 Mbps	17.3 dB	13.1 dB	4.2 dB	-231.1 + 10 log (dr)

Notes:

1. Unless otherwise noted, all values are based upon a customer transmitter power amplifier operating point of 1 dB OBO, i.e., AM/PM = 12°/dB and AM/AM = 0.47 dB/dB. Values assume baseband equalization used. Values do not include margin. All values are given for a receiver with reasonable loss. Better performance may be achievable with better power amplifier and/or filters, etc.
2. These service configurations and maximum data rates were based upon simulation results only and have not been verified by testing. Other data rates and modulation schemes may be possible. Please contact GSFC Code 450 for further information.
3. For BPSK, QPSK, SQPSK with uncoded or rate ½ convolutional coded through the 225 MHz bandwidth, see Table 7-7 for expected performance.
4. For the 225 MHz IF service, data rates up to 410 Mbps may be possible for QPSK/SQPSK modulation with either TPC or (8176,7136) LDPCC. For the 225 MHz IF service, data rates up to 625 Mbps may be possible for 8PSK with either TPC or (8176,7136) LDPCC. Please contact GSFC Code 450 for further information.
5. For the QPSK/SQPSK configurations, the required P_{rec} was determined for support through KuSAR composite downlink to the GRGT IF interface point. For the 8PSK configurations, the required P_{rec} was determined for support through the KuSAR composite downlink to the WSC IF interface point, except for the 8PSK uncoded service, which assumes a dedicated downlink to the WSC IF interface point.
6. The code being supported is the (8160, 7136), the shortened version of the (8176, 7136) code.

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Section 8. KaSA Telecommunications Services

8.1 General

8.1.1 Available Services

TDRSS KaSA services include forward and return telecommunications services. KaSA Return service includes 225 MHz service through the SN receive equipment and automated IF service for the KaSA 225 MHz and KaSA 650 MHz channels, where SN IF services are available to customers on a case-by-case basis. IF service requires the customer to provide the receiver equipment and the SN only provides the signal at the IF. Tracking services are not provided via KaSA. This section focuses on the RF interface between the TDRS and the customer platform. This interface is characterized by the technical requirements imposed and the operational capabilities provided by the TDRSS. The operational interfaces are described in further detail in Section 10. Data interfaces between the customer MOC and the SN are described in Section 3, paragraph 3.6.

NOTE:

The NCCDS issues NAMs to provide up-to-date information on network conditions and constraints. These messages are accessible via the NCCDS active NAM web site at https://cds.gsfc.nasa.gov/. GSFC Code 450 uses the NAMs as a means of letting customers know of any performance constraints associated with TDRS spacecraft. Additionally, TDRS constellation information can be found in the TDRS Constellation Management Plan, 452-PLAN-0002.

8.1.2 Interface Definition

The RF interface between the TDRS and a customer platform is defined in terms of signal parameters, RF characteristics, and field of view.

a. The RF interface for forward service represents the transmission by a TDRS of an appropriately modulated signal at or greater than a minimum specified signal EIRP in the direction of the desired customer platform. KaSA forward (KaSAF) service is discussed in paragraph 8.2.

b. The RF interface for return service defines a minimum received power (P_{rec}) at the TDRS antenna input for a specified data quality at the SN ground terminal receiver output. KaSA return (KaSAR) service is discussed in paragraph 8.3.

NOTE:

The KaSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.

8.1.3 Customer Acquisition Requirements

Acquisition and reacquisition by the customer platform of the TDRS transmitted signal requires prediction by the customer MOC of the customer platform receive frequency over various projected time periods. Similarly, acquisition and reacquisition by the SN ground terminal of the customer platform signal requires prediction by the customer MOC of the customer platform transmitter frequency over various projected time periods. The frequency predictions are ultimately incorporated into the SHO as customer platform frequencies for the specific service support periods.

8.1.4 TDRSS Acquisition Support to Customers

For each scheduled TDRSS service support period, the customer requirements for signal acquisition/reacquisition, and the TDRSS capabilities to aid acquisition/reacquisition, are as follows:

a. Customer Epoch Uncertainty

1. Autotrack. The maximum epoch time uncertainty of the applicable customer platform ephemeris supplied to the TDRSS shall be ±2.0 seconds for customer platform operations requiring the TDRSS KaSA return service autotrack process within the TDRSS Primary FOV and EEFOV. Similarly, the maximum epoch time uncertainty of the customer platform ephemeris shall be ±1.5 seconds for the KaSA return service autotrack process within the TDRSS LEOFOV.

NOTE:

KaSAR EEFOV autotrack support shall be coordinated through GSFC Code 450. Autotrack service is not available through the Ka-band 225 MHz and 650 MHz bandwidth IF service.

2. Program track. The maximum epoch time uncertainty of the applicable customer platform ephemeris supplied to the TDRSS shall be ±2.0 seconds for customer platform operations using TDRSS KaSA open-loop pointing within the TDRSS Primary FOV.

3. LEO Program track. The maximum epoch time uncertainty of the applicable customer platform ephemeris supplied to the TDRSS shall be ±1.5 seconds for customer platform operations requiring the TDRSS KaSA open-loop pointing for customers within the TDRSS LEOFOV.

b. Customer Frequency Uncertainty. The customer MOC must know the operating frequency of the customer platform to within ±6 kHz.

c. Frequency Sweep on the Forward Link. After the start of the forward link service, the TDRSS has a forward service frequency sweep capability of ±30 kHz.

d. Noncoherent Return Expanded Frequency Search. After the start of the return link service, the TDRSS has a return service expanded frequency search capability of ±21 kHz.

8.2 KaSA Forward Services

8.2.1 General

The characteristics of the data provided to the SN ground terminal interface and the RF signals provided by the TDRS to the customer platform during TDRSS KaSA forward services are described in paragraphs 8.2.2 through 8.2.5. This discussion assumes that an appropriate forward service has been scheduled and a data signal is present at the SN ground terminal interface.

8.2.2 Signal Parameters

The TDRSS KaSA forward service signal parameters are defined in Table 8-1. The center frequency, f_O, of the customer platform receiver must be defined by the customer MOC in its service specification code for TDRSS KaSA forward service (refer to Section 10, paragraph 10.2.2). A description of the features inherent in the QPSK and BPSK signal parameters listed in Table 8-1 are discussed in paragraphs 8.2.2.1 and 8.2.2.2, respectively.

8.2.2.1 QPSK Signal Parameters

a. Unbalanced QPSK Modulation (PN Modulation Enabled). The I channel is used to transmit the customer command data and is referred to as the command channel. The Q channel transmits a range signal and is referred to as the range channel. The command channel/range channel power ratio for SS-UQPSK forward service signals is +10 dB. This unbalanced QPSK modulation minimizes the power in the range channel to a level adequate for customer platform range channel acquisition and tracking. This feature increases the power in the command channel by 2.6 dB over that for balanced QPSK modulation without increasing customer platform receiver complexity, increasing customer platform command channel acquisition time, or decreasing TDRSS range tracking accuracy.

NOTE:

Tracking services are not provided via KaSA.

b. Spread Spectrum. All TDRSS KaSA forward services with data rates $\leq$300 kbps should incorporate spread spectrum modulation techniques to satisfy flux density restrictions imposed upon TDRSS forward services by the NTIA.

Table 8-1. TDRSS KaSA Forward Service Signal Parameters

Parameter	Description
TDRS transmit carrier frequency (Hz)	F
Carrier frequency arriving at customer platform (note 1)	F_R
Carrier frequency sweep (note 4)	$\pm$30 kHz
Carrier frequency sweep duration (note 4)	120 seconds
UQPSK (PN modulation enabled)	
$\frac{\text{Command channel radiated power}}{\text{Range channel radiated power}}$	+10 dB
SS-UQPSK Command Channel	
Carrier frequency (Hz)	Transmit carrier frequency (F)
PN code modulation	PSK, $\pm$ π/2 radians
Carrier suppression	30 dB minimum
PN code length (chips)	2^{10} - 1
PN code epoch reference	Refer to 451-PN CODE-SNIP
PN code family	Gold codes
PN code chip rate (chips/sec) (note 5)	$\frac{31}{1469 \times 96} \times (\frac{F}{10^9} - 8.78 - 0.005\,K) \times 10^9$
Data modulation	Modulo-2 added asynchronously to PN code
Data format (note 2)	Not applicable
Data rate restrictions (note 2)	1 kbps - 300 kbps
SS-UQPSK Range Channel	
Carrier	Command channel carrier frequency delayed π/2 radians
PN code modulation	PSK, $\pm$ π/2 radians
Carrier suppression	30 dB minimum
PN code chip rate	Synchronized to command channel PN code chip rate
PN code length (chips)	$(2^{10} - 1) \times 256$
PN code epoch reference	All 1's condition synchronized to the command channel PN code epoch.
PN code family	Truncated 18-stage shift register sequences

Table 8-1. TDRSS KaSA Forward Service Signal Parameters (cont'd)

Parameter	Description
BPSK (PN modulation enabled) (note 6)	
Carrier frequency (Hz)	Transmit carrier frequency (F)
PN code modulation	PSK, $\pm \pi/2$ radians
Carrier suppression	30 dB minimum
PN code length (chips)	$2^{10} - 1$
PN code epoch reference	Refer to 451-PN CODE-SNIP
PN code family	Gold codes
PN code chip rate (chips/sec) (note 5)	$\frac{31}{1469 \times 96} \times (\frac{F}{10^9} - 8.78 - 0.005\,K) \times 10^9$
Data modulation	Modulo-2 added asynchronously to PN code
Data format (note 2)	Not applicable
Data rate restrictions (note 2)	1 kbps - 300 kbps
BPSK (PN modulation disabled)	
Carrier frequency (Hz)	Transmit carrier frequency (F)
Data modulation	PSK, $\pm\pi/2$ radians
Carrier suppression	30 dB minimum
Data format (note 2)	Not Applicable
Data rate restrictions (notes 2, 3)	300 kbps - 7 Mbps

Notes:

1. The center frequency, f_O, of the customer platform receiver must be defined by the customer MOC in its service specification code to an integral multiple of 10 Hz. Doppler compensation will be available for $\dot{R} \leq 7.9$ km/sec. During periods of Doppler compensation, $F_R = f_O \pm E$ Hz, where f_O = nominal center frequency of customer platform receiver as defined by the customer MOC and $E = |e \times f_O \times \ddot{R}/c| + C$; $e \leq \pm 2.0$ sec is the customer epoch uncertainty, $\ddot{R} \leq 11.4$ m/sec^2, c is the free space speed of light in m/sec, and C = 1900 Hz. If Doppler compensation is inhibited after the start of the forward service, the customer receive frequency will be fixed at the frequency of the Doppler compensation profile at the time of inhibition.

   Forward service Doppler compensation will not increase the effective frequency rate of change seen at the customer receiver more than 560 Hz/sec relative to the frequency for a Doppler free carrier.

Table 8-1. TDRSS KaSA Forward Service Signal Parameters (cont'd)

Notes (cont'd):

2. The forward data rate in this table is the baud rate that will be transmitted by the TDRSS (includes all coding and symbol formatting). For non-WDISC customers, forward data conditioning is transparent to the SN. For all customers, forward convolutional coding is transparent to the SN. These transparent operations should be performed by the customer prior to transmission to the SN data interface. Refer to Section 3, paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities. WSC/GRGT is capable of 25 Mbps with changes.
3. The SN is capable of supporting BPSK signals at data rates less than 300 kbps; however, its use will be controlled and must be coordinated with GSFC Code 450.
4. After the start of the KaSA forward service, if a customer MOC is unable to accurately define f_o (the nominal center frequency of the customer platform receiver), the forward service carrier frequency can be swept. The KaSA forward service frequency sweep will be initiated by the SN ground terminal at f_o-30 kHz and linearly swept to f_o+30 kHz in 120 seconds and held at f_o+30 kHz thereafter. The KaSA forward service frequency sweep does not impact simultaneous SN ground terminal Doppler compensation of the KaSA forward service carrier and PN code rate (if applicable).
5. "K" = $\dfrac{\frac{f_o}{10^6} - 22555}{5}$ Rounded to the nearest integer if K $\neq$ integer and $0 \leq K \leq 198$.

   f_o is the nominal center frequency in Hz of the customer platform receiver as defined by the customer MOC.
6. Customers who operate in a SS-BPSK mode for one service cannot reconfigure any of their Forward Services (i.e., MAF, SMAF, SSAF, KuSAF, or KaSAF) to an SS-UQPSK mode. Contact Code 450 if additional flexibility is required.

This modulation scheme includes separate but simultaneous command and range channels. The command channel includes a rapidly acquirable PN code and contains the forward service data. The range channel is acquired separately and contains a PN code which satisfies the range ambiguity resolution requirements. The length of the command channel PN code is 2^{10}-1, where the length of the range channel PN code is 256 times the command channel PN code length. The customer platform command channel acquisition can precede customer platform range channel acquisition; this feature permits rapid acquisition of the range channel by limiting the range channel PN code search to only 256 chip positions while the range channel PN code itself contains 261,888 chips. The PN code chip rate is coherently related to the TDRS transmit frequency in all cases. This feature permits the customer platform receiver to use the receiver PN code clock to predict the received carrier frequency, thereby minimizing receiver complexity and reducing acquisition time. 451-PN CODE-SNIP defines all the salient characteristics for the forward range and command channel PN code libraries. The Agency Spectrum Manager responsible for PN code assignments will allocate a customer platform-unique PN code assignment from these libraries. The GSFC Spectrum Manager is responsible for NASA PN code assignments.

c. Asynchronous Data Modulation. For data rates ≤ 300 kbps, the forward service data received at the SN ground terminal from the NISN data transport system is directly modulo-2 added by the SN ground terminal to the command channel PN code sequence. The forward service data will be asynchronous with the carrier and the PN code.

NOTE:

When the command channel does not contain any actual forward service data, the forward service command channel signal is the command channel PN code sequence with or without an idle pattern.

d. Functional Configurations. A further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in Appendix B, paragraph B.2.2.

e. Doppler Compensation. The TDRSS KaSA forward service carrier frequency (F) and the PN chip rate transmitted by a TDRS can optionally be compensated by the SN ground terminal for Doppler. When compensated, the carrier, F_R, arrives at the customer platform receiving system within a predictable tolerance (E) of f_O as defined in Table 8-1. This feature minimizes the Doppler resolution requirements of the customer platform receiver and is available continuously to facilitate reacquisition by the customer platform in the event of loss of lock of the TDRSS KaSA forward service signal. Doppler compensation may be inhibited and the TDRSS will transmit a fixed-frequency KaSA forward service carrier and PN code chip rate.

8.2.2.2 BPSK Signal Parameters:

a. BPSK Modulation (PN Modulation Enabled). The I channel is used to transmit the customer command data and is referred to as the command channel. TDRSS KaSA forward services with data rates equal to and below 300 kbps should incorporate spread spectrum modulation techniques to satisfy flux density restrictions imposed on the TDRSS forward services by the NTIA. The command channel includes a rapidly acquirable PN code and contains the forward service data. The PN code chip rate is coherently related to the TDRS transmit frequency in all cases. This feature permits the customer platform receiver to use the receiver PN code clock to predict the received carrier frequency, thereby minimizing receiver complexity and reducing acquisition time. 451-PN CODE-SNIP defines all the salient characteristics for the forward command channel PN code libraries. The Agency Spectrum Manager responsible for PN code assignments will allocate a customer platform-unique PN code assignment from these libraries. The GSFC Spectrum Manager is responsible for NASA PN code assignments.

NOTE:

Customers who operate in a SS-BPSK mode for one service cannot reconfigure any of their Forward Services (i.e., MAF, SMAF, SSAF, KuSAF, or KaSAF) to an SS-UQPSK mode. Contact Code 450 if additional flexibility is required.

b. BPSK Modulation (PN Modulation Disabled). For data rates greater than 300 kbps, there is no PN code modulation and the customer data directly BPSK modulates the carrier by $\pm\pi/2$ radians.

NOTE:

The SN is capable of supporting non-spread BPSK signals at data rates less than 300 kbps; however, its use will be controlled and must be coordinated with GSFC Code 450.

c. Asynchronous Data Modulation. The forward service data will be asynchronous with the carrier.

NOTE:

When the command channel does not contain any actual forward service data, the forward service command channel signal is carrier only.

d. Functional Configurations. A further description of the functional configurations and data polarity ambiguity is found in Appendix B, paragraph B.2.2.

e. Doppler Compensation. The TDRSS KaSA forward service carrier frequency (F) transmitted by a TDRS can optionally be compensated by the SN ground terminal for Doppler. When compensated, the carrier, F_R, arrives at the customer platform receiving system within a predictable tolerance (E) of f_o as defined in Table 8-1. This feature minimizes the Doppler resolution requirements of the customer platform receiver and is available continuously to facilitate reacquisition by the customer platform in the event of loss of lock of the TDRSS KaSA forward service signal. Doppler compensation may be inhibited and the TDRSS will transmit a fixed-frequency KaSA forward service carrier.

8.2.3 Communications Services

The TDRSS KaSA forward services available are listed in Table 8-2. Table 8-3 lists their salient characteristics. The definitions for the parameters listed in Table 8-3 are contained in Appendix E.

Table 8-2. TDRSS KaSA Forward Service

Parameter	Description		
Field of view (FOV) (each TDRS) (note 5 and 6)	PFOV ±22 degrees east-west ±28 degrees north-south		LEOFOV ±10.5 degree conical
Customer Ephemeris Uncertainty (along the customer orbital track) (note 7)	≤ ± 2.0 sec		≤ ± 1.5 sec
TDRS antenna polarization (note 1)	RHC or LHC selectable		
	Autotrack (PFOV) (note 3)	LEO Program Track (LEOFOV)	Program Track (PFOV)
TDRS antenna axial ratio (maximum)	1.5 dB over 3-dB beamwidth	1.6 dB	1.7 dB
TDRS signal EIRP (minimum) (note 4)	+63.0 dBW	+59.5 dBW	+56.2 dBW
Transmit center frequency (nominal) (note 2)	22.555 to 23.545 GHz ±1.28 MHz in 5 MHz steps		
RF bandwidth (3dB, minimum)	50 MHz		
Duty factor	100 percent (normal and high power)		

Notes:

1. Operational considerations may limit choice of TDRS antenna polarization. The KaSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.
2. The customer MOC must include the best estimate of the customer platform receiver center frequency at the time of startup of each scheduled service support period in its service specification code (refer to Section 10, paragraph 10.2.2). The TDRSS KaSA forward service carrier frequency is then implemented by the SN ground terminal to the accuracy of the SN ground terminal frequency standard except during Doppler compensation. The SNIP recommends that only the following six center frequencies be used for KaSA forward service: 23.205 GHz, 23.265 GHz, 23.325 GHz, 23.385 GHz, 23.445 GHz, and 23.505 GHz. The Space Frequency Coordination Group (SFCG) recommends that only the following sixteen center frequencies be used for KaSA forward service: 22.695 GHz, 22.665 GHz, 22.725 GHz, 22.785 GHz, 22.845 GHz, 22.905 GHz, 22.965 GHz, 23.025 GHz, 23.085 GHz, 23.145 GHz, 23.205 GHz, 23.265 GHz, 23.325 GHz, 23.385 GHz, 23.445 GHz, and 23.505 GHz. Additionally, the SFCG recommends that, whenever practicable, priority should be given to making assignments outside the range 23.183 – 23.377 GHz. The data rate and carrier frequency will be constrained such that the first null of the spectrum falls between 22.55 and 23.55 GHz.
3. EIRP values are for a TDRSS forward service with a TDRSS return autotrack service acquired. Return service autotrack acquisition will be achieved within 10 seconds of KaSA return service P_{rec} consistent with the BER or autotrack acquisition, whichever is larger. Autotrack service is not available through the Ka-band return 225 MHz and 650 MHz bandwidth IF service.

Table 8-2. TDRSS KaSA Forward Service (Cont'd)

Notes (cont'd):

4. The autotrack EIRP will be transmitted towards a customer that meets the required ephemeris uncertainties for the Primary FOV. The program track EIRP will be transmitted towards a customer that meets the required ephemeris uncertainties for the Primary FOV. The LEO program track EIRP will be transmitted towards a customer that meets the required LEO ephemeris uncertainties for the LEO FOV. Customers may experience better performance through the KaSA program track and LEO program track services than listed in this document. Performance improvements particular to each customer should be discussed with GSFC Code 450.
5. GRGT SGLT 6 is not currently planned to support a TDRS F8-F10 and K, L, M spacecraft. Therefore, KaSA services are not available through GRGT.
6. TDRS SA antenna pointing beyond ±13.5°E-W and ±13.5°N-S must be coordinated with GSFC Code 450 due to the potential to significantly impact TDRSS efficiency.
7. User ephemeris uncertainty allowance is based upon the assumption of a low eccentricity LEO user orbit. User orbits with high eccentricity and large variations in velocity may need to comply with a more stringent user ephemeris uncertainty.

Table 8-3. Salient Characteristics for TDRSS KaSA Forward Services

Parameter (Note 1)	**Value** (Note 1)	
Command channel radiated power Range channel radiated power	QPSK +10 ±0.5 dB	BPSK NA
Modulator phase imbalance (peak) Modulator gain imbalance (peak)	±3 degrees (for each BPSK channel) ±0.25 dB	
Relative phase between command and range channels	QPSK 90 ±3 degrees	BPSK NA
Data asymmetry (peak) (Note 2) Phase nonlinearity (peak) (Note 3) Gain flatness (peak) (Note 3) Gain slope (peak) (Note 3) AM/PM	±3 percent ±0.15 radian over ±17.5 MHz ±0.8 dB over ±17.5 MHz ±0.1 dB/MHz ≤7 degrees/dB	
PN chip jitter (rms) (including effects of Doppler compensation)	QPSK/SS-BPSK ≤1 degree	BPSK NA
Data clock phase jitter (peak) (Note 2) Spurious PM (rms) In-band spurious outputs Incidental AM (peak) Phase noise (rms) 1 Hz - 10 Hz 10 Hz - 32 Hz 32 Hz - 1 kHz 1 kHz - 25 MHz	≤1 percent ≤1 degree ≥27 dBc ≤2 percent ≤2.4 degrees ≤2.5 degrees ≤5.3 degrees ≤2.0 degrees	
	QPSK/SS-BPSK	BPSK
Command/range channel PN chip skew (peak)	≤0.01 chip / NA	NA
PN chip asymmetry (peak)	≤0.01 chip	NA
PN chip rate (peak) (relative to absolute coherence with carrier rate)	≤0.01 chips/sec at PN code chip rate	NA

Notes:

1. The definitions and descriptions of the salient characteristics are provided in Appendix E.
2. These values are the TDRSS contributions for data asymmetry and data clock phase jitter assuming perfect forward service data is provided to the SN ground terminal. The actual contributions by the NISN data transport system are negligible compared to those contributed by the TDRSS, since the SN ground terminal reclocks the data before it is processed by the SN ground terminal into the forward service signal.
3. Bandwidth limitation for gain flatness, phase nonlinearity and gain slope while maintaining consistency with NTIA spectral emission mask (Appendix D):70% of the signal main lobe width or 70 % of the necessary bandwidth whichever is smaller.

8.2.4 Real-Time Configuration Changes

Changes to the operating conditions or configuration of a TDRSS KaSA forward service during a scheduled service support period are usually initiated by a GCMR from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the GCMR at the SN ground terminal. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning SN ground terminal response times for the GCMRs is provided in Section 10. Table 8-4 lists the KaSA forward service real-time configuration changes and their effects on the forward service signal.

Table 8-4. KaSA Forward Service Real-Time Configuration Changes

Real-Time Configuration Changes	GCMR	OPM	Forward Service Signal Interruption
Customer Receiver Center Frequency	98/04	OPM 03	Yes
Doppler Compensation Inhibit	98/08	OPM 11	No
Doppler Compensation Reinitiation	98/04	OPM 03	No
Forward Service Reacquisition (note 1)	98/03	OPM 02	Yes
Forward Service Sweep Request (refer to Table 8-1)	98/05	OPM 04	Yes
Data Rate	98/04	OPM 03	No
Polarization	98/04	OPM 03	Yes
Initiation or termination of the command channel PN code (note 2)	98/04	OPM 03	No

Notes:

1. Forward service reacquisition is a TDRSS reinitiation of forward link service by applying a 1 MHz frequency offset for 3 seconds to the predicted customer receive frequency specified in the customer's service specification code (refer to Section 10, paragraph 10.2.2).
2. Initiation or termination of the command channel PN code enables or disables all forward link PN modulation (including the command and range channel, if applicable), respectively.

8.2.5 Acquisition Scenarios

The following acquisition scenarios identify only the technical aspects of TDRSS KaSA forward service signal acquisition by the customer platform and do not include operational procedures related to acquisition:

a. KaSAF Program Track and LEO Program Track Scenarios:

   1. The TDRSS KaSA forward service signal does not depend on a customer platform return service.
   2. Prior to the start of the TDRSS KaSA forward service, the TDRSS KaSA antenna will be open-loop pointed in the direction of the customer platform.
   3. At the start of the TDRSS KaSA forward service as defined by the SHO, the TDRS will radiate, in the direction of the customer platform, a signal compatible with the TDRSS KaSA forward service signal parameters listed

in Table 8-1. The EIRP directed towards the customer platform is dependent upon the customer providing an ephemeris uncertainty within the values defined in Table 8-2

4. The customer platform receiving system will search for and acquire the command channel PN code (if applicable) and carrier. Normally, a customer MOC will not be transmitting forward service data to the NISNdata transport system until the forward service signal has been acquired by the customer platform and the acquisition verified by the customer MOC from customer platform return service telemetry. Some customer platforms may require that there be no data transitions during the signal acquisition process, while others may merely result in longer acquisition times.
5. For QPSK modulation, the customer platform receiving system will search for and acquire the range channel PN code upon acquisition of the command channel PN code and carrier.
6. Upon completion of forward link acquisition and subsequent customer platform transition to signal tracking, the customer platform transmitting system must remain in a noncoherent mode as coherent operation is not supported through KaSA service.
7. The SN ground terminal will continue Doppler compensation of the TDRSS KaSA forward service signal unless requested by the customer MOC to inhibit the Doppler compensation.
8. T_{acq} in the customer platform receiver is a function of the customer platform receiver design and signal-to-noise density ratio.
9. Appendix A provides example link calculations for the TDRSS KaSA forward service.

b. KaSAF Acquisition Scenario with Return Autotrack Services:

1. Prior to return autotrack acquisition, the TDRSS forward service EIRP will be the program or LEO program track values, whichever is applicable based upon customer characteristics (see paragraph 8.2.5.a for a description of the program and LEO program track acquisition scenarios). The EIRP directed towards the customer platform prior to return autotrack acquisition is dependent upon the customer providing an ephemeris uncertainty within the values defined in Table 8-2. The TDRS KaSA autotrack signal EIRP listed in Table 8-2 will be provided after return service autotrack acquisition is achieved.

8.3 KaSA Return Services

8.3.1 General

The RF signals provided by the customer platform to the TDRS and the characteristics of data provided at the SN ground terminal interface are defined in paragraphs 8.3.2 through 8.3.6. This discussion assumes that an appropriate return service has been

scheduled and a data signal is present at the TDRS interface. The KaSA return service supports data services through the 225 MHz channel and automated IF services through both the 225 MHz and 650 MHz channels.

8.3.2 Signal Parameters

The TDRSS 225 MHz KaSA return service signal parameters are listed in Table 8-5. Refer to paragraph 8.3.6 for 225 MHz and 650 MHz KaSA return IF service signal parameter characteristics and recommendations. The KaSA return supports only noncoherent, non-spread (DG2) service. Within DG2, there are several types of modulation and a description of these general characteristics is provided in paragraph 8.3.2.1. A description of the features inherent in the DG2 noncoherent services is discussed in paragraph 8.3.2.2.

8.3.2.1 General Modulation and Noncoherent Description

a. SQPSK Modulation. SQPSK modulation staggers one channel with respect to the other to prevent synchronous transitions. For signal configurations with identical I and Q symbol rates that are NRZ symbol formatted, SQPSK modulation must be used. The symbols of the Q channel are delayed 1/2 symbol relative to the I channel.

b. QPSK Modulation. QPSK modulation is available when there is no relation between the I and Q channel transitions. For dual data source configurations, in which SQPSK is not required, QPSK modulation is used.

c. BPSK Modulation. BPSK modulation is available for single data source configurations that use only one channel of the link.

NOTE:

For SQPSK modulation, the spectral characteristics of a customer platform saturated power amplifier will, to a great degree, retain the spectral characteristics of the band-limited input signal to that amplifier. This should result in better control of out-of-band emissions, which, in turn, provides more efficient communications and less interference to customer platform using adjacent frequency channels on the TDRS links.

Table 8-5. TDRSS KaSA Return 225 MHz Service Signal Parameters

Parameter (Note 2)	**Description** (Note 2)
DG2 (notes 1, 3)	
Transmit carrier frequency (Hz) (note 4)	F_2
Carrier (F_2) reference (Hz)	
DG2 Noncoherent	Customer platform oscillator
Data modulation (notes 1, 3)	BPSK, SQPSK, or QPSK (refer to Appendix B and Table 8-6)
Data format	NRZ-L, NRZ-M, NRZ-S
Data rate restrictions	
Total (notes 1, 2)	1 kbps - 300 Mbps
I channel	1 kbps - 150 Mbps
Q channel	1 kbps - 150 Mbps
DG2 $\frac{\text{I channel power}}{\text{Q channel power}}$ restrictions	
Single data source-alternate I/Q bits	1:1
Single data source-alternate I/Q encoded symbols	1:1
Single data source-single data channel	NA
Dual data sources	1:1

Notes:

1. Customer platform data configurations, including specific data rate restrictions for coding and formatting, are defined in Table 8-6 for TDRSS KaSA return service (refer also to Appendix B). Unless otherwise stated, the data rate restrictions given in this table assume uncoded and NRZ formatted signals.
2. Unless otherwise noted, all data rate values are to be interpreted as data bit rates, and not as data symbol rates.
3. Data rates and modulation schemes are based upon support through the KaSAR 225 MHz SN ground terminal receivers. Other data rates and modulation schemes are possible through the Ka-band 225 MHz and 650 MHz bandwidth IF services. Please refer to paragraph 8.3.6 and contact GSFC Code 450 for further information.
4. The center frequency, f_O, of the customer platform transmitter must be defined by the customer MOC in its service specification code to an integral multiple of 10 Hz.

d. Noncoherent Mode. For noncoherent modes, the customer platform transmitted return link carrier frequency is derived from an on-board local oscillator. The customer platform transmit frequency for noncoherent service must be defined by the customer MOC to an accuracy of ±6 kHz in its service specification code when requesting TDRSS KaSA return service. For customers whose frequency uncertainty is greater than ±6 kHz, an expanded frequency search capability is available.

e. Asynchronous Data Modulation. The data modulation is asynchronous to the carrier.

8.3.2.2 DG2 Signal Parameters

KaSA DG2 signal parameters are discussed for noncoherent operation only. Tracking services are not provided via KaSA operations.

a. DG2 Noncoherent. The DG2 carrier is independent of the TDRSS KaSA forward service carrier frequency. The customer platform transmit frequency for DG2 noncoherent service must be defined by the customer MOC to an accuracy of ±6 kHz in its service specification code when requesting TDRSS KaSA return service. For customers whose frequency uncertainty is greater than ±6 kHz, an expanded frequency search capability of ±21 kHz is available after start of the return service.

b. Functional Configurations. Table 8-6 lists the DG2 KaSA return service functional configurations for 225 MHz return service through the SN ground terminal receiver and a further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in Appendix B, paragraph B.3.3. Refer to paragraph 8.3.6 for the 225 MHz and 650 MHz IF service functional configurations.

8.3.3 Communications Services

To obtain TDRSS KaSA return service performance defined in this paragraph, the customer platform transmit signal must meet the requirements found in Table 8-7 and signal characteristics specified in Table 8-9. The TDRSS KaSA return service performance defined in this paragraph also assumes return service operation in an AWGN environment. Appendix G discusses performance degradations to the TDRSS KaSA return service due to RFI. Example link calculations are provided in Appendix A. TDRSS KaSAR supports only non-powered flight customer dynamics ($\dot{R} \leq 7.9$ km/sec, $\ddot{R} \leq 11.4$ m/sec^2, and $\dddot{R} \leq 0.013$ m/sec^3).

8.3.3.1 Acquisition

The KaSAR service supports acquisition for customer platforms operating under non-powered flight dynamics as defined in Table 8-7. The KaSAR service total channel T_{acq} will be less than or equal to the sum of the following, which are given in Table 8-7:

a. Autotrack acquisition time (when the TDRSS KaSA return service autotrack mode is enabled)

Table 8-6. KaSA Return 225 MHz Service Configurations

Return Service Configuration[5]				Source Data Rate Restrictions and Availability[3,4]			
				DG1 Mode 1, 2, 3 and DG2 Coherent		DG2 Noncoherent[1,2]	
				Data format	Data rate	Data format	Data rate
Single Data Source	BPSK	Rate 1/2 coded		-	-	NRZ	1 kbps – 75 Mbps
		Rate 1/3 coded		-	-	-	-
		Uncoded		-	-	NRZ	1 kbps – 150 Mbps
	SQPN	Identical I & Q channel data	Rate 1/2 coded	-	-	-	-
			Uncoded	-	-	-	-
	SQPSK	Rate 1/2 coded alternate I/Q encoded symbols		-	-	NRZ	1 kbps – 10 Mbps
	SQPSK[3]	Alternating I/Q data	Individually rate 1/2 coded	-	-	NRZ	>10 – 150 Mbps
			Individually rate 1/3 coded	-	-	-	-
			Uncoded	-	-	NRZ	1 kbps – 300 Mbps
Dual Data Sources (data rates are for each source separately)	QPSK[1] or SQPSK[1]	Rate 1/2 coded		-	-	NRZ	1 kbps – 75 Mbps
		Rate 1/3 coded		-	-	-	-
		Uncoded		-	-	NRZ	1 kbps – 150 Mbps

✓ Configuration supported
- Configuration not supported

Notes:

1. For DG2 configurations:
   a. Single data source configurations with data on one channel: BPSK modulation is used.
   b. Single data source configurations with data on both channels: SQPSK modulation and an I:Q power ratio of 1:1 is used. For the alternate I/Q bit configuration, the SN requires the I and Q channels be independently and differentially formatted (-M,-S).
   c. Dual data source configurations: SQPSK must be used when there are identical baud rates on the I and Q channels (see paragraph 8.3.2.1.a); QPSK is used for all other configurations; for both SQPSK and QPSK, an I:Q power ratio of 1:1 is supported.
2. Noncoherent configurations require a customer transmit frequency uncertainty of ± 6 kHz. If a customer cannot accurately define their transmit frequency to within ± 6 kHz, a customer can request a reconfiguration which would expand the oscillator frequency search to ± 21 kHz after the start of service.
3. Data rates and modulation schemes are based upon support through the KaSAR 225 MHz SN ground terminal receivers. Other data rates and modulation schemes are possible through the Ka-band 225 MHz and 650 MHz bandwidth IF services. Please refer to paragraph 8.3.6 and contact GSFC code 450 for further information.
4. Unless otherwise noted, all data rates are to be interpreted as data bit rates, and not as data symbol rates. Refer to Section 3, paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities.
5. Appendix B describes the functional configurations and associated I-Q channel and data polarity ambiguities. Additionally, Figure B-10 depicts the SN supported convolutional coding schemes. For a channel with rate 1/2 coding and data rates greater than 10 Mbps, the customer transmitter must be configured to use an N-parallel encoder, where N is the number of branch rate 1/2 encoders for the channel. N = channel data rate in bps/$1x10^7$, where N is rounded to the next higher integer if N is not an integer.

Table 8-7. TDRSS KaSA Return Service

Parameter (Note 4)	**Description** (Note 4)		
Field of view (FOV) (each TDRS) (note 14)	PFOV ± 22 degrees east-west ± 28 degrees north-south	LEOFOV ±10.5 degree conical	Extended Elliptical (EEFOV) (F8-F10 and K, L, M) (note 12) 24.0 degrees inboard east-west 76.8 degrees outboard east-west ±30.5 degrees north-south
Customer Ephemeris Uncertainty (along the customer orbital track) (note 15)	≤ ± 2.0 sec	≤ ± 1.5 sec	≤ ± 2.0 sec
TDRS antenna polarization (note 1)	RHC or LHC selectable		
TDRS antenna axial ratio (maximum)	After Autotrack Acquisition (PFOV, and EEFOV) (notes 12, 13) 1.8 dB over 3 dB beamwidth	LEO Program Track (LEOFOV) 2.4 dB (225 MHz service) 1.0 dB (650 MHz IF service)	Program Track (PFOV) 2.7 dB (225 MHz service) 1.0 dB (650 MHz IF service)
Receive frequency (nominal)	25.25 to 27.50 GHz (note 9)		
225 MHz Bandwidth Service	25.2534 to 27.4784 GHz ± 1.28 MHz in 25 MHz steps SNIP/SFCG Recommended Center Frequencies: 25.60 GHz, 25.85 GHz, 26.10 GHz, 26.35 GHz, 26.60 GHz, 26.85 GHz, 27.10 GHz, 27.35 GHz ± 1.28 MHz		
650 MHz Bandwidth Service	25.545 to 27.195 GHz ± 1.28 MHz in 25 MHz steps		
RF channel bandwidth (3 dB, minimum)	225 MHz or 650 MHz (note 10)		
10^{-5} Bit Error Rate (notes 2, 3, 4)	All P_{rec} values are in dBW; dr=data rate in bps		
Orbital Dynamics (free flight)	$\dot{R} \leq 7.9$ km/sec, $\ddot{R} \leq 11.4$ m/sec^2, jerk $\leq .013$ m/sec^3		

Table 8-7. TDRSS KaSA Return Service (cont'd)

Parameter (Note 4)	**Description** (Note 4)		
10^{-5} Bit Error Rate (notes 2, 3, 4) (cont'd)	All P_{rec} values are in dBW; dr=data rate in bps		
Minimum Required P_{rec} (dBW) for 225 MHz service uncoded channels (note 11):	Autotrack (PFOV, and EEFOV) (note 12)	LEO Program Track (LEOFOV)	Program Track (PFOV)
DG2			
Data rate ≤ 25 Mbps	$-242.6 + 10\log_{10}(dr)$	$-239.1 + 10\log_{10}(dr)$	$-235.2 + 10\log_{10}(dr)$
Data rate > 25 Mbps	$-241.1 + 10\log_{10}(dr)$	$-237.6 + 10\log_{10}(dr)$	$-233.7 + 10\log_{10}(dr)$
Minimum Required P_{rec} (dBW) for 225 MHz service Rate 1/2 convolutional encoded channels (note 11):			
DG2			
Data rate ≤ 10 Mbps	$-248.5 + 10\log_{10}(dr)$	$-245.0 + 10\log_{10}(dr)$	$-241.1 + 10\log_{10}(dr)$
Data rate > 10 Mbps	$-247.6 + 10\log_{10}(dr)$	$-244.1 + 10\log_{10}(dr)$	$-240.2 + 10\log_{10}(dr)$
Acquisition (notes 5, 8):			
Orbital dynamics (free flight)	$\dot{R} \leq 7.9$ km/sec, $\ddot{R} \leq 11.4$ m/sec^2, jerk $\leq .013$ m/sec^3		
Total Channel Acquisition Time (assumes the customer return service signal is present at the SN ground terminal at the start time of the return service support period) (225 MHz service)	Sum of the following: 1. Autotrack acquisition time (when the TDRSS KaSA return service autotrack mode is enabled) 2. Carrier acquisition time 3. Symbol/Decoder synchronization time (coded channel) or Symbol synchronization time (uncoded channel)		

Table 8-7. TDRSS KaSA Return Service (cont'd)

Parameter (Note 4)	**Description** (Note 4)		
Acquisition (notes 5, 8):			
Autotrack Acquisition (if applicable) for 225 MHz service:			
Minimum Required P_{rec} with probability > 99% (note 11)	PFOV ≥-184.1 dBW or consistent with the P_{rec} for BER, whichever is greater	LEOFOV ≥-188.0 dBW or consistent with the P_{rec} for BER, whichever is greater	EEFOV (note 12) ≥-184.1 dBW or consistent with the P_{rec} for BER, whichever is greater
Acquisition Time :	≤ 10 seconds		
Carrier Acquisition for 225 MHz service:			
Minimum Required P_{rec} (note 11)	Autotrack (PFOV, and EEFOV) (note 12) ≥ -185.5 dBW or consistent with the P_{rec} for BER, whichever is greater	LEO Program Track (LEOFOV) ≥ -182.0 dBW or consistent with the P_{rec} for BER, whichever is greater	Program Track (PFOV) ≥ -178.1 dBW or consistent with the P_{rec} for BER, whichever is greater
Acquisition Time (P_{acq} ≥ 90%)			
Noncoherent operations with frequency uncertainty (note 6):			
≤ ± 6 kHz	≤ 1 sec		
≤ ± 21 kHz	≤ 3 sec		

Table 8-7. TDRSS KaSA Return Service (cont'd)

Parameter (Note 4)	**Description** (Note 4)
Acquisition (notes 5, 8):	
Channel Decoder/Symbol Synchronization Acquisition for 225 MHz service (coded data) (note 7):	
Minimum data bit transition density	$\geq$ 64 randomly distributed data bit transitions within any sequence of 512 data bits
Number of consecutive data bits without a transition	$\leq$ 64
P_{rec} (dBW)	consistent with the P_{rec} for BER
Acquisition time (in seconds) with >99% probability:	
NRZ	< 6500/(Channel Data Rate in bps)
Channel Symbol Synchronization Acquisition for 225 MHz service (uncoded data) (note 7):	
P_{rec} (dBW)	consistent with the P_{rec} for BER
Synchronization	Achieved when error rate for next 1000 bits is $\leq 10^{-5}$
Channel Symbol Synchronization Acquisition for 225 MHz service (uncoded data) (note 7) (cont'd):	
Acquisition time (in seconds) with >99% probability:	
NRZ	< 3000/(Channel Data Rate in bps)
Signal Tracking	refer to paragraph 8.3.3.3
Orbital dynamics (free flight)	$\dot{R} \leq 7.9\,\text{km/sec}, \ddot{R} \leq 11.4\,\text{m/sec}^2$, jerk $\leq .013\,\text{m/sec}^3$

Table 8-7. TDRSS KaSA Return Service (cont'd)

Parameter (Note 4)	**Description** (Note 4)
Reacquisition	refer to paragraph 8.3.3.4
Orbital dynamics (free flight)	$\dot{R} \leq 7.9\,\text{km/sec}, \ddot{R} \leq 11.4\,\text{m/sec}^2$, jerk $\leq .013\,\text{m/sec}^3$
Duty Factor	100 percent

Notes:

1. Operational considerations may limit choice of TDRS antenna polarization. The KaSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.
2. The BER is for a customer platform transmitting a signal on an AWGN channel which complies with the constraints defined in Table 8-9. Refer to Appendix G for a discussion of the additional degradation applicable to the TDRSS KaSA return service performance due to Ka-band RFI.
3. The required customer P_{rec} must meet the P_{rec} for BER, autotrack acquisition, or signal acquisition, whichever is greatest. Paragraph 8.3.3.2.b provides the required P_{rec} description for each possible KaSAR data configuration. Refer to Appendix A, paragraph A.4, for a definition of P_{rec}. The minimum required P_{rec} equations for BER produce the minimum P_{rec} for a given data rate for all possible signal characteristics. CLASS analysis will produce a more accurate performance projection based upon desired customer signal characteristics, such as data rate, data type, and jitter values. SN support may be possible for customers whose P_{rec} is less than the required P_{rec} for 10^{-5} BER performance; however, such support shall be coordinated through GSFC Code 450.
4. All data rate values (and notes which modify these values, based upon specific signal format and encoding restrictions) are to be interpreted as data bit rates, and not as data symbol rates.
5. For acquisition, the minimum P_{rec} value listed applies to the total $(I+Q)P_{rec}$. Acquisition requires the P_{rec} to also be consistent with the P_{rec} required for BER, whichever is greater. Failure to provide the minimum P_{rec} for autotrack acquisition at the start of service may preclude successful TDRSS autotrack pull-in.

Table 8-7. TDRSS KaSA Return Service (cont'd)

Notes (cont'd):

6. DG2 noncoherent configurations require a customer transmit frequency uncertainty of ± 6 kHz. If a customer cannot accurately define their transmit frequency to within ± 6 kHz, a customer can request a reconfiguration which would expand the oscillator frequency search to ± 21 kHz after the start of service.
7. For symbol synchronization and symbol/decoder synchronization, the minimum symbol transition density and consecutive symbols without a transition must meet the specifications defined in Table 8-9. For encoded channels, it is recommended that customers use G_2 inversion to increase symbol transition density.
8. All minimum P_{rec} values include atmospheric and rain attenuation on the link from TDRS to the SN ground terminal; however, service outages may be experienced during periods of heavy rain.
9. The data rate and carrier frequency will be constrained such that the first null of the spectrum falls between 25.25 and 27.50 GHz.
10. The SN ground terminal receivers support KaSAR service for the 225 MHz. The KaSA return 225 IF service and KaSA return 650 MHz bandwidth IF service are automated. The KaSAR 225 MHz bandwidth IF service operates at a center frequency of 370 MHz and 650 MHz bandwidth IF service operates at a center frequency of 1.2 GHz. Please refer to paragraph 8.3.6 and contact GSFC Code 450 for further information.
11. The required P_{rec} for autotrack performance is based upon a customer that meets the required ephemeris uncertainties for the Primary FOV, or the EEFOV. The required P_{rec} for program track performance is based upon a customer that meets the required ephemeris uncertainties for the Primary FOV. The required P_{rec} for LEO program track performance is based upon a customer that meets the required LEO ephemeris uncertainties for the LEOFOV. Customers may experience better performance through the KaSA program track and LEO program track services than listed in this document. Performance improvements particular to each customer should be discussed with GSFC Code 450.
    a. KaSAR EEFOV autotrack support shall be coordinated through GSFC Code 450.
12. Autotrack service is not available through the Ka-band 225 MHz and 650 MHz bandwidth IF services.
13. TDRS SA antenna pointing beyond ±13.5°E-W and ±13.5°N-S must be coordinated with GSFC Code 450 due to the potential to significantly impact TDRSS efficiency.
14. User ephemeris uncertainty allowance is based upon the assumption of a low eccentricity LEO user orbit. User orbits with high eccentricity and large variations in velocity may need to comply with a more stringent user ephemeris uncertainty.

b. Carrier acquisition time

c. Symbol/Decoder synchronization time (for coded data) or Symbol synchronization time (for uncoded data).

T_{acq} assumes that the customer platform return service signal is present at the SN ground terminal at the start time of the scheduled return service support period. The total acquisition process consists of the following acquisition sub-processes:

a. If autotrack is enabled, autotrack acquisition will commence upon the start of the scheduled return service support period or at the instant at which user signal energy is present at the KaSAR autotrack signal processing input, whichever occurs last, and will occur within the time given in Table 8-7 for P_{rec} greater than or equal to the values in Table 8-7.

b. Carrier acquisition will occur within the time given in Table 8-7. Carrier acquisition may not commence until the P_{rec} is greater than or equal to the value commensurate with the applicable minimum Program Track P_{rec} under the applicable Program Track scenario. If autotrack is disabled, the time allowed for PN code and carrier acquisition will commence at the start of scheduled return service support period or when the minimum P_{rec} is achieved, whichever occurs last. If autotrack is enabled, carrier acquisition may commence at any time after the start of scheduled return service support period, but the time allowed will not commence until the minimum P_{rec} is achieved. If autotrack is enabled and required to achieve this minimum P_{rec}, the total time allowed to achieve PN code and carrier acquisition will be the sum of the time allowed for autotrack acquisition and PN code and carrier acquisition.

c. Symbol/Decoder and Symbol synchronization times will be measured from the time carrier acquisition is achieved to the time either symbol synchronization is achieved for uncoded channels or decoder synchronization is achieved for rate 1/2 coded channels. Decoder synchronization is achieved when the Viterbi decoder has selected and implemented the correct blocking of the input symbols (into groups of (G1, G2) symbol pairs) for rate 1/2 codes.

d. After symbol/decoder and symbol synchronization is achieved, KaSA return service channel data is available at the SN ground terminal interface.

e. To minimize return data loss, it is recommended that the customer platform transmit an idle pattern on its data channels until after it has observed (via the UPD data) that the SN ground terminal has completed all of its data channel signal acquisition processes.

f. Requirements for bit error probability and symbol slipping take effect at the time decoder synchronization is achieved for convolutional encoded data and at the time symbol synchronization is achieved for uncoded data.

NOTE:

Data and symbol transition density values higher than the minimums required will reduce these acquisition times.

8.3.3.2 Bit Error Rate (BER)

Table 8-7 provides P_{rec} equations that will result in a customer achieving a BER of 10^{-5} for TDRSS compatible signals. The 225 MHz and 650 MHz IF service BER depends on the customer receiver characteristics. Refer to paragraph 8.3.6 for more information on the 225 MHz and 650 MHz IF services. The BER P_{rec} equations are applicable for non-powered flight dynamics and the following conditions:

a. Data encoding. Customer platform transmission of Rate 1/2 convolutional encoded or uncoded signals are supported for KaSA return services. Detailed rate 1/2 coding design is described in Appendix B. Reed-Solomon decoding is available to WDISC customers; typical performance is given in Appendix K.

b. Received Power. P_{rec} is in units of dBW. The customer project, in determining its design requirements for minimum customer platform EIRP, must take into account customer platform transmit antenna pointing losses, the space loss between the customer platform and the TDRS, and the polarization loss incurred between the customer platform transmit antenna and the TDRS receive antenna. The maximum TDRS receive antenna axial ratio is given in Table 8-7 (also refer to Appendix A). For DG2 services, the following conditions apply:

   1. Balanced Power Single Data Source-Alternate I/Q Bits. For a customer platform transmitting alternate I and Q data bits from a data source (single data source-alternate I/Q bits), the total (I+Q) P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 8-7, where dr is the single data source data rate prior to separation into the I and Q channels. The Q/I (power) must be equal to 1:1. Refer to Appendix B for further information on this data configuration.

   2. Balanced Power Single Data Source-Alternate I/Q Encoded Symbols. For a customer platform transmitting alternate I and Q encoded symbols from a data source (single data source-alternate I/Q encoded symbols), the total (I+Q) P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 8-7, where dr is the single data source data rate prior to the rate 1/2 encoder. The Q/I (power) must be equal to 1:1. Refer to Appendix B for further information on this data configuration.

   3. Dual Data Sources. For a customer platform transmitting independent data on the I and Q channels (dual data sources), each channel's P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 8-7, where dr is that channel's data rate. Refer to Appendix B for further information on this data configuration.

   4. Single Data Source with Single Data Channel. For a customer platform transmitting one channel, the channel's P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 8-7, where dr is the channel data rate. Refer to Appendix B for further information on this data configuration.

c. Customer Degradations. Further reductions in the TDRSS KaSA return service performance identified in Table 8-7 can occur. The TDRSS KaSA return services and tracking services will be provided without degradation for user

customer platform transmitted signal characteristics within the constraints specified in Table 8-9. Customer platform parameters exceeding these constraints can also degrade TDRSS KaSA return service performance. Refer to Section 3, paragraph 3.5 for guidelines if the constraints in this paragraph cannot be met. Definitions of user customer platform constraints are given in Appendix E.

d. Multipath. The SN ground terminal will provide lockup and interference protection from multipath signals reflected from the Earth.

8.3.3.3 Signal Tracking

TDRSS provides KaSA 225 MHz return signal tracking (carrier, symbol synchronization, Viterbi decoder synchronization) for non-powered flight dynamics. During a customer KaSA return service support period, loss-of-lock (carrier, symbol synchronization, and Viterbi decoder) indications appear in the periodically updated UPD (every 5 seconds). The KaSA return service shall maintain signal tracking for the following conditions:

a. Cycle Slips. The mean time-between-cycle slip in the SN ground terminal carrier tracking loop for each TDRSS KaSA return service will be 90 minutes minimum. This value applies at carrier tracking threshold, which is 3 dB less than the minimum P_{rec} for BER listed in Table 8-7, and increases exponentially as a function of linear dB increases in P_{rec}. Cycle slips may result in channel and/or data polarity reversal. The SN ground terminal can correct for these reversals under the same conditions as the SN ground terminal can resolve channel and/or data polarity ambiguity as discussed in Appendix B. The time for the SN ground terminal to recover from a cycle slip will be consistent with the time required for the SN ground terminal receiver to detect and automatically reacquire the signal.

b. Bit Slippage. For each TDRSS KaSA return service operating with a minimum P_{rec} required consistent with the P_{rec} for BER of Table 8-7 and data transition densities greater than 40% for NRZ symbols, the minimum mean time between slips caused by a cycle slip in the SN ground terminal symbol clock recovery loop is either 90 minutes or 10^{10} symbol periods, whichever is greater. For a KaSA return service operating with 1 dB more than the minimum P_{rec} required for the BER, and NRZ symbol transition densities between 25% and 40%, the minimum mean time between slips is either 90 minutes or 10^{10} symbol periods, whichever is greater.

c. Loss of Symbol Synchronization. For each TDRSS KaSA return service with data transition densities greater than 40% for NRZ symbols, the SN ground terminal symbol synchronization loop will not unlock for a P_{rec} that is 3 dB less than the minimum P_{rec} required for BER in Table 8-7 (refer also to note 3 of Table 8-7). For NRZ symbol transition densities between 25% and 40%, the SN ground terminal symbol synchronizer loop will not unlock for a P_{rec} that is 2 dB less than the minimum P_{rec} required for the BER. In both cases, the BER performance will be degraded when the P_{rec} is less than the minimum required for BER.

d. Loss of Autotrack. Loss of autotrack is detected by the SN ground terminal when either:

1. The autotrack SA antenna azimuth/elevation angles diverge from the program track SA antenna azimuth/elevation angles. The check on angle divergence protects the autotrack system from false tracking an interfering signal. When loss of autotrack is detected due to angle divergence, the SN ground terminal will automatically begin the autotrack reacquisition process.

2. There is a drop in received power that causes the receiver to drop carrier lock. The receiver will maintain carrier lock for a P_{rec} that is 3 dB less than the minimum P_{rec} for BER.

   (a) When loss of autotrack is detected due to signal fades during TDRS F8-F10 and K, L, M KaSAR support, the SN ground terminal will revert to return program track, transmit a forward link signal towards a customer who is using the program track EIRP values listed in Table 8-2 (if forward service is scheduled), and automatically begin the return autotrack reacquisition process.

   (b) For a maximum of 60 seconds after the first loss of autotrack is detected due to signal fades during TDRS F8-F10 and K, L, M KaSAR support, the TDRS SA antenna will continue to move at the calculated customer platform angular rate. If, within that 60 seconds, the KaSA return service P_{rec} has increased back to or above the minimum level required by the TDRSS KaSA return carrier acquisition, the process should transfer almost immediately to its fine-track mode as the TDRS SA antenna boresight should still be pointed fairly close to the actual direction of the customer platform position. However, if after 60 seconds the KaSA return service P_{rec} has not increased back to or above the minimum level required by the TDRSS KaSA return service carrier acquisition, the SN ground terminal reverts to open-loop pointing (program track) the TDRS SA antenna in the calculated direction of the customer platform position. When the SN ground terminal reverts to program track, the TDRSS will transmit a forward link signal towards a customer who is using the program track EIRP values listed in Table 8-2 (if forward service is scheduled). The TDRSS KaSA return service autotrack process will not restart until the KaSA return service P_{rec} has increased back to or above the minimum level required by that process.

8.3.3.4 Reacquisition

For return service autotrack reacquisition process, refer to paragraph 8.3.3.3.d. While in the carrier tracking state, a loss of lock condition induced by a cycle slip will be automatically detected and a reacquisition will be automatically initiated. For a customer platform that continues to transmit the minimum P_{rec} for acquisition and maintains an ephemeris uncertainty as defined in Table 8-7, the normal total channel reacquisition time for non-powered flight dynamics will be less than or equal to that for

the initial total channel acquisition, with a probability of at least 0.99. If lock is not achieved within 10 seconds of loss of lock, an acquisition failure notification message will be sent to the MOC and the SN ground terminal will reinitiate the initial service acquisition process. Upon receipt of the loss-of-lock indications in the UPD, the customer MOC may request a TDRSS KaSA return service reacquisition GCMR (refer to Section 10). It is recommended that the customer MOC delay initiation of the GCMR for at least 35 seconds after initial receipt of the loss-of-lock indications in the UPD.

8.3.3.5 Additional Service Restrictions

a. Sun Interference. The TDRSS KaSA return service performance will not be guaranteed when the center of the sun is within 0.5 degrees of the TDRS KaSA receiving antenna boresight. Additionally, the TDRSS KaSA return service performance will not be guaranteed when the center of the sun is within 1 degree of the boresight of the SN ground terminal receiving antenna supporting the TDRS.

b. Mutual Interference. It is possible for mutual interference to exist between KaSA customer platforms operating with the same polarization and frequency. The SN can provide tools to assist customers in interference prediction and interference mitigation.

8.3.4 Real-Time Configuration Changes

Changes to the operating conditions or configuration of a TDRSS KaSA return service during a scheduled service support period are initiated by a GCMR from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the GCMR at the SN ground terminal. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning SN ground terminal response times for GCMRs is provided in Section 10. Table 8-8 lists the KaSA return service real-time configuration changes and their effects on the return service.

8.3.5 Autotrack/Signal Acquisition Scenarios

The following acquisition scenario identifies only the technical aspects of TDRSS KaSA return service autotrack (if enabled) and signal acquisition by the SN ground terminal and does not include operational procedures related to acquisition. Acquisition is dependent upon the customer providing an ephemeris with a maximum epoch uncertainty as defined in Table 8-7.

Table 8-8. KaSA Return Service Real-Time Configuration Changes

Real-Time Configuration Changes	GCMR	OPM	Return Service Interruption
Return Service Reacquisition	98/03	OPM 03	Yes
Noncoherent Expanded Customer Spacecraft Frequency Uncertainty	98/07	OPM 07	No
Channel Data Rate	98/04	OPM 03	No
Noncoherent Transmit Frequency	98/04	OPM 03	Yes
Redefinition of customer minimum EIRP	98/04	OPM 03	Yes
Redefinition of customer maximum EIRP	98/04	OPM 03	No
Channel Data Format	98/04	OPM 03	No
Channel Data Bit Jitter	98/04	OPM 03	No
Polarization	98/04	OPM 03	No
DG2 Carrier Modulation	98/04	OPM 03	Yes
TDRSS Autotrack Mode	98/04	OPM 03	No
Data Source/Channel Configuration	98/04	OPM 03	Yes
G_2 inversion	98/04	OPM 03	No
Frame Length	98/04	OPM 03	No
Frame Sync Word Length	98/04	OPM 03	No
Frame Sync Word Bit Pattern	98/04	OPM 03	No
Sync Strategy Parameters	98/04	OPM 03	No

Note:
Items that are indicated to cause return service interruption will cause the SN ground terminal receiver to discontinue signal tracking and attempt to reacquire the return service signal after the appropriate reconfiguration. Any other reconfigurations of the SN ground terminal may momentarily affect signal tracking.

a. TDRS SA Antenna Pointing:

1. KaSA Autotrack Description. The TDRSS KaSA return service autotrack process (if enabled) will acquire and track a customer platform KaSA return service signal providing improved pointing of the TDRS SA antenna in the direction of the customer platform. This decreases the required P_{rec} at the input to the TDRS antenna. TDRSS KaSA return autotrack service is independent of whether a TDRS forward service signal is concurrently scheduled.

2. Autotrack Power Requirement. For the TDRSS KaSA return service autotrack process to acquire a customer platform signal, the KaSA return service P_{rec} must be consistent with either the P_{rec} required for autotrack acquisition or the P_{rec} required for BER, whichever is greater (please refer to Table 8-7).

3. Program track Operational Process. The SN ground terminal open-loop points the TDRS SA antenna in the calculated direction of the customer platform. The acquisition process begins with carrier acquisition as described below for coherent or noncoherent operations as applicable.

4. Autotrack Operational Process. The SN ground terminal initially open-loop points the TDRS SA antenna in the calculated direction of the customer platform. If the TDRSS KaSA return service autotrack process is initiated (or reinitiated), the SN ground terminal then processes error signals derived from the received customer platform KaSA return service signal to correct for small error build-ups in moving the TDRS antenna at the calculated angular rate of the customer platform. After the time when the signal is first present at the TDRS with adequate KaSA return service P_{rec} [refer to paragraph 2 above], autotrack acquisition will be achieved within the autotrack acquisition time listed in Table 8-7. The acquisition process continues with carrier acquisition as described below for coherent or noncoherent operations as applicable.

5. TDRS Forward EIRP Level. If the TDRSS KaSA return service autotrack process is enabled, the forward service EIRP will default to program track values listed in Table 8-2 during autotrack acquisition. Following the completion of return autotrack acquisition, the forward EIRP will be consistent with the autotrack values listed in Table 8-2. If the return autotrack service experiences a reacquisition, the forward EIRP values may decrease to the program track values. If the TDRSS KaSA return service autotrack process is inhibited, the forward EIRP will be consistent with the program track values listed in Table 8-2, where either LEO program track or program track values depend upon customer platform orbital characteristics.

b. Noncoherent Signal Acquisition Scenario:

1. This mode of customer platform operation does not require a TDRSS forward service signal to be received by the customer platform. However, the customer platform transmitter must be commanded to turn on when

noncoherent transmissions are desired, either by stored commands, on-board configuration settings, or direct commands from its customer MOC.

2. The customer platform P_{rec} must be compatible with the minimum P_{rec} required for BER and the other TDRSS KaSA return service signal parameters listed in Table 8-5.
3. At the service start time specified by the SHO, the SN ground terminal will begin the search for the customer platform signal based upon predicted Doppler. The SN ground terminal corrects the received customer platform signal for Doppler to allow for SN ground terminal implementation of receivers with narrow acquisition and tracking bandwidths. The Doppler correction used by SN ground terminal is one-way and based on the customer platform transmission frequency stated in the SHO and any subsequent OPMs.
4. The SN ground terminal will begin carrier acquisition when the P_{rec} meets the minimum required value for this acquisition process. Carrier acquisition may occur prior to completion of autotrack acquisition (if enabled). The SN ground terminal will complete acquisition of the customer platform signal (carrier) within the time limits listed in Table 8-7. Return service will be achieved at the SN ground terminal receiver output within the total acquisition time limits listed in Table 8-7, which includes SN ground terminal symbol and Viterbi decoder synchronization.

8.3.6 225 MHz and 650 MHz IF Service

This section specifies characteristics and recommendations for the KaSA 225 MHz and KaSA 650 MHz IF services. SN IF services are available to customers on a case-by-case basis. The IF service is supported through TDRS F8-F10 and K, L, M via the SN ground terminal infrastructure, where the customer provides the receiver equipment and the SN only provides the signal at the IF with the characteristics described in this section. Paragraph 8.3.6.1 describes the aggregate channel characteristics of the TDRS F8-F10 and K, L, M spacecraft and SN ground segment for understanding the IF interface.

NOTE:

Use of KaSAR IF services must be coordinated with GSFC Code 450.

The performance of the customer link greatly depends on the customer signal characteristics and the receiver used. Paragraph 8.3.6.2 describes potential signal characteristics and expected performance through the TDRS F8-F10 and K, L, M spacecraft and SN ground segment. The expected performance is based upon simulation results only and has not been verified by testing. Data rates and coding techniques should be carefully considered and coordinated with Code 450 to achieve desired performance.

NOTE:

Autotracking is not provided for the 225 MHz and 650 MHz IF services.

Table 8-9. TDRSS KaSA Return 225 MHz Service Customer Platform Signal Constraints

Parameter (Notes 1, 2, 3, and 12)	**Description** (Notes 1, 2, 3, and 12)
Minimum channel data bit transition density (required for acquisition only)	≥ 64 randomly distributed data bit transitions within any sequence of 512 data bits
Consecutive channel data bits without a bit transition (required for acquisition only)	≤ 64
Minimum channel symbol (bit) transition density (Note 4)	≥128 randomly distributed symbol (bit) transitions within any sequence of 512 symbols (bits)
Consecutive channel symbols (data bits) without a symbol (data bit) transition (Note 4)	≤64 symbols (data bits)
Data asymmetry (peak) (Note 4)	≤ ± 3 percent
Symbol (data) bit jitter and jitter rate (Note 4)	≤ 0.1 percent (see Appendix E)
Phase imbalance	≤ ± 3 degrees
Gain imbalance	≤ ± 0.25 dB
Phase nonlinearity (applies for all types of phase nonlinearities) (peak) (Note 11)	≤3 degrees over ±80 MHz
Gain flatness (peak) (Note 11)	≤0.3 dB over ±80 MHz
Gain slope (Note 11)	≤0.1 dB/MHz over ±80 MHz
AM/PM	≤12 deg/dB (for the 225 MHz service)
Noncoherent frequency stability (peak) (Notes 5, 6)	
±6 kHz customer oscillator frequency uncertainty	
1-sec observation time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 7.2 \times 10^{-8}$
48-hr observation time	$\leq 2.18 \times 10^{-7}$
±21 kHz customer oscillator frequency uncertainty	
1-sec observation time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 2.54 \times 10^{-7}$
48-hr observation time	$\leq 7.64 \times 10^{-7}$
Incidental AM (peak)	
For open-loop pointing	
At frequencies ≥100 Hz	≤5 percent
For autotrack performance	
At frequencies: 10 Hz-10 kHz	≤3 percent
At frequencies: 10 Hz-2 kHz	≤0.6 percent (Note 7)

Table 8-9. TDRSS KaSA Return 225 MHz Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1, 2, 3, and 12)	**Description** (Notes 1, 2, 3, and 12)
Spurious PM	≤2 degrees
Minimum 3-dB bandwidth prior to power amplifier	≥2 times maximum channel baud rate
Phase noise (rms) (Note 8 and 9)	
DG2 Noncoherent	
Channel baud rate < 108.5 ksps	
1 Hz – 10 Hz	≤4.0° rms
10 Hz – 100 Hz	≤2.5° rms
100 Hz – 1 kHz	≤1.4° rms
1 kHz – 150 MHz	≤1.4° rms
108.5 ksps ≤ Channel baud rate ≤ 6 Msps	
1 Hz – 10 Hz	≤50.0° rms
10 Hz – 100 Hz	≤5.5° rms
100 Hz – 1 kHz	≤2.4° rms
1 kHz – 150 MHz	≤2.4° rms
Channel baud rate > 6 Msps	
1 Hz – 10 Hz	≤50.0° rms
10 Hz – 100 Hz	≤10.0° rms
100 Hz – 1 kHz	≤2.0° rms
1 kHz – 150 MHz	≤2.0° rms
In-band spurious outputs, where in-band is twice the maximum channel baud rate	≥30 dBc
Out-of-band emissions	See Appendix D for allowable limits on out-of-band emissions, including spurs
I/Q data skew (relative to requirements for I/Q data synchronization where appropriate) (peak) (Note 4)	≤3 percent
Axial ratio for autotrack	≤1 dB
Data rate tolerance	≤+0.1 percent
I/Q power ratio tolerance	≤+0.4 dB
Permissible P_{rec} variation (without reconfiguration GCMR from customer MOC) (Note 10)	≤12 dB

Table 8-9. TDRSS KaSA Return 225 MHz Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1, 2, 3, and 12)	**Description** (Notes 1, 2, 3, and 12)
Permissible rate of P_{rec} Variation	$\leq$10 dB/sec
Maximum P_{rec}	-143.0 dBW

Notes:

1. The definitions and descriptions of the customer constraints are provided in Appendix E.
2. When a constraint value is listed for a baud rate range and data is transmitted on both channels, the maximum baud rate of the 2 channels should be used to determine the constraint value applicable.
3. These signal constraints apply to the KaSAR 225 MHz through the SN ground terminal receivers. Refer to paragraph 8.3.6 and contact GSFC Code 450 for signal constraints pertaining to the KaSAR 225 MHz and 650 MHz IF service.
4. When the data is Rate 1/2 convolutionally encoded, these data bit parameters should be interpreted as symbol parameters. For encoded channels, it is recommended that customers use G_2 inversion to increase symbol transition density. CCSDS randomization is recommended to aid in compliance with the data randomness requirements.
5. The frequency stability requirements are valid at any constant temperature ($\pm$0.5° C) in the range expected during the mission. At a minimum, a temperature range of -10° C to +55° C shall be considered.
6. Noncoherent configurations require a customer transmit frequency uncertainty of $\pm$ 6 kHz. If a customer cannot accurately define their transmit frequency to within $\pm$ 6 kHz, a customer can request a reconfiguration which would expand the oscillator frequency search to $\pm$ 21 kHz after the start of service.
7. The TDRSS design implementation may not provide the stated TDRSS KaSA return service autotrack performance when P_{rec} = P_{rec} (minimum) and the Incidental AM (peak), at frequencies $\leq$2 kHz, is close to or at 0.6 percent. For TDRSS KaSA return service autotrack performance, either P_{rec} must be increased above P_{rec} (minimum), or the Incidental AM (peak), at frequencies $\leq$2 kHz, must be more tightly controlled.
8. Derivation of the phase noise requirements involved making assumptions about the distribution of the phase noise power in each frequency region. Since no phase noise PSD will exactly match the phase noise power distribution assumed for this derivation, phase noise PSDs which are close to violating the phase noise limits or phase noise PSDs which do violate the phase noise limits should be evaluated on a case-by-case basis to determine their acceptability.
9. KaSA service does not support Doppler tracking.
10. The minimum SHO EIRP should reflect the minimum P_{rec} expected over the service period, where the P_{rec} can exceed this minimum by no more than 12 dB. An actual customer P_{rec} value that is 12 dB greater than the minimum may cause false PN lock or non-acquisition.
11. Bandwidth limitation for gain flatness, phase nonlinearity and gain slope while maintaining consistency with NTIA spectral emission mask (Appendix D):70% of the signal main lobe width or 70% of the necessary bandwidth whichever is smaller.
12. Customers are recommended to provide to the SN a transmitter EVM measurement for each of their service modes.

Changes to the operating conditions or configuration of a TDRSS KaSA 225 MHz or 650 MHz return IF services during a scheduled service support period are initiated by a GCMR from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the GCMR at the SN ground terminal. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning SN ground terminal response times for GCMRs is provided in Section 10. Table 8-10 lists the KaSA IF return service real-time configuration changes and their effects on the return service.

Table 8-10. KaSA Return IF Service Real-Time Configuration Changes

Real-Time Configuration Changes	GCMR	OPM	Return Service Interruption
Polarization	98/04	OPM 03	Yes
Note: Items that are indicated to cause return service interruption will cause the SN ground terminal receiver to discontinue signal tracking and attempt to reacquire the return service signal after the appropriate reconfiguration. Any other reconfigurations of the SN ground terminal may momentarily affect signal tracking.			

8.3.6.1 Channel Characteristics

As discussed above, this is not an end-to-end service so a set of customer platform signal constraints is not available due to the dependencies on the exact customer signal characteristics as well as receiver capabilities. The 225 MHz and 650 MHz IF services provide a KaSAR signal through the TDRS F8-F10 and K, L, M spacecraft and SN ground segment, including IF output channel characteristics as specified in Table 8-11. This will allow customers to be able to understand the signal distortions that are outside of their control. For additional characteristics applicable to the KaSA 225 MHz and 650 MHz IF service, refer to Table 8-7.

Table 8-11. TDRS KaSAR 225 MHz and 650 MHz IF Service Spacecraft and Ground Segment Channel Characteristics

Parameter	225 MHz Description (expected operational in mid 2008)	650 MHz Description
TDRS Ka-band Receive Center Frequencies (note 1)	25.2534 - 27.4784 GHz in 25 MHz steps SNIP/SFCG Recommended Center Frequencies: 25.60 GHz, 25.85 GHz, 26.10 GHz, 26.35 GHz, 26.60 GHz, 26.85 GHz, 27.10 GHz, 27.35 GHz	25.545 – 27.195 GHz in 25 MHz steps
3-dB RF bandwidth	≥ 240 MHz (note 3)	≥ 650 MHz
Gain Flatness (peak) (note 2)	≤ 0.8 dB over ±80 MHz	≤ 0.8 dB over ±230 MHz
Gain Slope (note 2)	≤ 0.14 dB/MHz over ± 80 MHz	≤ 0.14 dB/MHz over ±230 MHz
Phase nonlinearity (applies for all types of phase nonlinearities) (peak) (note 2)	≤ 16.5° over ± 80 MHz	≤ 16.5° over ±230 MHz
AM/AM (note 2)	> 0.57 dB/dB	> 0.57 dB/dB
AM/PM (note 2)	≤ 7°/dB	≤ 7°/dB (for data rates > 300 Mbps)
Spurious PM (note 2)	≤ 2.24° rms	≤ 2.24° rms
In-band spurious outputs (note 2)		
Total	≥ 27 dBc	≥ 27 dBc
Individual	≥ 40 dBc	≥ 40 dBc
Incidental AM (peak) (note 2)	≤ 1% (within 3-dB RF bandwidth)	≤ 1% (within 3-dB RF bandwidth)
Phase noise (note 2)		
1 Hz to 10 Hz	≤ 4.3° rms	≤ 4.3° rms
10 Hz to 100 Hz	≤ 4.6° rms	≤ 4.6° rms
100 Hz to 1 kHz	≤ 4.6° rms	≤ 3.4° rms
1 kHz to 150 MHz	≤ 2.1 ° rms	NA
1 kHz to 400 MHz	NA	≤ 2.0° rms
Additional TDRS Ground Segment IF Characteristics:		
IF center frequency	370 MHz	1.2 GHz
Output level	-15 dBm ±3 dB	-15 dBm ±3 dB
Output VSWR	≤ 1.3:1 into 50Ω load, ± 80 MHz from center frequency	≤ 1.3:1 into 50Ω load, ±230 MHz from center frequency

Table 8-11. TDRS KaSAR 225 MHz and 650 MHz IF Service Spacecraft and Ground Segment Channel Characteristics (cont'd)

Notes:

1. The customer should schedule the TDRS receive center frequency setting closest to the customer transmit frequency, where the TDRS receive center frequency will be translated to the center of the IF bandwidth. The signal and carrier frequency will be constrained such that the first null of the spectrum falls between 25.25 and 27.50 GHz. The KaSAR only supports non-coherent frequencies. The KaSAR IF service supports only one Ka frequency through one TDRS at a time. These frequencies do not include the effects of frequency uncertainty and Doppler shift. The KaSAR IF service is not required to provide a Doppler-corrected IF output signal. The customer provided receiver needs to handle frequency uncertainty and Doppler.
2. Constraint parameters are contributions from the TDRS F8-F10 and K, L, M spacecraft and the SN ground segment to the IF interface. Not included in these aggregate distortion amounts are TDRS F8-F10 and K, L, M spacecraft gain flatness, linear and parabolic allowances, and phase nonlinearity parabolic and cubic allowances as described in 405-TDRS-RP-SY-001. Customer and receiver signal characteristics need to be considered to determine the end-to-end performance. Please contact GSFC Code 450 for further information.
3. The 3 dB RF bandwidth is larger than the specified 225 MHz bandwidth value specified in Table 8-7. This value has validated through spacecraft and ground terminal measurements, but may not be applicable to future TDRS.

8.3.6.2 Potential Signal Parameters for IF Service

As discussed earlier, this is not an end-to-end service so a set of well-defined customer signal parameters is not available. This section describes potential signal characteristics and expected performance through the TDRS F8-F10 and K, L, M spacecraft and SN ground segment. The KaSA return 225 MHz bandwidth IF service has been automated and operates at 370 MHz. The KaSA return 650 MHz bandwidth IF service has also been automated; however, it operates at 1.2 GHz. SN IF services are available to customers on a case-by-case basis. Customers should contact Code 450 if they are interested in this service to determine expected performance for their specific signal characteristics and receiver. Potential TDRS 225 MHz and 650 MHz KaSA return service signal configurations are provided in Table 8-12.

8.3.6.3 Potential Signal Performance for IF Service

The performance of the IF link is greatly dependent on the customer provided receiver. Typically, the SNUG specifies performance at BER of 10^{-5}; BERs better than 10^{-5} may be possible for the IF service.

NOTE:

The expected performance is based upon simulation results only and has not been verified by testing. Data rates and coding techniques should be carefully considered and coordinated with GSFC Code 450 to achieve desired BER.

Table 8-12. Potential TDRSS KaSA 225 MHz and 650 MHz IF Return Service Configurations (Customer interfaces with the SN at a 370 MHz IF for 225 MHz and 1.2 GHz IF for 650 MHz and Customer provides the Receiver)

Return IF Service Configuration (notes 1, 2, 7)		Potential Maximum Data Rates (225 MHz IF Service)	Potential Maximum Data Rates (650 MHz IF Service) (note 7)
BPSK	Rate 1/2 convolutional coded	See Table 8-6	300 Mbps
	Uncoded	See Table 8-6	400 Mbps
QPSK / SQPSK	Rate 1/2 convolutional coded	See Table 8-6	600 Mbps
	Uncoded	See Table 8-6	800 Mbps
	(128,120)x(128,120) TPC	400 Mbps (note 4)	1.0 Gbps (note 3)
	(8176,7136) LDPCC (note 6)	400 Mbps (note 4)	1.0 Gbps (note 3)
	(2048, 1024) AR4JA LDPCC	200 Mbps	Not Available
8PSK	(128,120)x(128,120) TPC	600 Mbps (note 4)	1.5 Gbps
	(8176,7136) LDPCC(note 6)	600 Mbps (note 4)	1.5 Gbps
	Uncoded	450 Mbps	600 Mbps (note 5)

Notes:

1. All data rates assume NRZ data format.
2. These service configurations and maximum data rates were based upon simulation results only and have not been verified by testing. Other data rates and modulation schemes may be possible. Please contact GSFC Code 450 for further information.
3. For the 650 MHz IF service, data rates up to 1.2 Gbps may be possible for QPSK/SQPSK modulation with either TPC or LDPCC. Please contact GSFC Code 450 for further information. A customer P_{rec} greater than –143.0 dBW shall not be permitted.
4. For the 225 MHz IF service, data rates up to 410 Mbps may be possible for QPSK/SQPSK modulation with either TPC or (8176,7136) LDPCC. For the 225 MHz IF service, data rates up to 625 Mbps may be possible for 8PSK with either TPC or (8176,7136) LDPCC. Please contact GSFC Code 450 for further information.
5. The data rate is limited by SGL downlink strength, not the TDRS channel.
6. The code being supported is the (8160, 7136), the shortened version of the (8176, 7136) code.
7. Use of KaSAR-650 MHz IF service must be coordinated with GSFC Code 450.

All values in this section assume using a receiver with reasonable implementation loss. Table 8-13 provides expected, required Eb/No values for various data rates and modulation schemes for a 10^{-5} BER. Additionally, Table 8-13 also provides the theoretical Eb/No and implementation loss values for those modulation and coding schemes at 10^{-5} BER over a simple AWGN channel. Table 8-13 also provides a potential minimum required P_{rec} (dBW) equation for various data rates, coding and modulation schemes through the IF service assuming these expected, required Eb/No values, which were based upon simulation results and have not been verified by testing.

NOTE:

Autotracking is not provided for the IF service.

Table 8-13. Potential KaSAR IF Service Implementation Loss and LEO Program Track Required P_{rec} Equations for Various Data Rates Using Different Modulation and Coding Techniques

Return IF Service Configuration (notes 4, 9)		Data Rates	Required Eb/No at input to receiver for 10^{-5} BER (notes 1, 4)	Theoretical Required Eb/No (note 1)	Implementation Loss Amounts (notes 1, 4)	Required P_{rec} (K) at TDRS (dBW) for a 10^{-5} BER (LEO Program Track) (note 4)
BPSK (650 MHz IF service; note 5)	Rate 1/2 convolutional coded	300 Mbps	9.0 dB	4.5 dB (note 2)	4.5 dB	-242.9 + 10 log (dr)
	Uncoded	400 Mbps	16.9 dB	9.9 dB (note 2)	7.0 dB	-233.7 + 10 log (dr)
QPSK/ SQPSK (650 MHz IF service)	Rate 1/2 convolutional coded	600 Mbps	9.0 dB	4.5 dB (note 2)	4.5 dB	-242.7 + 10 log (dr)
		≤ 450 Mbps	7.5 dB		3 dB	-244.4+ 10 log (dr)
	Uncoded	800 Mbps	16.9 dB	9.9 dB (note 2)	7.0 dB	-231.5 + 10 log (dr)
		600 Mbps	15.4 dB		5.5 dB	-235.1 + 10 log (dr)
		≤ 450 Mbps	14.0 dB		4.1 dB	-237.3 + 10 log (dr)
	(128,120)x(128,120) TPC (note 3)	1.0 Gbps	7.9 dB	3.9 dB	4.0 dB	-243.8 + 10 log (dr)
		800 Mbps	7.0 dB		3.1 dB	-244.9 + 10 log (dr)
		≤ 600 Mbps	6.4 dB		2.5 dB	-245.5 + 10 log (dr)
	(8176,7136) LDPCC (notes 3, 8)	1.0 Gbps	8.3 dB	4.4 dB	3.9 dB	-243.3 + 10 log (dr)
		800 Mbps	7.4 dB		3.0 dB	-244.4 + 10 log (dr)
		≤ 600 Mbps	6.8 dB		2.4 dB	-245.1 + 10 log (dr)

Table 8-13. Potential KaSAR IF Service Implementation Loss and LEO Program Track Required Prec Equations for Various Data Rates Using Different Modulation and Coding Techniques (cont'd)

Return IF Service Configuration (notes 4, 9)		Data Rates	Required Eb/No at input to receiver for 10^{-5} BER (notes 1, 4)	Theoretical Required Eb/No (note 1)	Implementation Loss Amounts (notes 1, 4)	Required P_{rec} (K) at TDRS (dBW) for a 10^{-5} BER (LEO Program Track) (note 4)
8PSK (650 MHz IF service)	(128,120)x(128,120) TPC	1.5 Gbps	10.8 dB	6.9 dB	3.9 dB	-240.0 + 10 log (dr)
		1.2 Gbps	10.1 dB		3.2 dB	-241.1 + 10 log (dr)
		≤ 1 Gbps	9.4 dB		2.5 dB	-242.1 + 10 log (dr)
	(8176,7136) LDPCC (note 8)	1.5 Gbps	12.0 dB	7.3 dB	4.7 dB	-238.2 + 10 log (dr)
		1.2 Gbps	11.1 dB		3.8 dB	-239.9 + 10 log (dr)
		≤ 1 Gbps	10.0 dB		2.7 dB	-241.4 + 10 log (dr)
	Uncoded (650 MHz IF service)	≤ 600 Mbps	18.0 dB	13.1 dB	4.9 dB	-230.6 + 10 log (dr)
QPSK/ SQPSK	(128,120)x(128,120) TPC (note 6)	400 Mbps	7.9 dB	3.9 dB	4.0 dB	-243.9 + 10 log (dr)
		300 Mbps	6.6 dB		2.7 dB	-245.3 + 10 log (dr)
		≤ 200 Mbps	6.1 dB		2.2 dB	-245.9 + 10 log (dr)
	(8176,7136) LDPCC (notes 6, 8)	400 Mbps	8.4 dB	4.4 dB	4.0 dB	-243.3 + 10 log (dr)
		300 Mbps	7.3 dB		2.9 dB	-244.6 + 10 log (dr)
		≤ 200 Mbps	6.4 dB		2.0 dB	-245.6 + 10 log (dr)
	(2048, 1024) AR4JA LDPCC	200 Mbps	4.0 dB	1.7 dB	2.3 dB	-248.0 + 10 log (dr)
		≤ 150 Mbps	3.6 dB		1.9 dB	-248.4 + 10 log (dr)

Table 8-13. Potential KaSAR IF Service Implementation Loss and LEO Program Track Required Prec Equations for Various Data Rates Using Different Modulation and Coding Techniques (cont'd)

Return IF Service Configuration (notes 4, 9)		Data Rates	Required Eb/No at input to receiver for 10^{-5} BER (notes 1, 4)	Theoretical Required Eb/No (note 1)	Implementation Loss Amounts (notes 1, 4)	Required P_{rec} (K) at TDRS (dBW) for a 10^{-5} BER (LEO Program Track) (note 4)
8PSK	(128,120)x(128,120) TPC (note 6)	600 Mbps	10.5 dB	6.9 dB	3.6 dB	-240.7 + 10 log (dr)
		500 Mbps	9.4 dB		2.5 dB	-242.1 + 10 log (dr)
		≤ 400 Mbps	8.8 dB		1.9 dB	-242.9 + 10 log (dr)
	(8176,7136) LDPCC (notes 6, 8)	600 Mbps	11.5 dB	7.3 dB	4.2 dB	-239.4 + 10 log (dr)
		500 Mbps	10 dB		2.7 dB	-241.4 + 10 log (dr)
		≤ 400 Mbps	9.5 dB		2.2 dB	-242.1 + 10 log (dr)
	Uncoded	≤ 450 Mbps	17.3 dB	13.1 dB	4.2 dB	-230.1 + 10 log (dr)

Notes:

1. Unless otherwise noted, all values are based upon a customer transmitter power amplifier operating point of 1 dB OBO, i.e., AM/PM = 12°/dB and AM/AM = 0.47 dB/dB. Values assume baseband equalization used. Values do not include margin. All values are given for a receiver with reasonable loss. Better performance may be achievable with a better power amplifier and/or filters, etc.
2. Includes effects of NRZ-M or NRZ-S coding.
3. For the 650 MHz IF service, data rates up to 1.2 Gbps may be possible for QPSK/SQPSK modulation with either TPC or (8176,7136) LDPCC. Please contact GSFC Code 450 for further information. A customer P_{rec} greater than –143.0 dBW shall not be permitted.
4. These service configurations and maximum data rates were based upon simulation results only and have not been verified by testing. Other data rates and modulation schemes may be possible. Please contact GSFC Code 450 for further information.
5. For BPSK, QPSK, SQPSK with uncoded or rate ½ convolutional coded through the 225 MHz bandwidth, see Table 8-7 for expected performance.
6. For the 225 MHz IF service, data rates up to 410 Mbps may be possible for QPSK/SQPSK modulation with either TPC or (8176,7136) LDPCC. For the 225 MHz IF service, data rates up to 625 Mbps may be possible for 8PSK with either TPC or (8176,7136) LDPCC. Please contact GSFC Code 450 for further information.
7. For the 650 MHz, the required P_{rec} was determined for support through the KaSAR dedicated downlink to the WSC IF interface point. For the 225 MHz, the required P_{rec} was determined for support through the KaSAR composite downlink to the WSC IF interface point.
8. The code being supported is the (8160, 7136), the shortened version of the (8176, 7136) code.
9. Use of KaSAR-650 MHz IF service must be coordinated with GSFC Code 450.

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Section 9. Tracking and Clock Calibration Services

9.1 General

The SN can provide customer platform tracking and clock calibration services for MA, SSA (including cross-support), and KuSA telecommunications services. The SN does not provide tracking or clock calibration services for KaSA customers or DAS customers.

NOTE:

For tracking services, the related forward and/or return services must be scheduled for the entire duration of the tracking service and must be described in the same SHO. Tracking data is delivered in Tracking Data Messages (TDMs) from the SN ground terminal to the FDF, the format of which is provided in the ICD Between the SN and the FDF, 452-ICD-SN/FDF.

The SN provides measurements that help customers:

- Track their platform (range and Doppler)
- Calibrate their platform's clock (time transfer and return channel time delay)

Each of the measurements is briefly described below:

a. Range – The ground terminal measures range during DG1 mode 1 and 3 operations by counting the time elapsed between the transmission of a PN code epoch on the forward link and the reception of the turned-around PN code epoch on the return link. Only two-way range measurements are provided.

b. Doppler – GT measured Doppler is the frequency difference between the carrier and a reference frequency. One-way forward Doppler is the frequency difference between the fixed frequency forward link carrier as defined in the SHO, where Doppler compensation must be disabled, and a reference frequency on the customer platform. The customer platform is required to perform onboard compensation for Doppler to acquire the signal. For a return link with coherent operations and <u>two-way</u> Doppler measurement required, the reference frequency is the forward link customer platform "receiver frequency" provided to WSC in the SHO; for <u>one-way</u> return Doppler, it is the return link customer platform "transmit frequency" defined in the SHO. The Doppler count at the ground terminal accumulates "non-destructively" – that is, the counter is not reset during the service.

c. Time transfer – Time transfer measurements are used by MOCs to calibrate their platform's clock. These measurements provide the customer MOC the ability to determine the time difference between the on-board platform clock and the UTC. Only two-way time transfer measurements are provided by the

ground terminal, and only with coherent services. The customer platform must also provide a time receipt of the PN epoch onboard.

d. Return channel time delay (RCTD) – RCTD measurements, in conjunction with other data delays, enable the MOCs to calculate the time onboard their platform. RCTD measures the time delay from the ground terminal antenna input to the ground terminal baseband output (at the point of time tagging within the data transport) for each I and Q channel in the return link. Unlike time transfer, RCTD can be measured with either a coherent or noncoherent service.

Table 9-1 describes the tracking services available for each return link data group and mode. Tracking data messages can be provided to the FDF, the customer MOC or both.

NOTE:

Cross-support service consists of either MA forward with SSA return, or SSA forward with MA return.

Table 9-1. Tracking Services by Data Group and Mode

Data Group and Mode (note 4)		Doppler Measurement			Range Measurement (note 2)	Time Transfer Measurement (note 2)	Return Channel Time Delay (note 5)
		1-Way Return	1-Way Forward (note 6)	2-Way (note 1)			
DG1	Mode 1		✓	✓	✓	✓	✓
	Mode 2	✓	✓				✓
	Mode 3 (note 3)		✓	✓	✓	✓	✓
DG2 (note 3)	Coherent		✓	✓			✓
	Noncoherent	✓	✓				✓

Notes:

1. Requires that the customer transponder coherently turns around the received forward service carrier.
2. Requires that the customer transponder coherently turns around the PN code epoch received in the forward service range channel.
3. MAR DG1 mode 3 and DG2 services are only available through TDRSs F8-F10 and K, L, M. KuSAR DG1 mode 3 services are not supported.
4. Tracking services are not available for KaSA service.
5. Return channel time delay is available for symbol rates ≤ 6 Msps for NRZ and ≤ 3 Msps for biphase formats (S-band DG2 only) per I or Q channel.
6. Requires customer receiver capability to measure Doppler on forward carrier. Additionally, ground terminal Doppler compensation must be disabled.

9.2 Range Measurement

a. General. Range measurement is available when the customer platform transmits a PN code on the return link with the epoch synchronized to the received forward link PN code epoch of the range channel transmitted from the ground terminal (i.e., DG1 mode 1 or DG1 mode 3 service configurations). The TDRSS tracking service will be capable of providing accurate and independent

(sample-to-sample) range data as indicated in paragraphs b through k with customer platform signal Doppler frequencies and Doppler rates within the ranges listed in Table 9-2.

Table 9-2. Signal Doppler Maxima

Service	Doppler Frequency	Doppler Rate
MA	± 230 kHz	± 1.5 kHz/sec
SSA	± 230 kHz	± 1.5 kHz/sec
KuSA	± 1.6 MHz	± 10.5 kHz/sec

b. Range Measurement Random Error. The random error contribution to range measurement resulting from the TDRSS will not exceed the 1σ values listed in Table 9-3 for P_{rec} values consistent with the minimum P_{rec} for BER for the particular service; 3σ error is three times the value shown. The range error given in Table 9-3 pertains to two-way time measurements. To obtain the range error in distance units take one-half of the range measurement error (nsec) and multiply it by the speed of light; e.g., 10 nsec range measurement error (nsec) is equivalent to a range error of 1.5 m.

Table 9-3. TDRSS Tracking Service Range Measurement Error

Data Rate	Maximum Range Error
< 1000 bps	20 nsec (rms)
≥ 1000 bps	10 nsec (rms)
Note: All data rate values (and notes which modify these values, based upon specific signal format and encoding restrictions) are to be interpreted as data bit rates, and not as data symbol rates.	

c. Range Measurement Systematic Error. The systematic range error contribution from a TDRS will be less than ±35 nsec based on pre-launch measurement and predicted on-orbit performance. The systematic range error contribution from the ground terminal will be less than ±30 nsec. The combined systematic error can be obtained by adding the two contributing factors on a root sum square (RSS) basis, and is equal to ±46 nsec.

d. Range Measurement Overall Error. The overall range measurement error is the RSS addition of the systematic error and the random error. Thus, nσ range measurement error is equal to $((\text{systematic error})^2 + (\text{n x rms random error})^2)^{0.5}$. As an example, the overall 3σ range error for data rates > 1 kbps = $(46^2 + (3\text{x}10)^2)^{0.5}/2$ x speed of light = 8.2 m.

e. Range Granularity. The range granularity, which is the smallest discrete output of the ground terminal receiver, is 1 nsec.

f. Range Ambiguity Interval. The minimum unambiguous range measurement is equal to the period (nominally 85 msec or 25,500 km which is obtained by multiplying the code period, 85 msec, by the speed of light, ~300,000 km/sec) of the TDRSS forward service range channel PN code.

g. TDRSS Delay Compensation. The ground terminal ranging system will compensate the range measurement for the known absolute delays internal to the TDRSS (WSC/GRGT and TDRS).

h. Data Sampling. Range measurement data is sampled on-time to within ± 1 μsec of the ground terminal epoch times. "On-time" refers to that portion (leading or trailing edge) of the timing signal that is synchronized with UTC at the output of the ground terminal timing system and is used for sampling the measurement data.

i. Timing Accuracy. The ground terminal epoch times for range measurement will have a systematic error of less than ± 5 μsec of UTC. The ground terminal epoch times will be traceable to within ± 100 nsec of UTC time.

j. Sample Intervals. The sample intervals between range measurement data can be selectable at intervals of 1, 5, 10, 60, and 300 sec/sample.

k. Tracking Data Latency. Tracking data latency $\leq$ 5 seconds relative to the time of measurement.

9.3 Doppler Measurement

a. General. The Doppler frequency is the difference between the recovered carrier frequency and the reference frequency. Two-way Doppler measurement is available when the customer platform transmits a return link carrier frequency that is coherently related to the received forward link carrier frequency (i.e., DG1 mode 1, DG1 mode 3, or DG2 coherent service configurations). One-way return Doppler measurement is available for signals with a noncoherent return link carrier frequency. The TDRSS tracking service will be capable of providing Doppler information with the accuracy and characteristics specified in paragraphs b through k for customer platform signal Doppler frequencies and Doppler rates within the ranges listed in Table 9-2. The Doppler signal is biased and processed so that a signal of 240. MHz + M f_d is obtained, where M=100 for Ku-band, M=1000 for S-band, and f_d is the Doppler. The Doppler count at the ground terminal is non-destructive with a ground terminal capability of maintaining a continuous count for a minimum of 50 minutes at maximum Doppler rate. The counter is set to 0 at least 1 second before the start of the tracking service and will not be reset during a service. One-way forward Doppler can be measured onboard the customer platform from any forward link carrier (coherent or noncoherent). The characteristics of the observation depend on the customer implementation.

NOTE:

The definition of 240. MHz is 240.0000 MHz, where the magnitude of the fraction portion is the accuracy of the ground terminal frequency standard.

b. One-way Forward Doppler. One-way Doppler data can be measured on any uncompensated forward link communications signal from the SN; a scheduled tracking service is not necessary for this data type. The measurement is valid in any: mode (coherent or non-coherent), data modulation (i.e., spread spectrum or unspread), and for any frequency forward link. The only requirement is that the SN forward communication service must be scheduled with Doppler Compensation Inhibited (DCI) for the entire service and the user is responsible for compensating for the expected Doppler of the signal for initial onboard acquisition. In order to measure the Doppler, a user spacecraft needs the software in the user receiver to measure the frequency offset of the incoming receive signal, the basis for which is nominally found in the carrier tracking loop of the receiver. The stability of the reference oscillator for the receiver is one factor in determining the accuracy of the orbital state estimated using the one-way forward Doppler data. Generally, a Temperature Compensated Crystal Oscillator (TCXO) reference with stability of 10^{-6} over 1 – 10 seconds can, at a minimum, provide a state solution accurate enough to be used for signal acquisition and some science missions. An Oven Controlled Oscillator (OCXO) reference with stability of 1^{-10} over 1 – 10 seconds can provide a state solution that is accurate to the 5 to 40 meter level (RSS, 3-sigma). Please contact NASA/GSFC Navigation and Mission Design (Code 595) for additional information.

c. Two-way and One-Way Return Doppler Measurement rms Phase Noise. The rms phase noise contribution to Doppler tracking, resulting from the TDRSS, will not exceed the values given in Table 9-4 for P_{rec} values consistent with the minimum P_{rec} for BER for the particular service.

Table 9-4. TDRSS Tracking Service Doppler Measurement rms Phase Noise

Achievable Data Rate (ADR) (note 1)(bps)	Maximum Phase Noise (note 2) (radians, rms)
≤ 500	0.4
> 500	0.3
≤ 1000	0.3
> 1000	0.2

Notes:

1. All data rate values (and notes which modify these values, based upon specific signal format and encoding restrictions) are to be interpreted as data bit rates, and not as data symbol rates.
2. The error values are in addition to the uncertainty introduced to the Doppler frequency measurement by the allowed ± 25 nsec uncertainty of the 1-second measurement time reference.

d. Reference Frequency.

1. For two-way Doppler measurements, the reference frequency for the ground terminal Doppler extraction process is coherently related to the forward service transmit frequency consistent with the appropriate frequency turnaround ratio (240/221 for MA and SSA or 1600/1469 for KuSA), not accounting for the relative motion between the TDRS and the ground terminals. The TDRS forward transmit frequency defined in the SHO is an integral multiple of 10 Hz. During Doppler compensation inhibit, the TDRS forward service transmit frequency is an integral multiple of 221 for S-band services or 146.9 for Ku-band services. The reference frequency is therefore given by:

$$f_{ref} = f_T\left(\frac{240}{221}\right) \text{ for MA and SSA}$$

$$f_{ref} = f_T\left(\frac{1600}{1469}\right) \text{ for KuSA}$$

where f_T is the TDRS forward service transmit frequency. Two-way Doppler measurements can be provided when Doppler compensation is enabled (DCE) or Doppler compensation is inhibited (DCI). When Doppler compensation is enabled, the forward carrier frequency and PN chip rate are adjusted at ground terminal so that the customer platform receives its nominal frequency and chip rate. If Doppler compensation inhibit is scheduled by the SHO, the TDRS forward service transmit frequency is held constant by the ground terminal. When Doppler compensation is inhibited through an OPM from the NCCDS, a transition profile is initiated within 5 seconds from receipt of DCI to slowly change the frequency from the compensation profile to the nearest multiple of 221 (S-band) or 146.9 (K-band). Within an additional 10 seconds, the forward link frequency is held fixed at a set value, where it will remain throughout the remainder of the service unless Doppler compensation is re-enabled.

2. For one-way return Doppler measurements, the reference frequency for the ground terminal Doppler extractor will be the customer platform transmit frequency as defined in the SHO to the accuracy of the ground terminal frequency standard.

3. For one-way forward Doppler measurements, the reference frequency for the spacecraft Doppler determination will be the ground terminal forward transmit frequency as defined in the customer platform SHO.

e. Two-way and One-Way Return Doppler Granularity. Doppler granularities of 1×10^{-3} cycles for MA and SSA or 1×10^{-2} cycles for KuSA cycle are provided.

f. Two-way and One-Way Return Data Sampling. Doppler measurement data is sampled on-time to within $\pm$25 nsec of the ground terminal epoch times. "On-

time" refers to that portion (leading or trailing edge) of the timing signal that is synchronized with UTC at the output of the ground terminal timing system and is used for sampling the measurement data.

g. Two-way and One-Way Return Timing Accuracy. The ground terminal epoch times for Doppler measurement will have a systematic error of less than ±5 μ sec of UTC. The ground terminal epoch times will be traceable to within ±100 nsec of UTC time.

h. Two-way and One-Way Return Sample Intervals. The sample intervals between Doppler measurement data can be selectable at intervals of 1, 5, 10, 60, and 300 sec/sample.

i. Tracking Data Latency. Tracking data latency ≤ 5 seconds relative to the time of measurement.

j. Range Rate Accuracy. To convert phase noise in Table 9-4 to an equivalent range rate accuracy ($\Delta\dot{r}$) for two-way measurements, the following equation can be used:

$$\Delta\dot{r} = \frac{c\phi_e}{2\sqrt{2}\pi f_r T}$$

where c – speed of light (m/s), ϕ_e – rms phase noise (radians), f_r- return link frequency (Hz), T – averaging time (s). For example, for a data rate > 1 kbps, averaging time of 1s, and a down link frequency of 2.2 GHz, 1σ range rate error is 3.1 mm/s.

For one-way Doppler measurements, the range rate error is 1/2 times that of the two-way error.

k. Local Oscillator Frequency Estimation. If the Customer's onboard transmitter and receiver are referenced to the same oscillator, then the customer may determine their own local oscillator frequency offset using data available from the onboard receiver. The receiver must provide an output telemetry parameter that defines the frequency offset of the receiver relative to the incoming signal. At nominal receive center frequency, this frequency offset telemetry parameter indicates the current delta frequency from nominal derived from the drift in the onboard reference oscillator. The customer may trend the frequency offset over time to determine the local oscillator drift and predict their margin to the ±700Hz acquisition offset requirement and/or the need to update the customer nominal center frequency in the Scheduling configuration.

9.4 Time Transfer Measurement

a. General. Time transfer measurements can be used by MOCs to calibrate their platform's clock. Time transfer measurement is available when the customer platform transmits a PN code on the return link with the epoch synchronized to

the received forward link PN code epoch of the range channel (i.e., DG1 mode 1 or DG1 mode 3 service configurations). The TDRSS two-way tracking service will be capable of providing time transfer data as indicated in paragraphs b through j with customer platform signal Doppler frequencies and Doppler rates within the ranges listed in Table 9-2.

Each time transfer measurement consists of two elapsed times…

1. The time elapsed between a reference 1 second time mark and the first forward PN epoch occurring after that reference time.
2. The time elapsed between that same reference time mark and the first return PN epoch received after the first forward PN epoch after that same reference time mark.

…and two corrections that account for the transit times through the SGLT. These corrections are estimates of the following times:

1. Delay from generation of the forward PN epoch until it departs the ground terminal antenna.
2. Time delay between when a return PN epoch arrives at the ground terminal antenna and it reaches the point where a time tag (TT) is applied.

Time transfer measurements are requested in the SHO. After the scheduled service ends, the NCCDS provides the measurements to the customer MOC.

NOTE:

Time transfer measurements can be used by customer MOCs for customer platform clock calibration. GSFC Code 450 has developed the "User Spacecraft Clock Calibration System (USCCS) Users' Guide" (https://code450ngin.gsfc.nasa.gov/) and will provide assistance, as necessary. This method can provide improved accuracy over RCTD measurements. USCCS support is not currently available from the GRGT.

b. Time Transfer Measurement rms Error. The jitter in the TDRSS time transfer measurement will be within ±25 nsec.

c. Time Transfer Measurement Systematic Error. Systematic two-way time transfer error contributions will be less than ±35 nsec from a TDRS and less than ±30 nsec from the SN ground terminal.

d. Time Transfer Measurement Granularity. The elapsed time between the reference time epoch and the next outgoing forward link PN epoch pulse will have a granularity of 200 nsec. The elapsed time between the reference time epoch and the next arrival of the return link PN epoch pulse will have a granularity of 200 nsec.

e. TDRSS Delay Compensation. The WSC time transfer system provides delay information internal to the TDRSS (WSC/GRGT and TDRS) that enables the MOC to compensate for those delays in the time transfer measurements.

f. TDRSS Delay Compensation. The WSC time transfer system provides delay information internal to the TDRSS (WSC/GRGT and TDRS) that enables the MOC to compensate for those delays in the time transfer measurements.

g. Timing Accuracy. The ground terminal epoch times for time transfer measurement will have a systematic error of less than ±5 μsec of UTC. The ground terminal epoch times will be traceable to within ±100 nsec of UTC time.

h. Sample Interval. The interval between time transfer measurements is 1 second.

i. Time Transfer Overall Accuracy. The dominant contributor to the time transfer measurement error is the systematic error associated with the ground terminal epoch time. All other measurement error contributors are significantly smaller, and as such, the overall accuracy of the measurement is approximately equal to ±5 μsec.

j. Tracking Data Latency. Tracking data latency ≤ 5 seconds relative to the time of measurement.

9.5 Return Channel Time Delay (RCTD) Measurement

a. General. RCTD measurements are available to any customer platform that transmits a return link signal, coherent or noncoherent. The WSC measures RCTD for each I and Q channel in the return link. The reported value is the time delay from the range-to-zero set reference point in the WSC antenna input to the WSC baseband output reference point, where a UTC time tag is placed on the data stream.

NOTE:

RCTD measurement can always be requested in the SAR without causing errors or rejections. However, there will be no RCTD measurement message if support is scheduled via the GRGT or if the return service is in the IF service configuration.

RCTD, in conjunction with other data delays and the time tags placed on the return data stream at WSC, allows the customer MOC to calculate the time onboard their platform to within about 30 msec, typically. http://scp.gsfc.nasa.gov/tdrss/return_data_delay.htm

NOTE:

For details on how RCTD measurements can be used by customer MOCs to calculate the time onboard

their platform, see "Return Data Delay" at http://scp.gsfc.nasa.gov/tdrss/return_data_delay.htm.

RCTD measurements are requested in the SHO. After the scheduled service ends, the NCCDS provides the measurements to the customer MOC.

b. Measurement Times. The WSC measures RCTD at the following times:

1. Immediately before the scheduled service begins.
2. Whenever equipment or services are reconfigured during the service period. Multiple measurements will be made if there are multiple reconfigurations.
3. Immediately after the scheduled service ends.

c. Maximum Symbol Rate. Measurements are provided for symbol rates $\leq$ 6 Msps for NRZ and $\leq$ 3 Msps for biphase formats (S-band DG2 only) per I or Q channel.

d. Measurement Accuracy. RCTD measurements have the following accuracies:

Data rates $<$ 250 kbps: $\pm$25% of the data bit period.

Data rates $\geq$ 250 kbps: $\pm$1 μsec. (The maximum symbol rate is defined in "c above.)

e. Measurement Resolution. RCTD measurements are provided in units of microseconds.

f. Time Tag Accuracy. Time tagging accuracy depends on the baseband equipment used for the service:

MDM (4800-bit data block customers): $\pm$5 μsec

SN Gateway (TCP/IP customers): $\pm$100 μsec

WDISC ((TCP/IP customers): 10 ms

Section 10. SN Operations for TDRSS Services

10.1 Purpose and Scope

10.1.1 Purpose

This Section provides a general description of scheduling capabilities, performance monitoring capabilities, and operations interfaces available to SN customers; and discusses how a customer must interface with the SN to obtain TDRSS support.

All SN elements have particular roles to fulfill in support of SN operations (refer to Section 2, paragraph 2.3 for an SN element description). The most basic of these responsibilities rest with the customer Mission Operations Control Center (MOCC), NCCDS, the GTs, and FDF. Although the MOCC and FDF are not part of the SN, the SN's interactions with the MOCC and FDF are an integral part of SN operations. Table 10-1 presents the basic responsibilities and functions provided by the MOCC, NCCDS, the GTs, and FDF.

NOTE:

The NASA Comprehensive Discrepancy System (CDS) issues NAMs and Space Network Directives (SNDs) to provide up-to-date information on network conditions and constraints. These messages are accessible via the CDS active NAM web site at https://cds.gsfc.nasa.gov/. GSFC Code 450 uses the NAMs and SNDs as a means of letting customers know of any performance constraints associated with TDRS spacecraft. Additionally, TDRS constellation information can be found in the TDRS Constellation Management Plan, 452-PLAN-0002.

10.1.2 Scope

Information covered in this section includes:

a. Scheduling operations (see paragraph 10.2).

b. Real-time operations (see paragraph 10.3).

c. Customer platform emergency operations (see paragraph 10.4).

10.1.3 SN Message Terminology

Different terminology is used to describe the messages exchanged between the NCCDS and the TDRSS ground terminals (GT) than is used to describe the equivalent messages exchanged between the NCCDS and the MOCC. Table 10-2 provides an overview of some of the SN message terminology used throughout this section.

Table 10-1. MOCC, NCCDS and TDRSS Ground Terminals Responsibilities and Functions

MOCC (note 1)	**NCCDS** (note 1)	**Ground Terminals** (note 1)	**FDF** (note 1)
Focal point for customer platform on orbit operations Provide interface for experiment operations requirements Support experiment scientific data analysis and planning Customer platform evaluation and operations Project operations planning, analysis, and scheduling Health and status maintenance of customer platform and experiments Coordinate computing support Coordinate support requiring multiple customer ground facilities Customer platform command generation Customer platform telemetry processing Customer platform attitude data handling Payload operations and control Experiment sensory analysis and control	Allocate and regulate SN resources Control SN/customer interface Support scheduling SN testing and simulation SN performance monitoring Performance data distribution SN status monitoring Distribution of scheduling and acquisition data Documentation control SN planning Acquisition and tracking control support Data base management Service accountability SN fault isolation (How is this done?)	Allocate and control TDRSS services and equipment Provide customer platform telemetry to customer specified destinations (MOCC, Data Processing Facility, etc.) via NISN and Local Interfaces (LI) Provide customer platform tracking data to FDF (note 2) Accept customer spacecraft command data from the MOCC via NISN and Local Interfaces (LI) Coordinate administrative operations TDRSS performance monitoring Maintain TDRS-to-customer platform communications TDRS health and status operations SN schedule data processing TDRS TT&C operations End-to-End test services	Process BRTS data Generate ground trace predictions Process customer tracking data Generate and transmit real-time state vectors Generate customer orbit and ephemeris data Generate TDRS orbit and ephemeris data from TT&C range and BRTS data Receive and process Tracking Data Messages (TDMs) from the GT Perform trajectory support to ELVs Perform mission and trajectory design, and orbit maneuver planning Evaluate and calibrate tracking data for the DSN for satellites supported by FDF Evaluate, calibrate, and validate tracking data for the SN, GN, and other satellites supported by FDF Maintain NASA Directory of Station Locations and environmental files for operational use by FDF and supported users

Notes:

1. There is no horizontal correlation among these lists of MOCC, NCCDS, GT, and FDF responsibilities and functions. The four lists are independent.
2. In general, raw tracking data is not provided to the customer specified destinations.

Table 10-2. Overview of SN Message Terminology

Purpose	Message Name	From	To
Transmit a schedule message	User Schedule Message (USM)	NCCDS	MOCC
	Schedule Order (SHO)	NCCDS	GTs
Real-time service reconfiguration request	Ground Control Message Request (GCMR)	MOCC	NCCDS
	Operations Message (OPM)	NCCDS	GTs
Real-time service reconfiguration disposition/status	Operations Message (OPM)	GTs	NCCDS
	Ground Control Message (GCM)	NCCDS	MOCC
Real-time performance data	Operations Data Message (ODM)	GTs	NCCDS
	User Performance Data (UPD)	NCCDS	MOCC

10.2 SN Scheduling Operations

10.2.1 General

Scheduling operations are the step-by-step interactions of MOCCs and particular SN elements that collectively result in the instructions and information required to direct the SN. This interaction enables the SN to produce the communications and data processing support necessary to conduct real-time customer platform operations.

10.2.2 Database Setup

10.2.2.1 General

The initial step of the scheduling process occurs during the mission planning phase (see paragraph 10.2.3.2). The prospective customer projects supply the NCCDS with information needed to fulfill mission support requirements. The customer information is maintained in the NCCDS database. The NCCDS is the system that schedules SN support. Customer-specific information in the NCCDS database includes:

a. Customer Platform Parameters.
b. Service types.
c. Service Parameter Records.
d. NISN Parameters.
e. Schedule Distribution List.
f. Support Identification (SUPIDEN) and TDRS.
g. Customer Authorization.
h. Data Quality Monitoring (DQM) Setup Parameters.
i. Service Specification Codes (SSCs).
j. Prototype Events.

10.2.2.2 Customer Platform Parameters

For each customer, the customer platform parameters must be specified before any other data can be specified. The customer platform parameters include the customer's Support Identification Code (SIC), Vehicle Identification Code (VIC), Vehicle Identification (VID), and Pseudo-Noise (PN) codes.

10.2.2.3 Service Types

For each customer, the types of service that can be scheduled for that customer must be identified. The service types must be determined before the Service Parameter Records can be specified. Service types include MAF (via F3-F7), SMAF (via F8-F10 (and K, L, M once launched)), SSAF, KuSAF, KaSAF (via F8-F10 (and K, L, M once launched)), MAR (via F3-F7), SMAR (via F8-10 (and K, L, M once launched)), SSAR, KuSAR, KaSAR (via F8-F10 (and K, L, M once launched)), tracking, and end-to-end test services.

10.2.2.4 Service Parameter Records

For each service type for each customer, the Service Parameter Records define how each schedulable parameter is to be validated as the SSCs for that service type and customer are entered into the NCCDS database. The Service Parameter Records comprise similar parameters as the SSC definitions described in Appendix A of the *Interface Control Document Between the Space Network and Customers for Service Management*, 452-ICD-SN/CSM (formerly 451-ICD-NCCDS/MOCC). Appendix A shows the range, or set, of values that is generally valid in terms of the NCCDS/GT interface. In contrast, the Service Parameter Records can be customized to specify ranges, or sets, of values unique to each customer.

10.2.2.5 NISN Parameters

For each customer, the NISN parameters specify the settings of certain parameters used in the schedules transmitted to the GTs. These parameters are used for purposes such as configuring the MDM system and do not appear in the User Scheduling Messages (USMs).

10.2.2.6 Schedule Distribution List

For each customer, the Schedule Distribution List specifies the destinations to which the NCCDS will transmit fixed USMs. One of these destinations will also be specified as the customer's "primary logical destination" and will receive Schedule Result Messages (SRMs) transmitted in response to schedule requests. Any or all of these destinations may also be specified to receive flexible USMs.

10.2.2.7 SUPIDEN and TDRS

For each customer, the NCCDS database contains a list of valid SUPIDENs. For each valid SUPIDEN, the NCCDS database contains a list of valid TDRSs.

10.2.2.8 Customer Authorization

For each customer, the NCCDS database contains a list of valid customer IDs and associated passwords.

10.2.2.9 DQM Setup Parameters

For a combination of SIC, return service Data Stream ID and data rate, the NCCDS database may contain a set of DQM Setup Parameters. The NCCDS uses the DQM Setup Parameters in the construction of SHOs transmitted to the GT. They do not appear in USMs.

10.2.2.10 Service Specification Codes

The format of the customer data that is contained in a SSC is described in Appendix A of the *Interface Control Document Between the Space Network and Customers for Service Management*, 452-ICD-SN/CSM (formerly 451-ICD-NCCDS/MOCC). For each service type to be scheduled, each customer must have at least one SSC specified in the NCCDS database. For each customer, each SSC specifies a set of initial parameter values for the applicable service type. When SSCs are entered into the database, they are validated according to the Service Parameters Records.

10.2.2.11 Prototype Events

After the SSCs have been established for a customer, it is then possible to define prototype events for that customer. Each prototype event specifies a set of SSCs with associated service durations, service start time offsets, and service-level flexibility parameters. Prototype events are optional. It is possible to schedule SN events without the use of prototype events. However, prototype events can simplify scheduling for customers that repeatedly schedule events with the same structure (i.e., the same set of services with the same durations, relative start times, and flexibility options).

10.2.3 NCCDS Scheduling

10.2.3.1 General

The NCCDS is responsible for operations management and scheduling SN resources. Scheduling activities consist of the mission planning phase, event scheduling, forecast scheduling, active schedules, scheduling conflicts, and support scheduling.

10.2.3.2 Mission Planning Phase

During the mission planning phase, SN and MOCC personnel acquaint each other with the kind of data the MOCC must transfer between the SN and the customer platform and with the services the NCCDS can make available to the MOCC. During this period, the TDRSS service configurations needed to meet the various customer data transfer requirements are defined. Each of these configurations is identified by an SSC used in scheduling SN service.

10.2.3.3 Event Scheduling

a. All customer platform operations supported by the SN are scheduled through the NCCDS. The NCCDS-generated events schedule is constructed from specific schedule requests submitted by the MOCCs. These requests may be either event additions, deletions, or replacements. Refer to Table 10-3 for a description of the schedule request types.

b. If the request is for a schedule addition, its addition to the schedule is contingent upon the availability of the SN equipment required to support it. A MOCC is responsible for ensuring its own customer platform-to-TDRS visibility prior to adding a schedule event. The MOCC may do this directly by submitting schedule requests with start time tolerances that comply with customer platform-to-TDRS visibility requirements or indirectly by submitting TDRSS Scheduling Windows (TSWs) to the NCCDS and then submitting schedule requests that specify that they are to fit within these TSWs. Use of TSWs makes it feasible to submit schedule requests that specify TDRS flexibility and with start time tolerances that exceed a single TDRS view. Refer to paragraph 10.2.4.3 for more information on TSWs.

c. There are several ways MOCCs can increase the “schedulability” of their submitted requests. SARs submitted to the NCCDS by SN customers may specify time and/or resource flexibility (refer to Table 10-4). Use of scheduling flexibility increases the probability of successfully scheduling a request, and allows for more efficient use of SN resources.

Table 10-3. Schedule Request Descriptions

Schedule Request Type	Description
Schedule Add Request (SAR) (message type 99, message class 10)	Specifies an event to be added to the schedule in terms of: 1. Specific event start and stop times 2. Either a prototype event ID or one or more SSC IDs together with service-level time-related information
Alternate SAR (message type 99, message class 21)	References either a SAR or another Alternate SAR to form a chain of requests. Specifies an event to be added to the schedule.
Schedule Delete Request (message type 99, message class 11)	Identifies an event to be deleted and does not include information such as SSCs
Schedule Replace Request (message type 99, message class 12)	Identifies an event to be deleted, and includes all of the information needed to add a new event

d. Event scheduling in the NCCDS complies with the SN scheduling ground rules as specified in paragraphs 2.2.2 and 2.2.3 of the *Interface Control Document (ICD) between the Network Control Center Data System (NCCDS) and the White Sands Complex (WSC),* 452-ICD-NCCDS-WSC. Compliance with these ground rules ensures that the schedules generated by the NCCDS can be supported by the TDRSS. In particular, these ground rules ensure adequate time to configure a resource prior to its use. The actual time required to configure a service within an event varies depending on the resources allocated to the service. In general, the time scheduled by the NCCDS to configure a service is the longest time needed to configure any one of the resources allocated to the service. Additional rules also apply to event scheduling. Table 10-5 summarizes the SN scheduling ground rules with an emphasis on the ground rules that apply to time relationships. In general, individual schedule requests submitted by customers must comply with rules that apply to individual events or services while rules that apply to the relationships between events are beyond the control of individual customers.

e. Event scheduling in the NCCDS is performed when processing modifications (add, replace and delete requests) to the active schedule and when generating the next forecast schedule. The NCCDS Scheduling Operator (SO) is responsible for monitoring and coordinating all scheduling activities within the active period. The NCCDS Forecast Analyst (FA), who is chiefly responsible for coordinating future scheduling requirements (forecast periods), assists the NCCDS SO in monitoring schedule-related database information, analyzing schedule resource problems, and coordinating alternative support solutions with MOCCs.

Table 10-4. Scheduling Flexibility Options

Scheduling Flexibility
1. The NCCDS scheduling engine will apply scheduling flexibility in the following order when attempting to schedule a SAR: • Resource flexibility (if any) as specified by the SAR. This may include TDRS flexibility, SA antenna flexibility, and User Interface Channel flexibility. (note 1) • Start time flexibility (if any) as specified by the SAR. This may include event start time flexibility and/or service start time flexibility. (note 2) • Service duration flexibility (if any) as specified by the SAR. (note 3) 2. If a SAR cannot be scheduled after application of all of above flexibility, the NCCDS scheduling engine will attempt to schedule an Alternate SAR if the customer has submitted one that references the original SAR. • An Alternate SAR has nearly the same format as a SAR, and can specify flexibility in the same way. • Alternate SARs can reference SARs or other Alternate SARs. This feature can be used to form a chain of requests which will be processed in sequence until one of the requests is successfully scheduled or until all have been declined. 3. If a SAR and all linked Alternate SARs (if any) are declined and the SAR specified Wait List type processing, the SAR and all of its alternates will be placed on the Wait List. The customer may also submit a Wait List Request after receiving notice that the SAR was declined. (note 4)
Notes: 1. Flexibility always applies to the NCCDS's selection of MAR and SMAR links. The customer does not have the option of specifying a particular MAR or SMAR link. 2. Allows specification of plus and minus tolerances on event and/or service start time. 3. Allows reduction of service duration within specified limits; however, duration will never be less than the minimum requested. 4. The Wait List can be scheduled to run periodically or on demand.

Table 10-5. SN Scheduling Event Time Ground Rules

Applicable Event, Service or Resource	**Ground Rules** (note 8)
Event	• Duration cannot be less than one minute • Duration cannot be more than 24 hours • All services in an event are scheduled on the same TDRS and the TDRS must be used continuously from the beginning of the event to the end of the event. There can be no time period within the event in which a service is not scheduled.
Single Access (SA) services and event	• Except for SSAR combining services, all SA services in an event are scheduled on the same SA antenna • SSAR combining services actually use both SA antennas, but message formats will show that SA1 is used. All other SA services in an event containing a SSAR combining services must use SA1.
SA Antenna	• A minimum of 120 seconds is required between consecutive uses of the SA antenna (note 2)
MAF or SMAF service	• A minimum of 30 seconds is required between MAF services on the same TDRS (F3 – F7) but in different events • A minimum of 30 seconds is required between SMAF services on the same TDRS (F8 – F10 and K, L, M) but in different events
MAR or SMAR Link	• A minimum of 30 seconds is required between uses of the same MAR link on the same TDRS (F3 – F7) but in different events • A minimum of 30 seconds is required between uses of same SMAR link on the same TDRS (F8 – F10 and K, L, M) but in different events
EET equipment	• A minimum of 3 minutes and 30 seconds is required between uses of S-band EET for the same TDRS • A minimum of 3 minutes and 30 seconds is required between uses of Ku-band EET for the same TDRS
User Interface Channels	• A minimum of 20 seconds is required between uses of the same user interface channel (note 4, note 5)
Any service	• A minimum of 15 seconds is required between services of the same type within an event

Table 10-5. SN Scheduling Event Time Ground Rules (cont'd)

Applicable Event, Service or Resource	**Ground Rules** (note 8)
Ku band and Ka band services	• A minimum of 20 seconds is required between Ku and Ka band services in the same event (note 3)
Customer SA and MA/SMA resources	• The gap between two consecutive events for the same customer must be no less than the gap specified by that customer in the NCCDS database. (note 6)
Coherent pair of forward and return services (note 7)	• Any return service configured in coherent mode must be associated with a forward service • The forward and return services should start at the same time for optimal performance • If operational considerations require starting the forward service before the return service, no reconfigurations of the forward service (i.e., OPMs 02, 03, and 11) shall be sent within 30 seconds of the start of return service • Forward link sweep requests (OPM 04) shall not be sent within 150 seconds of the start of the return service
One-way tracking service	• Must be associated with an S-band or Ku-band return service
Two-way tracking service	• Must be associated with a pair of S-band forward and return services or a pair of Ku-band forward and return services
Time transfer service	• Must be scheduled with two-way range tracking service

Notes:

1. Deleted.
2. Longer times are needed for extended field of view support. This is handled through operations procedures.
3. Not implemented in NCCDS scheduling.
4. A user interface channel is a connection between the GTs and the customer facility. In most cases, these connections are via NISN circuits.
5. For many customers, this constraint precludes overlapping events even if the events are scheduled on different TDRSs. However, customers with a sufficiently large set of user interface channels may be able to schedule overlapping events for the same customer platform.
6. Customer-specified gaps are used to prevent scheduling flexibility from positioning two consecutive events for the same customer too close together to be supported by the MOCC. Use of customer-specified gaps is optional.
7. These messages will not be rejected, but could cause inaccuracies in subsequently scheduled tracking data.
8. Services are defined as MAF (via F3-F7), SMAF (via F8-F10 (and K, L, M once launched)), SSAF, KuSAF, KaSAF (via F8-F10 (and K, L, M once launched)), MAR (via F3-F7), SMAR (via F8-10 (and K, L, M once launched)), SSAR, KuSAR, KaSAR (via F8-F10 (and K, L, M once launched)), tracking, and end-to-end test.

10.2.3.4 Forecast Scheduling

Generation of the forecast schedule is a weekly occurrence in the NCCDS. The forecast schedule, which contains events resulting from FA actions and specific MOCC requests, consists of 7 days (0000Z Monday through 2359Z Sunday) of SN support commitments. As illustrated in Figure 10-1, MOCCs can start requesting support up to 21 days prior to the start of the event.

a. On Monday of each week, the NCCDS FA accepts customer SARs for the forecast week beginning 14 days from the current Monday.

b. The forecast schedule is generated by and totally under the control of NCCDS Scheduling. All requests for support for the forecast that are received by 1200Z Monday will be scheduled by priority. Any requests received after this time will be scheduled around the currently scheduled events. The NCCDS SO or FA will verbally coordinate the action necessary to resolve any conflicts within the schedule (see paragraph 10.2.3.6). The SO or FA continues the conflict resolution process until a conflict-free forecast schedule is produced satisfying as many requests as possible.

c. The forecast scheduling process culminates in the forecast schedule being issued to MOCCs on Monday, 7 days prior to the beginning of the week covered by that forecast schedule. The transmission of this confirmed schedule to the customer MOCCs automatically transfers the responsibilities for that time period to the NCCDS SO, and this now becomes the active schedule. The list of declined requests which did not make it into the schedule is also sent to the MOCCs automatically.

10.2.3.5 Active Schedules

a. The active schedule begins at the current time and covers the next 7 to 14 days into the future. Figure 10-1 shows how activation of the forecast schedule extends the active period by 7 days. On the first day of each week (immediately following activation of the forecast schedule), the active schedule is 14 days in length. The length of the active schedule continually decreases until (by the end of the week (Sunday)) the active schedule is 7 days in length. This cycle is then repeated each week with the activation of subsequent forecast schedules.

b. The NCCDS transmits an active schedule to the GTs, NISN, and other SN facilities on a daily basis. These schedules are used by appropriate SN elements to reserve the equipment required to meet daily support commitments. The GT schedule contains the support requirements for the operational TDRSs as well as associated requirements for the SGLTs and data distribution/processing services. The NISN schedule, which consists of all NISN data transport requirements into and out of the GTs in support of SN activities, is used by NISN to monitor utilization of those NISN resources

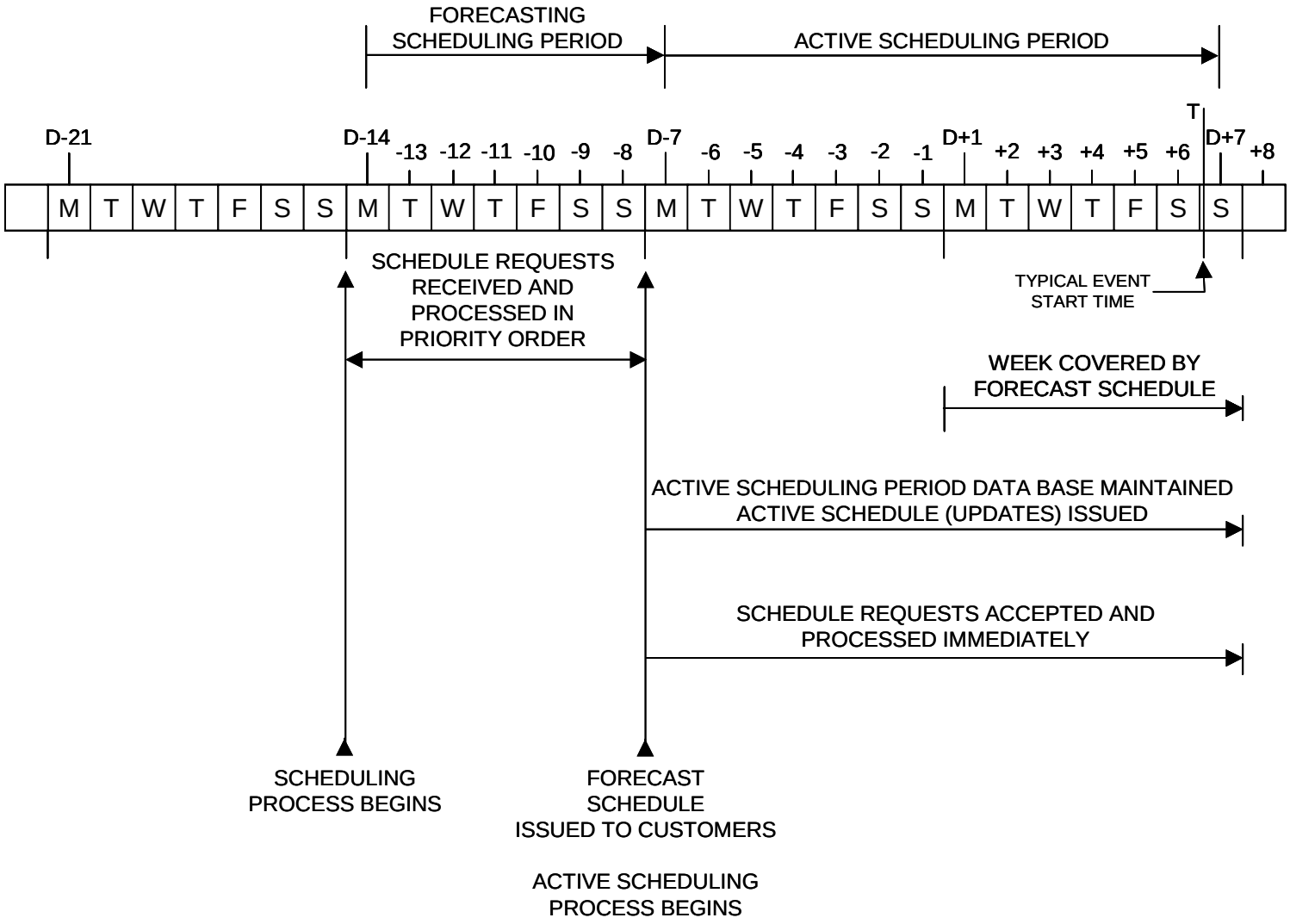

Figure 10-1. SN Event Schedule Process

which have been committed to the SN. Additionally, the NCCDS will transmit recorder/playback requirements to the GTs.

c. The active schedule is constantly being changed as a result of additions or deletions of specific schedule events, operator actions as a result of SN equipment status changes, and other actions. In addition, scheduled support may be affected by customer platform emergencies and/or priority requests by MOCCs for additional service. Any changes to the active schedule results in the transmission of active schedule updates to the affected facilities, if schedule information for that time frame had already been transmitted to them.

10.2.3.6 Scheduling Conflicts

a. Occasionally a direct conflict occurs between two requested events during the forecast scheduling process. In case of scheduling conflicts that cannot be automatically resolved by use of the resource and time flexibility specified in the schedule requests, the NCCDS SO may assist in the analysis of conflicts. Conflict analysis includes the use of priorities provided by NASA, and negotiations between the NCCDS SO or FA and impacted MOCCs on an individual basis. Conflict analysis is not performed for specific schedule requests applicable to the active schedule unless NCCDS SO assistance is verbally requested by the MOCC.

b. The NCCDS has two systems available to customers in predicting possible RFI. The Automated Conflict Resolution System (ACRS) predicts mutual interference (MI) between two or more customer platforms scheduled on the same TDRS at the same time. MOCCs receive ACRS output and may alter their schedules based upon the interference mitigation techniques provided by ACRS. The TDRS Look Angle System (TLAS) plots the TDRS look angles as it tracks the customer platform and predicts periods of ground based RFI and earth multipath. Both systems use TDRS and customer orbital data as well as customer schedules received directly at the NCCDS. ACRS predicts forward and return link mutual interference. For additional information, refer to the *CLASS ACRS/TLAS Operator's Manual and Reference*, NCC 98.

10.2.3.7 Support Scheduling

Whenever feasible, SN customers should use the forecast scheduling process to schedule SN events. However, a MOCC may submit routine specific schedule requests to the NCCDS up to 10 minutes prior to the event start time. A periodic SHO is transmitted from the NCCDS to the GTs for event start times that are greater than 2 hours and less than 48 hours from the time of SHO receipt at the GTs. The NCCDS transmits a Routine SHO to the GTs for event start times between 10 minutes and 2 hours from the time of SHO receipt at the GTs (see paragraph 10.4 for a discussion on customer platform emergency operations).

10.2.4 MOCC/NCCDS Interfaces

10.2.4.1 General

a. Deleted.

b. The SNAS is a standards-based, cross-platform compatible customer interface for performing TDRS scheduling and real-time service monitoring and control. Using the SNAS, SN customers can perform scheduling, real-time functions, and state vector storage with only a desktop computer or workstation, a web browser, and a Java Virtual Machine (JVM). The SNAS is designed to be accessed from the NISN Closed IONet or Open IONet. NISN's Open IONet allows access from the NASA Science Internet and the public Internet, thus allowing cooperation with NASA's university, enterprise, and inter-/intra-agency partners. A detailed description of SNAS is provided in Appendix P.

c. Scheduling messages may be exchanged between the NCCDS and any MOCC at any time. Figure 10-2 lists the messages exchanged via this interface. Descriptions of these messages are contained in paragraphs 10.2.4.2 through 10.2.4.6. Additional MOCC/NCCDS message traffic occurs during SN real-time operations (refer to paragraph 10.3). All messages exchanged between the NCCDS and the MOCCs must comply with the formats, protocols, and security provisions specified by the *Interface Control Document Between the Space Network and Customers for Service Management*, 452-ICD-SN/CSM (formerly 451-ICD-NCCDS/MOCC).

d. The NCCDS supports two classes of customers. They are referred to as “baseline customers” and “full support customers”. Refer to Table 10-6 for more information on the difference in available message types for each class of customer.

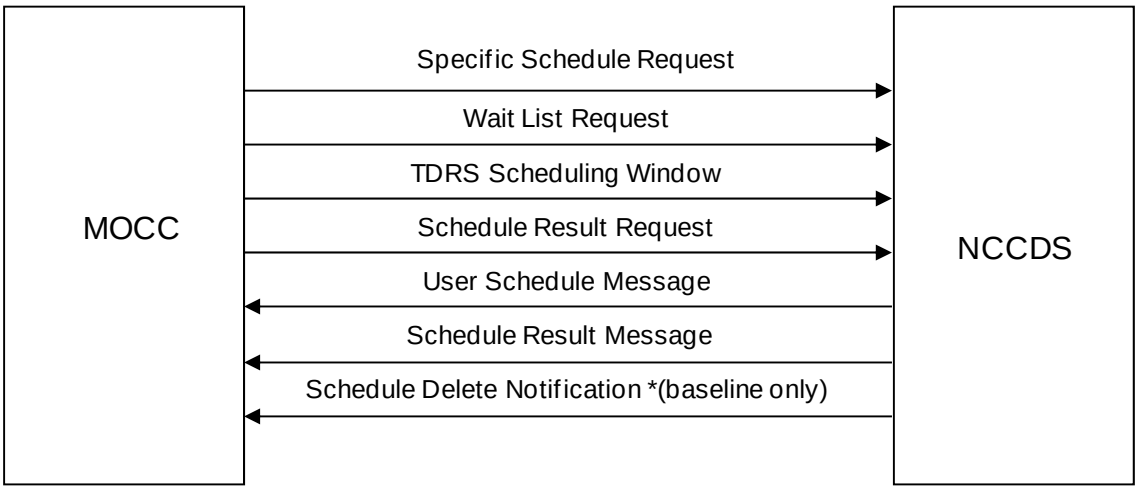

Figure 10-2. MOCC/NCCDS Scheduling Message Exchange

10.2.4.2 Specific Schedule Request

The Specific Schedule Request message is used to add, delete or replace scheduled events for SN resources. The following NCCDS constraints apply:

a. All related services (e.g., forward, return, tracking and end-to-end test) for one SUPIDEN, for one TDRS, and for one continuous period are generally contained in the same request. However, two independent events for the same SUPIDEN can be scheduled at the same time whenever this does not result in resource conflicts.

b. Deletion of a scheduled event may be accomplished only by the MOCC that has scheduling authority, the NCCDS SO, or the GT (with NCCDS approval or direction). If the GT deletes an event, this will not result in automatic generation of messages announcing the deletion.

c. Configuration changes to scheduled events, prior to the scheduled event start time, require the entire event to be replaced by submitting a Schedule Replace Request (message type 99, message class 12). Alternatively, the event can be deleted by submitting a Schedule Delete Request (message type 99, message class 11) and then a new Schedule Add Request (message type 99, message class 10) can be transmitted. Ordinarily these two methods will achieve equivalent results; however, use of the Schedule Replace Request ensures that the resources allocated to the original event are available to be used to schedule the replacement. Use of the Schedule Replace Request also leaves the original event on the schedule if the replacement cannot be scheduled.

d. For add requests, the configuration of services for the event may be specified either by reference to a set of SSCs or by reference to a prototype event which then references a predetermined set of SSCs stored in the NCCDS database.

Table 10-6. NCCDS Customer Types and Available Message Types

NCCDS Customer Types	
Baseline	**Full Support**
Support provided using all message formats in place prior to NCCDS 1998.	Customers capable of using the full set of NCCDS 1998 message formats and any (or all) of the new schedule features such as service duration flexibility.
Specifically:	Specifically:
1. A Schedule Delete Notification is used to notify customers of event deletions.	1. A Schedule result Notification is used to notify customers of event deletions.
2. A Schedule Result message will identify events through the combination of the SUPIDEN, TDRS, and Event Start Time parameters (not the Event ID).	2. A Schedule Result message will identify events through the use of an Event ID
3. A Schedule Delete Request message from the customer will identify events through the combination of the SUPIDEN, TDRS, and Event Start Time parameters (not the Event ID).	3. A Schedule Delete Request message will identify an event using an Event ID.
4. A Schedule Add Request (SAR) message format does not include parameters applicable to service-level flexibility.	4. A Schedule Add Request (SAR) message format includes parameters applicable to service-level flexibility.
	Message types available with NCCDS 1998: <u>Schedule Coordination Messages</u>: 1. Schedule Replace Request (99/12) 2. Alternate Schedule Add Request (99/21) 3. Wait List Request (99/24) 4. TDRS Scheduling Window (99/25) 5. Schedule Result Request (99/28) (note 1) <u>User Schedule Messages</u>: 1. Normal Support, Flexible Schedule (94/04) 2. Simulation Support, Flexible Schedule (94/05)
Note: A Schedule Result Request message is required by all customers whether they are baseline or full support. All MOCCs using the TCP/IP protocol must send a Schedule Result Request message even if they are not full support customers. For MOCCs which still use the NISN 4800-bit block protocol, the NCC Protocol Gateway (NPG) will generate a Schedule Result Request message for them.	

e. Each SSC represents a single service over one continuous period and designates a predefined set of initial parameter values. In addition, maximum data rate values are specified. SN data rate bandwidth allocation is based on these maximum values rather than on the initial values. The NCCDS will not allow data rate reconfigurations to exceed the specified maximum data rates.

f. Some SSC parameter values (e.g., initial data rate) may be replaced by values specified in the MOCC specific schedule request. These are called re-specifiable parameters.

g. For a specific request using SSCs, the MOCC is required to order the SSCs in the same order the services will be output in the USM (i.e., forward, return, tracking). (Refer to *Interface Control Document Between the Space Network and Customers for Service Management*, 452-ICD-SN/CSM (formerly 451-ICD-NCCDS/MOCC).

h. The continuous period covered by an event may range from a minimum of 1 minute to a maximum of 24 hours.

10.2.4.3 TDRS Scheduling Windows

a. TSWs are transmitted to the NCCDS by the MOCC in TSW messages (message type 99, message class 25). Each TSW message contains TSWs applicable to a specified time period for a single customer-defined TSW set for a single TDRS. The TSWs may be transmitted before, after, or at the same time as the schedule requests that depend on the TSWs. However, if a schedule request requires TSWs from a particular TSW set for a particular TDRS during a certain time period, it cannot be processed if applicable TSWs have not been received.

b. Each TSW set contains the TSWs applicable to a particular combination of customer visibility constraints based on factors such as antenna type, power, and frequency. Each customer may define as many TSW sets as needed, and may define new TSW sets at any time without negotiation with the NCCDS.

c. Each SSC either specifies the TSW set applicable to the scheduling of the service specified by that SSC, or specifies that TSWs are not applicable. A TSW set is a re-specifiable parameter.

10.2.4.4 User Schedule Message

a. SN schedules are transmitted to the MOCC via USMs. A USM consists of a message header followed by one or more service descriptions. The *Interface Control Document Between the Space Network and Customers for Service Management*, 452-ICD-SN/CSM (formerly 451-ICD-NCCDS/MOCC), provides a detailed description and explanation of the USM and of all other messages exchanged between the NCCDS and the MOCC.

b. A service description contains all service parameter values needed to initially configure a service. Each service description includes the values of the fixed

parameters and the initial values of the reconfigurable parameters required for that service. If more than one service description of the same type is required, they are placed in order as stipulated in the MOCC request.

c. The following constraints apply to USMs:

   1. Each USM describes a single event which is for one SUPIDEN, for one TDRS, and for one continuous time period. All of the services within the event are described by the USM.
   2. At least one service must be active at all times during the event.
   3. A single USM can include dissimilar services if they occur during the contiguous time period.
   4. For cross-support, the services for all related TDRSS elements are contained in the same USM for cross-correlation. Additional cross-support constraints exist and cross-support services should be coordinated through GSFC Code 450.

d. The NCCDS transmits the forecast schedule to the MOCCs on a weekly basis when it is activated. Subsequent modifications to the active schedule result in schedule messages being immediately transmitted to the appropriate MOCCs.

10.2.4.5 Schedule Result Message

a. SRMs are sent from the NCCDS to the MOCC to report the disposition of schedule requests submitted by the MOCC. The SRMs report all actions taken by the NCCDS, including both automatic processing performed by the NCCDS and manual actions performed by the NCCDS SO. In many cases, a single request will result in multiple SRMs.

b. SRMs are also used to report that an event has been deleted. For backwards compatibility, the NCCDS will transmit a Schedule Deletion Notification to baseline MOCCs that require this in lieu of the SRM.

10.2.4.6 TDRSS Unscheduled Time

Each MOCC receives only those USMs directly relevant to it. USMs do not provide the MOCCs with an overview of the SN schedule, and are of little use in attempting to formulate additional schedule requests that will not conflict with other customers' events. To overcome this limitation of the USMs, the NCCDS publishes TDRSS Unscheduled Time (TUT) reports on a Web page. These reports are updated periodically and allow the customer to identify time periods during which specific critical SN resources are not in use. Instructions for accessing the TUT Web page are contained in the *Interface Control Document Between the Space Network and Customers for Service Management*, 452-ICD-SN/CSM (formerly 451-ICD-NCCDS/MOCC).

NOTE:

TUT reports are not transmitted via formatted messages. However, if a MOCC is unable to access TUT reports via the web page, the NCCDS can provide TUT reports via e-mail.

10.2.5 NCCDS/FDF Scheduling Interface

10.2.5.1 General

The NCCDS/FDF SN scheduling interface is as shown in Figure 10-3. The scheduling information transferred across this interface consists of scheduling aids, acquisition data, and BRTS scheduling data.

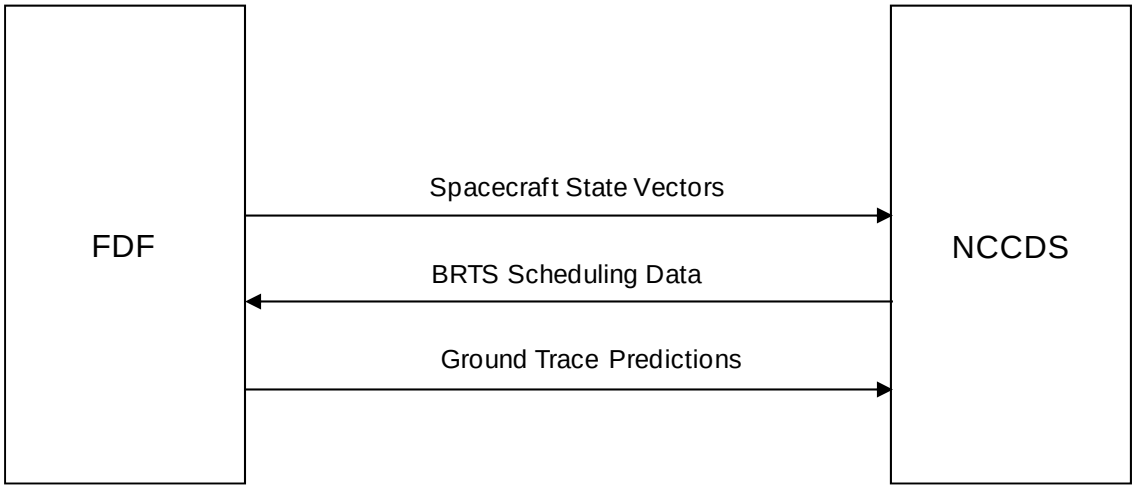

Figure 10-3. NCCDS/FDF Scheduling Information Exchange

10.2.5.2 Scheduling Aids

The scheduling aids for the SN are ground trace predictions generated by the FDF. These ground trace predictions contain one week of customer platform view periods, sun interference, and other information used by both the NCCDS and the MOCCs to effectively schedule support. The prediction accuracy of these ground traces will be 1-minute epoch time deterioration of the FDF's best estimated orbit. The FDF provides these scheduling aids via a web server rather than via formatted messages. These scheduling aids can be found on the Flight Dynamics Facility Product Center web page, http://fdf.gsfc.nasa.gov/.

10.2.5.3 Acquisition Data

Acquisition data messages transmitted by the FDF consist of customer platform state vectors in the IIRV format. The format for IIRVs is provided in Section 9.5 of the *Interface Control Document Between the Space Network and Customers for Service*

Management, 452-ICD-SN/CSM (formerly 451-ICD-NCCDS/MOCC). State vectors are transmitted to the NCCDS on a regular basis with vector epochs spaced at FDF determined intervals. A 2-day projection for each customer is available daily. The IIRVs are updated by the FDF in order to maintain the prediction accuracy required for S-band, Ku-band, and Ka-band services. The FDF also supplies IIRVs for the TDRSs and for permanent Earth stations.

NOTE:

MOCCs can provide the NCCDS with the IIRVs for their customer platforms rather than having the FDF perform this function for them.

NOTE:

The NCCDS has the capability to receive IIRVs sent via File Transfer Protocol (FTP) in addition to the capability to receive IIRVs sent via formatted message.

10.2.5.4 BRTS Scheduling

Generic scheduling of the BRTSs is performed by the NCCDS with the resultant schedule transmitted to the FDF. The FDF plans for, and requests scheduling of, BRTS calibrations and special TDRSS test events.

10.2.6 GT/NCCDS Scheduling Interface

10.2.6.1 General

The types of data exchanged between the NCCDS and the GTs are shown in Figure 10-4. The data transfers relevant to the scheduling process are discussed in paragraphs 10.2.6.2 through 10.2.6.4. OPMs, TDRSS Service Level Reports (SLRs), and Operations Data Messages (ODMs) are discussed in paragraph 10.3. Refer to Table 10-12 for further information on the real-time message flow between the NCCDS and GT.

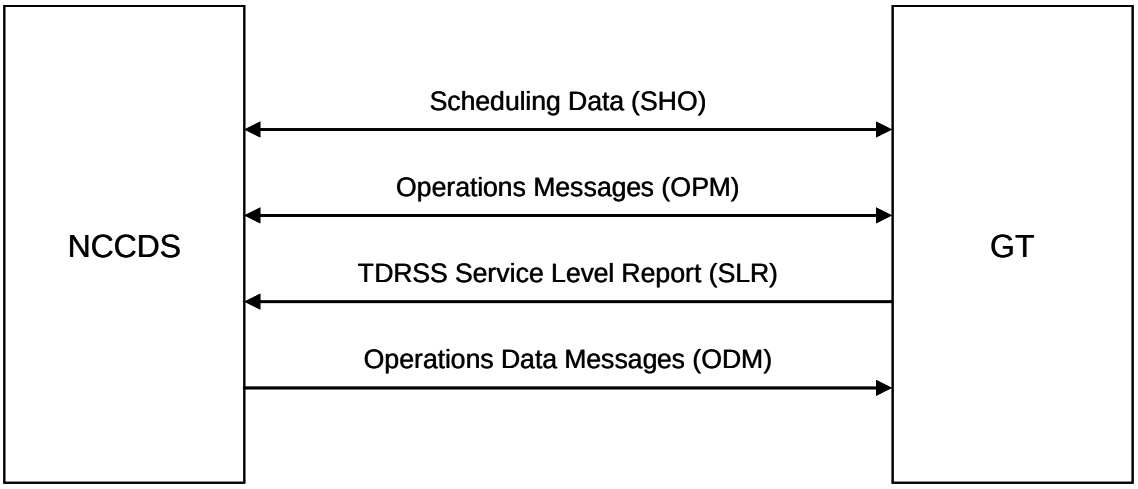

Figure 10-4. NCCDS/GT Data Exchange

10.2.6.2 NCCDS/GT Messages

Two message types are transferred between the NCCDS and the GTs that are a direct result of the SN scheduling process: the SHO and the SHO Status Message (OPM, Class 51).

10.2.6.3 SHO Messages

The NCCDS transmits a SHO to the GTs to schedule TDRSS services as part of SN support. Two types of electronic SHO messages are used by the NCCDS.

a. A Periodic SHO message is used by the NCCDS to transmit schedules for customer services whose event start times are equal to or greater than 2 hours and less than 48 hours from the time of SHO receipt at the GTs.

b. A Routine SHO message is used by the NCCDS to transmit schedules for services whose event start times are equal to or greater than 10 minutes and less than 2 hours from the time of SHO receipt at the GTs.

Each SHO is assigned a unique SHO ID number. The SHO contains the fixed and reconfigurable parameters for each TDRSS service (forward, return, tracking and end-to-end test). The SHO completely specifies the service type, subtype, the TDRS to be used, start/stop times, and the initial parameter values to be employed by the TDRSS in establishing the scheduled support services. SHOs will also contain requests for rate-buffering and data quality monitoring. One SHO may contain up to 16 services. The GT uses SHOs to allocate TDRSS resources in support of the scheduled events. There are many ground rules that govern the structure and transmission of SHOs. A complete listing of these ground rules can be found in paragraphs 2.2.2 and 2.2.3 of the *Interface Control Document (ICD) between the Network Control Center Data System (NCCDS) and the White Sands Complex (WSC),* 452-ICD-NCCDS-WSC.

10.2.6.4 SHO Status Messages

The SHO Status Message is an OPM (Class 51) transmitted to the NCCDS by the GT in response to received SHOs. It is used to inform the NCCDS of the condition (accepted or rejected) of each SHO. If the SHO has been rejected or has been accepted, but some problems exist, a problem code explaining the reason is included in the SHO Status Message. The SHO Status OPM is also used to inform the NCCDS when a SHO terminates or is canceled.

10.2.7 NCCDS/NEST Scheduling Interface

10.2.7.1 General

a. The NCCDS provides the NISN/NASA Event Scheduling Terminal (NEST) with schedules applicable to the utilization of NISN resources. Messages sent by the NCCDS to the NEST specify the NISN support required at particular times in terms of data rates, data types, data stream ID, sources, and destination. The individual communications service elements of these requests are referred to as data streams.

b. The schedule provided by the NCCDS allows NISN personnel to use the NEST to monitor utilization of those NISN resources committed to the SN and to troubleshoot anomalies. The NISN equipment and circuits are primarily data-driven, and do not normally require explicit configuration in response to the schedule; therefore, the NEST does not play a direct role in the configuration or activation of NISN resources. However, under unusual circumstances some NISN equipment requires manual configuration in response to the schedule.

c. The messages that are relevant to scheduling operations and are exchanged between the NCCDS and the NEST are listed on Figure 10-5 and are described in paragraphs 10.2.7.2 through 10.2.7.5.

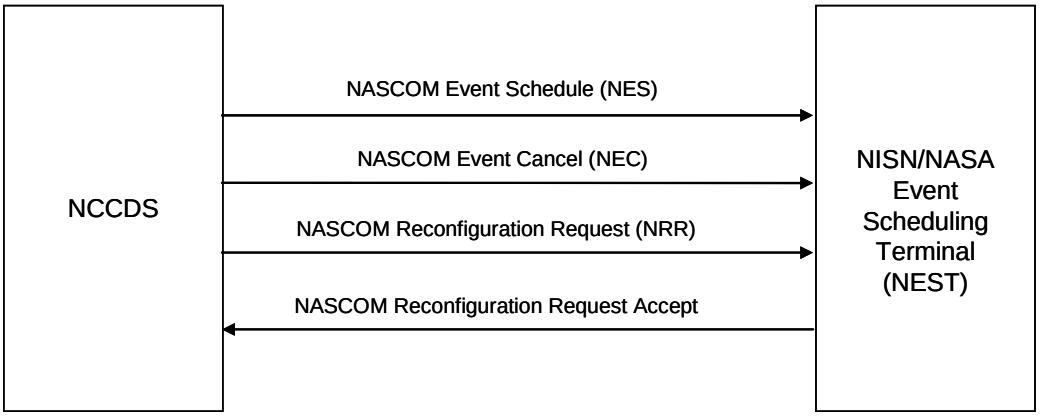

Figure 10-5. NCCDS/NEST Scheduling Data Exchange

10.2.7.2 NISN Event Schedule (NES) Message

At least once daily the NCCDS transmits an active schedule to the NEST consisting of no more than 24 hours of support approximately 24 hours in advance of the first event. Each event in this transmission is specified by an individual NES notifying NISN of all scheduled data streams required within the event.

10.2.7.3 NISN Event Cancel (NEC) Message

This message is used to notify the NEST of the cancellation of an event previously scheduled by the NES Message. The NEC Message may be transmitted at any time prior to or during an event.

10.2.7.4 NISN Reconfiguration Request (NRR)

NISN Reconfiguration Requests (NRRs) are sent by the NCCDS to notify the NEST that an active event has been reconfigured. The only parameter reconfigurations reported in this message are data stream ID and data rate. Refer to Table 10-13 for real-time message flow between the NCCDS and the NEST.

10.2.7.5 NISN Reconfiguration Request Accept Message

After receipt of an NRR message, the NEST replies with an NRR Accept message.

10.3 SN Real-Time Operations

10.3.1 General

The real-time operations period is the time frame in which the MOCC and the SN elements (e.g., NCCDS and GTs) perform the necessary activities to support the command, telemetry, and tracking operations of a customer platform. Real-time activities are initiated in a chronological sequence, as specified by the USMs.

10.3.2 Real-Time Operations Functional Overview

Routine SN real-time operations in support of a customer MOCC involve the major SN systems (TDRSS and the NCCDS) and the two major non-SN NASA elements that support SN operations (NISN and FDF). Table 10-7 provides an overview of real-time operational responsibilities and activities for the NCCDS. An overview of the MOCC's real-time operational activities is provided in Table 10-8. The real-time operational responsibilities and activities of the FDF and NISN are shown in Table 10-9. GT operations can be categorized as those occurring just prior to the scheduled support start time, those occurring during the real-time support period, and those occurring post-support. Table 10-10 provides an overview of GT real-time operational activities.

10.3.3 Real-Time Operations Messages

Instructions, information, and responses between SN elements, non-SN elements that support SN operations, and the customer MOCC during SN real-time operations are primarily accomplished by message exchange. These messages are designated by the combination of a two-digit type code together with a two-digit class code (e.g., 03/10). Table 10-11 describes the real-time message flow between the NCCDS and the MOCC, Table 10-12 describes the real-time message flow between the NCCDS and GT, and Table 10-13 describes real-time message flow between the NCCDS and NISN. Information in these tables provides an overview of why a message is sent and the actions that occur when it reaches its destination.

10.3.4 MOCC Real-Time Interfaces

10.3.4.1 SNAS

SNAS provides a user interface for real-time events. SNAS receives messages sent out from the NCCDS and DAS, filters the messages based on SIC, and displays the content of the messages in panels on its GUI. SNAS also provides support for control messages that the user can send to the NCCDS and DAS. A detailed description of SNAS is provided in Appendix P.

Table 10-7. Real-time Operations Activities Overview for NCCDS

System Element	Functional Responsibility	Activity Description	Applicable Timeline
NCCDS	Administrative management and coordination of SN	1. Initiating SN real-time operations	1. Ten minutes prior to the start time of the service support period
	Monitoring SN System performance	2. Forwarding Acquisition Failure Notification messages received from GTs to the MOCC	2. Whenever received from the GT during a return service
		3. Monitoring SN performance via GT DQM data in ODMs. When requested, sending UPDs to a MOCC	3. The NCCDS receives ODMs from the GT every 5 seconds during the total real-time support duration
		4. Verifying GCMRs from MOCCs and generating and transmitting the requested OPMs to the GT. If necessary, coordinating SN reconfigurations verbally with MOCC and SN resources	4. Any time during the scheduled SHO duration
		5. Processing OPMs from the GTs, coordinating with the MOCC if needed, and initiating the proper transactions required by the OPMs	5. Any time during the scheduled SHO duration
		6. Monitoring the implementation status of the OPM by examination of the OPM Status Message (OPM 62) from the GTs	6. Right after OPM transmission
		7. Transmitting nominal state vectors received from the FDF to the GT	7. During the scheduled service support period if state vector real-time update is required
		8. Canceling an ongoing event when requested by a MOCC	8. During the scheduled event support period, as requested by a MOCC
		9. Directing data quality monitoring during a customer real-time operation, if necessary	9. Upon customer request or when the SN fails to provide the required quality service to a customer

Table 10-7. Real-time Operations Activities Overview for NCCDS (cont'd)

System Element	Functional Responsibility	Activity Description	Applicable Timeline
NCCDS		10. Receiving from GTs and transmitting to the MOCC return channel time delay measurements	10. Measured at start, stop, and reconfigurations of return service for transmission after the scheduled support period
		11. Receiving from GTs and transmitting to the MOCC time transfer measurements	11. Measured a specified number of times during tracking service for transmission after the scheduled support period
		12. Conducting post support debriefing of support elements	12. After completion of scheduled service

Table 10-8. Real-time Operations Activities Overview for MOCC

System Element	Functional Responsibility	Activity Description	Applicable Timeline
MOCC	Management of customer platform operations	1. Receiving Acquisition Failure Notification messages from the NCCDS	1. Shortly after scheduled start of return service, but may also occur anytime during return service
	Monitoring of customer platform performance	2. Initiating of GCM requests	2. Any time during scheduled support period as required
		3. Monitoring customer platform performance data (UPD) and identifying customer platform emergency situations	3. Continuously during scheduled service support duration
		4. Receiving return channel time delay measurement data from the NCCDS	4. After completion of return service
		5. Receiving time transfer data from the NCCDS	5. After completion of tracking service
		6. Generating post-event reports informing the NCCDS of the service quality provided to the MOCC	6. After completion of event

Table 10-9. Real-time Operations Activities Overview for FDF and NISN

System Element	Functional Responsibility	Activity Description	Applicable Timeline
FDF	Processing of tracking data	1. Receiving and processing real-time TDMs from GTs	1. During the scheduled tracking period
	Generating orbit and ephemeris data	2. Generating and transmitting real-time state vectors	2. When the transmitted state vectors have epoch time deterioration which exceed the S-band and Ku-band service required values
NISN	Routing data/messages	1. Performing data-driven configuration and reconfiguration of the communications channels as needed	1. During the duration of customer real-time operations

Table 10-10. Real-time Operations Activities Overview for GTs

System Element	Functional Responsibility	Activity Description	Applicable Timeline
		<u>Prior to the Real-Time Service:</u>	
GTs	Providing TDRSS forward, return, and tracking services to customers Interfacing a TDRS with customer platform based upon specified RF characteristics Responding to NCCDS's administrative command and coordination	1. Processing the received SHOs from the NCCDS, including: a. Performing syntax checking b. Reserving the required equipment	1. Any time from 10 minutes to 48 hours before service start time
		2. Performing Pre Service Test	2. Up to three minutes prior to service start.
		3. Processing of the NCCDS-supplied state vectors	3. Prior to start of service
		4. Generating the TDRS antenna pointing angles (i.e., look angles) and range dynamics data	4. At about 6 minutes prior to service start time
		5. Generating commands to configure the ground equipment and the TDRS	5. At about 1-2 minutes prior to service start time
		6. Acquiring TDRS antenna: positioning the scheduled TDRS SA antenna boresight toward the scheduled customer platform	6. Two to 5 minutes prior to the service start time in an SA service SHO

Table 10-10. Real-time Operations Activities Overview for GTs (cont'd)

System Element	Functional Responsibility	Activity Description	Applicable Timeline
GTs		<u>During the Real-Time service:</u> 7. Initiating Forward, Return, and Tracking services 8. Acquiring a customer platform return service signal: a. Link acquisition sequence for MA return services: (1) PN code acquisition (2) Carrier acquisition (3) Bit synch/Viterbi decoder synch acquisition (4) Data phase ambiguity resolution, if required, after establishment of carrier lock b. Link acquisition sequence for SMA/SSA return services: (1) PN code acquisition, if applicable (2) Carrier acquisition (3) Bit synch/Viterbi decoder synch acquisition (4) Deinterleaver acquisition, if required (5) Data phase and data channel ambiguity resolution and baseband switching, if required, after the establishment of carrier lock	7. At the start of the scheduled support period 8. At the beginning of a service (for forward services, the customer platform performs a similar process for the TDRS forward service signal)

Table 10-10. Real-time Operations Activities Overview for GTs (cont'd)

System Element	Functional Responsibility	Activity Description	Applicable Timeline
GTs		c. Link acquisition sequence for KuSA/KaSA return services: (1) Antenna autotrack pull-in, if applicable (2) PN code acquisition, if applicable (3) Carrier acquisition (4) Bit synch/Viterbi decoder (if applicable) synch acquisition (5) Data phase and data channel ambiguity resolution, and baseband switching, if required, after the establishment of carrier lock **Note:** An acquisition failure message (OPM 63) would be sent to the NCCDS and forwarded to the MOCC if the GTs did not acquire a customer platform signal within the allocated time duration.	
		9. Notifying the NCCDS of entrance and exit into Real-Time Mode (OPM 64)	9. At start and end of real-time maneuver sequence
		10. Processing real-time vectors (type 2, 4, 5, 6, and 7)	10. During the scheduled support periods as required
		11. Determining GT RCTD, when required. **Note:** RCTD measurements are not provided for services scheduled through GRGT.	11. At the start and stop of a service and at service reconfigurations; for RCTD transmission after the service.
		12. Controlling TDRS antenna operations	12. As needed
		13. Reacquiring a customer platform return service signal if initial acquisition failure or loss of lock occurs	13. Reacquisition activated automatically by the GTs or by a reacquisition OPM from the MOCC via the NCCDS

Table 10-10. Real-time Operations Activities Overview for GTs (cont'd)

System Element	Functional Responsibility	Activity Description	Applicable Timeline
GTs		**Note:** An acquisition failure message would be sent to the NCCDS and forwarded to the MOCC if the GT did not acquire a customer platform signal within the allocated time duration	
		14. Transmitting ODMs to the NCCDS	14. ODMs transmitted every 5 seconds containing all the active services supported by the TDRSS
		15. Processing OPMs, including reconfiguration OPMs, sent from the NCCDS and initiating proper transactions	15. During the scheduled support period
		16. Transmitting the required OPMs (except OPM 52) to the NCCDS	16. During the scheduled support period
		17. Performing forward channel data presence monitoring (DPM) and return channel data quality monitoring (DQM) as directed by the NCCDS	17. During the scheduled support period
		18. Providing rate buffered recording for High Data Rate Service data rates (see Table 3-4) with playback rates of $\leq$ 48 Mbps	18. During the scheduled support period
		19. Providing line outage recording capability to support data recording **Note:** Line outage recording is provided automatically for the majority of data interfaces, but is not available for some types of data interface (see Table 3-4)	19. During the scheduled support period
		20. Transmitting SLRs to the NCCDS	20. After detection of equipment failures or upon verbal request.

Table 10-10. Real-time Operations Activities Overview for GTs (cont'd)

System Element	Functional Responsibility	Activity Description	Applicable Timeline
GTs		21. Transmitting Tracking Data Messages to the FDF	21. Every 5 seconds when requested.
		22. Transmitting time transfer message, OPM 66, to the NCCDS, when required	22. Within 1 minute of tracking service termination for which time transfer was requested
		23. Terminating a service or a SHO as scheduled or canceling a SHO as requested by the NCCDS	23. At the end of a SHO or at any time during the scheduled SHO duration as requested by a Cancel SHO OPM from the NCCDS
		<u>After the Real-Time Service:</u>	
		24. Transmitting RCTD, OPM 52, to the NCCDS **Note:** RCTD measurements are not provided for services scheduled through GRGT.	24. After service is complete.
		25. Participating in post event debriefing	25. After event is complete
		26. Transmitting playback of high rate customer return data; transmitting line outage recording data (see Table 3-4)	26. As scheduled; as required

Table 10-11. Real-time Message Flow Between the NCCDS and MOCCs

Message Category	Message Type/ Class	Message ID	Message Generation Frequency	Message Generation Conditions	Destination System Response
Messages from the NCCDS to the MOCCs					
User Schedule Messages **Note:** User schedule messages are normally used during scheduling operations, but may also be used during real-time emergency operations	94/01	Normal Support – Fixed Schedule		Forecast schedule or routine active period update-- event is fixed	Update schedule database
	94/02	Premium Support – Fixed Schedule		Schedule add with a lead time of 10 to 45 minutes of event start time – event is fixed	Update schedule database
	94/03	Simulation Support – Fixed Schedule		Forecast schedule or routine active period update – event is fixed	Update schedule database
	94/04	Normal Support – Flexible Schedule		Forecast schedule or routine active period update – event retains flexibility	Update schedule database
	94/05	Simulation Support – Flexible Schedule		Forecast schedule or routine active period update – event retains flexibility	Update schedule database
	99/01	Schedule Delete Notification		Event deleted during active period Note: Applicable only for baseline customers	Update schedule database
	99/02	Schedule Result Message		NCCDS reports disposition of MOCC submitted schedule request	Update schedule database. Declined request may be changed and resubmitted by MOCC
Real-time GCMs	98/01	GCM status		GCMR rejected by either the NCCDS or the GT, or accepted by the GT	
	98/02	GCM disposition		GT GCM receipt acknowledgment received by NCCDS	

Table 10-11. Real-time Message Flow Between the NCCDS and MOCCs (cont'd)

Message Category	Message Type/ Class	Message ID	Message Generation Frequency	Message Generation Conditions	Destination System Response
Messages from the NCCDS to the MOCCs (cont'd)					
Operations Performance	91/01	UPD	One every 5 seconds during event, when requested	TDRSS customer performance data requested by MOCC	
	92/62	Return Channel Time-Delay Measurement		RCTD requested in SHO transmitted to the NCCDS by the GT. Data transmitted by the GT to the NCCDS after termination of scheduled service or when equipment reconfiguration occurs and is sent on to the MOCC **Note:** RCTD measurements are not provided for services scheduled through GRGT.	
	92/63	Acquisition Failure Notification		GT has not achieved initial acquisition or reacquisition of the customer platform return service signal within the predetermined time	MOCC may send reacquisition request GCMR (98/03) to the NCCDS
	92/66	Time Transfer		Upon termination of a tracking service for which time transfer was requested	

Table 10-11. Real-time Message Flow Between the NCCDS and MOCCs (cont'd)

Message Category	Message Type/ Class	Message ID	Message Generation Frequency	Message Generation Conditions	Destination System Response (Note: Descriptions in this column apply to all GCMRs listed on this page)
Messages from MOCCs to the NCCDS					
Real-time GCMRs	98/03 98/04 98/05 98/06 98/07 98/08	Reacquisition Request Reconfiguration Request Forward Link Sweep Request Forward Link EIRP Reconfiguration Request Expanded User Frequency Uncertainty Request Doppler Compensation Inhibit Request		MOCC real-time service request	NCCDS verifies customer platform eligibility and service availability If valid, the NCCDS transmits an OPM to the GT. NCCDS sends GCM Disposition to MOCC when GT acknowledges OPM receipt GCM status message is sent to the MOCC, if GCMR/OPM is rejected by either NCCDS/GT. GCM status message indicating accept is sent if OPM is accepted by the GT
Operations Performance	92/04	Performance Data Request		MOCC request	NCCDS routes GT ODMs to the appropriate MOCC every 5 seconds during event

Table 10-11. Real-time Message Flow Between the NCCDS and MOCCs (cont'd)

Message Category	Message Type/ Class	Message ID	Message Generation Frequency	Message Generation Conditions	Destination System Response
Messages from MOCCs to the NCCDS (cont'd)					
Specific Schedule Requests **Note:** User schedule messages are normally used during scheduling operations, but may also be used during real-time emergency operations	99/10	Specific Schedule Add Request		MOCC Scheduling Operator request for normal, simulation, or premium event	99/02 sent to report disposition and 94/xx sent if event is added
	99/11	Specific Schedule Delete Request		MOCC Scheduling Operator request to delete active event, or queued request	99/02 sent to report disposition, 99/01 also sent to baseline customers
	99/12	Specific Schedule Replace Request		MOCC Scheduling Operator request to replace active event, or queued request	99/02 sent to report disposition, 94/xx sent if event is added
	99/21	Specific Schedule Alternate Add Request		MOCC Scheduling Operator request to link alternate request to a previously queued request	99/02 sent to report disposition, 94/xx sent if event is added
	99/24	Spedific Schedule Wait List Request		MOCC Scheduling Operator request to put referenced request on the wait list	99/02 sent to report disposition
	99/28	Schedule Result Request		MOCC using TCP/IP sends 99/28 to define communications path for receipt of 99/02 and 94/xx	99/02 and 94/xx sent on communications path defined by 99/28
TDRS Scheduling Windows	99/25	TDRS Scheduling Windows		MOCC sends to NCCDS to specify customer platform to TDRS visibility	NCCDS saves in database, and applies to scheduling

Table 10-12. Real-time Message Flow Between the NCCDS and the GTs

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the NCCDS to the GTs						
OPM 01						
Special Instruction or Request	03/01	Used in message exchange between controllers Not used in automatic processing/control		This message is used to send free-form alphanumeric text from the NCCDS to GTs	No processing required GT prints this message and displays it on a TOCC console	
OPM 02						
Reacquisition Request	03/02	Real-time control message		Initial link acquisition failure	NCCDS reformats and validates the MOCC GCMR (98/03)	GT response time is up to 20 seconds (forward) and 10 seconds (return) of OPM receipt and acceptance for all services
				Link unlocked		GT sends an OPM 63 (Acquisition Failure Notification) to the NCCDS if the acquisition process fails
				Link acquisition failure during a customer platform real-time configuration	GT verifies and validates the OPM and initiates the reacquisition process. It should be noted for coherent service mode, a forward reacquisition will cause both forward and return services to be reacquired	GT sends an OPM status message (OPM 62) upon successful reacquisition completion

Table 10-12. Real-time Message Flow Between the NCCDS and the GTs (cont'd)

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the NCCDS to the GTs (cont'd)						
OPM 03 Customer Reconfiguration Request	03/03	Real-time control message		A MOCC transmits a TDRSS reconfiguration request to the GT, via a GCMR to the NCCDS, if there is a need to reconfigure the GT and TDRS equipment supporting its customer platform	NCCDS reformats and validates the MOCC reconfiguration request (98/04) and transmits an OPM (03/03) to GT	The GT response time is up to 35 seconds of OPM receipt and acceptance for all services
					NCCDS responds to a GCM from a MOCC with GCM status (98/01) and GCM disposition (98/02) messages	The GT will respond to the OPM 03 with an OPM 62 after successful completion of the reconfiguration or a message rejection if the message is incomplete or invalid
					The GT verifies and validates the OPM and processes and implements the OPM if legal	
OPM 04 Forward Link Sweep Request	03/04	Real-time control message		Used as an acquisition aid when customer platform receiver acquisition failure is suspected because customer platform receiver frequency differs from expected values. Used in both initial and reacquisition situations. OPM-04 is also used for nominal Preventive Maintenance (PM) mode sweep initiation and termination.	NCCDS reformats and validates the MOCC-generated forward link sweep request (98/05) and transmits an OPM (03/04) to the GT	The GT initiates the forward link sweep within 10 seconds of OPM receipt and acceptance
					The GT verifies and validates the OPM and initiates the forward link sweep process	The GT will respond to the OPM 04 with an OPM 62 confirming that the sweep has started or a message is incomplete or invalid

Table 10-12. Real-time Message Flow Between the NCCDS and the GTS (cont'd)

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the NCCDS to the GTs (cont'd)						
OPM 06 Forward Service EIRP Reconfiguration Request	03/06	Real-time control message		This OPM is used to set the TDRS SSA and KaSA/KuSA EIRP to normal or high power as the situation requires	NCCDS reformats and validates the MOCC-generated forward link EIRP reconfiguration request (98/06) and transmits an OPM (03/06) to the GT. The GT validates, processes, and implements the OPM by changing the TDRS onboard power mode	The GT response time is up to 10 seconds of OPM receipt and acceptance for all services The GT will respond to the OPM 06 with an OPM 62 acknowledging receipt of an OPM without detecting errors or a message rejection if the message is incomplete or invalid
OPM 07 Expanded Customer Frequency Uncertainty Request	03/07	Real-time control message		This message is generated when the MOCC cannot accurately predict the customer platform transmit frequency for DG1 mode 2 and DG2 (non-coherent) operation	NCCDS reformats and validates the MOCC-generated expanded customer platform transmit frequency uncertainty request (98/07) and transmits an OPM (03/07) to GT The GT validates and processes the OPM and initiates the expansion of the return service frequency area examined	The GT response time is up to 5 seconds of PM acceptance for all services. The GT will respond to the OPM 07 with an OPM 62 acceptance status upon frequency expansion initiation or an OPM 62 reject if the message is incomplete or invalid

Table 10-12. Real-time Message Flow Between the NCCDS and the GTs (cont'd)

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the NCCDS to the GTs (cont'd)						
OPM 10 or 15 Spacecraft State Vector	03/10 or 15	Real-time or non real-time message	Daily or more often, if necessary, for each customer platform	This message is used to transmit customer platform state vector data to GT prior to the scheduled service support period start time	The data contents of the message are generated by FDF The message originates at FDF and is transmitted to the NCCDS for retransmission to the GT	The GT will respond to the OPM 10 message with an OPM 61 state vector rejection message if the vector is found to be unusable OPM 64 will be sent upon entrance and exit of the real-time mode. OPM 64 will be provided for type 2, 4, 5, 6, 7 state vectors received within 6 minutes prior to service or during service with epochs to be applied before service termination
OPM 11 Doppler Compensation Inhibit Request	03/11	Real-time control message		Prior to the beginning of a two-way tracking service	NCCDS reformats and verifies the MOCC-originated Doppler compensation inhibit request (98/08) and transmits an OPM (03/11) to the GT The GT validates and processes the OPM and initiates inhibition of the Doppler compensation on the referenced forward service	The GT will initiate Doppler Compensation Inhibit within 10 seconds of receipt of OPM 11 and fix the forward carrier frequency within 20 seconds after receipt of OPM 11. The GT sends an OPM status message (OPM 62) after successful initiation of the Doppler Inhibit

Table 10-12. Real-time Message Flow Between the NCCDS and the GTs (cont'd)

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the NCCDS to the GTs (cont'd)						
OPM 12 Cancel SHO Request	03/12	Real-time or non real-time message		When it is necessary for the NCCDS to request cancellation of either an on-going or an upcoming SHO	NCCDS transmits a Cancel SHO OPM (03/12) to the GT. The GT validates the message and cancels the specified SHO	The GT sends an OPM status Message (OPM 62) upon acceptance of the Cancel SHO OPM The GT sends and OPM 51 indicating referenced SHO was successfully deleted from the GT database
OPM 13 TDRS Maneuver Approval	03/13	Non real-time message	As required	NCCDS transmits approval/ disapproval in response to a TDRS Maneuver Request, OPM 59, from the GT	Manual – operationally this is handled via e-mail	The GT may initiate TDRS maneuver upon receipt of approval from NCCDS
OPM 18 Δt Adjustment	03/18	Real-time or non real-time message		NCCDS uses this message to adjust the epoch time parameter within stationary state vectors (launch holds) Not used for orbit correction	NCCDS formats and transmits the message to the GT prior to epoch reference time	The GT system response time is up to 30 seconds of OPM receipt and acceptance or at the new epoch reference time, whichever is later The GT will respond to the NCCDS with an OPM 65, Δt adjustment rejection to a state vector rejection message, if appropriate The GT may send OPM 64 real-time mode entry/exit, as appropriate

Table 10-12. Real-time Message Flow Between the NCCDS and the GTs (cont'd)

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the GTs to the NCCDS						
OPM 51 SHO Status	03/51	Real-time or non real-time message	Daily at SHO transmissions if status changes	Used by the GTs to inform the NCCDS of the status of a SHO	NCCDS processes the message, alerts the operators if problems exist	Problems handled by operators
OPM 52 Return Channel Time Delay	03/52	Real-time data message (not a control message)	MOCC initiated request. Not a re-configurable parameter	When a SHO includes a request for return service time delay data, the return channel time delay data will be obtained at the start and stop of the return service and at service reconfigurations. An OPM (03/52) is used to send NCCDS the data after termination of the return service	NCCDS receives and reformats the message and sends it to the appropriate MOCC	
OPM 53 Preventive Maintenance Request	03/53		1 week in advance of the preventive maintenance date	This message will be used to send free-form alpha-numeric text from the GTs to the NCCDS	NCCDS receives and verifies the message NCCDS alerts the NCCDS operator The NCCDS operator will block the affected resources to keep them from being scheduled for customer support	

Table 10-12. Real-time Message Flow Between the NCCDS and the GTs (cont'd)

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the GTs to the NCCDS (cont'd)						
OPM 54 Special Request or Information	03/54	Used in message exchange between controllers Not used in automatic processing/control		This message will be used to send free-form alpha-numeric text from the GTs to the NCCDS Operationally, an OPM 54 is used to request preventative maintenance	NCCDS receives and verifies the message NCCDS alerts the NCCDS operator	
OPM 57 Service Termination	03/57	Real-time report message		This message is sent from the GTs to the NCCDS for notification of the termination of a service	NCCDS logs the data	
OPM 59 TDRS Maneuver Request	03/59			When the GT desires to perform a TDRS maneuver, advance approval is requested from the NCCDS	NCCDS receives and validates the OPM Operationally this is handled via e-mail. NCCDS alerts the NCCDS operator NCCDS operator processes the request and attempts to resolve any possible impact during the requested maneuver duration	NCCDS responds to the GTs with an OPM 13, TDRS maneuver approval message, which will either grant or deny the GTs permission for the TDRS maneuver

Table 10-12. Real-time Message Flow Between the NCCDS and the GTs (cont'd)

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the GTs to the NCCDS (cont'd)						
<u>OPM 61</u>						
Spacecraft State Vector Rejection	03/61	Near real-time or non-real-time message reporting the rejection of an OPM 10 or 15 message		Before propagating the ephemeris data from a received state vector, the GT performs the required validity checks. If any of these NCCDS-GT messages fail validity checks, this rejection message is sent from the GT to the NCCDS	Receives and validates the OPM NCCDS alerts the NCCDS operator	NCCDS operator may respond to the GT with a new OPM 10, or 15 message
<u>OPM 62</u>						
OPM Status	03/62	Real-time or non-real-time message	One for each OPM	OPMs received by the GT from NCCDS will be checked for validity. This message is then used by the GT to inform the NCCDS that either the OPM has been accepted, or rejected as a result of the validity checks detecting an erroneous OPM If an OPM is rejected, OPM 62 will be sent immediately. If accepted, OPM 62 will be sent acknowledging receipt for OPMs 6 and 12 and OPM 62 will be sent upon OPM implementation for OPMs 2, 3, 4, 7, and 11.	The NCCDS receives and validates the OPM and notifies the NCCDS operator if the NCCDS OPM has been rejected For an NCCDS OPM that has been rejected, the NCCDS initiates the required handling to correct the problem code error	For an NCCDS OPM that has been rejected, the NCCDS or the impacted MOCC corrects the error and the NCCDS retransmits the corrected OPM to the GT

Table 10-12. Real-time Message Flow Between the NCCDS and the GTs (cont'd)

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the GTs to the NCCDS (cont'd)						
OPM 64 Real-Time Mode Notification	03/64		Enter Real-Time Mode upon receipt of any of the following messages less than 6 minutes prior to the start of service or during service: a. Delta-T message b. Type 1 or 8 vector with an epoch prior to the end of service c. Type 2, 4, 5, 6, or 7 vector as part of a maneuver sequence and with an epoch time in the future prior to the end of service. The GT must have at least 2 maneuver vectors with future epoch times	This message is used by the GT to inform the NCCDS that the GT has entered or exited the Real-Time Mode	The NCCDS receives and validates the OPM and notifies the NCCDS operator	Upon receipt of message indicating entry into real-time mode, the NCCDS refrains from initiating transmission of other data that could require real-time mode processing until the GT responds with a message indicating that it has exited from real-time mode
OPM 65 Δt Adjustment Rejection	03/65	Near real-time or non-real time message reporting the rejection of an OPM 18 message		The GT uses this message to advise the NCCDS that a requested Δt adjustment has not been implemented	NCCDS alerts the NCCDS operator NCCDS operator initiates processing to handle the problem	NCCDS may retransmit the corrected Δt adjustment (03/18) to the GTs

Table 10-12. Real-time Message Flow Between the NCCDS and the GTs (cont'd)

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the GTs to the NCCDS (cont'd)						
OPM 66 Time Transfer Data	03/66	Variable length dependent on number, n, of time transfer samples		Transmitted to NCCDS within 1 minute of tracking service termination for which time transfer was requested in the SHO	NCCDS receives and reformats the message and sends it to the appropriate MOCC	
Service Level Requests (SLRs)	04/NA (note)	SLRs with ID numbers 1 to 4,999,999 to 1 are a result of equipment status change. SLRs with ID numbers 5,000,000 to 9,999,999 to 5,000,000 are sent in response to NCCDS request		Upon verbal request from the NCCDS or upon change in any reported parameter within 15 minutes of change SLR information is also sent via e-mail	For resources reported as unavailable, the NCCDS operator will block the affected resources to keep them from being scheduled for user support	
Operations Data Messages (ODMs) SA/SMAR MA/SMAF End-to-End Test	 05/NA (note) 06/NA (note) 07/NA (note)	Real-time operations report	One every 5 seconds during active event	Separate ODMs are sent for SA/SMAR, MA/SMAF, and end-to-end test services for each TDRS whenever service is ongoing	ODMs are reformatted as UPD messages and routed to appropriate MOCC when requested	Route TDRSS customer performance data message to appropriate MOCC
Note: Message class information not applicable to SLRs and ODMs						

Table 10-13. Real-time Message Flow Between the NCCDS and NISN

Message ID	Message Type/ Class	Message Length	Message Generation Conditions	Message Destination System Response
Messages between the NCCDS and NEST				
NISN Event Schedule	90/01	1 to 6 blocks	Daily schedule transmission	Information used by NISN to monitor resource utilization
NISN Event Cancel	90/02	1 block	To cancel an accepted support event One message per event as needed	Information used by NISN to monitor resource utilization
NISN Event Schedule Update	90/04	1 to 6 blocks	Event added to daily schedule after normal transmission	Information used by NISN to monitor resource utilization
NISN Event Emergency Schedule	90/05	1 to 6 blocks	Event added with a lead time of 5 to 45 minutes of event start time	Information used by NISN to monitor resource utilization
NISN Reconfiguration Request	90/06	1 to 2 blocks	Change to requirements for ongoing event	Information used by NISN to monitor resource utilization
NISN Reconfiguration Request Accept	90/07	1 block	NEST always responds to 90/06 with Accept	Absence of this message will cause alert to NCCDS operator.

10.4 Customer Platform Emergency Operations

10.4.1 General

SN support to customer platform emergency operations can be divided into two portions: customer platform emergency requests, processing, and implementation; and real-time emergency operations. A thorough description of emergency scheduling and real-time emergency operations is given in paragraphs 10.4.2 and 10.4.3.

The SN capabilities available to support the MOCC in customer platform emergency operations consist of the use of SHO schedule requests, OPMs, and the use of the GT manual commands per NCCDS direction, as the situation requires. These capabilities may be used alone or in various combinations to support and resolve a specific operational emergency situation of a customer.

10.4.2 Emergency Scheduling

10.4.2.1 Customer Platform Emergency Requests for SN Support

a. Emergency scheduling spans the period from the point a MOCC declares a customer platform emergency to the NCCDS to implementation of the SHO by the GT. A Routine SHO message is transmitted if the required event start time is less than 2 hours from the time of SHO receipt at the GTs.

b. The MOCC requests emergency support by notifying the NCCDS of the nature of the declared emergency, desired start time, services required, and expected duration of the support. Customer platform emergency requests for SN support are submitted as Schedule Add Requests with the customer priority set to 1 to indicate that the request is for emergency support. If the start time is less than 10 minutes away, manual intervention by the NCCDS operator will be necessary.

10.4.2.2 NCCDS Processing of a Customer Platform Emergency

a. The procedure for processing the customer platform emergency request is similar to the regular scheduling process except for any unresolvable scheduling conflict. The NCCDS SO receives an alert from the NCCDS when the request is either successfully processed or rejected. If the scheduling request is rejected, the message from the NCCDS notifies the NCCDS SO of the details of the conflict. The NCCDS SO attempts to resolve the conflict by individual discussions with each impacted MOCC to determine if its scheduled service support period can be terminated or delayed. If these conflict resolution discussions are not successful, the NCCDS makes the scheduling decisions. When necessary, the NCCDS SO deletes conflicting events. This results in Schedule Result Messages being transmitted (refer to paragraph 10.2.4.5) to each impacted MOCC to notify them of the deletions. The NCCDS SO also informs the MOCC initiating the customer platform emergency request of appropriate details of the conflict resolution. Based upon the information supplied to that MOCC by the NCCDS SO, it prepares and transmits a new Schedule Add Request to the NCCDS for processing. However if the changes

needed to the original request are relatively simple, the NCCDS SO may edit the request rather than requiring the MOCC to submit a new request.

b. If the scheduling request causes no conflict, the NCCDS automatically approves it, generates a SHO, and transmits that SHO to the GT. The NCCDS also generates and transmits a Schedule Result Message to the MOCC and the schedules to other affected SN elements.

c. The NCCDS tests for conflicts in allocating services and, if a conflict exists, works with the MOCC to resolve the conflict. The following procedures apply:

    1. The NCCDS automatically attempts to resolve the conflict by shifting events within MOCC prescribed tolerances.
    2. If the conflict resolution attempt is unsuccessful, the NCCDS sends a Schedule Result Message to the requesting MOCC advising that the request has been declined.
    3. After evaluating the Schedule Result Message, the customer MOCC may contact the NCCDS SO for further assistance. The NCCDS scheduling operators perform the necessary conflict analysis.
    4. If the NCCDS SO approves the request, he deletes all conflicting events.
    5. If the request is denied, the original schedule remains unaffected.
    6. The requester and all those affected are notified of the NCCDS's final decision via either a schedule update, verbal communications, or a Schedule Result Message as appropriate at the time the decision is made.
    7. All schedule requests, including customer platform emergency requests, must specify an event start time. The resulting schedule messages are sent immediately to NISN, the GT, and the impacted MOCC.

10.4.2.3 GT Processing of the Customer Platform Emergency SHO

Once the customer platform emergency SHO arrives at the GT, the following GT processing takes place within 5 minutes of receipt of the SHO:

a. Start times for all services called out by the SHO are generated. Checks are made that service durations are at least 60 seconds but not greater than 24 hours.

b. A resource check is made and the equipment required is reserved. If the SHO is accepted, a SHO Status OPM is transmitted to the NCCDS indicating acceptance of the SHO. If the SHO is rejected, a SHO Status OPM is transmitted to the NCCDS indicating rejection of the SHO. This message contains an error code giving the reason for rejection. It is expected that there will be only minimal instances in which the GT rejects the SHO. Based upon the specific error code, the NCCDS scheduling operator will continue attempts to obtain support.

10.4.3 Real-Time Customer Platform Emergency Operations

As far as the GTs and the NCCDS are concerned, the use and processing of the MOCC reconfiguration GCMRs is the same for both normal and emergency real-time

operations. During a customer platform emergency operation, the MOCC may send a series of command messages to its customer platform to perform the troubleshooting and procedures necessary to correct the emergency condition. These messages could include channel data rate changes and may require corresponding changes within the TDRSS channel configurations. A MOCC can issue a GCMR to the NCCDS requesting a TDRSS real-time reconfiguration to support such unplanned channel data rate changes. After receipt of the corresponding OPM from the NCCDS, the GTs will nominally respond and complete the requested reconfiguration in less than 35 seconds, (refer to Table 10-12 under "Messages from the NCCDS to the GTs" for additional constraints). An OPM 62 status will be sent by the GT upon reconfiguration GCM completion.

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Appendix A. Example Link Calculations

A.1 General

This appendix contains example link calculations for forward and return services. All link calculations are based on the TDRSS telecommunications services defined in Sections 5 (MA), 6 (SSA), 7 (KuSA), and 8 (KaSA).

NOTE:

> The calculations in this appendix are provided for example only, and no data should be extracted from them for specific use. For specifics on preparing necessary RFICD's, contact GSFC Code 450.

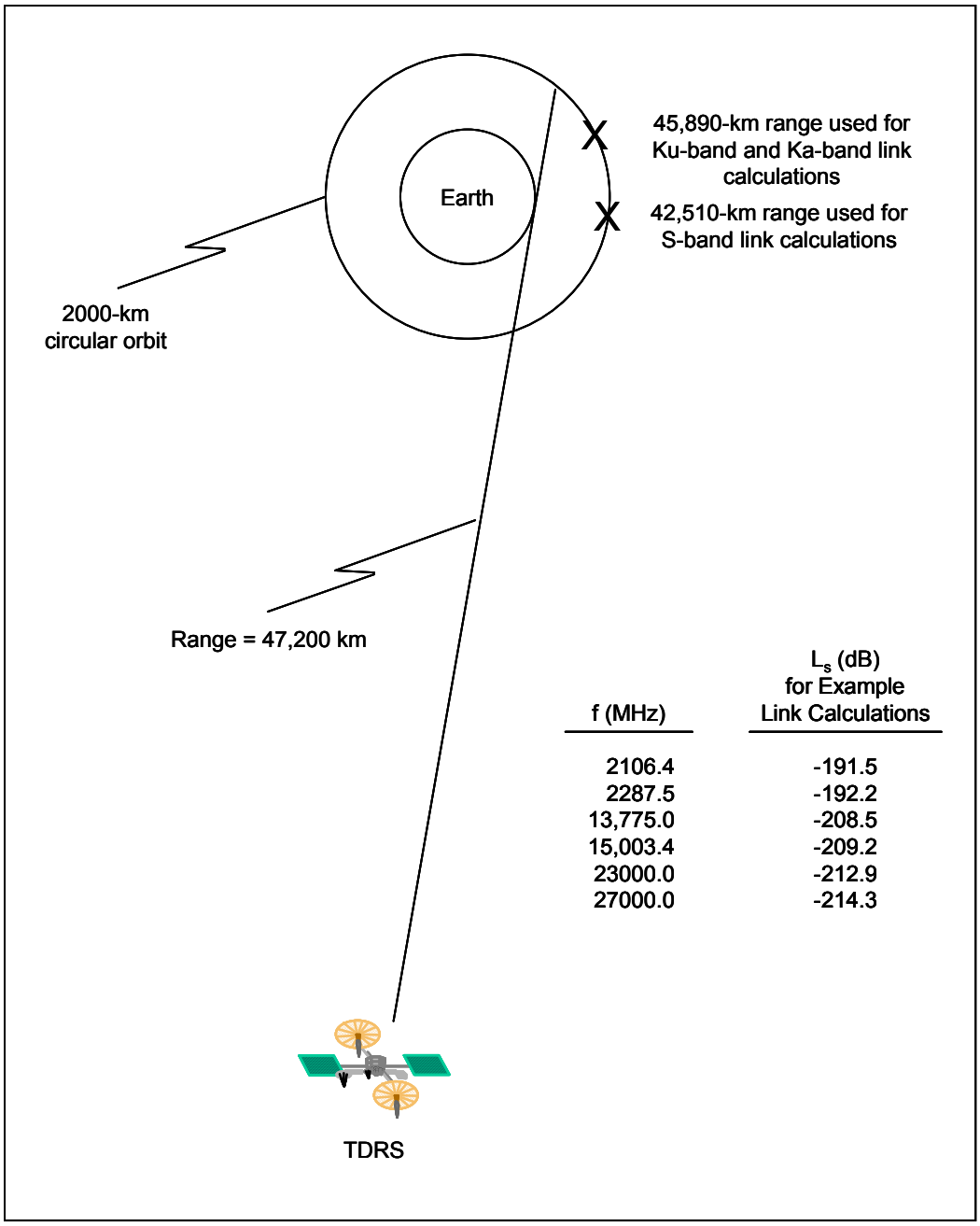
A.2 Customer Platform-to-TDRS Range

All forward and return service link calculations are based upon example customer platform-to-TDRS ranges of 42,510 km for S-band and 45,890 km for K-band (Ku and Ka). Figure A-1 illustrates the example communications range positions for a 2000-km customer platform orbit. The maximum communications ranges for particular customer platforms can differ from these values as a result of the actual orbit, Power Flux Density (PFD) constraints (refer to Appendix D), or other customer mission requirements and constraints.

A.3 Forward Service Link Calculations

A.3.1

Forward service performance is expressed in terms of having a sufficient data Bit Energy to Noise Spectral Density Ratio (E_b/N_o) at the customer platform receiving system for the desired link operating point (e.g., command data channel BER of 10^{-5}). Forward service performance is determined by calculating a predicted (E_b/N_o) and comparing it against the required (E_b/N_o).



f (MHz)	L_s (dB) for Example Link Calculations
2106.4	-191.5
2287.5	-192.2
13,775.0	-208.5
15,003.4	-209.2
23000.0	-212.9
27000.0	-214.3

Figure A-1. Geometry Depicting Nominal Ranges Used for Example Link Calculations

A.3.2

Forward service link calculations are based on the TDRS EIRPs and the transmitting antenna axial ratios shown in Tables 5-2 (MA), 6-3 (SSA), 7-2 (KuSA), and 8-2 (KaSA), the customer platform receiving system characteristics, the link operating frequency, and the customer platform-to-TDRS range. The following procedure may be used to determine the performance of the forward service command channel:

Equation A-1

$$\frac{P_{rec}}{N_o} = EIRP + L_s + L_p + L_\theta + (G/T) - 10\log(k)$$

where:

EIRP = The total TDRS EIRP in the direction of the customer platform (fixed by TDRS performance specification). The EIRP in the data channel is a function of the modulation type and the modulation index. The EIRP in the data channel is:

$EIRP_{data}$ (dBW) = EIRP – 0.4 (UQPSK when the baud rate ≤ 300 kbps)

$EIRP_{data}$ (dBW) = EIRP (BPSK and when baud rate > 300 kbps)

$EIRP_{data}$ (dBW) = EIRP $-20\log_{10}(\sin(mi))$ (SSA direct PM)

$EIRP_{data}$ (dBW) $= EIRP - 20\log_{10}(\sqrt{2} * J1(mi)) \cdot$ (SSA PSK sine - wave subcarrier PM)

$EIRP_{carrier}$ (dBW) = EIRP $-20\log_{10}(\cos(mi))$ (SSA direct PM)

$EIRP_{carrier}$ (dBW) = EIRP $-20\log_{10}(J0(mi))$ (SSA PSK subcarrier PM)

where mi is the modulation index, J1 is the first order Bessel function, J0 is the zero order Bessel function.

L_s = space loss (in dB) = $-[32.45 + 20 \log_{10} (R) + 20 \log_{10} (f)]$, ($L_s < 0$ dB).

R = maximum range (in km) between the TDRS and the customer platform over which communications will occur.

f = TDRS transmission frequency (in MHz).

L_p = polarization loss (in dB) due to the mismatch of the TDRS radiated polarization and that of the customer platform receiving antenna ($L_p \leq 0$ dB).

L_θ = pointing loss (in dB) in the customer platform received signal due to inability of the customer platform to point its receiving antenna directly at the TDRS ($L_\theta \leq 0$ dB).

G/T = customer platform receiving antenna gain to system thermal noise temperature ratio (in dB/K).

10 log (k) = -228.6 dBW/Hz-K (k is Boltzmann's constant).

Equation A-2

$$(E_b/N_o)_{predicted} = P_{rec}/N_o - 10 \log R_d + \gamma$$

where:

R_d	=	data rate in bps
γ	=	sum of customer platform receiving system and TDRSS forward service degradation factors (in dB), accounting for non-ideal degradations such as PN loss, demodulator degradation, bit sync loss, interference and multipath degradations, and distortion losses ($\gamma \leq 0$ dB).

Equation A-3

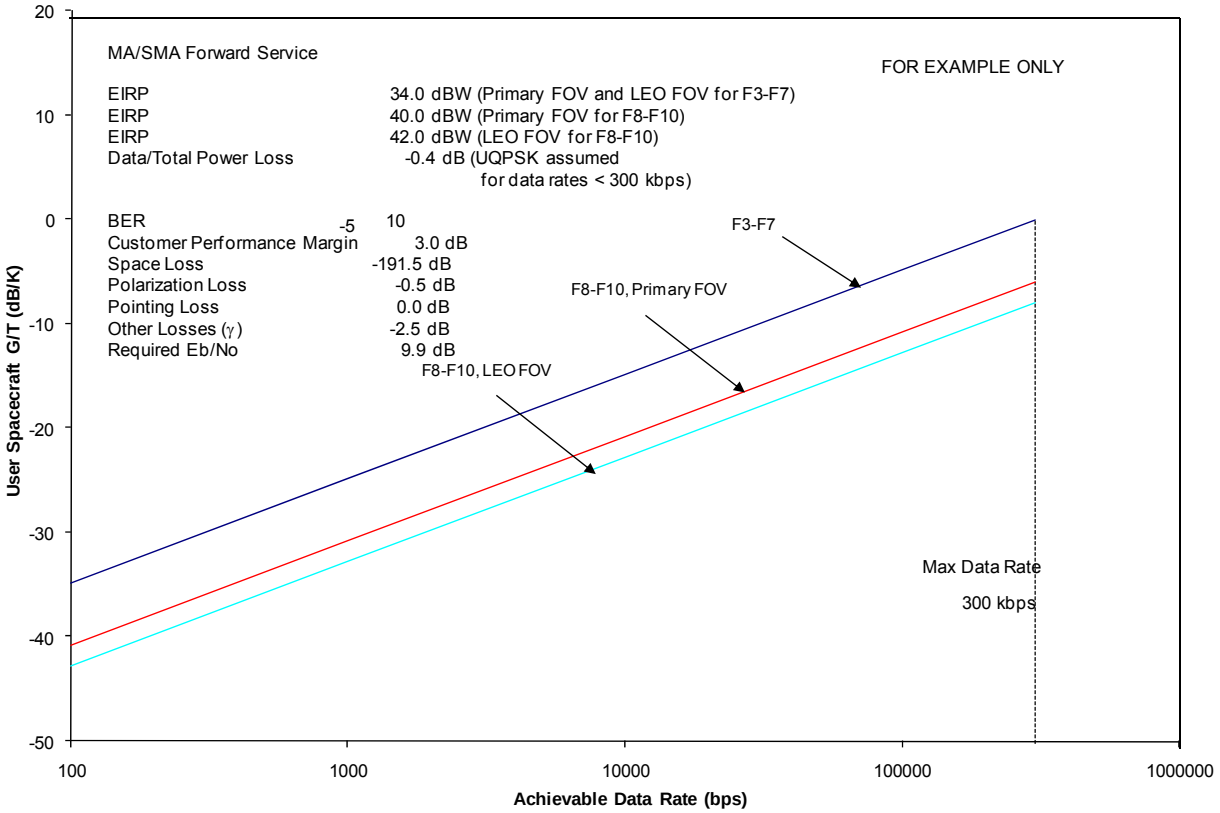
$$M = (E_b/N_o)_{predicted} - (E_b/N_o)_{required}$$

where:

M	=	customer performance margin (in dB) to allow for customer platform performance degradation throughout its operational lifetime ($M \geq 0$ dB).
$(E_b/N_o)_{required}$	=	the bit energy to noise spectral density ratio in (dB) theoretically required for the command data BER (e.g., 9.9 dB for a 10^{-5} BER with coherent differential PSK).

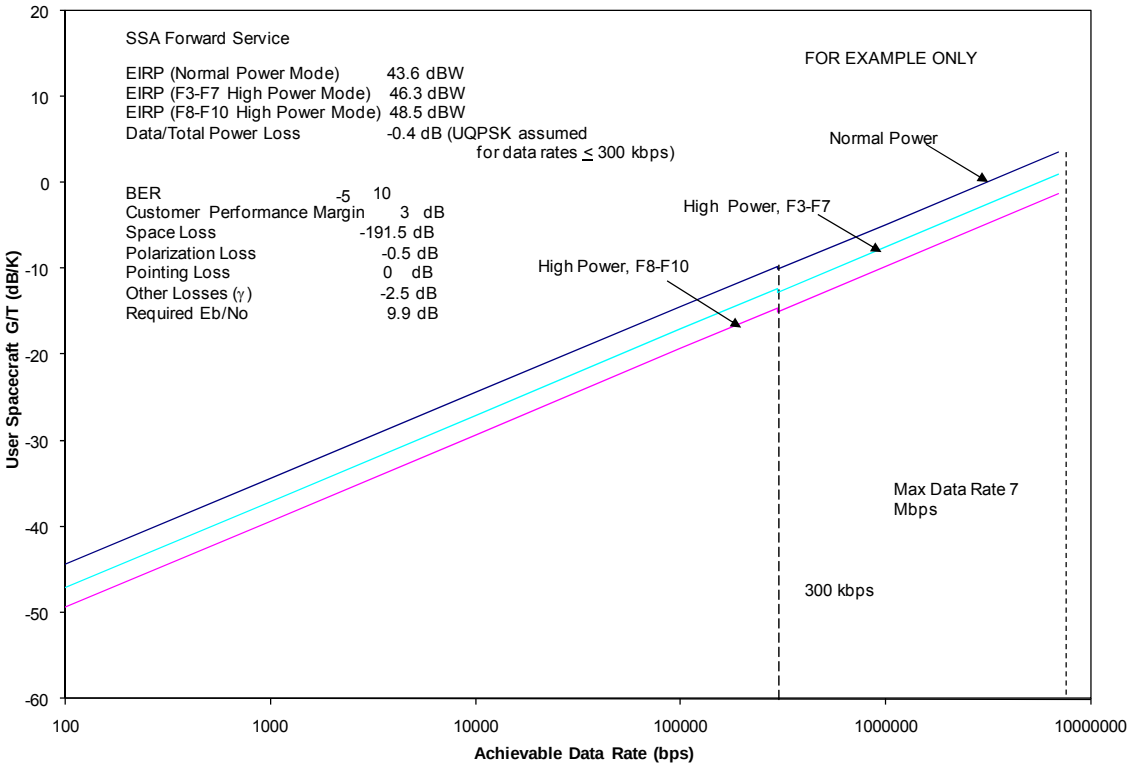
The forward service performance curves in Figure A-2 through Figure A-7 are <u>for example only</u> and show Achievable Data Rate (ADR) versus customer platform G/T for the command data channel. The ADR equation is derived by solving Equation A-1, Equation A-2, and Equation A-3 for 10 log R_d and using the values of the equation parameters defined in the appropriate figure, and the following assumptions:

a. The margin (M) is assumed constant at 3 dB – the amount of margin is a customer decision that should be coordinated with GSFC Code 450 and should consider long-term degradations in the customer platform.



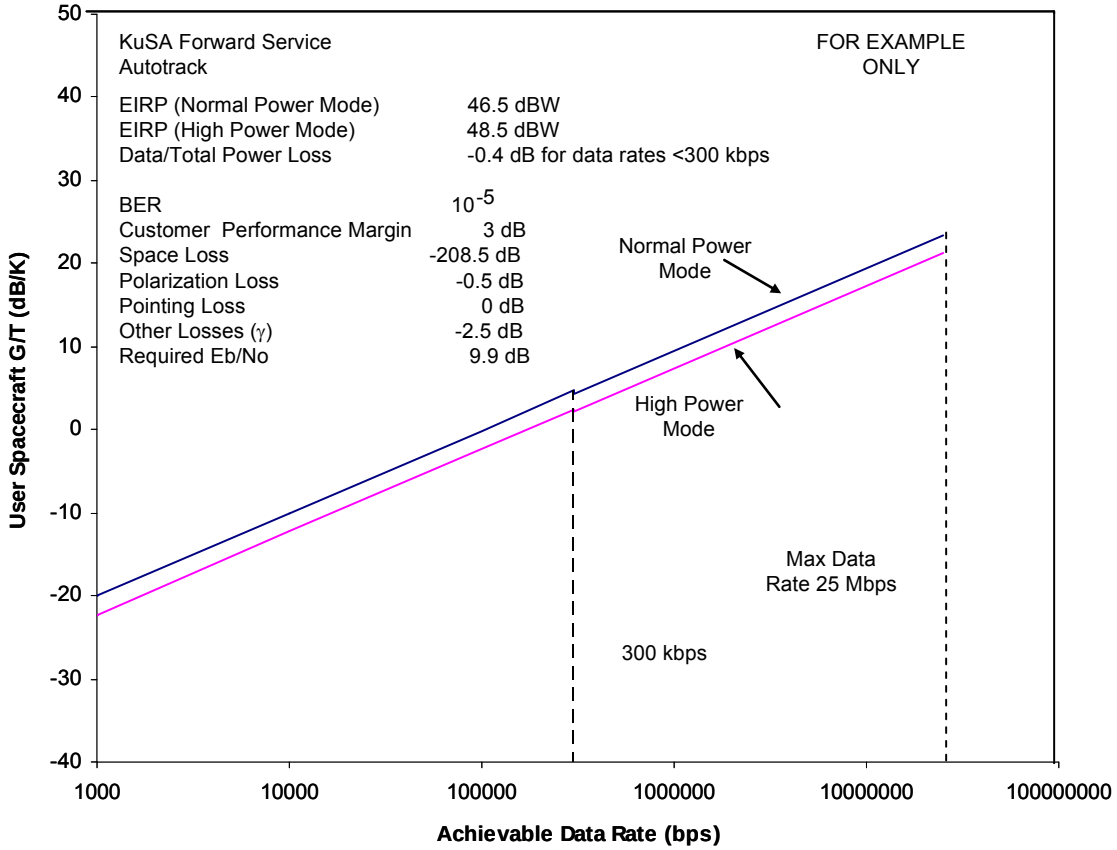
Note: Data/Total Power Loss assumes UQPSK for data rates ≤ 300 kbps

Figure A-2. MA/SMA Forward ADR versus G/T



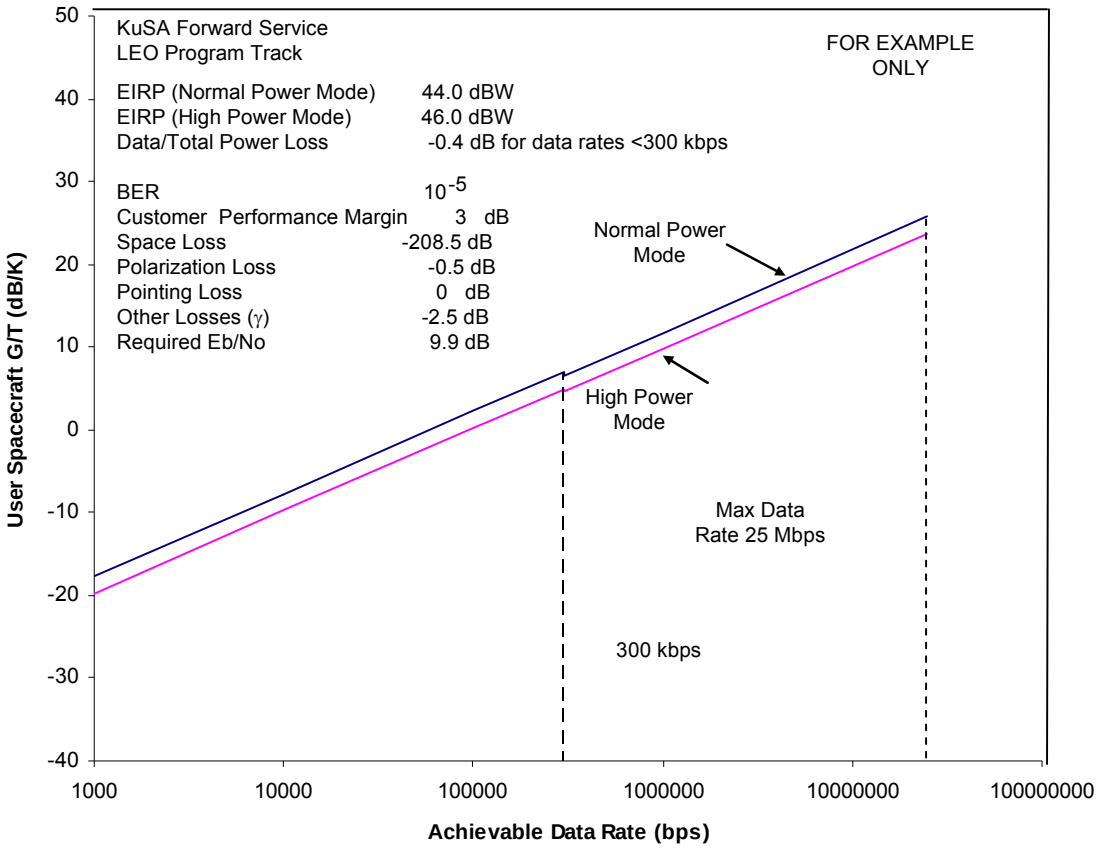
Note: Data/Total Power Loss assumes UQPSK for data rates ≤ 300 kbps

Figure A-3. SSA Forward ADR versus G/T for F3-F10



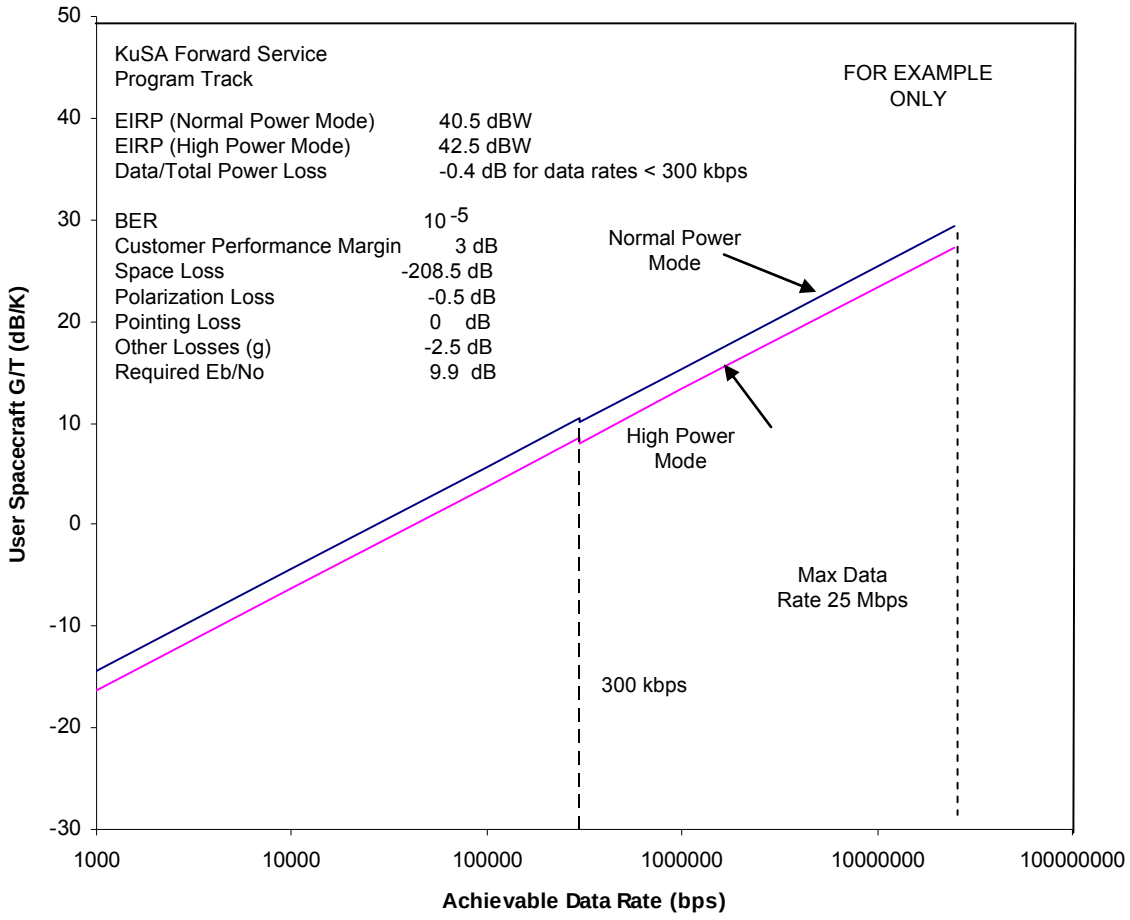
Note: Data/Total Power Loss assumes UQPSK for data rates ≤ 300 kbps

Figure A-4. KuSA Forward ADR versus G/T (Autotrack for F3-F10)



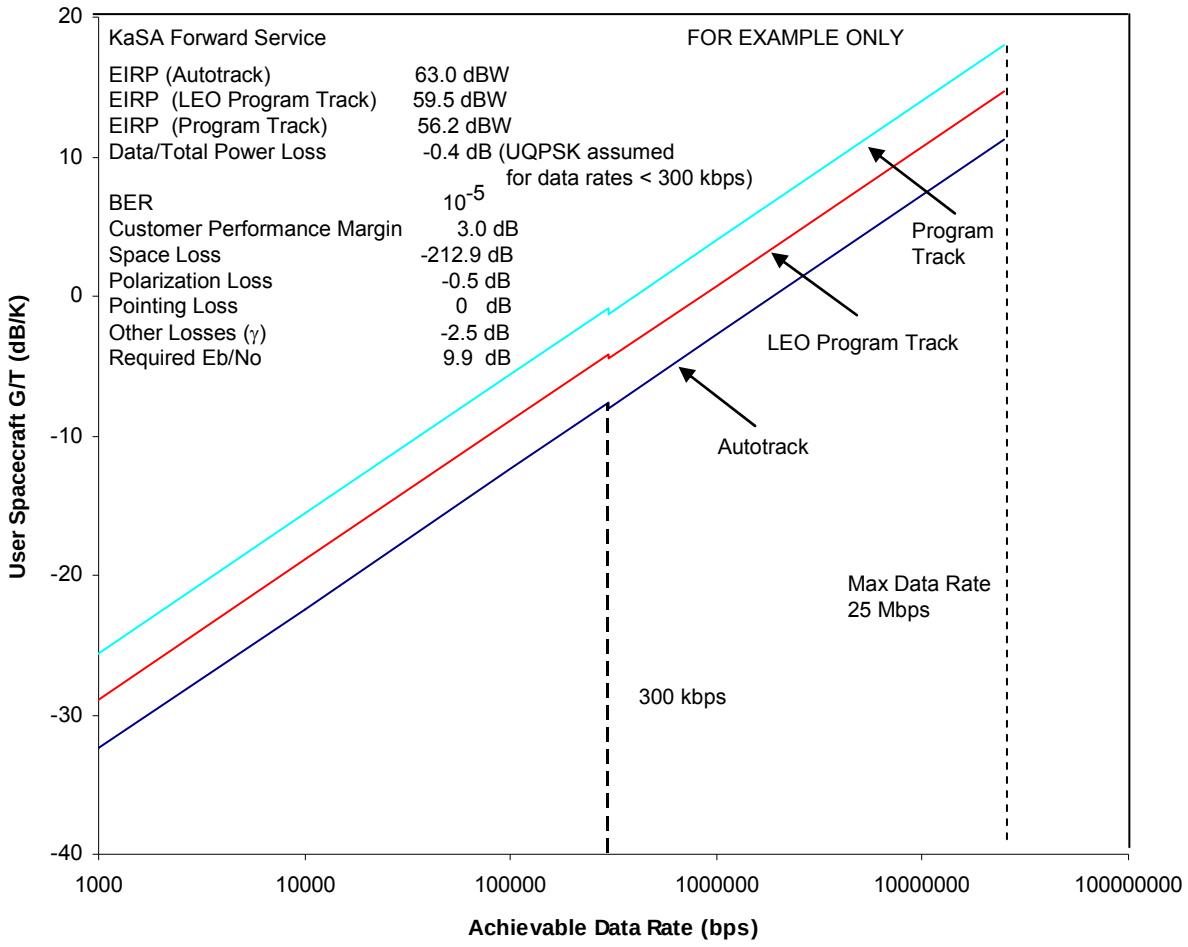
Note: Data/Total Power Loss assumes UQPSK for data rates ≤ 300 kbps

Figure A-5. KuSA Forward ADR versus G/T (LEO Program Track for F3-F10)



Note: Data/Total Power Loss assumes UQPSK for data rates ≤ 300 kbps

Figure A-6. KuSA Forward ADR versus G/T (Program Track for F3-F10)



Note: Data/Total Power Loss assumes UQPSK for data rates ≤ 300 kbps

Figure A-7. KaSA Forward ADR versus G/T (F8-F10)

b. Required E_b/N_o is 9.9 dB (BER of 10^{-5}).

The SSA and KuSA forward services are provided both with normal mode and high mode EIRP.

Customer platform/TDRSS incompatibility and RFI degradation (see paragraph A.3.3 below) is 0 dB.

A.3.3

CLASS is used to determine if any incompatibility or RFI degradation exists between the customer platform's receiving system terminal and the TDRSS. Detailed characteristics of the customer platform receiving system and the salient characteristics of the TDRSS forward services determine the magnitude of any compatibility loss. When applicable, these degradation factors, as determined by CLASS, must be included as loss terms on the right side of Equation A-1.

A.4 Return Service Link Calculations

A.4.1

Return service performance is expressed in terms of having sufficient received power (P_{rec}) at the TDRS to achieve a specific data rate (referred to as ADR) for a return service data channel BER of 10^{-5}. The received power (P_{rec}) at the TDRS is defined as the "Unity" Power Received at the Input to TDRS (i.e., with a TDRS gain of 0 dBi). Customers do not need to understand the details of the TDRS, TDRS-to-ground terminal link, and the ground terminal specifics for link margin performance.

Return service performance is determined by calculating the predicted required P_{rec} at a TDRS (accounting for all system losses), and comparing it to the ideal required P_{rec} at the TDRS for a given data rate.

A.4.2

The ideal required P_{rec} is determined as follows:

Equation A-4

$$\text{Ideal required } P_{rec} = 10 \log_{10} R_d + K$$

where: K is a constant depending on the service, type of tracking and/or field of view, coding, data rate, and mode. These relationships are as shown in Tables 5-8 (MA), 6-9 (SSA), 7-7 (KuSA), and 8-7 (KaSA).

A.4.3

The predicted required P_{rec} is determined by the following equation:

Equation A-5

$$\text{Predicted Required } P_{rec} = \text{Ideal Required } P_{rec} - L_\theta - L_p - L_I - L_{nc}$$

where:

L_θ	=	pointing loss (in dB) due to the inability of the customer platform to point its antenna directly at the TDRS ($L_\theta \leq 0$ dB).
L_p	=	polarization loss (in dB) due to mismatch of the customer platform radiated polarization and that of the TDRS receiving antenna ($L_P \leq 0$ dB).
L_I, L_{nc}	=	RFI and customer platform incompatibility factors (in dB) as determined by CLASS (refer to paragraph 3.5.2) ($L_I \leq 0$ dB, $L_{nc} \leq 0$ dB).

A.4.4

By extension, the minimum customer platform EIRP, $(EIRP)_{min}$, required to produce the predicted required P_{rec} is as follows:

Equation A-6

$$(EIRP)_{min} = \text{Predicted Required } P_{rec} - L_s$$

where: L_s is space loss as defined in paragraph A.3.2.

A.4.5

The return service performance margin M (in dB) is a customer decision that should be coordinated with GSFC Code 450 and should consider long-term performance degradation of the customer platform throughout its operational lifetime. M is defined as follows:

Equation A-7

$$M = EIRP - (EIRP)_{min} \qquad (M \geq 0 \text{ dB})$$

A.4.6

The return service performance curves in Figure A-8 through Figure A-42 show ideal required (P_{rec}) versus ADR for selected services, type of tracking and/or field of view, codings, modes, data rates and channels. Figure A-43 shows an example ADR versus customer platform EIRP for a hypothetical customer platform, for an assumed performance margin, M, as illustrated in Equation A-7. The service, coding, mode, and channel in Figure A-43 are assumed to be those given in Figure A-15, so as to illustrate how the predicted required P_{rec} is realized, (or alternatively, how the ideal required P_{rec} plus performance margin is realized).

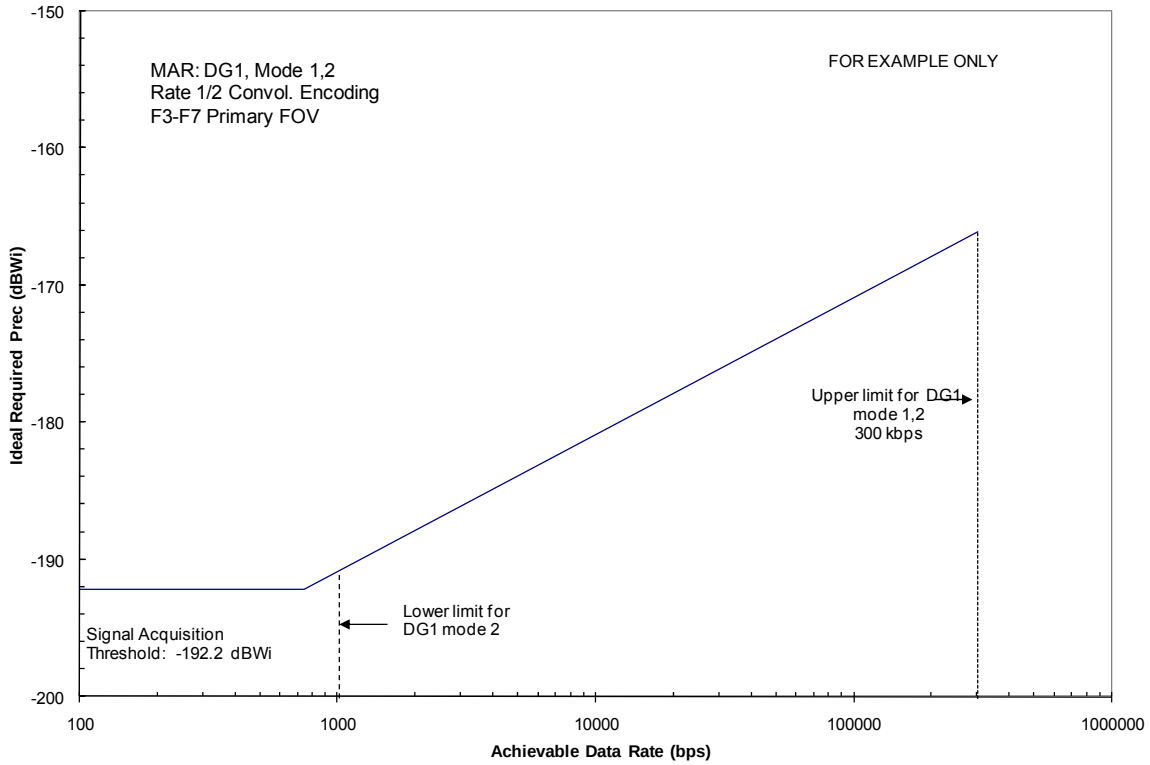


Figure A-8. MA DG1 Modes 1, 2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (Primary FOV for F3-F7)

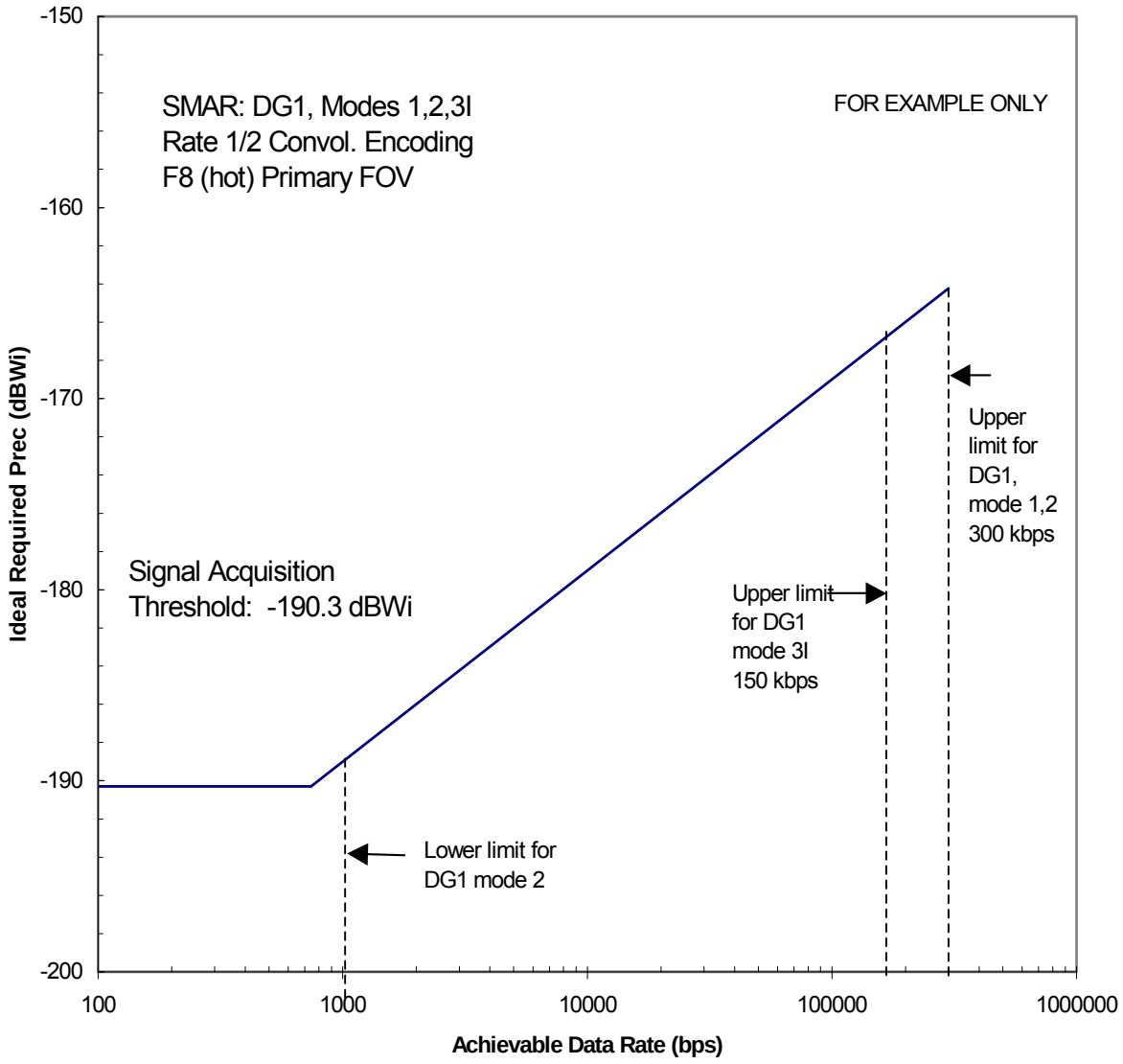


Figure A-9. SMA DG1 Modes 1, 2, 3I (Rate1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (Primary FOV for F8 (hot))

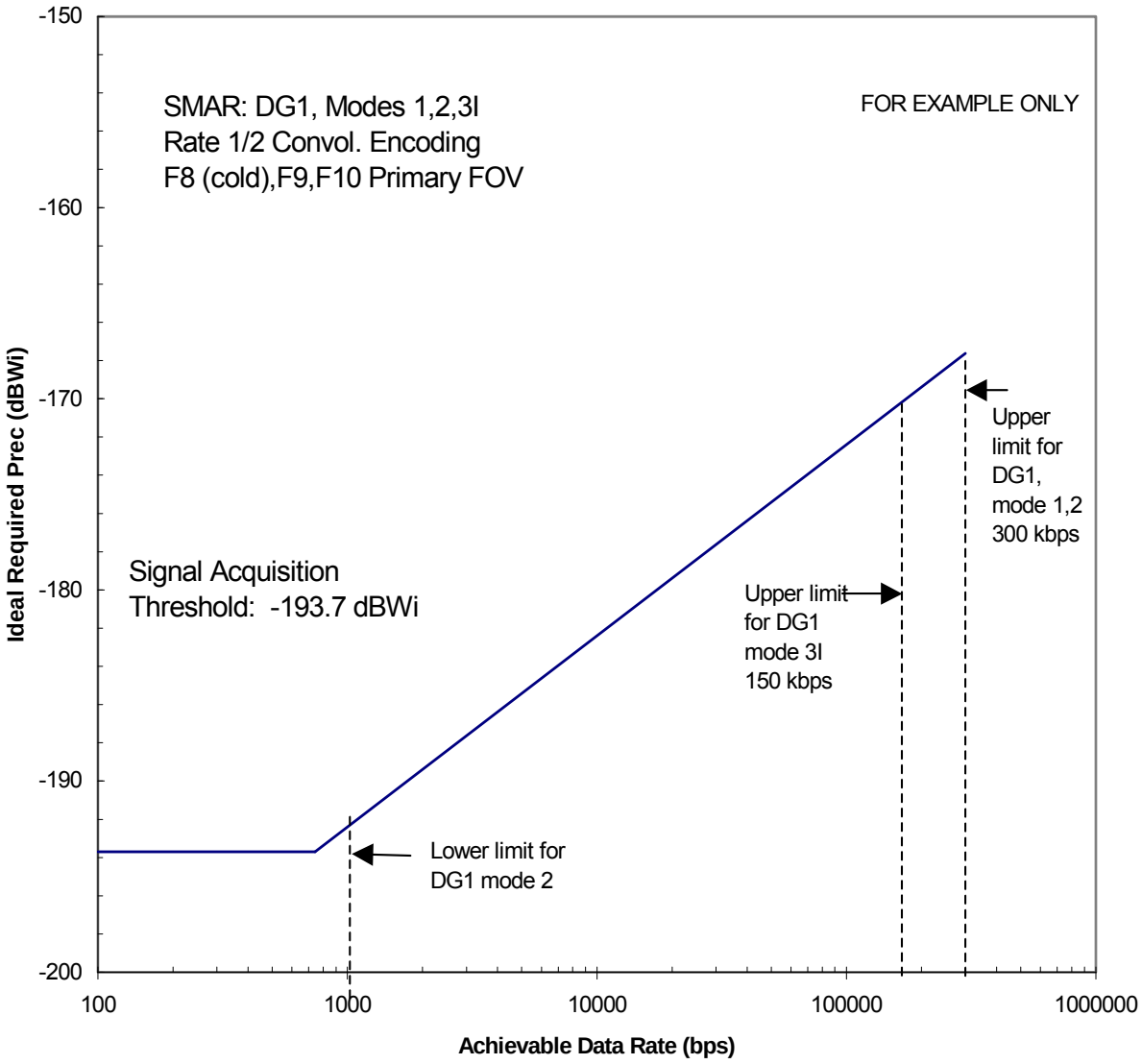


Figure A-10. SMA DG1 Modes 1, 2, 3I (Rate1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (Primary FOV for F8 (cold), F9, F10)

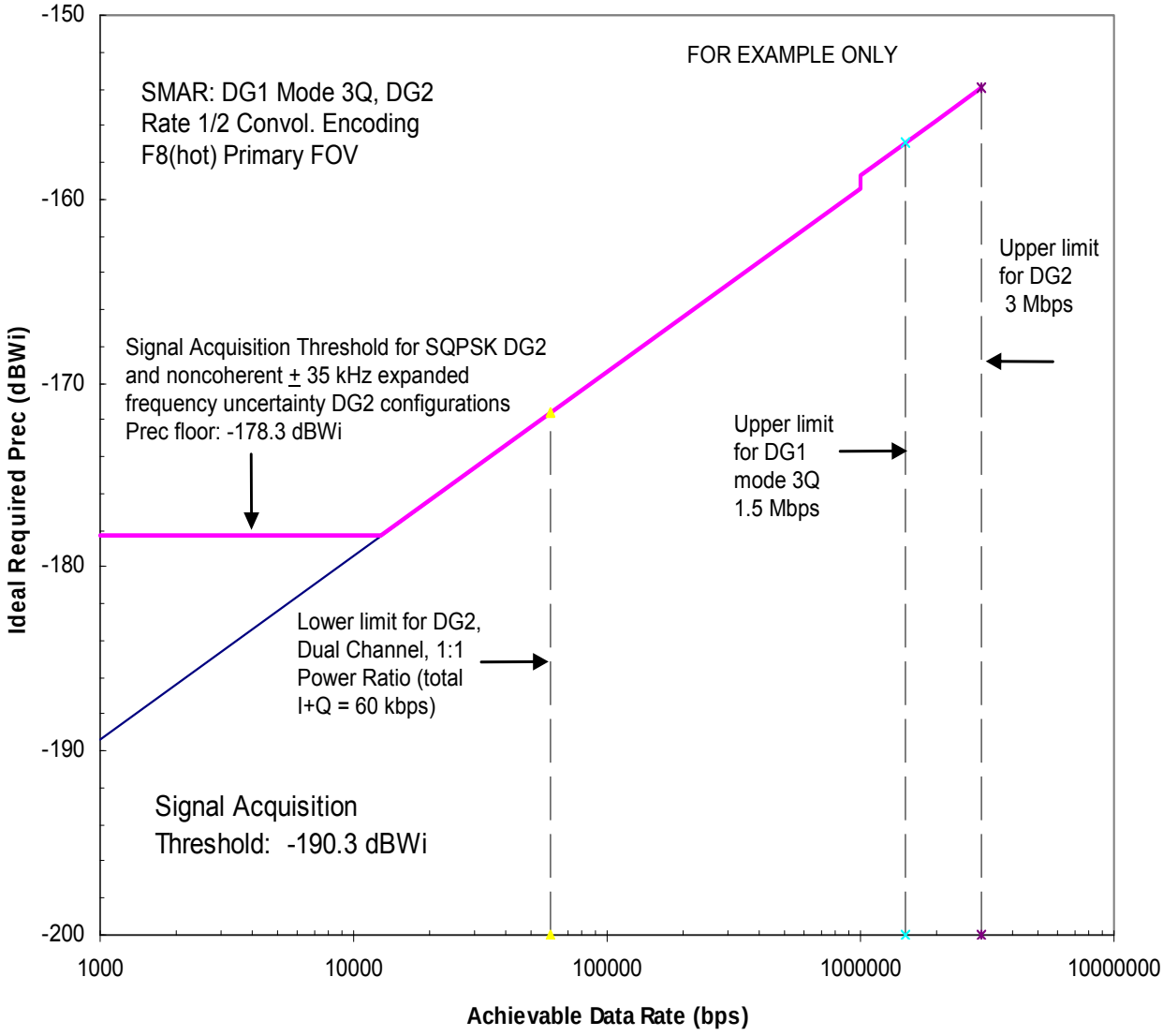


Figure A-11. SMA DG1 Mode 3Q and DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (Primary FOV for F8 (hot))

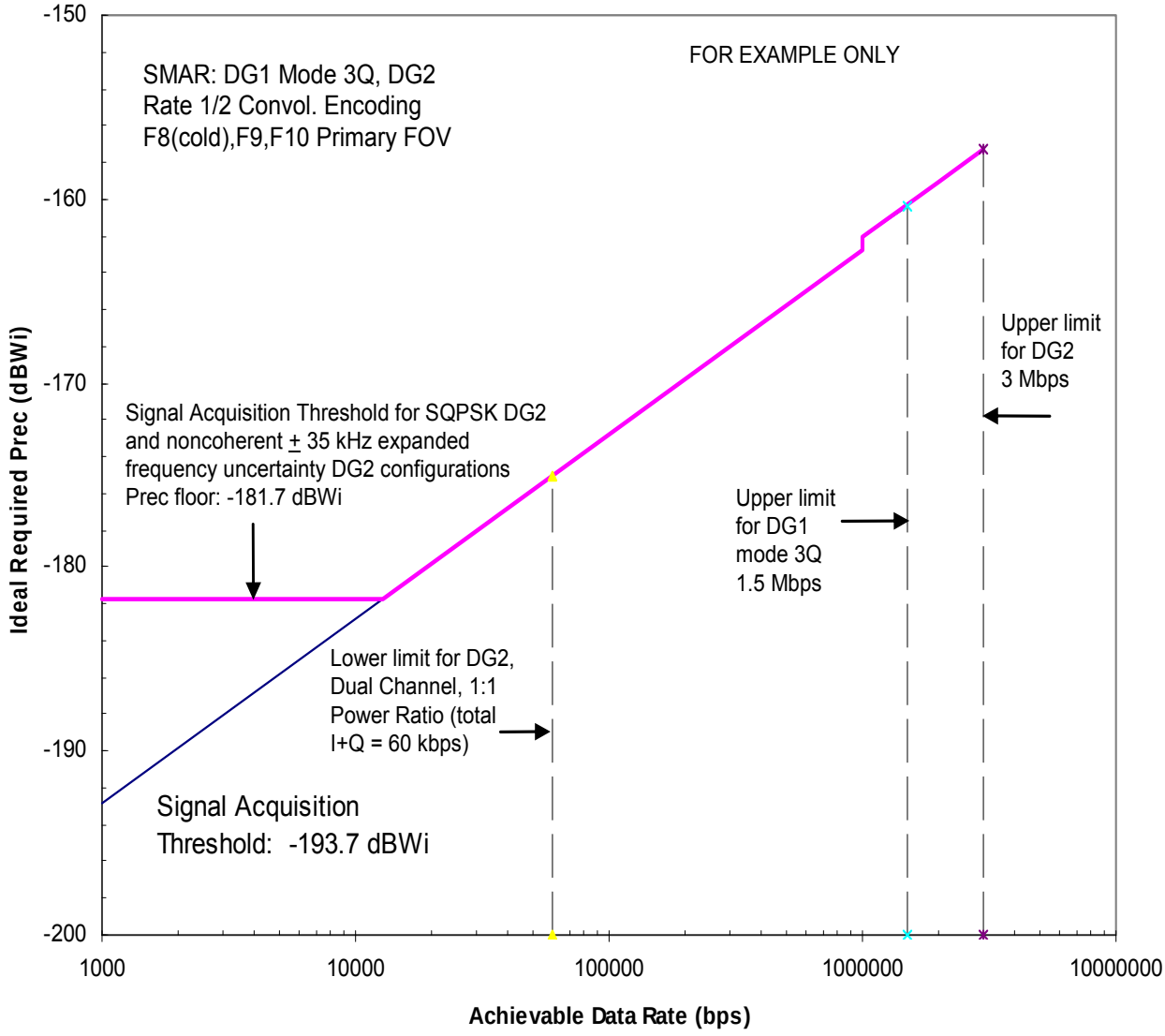


Figure A-12. SMA DG1 Mode 3Q and DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (Primary FOV for F8 (cold), F9, F10)

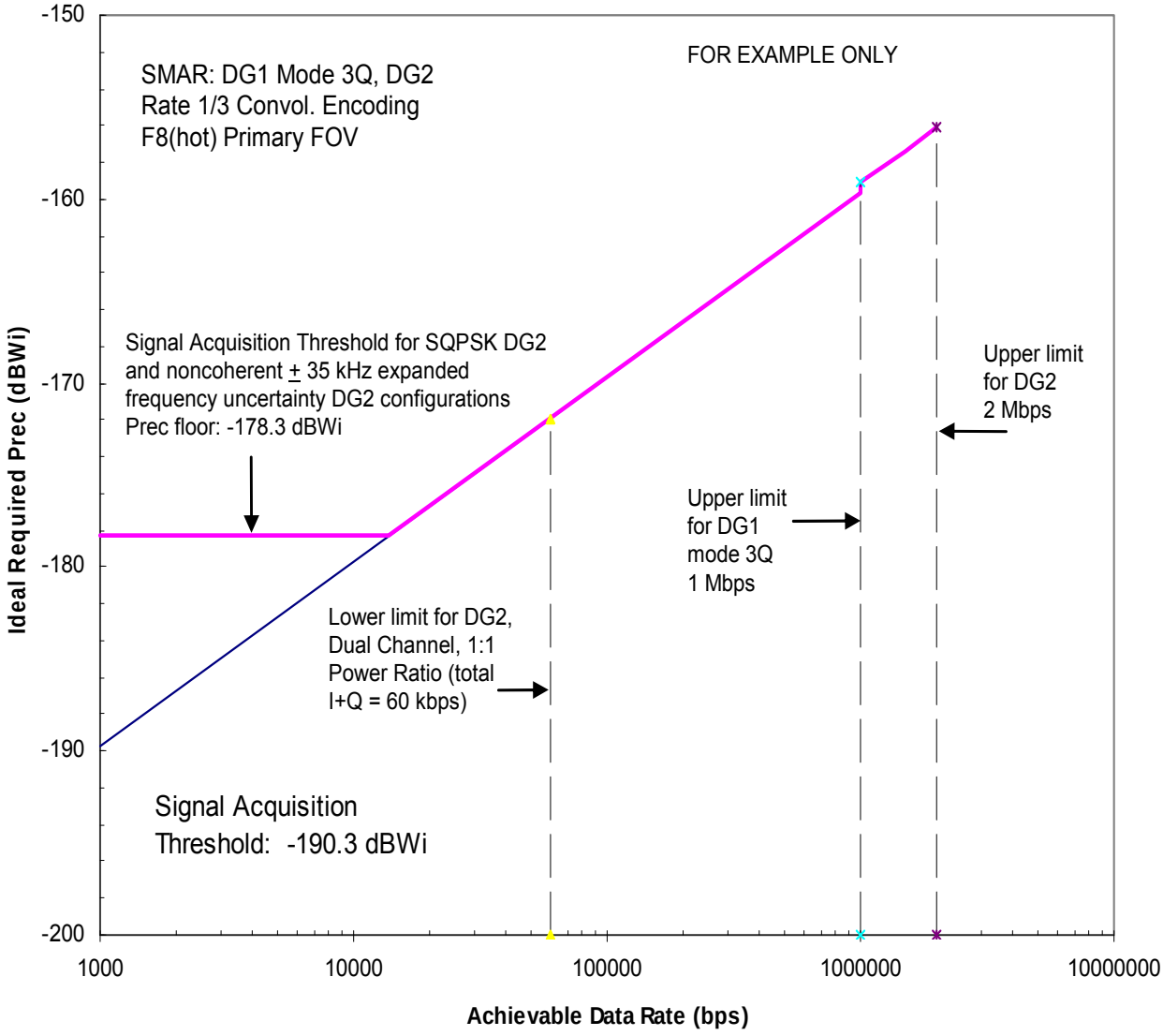


Figure A-13. SMA DG1 Mode 3Q and DG2 (Rate1/3) Return ADR versus Required Received Power at the TDRS (P_{rec}) (Primary FOV for F8 (hot))

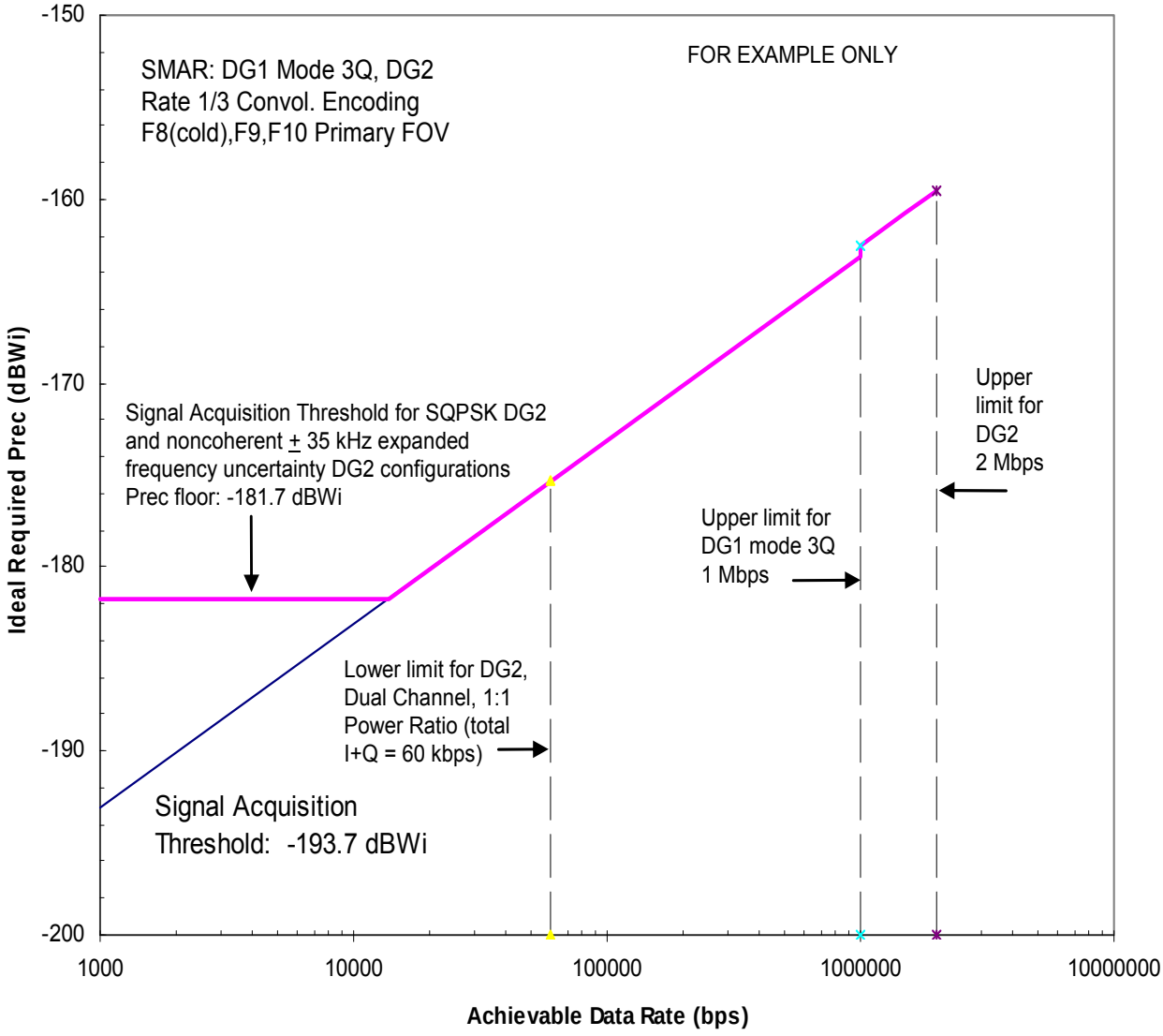


Figure A-14. SMA DG1 Mode 3Q and DG2 (Rate 1/3) Return ADR versus Required Received Power at the TDRS (Prec) (Primary FOV for F8 (cold), F9, F10)

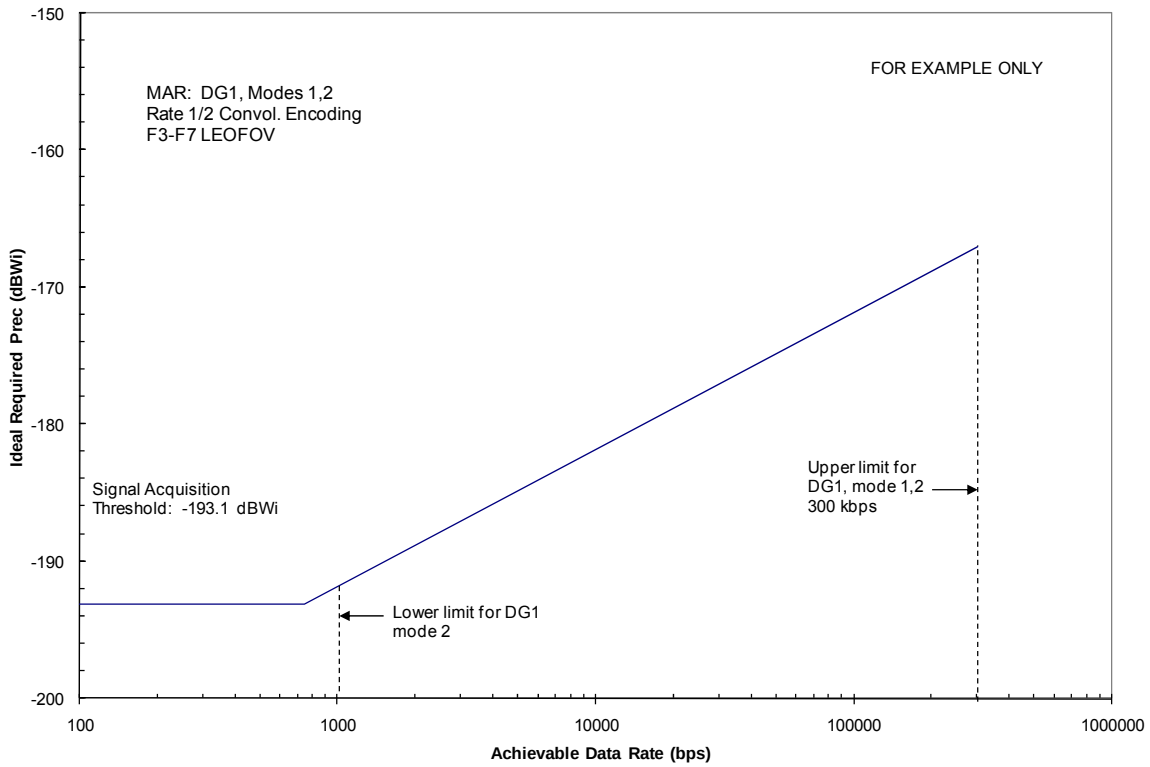


Figure A-15. MA DG1 Modes 1, 2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (LEOFOV for F3-F7)

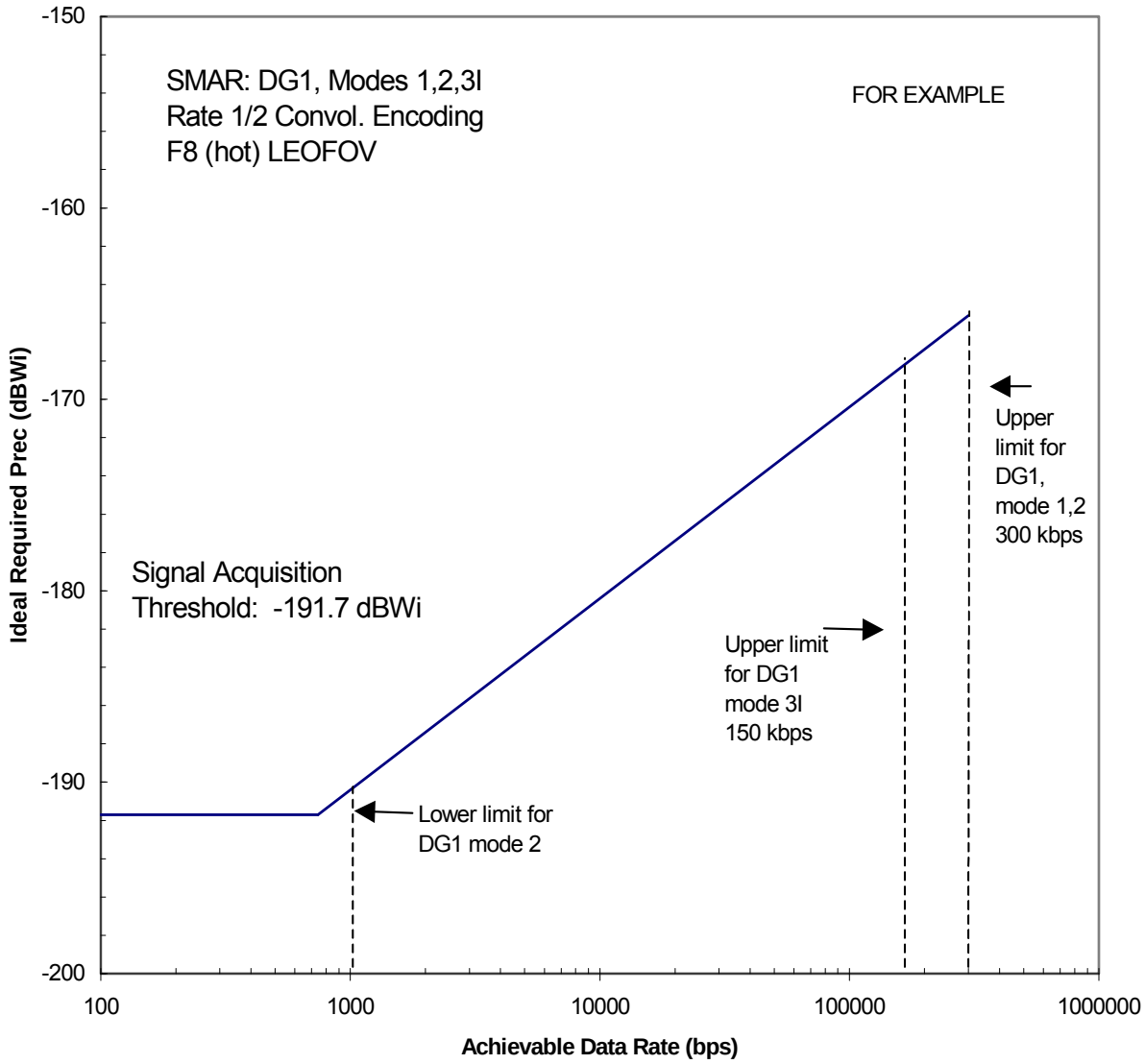


Figure A-16. SMA DG1 Modes 1, 2, 3I (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (LEOFOV for F8 (hot))

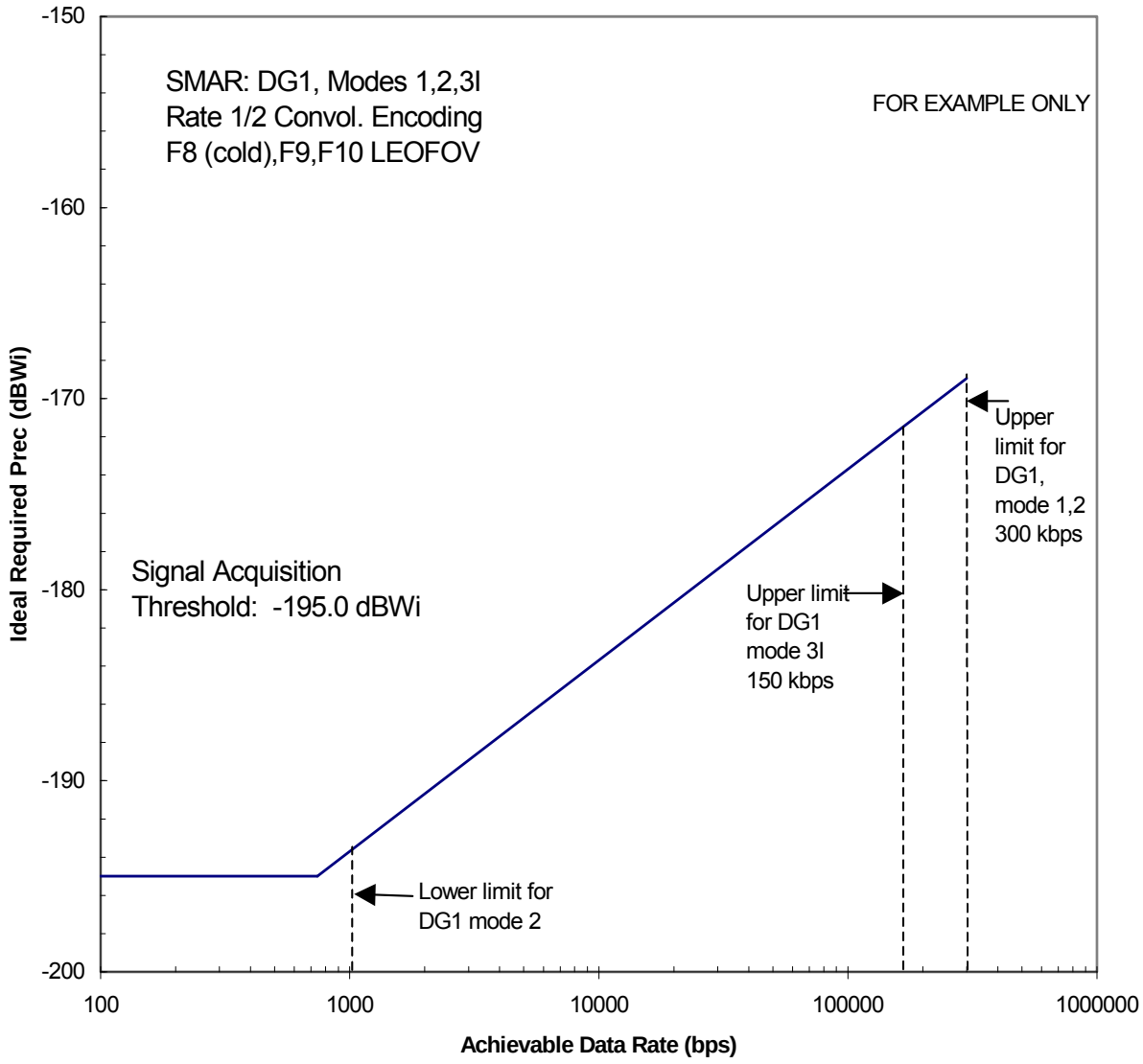


Figure A-17. SMA DG1 Modes 1, 2, 3I (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (LEOFOV for F8 (cold), F9, F10)

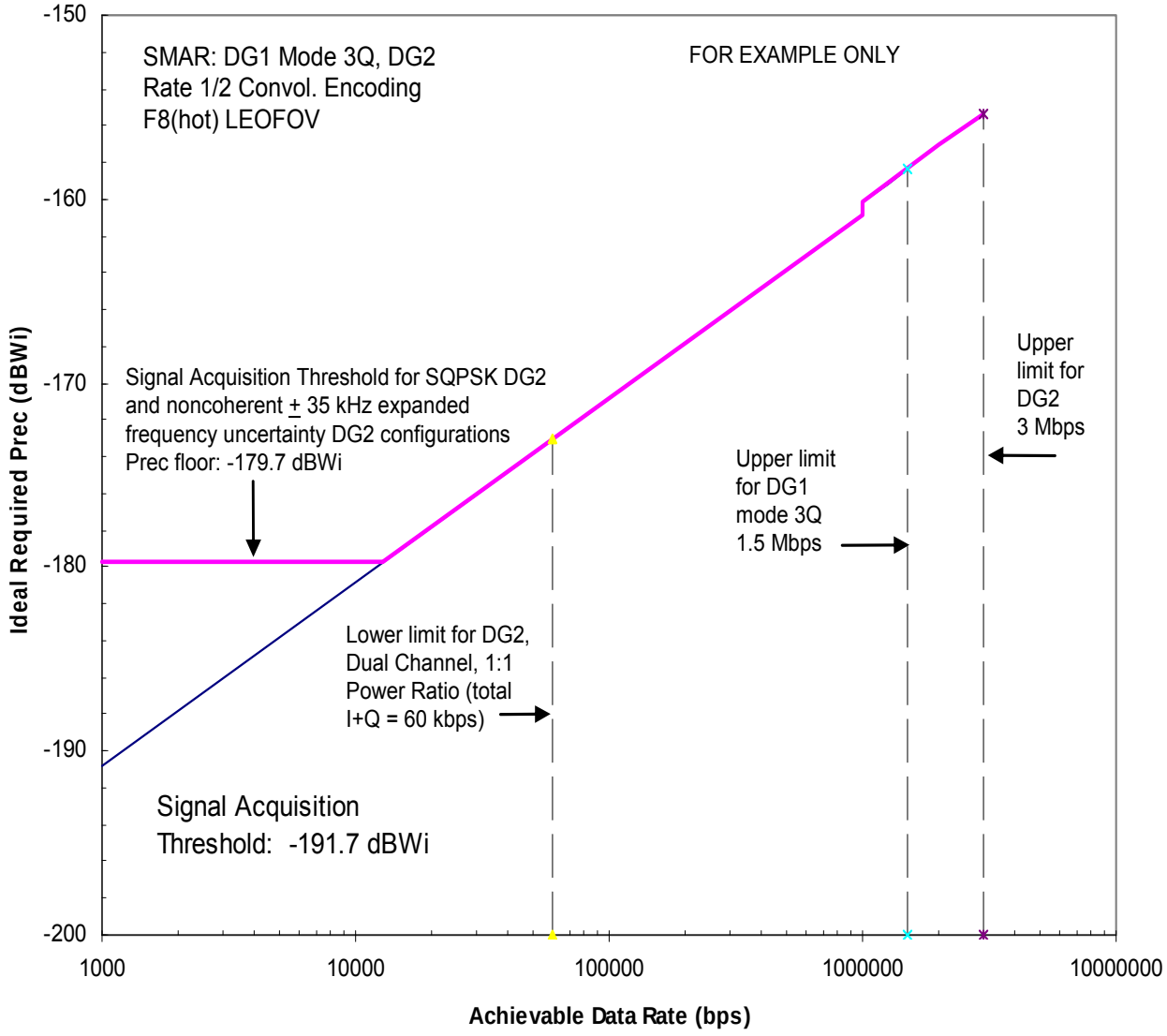


Figure A-18. SMA DG1 Mode 3Q and DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (LEOFOV for F8 (hot))

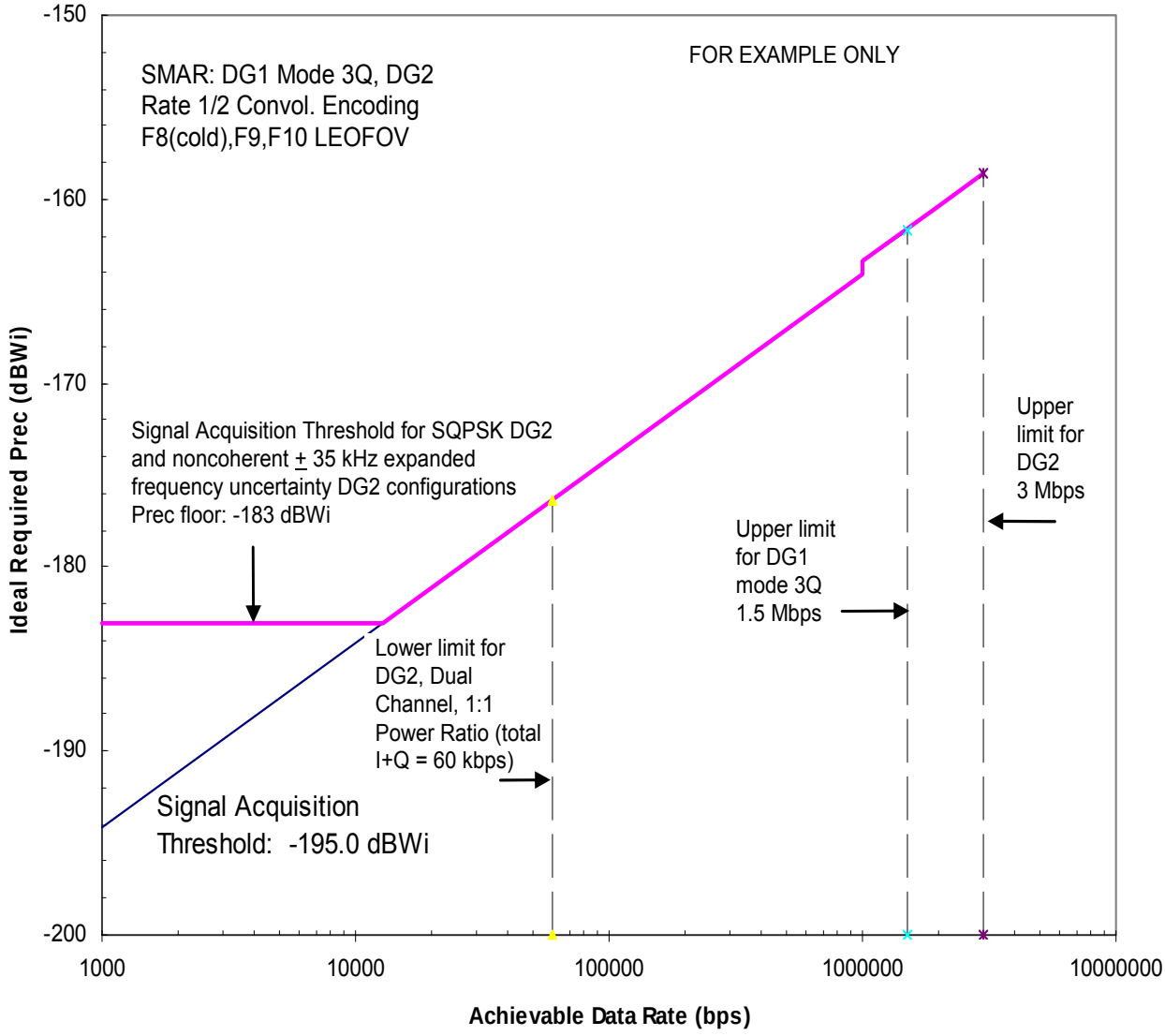


Figure A-19. SMA DG1 Mode 3Q and DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (LEOFOV for F8 (cold), F9, F10)

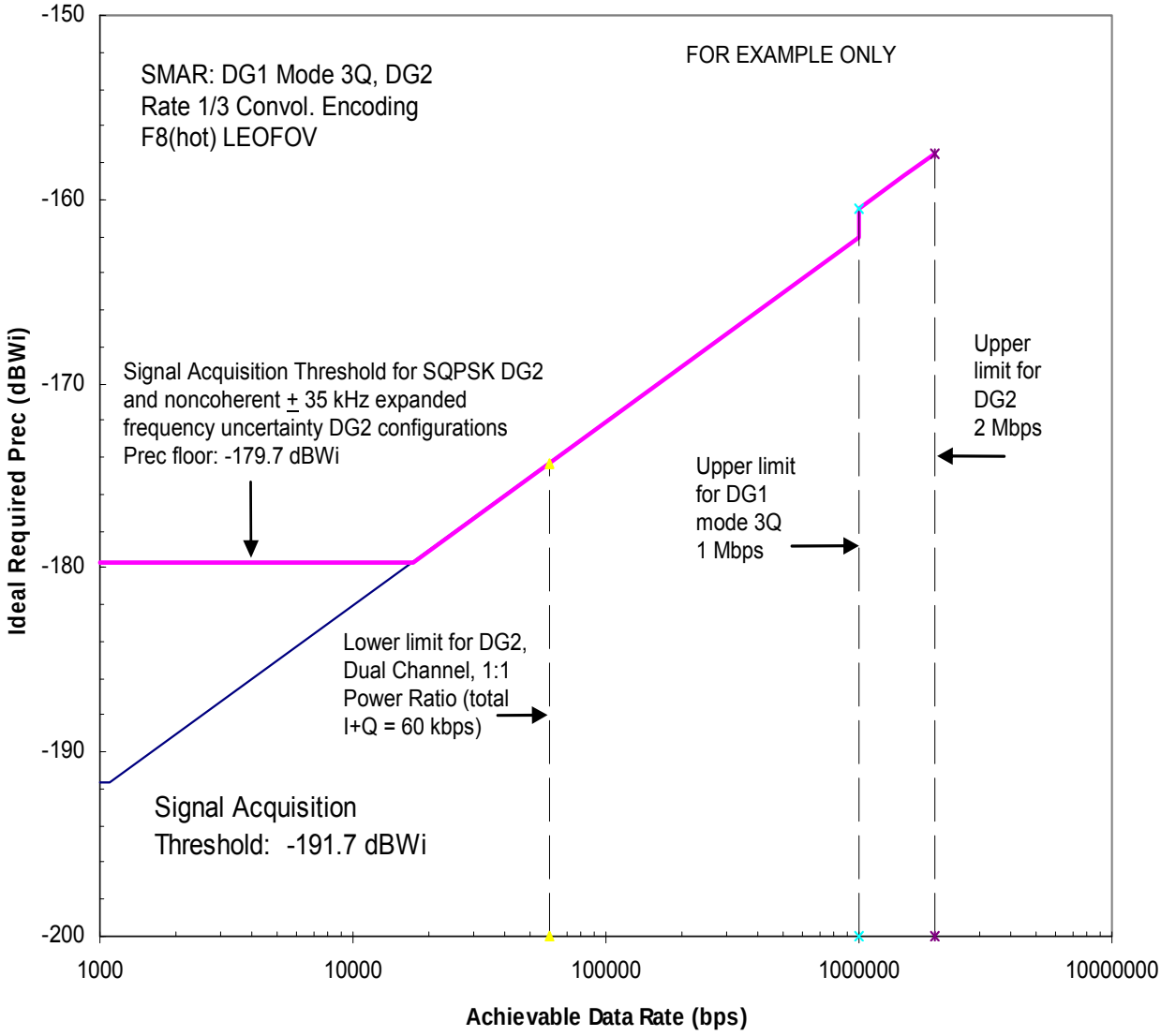


Figure A-20. SMA DG1 Mode 3Q and DG2 (Rate 1/3) Return ADR versus Required Received Power at the TDRS (P_{rec}) (LEOFOV for F8 (hot))

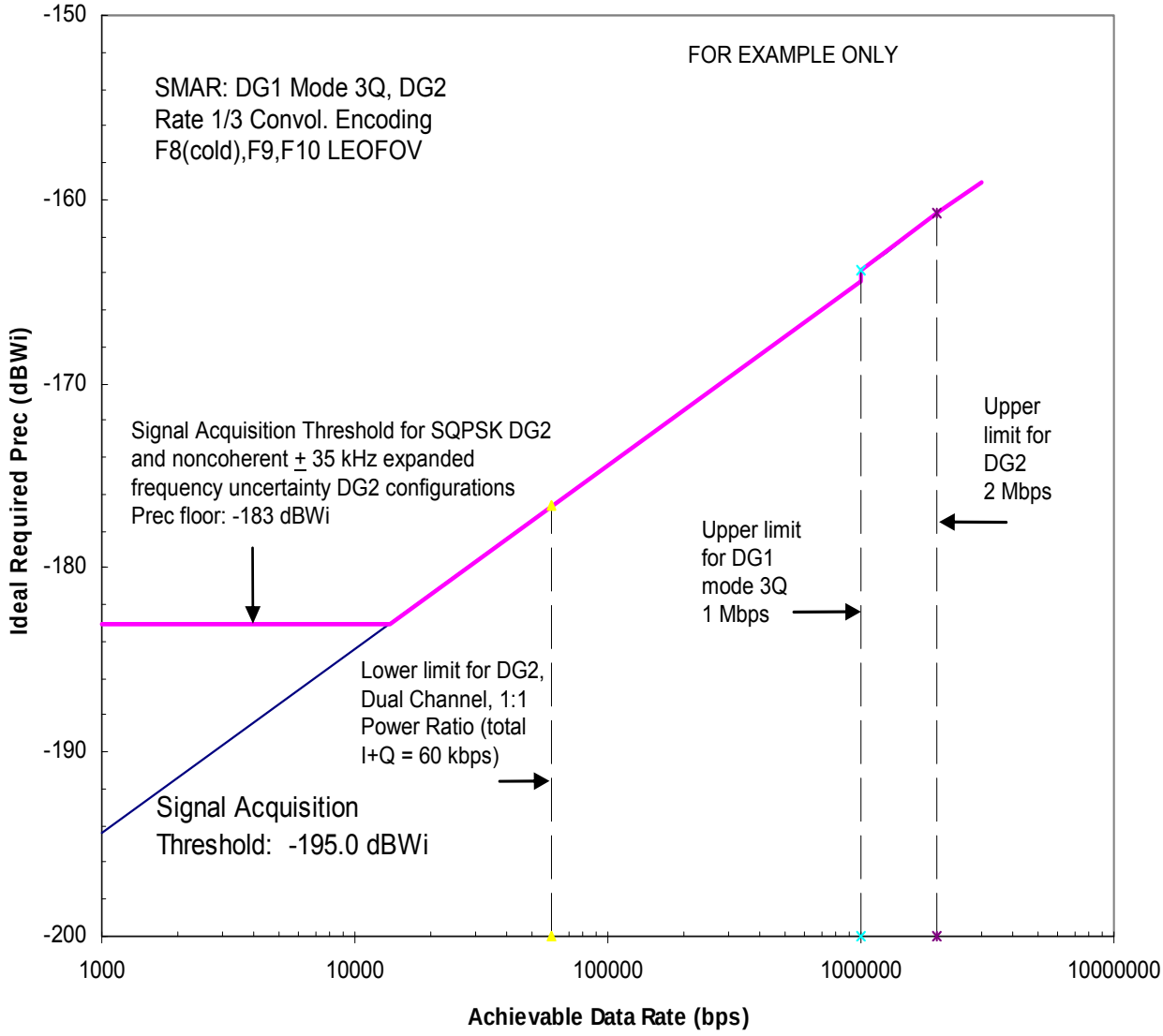


Figure A-21. SMA DG1 Mode 3Q and DG2 (Rate 1/3) Return ADR versus Required Received Power at the TDRS (P_{rec}) (LEOFOV for F8 (cold), F9, F10)

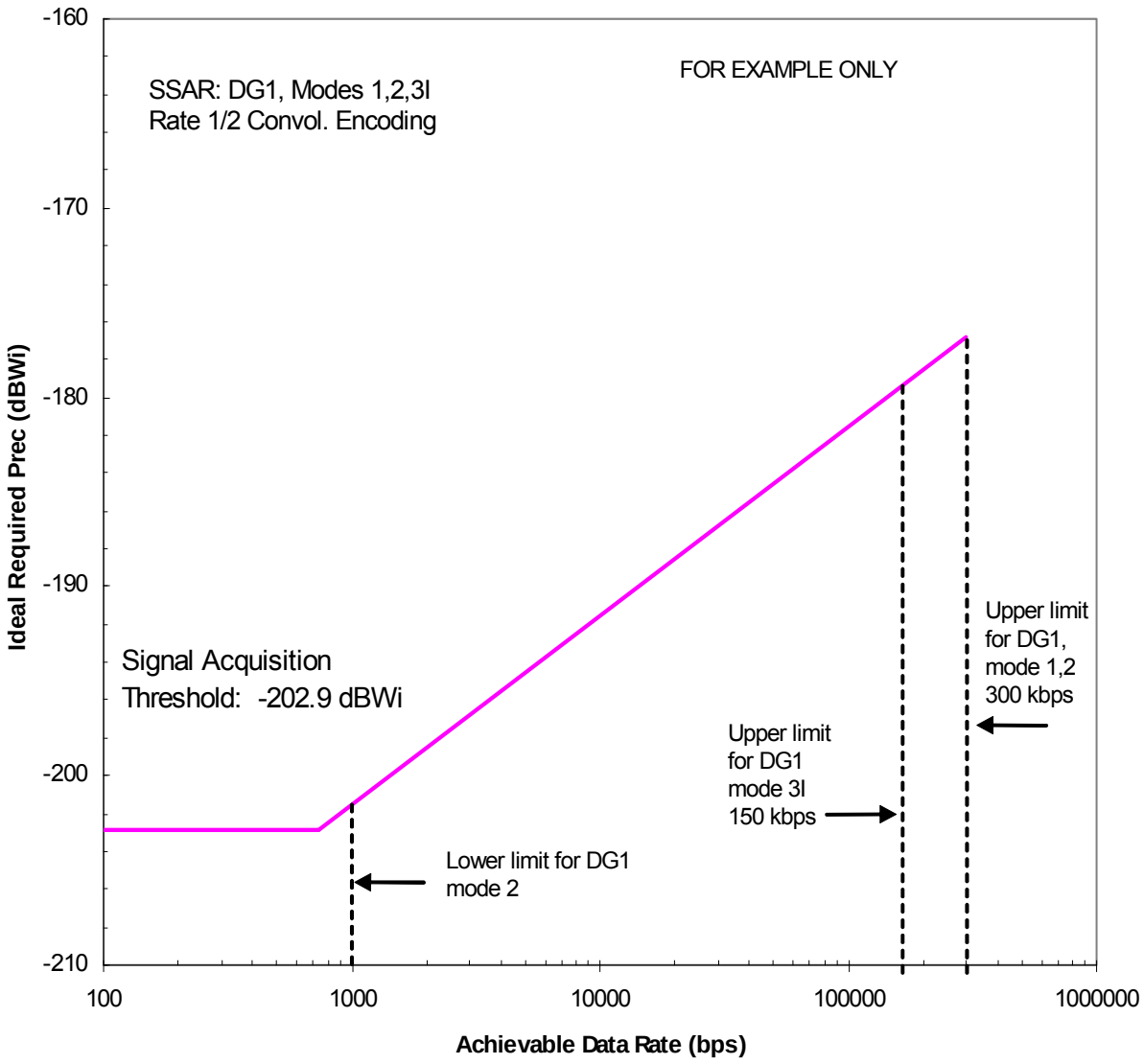


Figure A-22. SSA DG1 Modes 1, 2, 3I (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

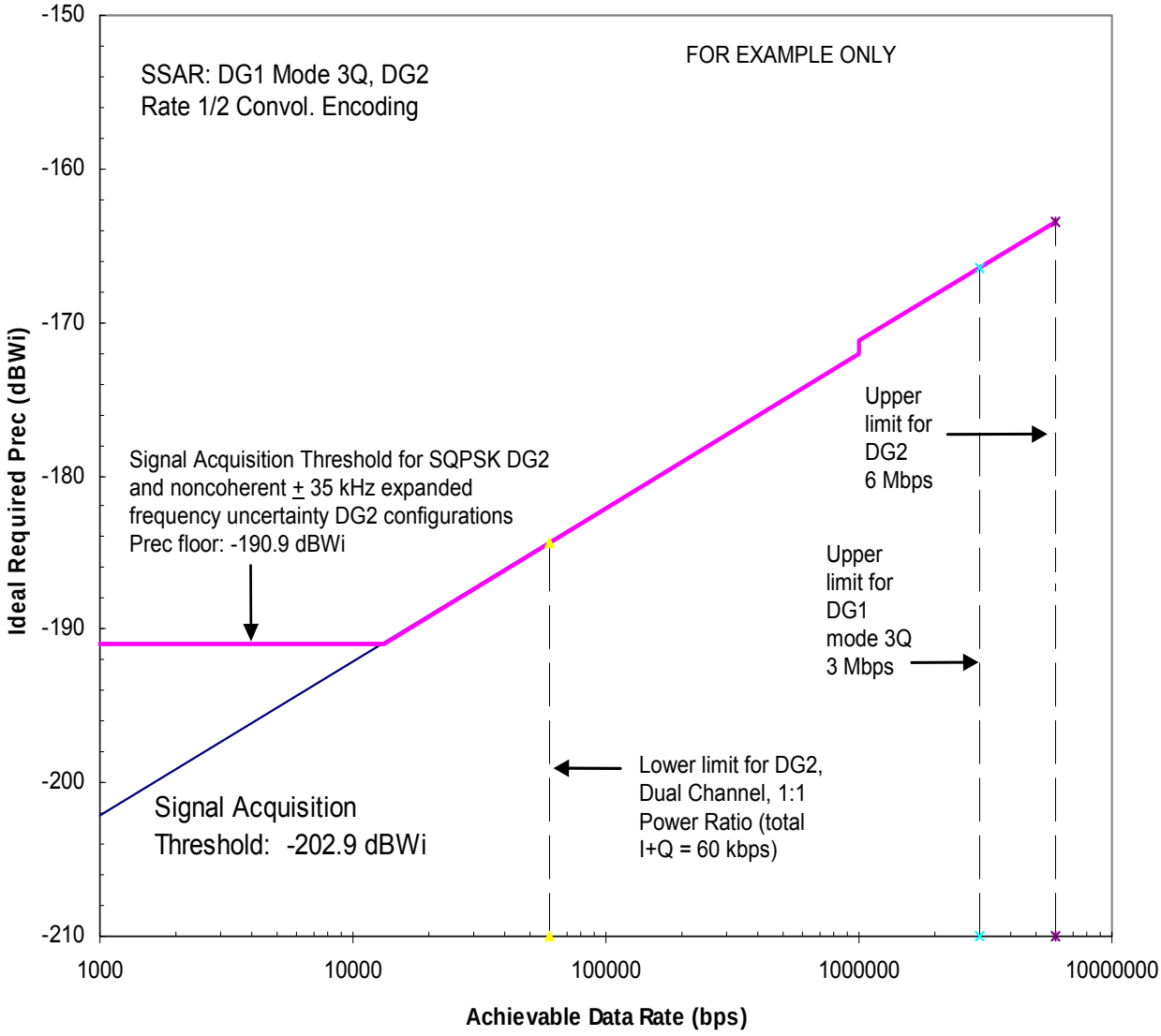


Figure A-23. SSA DG1 Mode 3Q and DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

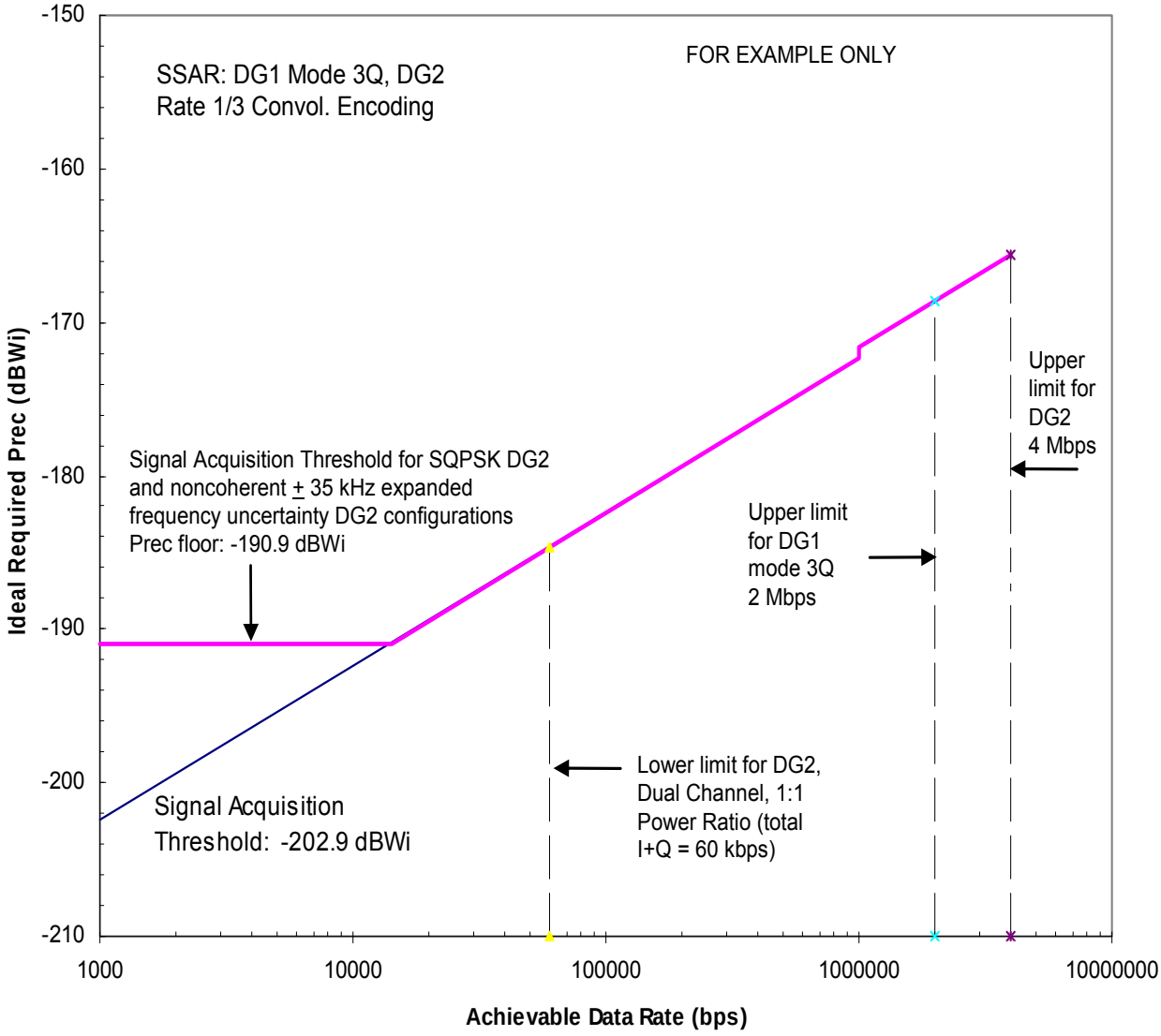


Figure A-24. SSA DG1 Mode 3Q and DG2 (Rate 1/3) Return ADR versus Required Received Power at the TDRS (P_{rec})

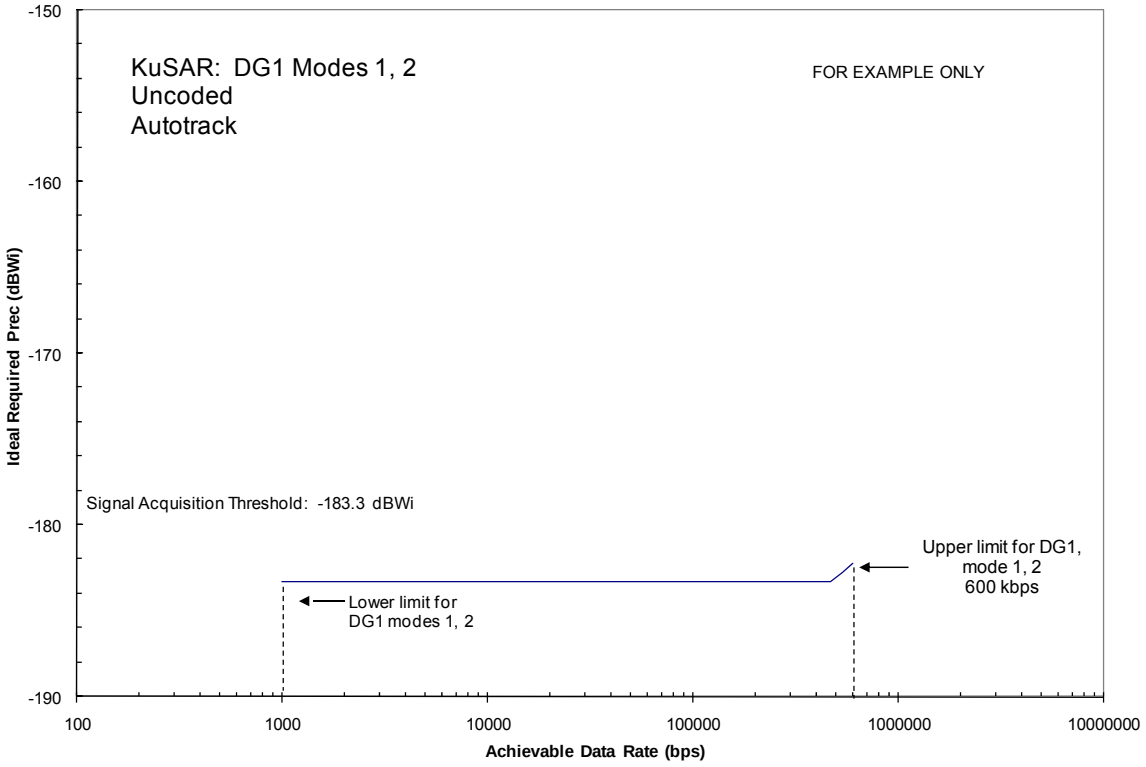


Figure A-25. KuSA Autotrack DG1 Modes 1, 2 (Uncoded) Return ADR versus Required Received Power at the TDRS (P_{rec})

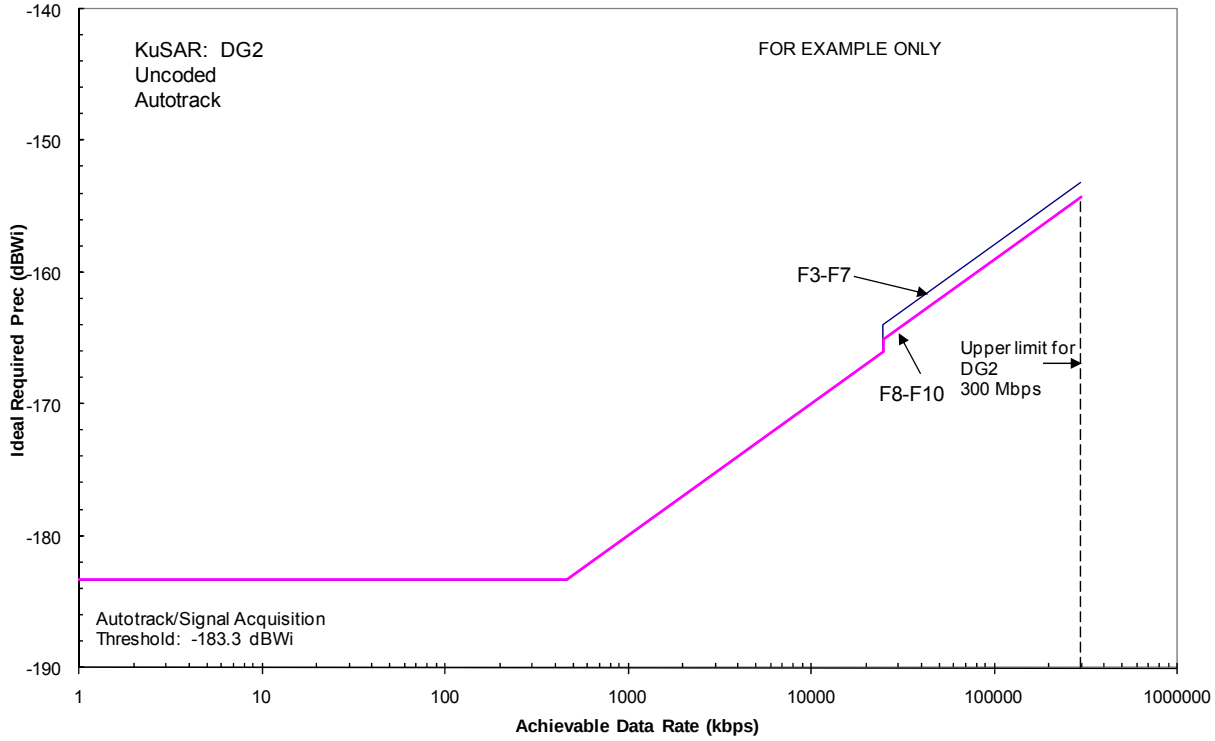


Figure A-26. KuSA Autotrack DG2 (Uncoded) Return ADR versus Required Received Power at the TDRS (P_{rec})

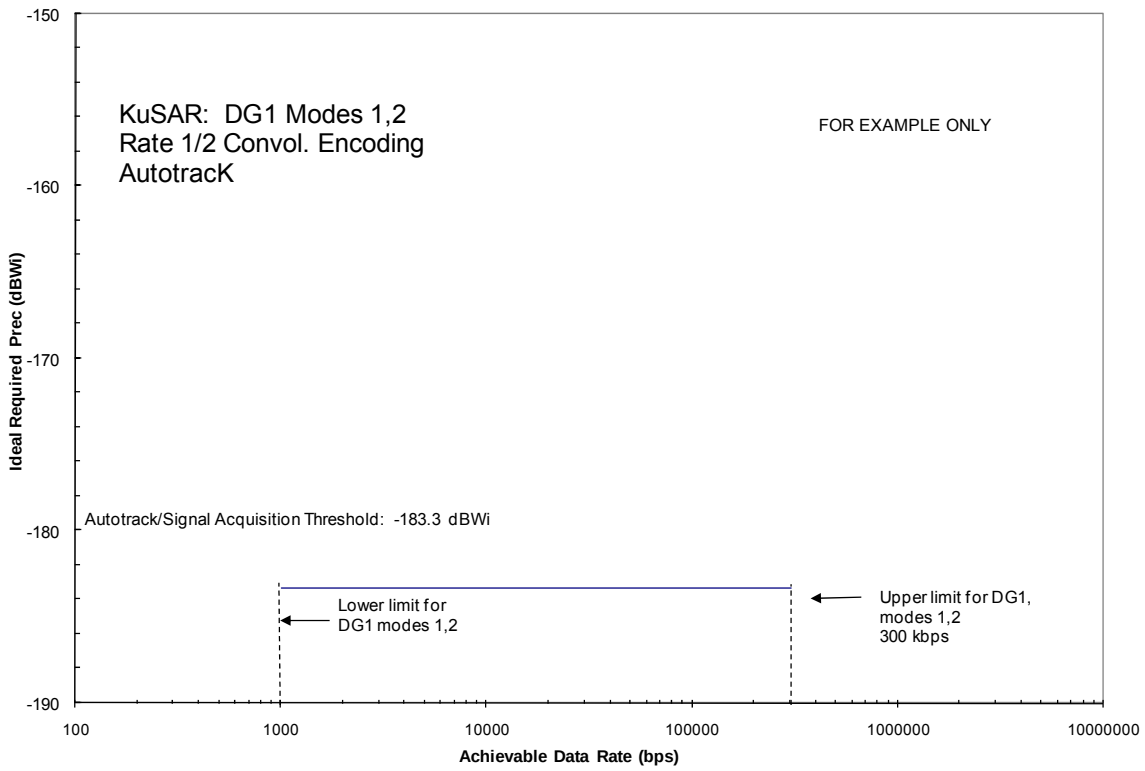


Figure A-27. KuSA Autotrack DG1 Modes 1, 2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

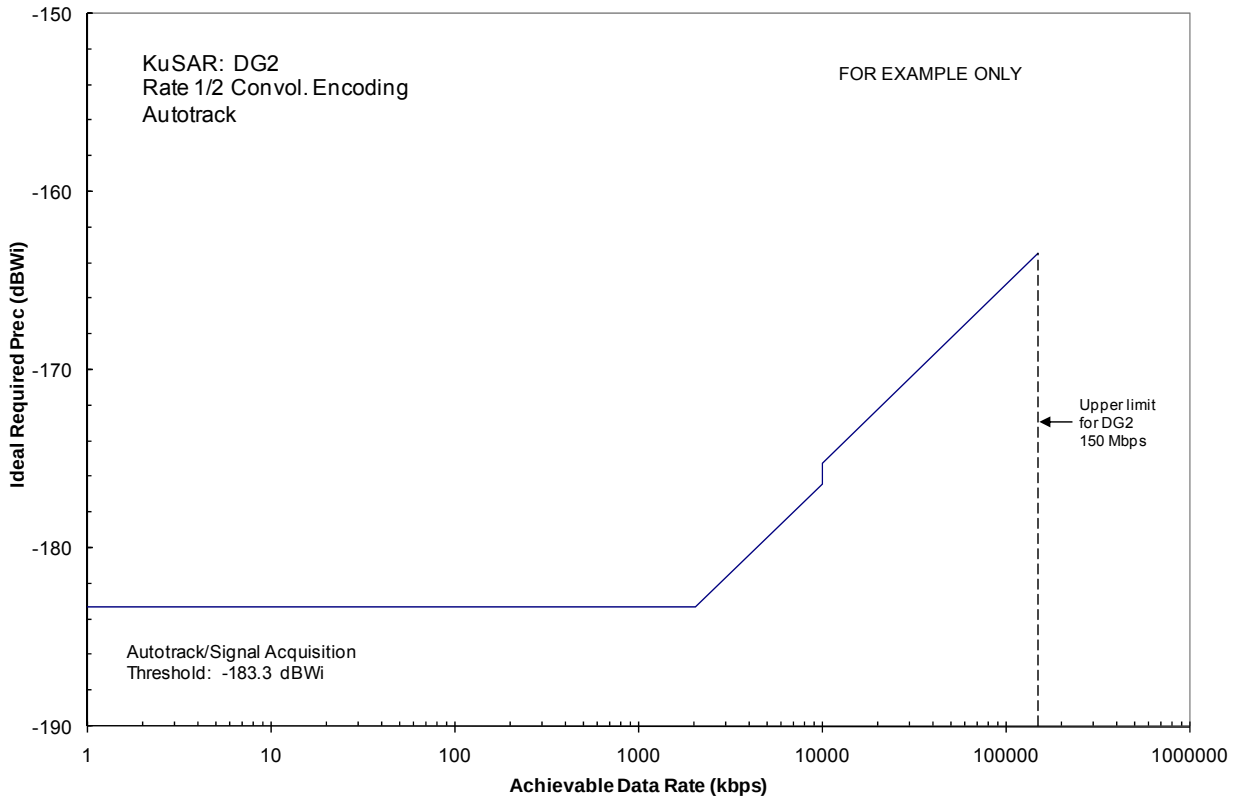


Figure A-28. KuSA Autotrack DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

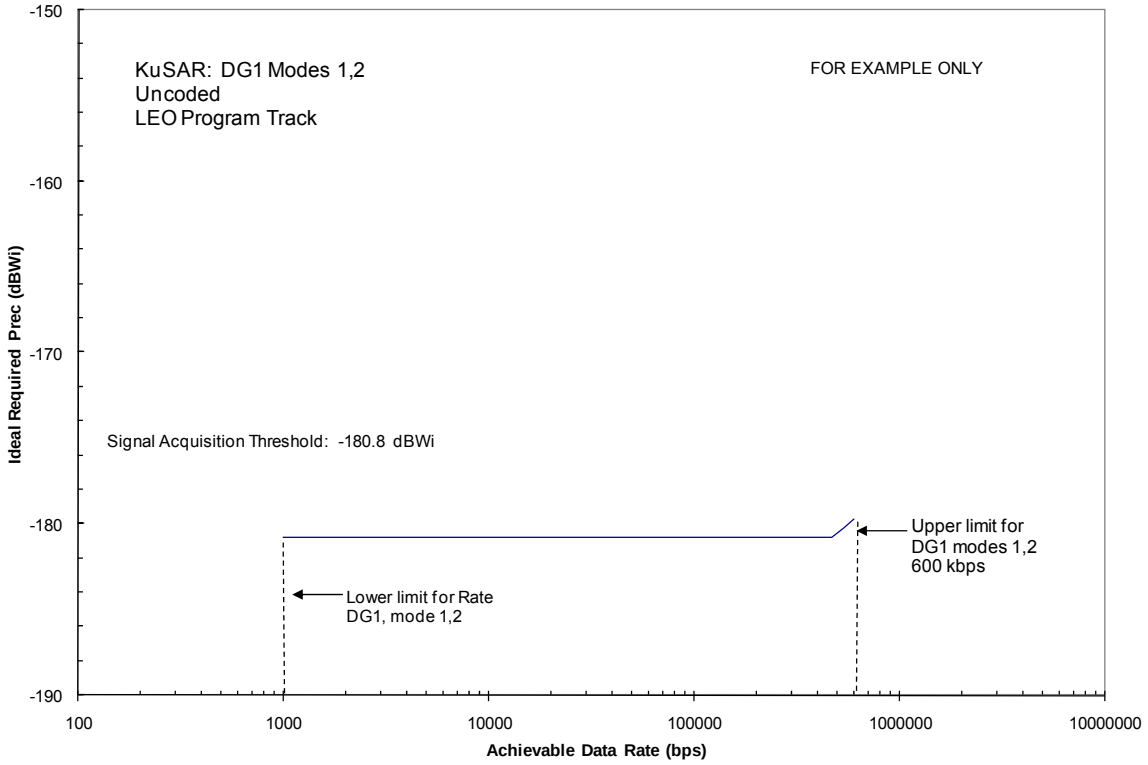


Figure A-29. KuSA LEO Program Track DG1 Modes 1, 2 (Uncoded) Return ADR versus Required Received Power at the TDRS (P_{rec})

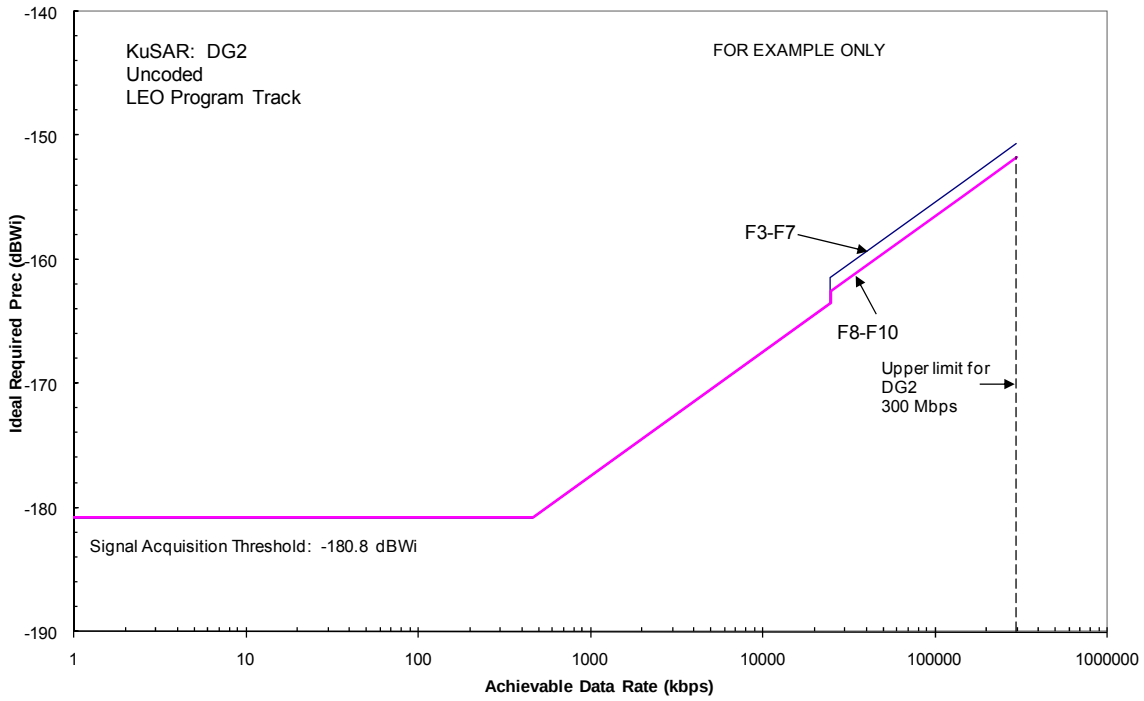


Figure A-30. KuSA LEO Program Track DG2 (Uncoded) Return ADR versus Required Received Power at the TDRS (P_{rec})

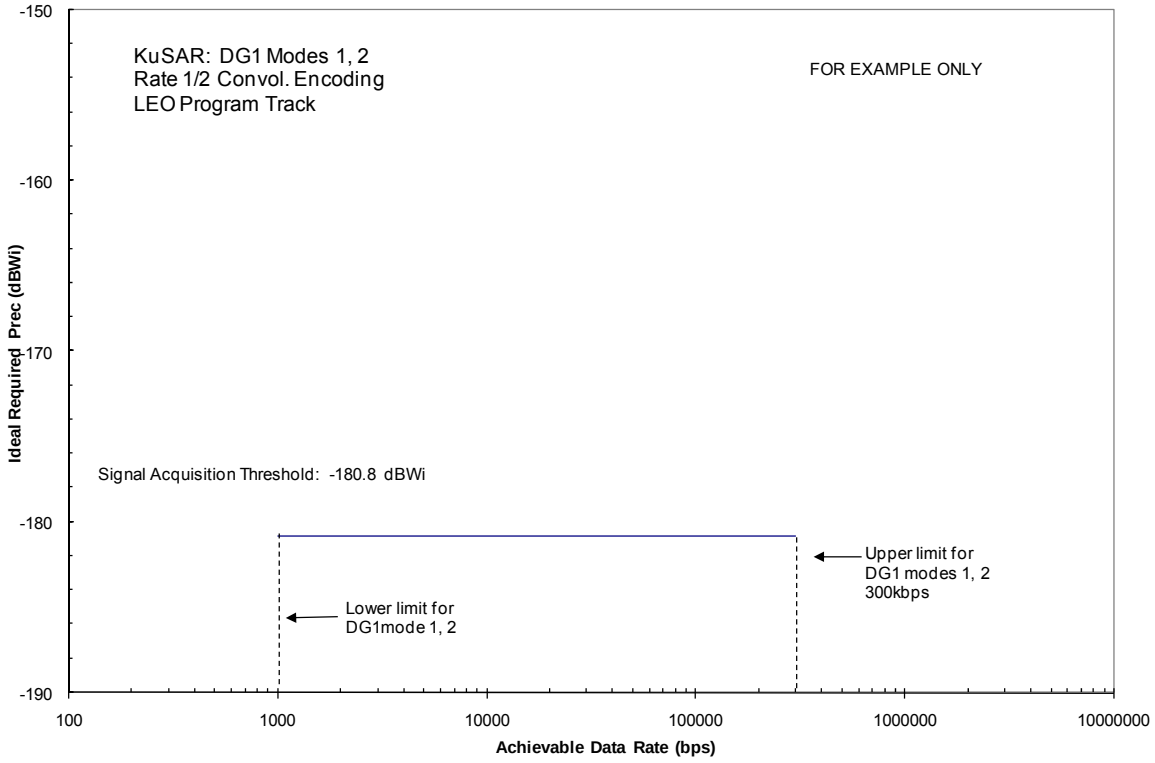


Figure A-31. KuSA LEO Program Track DG1 Modes 1, 2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

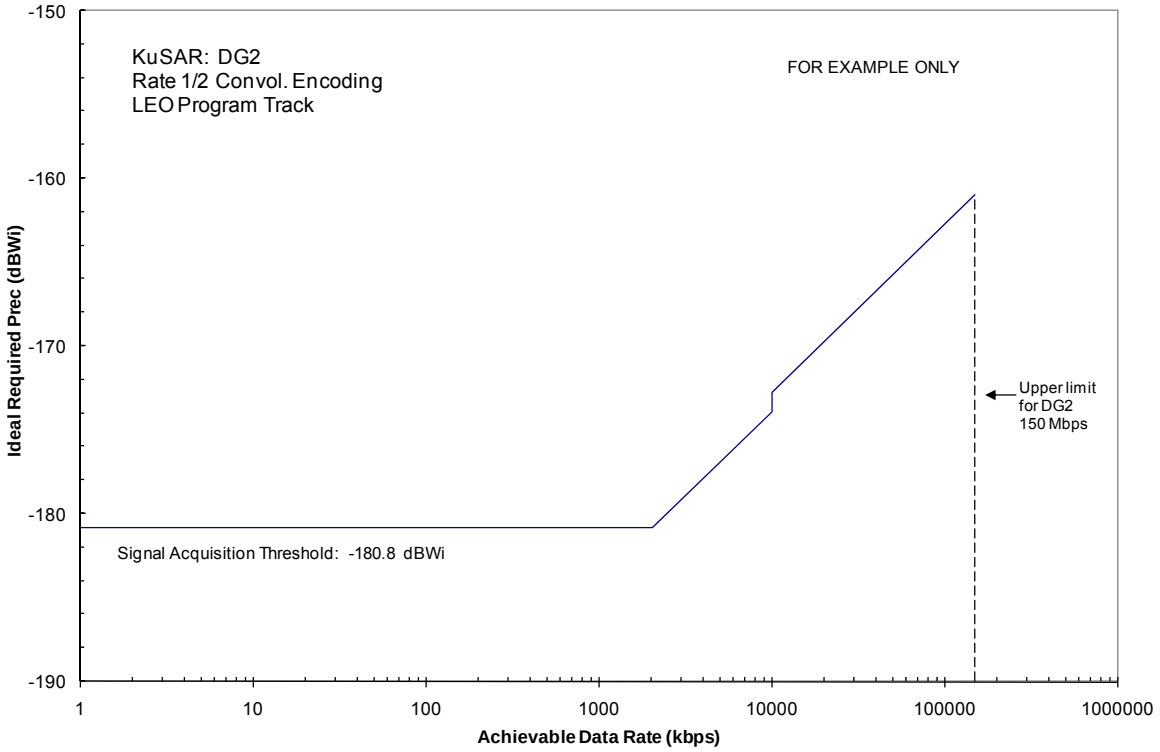


Figure A-32. KuSA LEO Program Track and DG2 (Rate1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

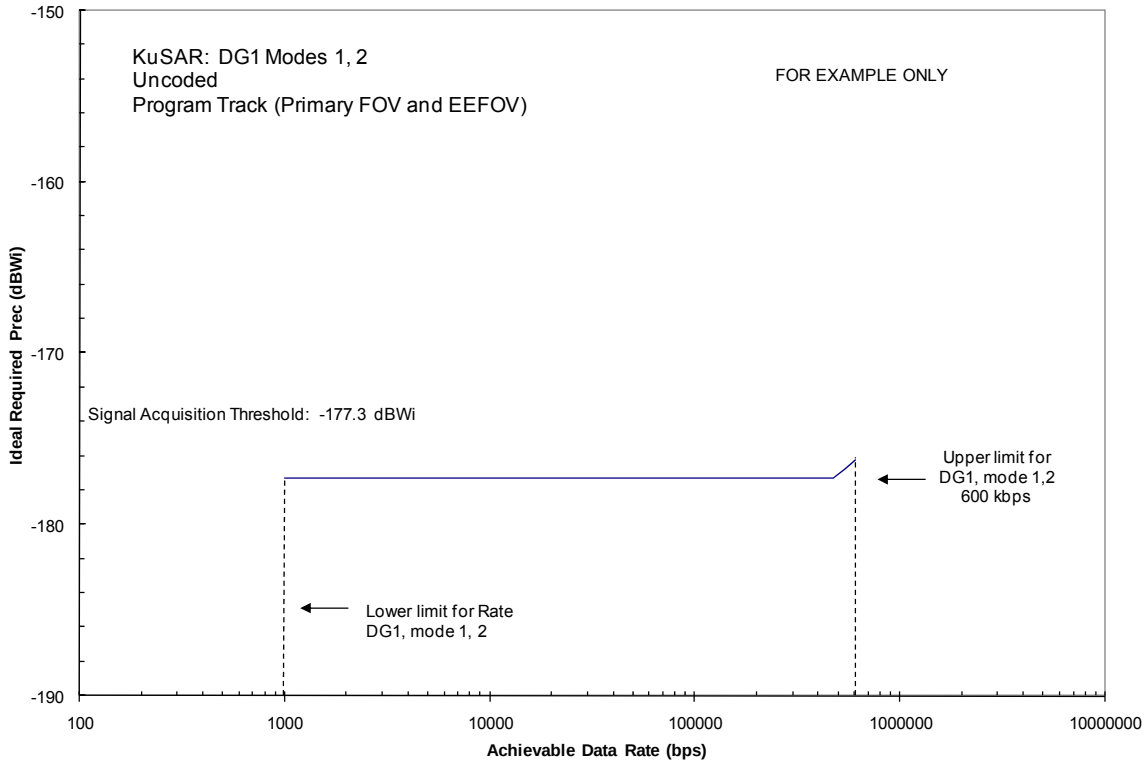


Figure A-33. KuSA Program Track DG1 Modes 1, 2 (Uncoded) Return ADR versus Required Received Power at the TDRS (P_{rec})

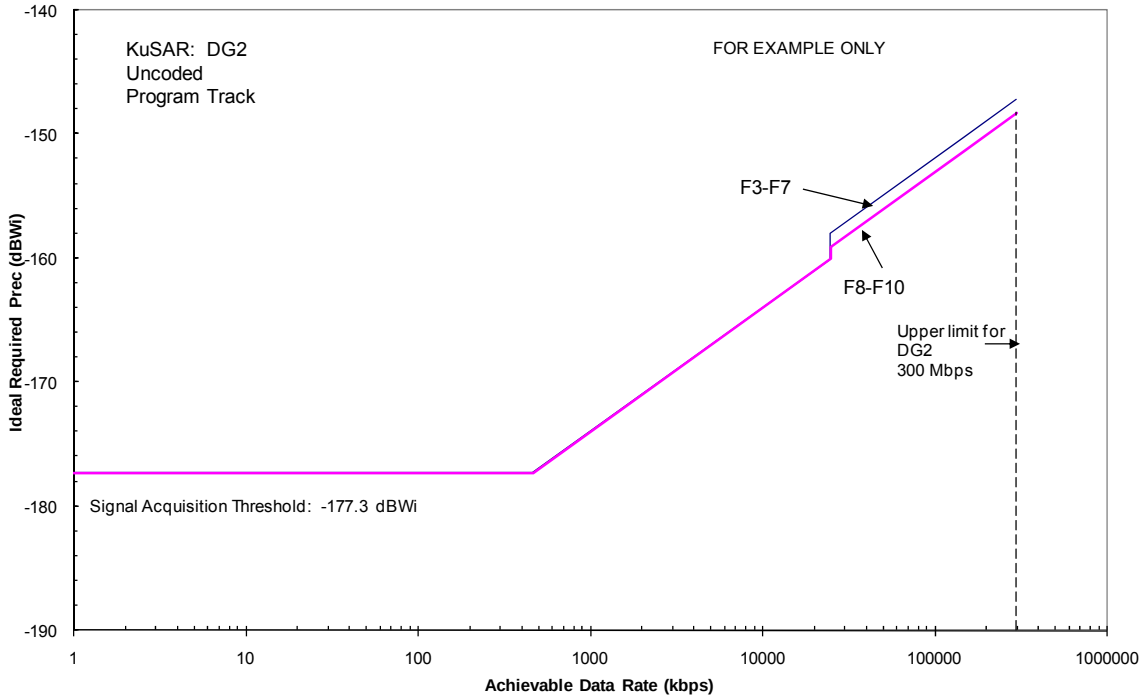


Figure A-34. KuSA Program Track DG2 (Uncoded) Return ADR versus Required Received Power at the TDRS (P_{rec})

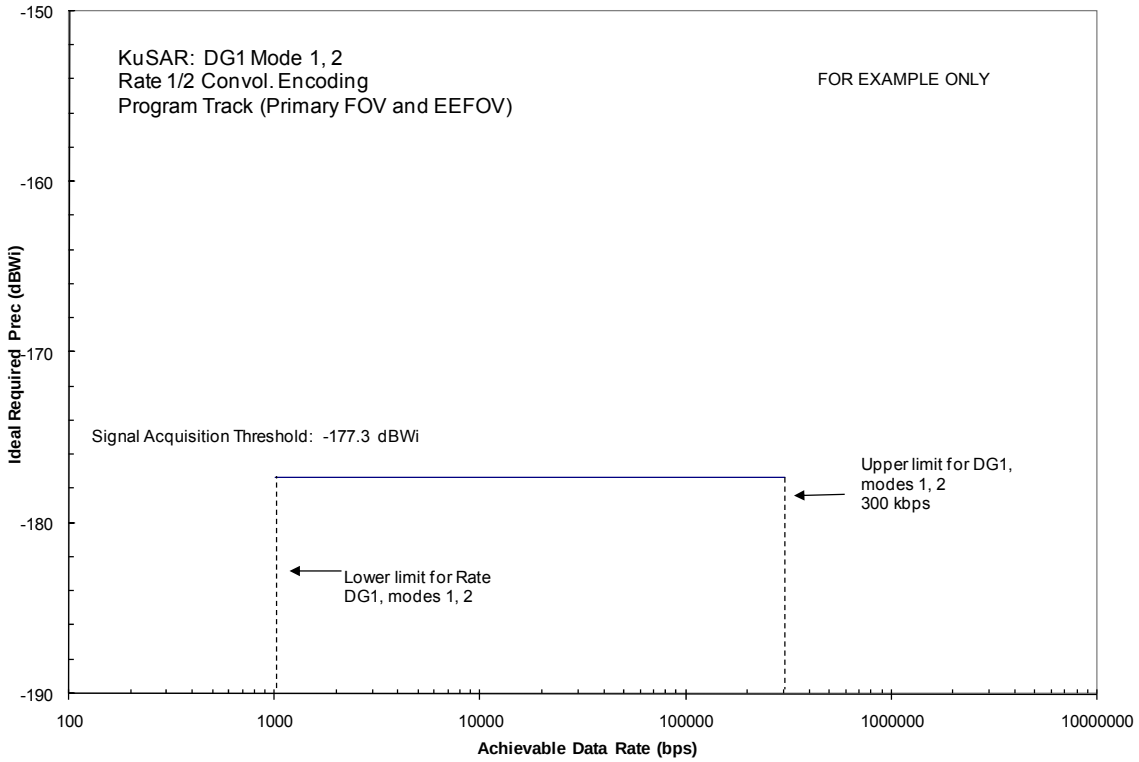


Figure A-35. KuSA Program Track DG1 Modes 1, 2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

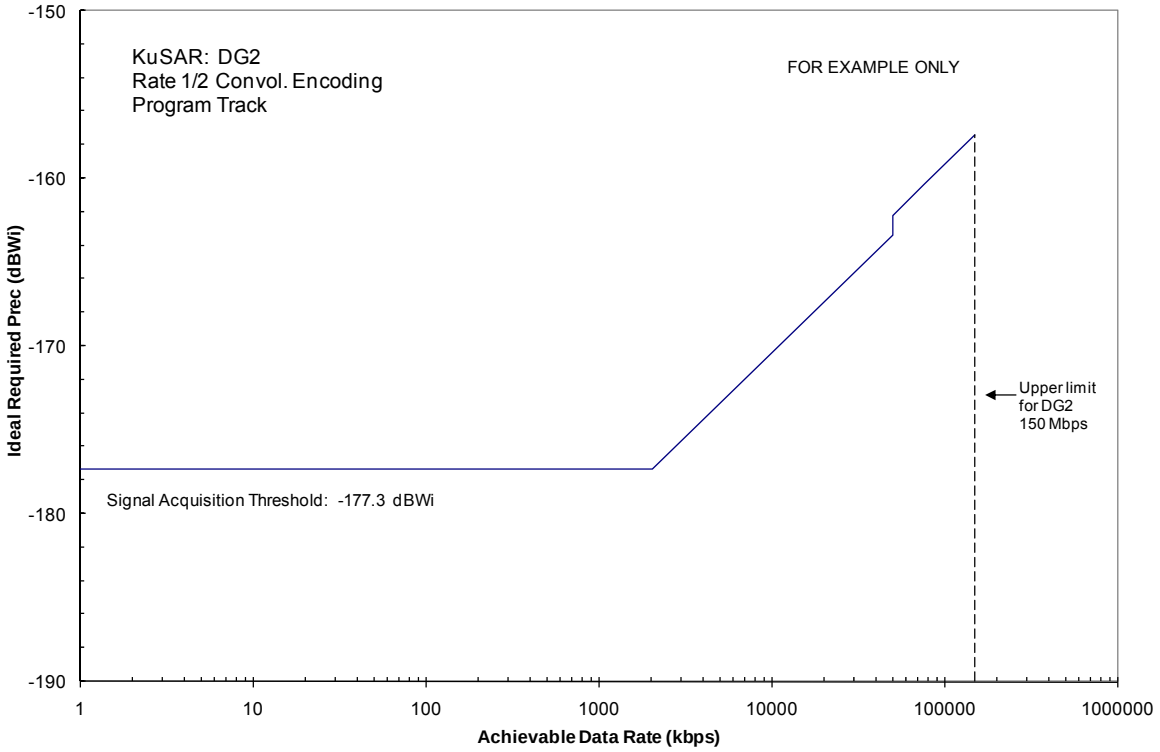


Figure A-36. KuSA Program Track DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

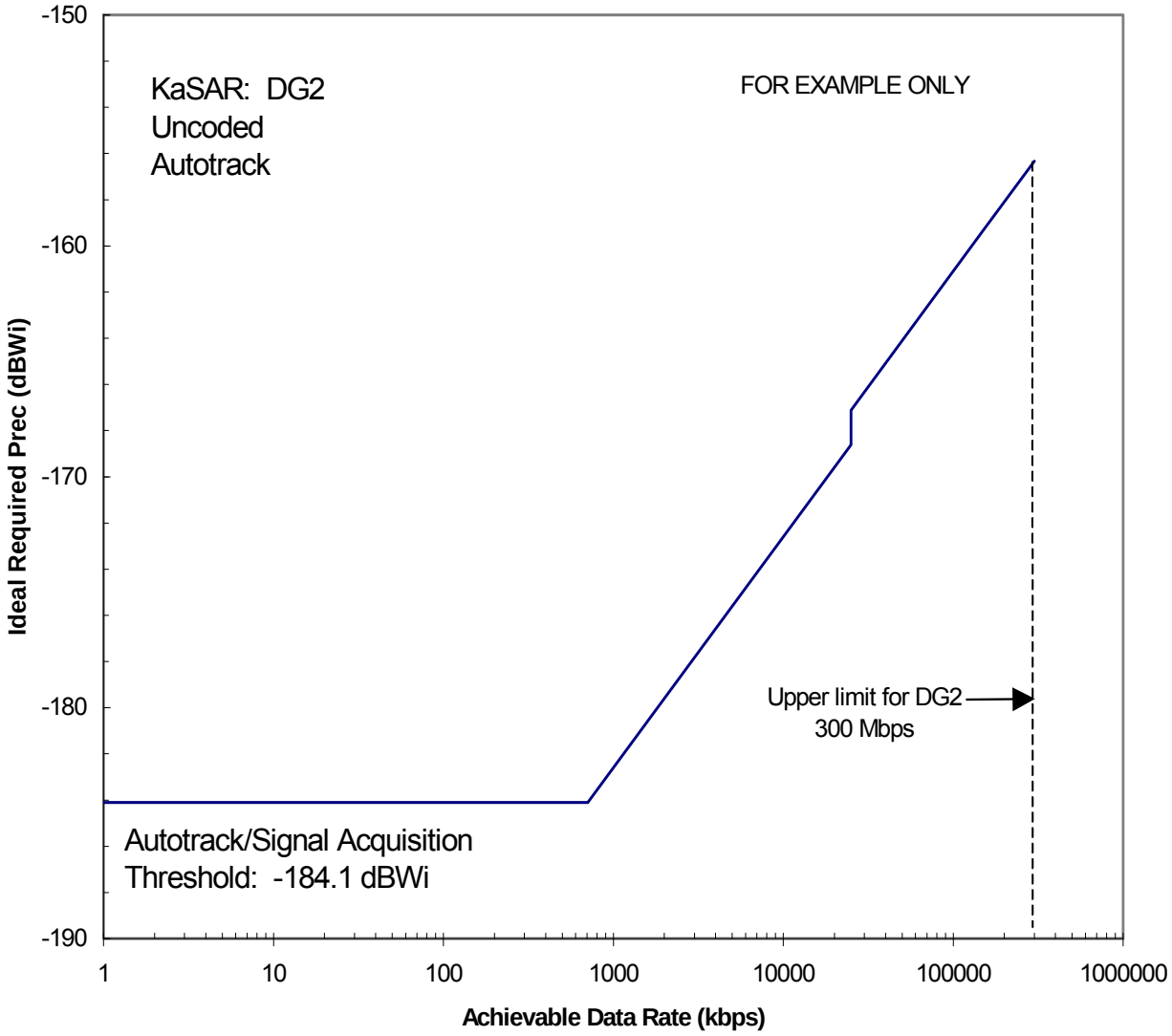


Figure A-37. KaSA Autotrack DG2 (Uncoded) Return ADR versus Required Received Power at the TDRS (P_{rec})

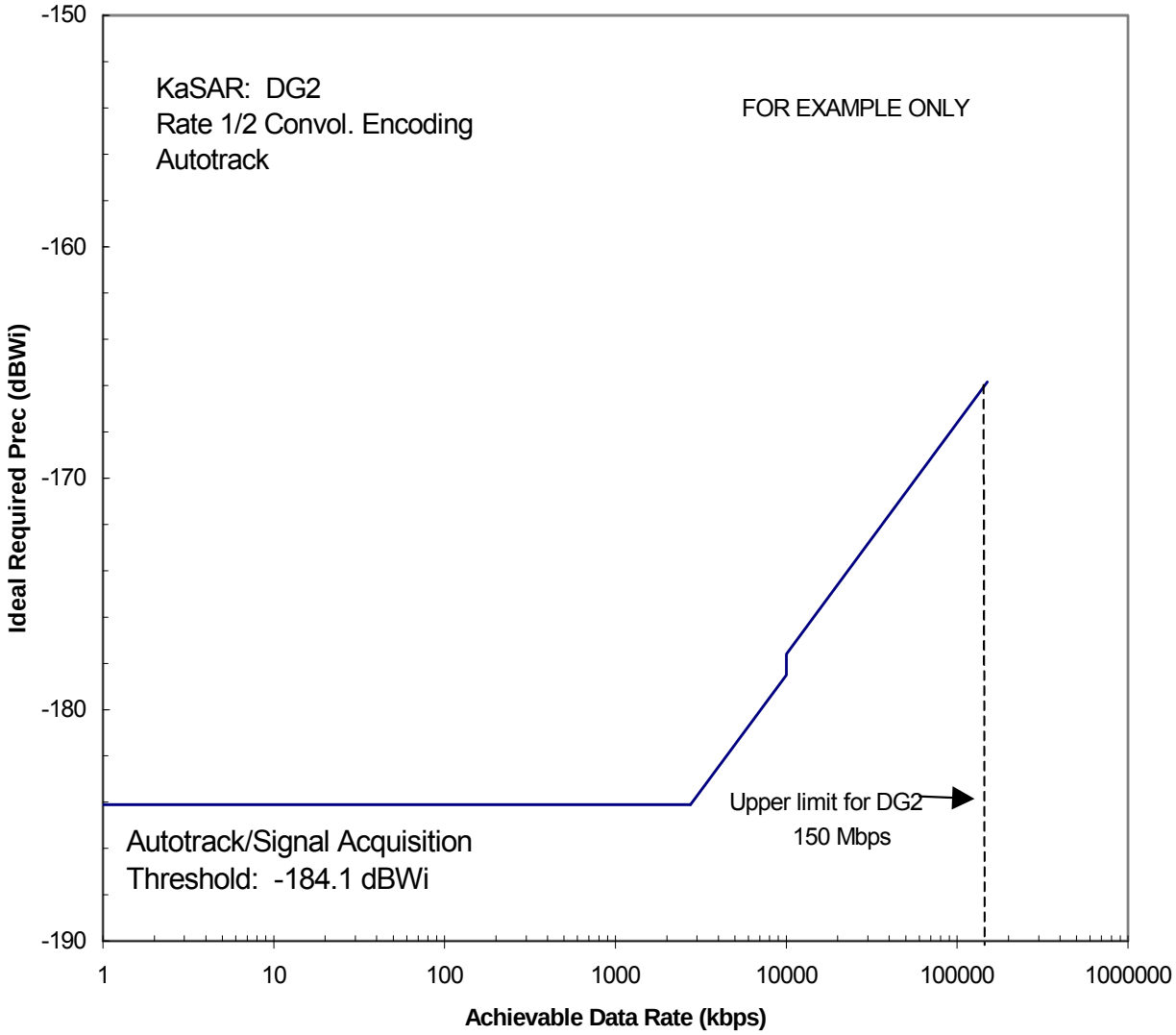


Figure A-38. KaSA Autotrack DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

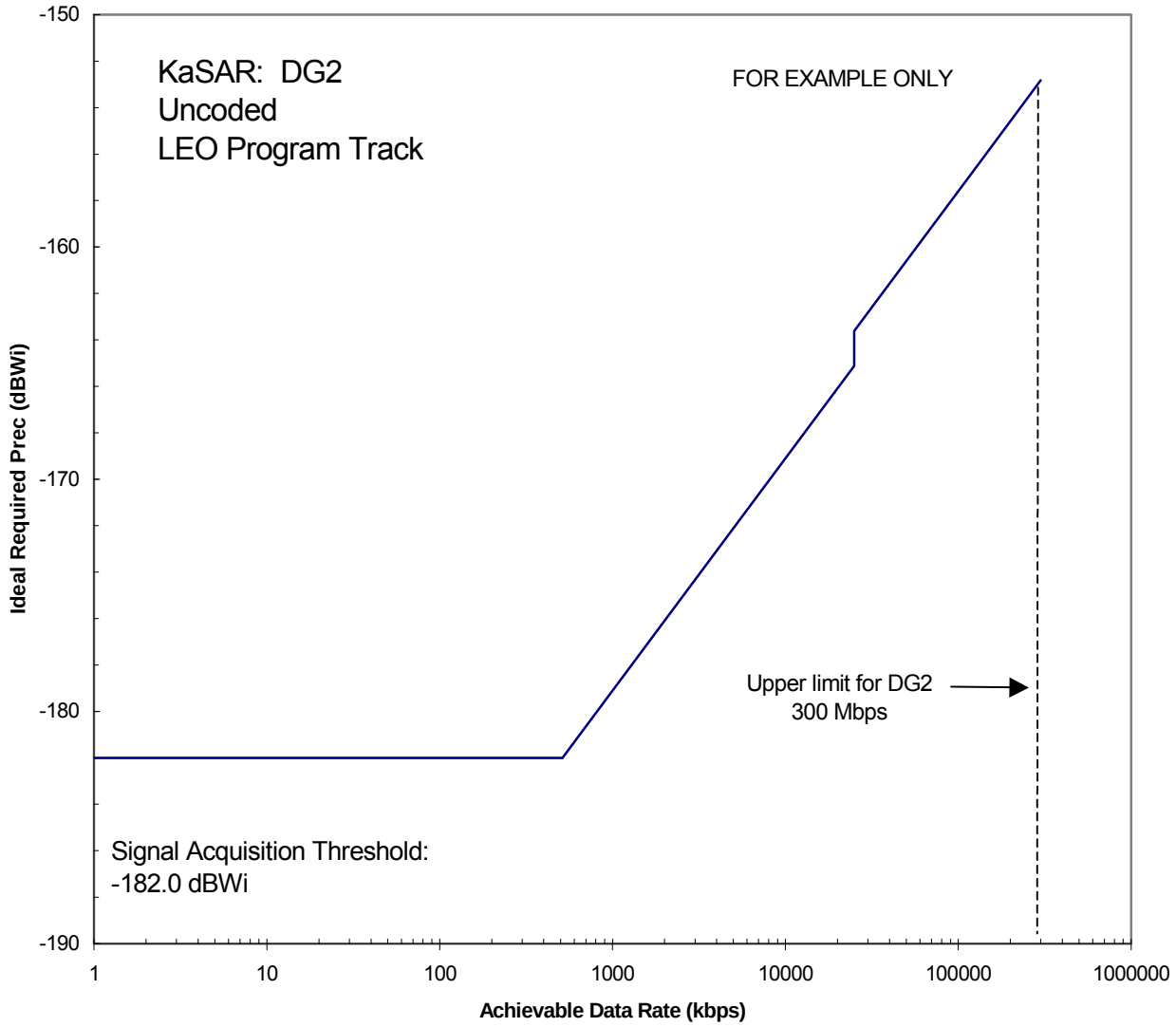


Figure A-39. KaSA LEO Program Track DG2 (Uncoded) Return ADR versus Required Received Power at the TDRS (P_{rec})

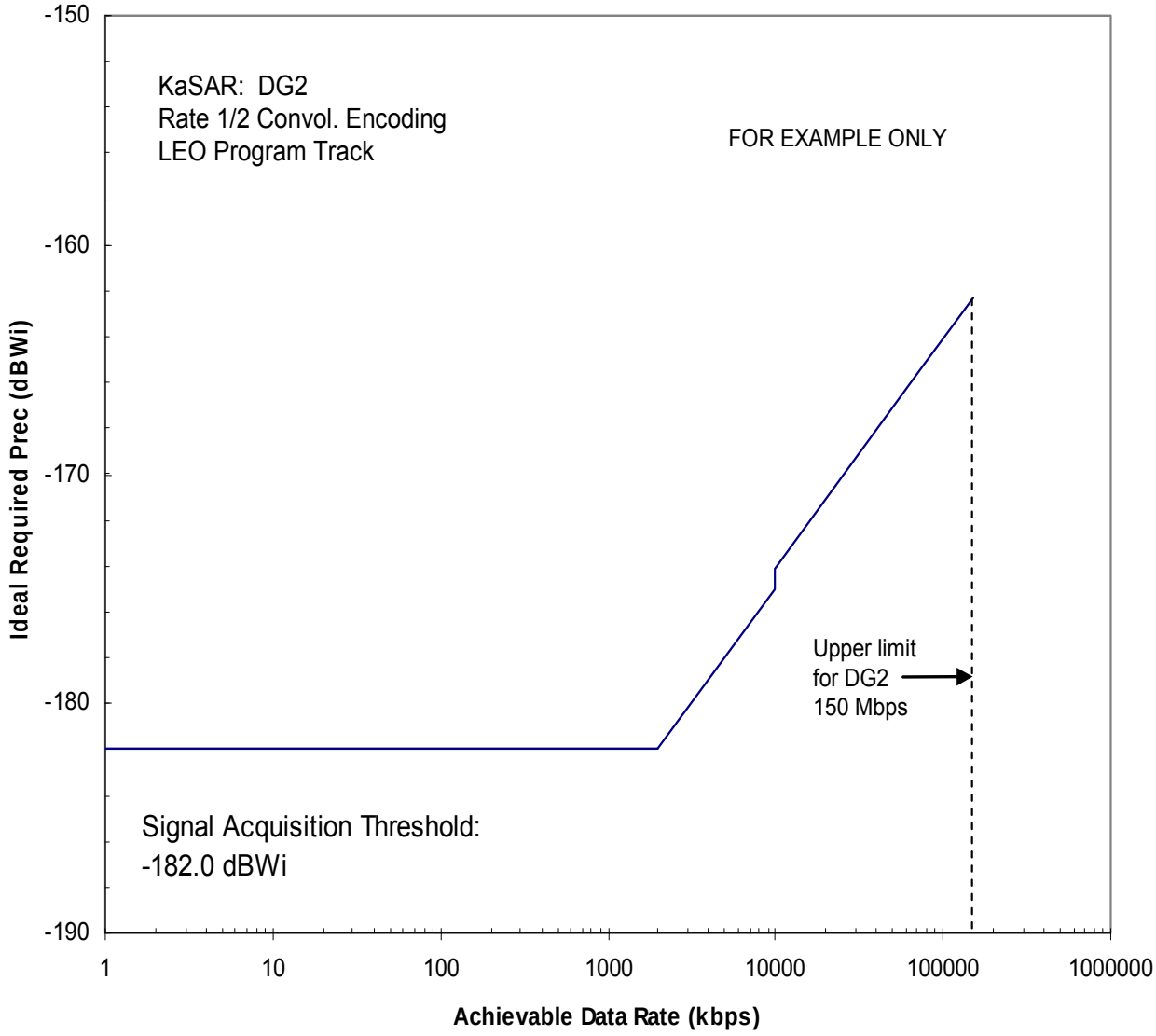


Figure A-40. KaSA LEO Program Track DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

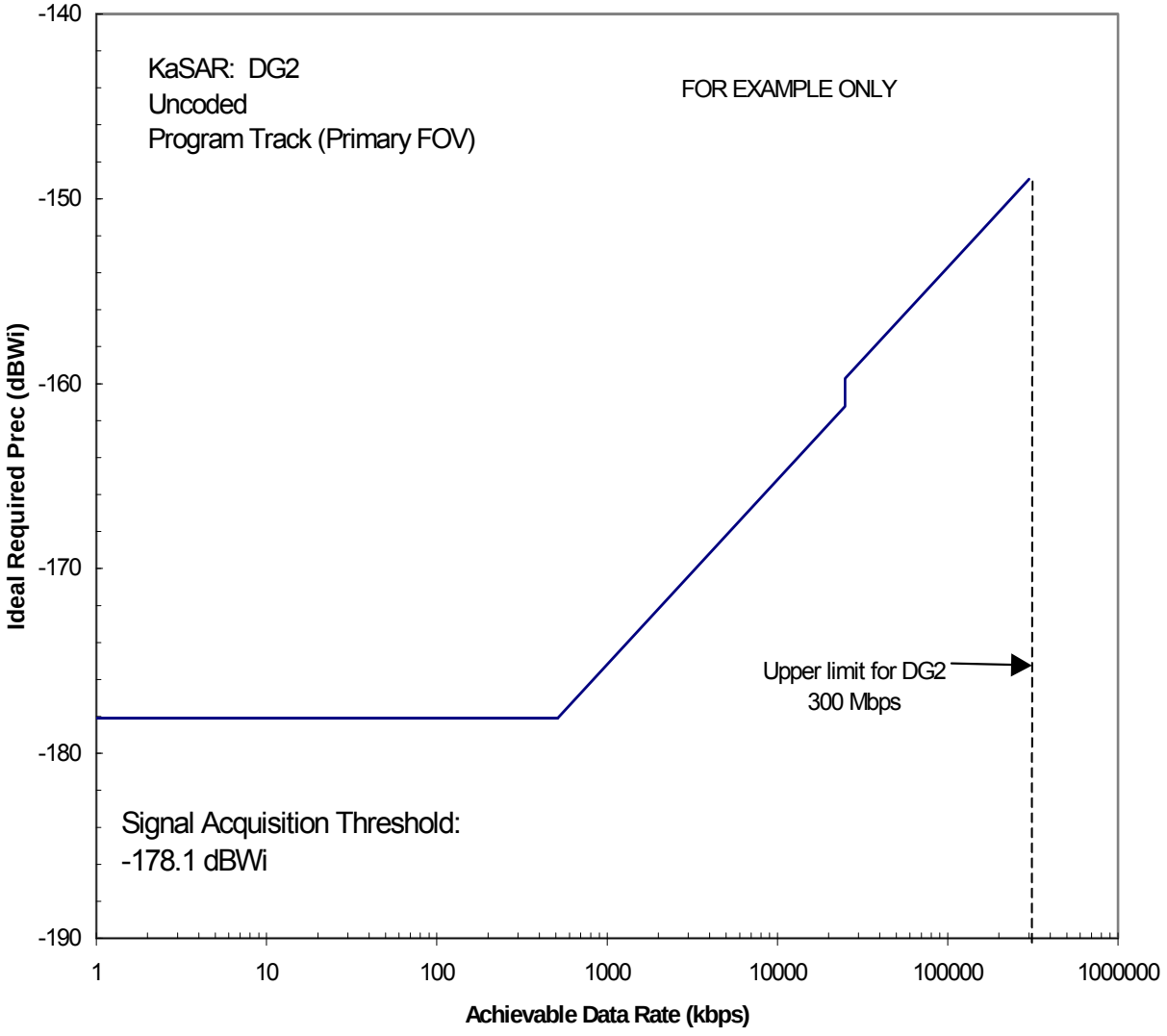


Figure A-41. KaSA Program Track DG2 (Uncoded) Return ADR versus Required Received Power at the TDRS (P_{rec})

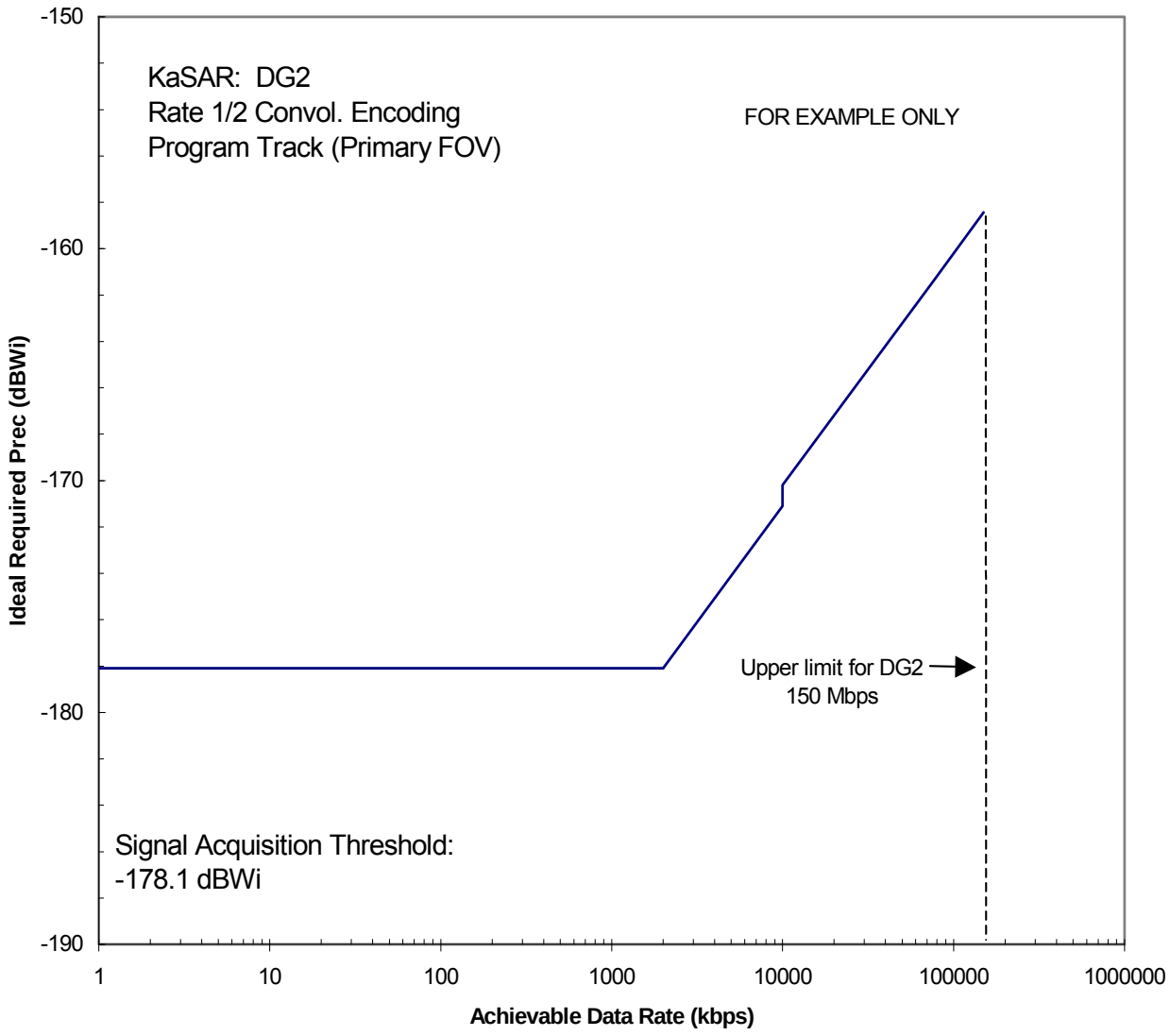


Figure A-42. KaSA Program Track DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

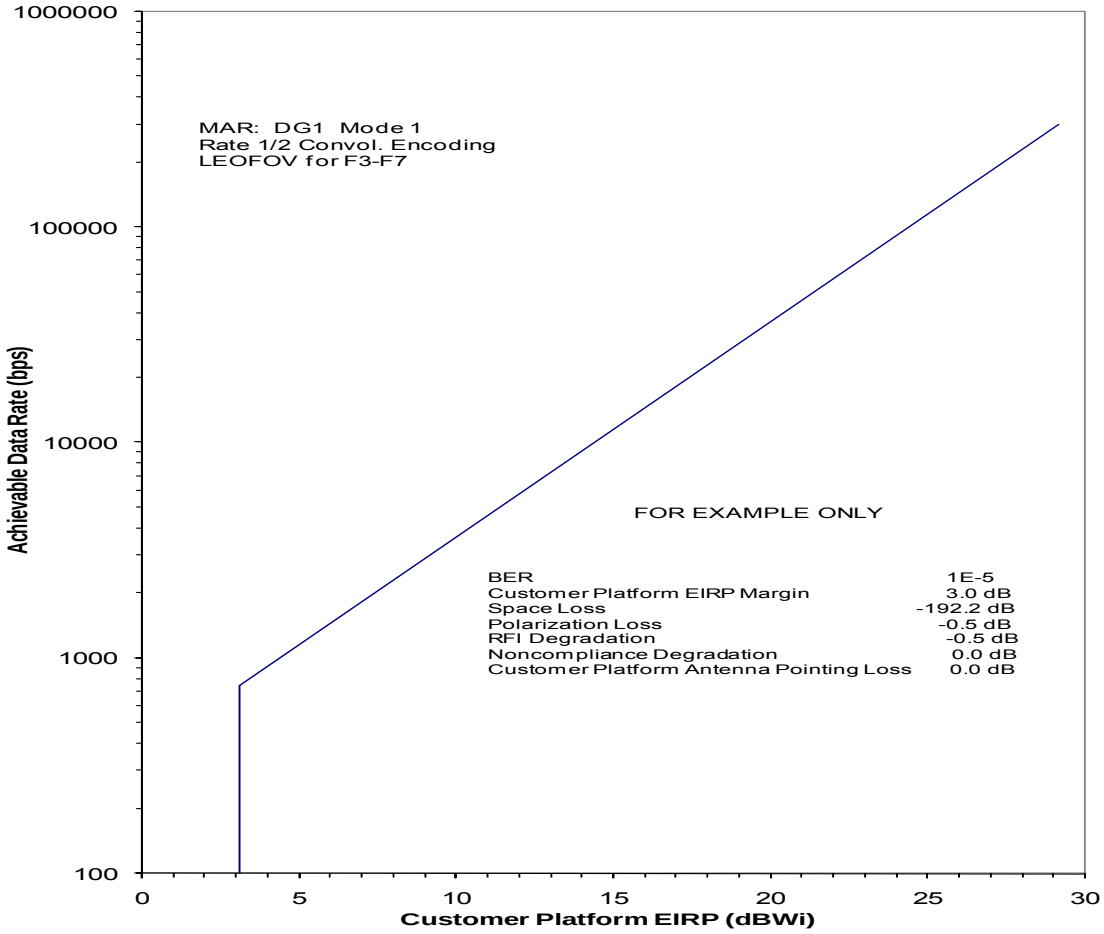


Figure A-43. MAR DG1 Mode 1 (Rate 1/2) ADR versus EIRP (LEOFOV for F3-F7)

Appendix B. Functional Configurations for TDRSS Forward and Return Services (with Emphasis on Resolving Customers' Data Polarity and I-Q Channel Ambiguities)

B.1 General

B.1.1 Purpose

The purpose of this Appendix is to describe the transmitter data communication functional configurations for TDRSS forward services and return services. Additionally, for each configuration, this Appendix identifies the conditions under which either data polarity ambiguity or I-Q channel ambiguity may exist at the SN/customer data interface.

B.1.2 Data Polarity Ambiguity and I-Q Channel Ambiguity

When data polarity ambiguity exists at the SN/customer data interface, the logical sense of the data may be either true or inverted. When I-Q channel ambiguity exists at the SN/customer data interface for the dual-source configurations, received I-channel or Q-channel data may appear on the designated interface port for the I-channel data, and received Q-channel or I-channel data may appear on the designated interface port for the Q-channel data. Data polarity ambiguity and I-Q channel ambiguity are addressed in paragraph B.2 for forward service and paragraph B.3 for return service.

B.1.3 Definitions

In this Appendix, "data format" refers to the format of the source data either prior to transmission (uncoded operation) or prior to convolutional encoding (coded operation). "Symbol format" refers to the format of the channel data that is modulated onto the carrier. Figure B-1 depicts the definition of the various NRZ and Biphase formats.

B.2 Forward Service

B.2.1 General

The customer/SN end-to-end system functional configuration for forward service is shown in Figure B-2. Forward service data generated in the customer MOC is transmitted to the SN data interface. Refer to Section 3, paragraph 3.6, for information concerning data interface capabilities and restrictions. The NISN, WSC, GRGT and TDRS are transparent to the data format and coding scheme of the forward link data originating in the customer MOC, except for WDISC and SSA PM customers. The SN supports forward data conditioning operations for WDISC and SSA PM forward link customers.

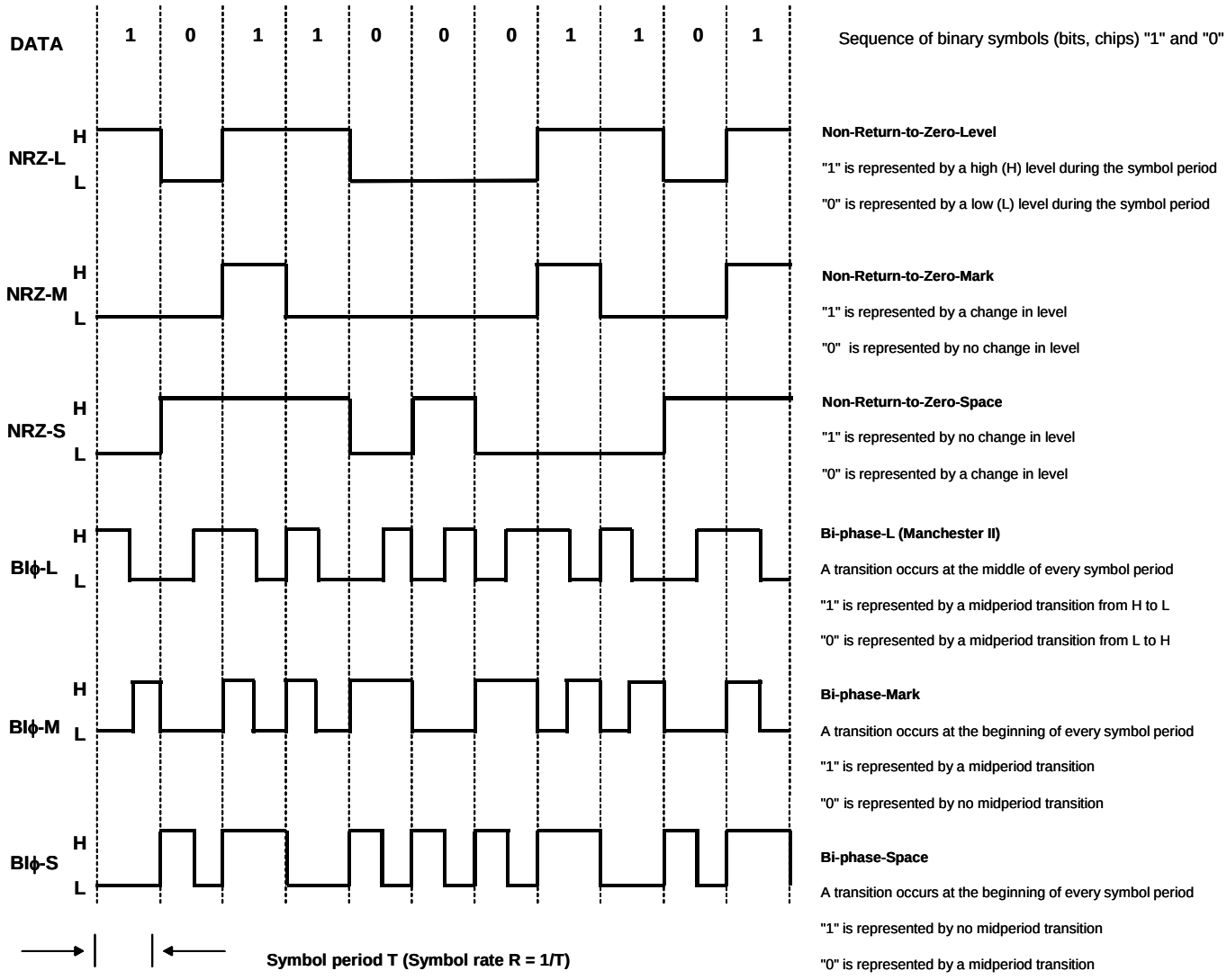


Figure B-1. Digital Signal Formats

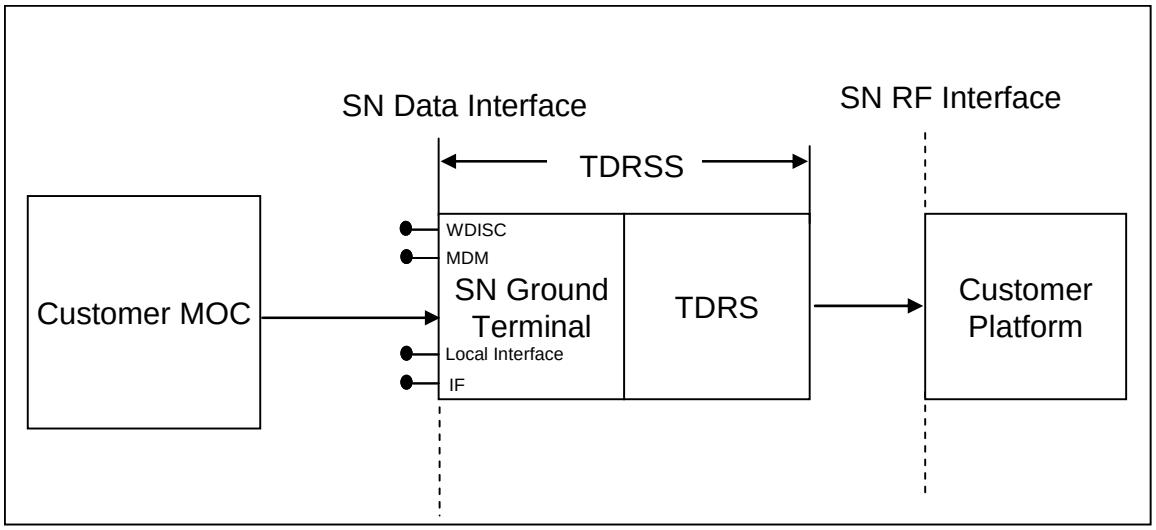


Figure B-2. Forward Service End-to-End System Functional Configuration

These data-conditioning operations include forward link rate 1/2 convolutional coding, BCH encoding and data format conversion for WDISC customers, and data format conversion for SSA PM customers.

The SN supports two modulation categories referred to as PSK and PM. The PSK category is supported for MA, SSA, KuSA, and KaSA forward services. The PM category is supported for only SSA forward service. Table B-1 lists the data rate restrictions and the modulation types that are supported for each SN forward service. The TDRS spacecraft is capable of bent-pipe operation to support customer-defined (non-TDRSS) signal formats. Non-TDRSS signal formats may require the addition of SN ground terminal modulation/demodulation equipment. Precise performance and SN support of these customer-defined signals will have to be handled on a case-by-case basis.

B.2.2 PSK Services

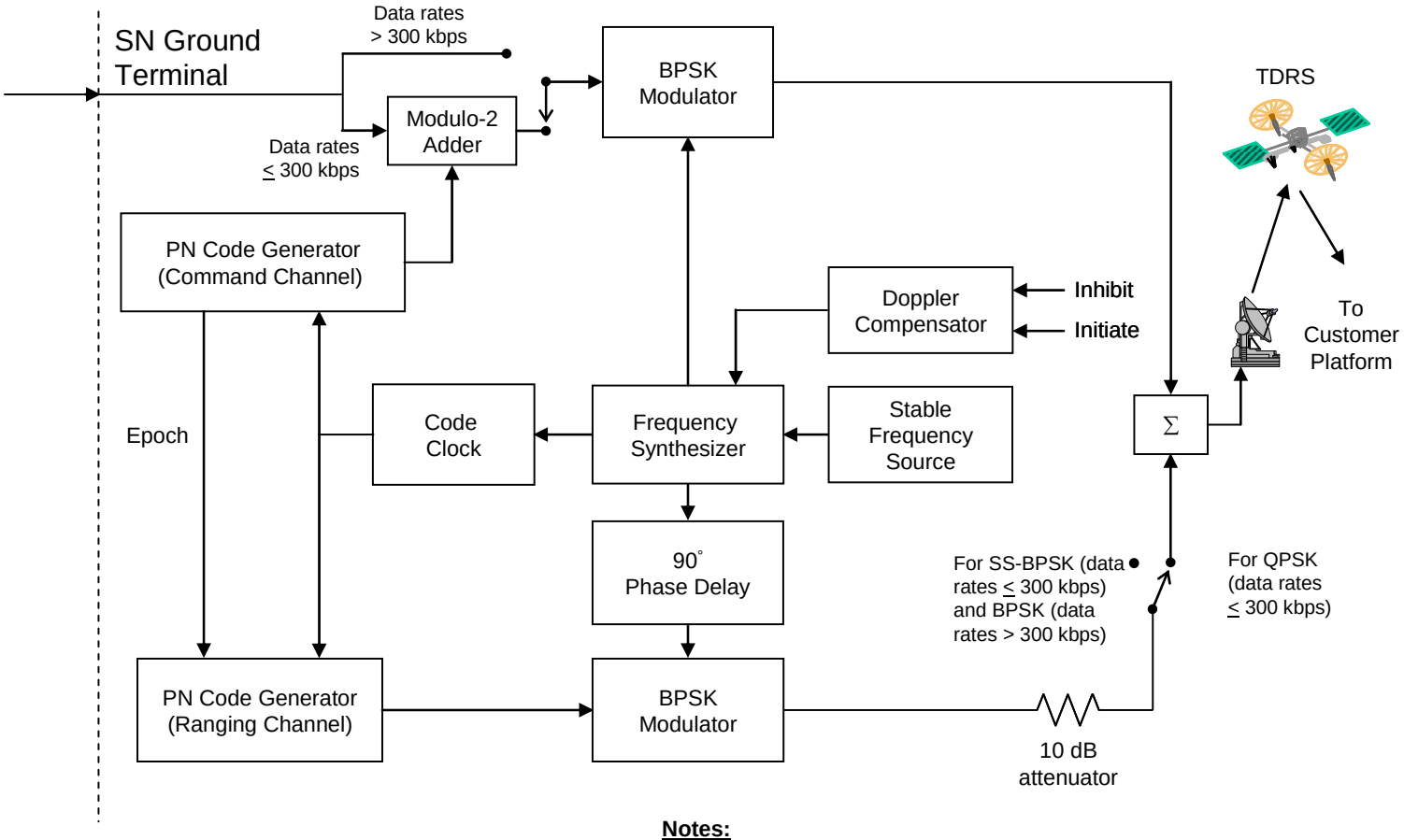
Figure B-3 depicts the functional configuration for the TDRSS for MA, SSA, KuSA and KaSA forward PSK modulation services, which are BPSK, SS-BPSK and SS-UQPSK. For SS-UQPSK modulation, the I channel contains the command data and is modulo-2 added to a 3 Mcps PN code and the Q channel is a 3 Mcps PN code, which is used for ranging. For BPSK modulation, the I channel contains the command data and directly PSK modulates the carrier. Forward data formatting, rate 1/2 convolutional, and BCH encoding are available for WDISC customers and should be discussed with GSFC Code 450. Otherwise, the TDRSS does not perform any type of data conditioning on the forward service data.

Table B-1. Forward Service Modulation and Data Rate Restrictions

Modulation Category	Modulation Scheme (note 1)	Service and Data Rate Restrictions (note 5)			
		MA/SMA	SSA	KuSA	KaSA
PSK	SS-UQPSK (note 2)	0.1 – 300 kbps	0.1 – 300 kbps	1 – 300 kbps	1 – 300 kbps
	SS-BPSK (note 8)	0.1 – 300 kbps	0.1 – 300 kbps	1 – 300 kbps	1 – 300 kbps
	BPSK (note 7)	Not available	300 kbps < data rate ≤ 7 Mbps	300 kbps < data rate ≤ 25 Mbps (note 3)	300 kbps < data rate ≤ 7 Mbps (note 9)
PM	Direct PM (note 6)	Not available	0.125 kbps -1 Mbps	Not available	Not available
	PSK Subcarrier PM (note 6)	Not available	0.125 kbps –8 kbps (note 4)	Not available	Not available

Notes:

1. The TDRSS spacecraft is capable of bent-pipe operation to support customer defined (non-TDRSS) signal formats. Non-TDRSS signal formats may require the addition of SN ground terminal modulation/demodulation equipment. Precise performance and the SN support of these customer-defined signals will have to be handled on a case-by-case basis.
2. The I channel contains the command data and is modulo-2 added to a 3 Mcps PN code and the Q channel is a 3 Mcps PN code.
3. Current GRGT SGLT-6 software limitations constrain the KuSAF data rate to 7 Mbps or less.
4. The command data is used to BPSK modulate a sinusoidal or square-wave subcarrier, which will linearly phase modulate the carrier. Subcarrier frequency/bit rate ratio = 2^n, where n=1...7 for NRZ formats and n=2…7 for Biphase formats, where subcarrier frequencies supported are 2, 4, 8, or 16 kHz.
5. For PSK customers, the forward data rate in this table is the baud rate that will be transmitted by the TDRSS (includes all coding and symbol formatting). For PM customers, the data rate restrictions given in this table assume an uncoded signal that is NRZ formatted. The SN supports forward data conditioning operations for WDISC and SSA PM forward link customers. These data conditioning operations include forward link rate 1/2 convolutional coding, BCH encoding, and data format conversion for WDISC customers and data format conversion for SSA PM customers. For all other SN customers, forward link data conditioning is transparent to the SN and, if used, should be performed by the customer prior to transmission to the SN data interface. Refer to Section 3, paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities.
6. The PM modulation index can be: 1) 0.2 to 1.5 radians or $\pi/2$ radians for Direct PM and PSK Squarewave Subcarrier PM and 2) 0.2 to 1.8 radians for PSK Sinewave Subcarrier PM.
7. For BPSK modulation, the I channel contains the command data and directly PSK modulates the carrier. The SN is capable of supporting BPSK signals at data rates ≤ 300 kbps; however, its use will be constrained and must be coordinated with GSFC Code 450.
8. Customers who operate in a SS-BPSK mode for one service cannot reconfigure any of their Forward Services (i.e., MAF, SMAF, SSAF, KuSAF, or KaSAF) to an SS-UQPSK mode. Contact Code 450 if additional flexibility is required.
9. Current WSC/GRGT is capable of 25 Mbps with changes.



Notes:

1. Data conditioning operations are available to WDISC customers. Otherwise, the TDRSS is transparent to the data format and the particular data format to be used will be established in the customer MOC. Data polarity ambiguity is resolved on the customer platform.
2. The resulting signal to a customer platform must not violate flux density considerations. Operational restrictions must be observed.
3. For data rates > 300 kbps, PN modulation is never used.
4. The SN is capable of supporting BPSK signals at data rates less than 300 kbps; however, its use will be constrained and must be coordinated with GSFC Code 450.

Figure B-3. TDRSS Functional Configuration for PSK Forward Services

B.2.2.1 PSK I-Q Channel Ambiguity

When two channels are used on the forward link (i.e., SS-UQPSK modulation), the I-Q channel ambiguity is resolved by the PN code and power ratio separation between the command and range channels. When there is a single data channel on the forward link (i.e., SS-BPSK and BPSK modulation), there is no I-Q channel ambiguity for these modulation types.

B.2.2.2 PSK Data Polarity Ambiguity

If NRZ-M, NRZ-S, Biphase-M, or Biphase-S data formats are used, the customer platform can resolve the data polarity ambiguity by differential decoding of the data; i.e., -M or -S to -L format conversion. If NRZ-L or Biphase-L data format is used, data polarity ambiguity will exist and it is the customer's responsibility to utilize other techniques, such as frame synchronization to an a priori data (sync) word or its complement, to resolve the data polarity ambiguity.

B.2.3 PM Forward Services (SSA Only)

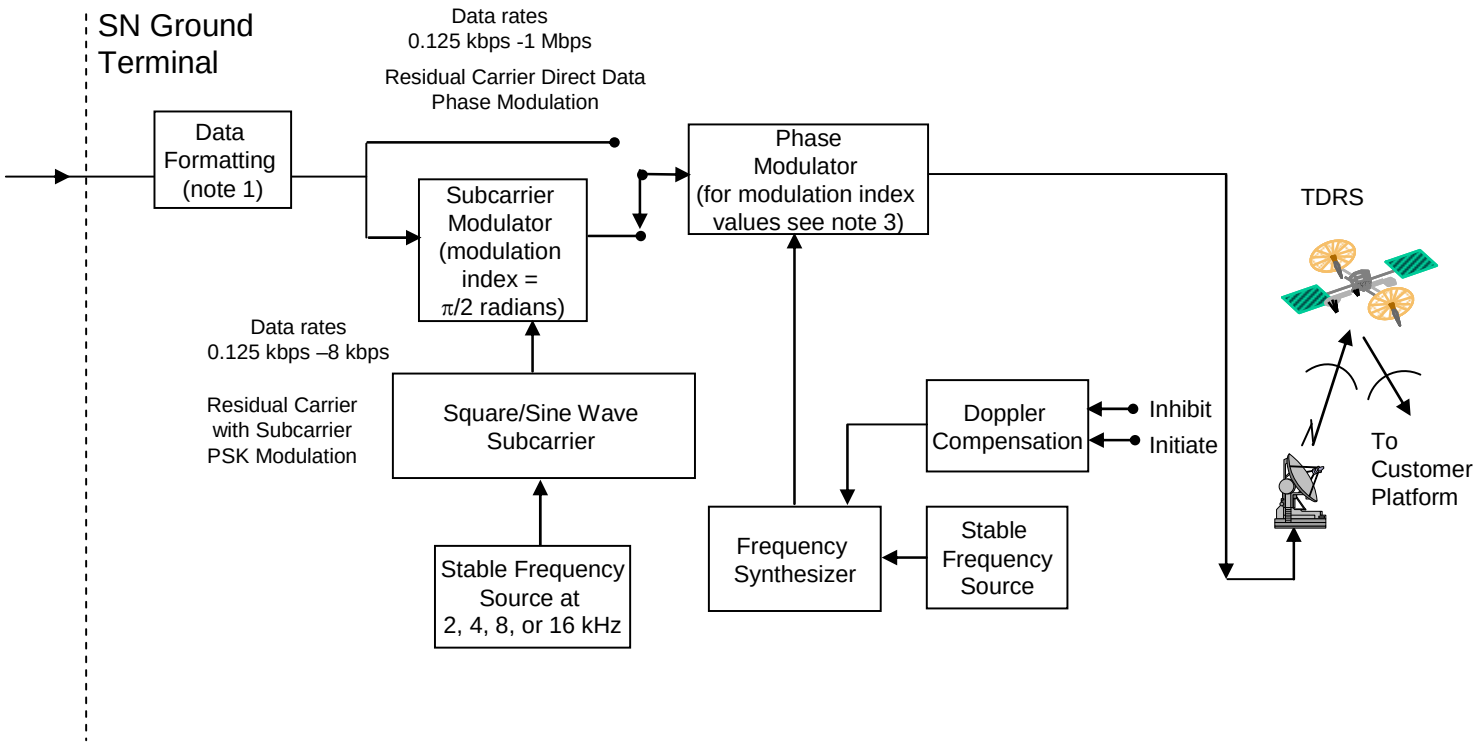
Figure B-4 depicts the functional configuration for the TDRSS SSA PM services. For a Direct PM scheme, the command data directly phase modulates the data with a modulation index of 0.2 to 1.5 radians or $\pi/2$ radians. For a PSK subcarrier PM scheme, the command data BPSK modulates either a sinusoidal or square-wave subcarrier, which linearly phase modulates the carrier. The SN can perform data formatting operations; these customer signal characteristics should be discussed with GSFC Code 450 prior to service to determine if the formatting will be performed by the customer MOC prior to the SN interface or at the SN.

B.2.3.1 PM I-Q Channel Ambiguity

There is no I-Q channel ambiguity for these modulation types as they use a single data channel.

B.2.3.2 PM Data Polarity Ambiguity

If NRZ-M, NRZ-S, Biphase-M, or Biphase-S data formats are used, the customer platform can resolve the data polarity ambiguity by differential decoding of the data; i.e., -M or -S to -L format conversion. If NRZ-L or Biphase-L data format is used, data polarity ambiguity will exist and it is the customer's responsibility to utilize other techniques, such as frame synchronization to an a priori data (sync) word or its complement, to resolve the data polarity ambiguity.



Notes:

1. The TDRSS may be transparent to the data format; however, the SN can perform symbol/data formatting operations and these customer signal characteristics should be discussed with GSFC Code 450 prior to service. Data phase ambiguity is resolved on the customer platform.
2. The resulting signal to a customer platform must not violate flux density considerations. Operational restrictions must be observed.
3. The PM modulation index can be: 1) 0.2 to 1.5 radians or $\pi/2$ radians for direct data phase modulation and PSK squarewave subcarrier PM and 2) 0.2 to 1.8 radians for PSK sinewave subcarrier phase modulation.
4. The SN supports subcarrier frequency/bit rate ratio = 2^n, where n=1...7 for NRZ formats and n=2…7 for Biphase formats.

Figure B-4. TDRSS Functional Configuration for PM Forward Services

B.3 Return Service

B.3.1 General

The customer/SN end-to-end system functional configuration for return service is shown in Figure B-5. Return data generated in the customer platform undergoes various baseband data conditioning operations (i.e., data format conversion, data demultiplexing for alternate bits on the I and Q channels, convolutional encoding, symbol format conversion, and symbol interleaving) and RF signal processing (spectrum spreading, modulation, I/Q-channel power weighting, and frequency upconversion) prior to transmission to the TDRSS. At the WSC, the inverse RF signal processing (frequency downconversion, despreading, and demodulation) and baseband signal processing (symbol synchronization, symbol format conversion, symbol deinterleaving, Viterbi decoding, data format conversion, and data interleaving of the I- and Q-channel data bits) are performed. The return service data at the WSC/SN data interface will always be treated as NRZ-L. For example, if NRZ-M data formatting is scheduled, the SN will perform NRZ-M to NRZ-L data format conversion. If SN customers would like their data format to be unaltered by the SN (i.e., in the example just given, they would like to receive NRZ-M data rather than NRZ-L data at the SN data interface), then customers need to schedule through the SN as if their data format is NRZ-L; then the SN will not perform any data format conversion. Refer to Section 3, paragraph 3.6, for information concerning data interface capabilities and restrictions.

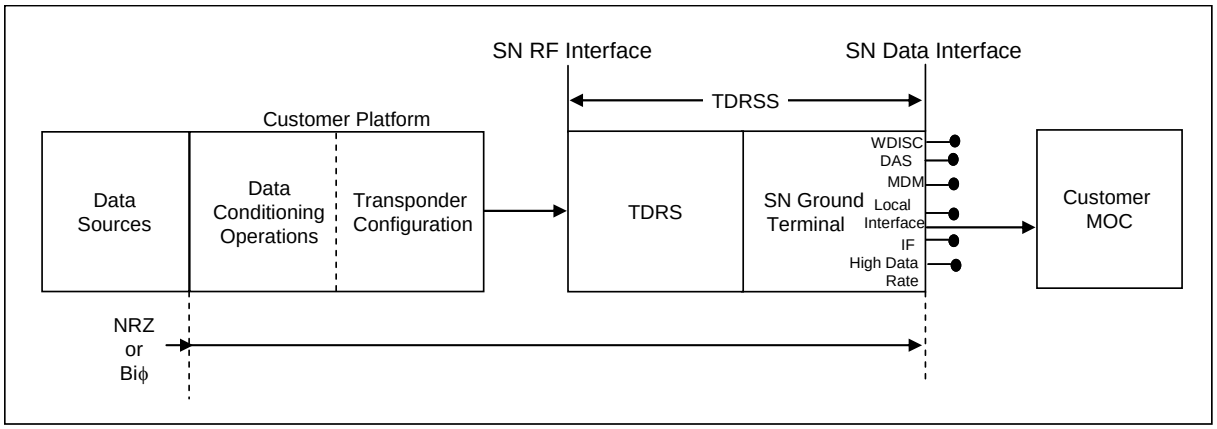


Figure B-5. Return Service End-to-End System Functional Configuration

The SN return services are divided into 2 major groups, Data Group 1 (DG1) and Data Group 2 (DG2). DG1 services utilize spread spectrum modulation while DG2 services are non-spread. Figure B-6 depicts the customer platform data communication functional configurations for DG1 and DG2 return services, where the data conditioning operations are shown in Figure B-7 through Figure B-9 for the specific Data Group and mode configuration.

NOTE:

KaSA return does not support DG1 services.

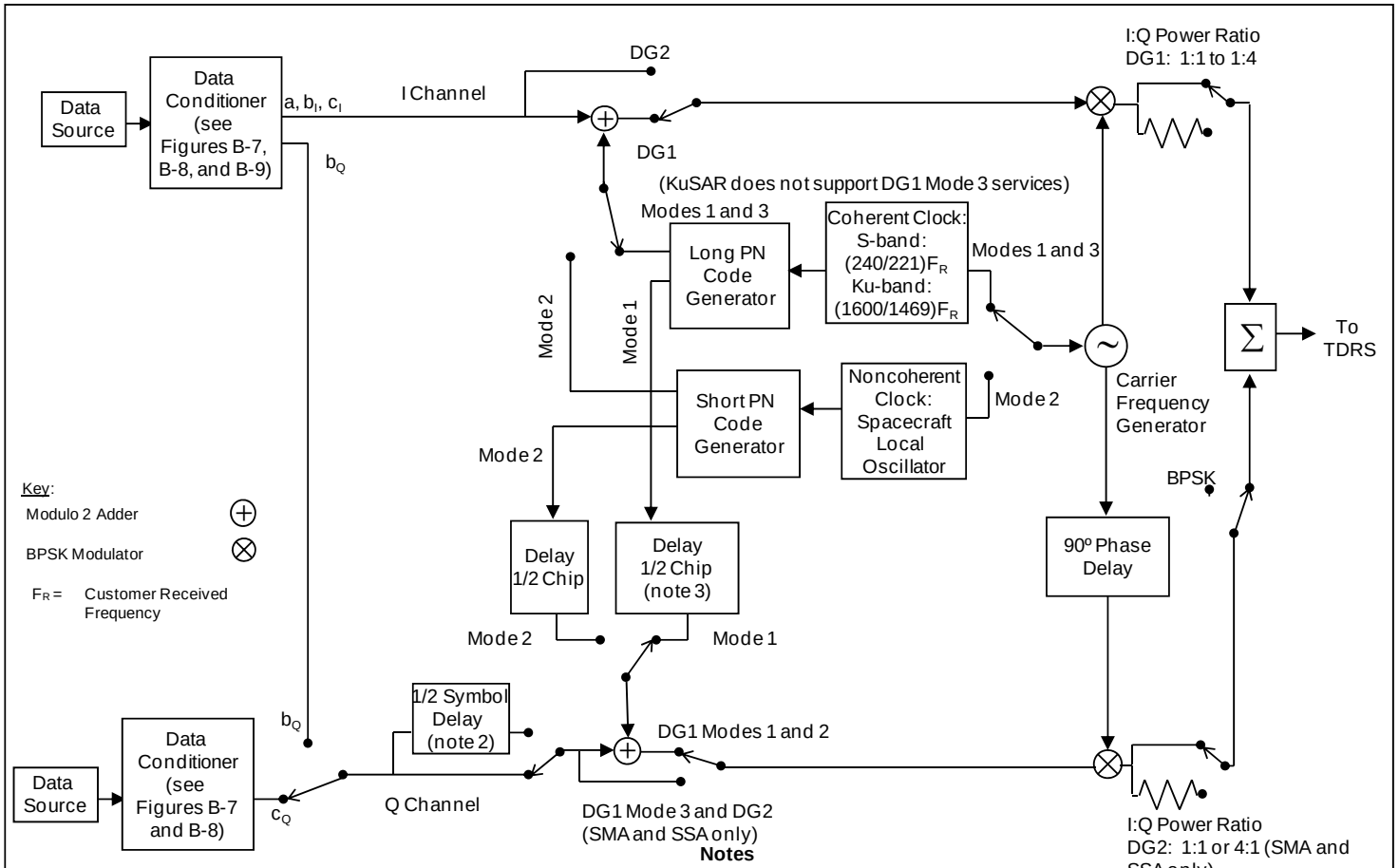
B.3.2 DG1 Services

Within each data group, there are several types of modulation. DG1 services are subdivided into three modes of operation, DG1 modes 1, 2, and 3. KuSA return service does not support DG1 mode 3 services. DG1 services support several types of modulation and configurations, which are described in paragraph B.3.2.1. Paragraphs B.3.2.2 and B.3.2.3 describe DG1 I-Q channel ambiguity and data polarity ambiguity, respectively.

B.3.2.1 DG1 Configurations

a. Balanced Power Single Data Source-Identical Data on the I and Q Channels (DG1 mode 1 and 2 only). I and Q channels consist of identical data that is synchronous and identically formatted, and rate 1/2 convolutionally coded (if applicable). The signal is transmitted using balanced (I/Q power ratio is 1:1) SQPN modulation. Table B-2 lists the service configuration constraints, where the I channel data rate = Q channel data rate = source data rate. The data conditioning operations supported are shown in Figure B-7 for this configuration, where the channel data source represents the single data source with identical data conditioning operations performed on both the I and Q channels. Figure B-10 describes the rate 1/2 convolutional encoder supported by the SN.

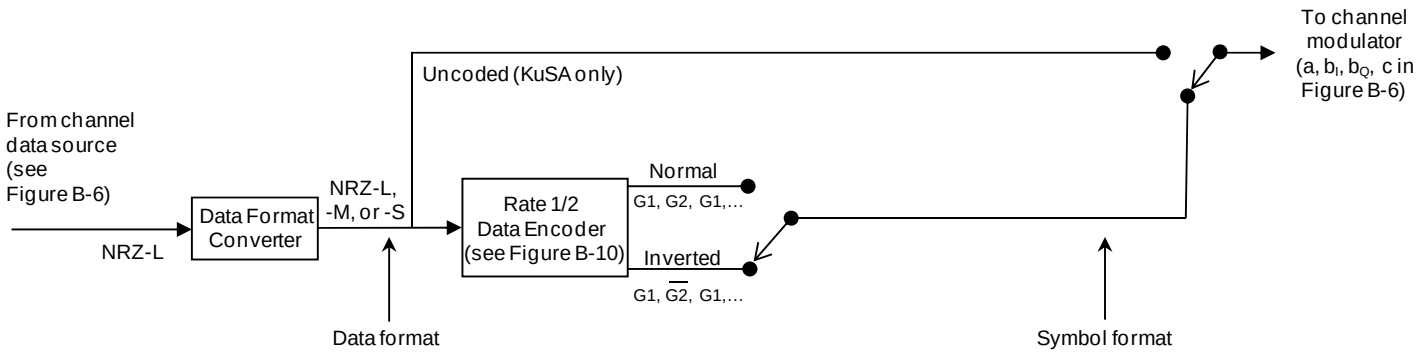
b. Balanced Power Single Data Source-Alternate I/Q Bits (SMAR and SSAR DG1 mode 1 and 2). I and Q channels consist of alternate bits of the same data source and each channel will be identically but independently and differentially formatted and rate 1/2 convolutionally encoded. The Q channel encoder output symbol will be delayed by a half symbol period relative to the I channel encoder output symbol. The signal is transmitted using balanced (I/Q power ratio is 1:1) SQPN modulation. Table B-2 lists the service configuration constraints, where the I channel data rate = Q channel data rate = 1/2 source data rate. The data conditioning operations supported are shown in Figure B-7 for this configuration, where the channel data source represents the I and Q channels after decommutation from the single data source and the I and Q channels are identically but independently data conditioned. Figure B-10 describes the rate 1/2 convolutional encoder supported by the SN.



Notes

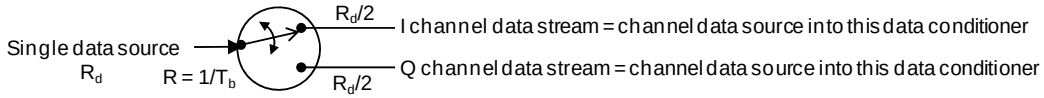
1. a, b, c denote the output of the data conditioner, where:
   a = Single data source with data on single data channel (BPSK)
   b = Single data source with data on both the I channel (b_I) and Q channel (b_Q), which can be configured as either:
      1) Identical data on I and Q channels (DG1 Modes 1 and 2);
      2) Alternate I/Q data bits (DG1 Modes 1 and 2 for SSA and SMA and DG2) with 1:1 I:Q power ratio;
      3) Alternate I/Q encoded symbols (DG2) with 1:1 I:Q power ratio
   c = Dual data sources with data on both the I channel (c_I) and Q channel (c_Q). Dual data sources, I/Q power ratio must be = 1:1 for KuSA services.
2. Delay is required for DG1 and DG2 alternate I/Q data bit configuration, DG2 alternate symbol configuration, and DG2 dual data source SQPSK configuration.
3. Q channel PN code sequence is identical to the I channel PN Code sequence, but delayed by X + 1/2 chip, where X is dependent upon the unique customer PN code assignment.

Figure B-6. Customer Platform Functional Configuration for DG1 and DG2



Where channel data source is as follows for each possible configuration:

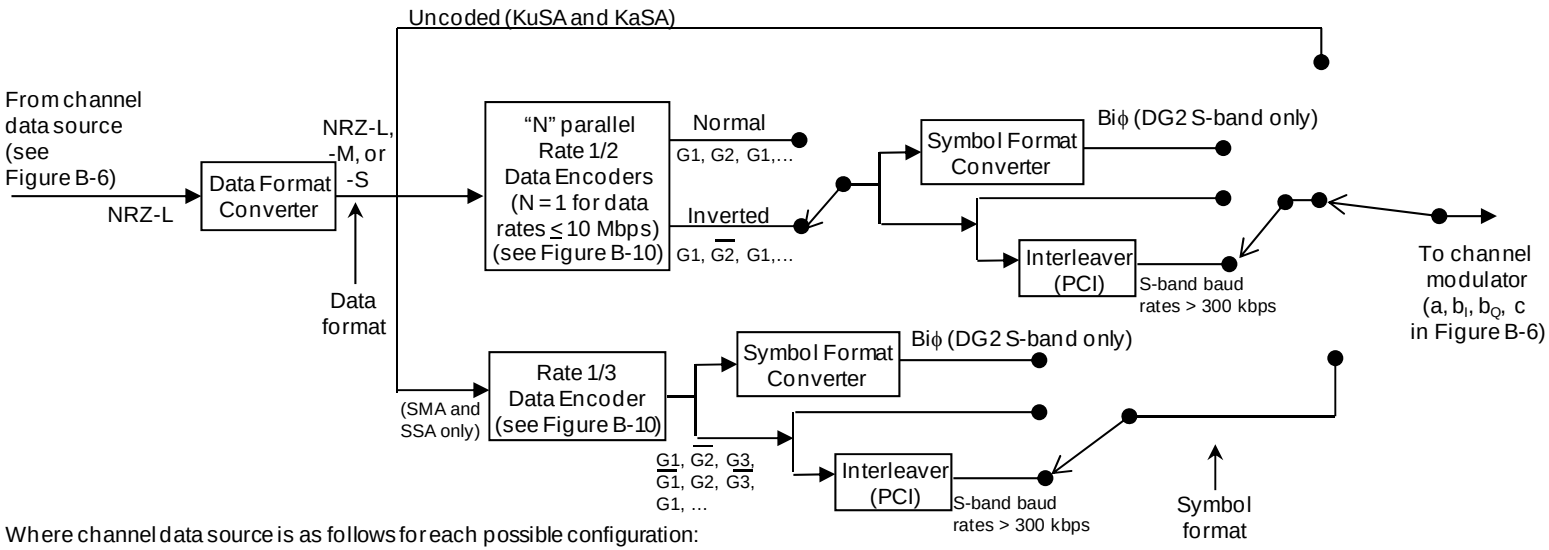
a. Single data source with single data channel (BPSK): I channel data stream = channel data source
b. Single data source with data on both the I channel and Q channel, which can be configured as either:
   1) Identical data on I and Q channels: channel data source = I channel data source = Q channel data source [identical data conditioning operations on I and Q channels (i.e., data/symbol format/coding and synchronous data (time aligned)]
   2) Alternate data bits on I and Q channels (SSA and SMA only): I and Q channel data streams are alternate data bits of the same single data source [identical but independent data conditioning operations on I and Q channels (i.e., identical formatting and coding)]



Switch is at each position for T_d seconds, where $T_d=1/R_d$

c. Dual Data Sources: channel data source represents I and Q channel data sources separately [independent data conditioning operations]; channel data source = I Channel of DG1 mode 3. KuSAR does not support DG1 Mode 3 services. Dual data sources, I/Q power ratio must be = 1:1 for KuSAR services.

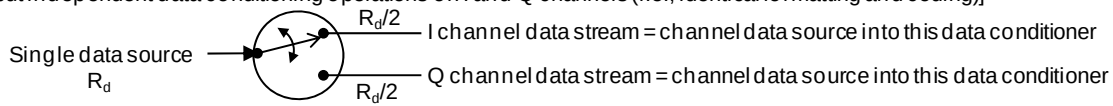
Figure B-7. Data Conditioning Operations for DG1 Modes 1 and 2 (I and Q Channels) and DG1 Mode 3 I Channel



Where channel data source is as follows for each possible configuration:

a. Single data source with single data channel (BPSK): I channel data stream = channel data source

b. Single data source with data on both the I channel and Q channel, which can be configured as:
1) Alternate data bits on I and Q channels: I and Q channel data streams are alternate data bits of the same single data source [identical but independent data conditioning operations on I and Q channels (i.e., identical formatting and coding)]



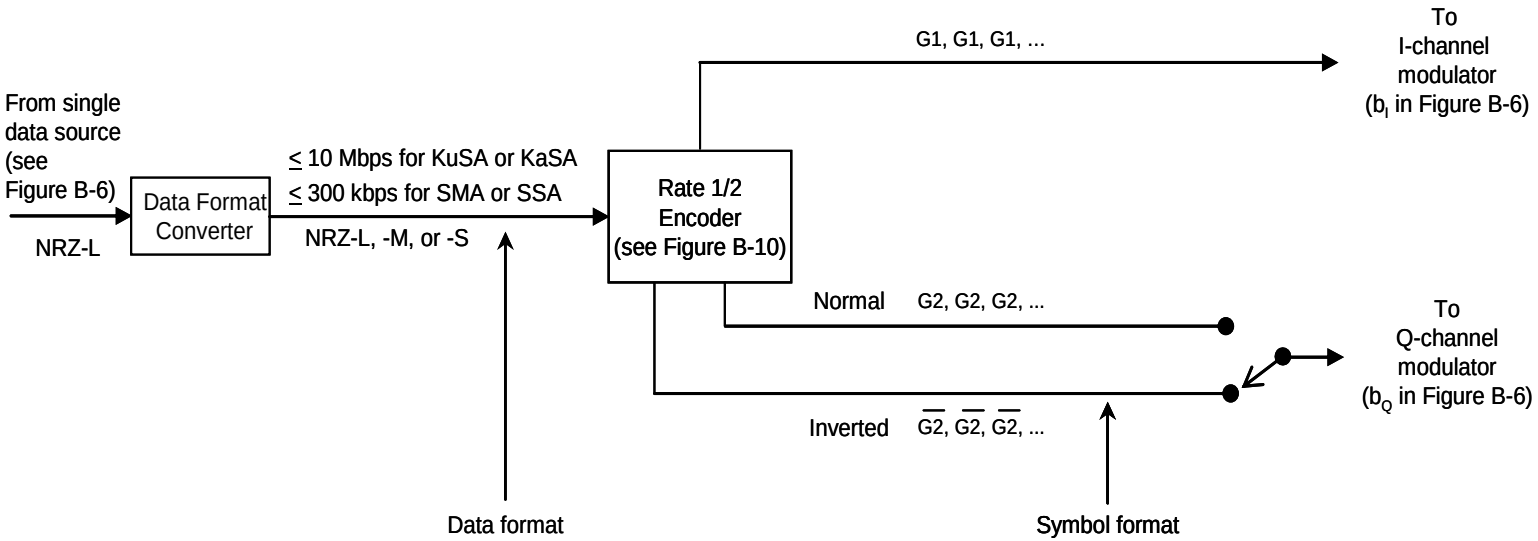
Switch is at each position for T_d seconds, where $T_d=1/R_d$

c. Dual Data Sources: channel data source represents I and Q channel data sources separately [independent data conditioning operations]; channel data source = Q Channel of DG1 mode 3 . KuSAR does not support DG1 Mode 3 services. Dual data sources, I/Q power ratio must be = 1:1 for KuSAR services.

Notes:

1. For the SQPSK alternate I/Q data-bit configuration, NRZ to Biϕ conversion is not allowed. However, NRZ-M or NRZ-S data format conversion is required to resolve the data polarity ambiguity and to reconstruct the single data channel at the SN ground terminal. This configuration is supported for KuSAR and KaSAR single data sources > 10 Mbps.
2. If the data format is NRZ-L or Biphase-L, the SN ground terminal does not resolve the data polarity ambiguity. If the data format is NRZ-M, NRZ-S, Biphase-M, or Biphase-S, the SN ground terminal resolves the data polarity ambiguity.
3. Biphase symbol formatting is only allowed for S-band DG2 BPSK or QPSK modes.

Figure B-8. Data Conditioning Operations for DG1 Mode 3 Q Channel and DG2 (except SQPSK with Alternate I/Q Encoded Symbols)



Notes:

1. If the data format is NRZ-L, the SN ground terminal does not resolve the data polarity ambiguity.
2. If the data format is NRZ-M or NRZ-S, the SN ground terminal resolves the data polarity ambiguity.

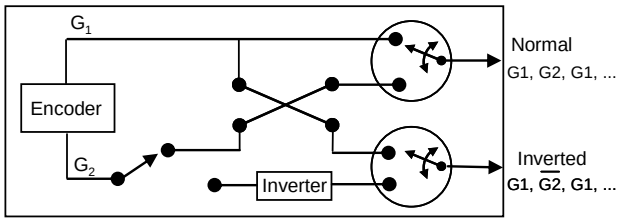
Figure B-9. Data Conditioning Operations for DG2 SQPSK with Alternate I/Q Encoded Symbols

Table B-2. Data Configuration Constraints for DG1 Modes 1 and 2, Single Data Source

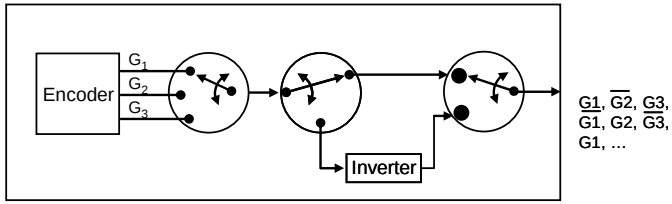
Coding (note 4)	Data Format	Configuration	Source Data Rate Restrictions and Availability (note 1)			
			MA (note 2)	SMA and SSA (note 2)	KuSA	KaSA
Rate 1/2	NRZ	Single Data Channel (BPSK)	≤ 150 kbps	≤ 150 kbps	1 kbps - 150 kbps	NA
		Identical Data on I and Q channels				
		Alternate I and Q bits	NA	≤ 300 kbps	NA	NA
Rate 1/3	NRZ	NA	NA	NA	NA	NA
Uncoded	NRZ	Single Data Channel (BPSK)	NA	Note 3	1 kbps - 300 kbps	NA
		Identical Data on I and Q channels				

Notes: NA: Not Available

1. The channel data rate restrictions are as follows:
   a. For single data source configurations with identical data on both I and Q channels:
      channel data rate = source data rate
   b. For single data source configuration with alternate bits on the I and Q channels:
      channel data rate = I channel data rate = Q channel data rate = 1/2 the source data rate. The I/Q (power) must be 1:1.
   c. For a BPSK signal configuration:
      channel data rate restriction is maximum data rate for the channel
2. Minimum data rate for MA, SMA, and SSA services:
   DG1 Mode 1: 0.1 kbps
   DG1 Mode 2: 1 kbps
3. The SN is capable of supporting SMA and SSA uncoded return link signals; however, its use will be constrained and must be coordinated with GSFC Code 450.
4. Figure B-10 describes the convolutional encoders supported by the SN.



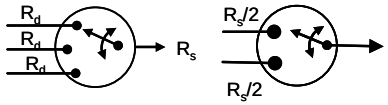
Rate 1/2 Data Encoder



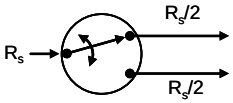
Rate 1/3 Data Encoder

Key:

Commutators:



Decommutator:



Switches are at each position for T_S seconds where T_S=1 /R_S= symbol duration

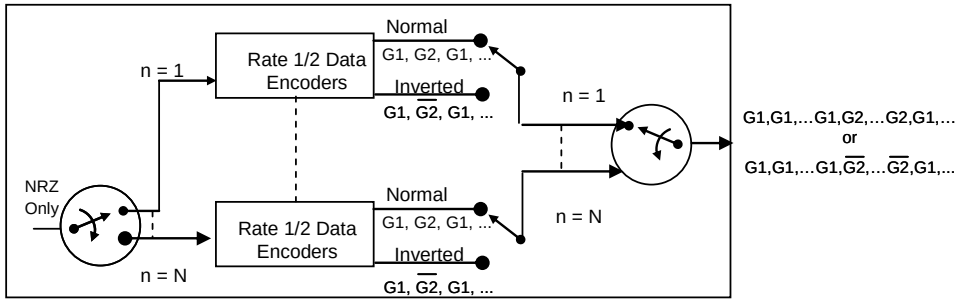
Encoders: convolutional, nonsystematic, transparent

Rate 1/2:

- Generator Functions: G1 = 1111001; G2 = 1011011
- Symbols generated from G1 must precede symbols generated from G2 relative to the data bit period.
- The SN can support symbols generated from G2 that are either true or complemented. However, G_2 symbol inversion provides an increased symbol transition density for a convolutional encoder input data signal with low transition density, which aids the SN ground terminal clock (symbol) synchronization.

Rate 1/3:

- Generator Functions: G1 = 1111001; G2 = 1011011; G3 = 1110101
- The symbol sequence must be generated from G1, G2, and G3 successively relative to the data bit period.
- Alternate symbols generated from the convolutional encoding must be complemented.



N Parallel Rate 1/2 Data Encoders

$$N = \frac{R_d}{1 \times 10^7}$$ Rounded to the next highest integer if N ≠ Integer

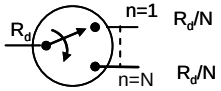
N = Number of parallel code 1 data encoders for the channel

R_d = Channel data rate (bps)

Key:

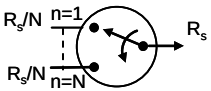
Parallel Encoders

Decommutator:



Switch is at each position for T_d seconds where T_d=1 /R_d= bit duration

Commutator:



Switch is at each position for T_S seconds where T_S=1 /R_S= symbol duration; R_S= 2 R_d

Figure B-10. Data Encoders

c. Unbalanced Power Single Data Source-Identical Data on the I and Q Channels (DG1 mode 1 and 2 only). I and Q channels consist of identical data that is synchronous and identically formatted, and rate 1/2 convolutionally coded (if applicable). The signal is transmitted using unbalanced (I/Q power ratio can be weighted up to a maximum of 1:4) SQPN modulation. Table B-2 lists the service configuration constraints, where the I channel data rate = Q channel data rate = source data rate. The data conditioning operations supported are shown in Figure B-7 for this configuration, where the channel data source represents the single data source with identical data conditioning operations performed on both the I and Q channels. Figure B-10 describes the rate 1/2 convolutional encoder supported by the SN.

d. Single Data Source with Single Data Channel (DG1 modes 1 and 2 only). Either the I or Q channel consists of data that has been formatted and rate 1/2 convolutionally encoded (if applicable). The channel is modulo-2 added asynchronously to the channel PN code. The signal is transmitted using BPSK modulation. Table B-2 lists the service configuration constraints. The data conditioning operations supported are shown in Figure B-7 for this configuration. Figure B-10 describes the rate 1/2 convolutional encoder supported by the SN.

e. Balanced Power Dual Data Sources. The I and Q channels consist of independent data that is independently formatted, convolutionally coded (if applicable), and symbol interleaved (if applicable on the Q channel only). For DG1 modes 1 and 2, the signal is transmitted using balanced (I/Q power ratio is 1:1) SQPN modulation. For DG1 mode 3, the I channel is modulo-2 added asynchronously to the channel PN code and the Q channel directly PSK modulates the carrier. The signal is transmitted using balanced (I/Q power ratio is 1:1) power. Table B-3 lists the service configuration constraints for DG1 modes 1 and 2, where the source data rate constraints apply to each channel separately. Table B-4 lists the service configuration constraints for DG1 mode 3, where the source data rate constraints apply to each channel separately. The data conditioning operations supported for this configuration are shown in Figure B-7 for DG1 modes 1, 2, and 3 I channel, where the channel data source represents each of the I and Q channel sources separately for independent data conditioning operations. Figure B-8 presents the data conditioning operations for DG1 mode 3 Q channel. Figure B-10 describes the convolutional encoders supported by the SN.

f. Unbalanced Power Dual Data Sources (MA, SMA and SSA only). The I and Q channels consist of independent data that is independently formatted, convolutionally coded (if applicable), and symbol interleaved (if applicable on the Q channel only). For DG1 modes 1 and 2, the signal is transmitted using unbalanced (I/Q power ratio can be weighted up to a maximum of 1:4) SQPN modulation. For DG1 mode 3, the I channel is modulo-2 added asynchronously to the channel PN code and the Q channel directly PSK modulates the carrier.

Table B-3. Data Configuration Constraints for DG1 Modes 1 and 2, Dual Data Sources

Channel Coding (note 4)	Data Format	Source Data Rate Restrictions and Availability (note 1)			
		MA and SMA (note 2)	SSA (note 2)	KuSA (note 5)	KaSA
Rate 1/2	NRZ	≤ 150 kbps	≤ 150 kbps	1 kbps - 150 kbps	NA
Rate 1/3	NRZ	NA	NA	NA	NA
Uncoded	NRZ	Note 3	Note 3	1 kbps - 300 kbps	NA

Notes: NA: Not Available

1. For dual data source configurations, the channel data rate restrictions are equivalent to the source data rate and apply to each channel separately.
2. Minimum data rate for MA, SMA, and SSA services:
   DG1 Mode 1: 0.1 kbps
   DG1 Mode 2: 1 kbps
3. The SN is capable of supporting uncoded SSA and SMA return link signals; however, its use will be constrained and must be coordinated with GSFC Code 450.
4. Figure B-10 describes the convolutional encoders supported by the SN.
5. For dual data source configurations, KuSAR service I/Q(power) = 1:1

Table B-4. Data Configuration Constraints for DG1, Mode 3

Coding (note 4)	Data Format	I Channel Data Rate and Availability				Q Channel Data Rate and Availability			
		SMA	SSA	KuSA	MA and KaSA	SMA	SSA	KuSA	MA and KaSA
Rate 1/2	NRZ	0.1 kbps - 150 kbps	0.1 kbps - 150 kbps	NA	NA	1 kbps - 1.5 Mbps (note 1)	1 kbps - 3 Mbps (note 1)	NA	NA
Rate 1/3	NRZ	NA	NA	NA	NA	1 kbps - 1 Mbps (note 1)	1 kbps - 2 Mbps (note 1)	NA	NA
Uncoded	NRZ	Note 2	Note 2	NA	NA	Note 2	Note 2	NA	NA

Notes: NA: Not Available

1. Periodic convolutional interleaving (PCI) recommended on SMA and SSA return service for baud rates > 300 kbps. When interleaving is not employed for baud rates > 300 kbps, SSA and SMA performance may not be guaranteed.
2. The SN is capable of supporting SMA and SSA uncoded return link signals; however, its use will be constrained and must be coordinated with GSFC Code 450.
3. Figure B-10 describes the convolutional encoders supported by the SN.

The signal is transmitted using unbalanced (I/Q power ratio can be weighted up to a maximum of 1:4) power. Table B-3 lists the service configuration constraints for DG1 modes 1 and 2, where the source data rate constraints apply to each channel separately. Table B-4 lists the service configuration constraints for DG1 mode 3, where the source data rate constraints apply to each channel separately. The data conditioning operations supported for this configuration are shown in Figure B-7 for DG1 modes 1, 2, and 3 I channel, where the channel data source represents each of the I and Q channel sources separately for independent data conditioning operations. Figure B-8 presents the data conditioning operations for DG1 mode 3 Q channel. Figure B-10 describes the convolutional encoders supported by the SN.

B.3.2.2 DG1 I-Q Channel Ambiguity

For DG1 modes 1 and 2 operation, there is no I-Q channel ambiguity because the PN codes on the I and Q channels are different. For DG1 mode 3 operation, there is no I-Q channel ambiguity since the WSC resolves the I and Q channels by PN correlation and knowledge of the I/Q power ratio.

B.3.2.3 DG1 Data Polarity Ambiguity

For NRZ-M or NRZ-S customer data formats, the WSC resolves the data polarity ambiguity by differentially decoding the return service data to NRZ-L. For NRZ-L customer data formats, data polarity ambiguity will exist at the WSC/SN data interface and it is the customer's responsibility to utilize other techniques, such as frame synchronization to an a priori data (sync) word or its complement, to resolve the data polarity ambiguity.

NOTE:

The DG1 modes 1 and 2 single data source configuration with alternate I/Q data bits requires that the I and Q channels be differentially encoded to either NRZ-M or NRZ-S in order to recover the single data source, as well as, resolve data polarity ambiguity. Without differential encoding, the single data source may have the alternate bits inverted.

B.3.3 DG2 Services

DG2 services support several types of modulation and configurations, which are described in paragraph B.3.3.1. Paragraphs B.3.3.2 and B.3.3.3 describe DG2 I-Q channel ambiguity and data polarity ambiguity, respectively.

NOTE:

MA return does not support DG2 services.

B.3.3.1 DG2 Configurations

a. Balanced Power Single Data Source-Alternate I/Q Bits. I and Q channels consist of alternate bits of the same data source and each channel will be identically but independently and differentially formatted, and rate 1/2 convolutionally encoded (if applicable). The Q channel symbol will be delayed by a half symbol period relative to the I channel symbol. The signal is transmitted using balanced (I/Q power ratio is 1:1) SQPSK modulation. Table B-5 lists the service configuration constraints, where the I channel data rate = Q channel data rate = 1/2 source data rate. The data conditioning operations supported are shown in Figure B-8 for this configuration, where the channel data source represents the I and Q channels after decommutation from the single data source and the I and Q channels are identically but independently data conditioned. Figure B-10 describes the rate 1/2 convolutional encoder supported by the SN.

b. Balanced Power Single Data Source-Alternate I/Q Encoded Symbols. I and Q channels consist of the two concurrent output symbols of a rate 1/2 convolutional encoder, where the G_1 output of the encoder is on the I channel and the G_2 output of the encoder is on the Q channel. The Q channel will be delayed by a half symbol period relative to the I channel. The channels are transmitted using balanced (I/Q power ratio is 1:1) SQPSK modulation. Table B-5 lists the service configuration constraints, where the I channel data rate = Q channel data rate = 1/2 source data rate. The data conditioning operations supported are shown in Figure B-9 for this configuration. Figure B-10 describes the rate 1/2 convolutional encoder supported by the SN.

c. Single Data Source with Single Data Channel. The source data, that has been formatted and convolutionally encoded (if applicable), directly BPSK modulates the carrier. Table B-6 lists the service configuration constraints. The data conditioning operations supported are shown in Figure B-8 for this configuration. Figure B-10 describes the convolutional encoders supported by the SN.

d. Balanced Power Dual Data Sources. The I and Q channels consist of independent data that is independently formatted, convolutionally coded (if applicable), and symbol interleaved (if applicable). The signal is transmitted using balanced (I/Q power ratio is 1:1) QPSK or SQPSK modulation. Table B-7 lists the service configuration constraints, where the source data rate constraints apply to each channel separately. The data conditioning operations supported are shown in Figure B-8 for this configuration, where the channel data source represents each of the I and Q channel sources separately for independent data conditioning operations. Figure B-10 describes the convolutional encoders supported by the SN.

Table B-5. Data Configuration Constraints for DG2, Single Data Source (SQPSK)

Coding (note 5)	Data Format	Configuration	Source Data Rate Restrictions and Availability (note 1)			
			MA	SMA	SSA	KuSA and KaSA
Rate 1/2	NRZ	Alternate I and Q bits (note 2)	NA	1 kbps - 3 Mbps (note 3)	1 kbps - 6 Mbps (note 3)	>10 Mbps - 75 Mbps (note 6)
		Alternate I and Q symbols		1 kbps - 300 kbps	1 kbps - 300 kbps	1 kbps - 10 Mbps
Rate 1/3	NRZ	Alternate I and Q bits (note 2)	NA	1 kbps - 2 Mbps (note 3)	1 kbps - 2 Mbps (note 3)	NA
Uncoded	NRZ	Alternate I and Q bits (note 2)	NA	Note 4	Note 4	1 kbps - 300 Mbps

Notes:

1. For SQPSK modulation, the I/Q (power) = 1:1 and the I channel data rate = Q channel data rate = 1/2 the source data rate.
2. For the alternate I and Q bit configuration, the data format must be NRZ-L. On each channel, the data bits are identically but independently and differentially encoded and then convolutionally encoded (if desired) prior to transmission.
3. Periodic convolutional interleaving (PCI) recommended on SMA and SSA return service for baud rates > 300 kbps. When interleaving is not employed for baud rates > 300 kbps, SSA and SMA performance may not be guaranteed.
4. The SN is capable of supporting SMA and SSA uncoded return link signals; however, its use will be constrained and must be coordinated with GSFC Code 450.
5. Figure B-10 describes the convolutional encoders supported by the SN.
6. For rate 1/2 coding and source data rates greater than 20 Mbps (i.e., channel data rates greater than 10 Mbps), the customer transmitter must be configured to use N-parallel encoders, where N is the number of branch rate 1/2 encoders for each of the I and Q channels. N = channel data rate in bps/$1x10^7$, where N is rounded to the next higher integer if N is not an integer.

e. Unbalanced Power Dual Data Sources (SMA or SSA only). The I and Q channels consist of independent data that is independently formatted, convolutionally coded (if applicable), and symbol interleaved (if applicable). The signal is transmitted using unbalanced (I/Q power ratio is 4:1) QPSK or SQPSK modulation. Table B-7 lists the service configuration constraints, where the source data rate constraints apply to each channel separately. The data conditioning operations supported are shown in Figure B-8 for this configuration, where the channel data source represents each of the I and Q channel sources separately for independent data conditioning operations. Figure B-10 describes the convolutional encoders supported by the SN.

Table B-6. Data Configuration Constraints for DG2, BPSK

Coding (note 5)	Data Format	Source Data Rate Restrictions and Availability			
		MA	SMA	SSA	KuSA and KaSA
Rate 1/2	NRZ	NA	1 kbps - 1.5 Mbps (note 1)	1 kbps - 3 Mbps (note 1)	1 kbps - 75 Mbps (notes 4, 6)
	NRZ with Biϕ symbols	NA	1 kbps - 0.75 Mbps (notes 1, 2)	1 kbps - 1.5 Mbps (notes 1,2)	NA
Uncoded	Biϕ	NA	Note 3	Note 3	NA
	NRZ	NA	Note 3	Note 3	1 kbps - 150 Mbps (note 4)
Rate 1/3	NRZ	NA	1 kbps - 1 Mbps (note 1)	1 kbps - 2 Mbps (note 1)	NA
	NRZ with Biϕ symbols	NA	1 kbps - 0.5 Mbps (notes 1, 2)	1 kbps - 1 Mbps (notes 1,2)	NA

Notes: NA: Not Available

1. Periodic convolutional interleaving (PCI) recommended on SMA and SSA return service for baud rates > 300 kbps. When interleaving is not employed for baud rates > 300 kbps, SSA and SMA performance may not be guaranteed.
2. Biϕ symbol formats are not allowed with PCI.
3. The SN is capable of supporting SMA and SSA uncoded return link signals; however, its use will be constrained and must be coordinated with GSFC Code 450.
4. Higher KaSA return link data rates are possible through the automated Ka-band 650 MHz bandwidth IF service. Please contact GSFC Code 450 for further information.
5. Figure B-10 describes the convolutional encoders supported by the SN.
6. For a channel with rate 1/2 coding and data rates greater than 10 Mbps, the customer transmitter must be configured to use an N-parallel encoder, where N is the number of branch rate 1/2 encoders for the channel. N = channel data rate in bps/$1x10^7$, where N is rounded to the next higher integer if N is not an integer.

B.3.3.2 DG2 I-Q Channel Ambiguity

For the DG2 single data source SQPSK configurations (i.e., alternate I/Q data bit and alternate I/Q encoded symbols), I-Q channel ambiguity is resolved by the stagger between the I and Q channels.

For a DG2 single data source BPSK configuration, I-Q channel ambiguity does not exist because there is no quadrature component of the customer platform transmitted carrier signal.

Table B-7. Data Configuration Constraints for DG2, Dual Data Sources (QPSK, SQPSK)

Coding (note 7)	Data Format	Source Data Rate Restrictions and Availability (note 5) (data rates are for each channel separately)			
		MA	**SMA (notes 6, 9)**	**SSA (notes 6, 9)**	**KuSA and KaSA**
Rate 1/2 (Either Channel)	NRZ	NA	1 kbps - 1.5 Mbps (note 1)	1 kbps - 3 Mbps (note 1)	1 kbps - 75 Mbps (notes 4, 8)
	NRZ with Biϕ symbols	NA	1 kbps - 0.75 Mbps (notes 1, 2)	1 kbps - 1.5 Mbps (notes 1, 2)	NA
Rate 1/3 (Either Channel)	NRZ	NA	1 kbps - 1 Mbps (note 1)	1 kbps - 2 Mbps (note 1)	NA
	NRZ with Biϕ symbols	NA	1 kbps - 0.5 Mbps (notes 1, 2)	1 kbps - 1 Mbps (notes 1,2)	NA
Uncoded (Either Channel)	NRZ	NA	Note 3	Note 3	1 kbps - 150 Mbps (note 4)
	Biϕ	NA	Note 3	Note 3	NA

Notes: NA: Not Available

1. Periodic convolutional interleaving (PCI) recommended on SMA and SSA return service for baud rates > 300 kbps. When interleaving is not employed for baud rates > 300 kbps, SSA and SMA performance may not be guaranteed.
2. Biϕ symbol formats are not allowed with PCI.
3. The SN is capable of supporting SMA and SSA uncoded return link signals; however, its use will be constrained and must be coordinated with GSFC Code 450.
4. Higher KaSA return link data rates are possible through the automated Ka-band 650 MHz bandwidth IF service. Please contact GSFC Code 450 for further information.
5. For DG2 dual sources with identical symbol rates that are NRZ formatted on the I and Q channels, the I and Q channels must be offset relative to one another by one half symbol period (i.e., SQPSK modulation). Additionally, for DG2 dual sources that use biphase symbol formatting (S-band only) on either channel and the baud rate of the two channels are identical, SQPSK modulation is used and the transition of one channel occurs at the mid-point of adjacent transitions of the other channel.
6. For unbalanced QPSK (SMA and SSA only), the I channel must contain the higher data rate and when the data rate on the I channel exceeds 70 percent of the maximum allowable data rate, the Q channel data rate must not exceed 40 percent of the maximum allowable data rate on that Q channel.
7. Figure B-10 describes the convolutional encoders supported by the SN.
8. For a channel with rate 1/2 coding and data rates greater than 10 Mbps, the customer transmitter must be configured to use an N-parallel encoder, where N is the number of branch rate 1/2 encoders for the channel. N = channel data rate in bps/$1x10^7$, where N is rounded to the next higher integer if N is not an integer.
9. For S-band DG2, dual data channel, balanced power configurations, the minimum total (I+Q) data rate must be 60 kbps or greater.

For the DG2 dual data source QPSK configuration, the WSC can resolve the I-Q channel ambiguity if at least one of the following conditions are met:

a. I/Q power ratio is 4:1 (SMA and SSA operation only).
b. One data channel is coded, the other channel is uncoded.
c. One channel is rate-1/3 coded and the other channel is rate-1/2 coded (SMA and SSA operation only).
d. One channel symbol rate differs by more than 25 percent from the other channel symbol rate and from a harmonic of that symbol rate.

For the DG2 dual data source SQPSK configuration, I-Q channel ambiguity is resolved when the I:Q power is 4:1 (SMA and SSA operation only). For this configuration with an I:Q power of 1:1, the I-Q ambiguity will exist at the WSC/SN data interface and it is the customer's responsibility to resolve this ambiguity.

B.3.3.3 DG2 Data Polarity Ambiguity

For NRZ-M, NRZ-S, Biphase-M (S-band only), or Biphase-S (S-band only) customer data formats, the WSC resolves the data polarity ambiguity by differentially decoding the return service data to NRZ-L. For NRZ-L or Biphase-L (S-band only) customer data formats, data polarity ambiguity will exist at the WSC/SN data interface and it is the customer's responsibility to utilize other techniques, such as frame synchronization to an a priori data (sync) word or its complement, to resolve the data polarity ambiguity.

For a DG2 single data channel configuration with alternate I/Q encoded symbols (Rate 1/2), the Viterbi decoder in the WSC resolves the carrier phase ambiguity and provides a single output data signal. For a single data channel configuration with alternate I/Q data bits, convolutionally coded or uncoded, and independent differential encoding on the I and Q channel symbols, the independent differential decoding of the symbols received on the I and Q channel in the WSC prior to multiplexing of these data signals into a single data channel signal resolves the data polarity ambiguity.

NOTE:

The DG2 single data channel configuration with alternate I/Q data bits requires that the I and Q channels be differentially encoded to either NRZ-M or NRZ-S in order to recover the single data source, as well as resolve data polarity ambiguity. Without differential encoding, the single data source may have the alternate bits inverted.

Appendix C. Operational Aspects of Signal and Autotrack Acquisition

C.1 General

C.1.1

This Appendix details the operational aspects associated with acquisition. A detailed description of both customer and TDRSS operations during acquisition is presented.

NOTE:

"Customer" is used in this Appendix as the general term. "Customer platform" or "customer MOC" is used where specificity is required.

C.1.2

The intent is to provide an understanding of the many processes that occur during acquisition. This will then indicate the operations which must be performed by the customer MOC and/or customer platform to acquire the scheduled TDRSS services.

C.1.3

Up to five distinct acquisition processes may be required by the combination of the customer MOC, the TDRSS, and the customer platform in acquiring a forward or return service signal. These are as follows:

a. Antenna acquisition
   1. Open-loop antenna pointing (MA, SSA, SSA cross-support, KuSA with autotrack inhibited, KaSA with autotrack inhibited).
   2. Autotracking (KuSA and KaSA).

b. PN code acquisition.

c. Carrier acquisition.

d. Symbol synchronization.

e. Deinterleaver (applicable only to certain SMA and SSA return service signals) and Viterbi decoder synchronization.

NOTE:

Not all of the above functions are required of every service, data group, or mode. The detailed acquisition sequences to be presented discuss how and when these operations are accomplished in establishing the appropriate forward and/or return service.

C.1.4

Paragraph C.2 highlights the various parameters that impact the acquisition event sequence and/or the time to acquire (T_{acq}). Using a detailed timeline, paragraph C.3 describes the event sequence associated with acquisition. Paragraph C.4 concludes by addressing various issues related to reacquisition.

C.2 Key Parameters which Impact Acquisition Sequences and Times

C.2.1 Customer MOC Controllable Parameters

C.2.1.1 General

Table C-1 summarizes the parameters which impact acquisition and which the customer MOC can either schedule prior to (refer to Section 10, paragraph 10.2) or initiate during (please see Section 10, paragraph 10.3) the scheduled service support period. The parameters are described in more detail in Sections 5 (MA), 6 (SSA), 7 (KuSA), and 8 (KaSA). Paragraphs C.2.1.2 through C.2.1.5 expand on certain aspects of these parameters.

C.2.1.2 Doppler Compensation

To aid in customer platform acquisition of both the forward service command and range channel PN codes and the forward service carrier, Doppler compensation should be scheduled or accommodated on the customer platform. If Doppler compensation is not scheduled, the WSC will transmit the carrier frequency and the derived PN code chip rate as specified in the SHO. If no accommodations are made on the customer platform, this fixed frequency forward service transmission may not allow acquisition and, therefore, it is recommended that the customer MOC schedule or accommodate Doppler compensation at all times so that the forward service PN code clocks and the carrier are continuously compensated to account for changing customer platform dynamics. The MOC may choose to disable Doppler compensation during ground tracking services; however, valid tracking service data is available with or without Doppler compensation enabled.

C.2.1.3 Start of Forward Service Data

It is recommended that the customer MOC not initiate forward service data transmission to the NISN data transport system until sufficient time has elapsed after the scheduled service support period start time for the customer platform to have acquired the forward

service PN codes (command and range channels) and the carrier, or until forward service lock is verified by return service data. This procedure will enhance the forward service T_{acq} and help to prevent false carrier lock. The specific acquisition events outlined in paragraph C.3 assume that commands are not sent by the customer MOC to its customer platform unless their receipt and/or implementation by that customer platform can be confirmed by the customer MOC via telemetry. For coherent turnaround services (i.e., return services using DG1 modes 1 or 3 or DG2 [coherent operations]), this implies that the start of forward service data transmission (by the customer MOC to the NISN data transport system) should not start until the return service acquisition process is complete.

C.2.1.4 Start of Return Service (Relative to the Start of the Corresponding Forward Service)

The start time of the scheduled return service support period, T_R, initiates the WSC return service acquisition sequence. For a customer platform in a coherent turnaround mode of operation, it is recommended that the forward service start time precede the return service start time by sufficient time to allow the customer platform acquire the forward service and provide the coherent return signal. Typically, the forward service start time precedes the return service start time by 30 seconds for coherent services.

C.2.1.5 Start of Return Service Data Transmission

a. The customer platform should be scheduled/commanded to initiate return service data transmission of desired customer platform data only after the WSC has completed all of its signal acquisition processes. This procedure helps prevent loss of desired customer platform data during this segment of the WSC acquisition process.

b. After ground terminal PN code and carrier lock has occurred, the next ground terminal processes involve symbol synchronizers, and (where applicable) Viterbi decoders and a deinterleaver. The number of symbols which must be processed by each of these devices for each to achieve lock depends on the P_{rec} and the symbol transition density of the individual customer spacecraft data channel. To avoid loss of data during these processes, it is advisable for the customer platform to transmit a preamble (e.g., a sequence of psuedo-random bits) before "real" data is sent. This may also reduce the synchronization time of this part of the return service acquisition process due to the high (50 percent) symbol transition density of such a preamble sequence.

Table C-1. Customer MOC Controllable Parameters Which Impact Acquisition

Parameter	Initiated or Scheduled by	Customer Services Affected	Impact on T_{acq}	Impact on Acquisition Sequence	Comments
Doppler Compensation	Customer MOC	All forward services	Decreased T_{acq}	None	Recommended. Not required if customer platform has capability to resolve Doppler by onboard processing.
Predicted Local Oscillator (LO) Frequency (f_o) (in SHO or reconfiguration OPM [Class 3])	Customer MOC	All forward services or noncoherent return services	Acquisition cannot be achieved unless the uncertainty of the predicted frequency and the unresolved Doppler are within the acquisition bandwidth of the receiver	Subsequent steps cannot be achieved	Crucial in establishing forward service and noncoherent return service OPM allows f_o reconfiguration if SHO f_o is outside of both the acquisition bandwidth of the receiver and the forward frequency sweep range (forward services) or the expanded frequency uncertainty range (non-coherent) return service.
Forward Service Frequency Sweep	Customer MOC	All forward services	Increased T_{acq}	Sweep is scheduled and implemented	Employed when the customer MOC cannot define f_o accurately Independent of Doppler compensation
Expanded Frequency Uncertainty	Customer MOC	Return service non-coherent operation: DG1 mode 2 DG2 (noncoherent)	Increased T_{acq}	None	Employed when the customer MOC cannot define f_o accurately

Table C-1. Customer MOC Controllable Parameters Which Impact Acquisition (cont'd)

Parameter	Initiated or Scheduled by	Customer Services Affected	Impact on T_{acq}	Impact on Acquisition Sequence	Comments
Start of Service	Customer MOC/NCCDS	All forward and/or return services	Enhances T_{acq}	None	Scheduling to minimize impact of customer platform LO frequency uncertainties
Start of Forward Service Data (relative to start of forward service)	Customer MOC	All forward services	Enhances T_{acq}	Customer MOC initially sends no data until PN codes and carrier are acquired by customer platform	Enhances forward service T_{acq} and helps prevent false carrier lock by customer platform
Start of Return Signal Transmission (relative to start of return service)	Customer MOC/NCCDS	All return services	Enhances T_{acq}	Customer platform transmits coherent carrier and PN codes prior to scheduled start of return service	Minimizes ground terminal PN code (if applicable) and carrier acquisition times For coherent operations, customer should allow time for forward service acquisition before starting return service. Typically start of return service equals start of forward service plus 30 seconds.
Start of Return Service Data (relative to start to return service)	Customer MOC	All return services	Enhances T_{acq}	Customer platform may initially transmit data preamble (pseudo-random bits recommended)	May prevent a potential ground terminal false lock condition and minimize ground terminal loss of data during acquisition
TDRS High Power Mode	Customer MOC	SSA and KuSA forward services	Decreases T_{acq} with power mode	None	

Table C-2. Additional Items and Parameters Which Impact Acquisition

Item	Customer Services Affected	Impact on T_{acq}	Impact on Acquisition Sequence
Customer Platform Receive G/T	All forward services	T_{acq} varies inversely with customer spacecraft G/T	None
Customer Platform EIRP	All return services	T_{acq} varies inversely with customer Platform EIRP	None
KuSA Return Service Start-up for High Power Customer Platform	KuSA return service for P_{rec} values >-159.2 dBW	May increase T_{acq}	Acquisition process must limit instantaneous rate of change of P_{rec} ≤10 dB/sec

C.2.2 Other Key Parameters

Table C-2 summarizes other key parameters which can impact the acquisition process, but which are a result of basic customer platform design decisions (e.g., G/T, EIRP) or are constrained by TDRSS characteristics.

C.3 Acquisition Events

C.3.1

This paragraph presents a detailed description of both customer's and TDRSS' operations during acquisition. Included are an acquisition timeline and table which are intended to present an accurate description of the many processes which must occur to establish service. Due to the large number of TDRSS services, only a normal support configuration has been included.

C.3.2

Table C-3 provides a step-by-step account from the customer's point of view of the key events which must occur in establishing various services. The table assumes the TDRSS return service autotrack mode is enabled. If this mode is disabled, the table assumes that the customer platform orbital parameters, available to the TDRSS/ground terminal, are sufficiently accurate that program-track pointing of the TDRS SA antenna will provide the customer with satisfactory TDRSS KuSA/KaSA return service performance.

Wherever possible, specific T_{acq} values have been included to provide an estimate for the amount of acquisition overhead to be expected during scheduled service. However, these T_{acq} values are only estimates or predictions and should not be regarded as operational specifications.

Table C-3. Acquisition Events for TDRSS Services (Normal Forward and Return)

Event	Time	Equipment Status		Remarks
		Customer Platform	TDRS/Ground Terminal	
Service parameters defined by customer MOC	Up to 21 days prior to T_F or T_R depending on start time of first service, but at least T_F - 10 min or T_R –10 min depending on start time of first service	Not applicable	Not applicable	T_F is the scheduled start of forward service. T_R is the scheduled start of return service. For coherent services T_F must occur simultaneously with T_R or before T_R, i.e., $T_R = T_F + \Delta$, $\Delta \geq 0$ (typically Δ=30 sec for coherent services). For noncoherent services, T_F and T_R are independent. Refer to paragraph C.2.1 for customer MOC controllable parameters applicable to acquisition.
TDRS and ground terminal configures for services	T_F-5 min to T_F, T_R-5 min to T_R [SA], or T_F-15 sec to T_F[MA]	Idle	TDRS SA antenna slewed towards platform under WSC control; WSC Ground Control Equipment (GCE) initialized; TDRS configured	Up to 5 minutes are required for slewing TDRS SA antenna; ground terminal commands TDRS configuration as required by SHO frequency, pin diodes, MA phase shifters, etc.
Ground terminal performs pre-service testing if applicable	T_F - 3 min to T_F - 15 sec and T_R - 3 min to T_R - 15 sec	Not applicable	WSC performs pre-service testing	

Table C-3. Acquisition Events for TDRSS Services (Normal Forward and Return) (cont'd)

Event	Time	Equipment Status		Remarks
		Customer Platform	TDRS/Ground Terminal	
Customer platform configured for forward service (note 1)	$T_F - \varepsilon$	Receiver configured; receiving antenna open-loop pointed toward TDRS; forward signal acquisition process enabled; autotrack process enabled (if applicable).	Continuing as above	Customer platform configured ε units of time prior to scheduled service start time (or prior to end of previous service support period); SHO must define customer platform receiver frequency to within ±700 Hz for S-band, and within ±5 kHz for Ku-band, and ±6 kHz (Ka-band).
Forward service begins	T_F	Continuing as above	Ground terminal GCE activated; ground terminal transmits forward service signal	Recommended that customer MOC not transmit forward service data until sufficient time has elapsed for customer platform acquisition of command channel PN code, carrier, and range channel PN code, or until return service data stream, if available, indicates customer platform receiver carrier lock; recommended that Doppler compensation (carrier, PN code clocks) be scheduled during forward service signal acquisition (not automatic, must be in SHO). No command channel PN code modulation for forward service data rates >300 kbps.

Table C-3. Acquisition Events for TDRSS Services (Normal Forward and Return) (cont'd)

Event	Time	Equipment Status		Remarks
		Customer Platform	TDRS/Ground Terminal	
Customer platform receives forward service signal	$T_1 = T_F + \tau_d$	Command channel PN code acquisition process starts; carrier acquisition process enabled. Autotrack acquisition process starts for Ku-band or Ka-band customers with autotrack enabled.	Continuing as above	τ_d reflects estimated propagation delay (approximately 240 msec): ground terminal → TDRS →customer platform For Ku-band and Ka-band customer platform and $T_R = T_F$, the customer platform autotrack process after T_R shall be at a rate which results in an instantaneous rate of change of $P_{rec} \leq 10$ dB/sec; the customer platform autotrack of forward service signal is not necessary if the customer platform antenna can be open-loop pointed with sufficient accuracy to meet KuSA or KaSA forward and return service requirements
Command channel PN code acquired	$T_2 = T_1 + \tau_{cmd}$	Command channel PN code despreader synchronized; carrier acquisition process starts	Continuing as above	$\tau_{cmd} \leq 20$ sec (example value for NASA 4th generation transponder); τ_{cmd} represents the time required for the customer receiver to acquire the command channel PN code. Command channel is PN modulated only if data rate ≤ 300 kbps.

Table C-3. Acquisition Events for TDRSS Services (Normal Forward and Return) (cont'd)

Event	Time	Equipment Status		Remarks
		Customer Platform	TDRS/Ground Terminal	
Carrier acquired	$T_3 = T_2 + \tau_{car}$	Carrier tracking loop locked; range channel PN code acquisition process enabled; command channel symbol synchronizer process enabled	Continuing as above	$\tau_{car} \leq 5$ sec (example value for NASA 4th generation transponder); τ_{car} represents the time required for the customer receiver to acquire the carrier
Range channel PN code acquired; coherent turnaround return service signal transmitted	$T_4 = T_3 + \tau_{rng} + \tau_m$	Range channel PN code despreader synchronized; return service carrier locked to forward service carrier; return service PN code generator locked (clock rate and PN code epoch) to range channel PN code	Continuing as above	$\tau_{rng} \leq 10$ sec (example value for NASA 4th generation transponder); $\tau_m \leq 1$ sec; τ_{rng} represents the time required for the customer receiver to acquire the range channel. τ_m represents the time required for the customer transponder to transition from noncoherent to coherent mode; a data preamble sequence may be desirable on each customer platform data channel during ground terminal return service signal acquisition to prevent real data (i.e., telemetry, scientific) loss and to aid in WSC symbol synchronization and Viterbi decoder acquisition (refer to paragraph C.2.1)
Customer platform autotrack acquisition complete, high accuracy tracking begins (if applicable and enabled)	$T_5 = T_1 + \tau_{auto}$	Autotrack locked; symbol synchronizer acquisition in progress; onboard computer searching for frame synch word in forward service data stream normal operation	Continuing as above	Autotrack acquisition may be complete before forward service signal is fully acquired or vice versa

Table C-3. Acquisition Events for TDRSS Services (Normal Forward and Return) (cont'd)

Event	Time	Equipment Status		Remarks
		Customer Platform	TDRS/Ground Terminal	
Customer Platform configured for return service (note 1)	$T_R - \varepsilon$	Transmitter configured; coherent or noncoherent mode enabled; transmitting antenna open-loop pointed toward TDRS	Continuing as above	Customer platform configured ε units of time prior to scheduled service start time (or prior to end of previous service support period)
Return service begins	τ_R	Continuing as above	Ground terminal PN code and/or carrier acquisition process starts; symbol, Viterbi decoder, and deinterleaving synchronization and autotrack acquisition process enabled (as required)	For coherent services, τ_R is the start time of return service. τ_R is equal to the maximum of T_R or $T_F + \Delta$, where Δ is approximately $2\tau_d + \tau_{cmd} + \tau_{car} + \tau_{rng} + \tau_m$ For noncoherent services τ_R is independent of the T_F start time and if the local oscillator is not within the required values of ± 700 Hz (S-band), ± 5 kHz (Ku-band), ± 6 kHz (Ka-band), then OPM 07 (Expanded User Frequency Uncertainty Request) must be sent after T_R; A data preamble sequence may be desirable on each customer platform data channel during WSC return service signal acquisition to prevent real (i.e., telemetry, science) data loss and to aid in ground terminal symbol synchronization and decoder acquisition.

Table C-3. Acquisition Events for TDRSS Services (Normal Forward and Return) (cont'd)

Event	Time	Equipment Status		Remarks
		Customer Platform	TDRS/Ground Terminal	
PN code (DG1 only) and carrier acquired	$T_5 = \tau_R + \tau_{acq}$	Continuing as above	PN code despreader and carrier acquired; symbol synchronizer and Viterbi decoder processes start	For coherent service, $\tau_{acq} \leq 1$ sec For noncoherent service, $\tau_{acq} \leq$ 1 sec if customer platform transmitter frequency uncertainty is ≤ ± 700 Hz (S-band), ± 5 kHz (Ku-band), ± 6 kHz (Ka-band) and $\tau_{acq} \leq 3$ sec if customer platform transmitter frequency uncertainty is ± 3 kHz (S-band), ± 35 kHz (S-band), ± 20 kHz (Ku-band), ± 21 kHz (Ka-band)
Symbol and Viterbi decoder Synchronizers acquired; return service(s) established	$T_7 = T_5 + \tau_{syn}$	Continuing as above	Symbol and Viterbi decoder, and deinterleaver synchronizers (if applicable) locked	τ_{syn} (seconds) ≤ 1100 / (channel data rate in bps) for biphase symbols (S-band DG2 only); τ_{syn} (seconds) ≤ 6500 / (channel data rate in bps) for NRZ symbols; For dual data channels, symbol and decoder synchronization must be achieved on each channel For DG2 services requiring channel ambiguity resolution by the ground terminal, additional time is required for the ground terminal to resolve the ambiguity.

Table C-3. Acquisition Events for TDRSS Services (Normal Forward and Return) (cont'd)

Event	Time	Equipment Status		Remarks
		Customer Platform	TDRS/Ground Terminal	
TDRSS autotrack acquisition complete, high accuracy tracking begins; return service(s) established; return service channel data stream(s) transferred from the ground terminal to NISN	$T_8 = \tau_R + \tau_{tauto}$	Continuing as above	Autotrack (if enabled) locked. Return service(s) established here	Signal acquisition will be completed before TDRSS autotrack (if enabled) acquisition is completed $\tau_{tauto} \leq 10$
Customer MOC receives return service data stream(s), begins forward service data transmission (e.g., preamble followed by commands)	$T_9 = T_8 + \tau_{has}$	Continuing as above	Normal operation	For τ_{has}; this acquisition sequence assumes that forward service data is sent by the customer MOC only after the return service acquisition is confirmed by the customer MOC via return service data (i.e., no forward return service data until successful return service acquisition); typical preamble consists of 128-bit alternating sequence followed by frame synchronization word to enable customer platform command processing

Table C-3. Acquisition Events for TDRSS Services (Normal Forward and Return) (cont'd)

Event	Time	Equipment Status		Remarks
		Customer Platform	TDRS/Ground Terminal	
Forward service symbol synchronization achieved and frame synch word identified; forward service established; customer platform begins forward service data processing	$T_{10} = T_9 + \tau_{bit}$	Symbol synchronizer locked and frame synch word recognized; command processing enabled	Continuing as above	τ_{bit} is approximately 128 bit times (i.e., 128 bits after customer platform receives data modulated forward service signal

Note:

This can be achieved at the end of the previous forward service support period or by stored on-board commands. If coherent return service operations are scheduled later in this same service support period, the transponder can be set to permit automatic transition to coherent turnaround mode at, or prior to, the scheduled start of the coherent return service operations. This can also be achieved either via stored on-board commands or via commands imbedded in the forward service data once the forward service is established.

C.4 Reacquisition

C.4.1 Introduction

C.4.1.1

Once a service has been established, there are a number of conditions or events that can cause the service to be degraded or to be interrupted, in which case the service may need to be reestablished. Reacquisition refers to that part of reestablishing service which includes the following:

a. Reinitiating the customer platform initial acquisition process if it is a forward service reacquisition; recalculating new settings for the current circumstances and initializing acquisition circuits if it is a return service.

b. Executing the acquisition events (please see paragraph C.3 above) as indicated for initial acquisition.

C.4.1.2

Reacquisition may also be required whenever there is a failure to establish service initially. In some cases of service interruption, additional ground terminal processing may be needed prior to initiation of the reacquisition process. This may include the need for the WSC to reconfigure the GCE and/or the TDRS and to calculate and implement new setup values. These two operations are referred to as TDRSS hardware reconfiguration and software resetup.

C.4.1.3

The events or conditions that initially trigger the need for a reacquisition may be categorized as arising from the customer MOC/NCCDS or from the TDRSS as follows:

a. Customer MOC/NCCDS Initiates Reacquisition. This may result indirectly from a customer MOC request to the NCCDS to reconfigure a service parameter (resulting in a reconfiguration OPM [Class 03] from the NCCDS to the WSC) or as a result of the customer MOC/NCCDS directly requesting reacquisition via an OPM [Class 02].

b. TDRSS Initiates Reacquisition. Conditions that may cause the ground terminal to initiate reacquisition include a loss of carrier lock, service alarms, and hardware or software failures. Detailed and precise scenarios in this regard are beyond the scope of the current discussion. However, some general concepts are presented in paragraphs C.4.2 and C.4.3 to provide some additional insight into the reacquisition process.

C.4.1.4

The primary focus here will be on reacquisition initiated by the customer MOC/NCCDS.

C.4.2 Customer MOC/NCCDS Initiated Reacquisition

C.4.2.1

Table C-4 and Table C-5 summarize the parameters controlled by the customer MOC which may lead to service interruption for the forward and return services, respectively. The tables indicate the consequence of requesting each parameter in regard to both reacquisition and TDRSS reconfiguration.

C.4.2.2

As indicated in Table C-4 and Table C-5, the customer MOC may request, via the NCCDS, a service reacquisition. Normally this request is initiated only after the customer MOC detects a problem and only if no TDRSS problems exist as indicated in the information conveyed from the WSC to the NCCDS via an ODM[1]. In this case, the customer MOC may instead choose to simply terminate service or to change some operating condition or parameter as cited in paragraph C.4.1.

C.4.2.3

As seen in the tables, the customer MOC has the option to select forward and return service reacquisitions independently. However, for coherent turnaround operations, a forward service reacquisition will lead to a return service interruption and the WSC will automatically initiate return reacquisition after forward reacquisition. For noncoherent operations, forward and return service reacquisitions are independent so that the corresponding customer MOC-initiated reacquisition requests may also be invoked independently.

C.4.2.4

Figure C-1 and Figure C-2 provide an overview of some of the key elements that lead to the requirement for reacquisition of the forward and return service signals, respectively. Also included is some of the logic associated with the ground terminal regarding reacquisition. Normally, the customer MOC will detect a service fault whenever problems are detected by the ground terminal (please see paragraph C.4.3 below). In this case, the ground terminal may automatically take the appropriate action, thereby perhaps alleviating the need for the customer MOC to request reacquisition.

C.4.2.5

The ground terminal monitors and reports on numerous elements of the ground terminal GCE and the TDRS, including performance data (such as loss of lock conditions) and equipment status (such as hardware faults). In addition, in some cases, the ground terminal automatically initiates reacquisition of the appropriate service. Consequently, with reference to the customer MOC, acquisition contingencies need be developed primarily for those situations in which the ground terminal does not initiate reacquisition.

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1 Transmission of ODMs from the NCCDS to the customer MOC must be requested (in advance) by the customer MOC. They are not automatically transmitted to the customer MOC by the NCCDS.

Table C-4. Parameters Which Impact Forward Service

Parameter or Operating Condition	Forward Service			Customer Platform Reacquisition Required	TDRSS Reconfiguration or Resetup Required
	MA	SSA	KuSA/ KaSA		
Forward Service Reacquisition	X	X	X	X	
Change in Customer Platform Receive Frequency	X	X	X	X	X
Doppler Compensation Inhibit (PN Codes and Carrier)	X	X	X	Note 4	Note 4
Reinitiation of Forward Service Doppler Compensation (PN Codes and Carrier)	X	X	X	Note 5	X
Forward Service Frequency Sweep (note 1)	X	X	X	X	X
Change in Customer Platform Receive Antenna Polarization		X	X	X	X
Initiation or Termination of the Command Channel PN Code		X	X	X	X
Forward Service EIRP (Normal and High Power)		X	X	Note 2	X
Change in Command Channel Data Rate	X	X	X	Note 3	X

Notes:

1. This request is normally used as an aid in customer platform acquisition of the TDRSS forward service signal.
2. Reacquisition by the customer platform of the forward service signal may or may not be required (usually depends on whether there is a loss of lock condition within the customer platform receiver as a result of the step change in received TDRSS forward service signal energy).
3. If the initial and final data rate are <300 kbps, MOC only customer platform symbol resynchronization and frame synchronization searches are required.
4. The ground terminal does not interrupt the TDRSS forward service signal if a Doppler compensation inhibit request OPM (Class 11) is used.
5. The ground terminal will minimize service interruptions due to Customer Reconfiguration OPMs. Customer platform reacquisition may be required.

Table C-5. Parameters Which Impact Return Service

Parameter or Operating Condition	Return Service			Ground Terminal Reconfiguration and Reacquisition Required
	MA	SSA	KuSA/KaSA	
Return Service Reacquisition	X	X	X	X
Expanded Customer Platform Frequency Uncertainty (note 1)	X	X	X	X
Change in I and/or Q Channel Data Rate	X	X	X	X
Change in Customer Platform Transmit Frequency	X	X	X	X
Redefinition of Maximum or Minimum Customer Platform EIRP	X	X	X	X
Change in I/Q (Power)	X	X	X	X
Change the I and/or Q Channel Data Bit Jitter	X	X	X	X
Change in DG1 Mode (1,2,3)	X	X	X (note 2)	X
Change in I and/or Q Channel Data Format	X	X	X	X
Change in Customer Platform Antenna Polarization		X	X	X
Change Between DG1 and DG2		X	X (note 2)	X
Change in DG2 Type (coherent/noncoherent)		X	X (note 2)	X
G_2 Inversion (I and/or Q Channel)	X	X	X	X

Notes:

1. This request is normally used as an aid in acquisition.
2. Not valid for KaSA service.

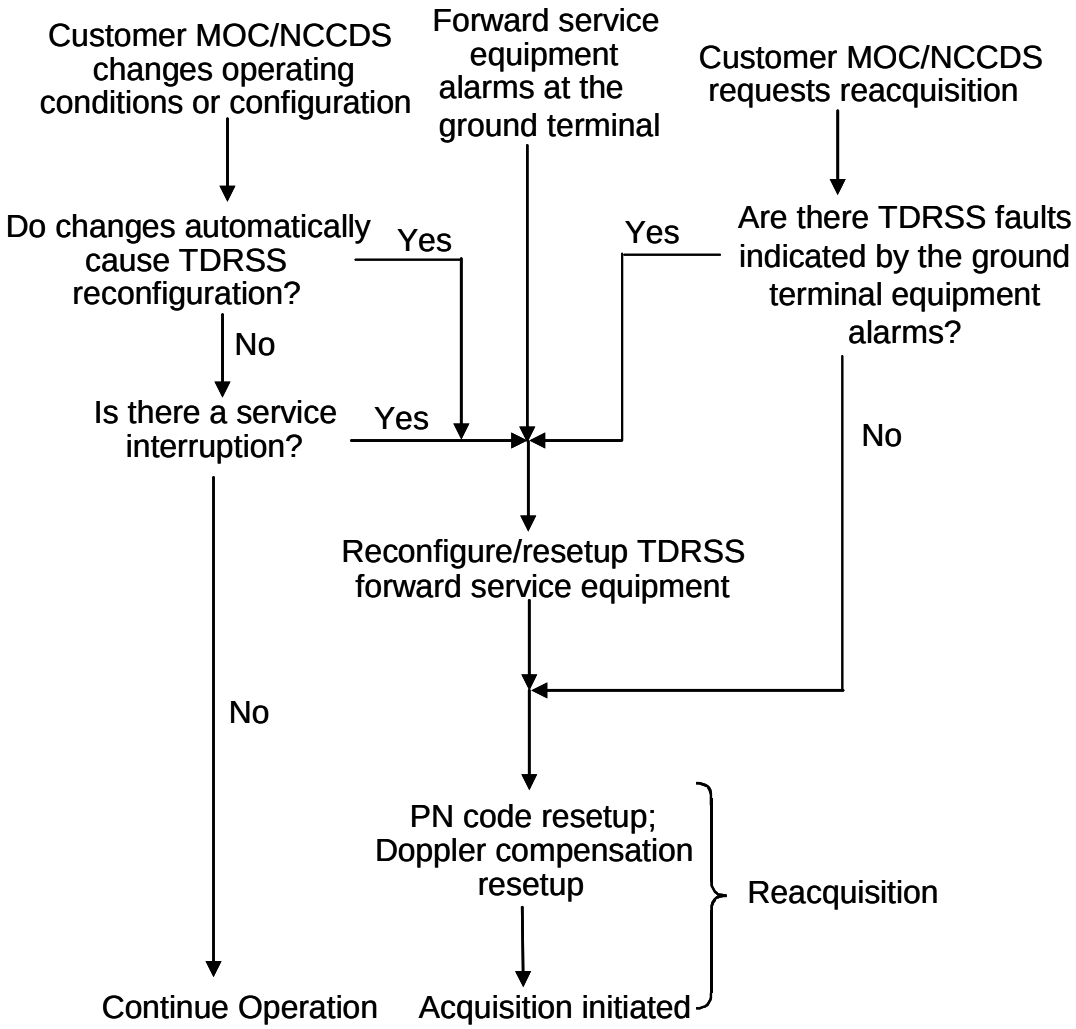

Figure C-1. Reacquisition Initiation Logic: Forward Service

Furthermore, these contingency procedures essentially consist of only those parameters listed in Table C-4 and Table C-5. The events which lead to customer MOC-initiated contingencies fall into four general classifications. These and possible customer MOC responses are as follows:

a. Initial acquisition not achieved (forward service).
   1. Forward service reacquisition.
   2. Forward service frequency sweep.
   3. TDRS high power mode.
   4. Reconfiguration of forward service parameters (please see Table C-4 above).

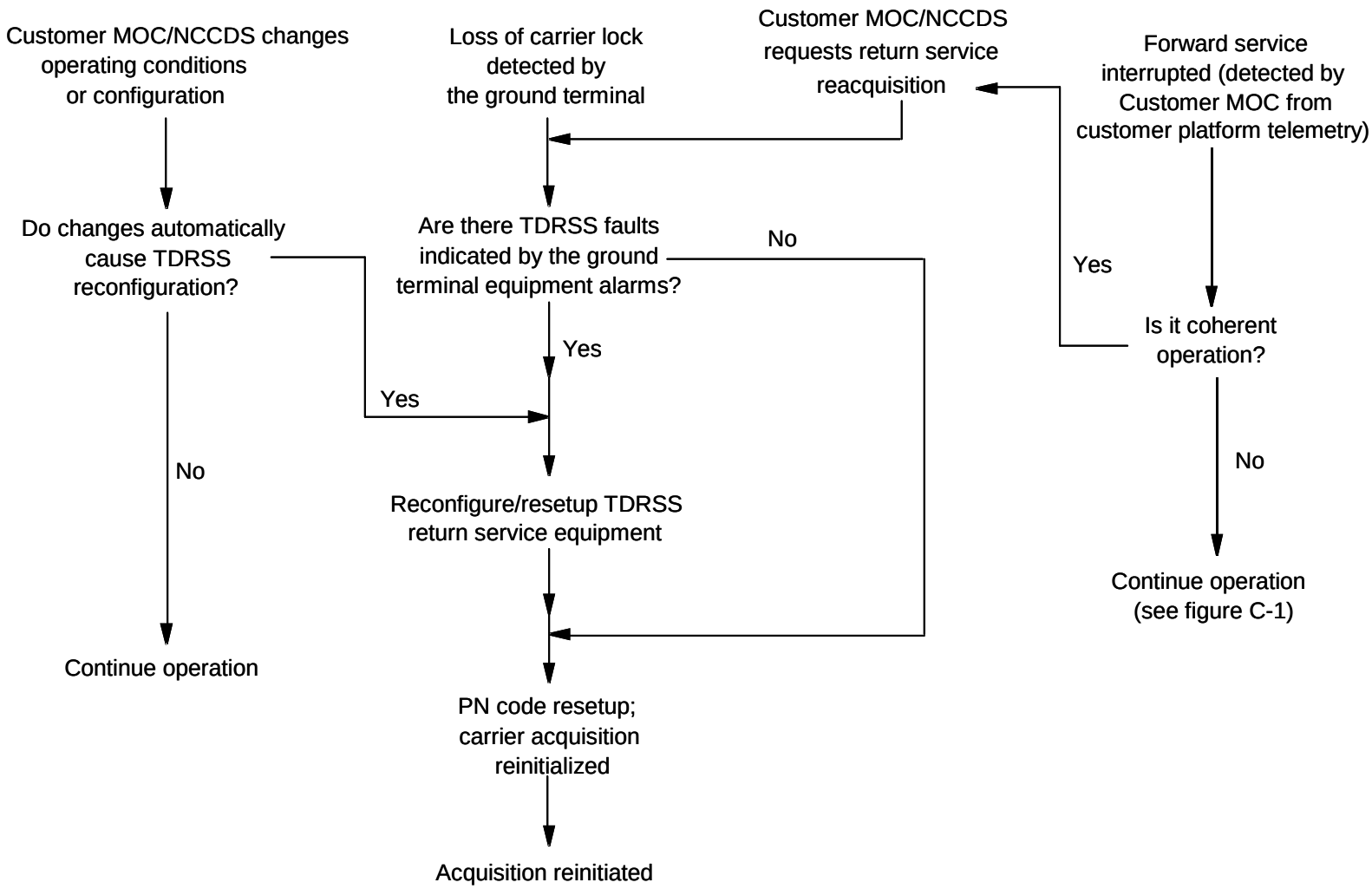

Figure C-2. Reacquisition Initiation Logic: Return Service

b. Initial acquisition not achieved (return service).
   1. Return service reacquisition.
   2. Expanded frequency uncertainty.
   3. Reconfiguration of forward and/or return service parameters please see Table C-4 and Table C-5 above).

NOTE:

If in coherent turnaround operations, forward service reacquisition may be advised.

c. Loss or degradation of forward service.
   1. Forward service reacquisition.
   2. Reconfiguration of forward service parameters.
   3. Terminate forward service.
d. Loss or degradation of return service.
   1. Return service reacquisition (forward service reacquisition also if coherent turnaround).
   2. Reconfiguration of forward and/or return service parameters.
   3. Terminate return service.

C.4.3 WSC/GRGT Initiated Reacquisition

As indicated earlier, there are a number of conditions whereby the ground terminal automatically initiates reacquisition. An exhaustive accounting of all conditions that lead to a ground terminal-initiated reacquisition is beyond the scope of this Appendix. Upon detection of a service degradation or interruption, the customer MOC should monitor the TDRSS status as conveyed from the NCCDS via an ODM. Based on this information the customer MOC can infer whether the ground terminal has automatically initiated reacquisition. If the ground terminal has automatically initiated reacquisition, the ground terminal will not accept any OPMs applicable to this specific customer service during this reacquisition period. Finally, the customer MOC needs to decide if a customer MOC-initiated reacquisition request to the ground terminal by the NCCDS is necessary or desirable.

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Appendix D. Spectrum Considerations

D.1 Introduction

The radio frequency spectrum is a national and international resource, and, as such, its use is governed by statutory requirements and treaty obligations. There are also NASA and NASA/GSFC policies and procedures governing the use of the radio frequency spectrum. This Appendix describes some of the applicable national and international obligations on its use to support space missions utilizing the Space Network. Additionally, the GSFC Spectrum Allocation and Management Site (GSAMS) http://classwww.gsfc.nasa.gov/GSAMS/ web site provides regulatory background information and technical guidance for GSFC organizations involved in licensing RF equipment. In the event of a conflict between the GSAMS website and this appendix, please contact the GSFC Spectrum Manager for clarification.

The National Telecommunications Information Agency (NTIA) Manual of Regulations & Procedures for Federal Radio Frequency Management defines the regulations and policies pertaining to United States (U.S.) Government agency use of RF spectrum in the United States and its possessions. (This manual is hereafter referred to as the NTIA manual.) The NTIA regulations are available from the following website: http://www.ntia.doc.gov/osmhome/osmhome.html.

The International Telecommunications Union (ITU) Radiocommunication Sector (ITU-R) provides an international forum to revise the technical and regulatory provisions affecting the use of the RF spectrum. The ITU-R regulations are contained in the Radio Regulations (RR), which, when ratified by the U.S. Senate, imposes treaty obligations on the United States. Selected portions of the Radio Regulations are available from the GSAMS website with a user ID and password (See the GSAMS website). The Space Frequency Coordination Group (SFCG) exists under the umbrella of the ITU and allows the world's space agencies to deal with coordination and other issues unique to space related operations.

Paragraph D.2 briefly provides guidance to projects that need to initiate RF equipment licensing. Paragraph D.3 describes the PFD limits, how they are calculated, and some of the operational implications to projects. Paragraph D.4 describes the limits for unwanted emissions. Paragraph D.5 describes the standards for frequency tolerance. Paragraph D.6 describes the regulations concerning cessation of emissions. Paragraph D.7 describes the protection afforded deep space Earth stations. Paragraph D.8 describes the preferred frequencies for launch vehicles. Paragraph D.9 describes national restrictions on return-link bandwidth. Paragraph D.10 describes SFCG recommendations on 23 GHz and 26 GHz bands. Paragraph D.11 provides additional ITU-R recommendations applicable to space-to-space links.

D.2 RF Equipment Licensing

All U.S. space missions, including commercial space systems that use the TDRSS system, must register frequency usage with the NTIA and are subject to all the NTIA

regulations and procedures. Non-U.S. missions must register their frequency usage internationally through their appropriate spectrum management agencies.

Early in the mission planning cycle, NASA projects must contact the appropriate center spectrum manager to get NTIA authorization to transmit. The NASA Center Spectrum Managers are responsible for management of the RF equipment licensing process, and are the final authority on the selection of the appropriate frequencies for all NASA RF equipment. Amongst other duties, these center managers will facilitate the licensing of RF equipment by coordinating with national and international organizations in: 1) making frequency selections, 2) evaluating RF equipment against applicable national and international RF standards, 3) performing RF analyses, and 4) completing frequency authorization applications to the NTIA.

Goddard Procedural Requirements (GPR) 2570.1, *Spectrum Management and Radio Frequency (RF) Equipment Licensing*, provides GSFC missions with the requirements for Radio Frequency (RF) equipment licensing in accordance with NASA Policy Directive (NPD) 2570.5, *NASA Electromagnetic Spectrum Management*. In accordance with NPD 2570.5, all missions must comply with domestic (NTIA) and international (ITU) regulations and SFCG recommendations.

D.3 Power Flux Density (PFD) Considerations

PFD limits on the surface of the Earth are the primary means to prevent harmful interference to terrestrial systems operating in bands shared with the TDRSS Space Network. In those bands which are shared on a primary basis between the space and terrestrial services, the PFD limits are incorporated into the Radio Regulations. PFD levels should be calculated early, preferably during the mission planning and system design phase, in order to determine whether or not the PFD limits would impose any unsatisfactory system requirements or operational constraints. For example, many missions with high gain antennas opt to delay the start of transmissions until some period of time after the TDRS comes in view over the horizon in order to satisfy the PFD limits. Additionally, mission planners are strongly urged to consider that satellite subsystems and components often exceed specifications and this can result in PFD levels being exceeded.

The applicable PFD limits for the TDRSS S-Band, Ku-band, and Ka-band links are provided in Paragraph D.3.1. Paragraph D.3.2 describes the impact of exceeding the PFD limits. Paragraph D.3.3 provides the equations used to determine PFD levels. Paragraph D.A.1 provides an example application.

D.3.1 PFD Limits

Power Flux Density limits are imposed on NASA missions by both the NTIA and the ITU. Although largely similar, there are a number of differences in the requirements, which can result in a mission meeting one requirement but not the other. The consequences of failure to meet NTIA and ITU PFD limits are outlined in paragraph D.3.2. This section lists the NTIA and ITU PFD limits in the TDRSS forward and return link bands.

For most Space Network users, the applicable ITU and NTIA PFD limits for the TDRSS S-Band, Ku-band, and Ka-band links are shown in Table D-1. The international PFD

Table D-1. International and National PFD Limits Applicable to TDRSS Links

TDRSS Service	Frequency Band, GHz	Reference Bandwidth	Angle of Arrival α	ITU-R RR PFD Limit (dBW/m^2)	NTIA PFD Limit (dBW/m^2)
SSAF MAF SSAR MAR	2.025 – 2.110 2.200 – 2.290	4 kHz (Note 1) 1 MHz (Note 2)	0° to 5°	-154 -130	-154 -130
		4 kHz (Note 1) 1 MHz (Note 2)	5° to 25°	-154 + 0.5*$(\alpha-5)$ -130 + 0.5*$(\alpha-5)$	-154 + 0.5*$(\alpha-5)$ -130 + 0.5*$(\alpha-5)$
		4 kHz (Note 1) 1 MHz (Note 2)	25° to 90°	-144 -120	-144 -120
KuSAF	13.4 – 14.05	4 kHz (Note 1)	0° to 90°	Not Applicable	-152
KuSAR	14.5 – 15.35	1 MHz	0° to 5°	Not Applicable	-124
			5° to 25°	Not Applicable	-124 + 0.5*$(\alpha-5)$
			25° to 90°	Not Applicable	-114
KaSAF KaSAR	22.55 – 23.55 25.25 – 27.50	1 MHz	0° to 5°	-115	-115
			5° to 25°	-115 + 0.5*$(\alpha-5)$	-115 + 0.5*$(\alpha-5)$
			25° to 90°	-105	-105

Notes:

1. As per Section 2 in NTIA Report 84-152, these PFD levels can be relaxed by 10 dB for GSO satellite transmissions and 16 dB for LEO satellite transmissions.
2. As per IRAC 31015, these PFD levels can be calculated in a 1 MHz bandwidth in determining compliance.

limits were extracted from the ITU-R Radio Regulations Article 21, Table 21-4. The national PFD limits were extracted from NTIA manual Table 8.2.36. In both cases, the PFD limit is defined at the Earth's surface as a function of the angle of arrival above the local horizontal plane, α, 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.

For S-band and Ku-band links, the requirements are given in a 4 kHz reference bandwidth. The NTIA may on a case-by-case basis permit space-to-space links to exceed the PFD limits in the 2200-2290 MHz band within the United States and its territories and possessions.

A primary allocation to a service allows systems of that service to operate in a band with full protection from interference from other systems of the same service and from

systems of other services which are also allocated on a primary basis. New systems cannot be introduced into that frequency band if they will result in interference to a system operating with a primary allocation. A secondary allocation to a service allows systems to operate in a band on the condition that it does not cause interference to, nor claims protection from, systems operating on a primary basis. However, systems operating on a secondary basis can claim protection from interference from other systems operating on a secondary basis.

D.3.2 Consequences of Exceeding PFD Limits

If the PFD levels do not meet the PFD limits given in the NTIA manual, the NTIA will not grant frequency authorization except as noted in paragraph D.3.1.

If the PFD levels do not meet the PFD limits given in the ITU-R RR, then the mission is subject to the conditions given in Article 4.4. Article 4.4 states "Administrations of the Member States shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations, except on the express condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations."

D.3.3 Calculation of PFD Levels

The calculation of PFD levels requires the following data for the spacecraft:

a. Maximum transmitter power contained in the reference bandwidth (i.e., 4 kHz or 1 MHz), under all conditions and modes of modulation measured at the antenna input. Please see paragraph D.3.3.1 below.
b. Transmitting antenna gain pattern.
c. Transmitting antenna mainbeam pointing characteristics, including any intentional or unintentional antenna mispointing.
d. Orbital altitude (nominally circular orbits are assumed for this analysis).

The PFD at an angle of arrival, α, is calculated as shown in

Equation D-1Equation D-1 with R(α) found using Equation D-2 and Equation D-3. The geometry is shown in Figure D-1:

Equation D-1:

$$\mathrm{PFD}(\alpha) = 10\log\left[\frac{G_t(\theta)P_{tB}}{4\pi R^2(\alpha)}\right]$$

where:

PFD (α) = maximum power flux density in dBW/m^2 in the reference bandwidth at the surface of the Earth for an angle of arrival "α" above the local horizontal plane.

$G_t(\theta)$ = platform transmitting antenna gain relative to an isotrope in the direction of the point on the Earth's surface corresponding to an angle of arrival "α". θ = 0 refers to the antenna boresight direction.

P_{tB} = maximum transmitter power in Watts in the reference bandwidth (i.e., 4 kHz or 1 MHz) measured under all conditions and modes of modulation.

R(α) = slant range in meters from the spacecraft to the earth for angles of arrival "α" (R is greater than or equal to the orbital altitude, depending on "α").

Equation D-2:

$$R(\alpha) = \sqrt{r_s^{\ 2} + r_e^{\ 2} - 2 * r_s * r_e * \cos(\varphi(\alpha))}$$

Equation D-3:

$$\beta(\alpha) = \sin^{-1}\left(\frac{r_e \cos(\alpha)}{r_s}\right)$$ is the off-nadir angle at the spacecraft

and

$$\varphi(\alpha) = 90^\circ - \alpha - \beta(\alpha)$$ is the geocentric angle between the point on the Earth and the spacecraft.

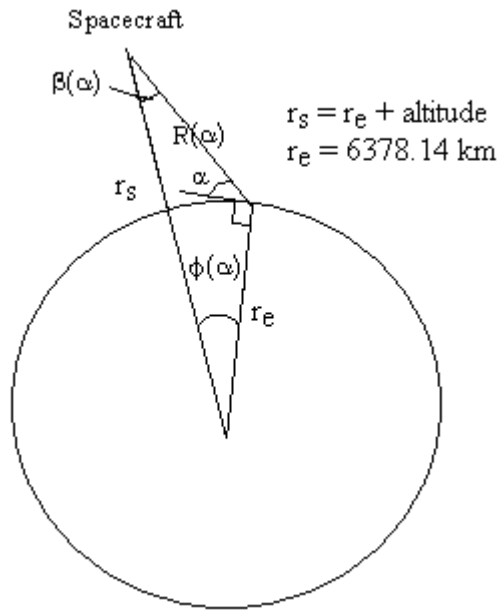


Figure D-1. Geometry for Determining PFD Conformance

As shown in Equation D-1, the calculation of PFD levels requires knowledge of the transmitting antenna gain pattern. A transmitting antenna gain pattern based on measured data may not be available. In this case, the antenna pattern given in Recommendation ITU-R S.672 may be used to model platform high gain antennas. If measured data is available, the gain pattern of interest is an envelope containing at least 90 percent of the sidelobe peaks, which decreases monotonically with increasing off-axis angle. The antenna pattern from Recommendation ITU-R S.672 is shown in Figure D-2.

Paragraph D.3.3.1 describes a procedure to calculate the maximum transmitter power in the reference bandwidth, P_{tB}. An Annex to this Appendix describes an operational method to ensure that Space-to-Space links with high gain transmitting antennas can meet PFD limits if transmissions are limited to times when the TDRS spacecraft appears sufficiently above the horizon.

D.3.3.1 Calculation of P_{tB}

The maximum transmitter power in the reference bandwidth, $P_{tB,}$ depends on the number of data channels, the data formats, and the modulation method. The standard TDRSS return links use suppressed carrier BPSK modulation, balanced or unbalanced QPSK modulation, balanced or unbalanced SQPSK modulation, or SQPN links. Channels are either in NRZ or Biphase format. For each channel, the transmitter Power Spectral Density (PSD) (W/Hz) as a function of frequency offset from the carrier, f, is:

Equation D-4:

$$\text{PSD}(f) = P\,T\,\frac{\sin^2(x)}{x^2}, \quad \textit{where } x = \pi f T \quad \textit{for NRZ and PN spread links}$$

Equation D-5:

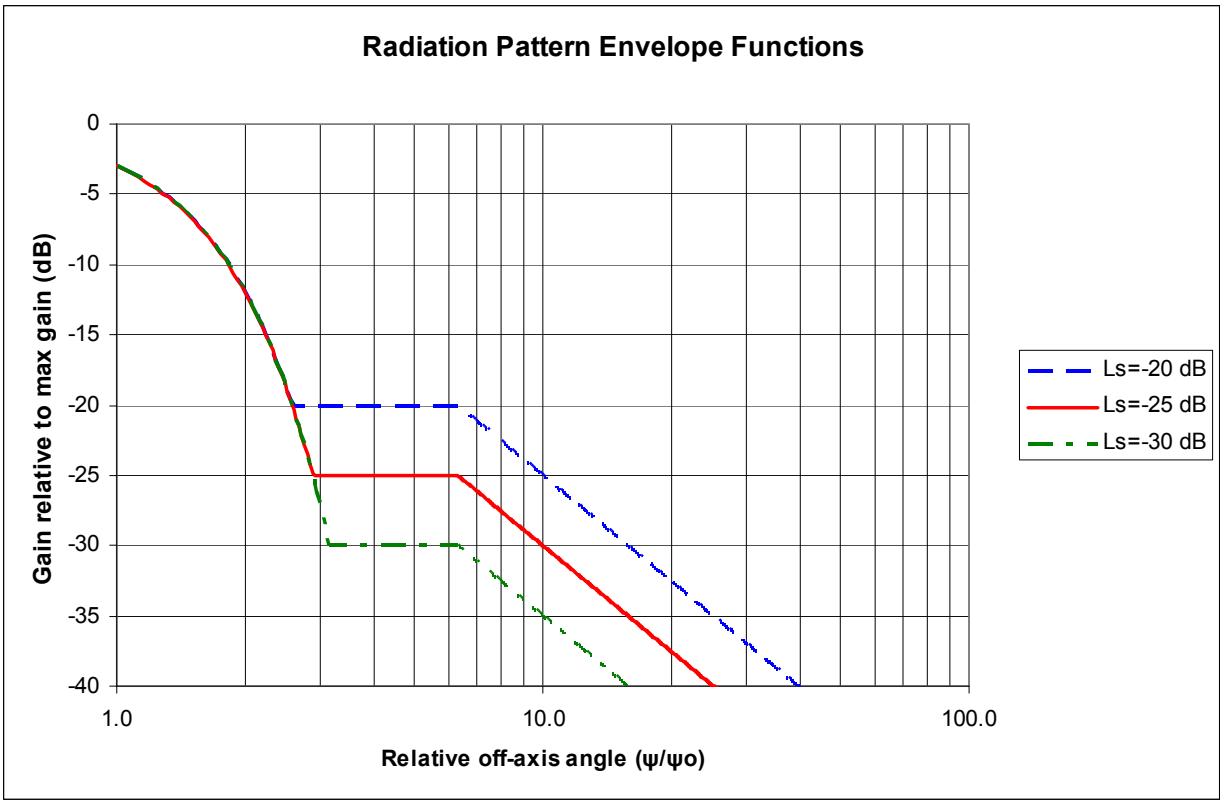
$$\text{PSD}(f) = P\,T\frac{\sin^4(x)}{x^2}, \quad where\ x = \pi\ f\ T/2 \quad for\ Biphase\ formatted\ links$$

where:

P = total power (measured in Watts) for the channel. P represents the total power delivered to the transmitting antenna, taking into account transmitter-to-antenna line losses and the I/Q channel ratio, where applicable.

T = $1/R_s$ = channel symbol duration (seconds).

R_s = symbol rate (symbols/second). The symbol rate includes PN spreading and convolutional encoding as appropriate, but excludes biphase encoding. PN spread links have a symbol rate of 3.08 Mcps. The symbol rate for a non-spread BPSK link is equal to the data rate times the coding rate (if applicable). For example, a 256 kbps link with rate ½ convolutional coding and BPSK modulation has a symbol rate of 512 ksps, because the “1/2” means that for each 1 input bit, there are 2 output bits.



$G(\psi) = G_m - 3\,(\psi/\psi_0)^2$	dBi	for	$\psi_0 < \psi \leq a\,\psi_0$	(I)
$G(\psi) = G_m + L_S$	dBi	for	$a\,\psi_0 < \psi \leq b\,\psi_0$	(II)
$G(\psi) = G_m + L_S + 20 - 25 \log(\psi/\psi_0)$	dBi	for	$b\,\psi_0 < \psi \leq \psi_1$	(III)
$G(\psi) = 0$	dBi	for	$\psi_1 < \psi$	(IV)

Where:

$G(\psi)$: Gain at angle (ψ) from the axis (dBi)

G_m: Maximum gain in the main lobe (dBi)

ψ_0: One-half the 3 dB beamwidth in the plane of interest (3 dB below G_m) (degrees)

ψ_1: Value of (ψ) when $G(\psi)$ in equation (III) is equal to 0 dBi

L_S: The required near-in-side-lobe level (dB) relative to peak gain

a, b: Numeric values are given below

L_S	a	b
-20	2.58	6.32
-25	2.88	6.32
-30	3.16	6.32

Figure D-2. ITU-R S.672 Antenna Pattern Recommendation

For signals with two channels, the total PSD(f) is found by summing the PSD(f) from both channels. The maximum PSD(f) is not affected by whether or not the Q channel is delayed with respect to the I channel.

Most TDRSS links operate with a symbol rate much greater than the reference bandwidth. In this case, the PSD(f) for a given channel is seen to be relatively constant over the reference bandwidth. The resulting P_{tB} for NRZ and PN spread signals is given by Equation D-6. The resulting P_{tB} for biphase formatted signals is given by Equation D-7:

Equation D-6:

P_{tB} (dBW/B_{ref}) = 10 LOG_{10}(P B_{ref} /R_s) for NRZ signals with R_s>>B_{ref}

Or, since each component of the above equation is usually already converted to decibels

P_{tB} (dBW/B_{ref}) = PdB + BdB_{ref} – RdB_s

Equation D-7:

P_{tB} (dBW/B_{ref}) = 10 LOG_{10}(P B_{ref} /R_s) –2.8 dB for Biphase signals with R_s>>B_{ref}

Or, with all components of the equation expressed in decibels,

P_{tB} (dBW/B_{ref}) = PdB + BdB_{ref} – RdB_s – 2.8 dB

where:

B_{ref} = reference bandwidth in Hz (4000 or 1,000,000)

PdB = Power expressed in decibels

BdB_{ref} = Reference bandwidth expressed in decibels

RdB_s = Symbol Rate expressed in decibels (36 dBHz for 4000 Hz and 60 dBHz for 1,000,000 Hz)

D.3.3.2 Verifying PFD Limits for Space-to-Space Links

In many cases, the PFD limits are easily met. This section describes a procedure to verify that the PFD limits are met for all angles of arrival, α. The geometry is as shown previously in Figure D-1.

Suppose there is a link consisting of a PN-coded data stream with a chip rate of 3.08 Mcps (which may be used as a symbol rate) and peak transmitter power of 1 Watt. The peak transmitter power in the 4 kHz reference bandwidth is found to be -28.9 dBW using Equation D-4. Tables D-2 and D-3 show the result of calculating the power flux density for all angles of arrival between 0° and 90° and the accompanying graph, Figure D-3, shows that the received PFD does not exceed the PFD limits for any angle of arrival.

Table D-2. Peak Power Calculations (bold values are input data)

Parameter Name	Units	Value
Earth Radius	km	6378.14
SC Altitude	km	**400**
SC Ant Gain	dBi	**5**
Symbol Rate	bps	**3.08E+06**
RF Power	W	**1**
	dBW	0.0
Peak PSD	dBW/Hz	-64.9
	dBW/4kHz	-28.9

Table D-3. Calculation of PFD at All Arrival Angles

Elevation Angle, α	Spacecraft Look Angle, β(α)	Earth Central Angle, φ(α)	Spacecraft Range, R(α)	Peak PFD on Earth	PFD Limit	PFD limit Exceedance
degrees	degrees	degrees	km	dBW/m^2/ 4 kHz	dBW/m^2/ 4 kHz	dB
0	70.2	19.8	2294.0	-162.1	-154.0	-8.1
5	69.6	15.4	1804.5	-160.0	-154.0	-6.0
10	67.9	12.1	1439.8	-158.0	-151.5	-6.5
15	65.4	9.6	1175.5	-156.3	-149.0	-7.3
20	62.2	7.8	984.2	-154.7	-146.5	-8.2
25	58.5	6.5	844.0	-153.4	-144.0	-9.4
30	54.6	5.4	739.4	-152.2	-144.0	-8.2
35	50.4	4.6	659.8	-151.2	-144.0	-7.2
40	46.1	3.9	598.2	-150.4	-144.0	-6.4
45	41.7	3.3	549.9	-149.7	-144.0	-5.7
50	37.2	2.8	511.7	-149.0	-144.0	-5.0
55	32.7	2.3	481.4	-148.5	-144.0	-4.5
60	28.1	1.9	457.4	-148.1	-144.0	-4.1
65	23.4	1.6	438.6	-147.7	-144.0	-3.7
70	18.8	1.2	424.0	-147.4	-144.0	-3.4
75	14.1	0.9	413.2	-147.2	-144.0	-3.2
80	9.4	0.6	405.8	-147.0	-144.0	-3.0
85	4.7	0.3	401.4	-146.9	-144.0	-2.9
90	0.0	0.0	400.0	-146.9	-144.0	-2.9

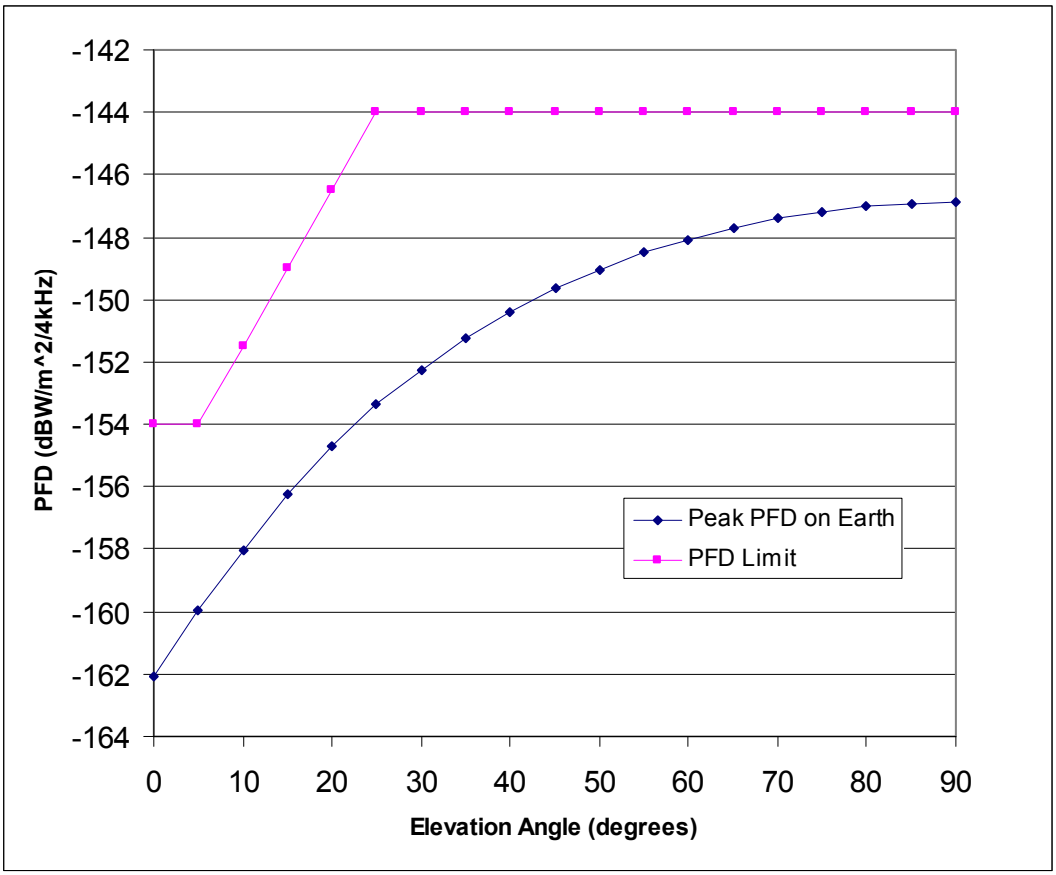


Figure D-3. Plot of PFD Limit and Actual PFD for All Arrival Angles

D.4 Unwanted Emissions

This section describes the regulations and recommendations concerning unwanted emissions. The Radio Regulations define unwanted emissions as all emissions outside the necessary bandwidth and includes both emissions resulting from the modulation process and spurious emissions.

The necessary bandwidth is a two-sided bandwidth and is defined as follows for a given *class of emission*: "the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions." For space telecommunication links, GSFC missions generally record the necessary bandwidth as the bandwidth that is just sufficient to contain the mainlobe of the signal spectrum. For TDRSS links, the necessary bandwidth is twice the highest baud rate on either channel.

Paragraph D.4.1 describes the unwanted emission regulations given in the NTIA manual. Paragraph D.4.2 provides examples for the calculation of NTIA emission masks. Paragraph D.4.3 describes the ITU-R recommendations on unwanted emissions.

D.4.1 NTIA Emission Mask

Figure D-4 shows the unwanted emission mask given in Section 5.6 of the NTIA Manual. This emission mask is applicable for all Earth and space stations operating above 470 MHz. The NTIA emission mask applies to the continuous spectrum and all discrete spectral lines, including spurious outputs and harmonics.

The NTIA mask is interpreted as follows:

- dBsd is dB attenuation in a 4 kHz bandwidth, relative to the maximum power in any 4 kHz band within the necessary bandwidth.
- For frequencies offset from the assigned frequency less than the 50% of the necessary bandwidth (B_n), no attenuation is required.

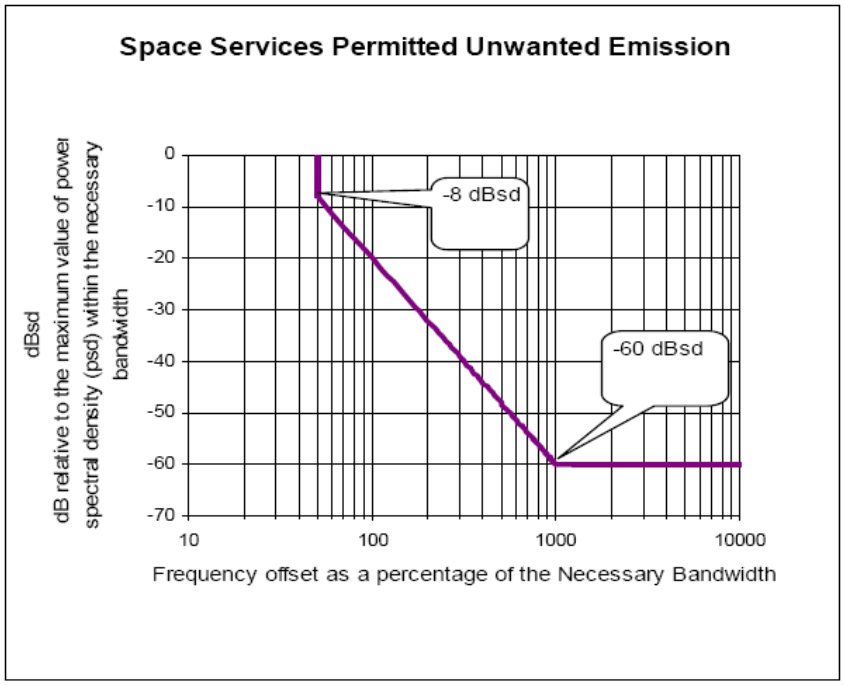


Figure D-4. NTIA Out-of-Band (OOB) Emission Mask for Space Services

- At a frequency offset equal to 50% of the necessary bandwidth, an attenuation of at least 8 dB is required.
- Frequencies offset more than 50% of the necessary bandwidth should be attenuated by the following mask:

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

  where f_d is the frequency displaced from the center of the emission bandwidth.
- For cases of very narrow-band emissions where the necessary bandwidth is less than the minimum bandwidth (B_L) given in Table D-4, B_L shall be used in place of B_n.

Table D-4. Minimum Bandwidth as Defined for NTIA OOB Emission Mask

Operating Frequency Range (fc)	Minimum Bandwidth (B_L)
470 MHz < fc < 1 GHz	25 kHz
1 GHz < fc < 10 GHz	100 kHz
10 GHz < fc < 15 GHz	300 kHz
15 GHz < fc < 26 GHz	500 kHz
fc > 26 GHz	1 MHz

For Carrier Frequencies above 15 GHz, a 1 MHz bandwidth may be used. Attenuation in this sense refers to the reduction in level relative to the reference, 0 dBsd, unless otherwise specified.

The NTIA "unwanted emission mask rolls off at 40 dB per decade to a maximum attenuation of 60 dBsd, at which point it continues on both sides of the carrier for all frequencies beyond this point. For any narrowband or single frequency unwanted emission which is not spread by the modulation process, the required attenuation shall be at least 60 dBc, where dBc is attenuation below the mean transmit power, rather than the dBsd value determined above."

In practice, NTIA evaluates spectral emissions by plotting a line intersecting the measured 3 dB, 20 dB, 40 dB, and 60 dB attenuation points (provided by the project) on the log scale PSD plots. The plotted line is then compared with the NTIA mask for compliance. Missions that do not meet this standard fall subject to Section 5.1.2 of the NTIA Manual. This section states, "In any instance of harmful interference caused by nonconformance with the provisions of this chapter, the responsibility for eliminating the harmful interference normally shall rest with the agency operating in nonconformance."

The NTIA mask applies for all unwanted emissions; the NTIA does not define separate regions for out-of-band emissions and spurious emissions.

D.4.2 NTIA Emissions Mask Example

This section presents an example of a test of conformance with the NTIA emissions mask, using an ideal unfiltered and a filtered 1.0 Mbps BPSK signal. In Figure D-5, the spectra are plotted versus percentage of necessary bandwidth (%). The -3, -20, -40, and -60 dB points of the Filtered BPSK spectral emissions are shown in Table D-5.

Table D-5. Spectrum Points of Filtered BPSK Signal

Necessary BW (MHz)	2.00		
Emission BW (dB)	**Two-sided BW (MHz)**	**One-sided BW (MHz)**	**Freq Offset (one-sided BW) as % of Necessary BW**
3.0	0.70	0.35	17.5
20.0	3.00	1.50	75
40.0	10.00	5.00	250
60.0	20.00	10.00	500

From Figure D-5, it can be seen that the Filtered BPSK spectral emissions meet the requirements of the NTIA mask over the applicable frequency range. However, the unfiltered BPSK exceeds the mask by a significant amount.

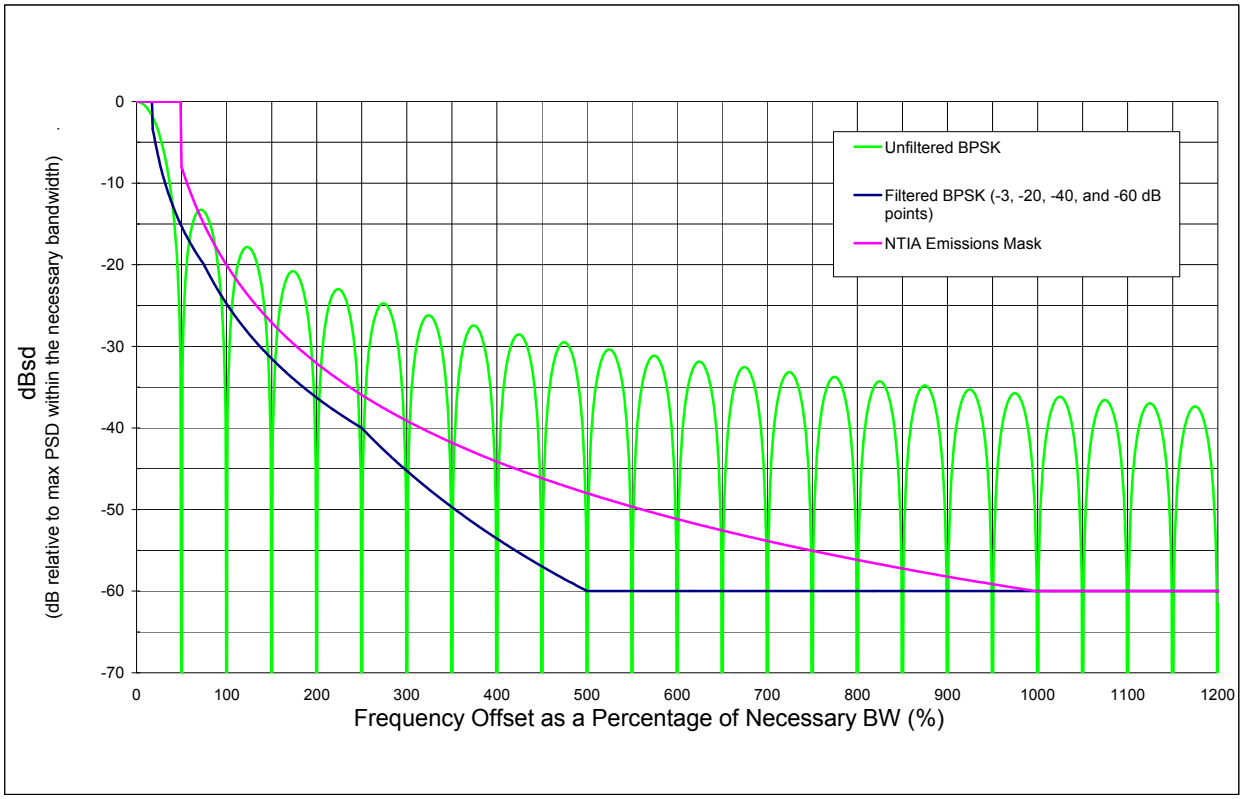


Figure D-5. Example of Unfiltered and Filtered BPSK PSDs and NTIA Mask

D.4.3 ITU Unwanted Emission Limits

This section provides information on the ITU-R unwanted emission limits. Satisfying the NTIA unwanted emissions mask is generally both a necessary and sufficient condition for satisfying the ITU-R requirements.

The ITU-R defines unwanted emissions in two separate regions. The region just outside the necessary bandwidth is the out-of-band region; the region further out is the region of spurious emissions. Recommendation ITU-R SM.1539-1 defines the boundary region. In general, the boundary between the out-of band emissions and the spurious emissions is 250% of the necessary bandwidth, but there are some exceptions.

ITU Radio Regulation RR No. 3.8 states that, in regards to out-of-band emissions, transmitting stations should, to the maximum extent possible, satisfy the most recent ITU-R Recommendation, which in this case is Recommendation ITU-R SM.1541-1. The out-of-band emission mask for space services is defined in Annex 5 of Recommendation ITU-R SM.1541. However, there is currently no ITU mask applicable for space services operating space-to-space links in the out-of-band region.

ITU Radio Regulation RR No. 3.7 states that transmitting stations shall conform to the maximum permitted spurious emission power levels specified in ITU RR Appendix 3. Table II of Appendix 3 shows that for space services, the peak attenuation in the spurious emission region is 43 + 10 log *P*, or 60 dBc, whichever is less stringent. P is defined to be the power (in Watts) supplied to the antenna transmission line.

D.5 Frequency Tolerance

Section 5.2.1 of the NTIA manual indicates that the frequency tolerance for space services is 20 parts per million (ppm). Missions that do not meet this standard fall subject to Section 5.1.2 of the NTIA Manual. This section states, “In any instance of harmful interference caused by nonconformance with the provisions of this chapter, the responsibility for eliminating the harmful interference normally shall rest with the agency operating in nonconformance.”

D.6 Cessation of Transmissions

Article 22.1 of the ITU Radio Regulations states that, “space stations shall be fitted with devices to ensure immediate cessation of their radio emissions by telecommand, whenever such cessation is required under the provisions of the ITU Regulations.”

The NTIA has a similar requirement. Section 8.2.32 of the NTIA manual indicates that the “use of space stations will be authorized only in those cases where such stations are equipped so as to ensure the ability to turn on, or to provide immediate cessation of emissions by telecommand.”

D.7 Protection of Deep Space Earth Stations

TDRSS S-band links operating in the upper portion of the 2200 – 2290 MHz band have the potential to cause unacceptable interference to deep space missions operating in the 2290 – 2300 MHz band. Recommendation ITU-R SA.1157 defines protection

criteria for deep space operations in the 2 GHz band. This recommendation indicates that the protection criterion for deep space Earth stations operating near 2 GHz is that the interference at the input to the deep space earth station receiver should not exceed -222 dBW/Hz and current NASA policy is that this criterion must be met 100% of the time. This protection criterion is measured at the deep space Earth station after accounting for the receiving antenna gain. Platforms operating in the upper portion of the 2200 – 2290 MHz band need very stringent filtering to meet the deep space protection criteria. In particular, a platform using the 2287.5 MHz TDRSS return links with a necessary bandwidth of 5 MHz or higher will easily violate the deep space protection criteria when it transmits sufficiently close to the beam of a DSN 70 meter or 34 meter antenna.

Mitigation techniques such as filtering out sideband emissions have been very successful to meet the deep space protection criterion. In particular, the "NASA/GSFC Recommended Filtering Referenced to the Output of the Power Amplifier (see Figure D-6)" minimizes the interference in the DSN band with a reasonable implementation loss. Figure D-7 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. The use of filtering with performance consistent or better than the "NASA/GSFC Recommended Filtering Referenced to the Output of the Power Amplifier" is strongly encouraged due to the considerable benefits that this provides. For example:

- The DSN coordination angle, which is defined as the angle off of the DSN main beam gain where the SN 2287.5 MHz customer meets the DSN protection criterion, is reduced by a factor of three and six in the 1st and 2nd sidelobes, respectively, for a mission with this filter as compared to a mission without this filter.
- This reduction in coordination angle results in filtered missions exceeding this coordination angle approximately one-tenth of the time that a mission without a filter exceeds the coordination angle.

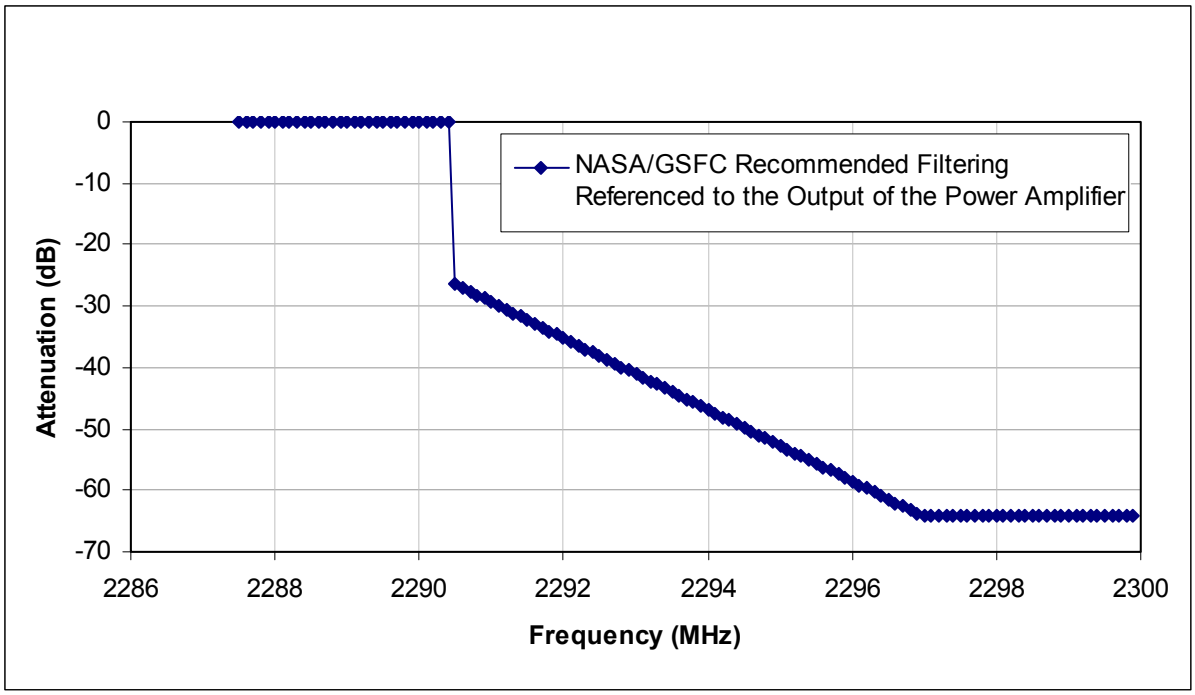


Figure D-6. Spectral Output for NASA/GSFC Recommended Filtering Referenced to the Output of the Power Amplifier

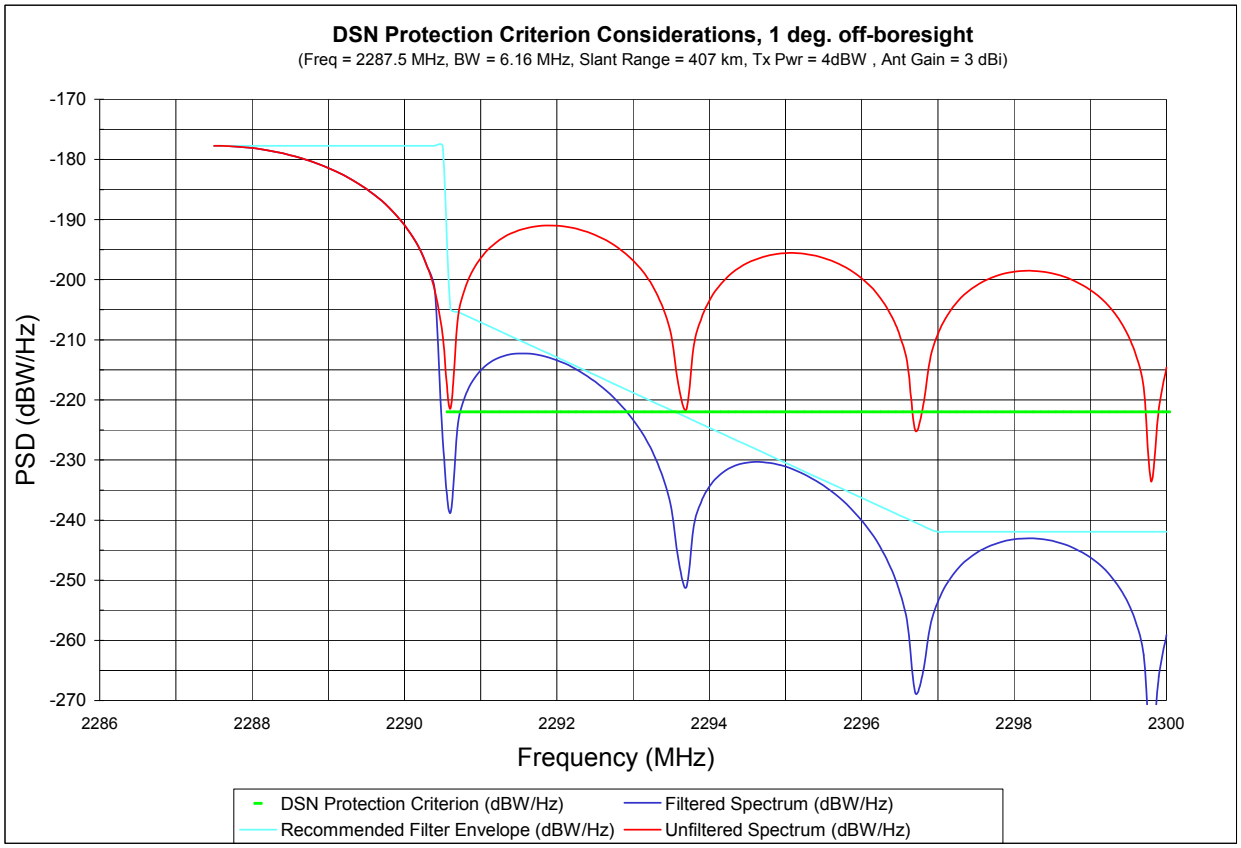


Figure D-7. Example of Unfiltered and Filtered 3.08 Mcps Code with DSN Protection Criteria

NASA/GSFC has reached certain agreements with NASA/JPL that will substantially reduce the amount of spacecraft turn-off for any TDRS user that implements the NASA/GSFC recommended filtering, and that exempts such missions from having to do the complex orbital conjunction analyses to predict spacecraft turn-off times. Under these agreements, the DSN, when not in a critical event or spacecraft emergency, will accept levels of interference above the DSN criterion from NASA/GSFC missions meeting the NASA/GSFC recommended filtering mask levels. However, spacecraft not satisfying the DSN protection criterion are required to turn-off their transmitters when in the vicinity of a DSN site during times when the following conditions are simultaneously true:

1) The DSN is in a critical event or spacecraft emergency.
2) The DSN criterion is exceeded.

These turn off times would be specified by JPL and GSFC reserves the right to verify and arrive at a mutually acceptable turn off time for the spacecraft. Those spacecraft platforms that cannot satisfy the DSN criterion at all times must have the capability to turn off their transmitters when they fly close to the bore sight of a DSN antenna. Additionally, the flight dynamics group for these missions must have the capability to

calculate the times of PFD excess and be able to command the spacecraft to cease transmissions during these periods of PFD excess.

To determine the best solution to protect the DSN Space Network, the mission Project Office should contact its corresponding Center Spectrum Manager.

The three NASA deep space Earth stations are located at Goldstone, CA; Madrid, Spain; and Canberra, Australia. Additional information on the deep space Earth stations can be found in the CCSDS 411.0-G Green Handbook on RF Frequency and Modulation Systems, Part 1, Earth Stations. This handbook is available at the following website: http://public.ccsds.org/publications/archive/401x0b09s.pdf. Information on the DSN is also available at the following website: http://deepspace.jpl.nasa.gov/dsn.

D.8 Preferred Frequencies for Launch Vehicles

NASA has agreements with other administrations to use the following preferred frequencies to support launch vehicles:

a. 2211 MHz +/- 4 MHz
b. 2215 MHz +/- 4 MHz
c. 2272.5 MHz +/- 2 MHz
d. 2285 – 2300 MHz

Frequencies outside the preferred frequencies are acceptable, but frequency coordination may be more difficult.

D.9 Restrictions on Bandwidth

D.9.1 Restrictions on S-band Return-Link Bandwidth

The NTIA Manual, paragraphs 8.2.41 and 10.8.3.A, constrains space links to Tracking and Data Relay Satellites to use a necessary bandwidth of 6.16 MHz or less in the 2200-2290 MHz band. If a necessary bandwidth greater than 6.16 MHz is required, justification for the wide bandwidth must be submitted to the Spectrum Planning Subcommittee.

The SFCG has formulated a Resolution related to the bandwidth of return links in the S-Band. It is Resolution 24-1R1, “Interference Mitigation Techniques for Future Systems Planning to Operate in the 2200-2290 MHz Band”, and it has the following Resolves: *that systems using this band be designed to minimize their bandwidths to reduce the potential interference to other systems in the band and that, whenever practical, bandwidths should not exceed 6 MHz, to reduce future congestion in the band.*

D.9.2 Restrictions on S-band Forward-Link Bandwidth

The SFCG has formulated a Resolution related to the bandwidth of forward links in the S-Band. It is Resolution 27-1, “Interference Mitigation Techniques for future Systems Planning to Operate in the 2025-2110 MHz Band”, and it has the following Resolves: *that systems using this band be designed to minimize their bandwidths to reduce the*

potential interference to other systems in the band to reduce future congestion in the band.

D.10 Guidance on 23 GHz and 26 GHz Bands

Recommendation SFCG 15-2R4 contains specific frequencies to avoid for inter-satellite links to users employing proximity links. This recommendation also lists preferred frequencies to use for proximity links. These frequencies are shown in Table D-6.

Table D-6. SFCG Recommendation for Inter-Satellite Links in the 23 and 26 GHz Bands

Type of Link	Frequency Band, GHz	Frequencies to Avoid for Data Relay LInks, GHz	Frequency Bands to Use for Proximity Links, GHz
Data Relay Satellite and Proximity	25.25-27.5	25.600 27.350	25.25-25.60 27.225-27.5

Recommendation SFCG 13-3R3 contains specific frequencies to use for inter-satellite links.

For forward links in the 22.55-23.55 GHz band, it recommends use of the following center frequencies, all in GHz: 22.695, 22.665, 22.725, 22.785, 22.845, 22.905, 22.965, 23.025, 23.085, 23.145, 23.205, 23.265, 23.325, 23.385, 23.445, and 23.505. These channels should have a minimum bandwidth of 50 MHz. Additionally, this Recommendation states that, whenever practicable, priority should be given to making assignments outside the range 23.183 – 23.377 GHz. These frequencies are also referenced in Table 8.2.

For return links in the 25.25-27.50 GHz band, it recommends use of the following center frequencies, all in GHz: 25.60, 25.85, 26.1, 26.35, 26.60, 26.85, 27.10, and 27.35. These channels should have a minimum bandwidth of 225 MHz. These frequencies are also referenced in Table 8.7

D.11 Additional Applicable Recommendations

The following ITU-R Recommendations are of particular interest to missions utilizing the Space Network.

a. **SA.1154** Provisions to protect the space research (SR), space operations (SO) and Earth-exploration satellite services (EES) and to facilitate sharing with the mobile service in the 2025-2110 and 2200-2290 MHz bands.

b. **SA.1155** Protection criteria related to the operation of data relay satellite systems.

c. **SA.1414** Characteristics of Data Relay Satellite Systems.

d. **S.672** Satellite Antenna Radiation Pattern for use as a Design Objective in the Fixed-Satellite Service Employing Geostationary Satellites.

Annex to Appendix D

D.A.1 Special Case: Satisfying PFD Limits for Space-to-Space Links by Ceasing Transmissions as the TDRS Spacecraft is Near the Horizon

In many cases, the PFD limits are difficult to meet when a spacecraft's directional antenna is pointed toward the Earth's horizon (i.e. when the TDRS is just entering or leaving the platform field of view.) In this case, many missions opt to delay the start of transmissions until the directional antenna is pointed sufficiently above the Earth's horizon. Similarly, the missions cease transmissions a few minutes prior to the time that the TDRS goes below the horizon. This section describes a procedure to calculate the minimum angle between the LOS vector to TDRS and the vector pointing to the horizon that is just sufficient to ensure that the PFD limits are met for all angles of arrival, α. The geometry is shown in Figure D.A-1.

The minimum angle, $\theta_m(\alpha)$, between the line of sight vector to or beyond TDRS and the horizon is found at each value of α by calculating the following items:

a. $\beta(\alpha)$, $\phi(\alpha)$, and $R(\alpha)$ found from Equation D-2 and Equation D-3.
b. $\theta_{qm}(\alpha)$, the angle between horizon vector and the Earth's surface for a given α, from Equation D.A-1.
c. $G(\theta_{qm}(\alpha))$, the gain at the off-axis angle $\theta_{qm}(\alpha)$.
d. the PFD(α), PFD Limit(α), and PFD Limit Exceedance(α).
e. the maximum gain that can be allowed toward the Earth at angle of arrival α.
f. θ(α). the off-axis angle needed to yield the desired gain.
g. $\theta_m(\alpha)$, by calculating $\theta(\alpha) - \theta_{qm}(\alpha)$.

The minimum angle between the LOS vector to TDRS and the vector pointing to the horizon needed to satisfy the PFD limits is simply the largest value of $\theta_m(\alpha)$ taken over all values of α. This angle is denoted as $MAX[\theta_m(\alpha)]$.

A geometrical analysis can be used to bound the time required for a platform to travel from the point where $\theta_m = 0$ to the point where $\theta_m = MAX[\theta_m(\alpha)]$. This bound represents a bound on the time period for which the transmission should be ceased to meet PFD limits as the platform comes around the limb of the Earth.

Equation D.A-1:

$$\theta_{qm}(\alpha) = \sin^{-1}\left(\frac{r_e}{r_s}\right) - \beta(\alpha)$$

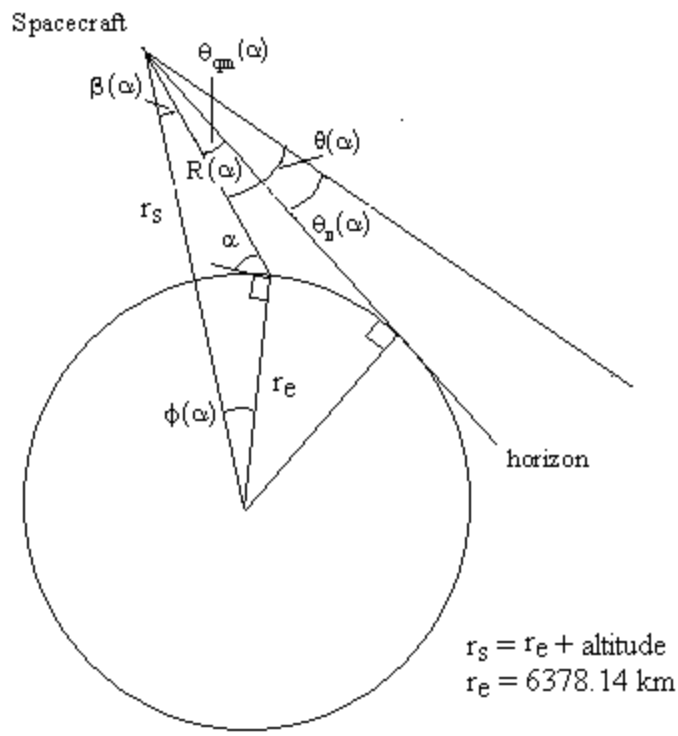


Figure D.A-1. Geometry for the Minimum Angle Between the Vectors Pointing Toward the Horizon and the TDRS

D.A.2 An Example Application

When the example of Section D.3.3.2 is redone with a sufficiently high value of spacecraft antenna gain, there will be some arrival angles for which the PFD limits are exceeded. The following example shows such a case. Table D.A-1 shows the parameters of the example and Table D.A-2 shows the PFD calculations. The resulting data are plotted in Figure D.A-2.

Table D.A-1. Peak Power Calculations
(**bold** values are input data)

Parameter Name	Units	Value
Earth Radius	km	6378.14
SC Altitude	km	**400**
SC Max Gain	dBi	**30**
1st Lobe	dB from Max	**-25**
Symbol Rate	bps	**3.08E+06**
RF Power	W	**1**
	dBW	0.0
Peak PSD	dBW/Hz	-64.9
	dBW/4kHz	-28.9

Table D.A-2. Calculation of PFD at All Arrival Angles for Directional Antenna

	Step a			Step b	Step c	Step d			Step e	Step f	Step g	
Elevation Angle, α	Spacecraft Look Angle, β(α)	Earth Central Angle, φ(α)	Spacecraft Range, R(α)	Horizon Angle, $\theta_{qm}(\alpha)$	Gain at Horizon Angle, G(θqm(α))	PFD(α)	PFD_Limit(α)	PFD limit Exceedance(α)	Maximum Gain Allowed	Total Offpointing Angle Needed, θ(α)	Angle Beyond Horizon, $\theta_m(\alpha)$	Adjusted PFD(α)
degrees	degrees	degrees	km	degrees	dBi	dBW/m^2/ 4 kHz	dBW/m^2/ 4 kHz	dB	dBi	degrees	degrees	dBW/m^2/ 4 kHz
0	70.2	19.8	2294.0	0.00	30.00	-137.1	-154.0	16.9	13.1	6.28	6.28	-154.07
5	69.6	15.4	1804.5	0.60	29.85	-135.1	-154.0	18.9	11.0	6.66	6.06	-155.37
10	67.9	12.1	1439.8	2.29	27.73	-135.3	-151.5	16.2	11.5	6.56	4.27	-158.02
15	65.4	9.6	1175.5	4.86	19.82	-141.4	-149.0	7.6	12.3	6.42	1.56	-156.26
20	62.2	7.8	984.2	8.06	5.00	-154.7	-146.5	-8.2	5.0	0.00	-	-154.72
25	58.5	6.5	844.0	11.70	5.00	-153.4	-144.0	-9.4	5.0	0.00	-	-154.22
30	54.6	5.4	739.4	15.64	5.00	-152.2	-144.0	-8.2	5.0	0.00	-	-155.22
35	50.4	4.6	659.8	19.79	3.12	-153.1	-144.0	-9.1	3.1	0.00	-	-156.12
40	46.1	3.9	598.2	24.09	0.99	-154.4	-144.0	-10.4	1.0	0.00	-	-155.39
45	41.7	3.3	549.9	28.51	0.00	-154.7	-144.0	-10.7	0.0	0.00	-	-154.66
50	37.2	2.8	511.7	33.00	0.00	-154.0	-144.0	-10.0	0.0	0.00	-	-154.04
55	32.7	2.3	481.4	37.55	0.00	-153.5	-144.0	-9.5	0.0	0.00	-	-153.51
60	28.1	1.9	457.4	42.15	0.00	-153.1	-144.0	-9.1	0.0	0.00	-	-153.06
65	23.4	1.6	438.6	46.78	0.00	-152.7	-144.0	-8.7	0.0	0.00	-	-152.70
70	18.8	1.2	424.0	51.44	0.00	-152.4	-144.0	-8.4	0.0	0.00	-	-152.40
75	14.1	0.9	413.2	56.12	0.00	-152.2	-144.0	-8.2	0.0	0.00	-	-152.18
80	9.4	0.6	405.8	60.81	0.00	-152.0	-144.0	-8.0	0.0	0.00	-	-152.02
85	4.7	0.3	401.4	65.51	0.00	-151.9	-144.0	-7.9	0.0	0.00	-	-151.93
90	0.0	0.0	400.0	70.22	0.00	-151.9	-144.0	-7.9	0.0	0.00	-	-151.90
										Max Angle	6.28	

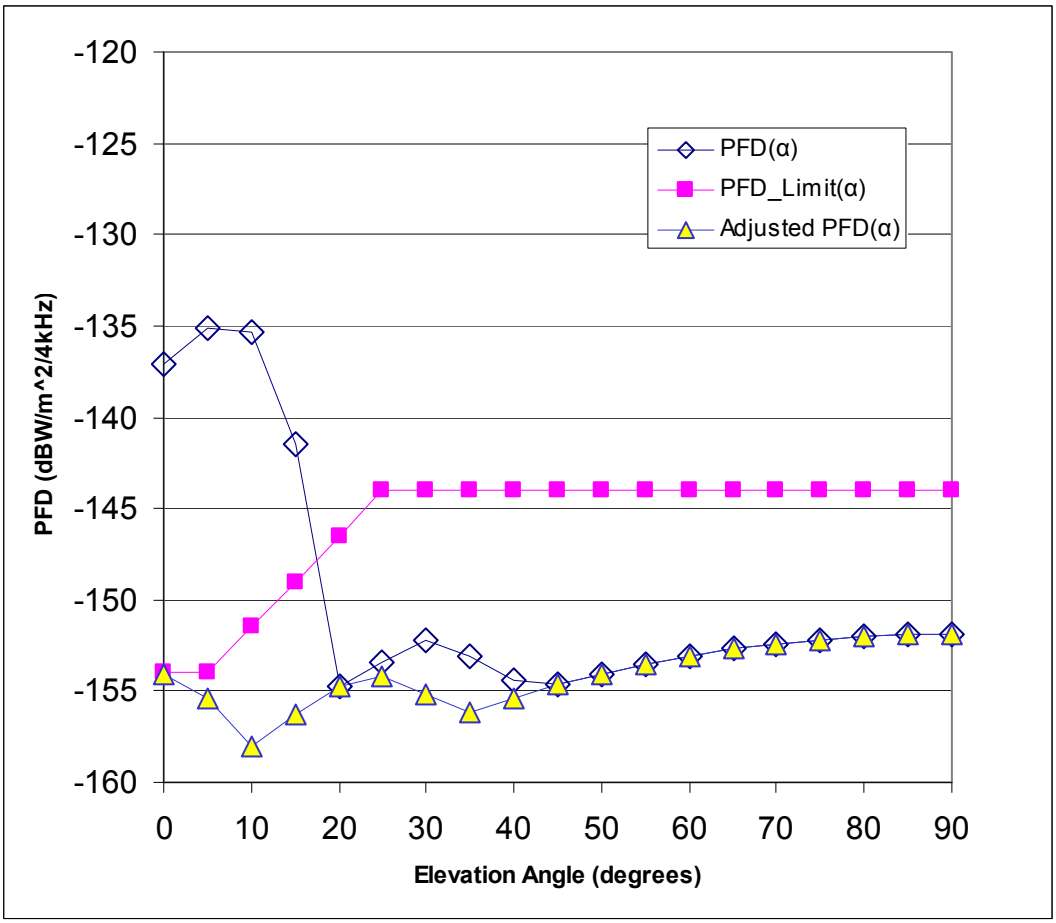


Figure D.A-2. Plot of PFD, PFD Limit, and Adjusted PFD for All Arrival Angles for ITU-R.672 Spacecraft Antenna Having 30 dBi Maximum Gain and -25 dB relative Side-Lobe Gain

Appendix E. Customer Platform and TDRS Signal Parameter Definitions

E.1 General

This Appendix defines the salient characteristics of the TDRSS forward service to a customer platform and the parameters which constrain the customer platform transmitted signal. The specifications of these parameters are given in Tables 5-3 (MAF), 6-4 (SSAF), 7-3 (KuSAF), 8-3 (KaSAF), 5-11 (MAR), 6-12 (SSAR), 7-9 (KuSAR), and 8-9 (KaSAR), respectively.

E.2 Symbol (Data) Asymmetry

a. For the NRZ signal format, symbol (data) asymmetry is defined as follows:

$$\frac{\text{length of long symbol - length of short symbol}}{\text{length of long symbol + length of short symbol}} \times 100\%$$

b. For the Biphase format signal (S-band DG2 only), data asymmetry applies to both the entire symbol and to each half-symbol pulse. Therefore, for Biphase, symbol (data) asymmetry is defined as follows:

1. For the entire symbol:

$$\frac{\text{length of long symbol - length of short symbol}}{\text{length of long symbol + length of short symbol}} \times 100\%$$

2. For the half-symbol pulse:

$$\frac{\text{length of long half symbol pulse - length of short half symbol pulse}}{\text{length of long half symbol pulse + length of short half symbol pulse}} \times 100\%$$

E.3 Symbol (Data) Rise Time

Symbol (data) rise time is the time required to switch from 90 percent of the initial data state to 90 percent of the final data state as a percentage of symbol duration. Symbol (data) rise time is illustrated in Figure E-1.

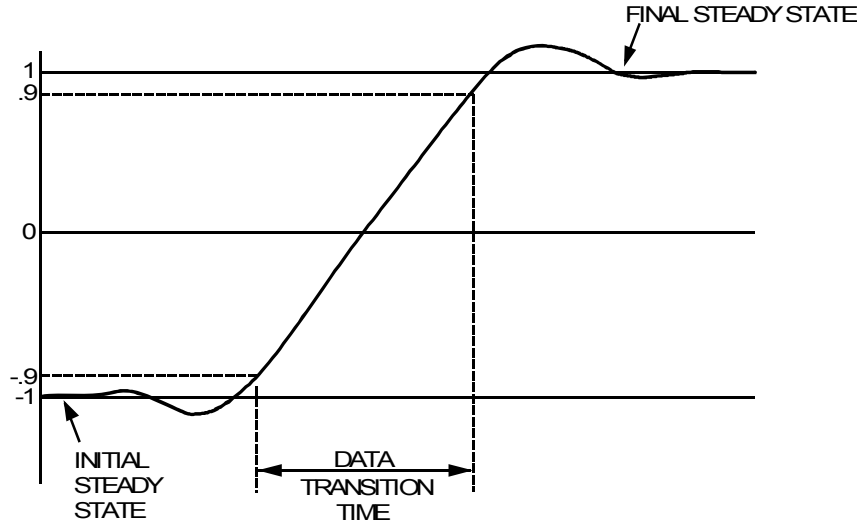


Figure E-1. Symbol (Data) Rise Time

E.4 Symbol (Data Bit) Jitter and Jitter Rate

Symbol (data bit) jitter is defined as the peak frequency deviation from the desired symbol clock frequency expressed as a percentage of the symbol clock frequency. A mathematical description of this definition follows.

A symbol clock with symbol jitter can be expressed as follows:

$$c(t) = \mathrm{sgn}\left[\cos(2\pi f_S t + \phi(t)\right]$$

where

$f_S =$ desired symbol rate

$\phi(t) =$ symbol clock <u>phase</u> jitter

$2\pi f_S t + \phi(t) = \theta(t) =$ symbol clock phase in radians

The frequency of the symbol clock is as follows:

$$f_C = \frac{d\theta(t)}{dt} \cdot \frac{1}{2\pi} = f_S + \frac{d\phi(t)}{dt} \cdot \frac{1}{2\pi} \quad \text{Hz}$$

It can be seen that the clock frequency is comprised of a constant component and a time-varying component. Symbol jitter is defined as the peak absolute value of the time-varying portion of the symbol clock <u>frequency</u>:

$$\Delta f = \left[\max\left(abs\left(\frac{d\phi(t)}{dt} \cdot \frac{1}{2\pi}\right)\right)\right] = \text{symbol jitter in Hz}$$

Symbol jitter expressed as a percentage of the symbol clock rate can be computed as follows:

$$\Delta f \cdot \frac{1}{f_S} \cdot 100\% = \left[\max\left(abs\left(\frac{d\phi(t)}{dt} \cdot \frac{1}{2\pi}\right)\right)\right] \cdot \frac{1}{f_S} \cdot 100\% = \text{symbol jitter as a \% of the symbol clock rate}$$

If the jitter is random, the 3σ value of the symbol clock frequency jitter may be used in the above expression.

The symbol jitter rate is defined as the maximum frequency component, f_m, in the symbol clock frequency jitter power spectral density (i.e., the symbol clock frequency jitter spectral distribution is from 0 to f_m Hz).

For KuSAR special constraints apply. These constraints are as follows:

a. The WSC will be provided with scheduling parameters from the NCCDS which categorizes the input jitter for each channel into one of six ranges: None, 0.01%, 0.1%, 0.5%, 1.0%, and 2.0%. The last three of these are valid only for the Shuttle. The constraints governing each of the first three cases are detailed below:

1. Jitter = None (Coded or Uncoded Data). When the scheduled jitter parameter for a data channel is "None" and the data is either coded or uncoded, then $\Delta f = f_m = 0$.

2. Jitter = 0.01% (Coded or Uncoded Data). When the scheduled jitter parameter for a data channel is "0.01%" and the data is either coded or uncoded, Δf and f_m will lie as shown in Figure E-2 for all symbol rates up to and including 150 Msps.

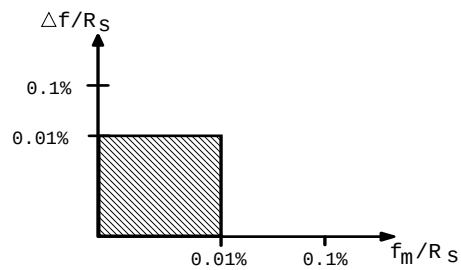


Figure E-2. Coded and Uncoded Data at 0.01% Jitter

3. Jitter = 0.1% (Coded or Uncoded Data). When the scheduled jitter parameter for a data channel is "0.1%" and the data is uncoded, Δf and f_m will lie as shown in Figure E-3 through Figure E-6, as appropriate, depending on symbol rate. When the data is coded, Δf and f_m will lie as shown in Figure E-6, independent of symbol rate.

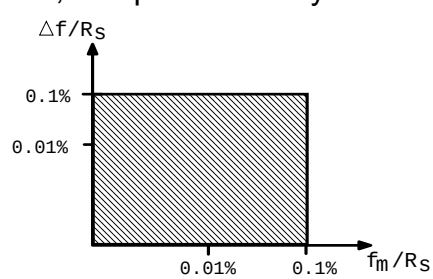


Figure E-3. Uncoded Data at 0.1% Jitter for $R_S \leq 20$ MSPS

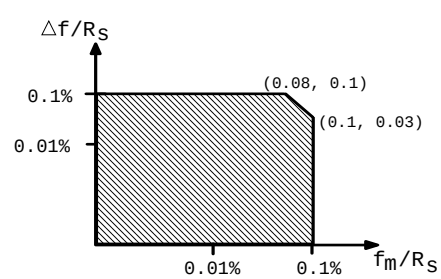


Figure E-4. Uncoded Data at 0.1% Jitter for ($20 < R_S \leq 40$) MSPS

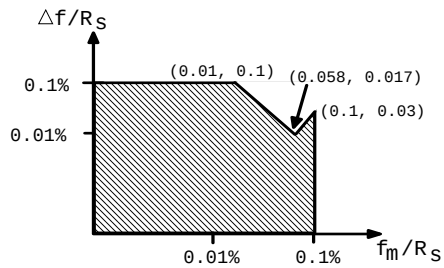


Figure E-5. Uncoded Data at 0.1% Jitter for (40 < Rs < 75) MSPS

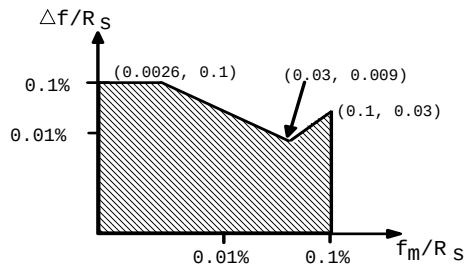


Figure E-6. Uncoded Data at 0.1% Jitter for (75 < $R_S \leq$ 150) MSPS
Coded Data at 0.1% Jitter for ($R_S \leq$ 150) MSPS

E.5 Phase Imbalance

E.5.1 Suppressed Carrier

E.5.1.1 BPSK

BPSK phase imbalance is defined as, $\phi = 180 - \psi$, where ϕ is the phase imbalance and ψ is the value of the phase angle between the two BPSK signal vectors; as shown in Figure E-7.

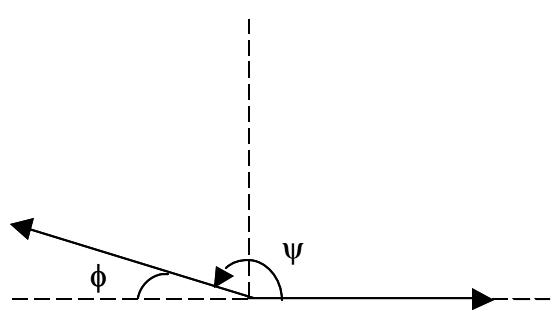


Figure E-7. BPSK Phase Imbalance

E.5.1.2 QPSK

QPSK phase imbalance is defined as $\phi = \max |\psi_i - \psi_{ideal}|$ where ϕ is the phase imbalance and the four actual phase angles $\{\psi_i\}$ are as shown in Figure E-8.

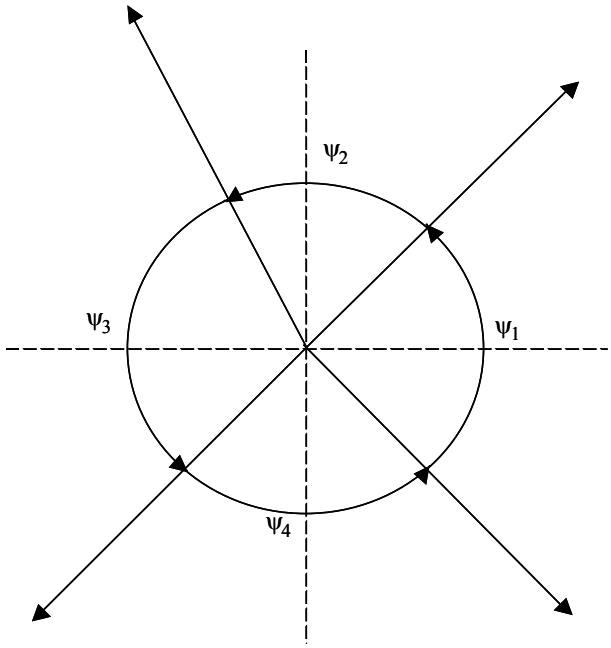


Figure E-8. QPSK Phase Imbalance

ψ_{ideal} is the value of each illustrated phase under distortion-free conditions and, for example, is given by:

ψ_{ideal} = 90 degrees; Q/I (power) = 0 dB

= 126.87 degrees or 53.13 degrees; Q/I (power) = 6 dB

E.5.2 Residual Carrier

For residual carrier modes of operation, a phase imbalance constraint is not specified because the modulation index tolerance constraint supersedes this constraint.

E.6 Gain Imbalance

E.6.1 Suppressed Carrier

Gain imbalance, G, is defined by the following relationship:

$G = 20 \log_{10} [\max (R_i/R_j)]$ at customer platform High Power Amplifier (HPA) output

where R_i and R_j are the magnitudes of the signal modulation vectors at the customer platform high power amplifier (HPA) output in the absence of incidental AM and varying modulation. Figure E-9 and Figure E-10 show BPSK and QPSK gain imbalance, respectively.

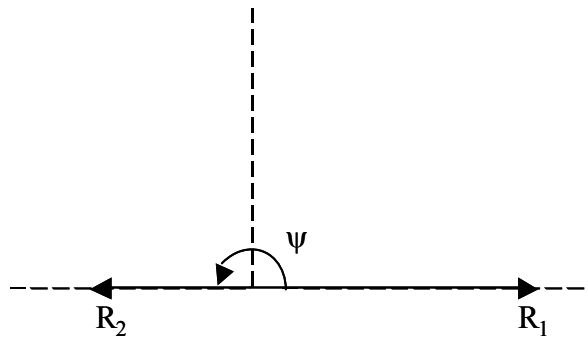


Figure E-9. BPSK Gain Imbalance

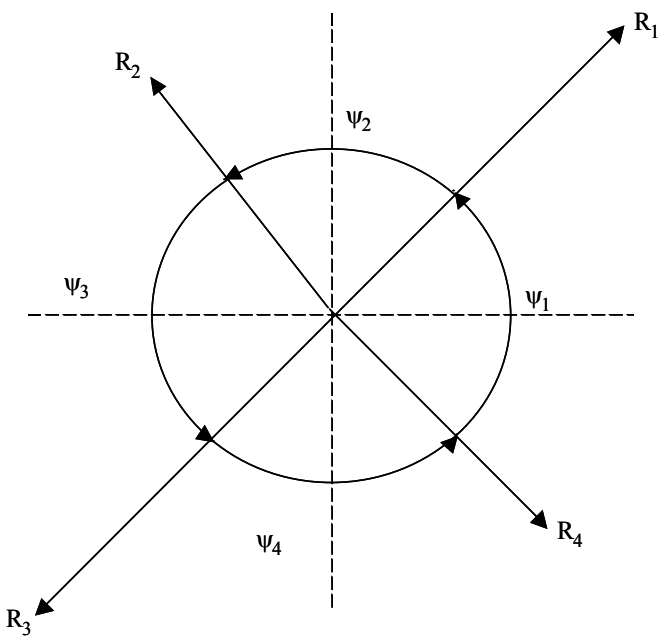


Figure E-10. QPSK Gain Imbalance

E.6.2 Residual Carrier

For residual carrier cases, gain imbalance is defined as follows:

$$G = 20 \log_{10} [\max (R_{ideal}/(R_{max} \text{ or } R_{min}))]$$

Gain imbalance is illustrated in Figure E-11.

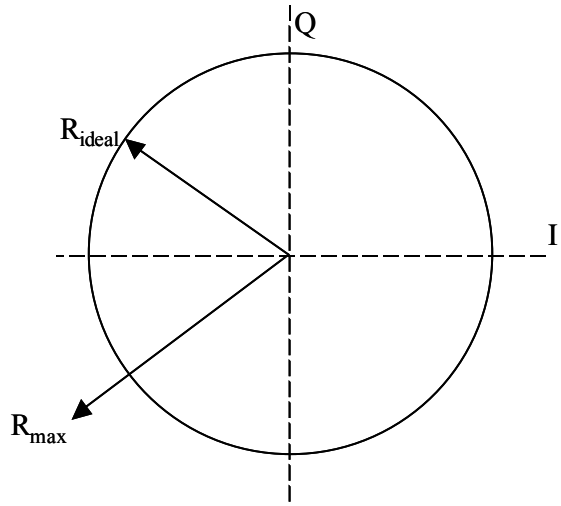


Figure E-11. Residual Carrier Gain Imbalance

E.7 Phase Nonlinearity

Phase nonlinearity is defined as the peak deviation of the phase from the best linear fit to the phase response over the bandwidth of interest, as illustrated in Figure E-12.

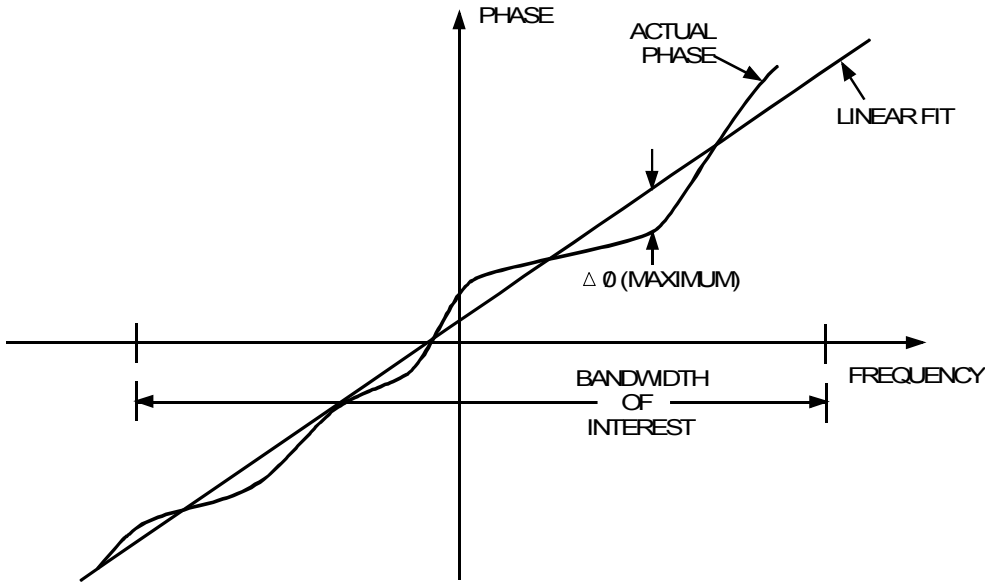


Figure E-12. Phase Nonlinearity

E.8 Gain Flatness

Gain flatness is defined as the peak deviation of the gain from the best horizontal fit to the gain response over the bandwidth of interest, as illustrated in Figure E-13.

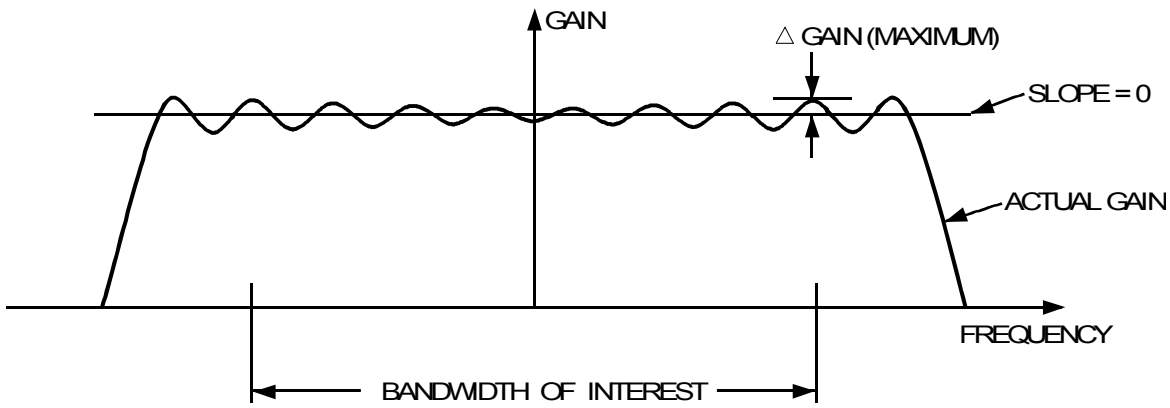


Figure E-13. Gain Flatness

E.9 Gain Slope

Gain slope is defined as the peak absolute value of the derivative of the gain response (relative to the frequency) over the bandwidth of interest, as illustrated in Figure E-14.

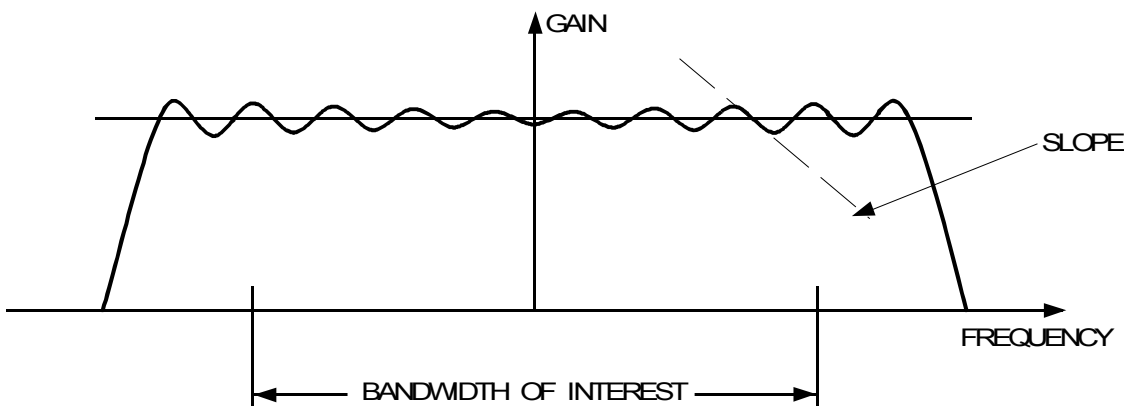


Figure E-14. Gain Slope

E.10 AM/PM

AM/PM is defined as the peak absolute value of the derivative of the amplifier output phase (relative to the input power) over the operating range of the RF output stages, as described by the following equation and as illustrated in Figure E-15.

AM/PM = worst-case $\frac{d\phi_{out}}{dP_{in}}$ over the range of operating points

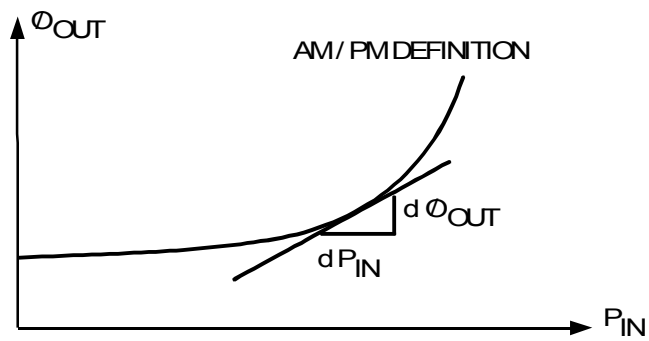


Figure E-15. AM/PM Definition

For forward service:

P_{in} = RF power input in dBW to cascaded WSC/GRGT and TDRS HPAs.

ϕ_{out} = RF phase output in degrees from cascaded WSC/GRGT and TDRS HPAs.

For return service:

P_{in} = RF power input in dBW to user transmitter HPA.

ϕ_{out} = RF phase output in degrees from user transmitter HPA.

E.11 Frequency Stability

Frequency stability is the peak instantaneous carrier frequency deviation from the nominal carrier frequency normalized by the nominal carrier frequency as observed over the specified time interval of interest. This includes frequency deviation due to all sources including deviations induced by environmental changes. (This parameter only applies to the noncoherent return mode of operation).

E.12 Incidental AM

Incidental AM is the undesired amplitude modulation superimposed on the carrier and present at the HPA output. This parameter is expressed as a modulation percentage relative to the carrier amplitude. This distortion can be shown mathematically on a continuous wave signal as follows:

$$A\left[1+\sum_i m_i \cos(\omega_i t+\varphi_i)\right]\cos\left[\omega_c t+\theta\right]$$

where m_i represents the amplitude of the ith AM component, ω_i represents the frequency of the ith component, ϕ_i represents the phase of the ith component, ω_c represents the carrier frequency, and θ represents the arbitrary phase of the carrier. The power of the ith component is $\frac{1}{2}m_i^2$.

The incidental AM (peak) is defined by:

$$\sum_i m_i \text{ x } 100 \text{ percent}$$

E.13 Spurious PM

Spurious PM is the residual or unwanted phase modulation at the HPA output, in the absence of data modulation, that is characterized by a discrete spectrum. This distortion can be shown mathematically on a continuous wave signal as follows:

$$A \cdot \cos\left[\omega_c t + \theta + \sum_i a_i \cos\left[(\omega_C + \omega_i)t + \phi_{Di}\right]\right]$$

where ω_c represents the carrier frequency, θ represents the arbitrary phase of the carrier, a_i represents the amplitude of the ith component, ω_i represents the frequency of the ith component, and ϕ_{Di} represents the phase of the ith component. The power of the ith component is $\frac{1}{2}a_i^2$.

Spurious PM is generally specified as a limit on total spurious PM power (in degrees rms). Total spurious PM can be computed as follows:

$$\sigma_{\varphi_D} = \frac{180}{\pi} \cdot \sqrt{\frac{1}{2}\sum_i a_i^2} \text{ deg rms}$$

E.14 Phase Noise

Phase noise is residual or unwanted phase modulation that is characterized by a continuous spectrum. This distortion can be shown mathematically on a continuous wave signal as follows:

$$A \cdot \cos\left[\omega_c t + \theta + \phi_n(t)\right]$$

where ω_c represents the carrier frequency, θ represents the arbitrary phase of the carrier, and $\phi_n(t)$ is the undesired phase modulation having a one-sided continuous spectrum, $S_{\phi_n}(t)$ rad^2. Phase noise is generally specified as a collection of phase noise limits (in degrees rms) over various frequency ranges offset from the carrier frequency. Phase noise in the frequency range f_a to f_b (offset from the carrier frequency) can be computed as follows:

$$\sigma_{\phi_n} = \frac{180}{\pi}\sqrt{\int_{f_a}^{f_b} S_{\phi_n}(f) \cdot df} \text{ deg rms}$$

For the coherent turnaround mode, constraint values assume no phase noise on the signal received by the customer platform; it, therefore, represents the phase noise added by the customer platform, including a contribution due to forward link carrier recovery. Values indicated for the coherent mode represent total output phase noise of the customer platform.

E.15 In-band Spurious Outputs

In-band spurious outputs is the sum of the power of all in-band spurs measured relative to the total signal power (dBc indicates dB below total signal power); where in-band is defined as 2x the maximum channel baud rate.

E.16 Out-of-Band Emissions

Out-of-band emissions are defined as emissions outside of the allocated band of operation. See Appendix D for a further description of out-of-band emissions.

E.17 I/Q Symbol (Data) Skew

For QPSK, the ideal time delay between the symbol (data) transitions on the I channel and the symbol (data) transitions on the Q channel is zero. For SQPSK, the ideal time delay between the symbol (data) transitions on the I channel and the symbol (data) transitions on the Q channel is $0.5T_s$ (where T_s is the channel symbol duration). I/Q symbol (data) skew is the deviation from this ideal relative time delay – measured as a percent of the symbol (bit) time. I/Q symbol (data) skew is defined mathematically as follows:

$$\text{I/Q symbol (data) skew} = \frac{\alpha}{\text{Ts}} \times 100\%$$

Where α is as defined in Figure E-16 for the QPSK case. For SQPSK, α is relative to the ideal $0.5T_s$ interval between symbol (data) transitions on the I and Q channels.

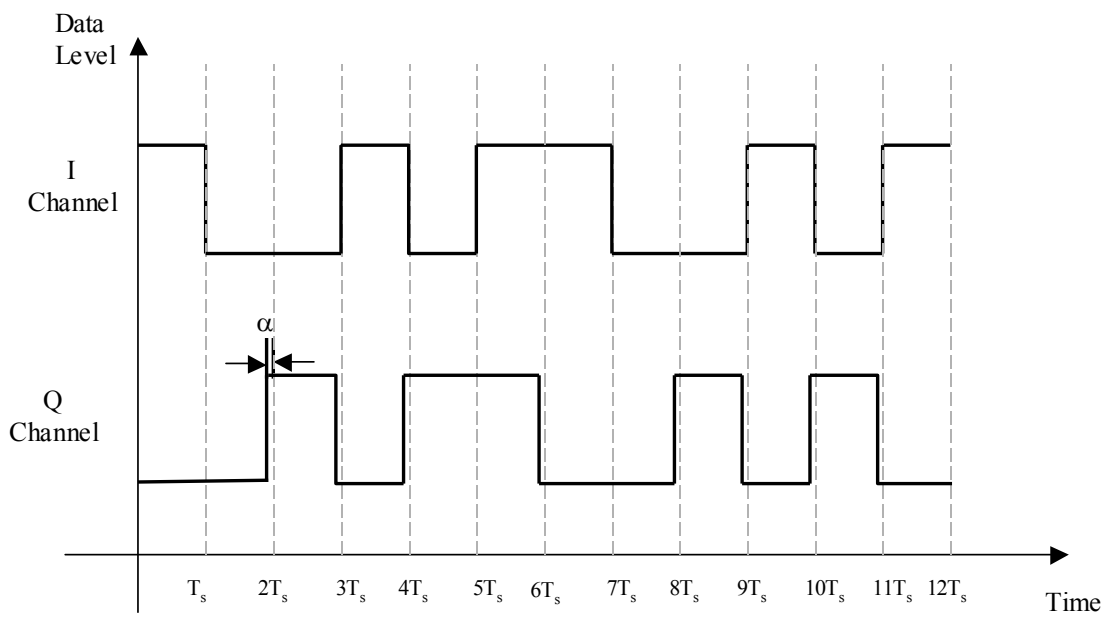


Figure E-16. Description of I/Q Data Skew Assuming QPSK Modulation

E.18 PN Chip Skew

PN chip skew is the deviation of the chip transitions between the I (or command channel for forward) and the Q (or range channel for return) from the ideal time delay.

E.18.1 Return I/Q PN Chip Skew

The ideal time delay between the chip transitions on the I channel and the chip transitions on the Q channel is $0.5T_c$ (where T_c is the PN code chip duration). I/Q chip

skew is the deviation from this ideal time delay. I/Q PN chip skew is defined in Figure E-17.

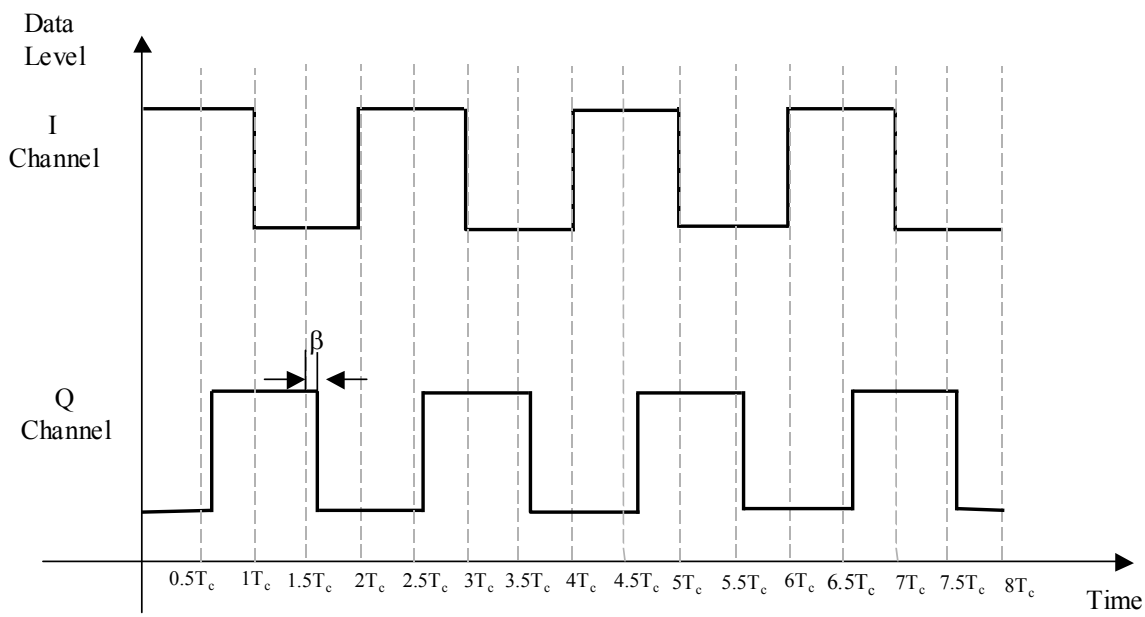


Figure E-17. Definition of I/Q PN Code Chip Skew

E.18.2 Command/Range Channel PN Chip Skew

The ideal time delay between the chip transitions on the command channel and the chip transitions on the range channel is zero. The command/range channel PN chip skew is the deviation from this ideal time delay.

E.19 PN Chip Asymmetry

PN chip asymmetry is defined as follows:

$$\frac{\text{length of long chip - length of short chip}}{\text{length of long chip + length of short chip}} \times 100\%$$

E.20 PN Chip Jitter

PN code chip jitter is defined as the unwanted phase variations of the PN code chip clock measured in degrees rms. A PN code chip clock with PN code chip jitter can be expressed as follows:

$$c(t) = \text{sgn}\left[\cos(2\pi f_{pn} t + \phi(t)\right]$$

where

$f_{pn} =$ desired PN code chip rate in Hz

$\phi(t) =$ PN code chip clock <u>phase</u> jitter in radians

The PN code chip jitter is the rms value of $\phi(t)$ expressed in degrees.

E.21 PN Chip Rate

PN code chip rate is defined as the peak deviation of the actual PN chip rate from the desired PN chip rate (where the desired PN chip rate is defined as the PN chip rate which results in absolute coherence with the carrier rate).

E.22 Noncoherent and Coherent Turnaround Customer-Induced PN Correlation Loss

Customer-induced PN correlation loss is the effective reduction in despread signal power due to the presence of timing imperfections (asymmetry and jitter) in the customer platform transmitter PN clock. Under noncoherent conditions, jitter will be solely due to the transmitter's oscillator. Under coherent turnaround conditions, it will also reflect forward link PN tracking in the absence of PN jitter on the signal received by the customer platform.

E.23 Deleted

E.24 Antenna-Induced PM

Antenna-induced PM is phase modulation inadvertently induced on the transmit signal by the antenna.

E.25 Axial Ratio

For circularly polarized antennas, the electrical field vector usually produced describes an ellipse instead of a circle. The axial ratio is a measure of ellipticity of the customer platform transmitting antenna and is the ratio of the major axis of the ellipse to the minor axis.

E.26 Data Rate Tolerance

Data rate tolerance is the allowable difference between the actual data rate and the desired data rate – measured as a percentage of the desired data rate.

E.27 Power Ratio Tolerance

Power ratio tolerance is the ratio of the actual I/Q channel power ratio to the desired I/Q channel power ratio.

E.28 Permissible EIRP Variation

Permissible EIRP variation is the range over which the customer platform EIRP, measured along the customer platform/TDRS line-of-sight, may vary without requiring customer platform reconfiguration. Performance is determined from customer platform transmitter power variation, transmit antenna pattern, worst case customer platform orientation, and maximum variation in range between the customer platform and the TDRS over the duration of a pass.

E.29 Rate of EIRP Variation

Rate of EIRP variation is the time derivative of the customer platform EIRP.

E.30 Maximum User EIRP

Maximum user EIRP is the maximum allowable user EIRP transmitted toward a TDRS.

E.31 Modulation Index Accuracy

Modulation index accuracy is the peak deviation of the modulation index from the desired modulation index as a percentage of the desired modulation index. Modulation index accuracy is defined as follows:

$$\frac{\text{peak deviation from the desired mod index}}{\text{desired mod index}} \times 100\%$$

E.32 Subcarrier Frequency Accuracy

Subcarrier frequency accuracy is the maximum deviation of the subcarrier frequency from the desired subcarrier frequency.

E.33 Data Transition and Subcarrier Coherency

Coherency between the data transition and the subcarrier zero-crossing is measured in degrees of the subcarrier cycle.

E.34 Subcarrier Phase Noise

Subcarrier phase noise is unwanted phase modulation to the subcarrier. See paragraph E.14 for a general description of phase noise.

E.35 Maximum Frequency Error of 8.5 MHz Subcarrier

The maximum frequency error of 8.5 MHz Subcarrier is the peak instantaneous subcarrier frequency deviation from the nominal subcarrier frequency normalized by the nominal subcarrier frequency.

E.36 Minimum EIRP for TDRSS Ku-Band Autotrack

This is the minimum EIRP required to ensure nominal autotrack acquisition and performance.

E.37 Short Term EIRP Stability

This is the peak variation in user EIRP over a time duration as described by the specification.

E.38 Minimum 3 dB Bandwidth Prior to the Power Amplifier

This is the double-sided 3 dB bandwidth introduced by the transmitter's channel filtering, including any modulator effects, prior to the power amplifier.

Appendix F. Periodic Convolutional Interleaving with a Cover Sequence for Synchronization

F.1 General

This Appendix describes (n, m) Periodic Convolutional Interleaving (PCI) which, when used with the appropriate periodic convolutional deinterleaving, guarantees separation of any two symbols within n of each other in the interleaved symbol sequence to be at least nm/(n-1) symbols between each other in the deinterleaved sequence. PCI is recommended on S-band DG1 mode 3 and DG2 return services for channel baud rates > 300 kbps. At these higher data rates, any single RFI pulse affects multiple adjacent transmitted symbols. The effectiveness of the ground terminal Viterbi decoding process decreases as the number of adjacent symbols overlapped increases. The purpose of the periodic convolutional interleaving (and associated ground terminal deinterleaving) is to break up or spread out these corrupted symbols so that they appear at the Viterbi decoder input to be random in their occurrence just as if they arose from a channel without memory. When interleaving is not employed for DG1 mode 3 and DG2 channel baud rates > 300 kbps, S-band return performance may not be guaranteed. Deinterleaving is not supported for baud rates ≤ 300 kbps. Additionally, biphase symbol formats are not allowed with PCI. Use of biphase symbol formats on DG2 S-band services at baud rates > 300 kbps should be coordinated with GSFC Code 450.

F.2 (30,116) Periodic Convolutional Interleaving

F.2.1 Interleaving

The encoded symbol sequence interleaving is shown in Figure F-1 as commutated delay elements. The input and output commutators are slaved, advanced for each encoded symbol, and recycled every 30 symbols. The input to the zero delay element of the interleaver is always a G_1 encoder symbol modulo-2 added to the initial cover sequence state (please see paragraph F.2.2).

F.2.2 Cover Sequence

The cover sequence is modulo-2 added bit-by-bit to the preinterleaved symbols to provide for perfect deinterleaving synchronization. The cover sequence is:

first bit last bit

000001110010001010111101101001

where the first bit is for the zero delay element and the last bit is for the 116 delay element of the interleaving.

F.2.3 Synchronization

F.2.3.1 Cover Sequence

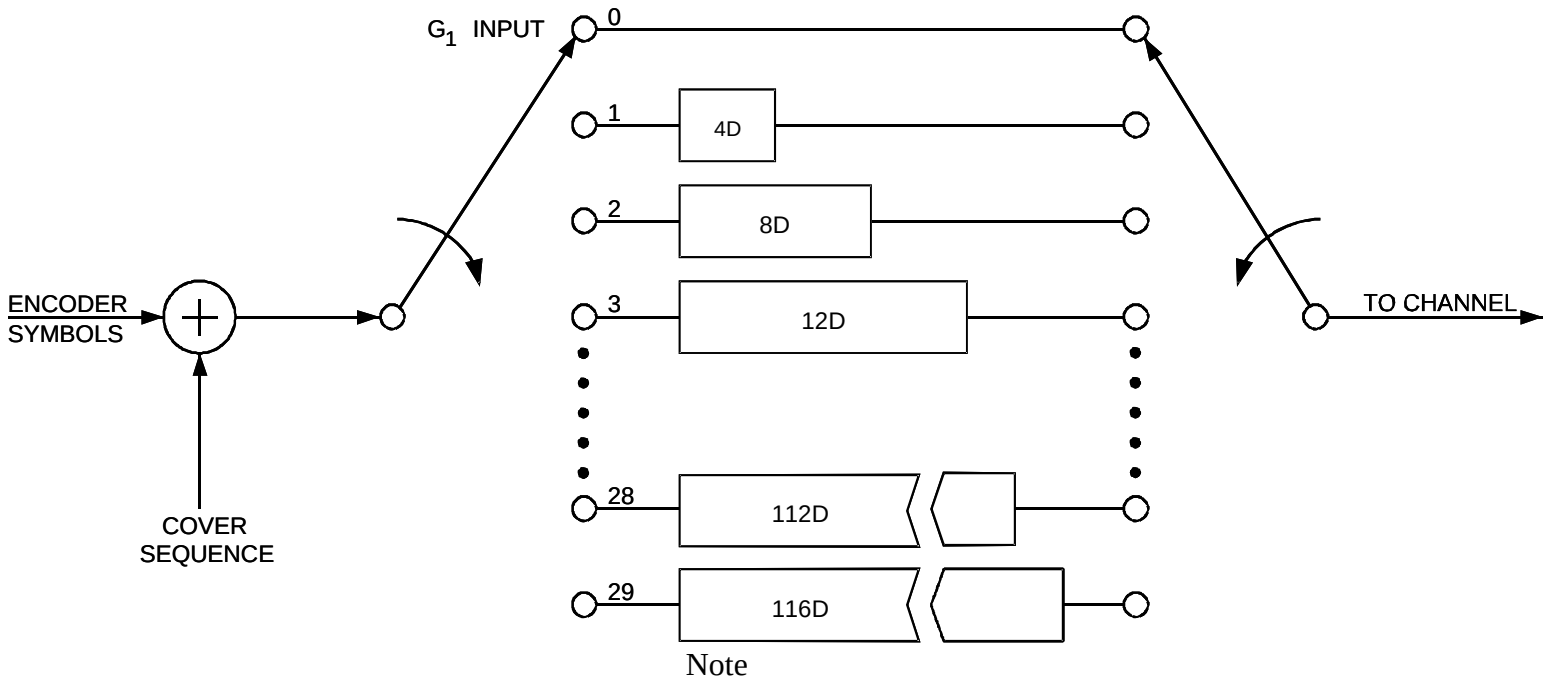
The cover sequence is synchronized with the interleaving delay selection so that the first bit occurs during the zero delay selection by the interleaving commutation (commutator positions as shown in Figure F-1).

F.2.3.2 Convolutional Encoding

The convolutional encoding is synchronized with the interleaving delay selection so that the symbol from the G_1 generator of the convolutional encoding occurs during the zero delay selection by the interleaving commutation (commutator positions as shown in Figure F-1).

F.2.3.3 Timing Synchronization

The encoding, cover sequence generation, modulo-2 addition, and interleaving (commutation and delay) will be time synchronous.



Note

D = Delay element

Figure F-1. Periodic Convolutional Interleaving

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Appendix G. Predicted Performance Degradations Due to RFI

G.1 General

G.1.1

Certain portions of the RF spectrum used by TDRSS are also occupied by independent ground-based transmitters, which may introduce RFI. Although RFI may be present at S-, Ku-, and Ka-band frequencies, current indications and performance evaluations suggest that only S-band RFI warrants concern at this time. The interference environment and any associated RFI model is constantly changing and RFI should be dealt with on a case-by-case basis for each customer. The customer community will, however, be kept abreast of significant changes if they occur. Please contact GSFC Code 450 for further information.

G.1.2

Both forward and return service performance may be affected by RFI, with the return service impact of most potential significance. The RFI impact on forward service performance is heavily dependent on the customer platform orbit and varies rapidly with time; therefore, forward service RFI must be treated on a customer-unique basis. On the other hand, the effects of return service RFI change much more gradually with time and an assessment may be developed which has broad applicability to virtually all TDRSS customers.

G.1.3

The major RFI problem to which this Appendix is devoted concerns S-band RFI emitters, which are expected to degrade the performances of the SSA and MA return service. These degradations are treated as increased required P_{rec} or, equivalently, as additional customer platform EIRP required above the value which would suffice in an RFI-free environment. As will be described, there are many variables and uncertainties associated with these degradation estimates, so that customers are urged to include additional margins in their customer platform EIRP specifications within: economic constraints, the maximum P_{rec} restrictions of Section 5 (MA) and Section 6 (SSA), and the allowable excess margin.

The Final Acts of the World Administrative Radio Conference-92 (WARC-92) re-allocated portions of S-band frequencies to fixed service users. As more fixed service users move into this band, this re-allocation may have an RFI impact on SN operations in S-band. Each customer should coordinate with GSFC Code 450 to determine the RFI levels and mitigation techniques for their specific mission.

Two systems are available to customers for predicting possible interference. The Automated Conflict Resolution System (ACRS) predicts mutual interference between two or more customer platforms scheduled on the same TDRS at the same time. Customer MOCs receive ACRS output and may alter their schedules based upon the

interference mitigation techniques provided by ACRS. The TDRS Look Angle System (TLAS) plots the TDRS look angles as it tracks the customer platform and predicts periods of ground based RFI and earth multipath. Both systems use TDRS and customer orbital data as inputs as well as customer schedules received directly at the NCCDS.

G.2 Factors Influencing Degradation

G.2.1

A number of factors or parameters determine the degree of performance degradation from RFI on any particular service. Different RFI environments are expected at the TDRSs (such as more RFI for TDRS-East than for TDRS-West). Intentional offpointing of the TDRS SA antenna away from the geographic zone containing the RFI emitters will serve as a direct means of RFI mitigation. Customer platform signal parameters are significant, particularly the return service used (MA or SSA), the convolutional code rate (rate 1/3 is optional for some SSA and SMA applications), and the degree of compliance with the signal quality customer platform constraints.

G.2.2

The largest element of uncertainty in determining RFI degradation estimates concerns the RFI environment itself. The environment is constantly changing and GSFC Code 450 will be kept informed of the changes in the environments in which the SN operates.

G.3 Need For Channel Coding and Periodic Convolutional Interleaving

G.3.1

Forward error control coding not only provides a performance improvement against thermal noise, but it also makes the service performance less sensitive to RFI degradations. Clearly, even very occasional bursts of interference drive the BER up to an unacceptable value on an uncoded system. These same errors on the encoded symbols of a coded system are unlikely to result in output errors after the decoding process. For this reason, convolutional encoding should be used on all MA and SSA return services, using the code formats and rates given in Appendix B.

G.3.2

At SSA return service data rates in which the encoded baud rate exceeds 300,000 symbols per second, the use of periodic convolutional interleaving (PCI) is required for the current estimated RFI environments. At these higher data rates, any single RFI pulse affects multiple adjacent transmitted symbols. The effectiveness of the ground terminal Viterbi decoding process decreases as the number of adjacent symbols overlapped increases. The purpose of the periodic convolutional interleaving (and associated WSC deinterleaving) is to break up or spread out these corrupted symbols so that they appear at the Viterbi decoder input to be random in their occurrence just as if they arose from a channel without memory.

G.3.3

If the RFI environment becomes more severe in the future than currently estimated, return service periodic convolutional interleaving may be necessary below 300,000 symbols per second. This will be ascertained during the mission planning and RFICD development activities between the customer project and GSFC Code 450.

G.4 SSA RFI Degradation Estimates

G.4.1

Prior to the fixed service re-allocation into the S-band, a detailed evaluation of the SSA return service RFI impact has been performed. This evaluation involved a rigorous BER analysis based on the use of analytical models of the customer platform communications terminal, the TDRSS channel, the RFI environment (both noiselike and sinusoidal pulses), and the ground terminal Viterbi decoding process. Corresponding RFI degradation results for the SSA maximum data rate (the worst case) and for the appropriate convolutional code rate and/or data group are shown in Table G-1. Assumptions used in determining these values are that all customer platform constraints are met and the EIRP offers no margin to offset RFI degradation. RFI degradation estimates for 0º offpointing (i.e., the TDRS SSA antenna beam is pointing directly at the location of the RFI sources) for TDRS-East are not included in the table due to the severe RFI degradation incurred ($\geq$5 dB) and the impracticality of operating under such conditions.

G.4.2

When an SSA customer has refined his return service communications system design sufficiently, the Communications Link Analysis and Simulation System (CLASS) is used to predict return service performance. During the RFICD process, the RFI degradation to SSA return service performance will be determined for each customer platform return service based on the customer platform transmit signal parameters (including code and data rates) and characteristics (customer platform constraints), operating frequency, and orbital parameters. These results also include the effect of any interaction between the RFI and the customer platform design partial compliance with the customer platform constraints. This degradation will then be incorporated into RFICD link calculations.

Table G-1. Estimates of RFI Degradations on SSA Return Services

Conditions (note 2)	Customer Platform EIRP Increase to Offset RFI (dB) (notes 1 & 3)		
	Rate 1/2 Convolutional Encoding		Rate 1/3 Convolutional Encoding
	DG1	DG2	DG2
TDRS-East			
1.5-degree Offpointing	2.7	3.3	1.5
4-degree Offpointing	1.0	1.2	0.5
TDRS-West			
0-degree Offpointing	2.3	2.6	1.0
1.5-degree Offpointing	1.0	1.2	0.6
4-degree Offpointing	0.5	≤ 0.5	0.5

Notes:

1. EIRP increase is determined for the maximum data rate applicable to the particular data group and code rate.
2. Offpointing is the number of degrees the TDRS SA antenna is pointed away from the location of the ground-based RFI sources.
3. RFI degradations are worst-case estimates based upon maximum data rate and will be determined during the customer platform RF ICD process. Link calculations will consider the customer's characteristics to determine the RFI degradation.

G.5 MA RFI Degradation Estimates

G.5.1

Prior to the fixed service re-allocation into the S-band, a detailed evaluation of the MA return service RFI impact has been performed as described in paragraph G.4. Using the estimate of the RFI environment in the MA return service band as seen by TDRS-East, the estimate of RFI degradation is ≤0.5 dB for all data rates between 1 and 300 kbps. The analysis assumes no MA antenna beam offpointing, that all customer platform constraints are met, and that the EIRP offers no margin to offset RFI degradation. Contact GSFC Code 450 for MA RFI degradation values for data rates greater than 300 kbps (SMA only). During the RFICD process, the RFI degradation to MA return service performance will be determined and incorporated into the RFICD link calculations.

G.5.2

CLASS is also used to predict MA return service performance as described for the SSA customer platform in paragraph G.4.

G.6 SSA and MA Forward Service RFI Degradation

As briefly indicated in paragraph G.1, the RFI impact on forward service operation is extremely sensitive to customer platform orbit and is a rapidly varying function of time. Accordingly, forward service RFI considerations are treated on a customer-unique basis.

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Appendix H. Demand Access System (DAS)

H.1 Overview and Purpose

H.1.1 Overview

The F3-F7 and K, L, M TDRSs provide communication services to customers by using ground-based electronics to process signals emanating from customer emitters that are relayed by the F3-F7 and K, L, M TDRS MA on-board phased array antenna systems (refer to SNUG Section 3, paragraph 3.2.1, MA Service Overview). The DAS allows the TDRSS F3-F7 and K, L, M MAR capability to be scheduled for extended durations or in a 'near real-time' manner. DAS provides DG1 mode 2 return services only. DAS is operated as a part of the SN using the first-generation satellites (F3-F7) and third-generation satellites (K, L, M) only. DAS is not capable of operations with the second-generation satellites (F8-F10). Please contact GSFC Code 450 for additional information.

NOTE:

DAS does not provide tracking services.

H.1.2 Purpose

The purpose of DAS is to:

a. Provide a capability to support continuous or intermittent, conflict-free, MAR link services 24 hours per day, 7 days per week upon demand from customers.

b. Provide an automated capability to transition customer services between TDRSs/SGLTs.

c. Provide a capability to support multiple, DAS MA return links per TDRS/SGLT/Ground Station.

d. Provide equivalent or better communications performance and capabilities for the TDRS F3-F7 and K, L, M MAR DG1 Mode 2 link services (please see MAR telecommunications services in Section 5) with the exceptions of no DAS tracking (i.e. no one-way return Doppler) and the functions not possible due to the lack of tie-ins with the MA forward link (coherent turnaround support, cross support, two-way ranging, and two-way Doppler).

NOTE:

Early testing showed that acquisition times for a Customer platform operating at < 2 Kbps could be worse than acquisition time performance specified in Table 5-8. The test results for the same system operating at 2 Kbps were

within the performance specified in Table 5-8. Contact Code 450 for additional information.

e. Provide both QPSK and BPSK demodulation for PN spread signals. Return Channel Time Delay or any other measuring service is not available from DAS since signal delay is variable (output from DAS to NISN to the Customer is TCP/ IP) depending on loading and the extent of DAS processing desired.

f. Provide beamforming, demodulating, data distributing and short term storage capabilities for each service.

g. Provide automated operation of all DAS resources.

h. Provide resource allocation accounting.

i. Provide Commercial Off-The-Shelf (COTS) data and control interfaces for DAS customers with the flexibility of accommodating non-standard/customer-unique telemetry interfaces (e.g. use of dedicated T1s and/or fiber).

j. Provide simple, modular beamforming, demodulating, routing and storage expansion functions, which can be modularly expanded to add DAS return link channels as needs change.

k. Provide customers with the capability of obtaining dedicated DAS services.

H.1.3 DAS Customer Categories

DAS supports two classes of customers: dedicated and non-dedicated. Dedicated Customers are guaranteed requested support from the shared set of DAS resources. Non-Dedicated Customers receive “first come, first served” support from shared resources that remain after allocations have been made for the dedicated customers. A non-dedicated customer may be preempted by a dedicated customer when both services require the same resources.

A customer that requires continuous (24x7) global coverage is a dedicated DAS customer. A dedicated customer may use DAS as a communications link to notify controllers of a spacecraft emergency (an “SOS” or “911” call), or to notify ground systems in real-time that some sort of science event occurred such as a gamma ray burst.

DAS may be used to support multiple spacecraft flying in a single formation. DAS could form a beam that covers an entire group of spacecraft and multiple DAS receivers could be configured to relay the data from all of the emitters simultaneously with an independent stream for each emitter. For multiple emitters that are not in a single formation, DAS could be used to support polling of the emitters in a time-sequenced fashion. These types of customers could be supported by DAS as dedicated or non-dedicated customers. Some customers may wish to start a service at a specific time or “upon demand” (ASAP). DAS can accommodate these types of customers on a non-dedicated basis.

H.1.4 DAS Service Modes

There are three DAS modes: Any -TDRS, All -TDRS, and Specific -TDRS. Each mode provides MAR services, but with slight differences in service performance and customer responsibilities.

Details on how the customer interacts with GSFC Code 450 and the SN Access System (SNAS) to obtain DAS services are given in paragraph H.2, below.

H.1.4.1 Any-TDRS Mode

The Any-TDRS mode is defined as near-continuous global service coverage via three or more designated TDRSs with up to 15 second service gaps during TDRS-to-TDRS transitions. It is intended to support an orbiting spacecraft with an antenna system that can be directly controlled and pointed at a specified TDRS by MOC commands. The spacecraft antenna pattern(s) should have no antenna pointing restrictions in the direction of the target TDRS. Figure H-1 is a high level depiction of this mode.

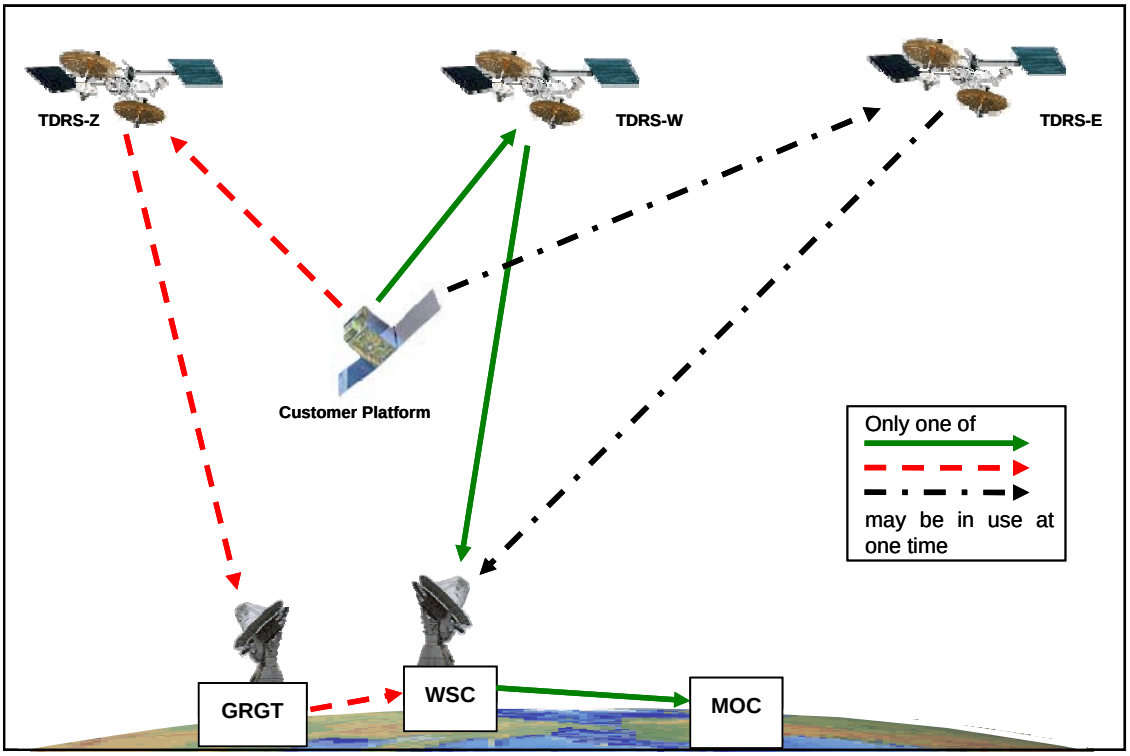


Figure H-1. DAS Any-TDRS Mode

The Customer MOC initiates the service by submitting one schedule request (Resource Allocation Request (RAR)), via the SNAS interface, designating the "Any" service preference for the duration of the Project's mission support. No further schedule requests should be required.

The DAS automatically selects which TDRS(s) will support the customer's request for service and schedules the necessary resources. Scheduling information is created by

DAS and passed back to the customer's MOC via the SNAS. If the customer platform requires commanding to acquire the selected TDRS(s), it is the customer's responsibility to send those commands to the platform coincident with the DAS scheduled TDRSs. This mode requires only one TCP/IP NISN IONet connection for each I and Q channel telemetry feed to the MOC, but encounters service interruptions during handovers.

H.1.4.2 All-TDRS Mode

The All-TDRS mode is defined as near-continuous, simultaneous support using all in-view DAS-designated TDRSs. It is primarily intended for an orbiting spacecraft that has autonomous spacecraft antenna switching control in the direction of the DAS designated TDRSs. The customer spacecraft antenna pattern(s) should have no antenna pointing restrictions. The customer spacecraft antenna switching may not be under direct MOC control at all times because of unpredictable occurrences such as a science event or a spacecraft emergency. This support mode of DAS MAR service scheduling minimizes the need for direct customer MOC command management of their onboard antenna switching. Figure H-2 is a high-level diagram of this mode.

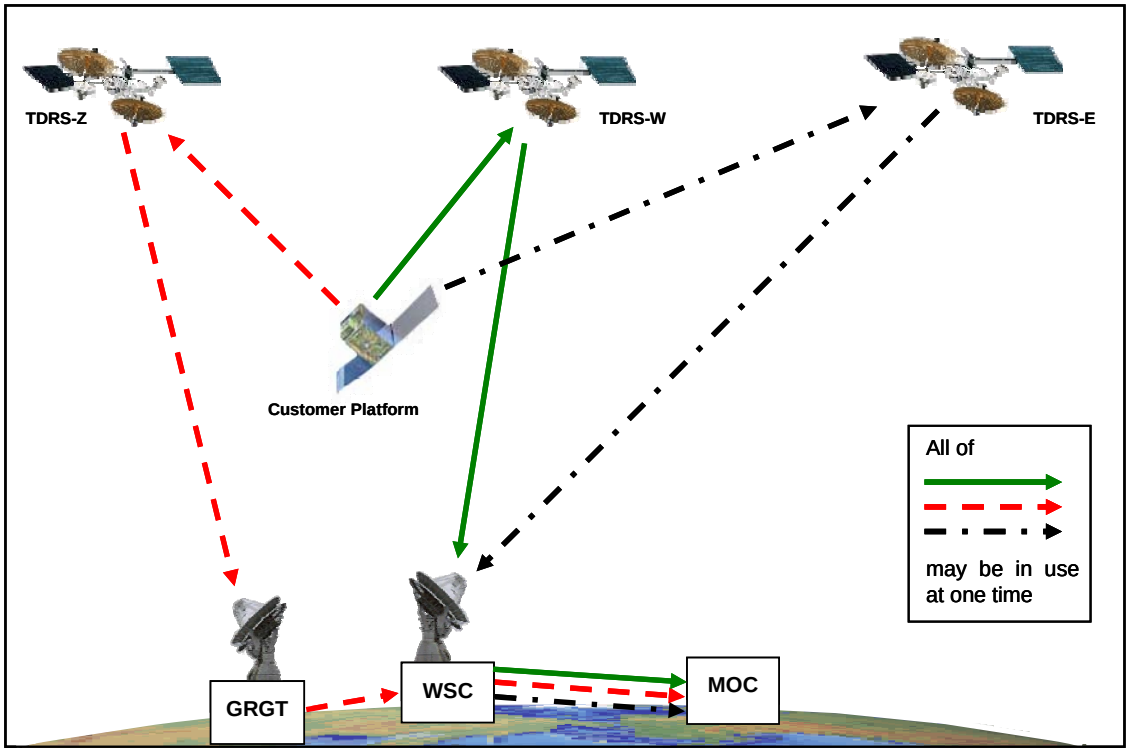


Figure H-2. DAS All-TDRS Mode

For orbiting global coverage, the Customer MOC would submit a schedule request for each TDRS via the SNAS interface. Each individual request could be for the duration of the Projects mission support.

DAS provides service through each scheduled TDRS that is in view of the customer spacecraft based on line of sight as determined by DAS using customer provided state vectors. Overlapping (or simultaneous) TDRS support coverage will occur for this mode. The Customer MOC determines scheduled event times by viewing the SNAS Schedule Request Summary window after issuing a Planned Events Request message.

The All-TDRS mode of scheduling requires the Customer MOC to have two (or more) IONet interfaces for each TCP/IP telemetry data stream (I or Q Channel), even though their spacecraft may be transmitting to only one TDRS at a time. The Customer MOC is responsible for selecting data from whichever TDRS(s) are receiving the telemetry data. Typically, a customer would specify different IP Ports to differentiate between TDRSs.

H.1.4.3 Specific-TDRS Mode

The Specific-TDRS mode is defined as the scheduling support through a specific TDRS at a specific time. Specific scheduling may be entirely customer driven or in part performed by the scheduling automation within DAS. This service mode of operation is primarily intended for a stationary, continuous use customer such as a ground base or a balloon. It also provides service to an orbiting or ground based customer that desires only occasional (or periodic) use of DAS. An orbiting customer with significant antenna pointing restrictions or obscurations that limit useable views to a single TDRS could use this mode effectively. A limited use customer should know their spacecraft antenna pattern characteristics and blockages, and also have a priori knowledge of their spacecraft attitude to efficiently schedule DAS services. Figure H-3 shows a high level diagram illustrating this mode.

A customer may schedule a specific TDRS over an extended period of time, regardless of the number of visibility periods within the scheduling period. DAS will automatically determine the event segments based on line-of-sight to the specified TDRS, and schedule efficient use of the DAS resources.

The customer MOC may also choose to determine their own visibility period estimates, for example, by using STK or by issuing a TDRS Visibility Request to DAS via the SNAS. DAS will respond to a TDRS Visibility Request with a list of available time windows based on customer supplied vectors and customer specified constraints. The customer MOC can use this information to schedule the time frames of desired service.

This mode of DAS scheduling is similar to scheduling of other SN customer service support in that the customer specifically schedules a required service through a specific TDRS during a period that DAS has identified as being useable through the TDRS Visibility Response. DAS does not have the capability of using customer defined TDRS Support Windows (TSWs).

The Specific-TDRS events scheduled may require the customer MOC to have one or more IONet interfaces for each TCP/IP telemetry data stream (I or Q Channel). The Customer MOC will be responsible for selecting data from whichever TDRS is receiving the telemetry data.

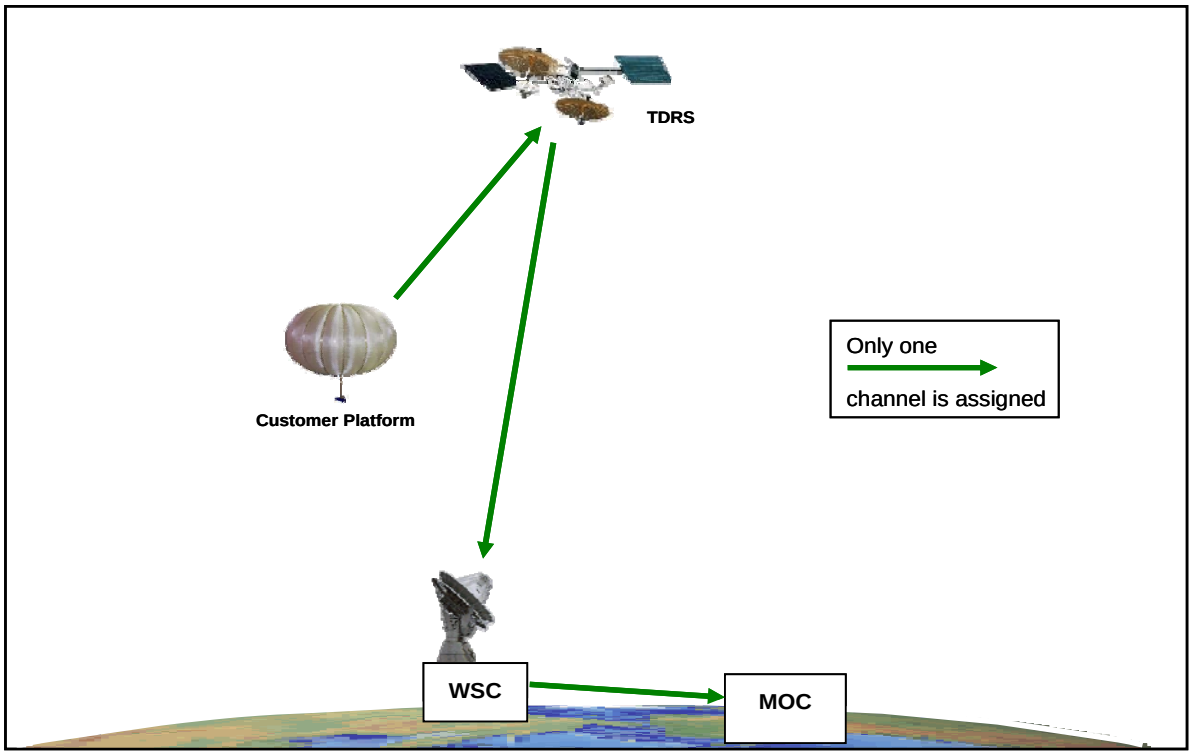


Figure H-3. DAS Specific-TDRS Mode

H.1.5 Customer Considerations When Selecting DAS Mode

Customers are encouraged to read the DAS Ground Rules for further details concerning the DAS modes. Also included in the DAS Ground Rules is information concerning scheduling, recording and playback, and customer responsibilities. Familiarity with Section 10 and Appendix C of this document will help customers choose the mode that best supports their missions. These considerations also drive requirements for fill data at the beginning of an event to prevent loss of valid data.

Some specific issues customers should consider are:

- Acquisition
- Transmission interruptions
- Transmission delays

H.1.5.1 Acquisition

The acquisition process will occur at the beginning of each event for all DAS service modes. Additional acquisition processes will occur at each handover during an event. The effect of these acquisitions on customer operations will depend on which DAS mode is being used, as well as on the customer configuration.

DAS provides MAR DG1 Mode 2 service as described in Section 5 and Appendix C of this document. The length of the acquisition process is dependent on several factors, including the frequency uncertainty of the customer's transmitter, the data rate, and the

modulation format. Acquisition by DAS does not include customer platform antenna pointing, data flow time to the platform transmitter, or any other preparation for the DAS event. All customer acquisition processes such as antenna pointing must have been completed prior to the start of signal acquisition by the DAS.

For DAS itself, the Total "Service Acquisition" time requirement is a combination of PN/Carrier Acquisition and Symbol/Decoder Synchronization. This acquisition process is complete when the DAS has selected and implemented the correct blocking of input symbols in the received data stream.

For DAS signal acquisition, the required customer P_{rec} must meet the P_{rec} for 10^{-5} BER or signal acquisition, whichever is greater (refer to Table 5-8). The DAS total channel acquisition times (T_{acq}) are given in Table 5-8 and are the sum of the following:

a. PN (DG1 only) and carrier acquisition time (probability of acquisition (P_{acq}) $\geq$ 90%)
   - $\leq$ 1 second for customer platform carrier frequency uncertainties of less than +/- 700 Hz
   - $\leq$ 3 seconds for customer platform carrier frequency uncertainties of less than +/- 3 kHz

b. Symbol/Decoder synchronization time ($P_{acq} \geq$ 99%)
   - $\leq$ 6500/(Channel Data Rate in bps)

NOTE:

Early testing showed that acquisition times for a Customer platform operating at < 2 Kbps could be worse than acquisition time performance specified in Table 5-8. The test results for the same system operating at 2 Kbps were within the performance specified in Table 5-8. Contact Code 450 for additional information.

T_{acq} assumes that the customer platform return service signal is present at the ground terminal.

In the Any-Service mode and the All-Service mode, events involve multiple TDRSs over extended periods of time. The events are subdivided into segments during which the customer platform communicates through one TDRS. There are periods during which the customer platform is receiving coverage from two or more TDRSs. DAS schedules a handoff from one TDRS to an upcoming TDRS when the calculated angle from the Customer zenith of the upcoming TDRS is less than or equal to the angle from the Customer zenith of the current TDRS as viewed from the DAS Customer satellite's center of mass.

A satellite handover during an Any-TDRS Mode event requires that the acquisition process be repeated. The maximum time for a handover between TDRSs is specified at 15 seconds. Additional delays may be caused by the customer platform, for example, the time required to repoint the customer platform antenna could delay the start of acquisition.

Satellite handovers in the All-TDRS Mode are affected by the customer platform's capability and orbit. If the platform is capable of communicating with two or more TDRSs simultaneously, and its orbit keeps it in view of more than one of the DAS-assigned TDRSs, it is possible for acquisition on the upcoming TDRS to proceed while data is still being transferred on the existing link. This can reduce the interruption at handover to the process of selecting which telemetry data stream is selected by the customer MOC. If the customer platform cannot communicate with more than one TDRS at a time, or if its orbit takes it out of areas covered by DAS-assigned TDRSs, the acquisition process proceeds as at the beginning of an event.

Satellite handovers do not occur with the Specific-TDRS Mode.

H.1.5.2 Transmission Interruptions

Equipment failures can lead to service interruptions. For the Any-TDRS Mode and the Specific-TDRS Mode, the length of the interruption will depend on what equipment failed. The DAS has redundant equipment in hot standby, but delays ranging from the equipment switchover time to signal re-acquisition time are possible. Customers using the All-TDRS Mode may be able to minimize the interruption by selecting a different telemetry channel received at the MOC.

In addition, replanning by the DAS can force a reacquisition. DAS maintains a committed 96 hour (4 day) schedule of planned events. This schedule is affected by updates to the TDRS vectors and to the customer platform vectors. As long as the vector updates do not indicate any drastic change in the expected position and/or orbit of either a TDRS or a customer platform, DAS accumulates the changes and incorporates them the next time it issues a schedule.

DAS updates the committed schedule every day at 0000Z (midnight Greenwich Mean Time (GMT)) by advancing to the next 24 hour period, appending a new 24 hour period to the end of the schedule and making all necessary schedule changes due to TDRS and Customer platform updates. A new committed 96 hour schedule is issued after all of these changes have been made.

Immediate replanning of the committed schedule is required when a new TDRS state vector indicates that the TDRS's position has changed by more than 180 km from the expected position or when a new customer state vector indicates that the customer platform's orbit has changed by more than 920 km from the expected orbit. These changes affect pointing angles and transition times and could result in degradation or even loss of service. In these cases, DAS immediately replans all events in the current 96 hour committed schedule for affected customer platforms and issues an alert(s) via SNAS to any affected Customer MOC(s). These alerts do not tell customers what changes were made to the schedule. The Customer MOC must use SNAS to get the revised schedules so that appropriate responses can be planned and executed.

H.1.5.3 Transmission Delays

The overall transmission time from the customer data source to the customer MOC is determined by a series of delay components. These include transmission of sampled data from the TDRS MA array antenna, processing of the sample to produce a signal that can be demodulated, demodulation and decoding of the data, formatting the data for transmission to the MOC, and transmission of the formatted data to the MOC. This section discusses delay components associated with processing by DAS. Figure H-4 illustrates a simplified DAS signal flow.

Factors a customer may consider are the delays inherent in format processing at the TDRSS ground terminal, the transmission delays possible in the IONet, and delays due to forward error correction (FEC) processing. Although TDRS specifies the FEC scheme, the delay is dependent on the data rate.

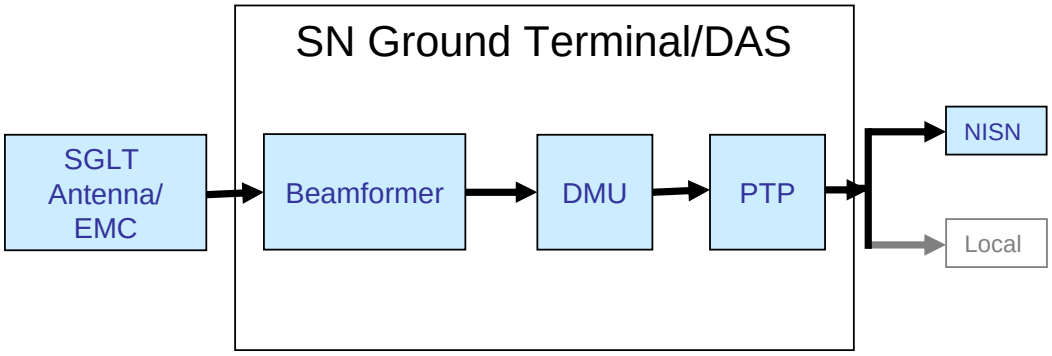


Figure H-4. Simplified DAS Signal Flow

H.1.5.3.1 Beamformer

The DAS Beamformer receives data samples from the 30 elements of the MA antenna array and creates a beam using a process of phase-shifting, summing, and filtering. The Beamformer then passes the resulting signal to a DAS Demodulator Unit (DMU).

H.1.5.3.2 DAS DMU

The DAS DMU demodulation process performs signal acquisition, which includes PN code and carrier acquisition, symbol synchronization and decoding. Acquisition, which is described above in paragraph H.1.5.1, begins when the received signal achieves sufficient C/N_0.

The acquisition and symbol/decoder synchronization processes must be restarted every time there is a disruption in the signal as described in paragraph H.1.5.2.

The recovered data are formatted in TCP/IP packets and transmitted by the Programmable Telemetry Processor (PTP).

H.1.5.3.3 PTP

The PTP is responsible for distributing customer data as TCP/IP packets over the Closed IONet or a Customer provided local interface, for storing a copy of the data, and

for retrieving the data from storage upon request. The real-time PTP output rate is always configured to clock the IP packets out at the scheduled data rate. The transmitted telemetry packet data is also simultaneously archived on a DAS Redundant Array of Independent Disks (RAID) Array storage device and can be played back as needed.

The PTP manages the fixed bandwidth allocated to it by NISN. As long as the aggregate demand for bandwidth does not exceed the bandwidth allocated by NISN, the PTP transmits all data streams at their nominal data rate. If the total demand exceeds the bandwidth available, the PTP reduces or throttles the data rate for all streams proportionally to keep the aggregate transmitted bandwidth within the available allocated bandwidth. This will result in some additional delay.

By default, customer data is transmitted without any Consultative Committee for Space Data Systems (CCSDS) processing or encapsulation in any structured header other than the normal TCP/IP transmission structures.

The PTP can provide three additional services upon Customer request, if the Customer data stream is properly structured. These services result in additional delays for PTP processing.

The PTP can frame synchronize a telemetry data stream using the frame length, sync pattern, and sync mask supplied by the Customer in the user service request.

The PTP can additionally provide CCSDS Virtual Channel Processing, if requested. The request must identify the byte location of the Cyclic Redundancy Check (CRC) in the data stream. The Customer may optionally specify R-S decoding along with the interleaving depth and the location and virtual fill of the RS codeword.

The PTP can also provide ground transport encapsulation for transmission over the NISN Closed IONet. The supported encapsulation headers include CCSDS Standard Formatted Data Units (SFDU), CCSDS EDOS Service Header (ESH), CCSDS fixed-length transfer frames used by the Advanced Composition Explorer (ACE) spacecraft, the Low Earth Orbiting-Terminal (LEO-T) Telemetry Frame Data Header (TFDH), and the NASA Internet Protocol Data Unit (IPDU) developed by Landsat 7.

NOTE:

For delays associated with PTP processing, please contact Code 450.

H.1.6 Nominal Operations

H.1.6.1 Customer Responsibilities

The Customer MOC is responsible for the following in a DAS nominal operational scenario:

- Requesting DAS services through SNAS nominally any time prior to two minutes before the start of services. DAS may support services requested up to 30 seconds prior to service initiation, if necessary.

- Receiving service request responses from DAS through SNAS indicating that DAS resources are available and line-of-sight visibility with requested TDRS(s) has been confirmed.
- Establishing a TCP socket connection with the appropriate DAS Programmable Telemetry Processor (PTP) at the addresses indicated, using a mission-specific data port number.
- Receiving either MAR data or playback service data throughout the scheduled support period.
- Disconnecting the TCP socket connection when all service data has been received from the PTP.

H.1.6.2 DAS Event Timeline

Figure H-5 illustrates the process by which DAS provides service to its customers. The customer and DAS must work together for successful communications. Their actions are coordinated by the current Active/Committed Schedule, which DAS updates and distributes every 24 hours (D_0). This schedule is based on service requests submitted by DAS Customers (C_0) and the visibility windows computed from state vectors submitted by those customers (C_1).

DAS customers may submit as many service requests and modifications to service requests as necessary to define the service that they need. The customers must keep their state vectors fresh. DAS uses these vectors to determine communications windows, form a beam that points toward the customer's platform, and schedule TDRS to TDRS handoffs.

Two minutes prior to a scheduled event, DAS issues an alert to the customer (D_1) and begins preparations for the event. At about the same time, the customer needs to have its platform begin the process of establishing a communications link with the target TDRS (C_3). The customer also needs to set up its ground equipment and its link to the DAS PTP so that it can receive the data relayed down to the SGLT. Just prior to the event the DAS controller issues commands (D_2) to configure the PTP and demodulator and cause the beam to be formed.

The customer's RF signal is picked up by the elements of the TDRS phased array antenna and relayed to the SGLT (D_4). Within the SGLT the signal elements are combined and processed by a beam forming unit where the signal is acquired and symbol and frame synchronization are performed.

Once the symbol and frame synchronization have been successfully completed, the signal is passed to a demodulator (D_6) which produces a stream of baseband data bits for the PTP (D_7). The PTP processes the data bits into data packets and either transmits the packets to the customer (D_8) or archives them, or both, as directed by the customer's service request.

H.2 Obtaining DAS Services

Potential customer service requirements will be subjected to a system loading analysis and an RF compatibility analysis prior to approval to use DAS. In this process, the

support identification codes (SIC) will be established. Key information including spacecraft mass, cross-sectional area, drag co-efficient, and solar reflectivity parameters will be collected. These platform-specific values are needed for accurate orbit modeling which allows DAS to determine visibility and service schedules up to five days into the future. In the event these values are not provided, baseline values will be substituted which will impact orbit modeling accuracy, especially for platforms with orbits less than 750 km in altitude. DAS Customers with orbit altitudes below 750 km should update the mass value whenever it varies more than 10% from the previously submitted value in order to maintain accuracy of their DAS 5-day orbit predictions.

Initial service specification codes (SSC), which will be the basis for allocating resources and setting up the RF links between the Customer Platform and the TDRSs, will be established and the required equipment allocation for each SSC will be calculated. NISN and GDIS access capacity will be determined.

If this analysis indicates that there are insufficient resources to support additional customers, GSFC Code 450 will determine if additional resources must be procured. A Project Service Level Agreement (PSLA) will be negotiated with the customer. DAS, NISN, and SNAS accounts will be established. The Planning activities shown in Table H-1 ideally take place a minimum of 18 months prior to commencement of services.

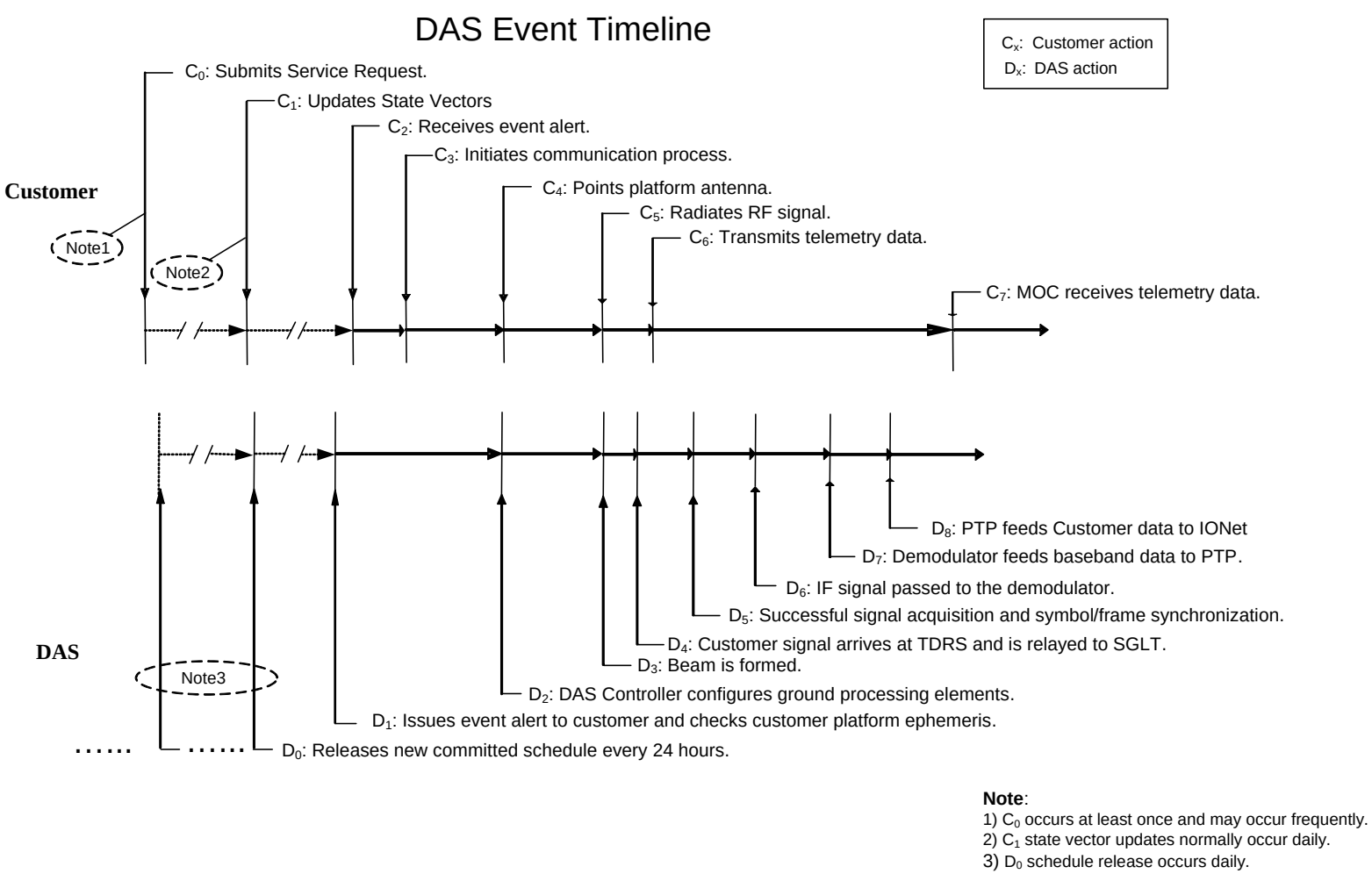
H.3 Customer Interface with the DAS

H.3.1 General

Communications between DAS and a MOC Customer involve two different classes of information. The first type is service data or telemetry, which is the data received from the Customer Platform and forwarded to the Customer MOC. The other type is a combination of planning and scheduling information, status information, real-time control information, and other miscellaneous administrative information.

DAS uses SNAS for all types of communications except the telemetry. The SNAS interface with DAS allows the customer insight into available resources, allows the customer to submit requests for DAS services, and permits monitoring DAS service performance.

Table H-2 lists information exchanged between DAS and the customer via SNAS. Please refer to Appendix P of this document, or the web site at: http://snas.gsfc.nasa.gov for further information on SNAS.



Note:
1) C_0 occurs at least once and may occur frequently.
2) C_1 state vector updates normally occur daily.
3) D_0 schedule release occurs daily.

Figure H-5. Generic DAS Acquisition and Transmission Timeline

Table H-1. Planning Sequence

1½ to 2 Years Prior to Operations	Customer Operations Begin
• Identification of DAS as Service Provider • RF Compatibility Analysis • Loading Analyses • Identification of Additional DAS equipment (if needed) • PSLA generation • Procure additional equipment (if needed)	<u>Dedicated Customers</u> 1. DAS configured for support <u>Non-Dedicated Customers</u> 2. Available resources configured for support

Table H-2. DAS/Customer Interaction via SNAS

DAS will receive the following information from the customer:	DAS will provide the following information to the customer:
<u>Resource Requests:</u> • Customer location and identification • TDRS ID • Type of Service • Period of Service • Signal Characteristics (to set up demodulation and other DAS components) • Archive Requests • Data routing • Emitter ephemeris data: a. Emitter type b. Epoch Time c. Emitter Position (X, Y, Z at epoch in meters) d. Emitter Velocity (X, Y, Z at epoch in meters/seconds) e. Mass of Satellite f. Average Cross-sectional Area of Platform g. Drag Coefficient h. Solar Reflectivity Coefficient • Reconfiguration Requests • Reacquisition Requests • Status Requests	• Acknowledgement and status of requests • Resource allocation assignments • Resource availability • Emitter visibility information • Real-time service status and performance

H.3.2 Communications Interface

H.3.2.1 Physical Communications Links Between DAS and DAS Customers

The following interfaces comprise the DAS to DAS Customer communications interfaces:

- DAS to NISN Closed IONet Interface and
- DAS Local Interface (LI) to selected Customers

DAS will use the NISN Closed IONet to deliver service data to Customers through the NISN secure gateway to their MOC unless the Customers provide LI connections at WSGT or GRGT. The Closed IONet supports the transport of real-time and archived service data from DAS to the Customer and also supports the transport of TCP control and status requests from the Customer to DAS. Representative MOC locations may be located off of the NISN Closed IONet, NISN Open IONet, Earth Observation System (EOS) Backbone Network (EBNet), NASA Internet, the Internet, or a University Local Area Network (LAN) on the Internet.

For the DAS to NISN interface, DAS complies with the provisions of the IONet Access Protection Policy and Requirements Document, 290-004, and implements appropriate security protocols to ensure compliance with NPR 2810.1, *Security of Information Technology*.

TCP/IP client/server relationships are established on a Customer-by-Customer basis by DAS. The preferred method is to configure the DAS PTP as the TCP client so that the PTP initiates the socket connection at the time that the Customer return data services are scheduled to begin. The Customer side of the TCP/IP connection is expected to be ready to receive return data from the PTP based on the IP address and TCP port number provided to DAS in the Service Specification Code (SSC) parameters associated with the Customer service request.

H.3.2.2 Service Data Processing

DAS transmits all formatted and unformatted service data over the NISN Closed IONet or customer supplied LI's in standard TCP/IP protocol packets. One TCP/IP socket connection will be provided for each return telemetry data stream or playback service requested by the Customer. Consultative Committee for Space Data Systems (CCSDS) header formats and optional ground transport header formats are supported by the DAS PTPs. The means for data entry through SNAS Customer terminal screens is specified in the ICD between the DAS and the SNAS, 452-ICD-DAS/SNAS, and described in the SNAS Client Software User's Guide.

DAS PTPs are compatible with specific CCSDS data formats and other ground transport headers are optional for space link communications. The ground transport

headers supported are the Standard Formatted Data Unit (SFDU), Advanced X-ray Astrophysics Facility – Imagery (AXAF-I), Advanced Composition Explorer (ACE), Low Earth Orbit-Terminal (LEO-T), and the IP Data Unit (IPDU).

DAS transmits Customer service data, both real-time and playback, as asynchronous data streams encapsulated in TCP/IP without any CCSDS processing or encapsulation unless otherwise specified by the Customer in a service request. In this case, the PTP is used to simply archive the data and to stream it as TCP/IP packets for delivery. With TCP/IP reliability, this method provides the highest assurance that the data received by the Customer MOC is exactly the same as the data received by the DAS demodulator.

DAS provides telemetry data with the least manipulation for Customers with their own PTPs.

H.3.3 Customer Interactions with DAS

The Customer can interact with DAS in two time frames: Planning/Scheduling prior to an event or events, and during an event. During the planning/scheduling phase, the Customer schedules resources for service by interacting with DAS through SNAS. During an event, the Customer can monitor the status of communications from the Customer platform and, if necessary, modify parameters that control the communications during the event.

H.3.3.1 The Planning/Scheduling Phase

DAS service support begins with planning sequences. Planning sequences include interaction between DAS and the Customer to set up a resource allocation request within the context of the available DAS MAR resource times and the resource utilization objectives. This customer interaction provides DAS with the time window(s) in which the Customer requests DAS resources. DAS in turn provides the Customer with the available service time(s) and the associated TDRS(s) available for the support within the specified time window. The customer can then vary parameters of their request derived from this information.

NOTE:

> If a dedicated customer preempts a non-dedicated customer, DAS will attempt to reschedule the non-dedicated customer's preempted support at another time within the requested window.

The customer sends a request via SNAS for the resources desired, including customer identification and location (ephemeris), identification of the TDRS(s) requested, parameters of resources requested, period of the request, demodulator parameters, archive and retrieval requests, and data forwarding requirements. DAS will interact with the Customer via SNAS to establish and confirm a customer request.

Upon receipt of a specific request for resources, DAS will examine the parameters required to set up the request and determine if they are feasible. If DAS determines that the request is not within the capability of the system, DAS will notify the customer to this effect.

Upon determining that the request is feasible, DAS will allocate and reserve appropriate resources. If there are no resources available for allocation during the time frame requested, DAS will notify the customer.

DAS will notify the customer via SNAS if updated ephemeris data for the service is needed.

H.3.3.2 Real-Time Monitor and Control

The customer is notified via a SNAS alert that the requested service has commenced. DAS commands archive and routing equipment for telemetry data capture before the service begins. DAS beamforming and demodulating elements are commanded before the signal acquisition sequence is to commence. During the service, the Customer will be allowed to modify some parameters of the service. Regular status will be reported to the customer while the service is ongoing, upon request. Data will be archived and routed in accordance with the customer request.

In general, the Customer's emitter transmits telemetry data to the designated TDRS as specified in the DAS Customer service request input through SNAS. The TDRS downlinks the Customer data through an SN ground terminal SGLT Antenna and the Element Multiplexer Correlator (EMC). After beamforming of the signal, a DAS PTP receives the data from a DAS receiver/demodulator(s), frame-syncs the data, and performs processing on the data. The data is archived and, if requested, sent in real-time to the Customer MOC via a TCP/IP connection.

H.3.3.3 Archived Data Retrieval

Data that has been archived will be made available for retrieval upon request by the customer. Data that has been archived will be retained for up to 30 days. The customer can request via SNAS that DAS retrieve and route this data to the customer for use. This request must include the identification of the data to be retrieved, the parameters for routing, and the time retrieval and routing is to occur.

H.3.3.4 Alerts

The alert messages advise the DAS Customer of time-critical events. Types of alert messages include: service status (granted or pending), service start times, service end times, data storage limits, signal loss, notification of Customer State Vectors (SVs) requiring updates, and others. Alert messages also support a free-text format to allow flexibility in advising DAS Customers of time-dependent or critical events.

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Appendix I. NASA Integrated Services Network (NISN) Services

I.1 General

This appendix describes the Communications Service Office's (CSO) NASA Integrated Services Network (NISN). CSO provides several facilities of networked data services. This Appendix discusses only those services that pertain to the direct utilization of the SN. Please note: NASA's current policy is that commanding spacecraft over Internet segments or domains is not permitted.

I.2 Services Available

In conformance with Agency direction, the Internet Protocol (IP) has been adopted as the standard for NISN's routed data services. The legacy SN interface was built on a serial clock and data interface using the 4800 bit block format (please see paragraph I.2.5). However, the data service has been transitioned to an IP routed data service requiring the use of conversion devices. New SN projects should design their interfaces to be consistent with IP interfaces without serial interfaces and 4800 bit block formats.

For further information, please contact the Communications Services Branch, NASA/GSFC Code 761 and/or refer to the CSO-managed NISN Services Document, (NISN/001-001).

I.2.1 IP Routed Data Services

The CSO provides Wide Area Network (WAN) voice and data communications services between the SN and SN customers using the Mission Critical and Real-Time Critical IP routed Data Service. CSO has implemented the CSO WAN to support operational data transfer between hosts and external projects called the IP Operational Network (IONet). IONet supports missions on a 24-hour basis transferring real-time data (attitude, orbit, ephemeris, telemetry, state vectors), as well as non-real-time data (data products, quick-look image data, and other data sets associated with small Explorer projects). The Network is monitored electronically 24 hours-per-day, 7 days-per-week. All project connections to the IOnet must be authorized via an application process defined in the Internet Protocol Operational Network (IONet) Access Protection Policy and Requirements, 290-004.

I.2.1.1 Types of IONet

The IONet is divided into three types: the more secure Closed segment (Closed IONet), the less secure Restricted segment (Restricted IONet), and the least secure Open Segment (Open IONet). Access between the Closed IONet and either of the other domains is strictly controlled via the IONet Secure Gateway at GSFC. The Restricted IONet network is outside of the Secure Gateway, and supports mission-critical real-time flows for projects which have requirements for connections to other networks. The most prevalent example for the Restricted IONet is mission control centers at Universities.

The Restricted IONet projects have a moderate degree of protection due to their perimeter negotiations and access control via the Restricted IONet Firewall, but support real-time mission-critical data. The Open IONet is intended to support the more liberal needs of the science community, but on a 24x7 service level. The Open IONet provides a modest level of protection with the implementation of the Open IONet Firewall that requires all Open IONet customers to register the data flows with external IONet customers. Customers may apply for connection to any of the domains as NISN requirements analysis determine and the IONet Access Protection Policy and Requirements, 290-004, dictate. This document uses the term *IONet* when referring to all three networks. Otherwise, it specifies whether the material pertains specifically to the Open, Restricted, or Closed IONet.

I.2.1.2 Legacy MDM/4800 Bit Block

The legacy interface is targeted for End-of-Life in the near future and as such, it is not recommended that any new project interfaces be implemented on it. The replacement interface has not been specified at this document's time of publishing.

The legacy interface delivers and accepts data via IP multicast packets with 4800 bit block formatted data units. Customers who use this interface must be connected via the IP multicast-enabled part of IONet, which is also the most secured domain of the IONet (see Figure I-1). Project interfaces are rigidly controlled and audited for this service, according to the IONet Access Protection Policy and Requirements.

I.2.1.3 WDISC IP

The WDISC IP interface (please see Appendix Q for WDISC information) is supported via Closed IONet interface (see Figure I-2 and the IONet Access Protection Policy and Requirements). Because this interface is Unicast IP, it is possible to interface to it via the IONet Secure Gateway System, from the Open IONet or beyond, as permitted in the IONet Access Protection Policy and Requirements.

I.2.1.4 Space Network Access System (SNAS)

The SNAS (please see Appendix P for detailed SNAS information) is designed to be accessed from the NISN Closed IONet or Open IONet (see Figure I-3). CSO's NISN Open IONet allows access from the NASA Science Internet (Restricted IONet) and the public Internet, thus allowing cooperation with NASA's university, enterprise, and inter/intra-agency partners.

I.2.1.5 SN Gateway

The SN Gateway IP interface (please see Appendix R for SN Gateway information) is supported via Restricted IONet interface (see Figure I-4 and the IONet Access Protection Policy and Requirements). The SN Gateway supports CCSDS SLE services, which require customers to initiate SLE bind operations with the SN Gateway. Customers on the Restricted IONet are allowed to make binds or TCP/IP connections with the gateway.

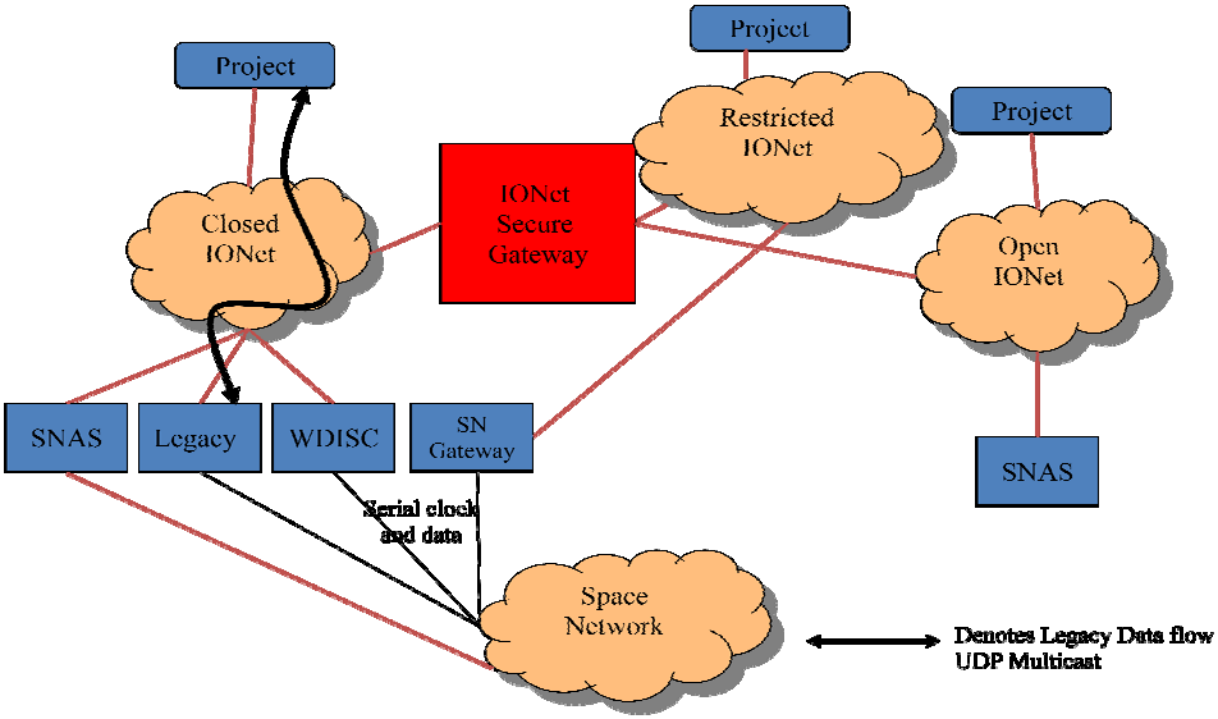

Figure I-1. NISN/SN Legacy Interfaces

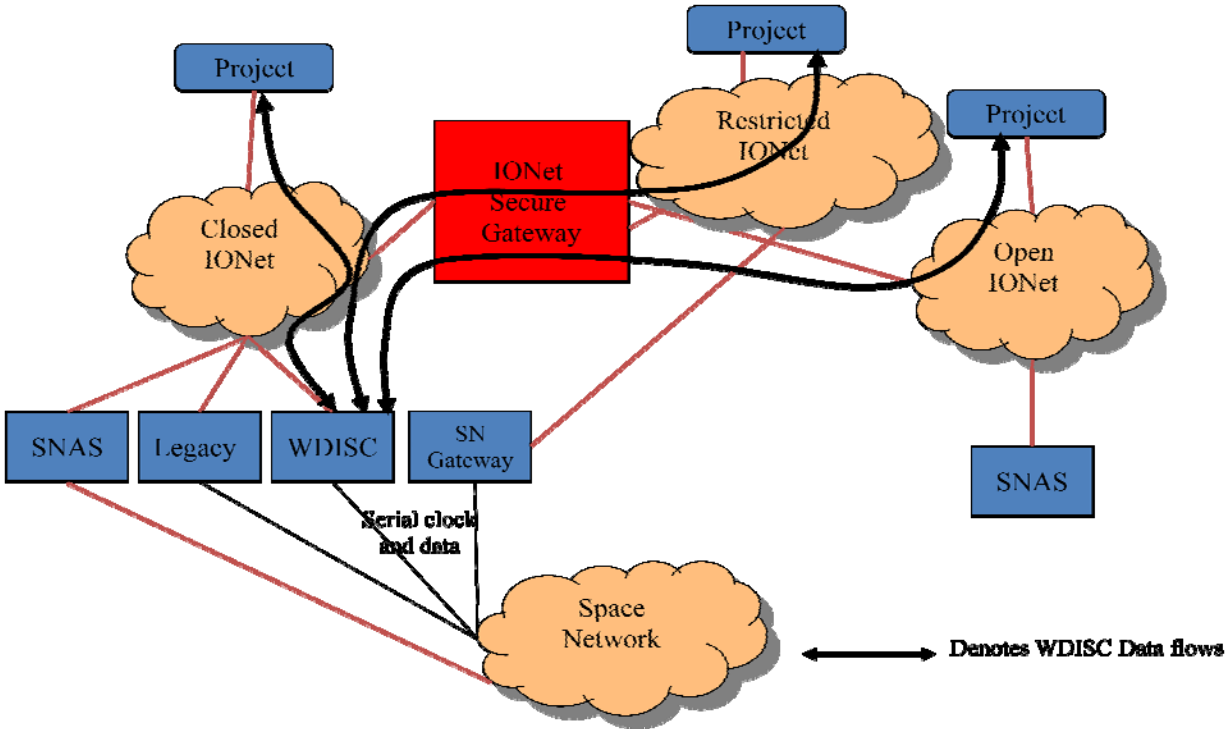

Figure I-2. NISN/SN WDISC Interfaces

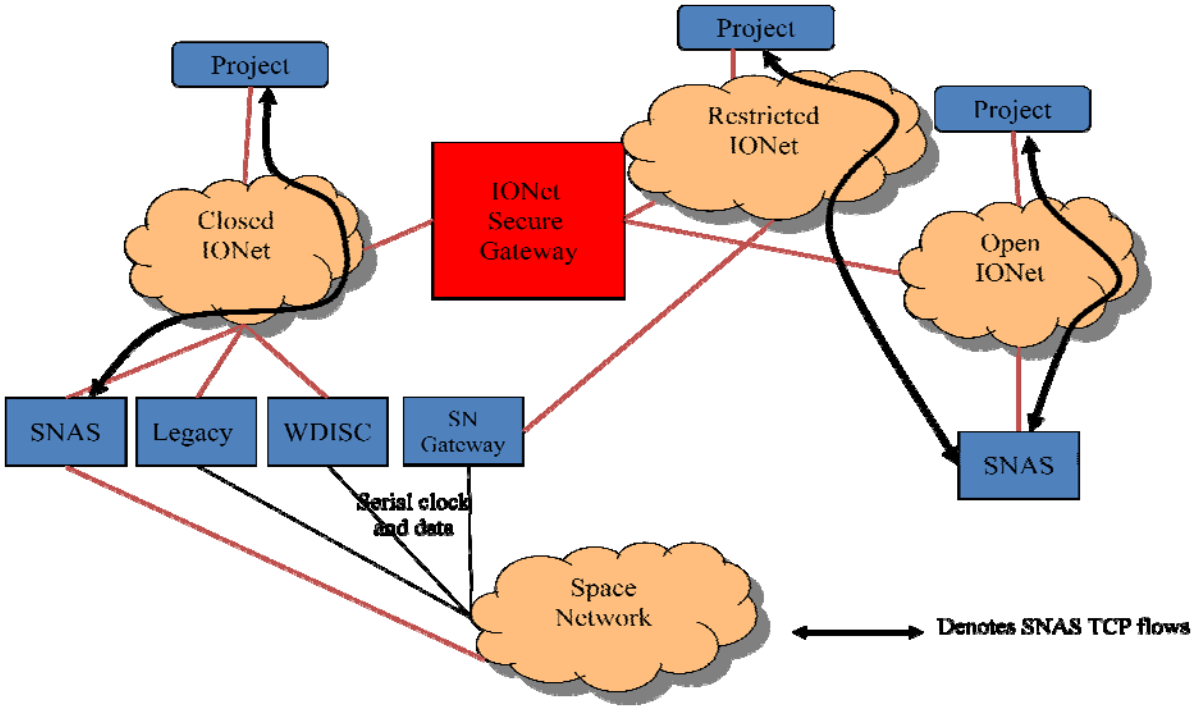

Figure I-3. NISN/SN SNAS Interfaces

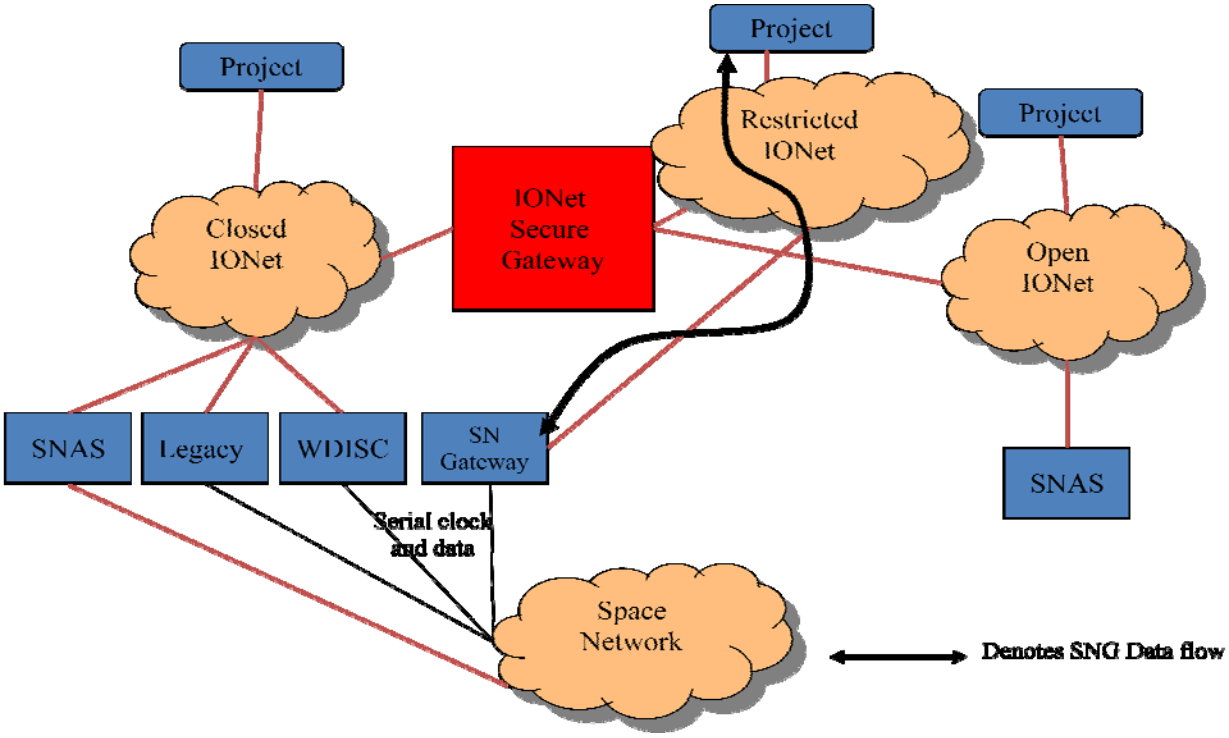

Figure I-4. SN Gateway Interfaces

I.2.2 Non-IP Routed Data Services

Per direction from the CSO, NISN continues to support those legacy protocols currently in use until they can be phased out. Requirements entailing the use of protocols other than those associated with the IP protocol suite will be processed on a case-by-case basis. However, the customer is well-advised to be developing or implementing plans for the modification of the supported information system(s) to interface the network using the IP protocol suite. If CSO assistance for NISN services in this regard is desired, CSO engineering support is available.

I.2.3 Network Consulting Services

Whether a customer's requirement is as small as a simple data link between two points or as complex as a dedicated subnetwork for a specific project, consulting and integration services are available to provide the customer with one-stop shopping for the satisfaction of communication and network requirements. If the requirement is unique or does not easily fall within standard service offerings, consulting CSO staff regarding NISN services is offered to work with the customer to provide a tailored solution to the unique needs of a project. Examples of available services include:

a. Requirements Analysis
b. Subnetwork Engineering & Design
c. Implementation Coordination
d. Prototyping Activities
e. Network Traffic Modeling

I.2.4 Dedicated Voice Services

Dedicated Voice Services encompass a wide range of service complexity. At the simplest, it can be a dedicated point-to-point "shout down" circuit with no signaling. The majority of Dedicated Voice Services consist of a system of highly reliable, dedicated four-wire voice circuits working in conjunction with switching and conferencing systems to create Mission-type voice loops. These voice loops interconnect the different voice distribution systems that support the diverse Mission Control Centers within NASA. It should be noted the customer is responsible for the procurement of the unique four-wire end equipment required for their termination and local distribution of the procured four-wire Dedicated Voice Services.

I.2.5 Block Format Description

For customers electing the blocked data format option of the MDM data system, the MDM data system will return telemetry data and forward command data in NISN (legacy NASCOM) TDRSS 4800-bit block format. The option for telemetry and command data may be independently selected. A description of the 4800-bit block is as follows:

a. General. The 4800-bit block for TDRSS-relayed telemetry and command data consists of the following elements (please see Figure I-5 for an illustration of the forward command and return telemetry block format):

1. Network header.
2. Customer header.
3. Time.
4. Data.
5. Block error control.

b. Bits 1-48: Network Header. The network header is the first 48 bits in the 4800-bit block format and contains the NISN sync code and information that may be needed by NISN for routing and accounting purposes. In the MDM forward channel application for command data via the TDRSS, its use is confined to block sync code detection.

1. Bits 1-24: NISN Sync. The 24-bit NISN sync code is a fixed code used to determine the beginning of the 4800-bit block (627627 Hex MSB first).
2. Bits 25-32: Spare. For telemetry data, the MDM sets this field to all binary 1's. For command data, the convention is open to the command originator. There is no requirement for the MDM.

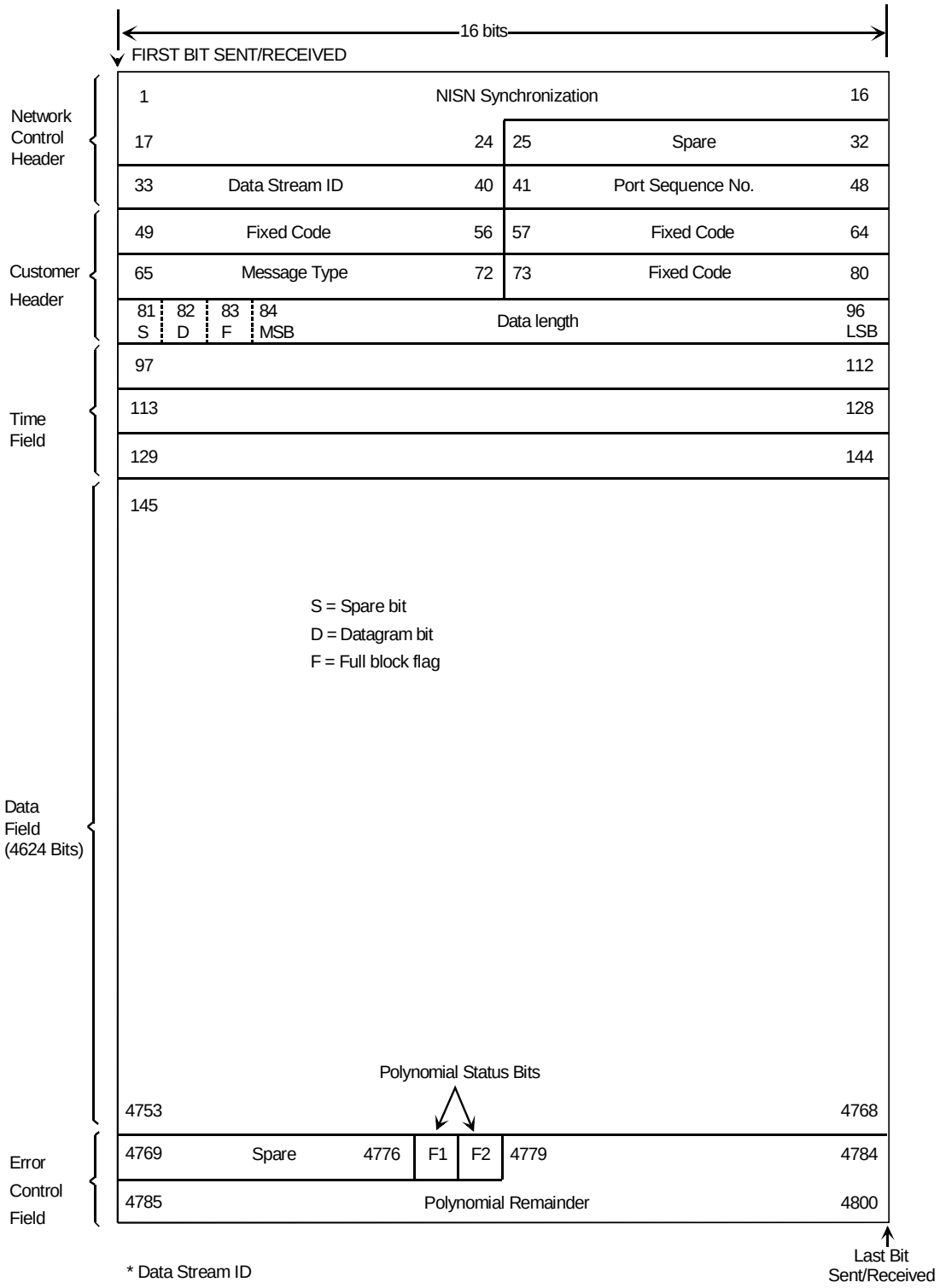

Figure I-5. NISN/TDRSS Forward Channel Command and Return Telemetry Transmission 4800-Bit Block Format

3. Bits 33-40: Data Stream ID. For telemetry data, the project data ID is assigned by the NCCDS in scheduling coordination with the customer. Operationally, it is inserted by the MDM data system for a scheduled data flow event in accordance with the required use of the MDM channel as provided in a schedule furnished to NISN by the NCCDS. For command data, the convention is open to the command originators. There is no requirement for the MDM data system.

4. Bits 41-48: Port Sequence Number. For telemetry, this is an 8-bit binary count incrementing number (sequentially assigned to the block) and is generated by the MDM data system on a port basis at the first transmitting multiplexer. It is used for block accounting. For command data, the convention is open to the command originator. There is no requirement for the MDM data system.

c. Bits 49-96: Customer Header. The 48-bit customer header is normally reserved for information required by customer ground facilities to route and process the data contained in the block. In the MDM forward channel TDRSS application, its functional use is limited to information necessary for NISN to strip the command data out of the block and maintain a bit-contiguous serial data stream to the WSC. In the TDRSS return channel application, use of the header is similar, but the data stripping function may be performed either in the MDM data system or by the customer ground facility. For return channels, fields other than the data length and full block flags are predetermined in MDM firmware. There are other differences in forward and return channels. Applications are as follows:

1. Bits 49-56: Fixed Code For Telemetry Data. This field contains a fixed code which is the American Standard Code for Information Interchange (ASCII) null character (binary bit pattern 00000001). For command data, the convention is open to the command originator. There is no requirement for the MDM data system.

2. Bits 57-64: Fixed Code. Same as bits 49-56.

3. Bits 65-72: Message Type Code. For telemetry, this field contains a fixed code identifying the block as one which originated at the WSC. The codes are 16(hex) for STGT, 15(hex) for WSGT and 13(hex) for JSC. For command data, the convention is open to the command originator. There is no requirement for the MDM data system.

4. Bits 73-80: Fixed Code. Same as bits 49-56.

5. Bit 81: Spare. This bit is always set to binary 0.

6. Bit 82: Single Block Command Flag. This bit is set to binary 0 when a command message exceeds 4624 bits; i.e., a multiblock command transmission. This bit is set to binary 1 when a command message is contained within a single block. For telemetry data, this bit is always set to binary 0.

NOTE:

A block with bit 82 set to binary 0 is held in the MDM terminal in the WSC until five blocks have been accumulated, until a block is received with the single block flag set, or after 200 milliseconds have elapsed.

7. Bit 83: Full Block Flag. This bit contains a flag which indicates whether the block contains fill bits in the data field. A binary 1 represents a full block condition.

8. Bits 84-96: Data Length. The last 13 bits of the customer header contain a binary count of the number of bits of data, exclusive of fill, contained in the block. This field is used by the WSC MDM terminal (command data) and by the customer ground facility (telemetry data) to assist in removal of fill data in processing the data block. The binary count equals 4624 (decimal) for the full block condition.

d. Bits 97-144: Time. For telemetry, the 48-bit time field is reserved for a time code which is in UTC having a resolution of 1 μsec. The format is NASA PB4. The time in the block represents the time that the WSC MDM terminal received the first data bit in the data field. For command data, the convention is open to the command originator. There is no requirement for the MDM data system.

e. Bits 145-4768: Data Field. The 4624-bit data field is used to transmit customer data. When the data field contains fill bits, they follow the customer's data and complete the data field. A specific fill data pattern code 311 (octal) is used (binary bit pattern 11001001).

f. Bits 4769-4800: Block Error Control. The block error control field is 32 bits in length and is reserved for information used to determine if bit errors have occurred during transmission of the block. For command data, the originator is expected to insert the polynomial computed for the data content of the block at his location using an MDM-compatible algorithm. For telemetry data, this field is computed and inserted by the transmitting MDM terminal, decoded and passed to the customer by the receiving MDM terminal.

1. Bits 4769-4776: Spare. These eight bits are not used and are set to all binary 1's.

2. Bits 4777-4778: F1 and F2 Polynomial Status Flags. These bits are reserved for flags which indicate that a block either passed or failed a polynomial check when it was decoded. These bits are set to binary 1 by the customer ground facility or the NISN MDM terminal originating (encoding) the block. For telemetry data, one of these (bit 4778) is set to binary 0 by the NISN MDM terminal decoder to indicate that the block passed the polynomial check or is left as a binary 1 if an error is detected in the block. The other bit (4777) may be used for a second decode process at the customer ground facility.

3. Bits 4779-4800: Polynomial Remainder: The last 22 bits of the block are reserved for the polynomial remainder which results from the originator or the NISN MDM terminal encoding the entire content of the block (excluding the NISN sync code and block error control fields). The decoding process of the NISN MDM terminal for telemetry data does not remove or alter this field. It is passed on to the customer ground facility where a second decode process may be used [see paragraph 2 above].

Appendix J. Customer Constraints for the Expendable Launch Vehicle Class of TDRSS Customers

J.1 General

This Appendix contains the customer constraints for the S-band DG2 noncoherent Expendable Launch Vehicle (ELV) class of TDRSS customers. In general, an S-band ELV customer typically uses DG2 noncoherent service (noncoherent, non-PN coded service) with BPSK or QPSK modulation, a baud rate between 12.5 ksps and 1024 ksps per channel, rate 1/2 convolutional coding, and requires 1-way Doppler tracking.

Compliance with the customer constraints of this Appendix is expected to ensure the performance described in this Appendix; however, compatibility testing with the SN must still be performed to confirm this performance.

J.2 Customer Constraints

Table J-1 provides a summary of the customer constraints for the S-band ELV class of TDRSS customers.

Table J-1. Customer Constraints for the S-Band ELV Class of TDRSS Customers

Parameter		Specification Value
Spurious Outputs	In-band	≥23 dBc
	Out-of-band	≥15 dBc (between data bw and 2x channel bw) ≥30 dBc (outside of 2x channel bw)
Frequency Stability (peak)	Short-Term Stability	≤ ±26 x 10^{-9} for a 1 second average time (notes 1 and 2)
	Long-Term Stability	≤ ±3.77 ppm for a 5 hour observation time (notes 1 and 2) ≤ ±11.3 ppm for a 48 hour observation time (notes 1 and 2)
	Temperature Stability	≤ ±11.3 ppm over the temperature range expected during the mission (note 3)
Phase Noise (note 3)	With a Doppler tracking requirement	1 Hz – 10 Hz: ≤2.0° rms 10 Hz – 100 Hz: ≤1.0° rms 100 Hz – 1 kHz: ≤1.0° rms 1 kHz – 3 MHz: ≤1.0° rms (SMA) 1 kHz – 6 MHz: ≤1.0° rms (SSA)
	Without a Doppler tracking requirement (note 5)	1 Hz – 10 Hz: ≤50.0° rms 10 Hz – 100 Hz: ≤5.5° rms 100 Hz – 1 kHz: ≤2.5° rms 1 kHz – 3 MHz: ≤2.5° rms (SMA) 1 kHz – 6 MHz: ≤2.5° rms (SSA)
Gain Imbalance	BPSK	±1.0 dB
	QPSK	±0.5 dB

Table J-1. Customer Constraints for the S-Band ELV Class of TDRSS Customers (cont'd)

Parameter		Specification Value
Phase Imbalance	BPSK	±9°
	QPSK	±5°
Gain Flatness		≤ ±0.4 dB over ±0.7 MHz
Gain Slope		Not specified
Phase Nonlinearity		≤ ±4° over ±0.7 MHz
Spurious PM		≤ 2° rms
AM/PM		≤ 15°/dB
AM/AM		Not specified
Incidental AM		≤ 5%
Symbol Asymmetry		≤ ±3%
Symbol Jitter		≤ 0.1%
I/Q Symbol Skew		≤ ±3%
Minimum 3-dB bandwidth prior to power amplifier		≥ 2 x maximum baud rate

Notes:

1. The short-term and long-term frequency stabilities determine the required stability over the time period specified and at any constant temperature (±0.5° C) in the range expected during the mission. At a minimum, a mission temperature range of -10° C to +55° C shall be considered.
2. Transmitter oscillator required to be characterized ≤ 48 hours prior to the scheduled service and the SHO be updated. Expanded customer frequency uncertainty request required in SHO, which allows a customer oscillator uncertainty of up to ±35 kHz for S-band DG2 BPSK and non-staggered QPSK signals.
3. At a minimum, a mission temperature range of -10° C to +55° C shall be considered.
4. Derivation of the phase noise requirements involved making assumptions about the distribution of the phase noise power in each frequency region. Since no phase noise PSD will exactly match the phase noise power distribution assumed for this derivation, phase noise PSDs which are close to violating the phase noise limits or phase noise PSDs which do violate the phase noise limits should be evaluated on a case-by-case basis to determine their acceptability.
5. Or can accept a total Doppler tracking error greater than the 0.2 rad/sec, perhaps as high as 3.79 rad/sec.

J.3 Acquisition

For S-band DG2 noncoherent return service, the total acquisition time is the sum of the following:

a. Carrier acquisition time

b. Symbol/Decoder synchronization time or Symbol/Deinterleaver/Decoder synchronization time (if deinterleaving is applicable).

The carrier acquisition time is discussed in paragraph J.3.1 (SMA) and paragraph J.3.2 (SSA). The synchronization time and associated requirements are given in Table 5-8 (SMA) and Table 6-9 (SSA).

J.3.1 SMA

TDRSS will achieve customer carrier acquisition within 3 seconds with a probability of 90% or greater ($P_{acq} \geq 90\%$) for customers who meet the customer constraints of Table J-1 and provide a total (I+Q) P_{rec} consistent with the required P_{rec} in note 3 of Table 5-8.

J.3.2 SSA

TDRSS will achieve customer carrier acquisition within 3 seconds with a probability of 90% or greater ($P_{acq} \geq 90\%$) for customers who meet the customer constraints of Table J-1 and provide a total (I+Q)$P_{rec} \geq$ -190.9 dBW or a P_{rec} consistent with paragraph J.5, whichever is greater.

J.4 Signal Tracking

J.4.1 SMA

TDRSS will provide SMA return signal tracking (carrier, symbol synchronization, convolutional deinterleaver synchronization, Viterbi decoder synchronization) as given in Section 5, paragraph 5.3.3.3.

J.4.2 SSA

TDRSS will provide SSA return signal tracking (carrier, symbol synchronization, convolutional deinterleaver synchronization, Viterbi decoder synchronization) as given in Section 6, paragraph 6.3.3.3.

J.5 BER Performance

TDRSS will provide 10^{-5} BER service for customers who meet the customer constraints of Table J-1 and the adjusted P_{rec} requirements as defined by Table J-2.

Table J-2. P_{rec} Adjustment for TDRSS ELV Customers

ELV Configuration		**P_{rec} Adjustment** (notes 1, 2 & 4)
		SMA/SSA
Minimum Customer Bandwidth	BPSK	-0.8 dB
	QPSK	+0.4 dB
Nominal Customer Bandwidth (note 3)	BPSK	-1.4 dB
	QPSK	-0.6 dB

Notes:

1. P_{rec} adjustment relative to the 10^{-5} BER P_{rec} requirements for DG2 channel data rates $\leq$ 1 Mbps of Table 5-8 (SMA) and Table 6-9 (SSA). The P_{rec} requirements for DG2 channel data rates $\leq$ 1 Mbps of Table 5-8 (SMA) and Table 6-9 (SSA) are based upon WSC specified implementation loss amounts of 2.6 dB and the adjustment indicated here effectively reduces the required P_{rec} by the value shown for negative numbers and increases the required P_{rec} by the value shown for positive numbers.
2. The P_{rec} amounts indicated by this table are expected to result in a 0 dB link margin; however, compatibility testing with the SN must be performed to confirm this performance. Customers are expected to take the necessary precautions to ensure an appropriate margin is maintained during the mission.
3. The nominal and minimum bandwidths are the double-sided 3 dB bandwidth introduced by the transmitter's filter. Nominal bandwidth is defined as 8x the I or Q channel baud rate, whichever is greater. Minimum bandwidth is defined as 2x the I or Q channel baud rate, whichever is greater.
4. The P_{rec} adjustment values are based upon analysis of the combined effect of all constraint parameters at their maximum values. The P_{rec} adjustment value may be improved for customers operating with constraints at less than the maximum values. Customers should contact GSFC Code 450 for compatibility testing and further analysis.

Appendix K. Use of Reed-Solomon Coding in Conjunction with SN User Services

K.1 General

This Appendix describes the use of Reed-Solomon (R-S) coding, both alone and combined with convolutional coding. The SN supports R-S decoding for WDISC customers only; however, the data rates supported by the WDISC are limited (please see Section 3, paragraph 3.6 for further information). Although the SN does not presently support R-S coding for all data rates, the customer MOC may perform R-S decoding for improved performance.

The Consultative Committee for Space Data Systems (CCSDS) has recommended the following telemetry coding standards for space communications [1]:

a. Rate-1/2 convolutional coding.

b. (255, 223) R-S coding.

c. Concatenated coding: a rate-1/2 convolutional inner code with a (255, 223) R-S outer code.

d. Turbo coding (not discussed in this Appendix).

In the discussion that follows, all operating points (BER vs E_b/N_o) are based on the theoretical (best-possible) performance of the forward error correction code. Thus, all operating points discussed are illustrated by the theoretical curves in Figure K-1. In practice, the actual E_b/N_o required for any SN-specified operating point is the theoretical value plus the SN's allowable implementation loss for the service type, configuration, data rate, and channel coding. The P_{rec} values in the main body of this document include this implementation loss. The P_{rec} reduction values given in paragraph K.4 below assume the customer is compliant with all constraint parameters.

K.2 Concatenated Coding: A (255, 223) R-S Outer Code with a Rate 1/2 Convolutional Inner Code

K.2.1

Throughout the SNUG, the customer's P_{rec} has been specified to maintain a 10^{-5} BER in an AWGN channel. At this BER, rate-1/2 coding allows customers to reduce their required P_{rec} by 5.4 dB relative to an uncoded signal. Concatenated coding – the use of R-S coding as an outer code with a rate-1/2 convolutional inner code – can further improve BER performance. Customers planning to operate at a BER worse than 10^{-5} at the output of the ground terminal convolutional decoder are required to negotiate support with GSFC Code 450.

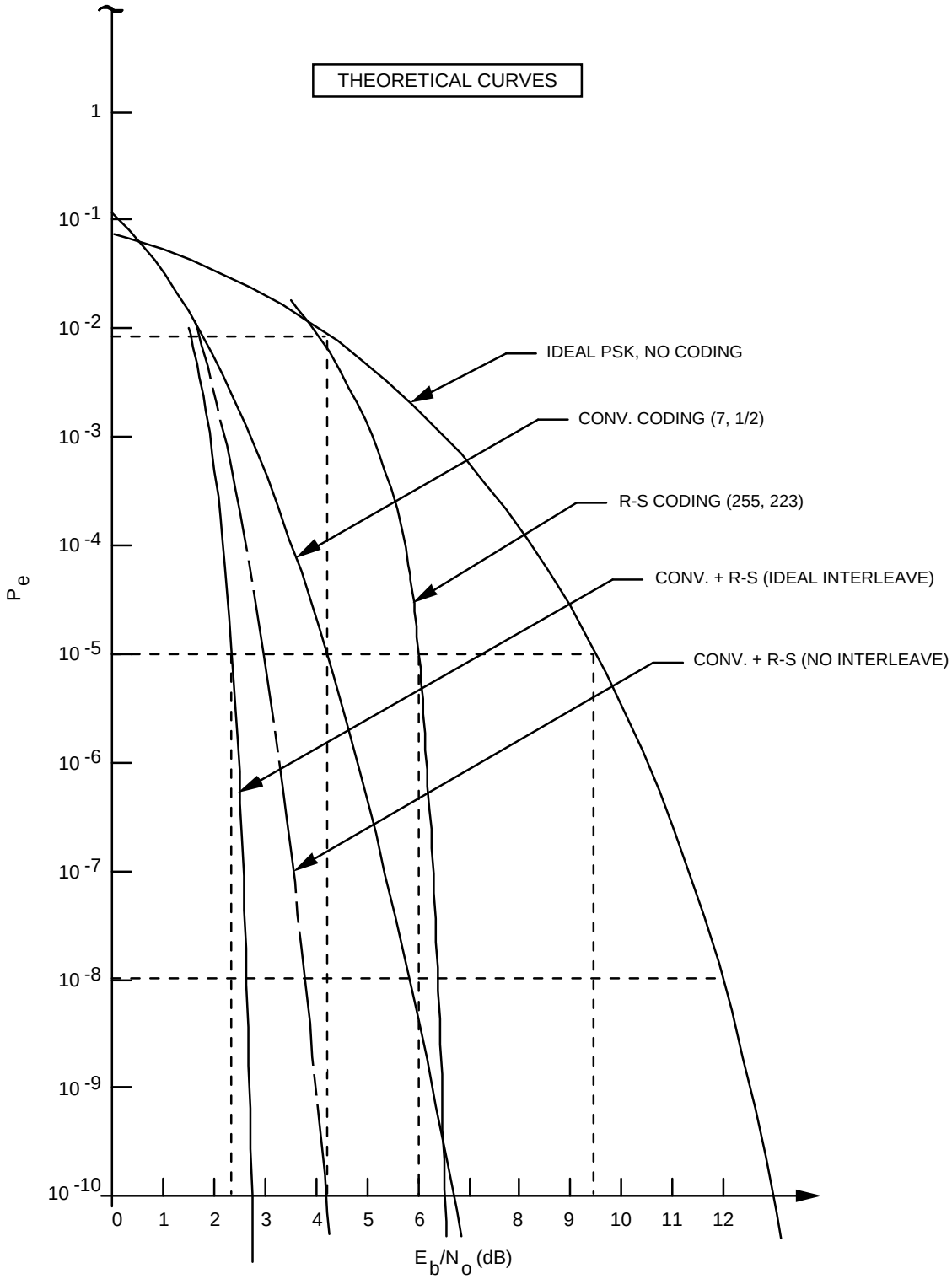

Figure K-1. Theoretical Performance of Concatenated, R-S, and Convolutional Coding (from [2])

NOTE:

Throughout this document, the coding gain achieved by using rate 1/2 convolutional coding is already included in the equations for determining the return link minimum required P_{rec} for a 10^{-5} BER.

K.2.2

Figure K-1 shows the theoretical performance of concatenated coding. Customers with an E_b/N_o of 4.2 dB (referenced to the data rate of the convolutional code) can achieve a BER of 10^{-5} at the output of the convolutional decoder at the ground terminal, and a BER of 10^{-10} at the output of the R-S decoder (without interleaving).

K.2.3

Although the CCSDS recommendation for telemetry coding does not include periodic convolutional interleaving (PCI) of the convolutional encoder output symbols, PCI is recommended for S-band customers with concatenated coding and channel baud rates > 300 kbps. When interleaving is not employed for channel baud rates > 300 kbps, S-band performance may not be guaranteed.

K.3 (255, 223) R-S Coding (Without Convolutional Coding)

K.3.1

Since all S-band return services (SSAR, MAR, and SMAR) require convolutional encoding, R-S coding alone (without the convolutional inner code) applies only to the KuSA and KaSA return services. Uncoded signals must maintain an E_b/N_o of 9.6 dB in an AWGN channel in order to achieve a 10^{-5} BER at the ground terminal. R-S encoding alone, in conjunction with KuSAR or KaSAR service, allows the customer to reduce their P_{rec} by up to 3.0 dB and still achieve a BER better than 10^{-7} at the output of the R-S decoder.

K.3.2

When transmitting at a reduced P_{rec} with an E_b/N_o less than 9.6 dB, the customer will be operating at a BER worse than 10^{-5} at the input of the R-S decoder.

K.4 Summary

K.4.1

The resultant P_{rec} reductions and BER performance with R-S encoding are summarized in Table K-1. R-S decoding is performed either by the SN for WDISC customers or at the customer MOC.

Table K-1. Performance of R-S Encoding in Conjunction with SN Services

Coding Scheme	Reference Point (notes 3 and 4)		Resultant P_{rec} Reduction for BER
	Input to R-S Decoder (note 1)	**Output of R-S Decoder (ground terminal or MOC)**	
Concatenated Coding (note 5)	E_b/N_o = 4.2 dB BER = 10^{-5}	BER ~ 10^{-10}	None; better BER at R-S decoder
(255, 223) R-S Coding Only	E_b/N_o = 9.6 dB BER = 10^{-5}	BER much better than 10^{-10}	None; better BER at R-S decoder
	E_b/N_o = 6.6 dB BER worse than 10^{-5} (note 2)	BER better than 10^{-7}	3 dB

Notes:

1. E_b prior to R-S decoding is referenced to the customer data rate at the input to the R-S decoder (that is, the information rate multiplied by 255/223).
2. Support for signals with BERs worse than 10^{-5} must be negotiated with GSFC Code 450.
3. BERs assume ideal R-S performance as well as an ideal communications channel between the ground terminal and the MOC.
4. Customers must also comply with the P_{rec} requirements for signal acquisition and antenna autotrack acquisition, if applicable.
5. This Appendix uses the term concatenated coding to represent a rate-1/2 convolutional inner code with a (255, 223) R-S outer code.

K.4.2

The reduction in P_{rec} applies only to the P_{rec} required for BER performance. Customers must also comply with the P_{rec} requirements for signal acquisition and antenna autotrack acquisition, if applicable. Support for signals with a BER worse than 10^{-5} must be negotiated with GSFC Code 450.

K.4.3

Customers operating in an RFI environment will experience additional losses that have not been characterized at this time. Such customers should coordinate with GSFC Code 450 to determine performance.

References

1. "Telemetry Channel Coding," Recommendation for Data System Standards, CCSDS 101.0-B-4, Blue Book, Issue 4, Consultative Committee for Space Data Systems, May 1999.
2. Advanced Orbiting Systems, Networks and Data Links: Summary of Concept, Rationale, and Performance," Recommendation CCSDS 700.0-G-3, Green Book, Issue 3, Consultative Committee for Space Data Systems, November 1992.

Appendix L. McMurdo TDRSS Relay System (MTRS)

L.1 General

The MTRS is a TDRS relay ground system, owned and operated by the Near Earth Network, located at McMurdo Station, Antarctica. The Wallops-managed McMurdo Ground Station (MGS) receives S-band and X-band data from orbiting missions. The X-band data can be sent from MGS to the MTRS via fiber to provide delivery of near real-time or stored high rate scientific data through TDRS to WSC for delivery to end users. The MTRS can be used to relay data at rates of up to 300 Mbps. The MTRS has gone through two demonstration phases (MTRS-1 and MTRS-2), and is currently (as of 2011) being upgraded (MTRSU) for use as a fully operational system to support polar orbit missions. Please contact GSFC Code 450 for the latest information and potential support.

L.2 Operational Overview

Figure L-1 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 TDRS visibility for data relay.

The MTRSU subsystem transmits the data via the TDRSS KuSA return service at total data rates up to 300 Mbps. 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 IP network. The MTRSU will support 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. TDRSS KuSA forward service would need to be enabled for network connectivity.

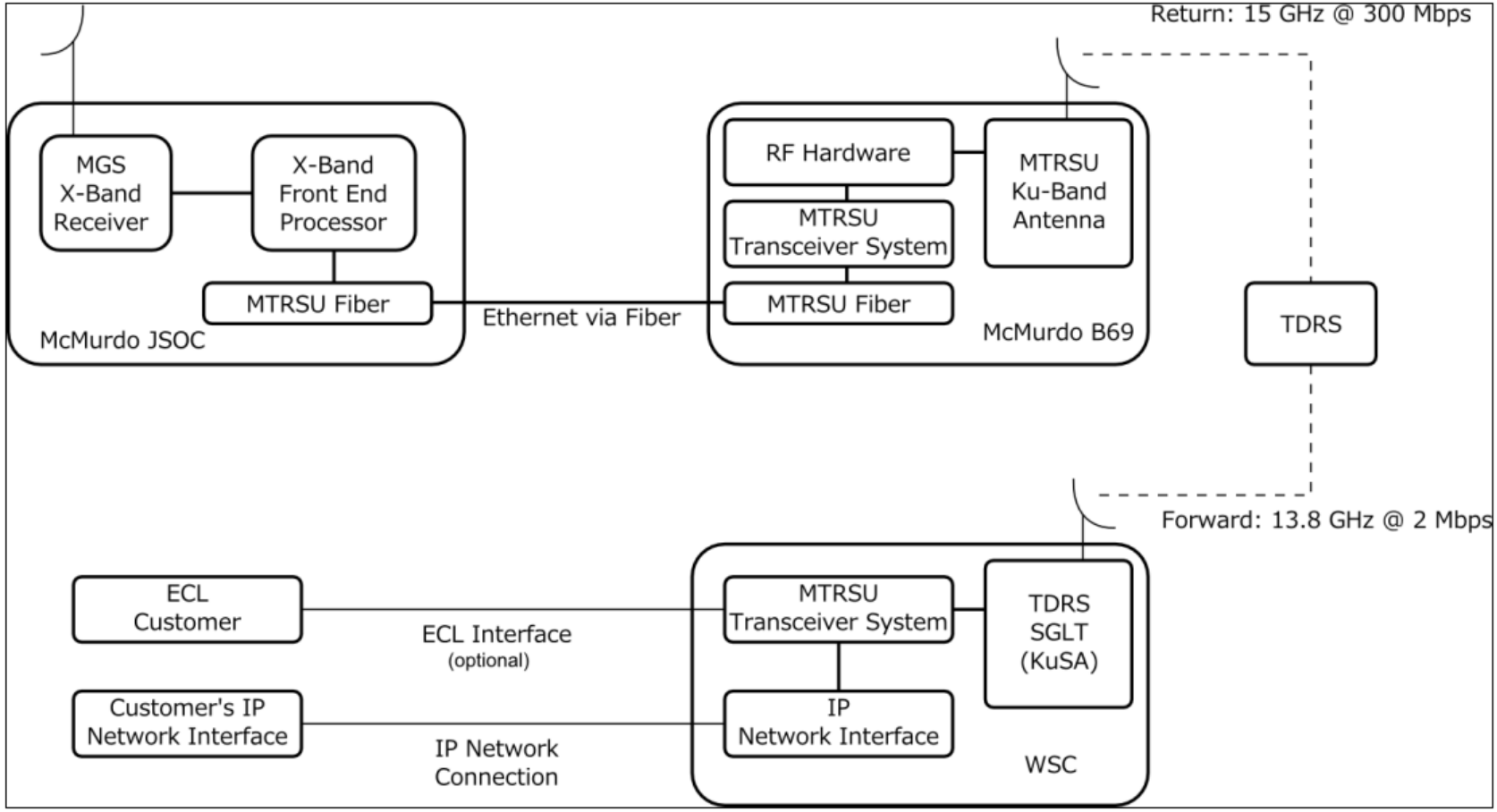

Figure L-1. MTRSU Data Flow

Appendix M. Deleted

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Appendix N. Network Test Services

N.1 General

This Appendix presents overview information that supplements existing NASA test documentation regarding NASA's compatibility test methodology and SN systems test methodology. The contents are completed to a level intended to summarize the test methodology, possible configurations, resources, participating organization responsibilities, and test planning activities.

N.2 Verification Methods

The following methods of verification can be applied to verify the customer functional, interface, and performance requirements.

a. Test
b. Evaluation
c. Demonstration

N.2.1 Test Method of Verification

Test is the method of verification whereby requirements are verified by measurement during or after the controlled application of functional and environmental stimuli. These measurements may require using laboratory equipment, recorded data, procedures, test support items, or services. For all test activities, pass or fail test criteria or acceptance tolerances are specified prior to conducting the test. This method ensures that the actual performance of tested equipment or systems meets or exceeds specification requirements.

N.2.2 Evaluation Method of Verification

The evaluation method of verification is used when actual operational conditions cannot be entirely simulated, the test parameters cannot be completely tested at the "box" level, or it is too costly to use the test method of verification. Evaluation may use the results from limited tests or multiple lower level tests and analyses. The data taken can be compared to the device under test (DUT) requirements, but are generally not sufficient to provide verification to the extent of the test method.

N.2.3 Demonstration Method of Verification

Demonstration is a method of verification used to imply the properties of an end item or component in which operations or physical characteristics of the end item are observed. This observation may exercise equipment operations, functions, and/or characteristics that are not specified as explicit end item requirements. Demonstration is used with or without special equipment or instrumentation to verify characteristics such as operational performance, human engineering features, maintainability, built-in transportability, and display data. When used as a formal verification activity, the observed demonstrated performance is recorded.

N.3 Test Services Description

Test services can be discussed in categories of testing. An example of the typical Phased Test & Verification Chronology is:

a. Component Level Testing
b. Integrated System Testing
c. End-to-End Testing
d. Simulations & Training Exercises/Launch Site Testing

N.3.1 Component Level Testing

Component level testing is defined as installation and setup of an individual communication element in a “stand-alone” box test configuration. The objectives are focused on the component’s functional performance capabilities in order to determine the unit’s adherence to specifications and operational goals. The testing also includes the installation, setup, and calibration of the test equipment to ensure proper configuration and test readiness. The testing checks new hardware and software to ensure that it will work in the existing network environment.

N.3.2 Integrated System Testing

The integrated system level of testing is performed when the customer communication subsystem is integrated as an operational system and ready for testing. Integration testing confirms hardware connectivity to support systems and that the support software is properly installed and operational. During this testing the overall system capabilities are tested, evaluated, or demonstrated. The objectives are focused on the integrated system functional capabilities in order to determine the unit’s adherence to specifications and operational goals. In the integrated configuration the effects of the avionic equipment are accounted for and compared with the expected functionality of the system to meet the necessary operational needs.

N.3.3 End-to-End Testing

End-to-end testing (ETE) is conducted to verify data flow through the entire system (space to ground). The testing ensures that all mission functional support elements perform in a mission configuration. The testing involves the control center, data circuits, and SN interfaces to the customer platform. Typically, an ETE is customer-driven to exercise operational procedures, flight operations team (FOT) training, and pre-launch exercises.

N.3.4 Simulations & Training Exercises/Launch Site Testing

Pre-launch customer/SN simulation testing can be used to validate SN readiness with customer communication equipment prior to the launch of the customer platform. This validation includes operations checkout, end-to-end tests, and fault simulation tests. This simulation testing can be performed at a customer facility or at the customer platform launch site. In addition, training for customer project personnel can be

accomplished. The guidelines for this support appear in individual Network Test Plans located on the NGIN website.

N.4 Network Test Support Organizations

N.4.1 RF Simulation Operations Center (RFSOC)

The RFSOC, located at GSFC, is a facility for conducting customer flight project mission simulations for SN customers. The RFSOC can monitor SN performance during these mission simulations, simulate a mission-unique customer platform, verify SN/customer MOC interfaces, and simulate a customer MOC in support of fault isolation.

N.4.2 Compatibility Test Area (CTA)

The CTA provides the means to test customer platforms at GSFC or at remote locations for RF compatibility with the SN, which includes a TDRSS Live Sky (also called RF relay) test after local compatibility testing is completed. The CTA can provide various RF interfaces to a customer platform for local measurements with portable racks of RF compatibility test equipment (CTE). The CTA also has an antenna system for TDRSS relay performance tests. The GSFC-based Compatibility Test Lab (CTL) can provide RF interfaces to a customer platform for local RF testing and a rooftop antenna for SN performance tests. In this case, the customer brings the platform RF components to the GSFC CTL and these components are set up in an RF-shielded screen room for testing. Refer to the document 450-SPEC-CTA, *Space and Near Earth Networks Compatibility Test Systems Specifications*.

N.4.3 TDRSS End-to-End Test (EET) Systems

Equipment is available at all three WSC ground terminals (STGT, WSGT, and GRGT) to provide customers with end-to-end system testing capabilities. The TDRSS EET systems provide customer projects the capability of testing the end-to-end SN data communications through a ground-based simulation of the customer platform-to-MOC link via TDRSS, thus eliminating the need for the actual customer platform (please see paragraph N.6.1.2.d). Each EET system can simultaneously provide end-to-end testing of forward, return, and tracking services for one S-band (SSA or MA) and one Ku-band (KuSA) customer. Please note that TDRSS does not provide EET services for Ka-band (KaSA) customers. Also note that since GRGT has no interface to support receiving and transmitting test data with the customer, EET via GRGT is limited to local mode.

N.5 Determining Required Testing

Through coordination with the GSFC Code 450 Networks Integration Management Office (NIMO) and Code 450 test personnel, the customer project will receive assistance in determining the appropriate testing necessary to confirm SN compatibility and configuration readiness. There are tests that are typically performed at the different levels of customer readiness. For example, a customer preparing for a mission that has proven TDRSS communications components will most likely require testing from the integrated system test perspective. On the other hand, a customer with a first-time

TDRSS component may require the whole range of testing. In addition, some testing might be optional (i.e., “ship-n-shoot” with no launch site testing).

N.6 Test Planning, Scheduling, and Reporting

N.6.1 Test Planning

N.6.1.1 Test Planning Process

Coordination with Code 450 personnel to obtain the necessary resources is essential. Code 450 management and test personnel will schedule WSC, CTL, CTA, and RFSOC resources accordingly to meet customer mission timeframes.

N.6.1.2 Basic Phases of Testing

The basic phases of testing supported by the SN are as follows:

a. TDRSS Compatibility Testing. The purpose of TDRSS compatibility testing is to verify that the flight communication unit or, when necessary, flight-like unit parameters and equipment are compatible with the TDRSS interface. Successful TDRSS compatibility testing is a prerequisite for a SN commitment to support a customer project and is a building block in the progression to certifying mission readiness. The customer’s RFICD with the SN is one of the primary documents used to develop the Compatibility Test Plan (CTP). Compatibility testing is performed by the CTA. Information about TDRSS compatibility testing is contained in 450-SPEC-CTA, *Space and Near Earth Networks Compatibility Test Systems Specifications*.

   In general, the CTA performs the following functions: (1) act as a SN simulator to verify the integrity of the RF link; (2) provide assurance that the SN tracking, telemetry and command parameters, as well as equipment and operational procedures, are adequate to meet the communication requirements; (3) serve as an RF relay between customer equipment and the TDRS; and, (4) serve as a test set for fault isolation.

   Compatibility tests are performed to analyze the SN command forward link and telemetry return link modes of transmissions to and from the unit. Testing is conducted with representative mission data and, when feasible, with pseudorandom data generated from a data transmission test set. RF tests are selected and conducted in accordance with 450-PROC-CTP/SN/NEN, *RF Compatibility Test Procedures Between Spacecraft and the Space Network and/or Near Earth Network*. These compatibility tests check the unit performance parameters and verify the interoperability of the system signals with the SN. These tests are designated by number groups which are categorized by customer platform carrier tests, command signal tests, acquisition and tracking tests, and forward/return link data quality and threshold tests. As mentioned earlier, some tests are specifically performed between the DUT and CTE; others are performed with the DUT, CTE, and a live-sky (RF relay) scheduled with a TDRS.

b. SN Interface Testing. SN Interface Testing is designed to test the end-to-end RF link requirements with an operational TDRS. These tests may be performed with a spacecraft or simulator. Verification tests are a variety of tests that are performed after engineering tests are complete. These series of tests provide an initial validation of command, telemetry, and tracking data services with the new customer. The testing encompasses verification of configuration codes, scheduling, status, and control functions. These tests emphasize problem resolution and assist a new customer with meeting all SN interface requirements. When agreed to by NIMO, the CTA, or RFSOC, resources may be utilized.

c. SN Performance Baseline Testing. The SN utilizes the TDRSS EET capability to validate the network's ability to support forward and return link services for a customer unit. This testing verifies the SN configurations required to support the return and forward links, configuration codes, and WSC modifications and configurations independent of the customer by conducting EET simulations. This evaluation confirms the SN configuration required to support customer testing, and provides SN performance evaluation and characterization baseline data. This testing is available for the simulation of SSA, MA, and KuSA services, however, it is not available for KaSA services. Figure N-1 provides a high-level illustration of SN Baseline Characterization.

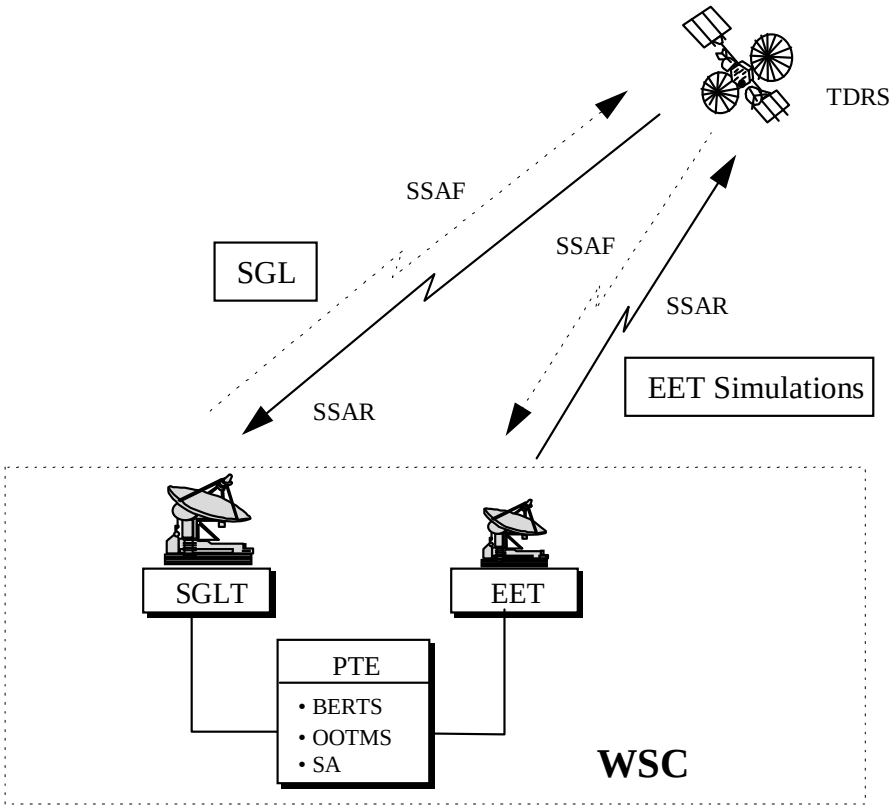

Figure N-1. SN Baseline Characterization

N.6.2 Test Scheduling

The use of all SN test resources must be formally coordinated through the GSFC MSP. These resources include, but are not limited to, the SN, CSO, and other supporting elements. Please refer to paragraph N.6.1 to see the process for test planning.

The scheduling of SN test resources is initiated by the Network Operations Manager (NOM), who is located at GSFC. Based on customer coordination with the GSFC Code 450 test group, the NOM submits planning inputs to the SN Forecast Schedule (please see Section 10 for a description of SN event scheduling), which is issued on a weekly basis for planning purposes. Contingency or backup test dates may also be scheduled for tests that require critical or scarce resources.

N.6.3 Network Configuration and Briefing Messages

The network configuration is specified in the Briefing Message (BM), which is issued for each TDRS test. Control of the overall network is maintained by WSC, which provides details of specific configurations for specific test dates. A BM is issued three days before the RF-through-TDRS test in order to orient and advise all SN participants and supporting elements. Draft BMs are circulated up to two weeks in advance for review and refinement. The BM is generated by the NOM, based on inputs from the test team, and contains a test title, the date and time for the test, a test time line, and a description of the element responsibilities for the test. BM coordination and scheduling normally begins four weeks prior to a test.

N.6.4 Test Readiness Review

Test personnel may conduct an internal Test Readiness Review (TRR) prior to the start of testing to verify equipment readiness and personnel safety.

A TRR may be held no later than 2 days prior to the performance of test events. At this meeting, all test activities and responsibilities are reviewed for completeness.

N.6.5 Test Reporting

Test results are documented in reports that cover all phases of testing.

a. RF Engineering Report. Test results are logged in an engineering notebook. A memorandum documenting the test results is prepared by test personnel and distributed the following workday after the completion of each day's tests.

b. Quick-Look Report (QLR). A quick-look report is a technical performance evaluation provided shortly after testing. This report also outlines the test objectives and notes whether all the objectives were met, or if a retest is required. For compatibility testing, compatibility test personnel generate a QLR memo that provides a preliminary look at the compatibility statement, anomalies or test comments and tests completed. This QLR is completed within seven days of the test completion.

c. CTA Compatibility Test Report. A test result report is produced by compatibility test personnel after detailed analysis of the data taken during the RF link compatibility tests. This report includes a compatibility statement,

equipment/setup drawings, test matrices, and a test results summary. The report is usually delivered within two months after test conclusion.

d. SN Test Report. A series of daily SN Test Reports (TRs) produced by the NOM provides the inputs required to conduct a post-test evaluation and data analysis contained in the SN TR. The report is usually delivered a few days after test conclusion.

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Appendix O. Self/Mutual Interference Considerations for New Customers at 2287.5 MHz

O.1 Introduction

This Appendix provides an assessment of self/mutual interference in the TDRSS MA environment at 2287.5 MHz, based on the results of an interference analysis performed on the 2287.5 MHz RF environment[1]. Self-interference is the interference incurred from other MAR/SMAR customers. Mutual interference is the interference incurred from SSAR customers operating at 2287.5 MHz. The amount of self and mutual interference included in a customer's MAR/SMAR link budget should be negotiated with GSFC Code 450.

Improving TDRSS capabilities potentially increase interference on the MAR link due to rising data rates. The F3-F7 series has a maximum data rate of 150 kbps per channel. In addition, the TDRS F8-F10 and K, L, M series has expanded the MAR capability to a data rate of 1.5 Mbps per channel. Finally, for the DAS, the quantity of customers is not limited by the SN ground infrastructure.

Currently 2 dB is built into the MAR/SMAR required P_{rec} equations given in Section 5 for self and mutual interference degradation. In addition, ACRS may be used to mitigate interference. ACRS is a tool that customers can utilize to determine potential future interference periods with other customers. The customers can then try and schedule their services around the times when they would be subject to high interference. GSFC Code 450 may support customers with a self and mutual interference degradation of less than 2 dB; however, this type of support needs to be coordinated with GSFC Code 450.

O.2 Interference Study

The MA interference study was conducted to examine the impact of the near-term interference environment, with different TDRSS constellations, on system interference. The current allocation of 2 dB for mutual and self-interference was evaluated on its ability to protect customers from data loss due to interference, as well as its appropriateness for Demand Access type customers.

The interference was studied using large Monte Carlo simulations, designating one customer as a victim, and the other customers as interferers. The simulation considered the orbits, antenna patterns, and TDRS link budgets of all the customers. A candidate mission model was developed for 2287.5 MHz customers in 2010. This mission model included: current customers, BRTS, and projected future customers through 2016. Besides identifying customers and their link characteristics, the mission

[1] "Interference Analysis Of SN S-Band Return Link Users in the Interference Environment at 2287.5 MHz", Prepared for Frank Stocklin by ITT, October, 2010.

model also determined duty cycles for each link. For the latest copy of the CLASS 2287.5 MHz Interference Analysis Report, please contact GSFC Code 450.

The simulations generated interference statistics for each customer in the mission model. The principal output was the percentage of time that a given customer experienced different levels of E_b/N_0 degradation due to the interference from other customers. The simulations accounted for geometric considerations as well as customer duty cycles. TDRS locations assumed in the simulations were 41W, 46W, 171W, 174W, and 275W. In the simulations, DAS customers were restricted to using only 174W, 41W, and 275W.

For all scenarios, customers were randomly assumed to receive support from available TDRS East (41W and 46W) and West (171W and 174W) satellites. Customers were only assumed to receive support from the TDRS zone of exclusion (ZOE) (275W) satellite when no other TDRS was in view.

O.3 Effect of P_{rec} Margin on Interference

The P_{rec} specified in the SNUG already includes a 2 dB allocation for self/mutual-interference. The amount by which an MA customer's P_{rec} differs from the SNUG P_{rec} is called the margin. The point at which service is impacted with loss of data is defined as the case when the margin against the P_{rec} has been used up, as well as the self and mutual 2 dB allocation for interference.

The results from the simulations were analyzed for the effect of P_{rec} margin on the interference. The plot below (Figure O-1) shows average service impact percentages for different victims, versus the P_{rec} margin above the 2 dB interference allocation. Certain conclusions can be drawn from this analysis of interference versus P_{rec} margin:

a. Prec margin is a strong predictor of performance against self/mutual interference.

b. Marginal MA return customers (margin <=0.7 dB) can expect to suffer noticeable impairment due to interference about 2.3% – 2.5% of the time.

c. By achieving a margin of 1.5 dB or greater, MA return customers, on average, can expect to lower their service impairment due to interference to under 1.0% of the time.

d. By achieving a margin of 3.0 dB or greater, MA return customers, on average, can eliminate the threat of self/mutual interference.

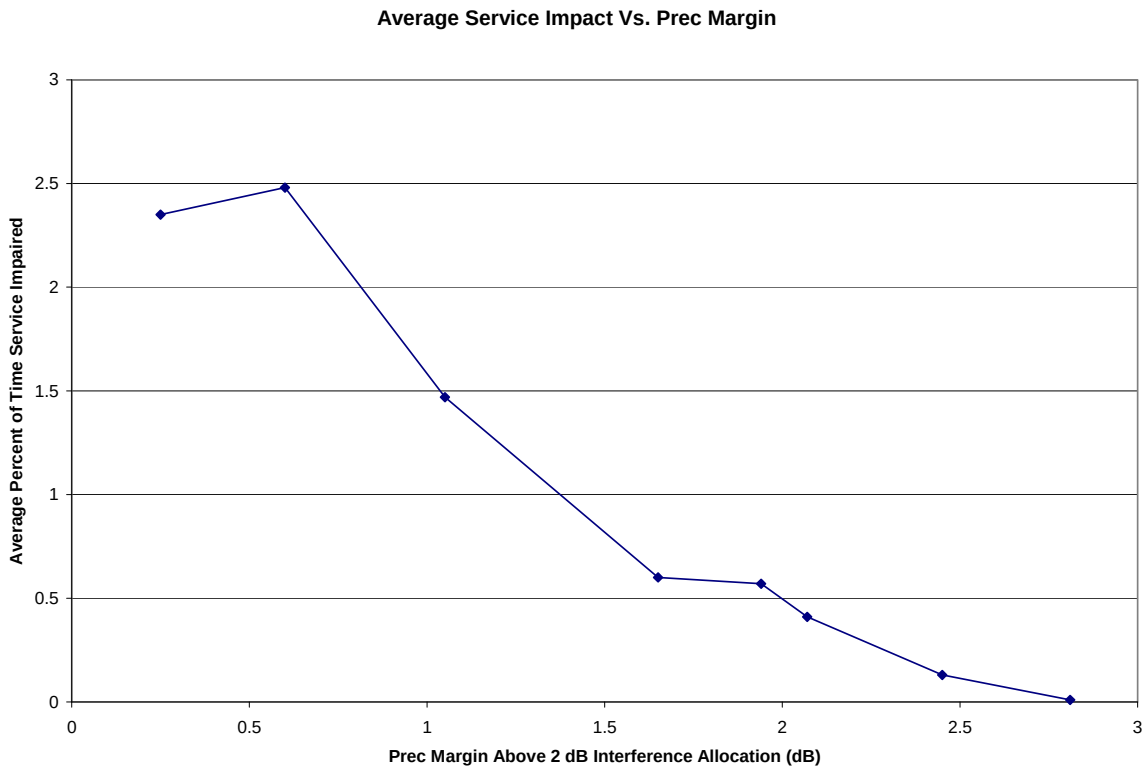

Figure O-1. Average Service Impact Versus P_{rec} Margin

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Appendix P. Space Network Access System (SNAS)

The Space Network Access System (SNAS) is intended to be a single, universally accessible, standards based, and full-featured Customer interface for performing Tracking and Data Relay Satellite System (TDRSS) planning, scheduling and real-time service monitoring and control. The SNAS will provide a flexible tool that is capable of supporting the diverse needs of the SN customer community.

The SNAS architecture is shown in Figure P-1.

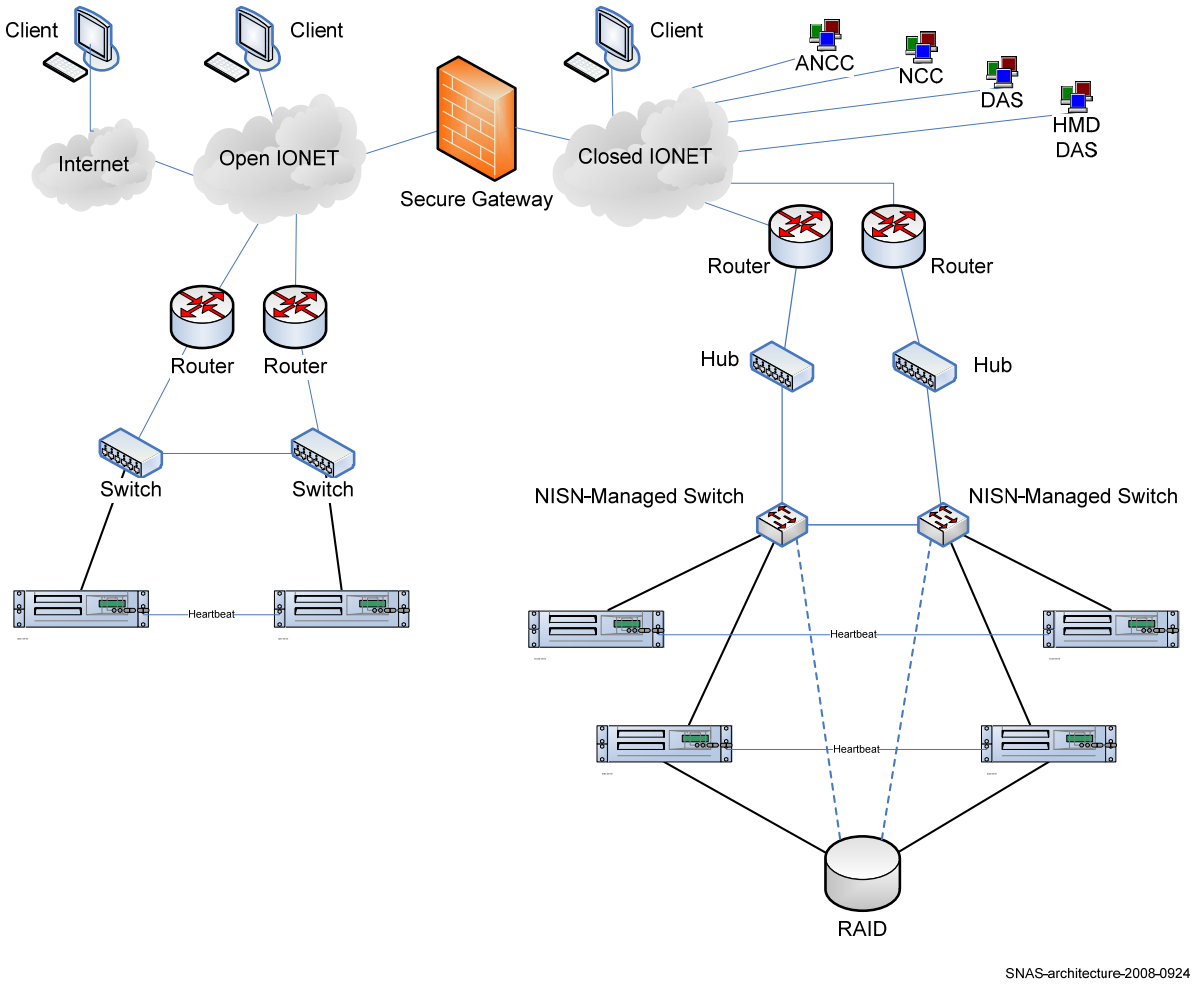

Figure P-1. High Level SNAS Architecture

P.1 Major System Components

P.1.1 Client

SNAS provides two client types that support distinct features, functions and access privileges in compliance with NPR 2810.1, *Security of Information Technology* requirements for separation of duties and least privilege.

The SNAS client workstation is the combination of the platform provided by the customer, including the hardware and software necessary to host the client application software, and the client application software, which is considered part of the SNAS product.

The SNAS MOC client application software provides customers with access to the SN via the Open or Closed SNAS servers. MOC Client users will be assigned access privileges depending upon their designated roles.

The SNAS SN Operations and Maintenance (O&M) client software provides SN O&M personnel access to the SNAS database and servers in support of administrative functions.

The MOC client workstation as depicted in Figure P-1 resides in the Customer MOC. The workstation platform may be any type of personal computer (PC) or other workstation that can access the Restricted IONet, the Open IONet, the Internet and/or the Closed IONet and that can run Sun Microsystems Java Virtual Machine (JVM). Operating systems such as UNIX, Linux, Mac OS and most versions of Windows support the JVM. Hardware requirements will depend on the OS, the version of the JVM and other applications to be run on the client workstation. It is estimated that modern computers with 1 Gbyte of RAM, 60 Gbytes of available disk space and a 1024X768, 16 bit color display will be sufficient for running the SNAS MOC Client application.

The MOC client can also interact with other computers, for example on a Local Area Network. These computers, referred to as External Processing Systems (EPS) by SNAS, provide specialized capabilities or functions that cannot be provided directly by the SNAS Client application. Either file sharing, using SFTP, or message streaming, using TCP/IP, can be used for communications between a MOC client and an EPS. The interface between a MOC client and an EPS is defined by 452-ICD-SNAS/EPS, *Interface Control Document between Space Network Access System (SNAS) and External Processing System (EPS)*.

P.1.2 Servers

SNAS maintains fully redundant servers on both the Closed IONet and the Open IONet. These servers act as proxies to route requests from the MOC client to the NCCDS and/or the DAS and return responses to the MOC client, establishing and maintaining all the required TCP connections. Traffic between the servers on the Open and Closed IONet passes through the NISN gateway. The Closed Server initiates the communications link between the Closed and the Open servers.

P.1.2.1 Closed Server

The SNAS Closed Server hosts most of the server applications; manages user login sessions, and the communications with NCCDS and DAS.

P.1.2.2 Open Server

The Open Server is a proxy server to allow users on the Open IONet and the Internet to connect to SNAS and to access TUT. User requests are directed to the Closed Server through the NISN Secure Gateway using a single predefined set of rules. This allows for the addition of new customers and users without the need for adding new Secure Gateway rules.

Internet, Open IONet and Restricted IONet communications will be routed through the Open IONet server.

P.1.2.3 Database Server

The SNAS database will operate on a dedicated data server that communicates exclusively with the SNAS Closed Server. Database tables will hold static data, semi-static data and dynamically updated data. The static tables will store data that is rarely changed like TDRS names, SIC and SUPIDEN values. The data in the static table will be used for building display panels and for processing NCCDS or DAS messages. The dynamically updated tables will include messages from the NCCDS to the MOC, e.g. schedule result messages, and the MOC schedules. The customer will not have direct access to the SNAS server database. Regardless of the database application used, MOCs will not be allowed to create/issue/send SQL commands to the SNAS server database.

P.1.2.4 Open TUT Server

The SNAS will retrieve the current TUT information from the NCCDS and display it. SNAS provides the capability of “pushing” TUT updates to MOC Clients as the updates become available. The SNAS will also maintain a file with the current TUT information on the Open IONet Server and make this file accessible to authorized users via the public internet. The Open TUT Server data is updated hourly.

P.1.2.5 Other Servers

Software servers will be maintained on the Open IONet and the Closed IONet so that users can download the SNAS Client application to their client platform.

SNAS will operate a local Certificate Authority (CA) on the Open IONet and the Closed IONet to support SSL connections between the SNAS servers and the MOC clients.

P.2 External Interfaces

P.2.1 Network Control Center Data System (NCCDS)

The SNAS communicates with the NCCDS on behalf of SNAS customers through implementation of the 452-ICD-SN/CSM protocol. All communications use TCP/IP.

P.2.2 Auxiliary Network Control Center (ANCC)

The SNAS interfaces with the ANCC to allow SNAS customers to perform interface testing and user training.

P.2.3 Demand Access System

SNAS accepts customer requests for DAS services. All DAS services are supported by SNAS. All communications between the SNAS and the DAS are specified in the 452-ICD-DAS/SNAS, *Interface Control Document between the Demand Access System and the Space Network Access System*. All communications between the DAS and the SNAS use TCP/IP.

P.2.4 NISN Secure Gateway

All communication between the SNAS Open Server and the SNAS Closed Server is channeled through the NISN Secure Gateway. When communicating with each other, the SNAS Open Server and the SNAS Closed Server employ protocols or communications techniques that are compliant with NISN Secure Gateway rules. The link between the SNAS Open Server and the SNAS Closed Server is the only communication link through the NISN Secure Gateway that SNAS uses. This link is independent of and isolated from links to SNAS MOC client workstations. Compatibility with the NISN Secure Gateway is not affected by the addition or removal of active SNAS MOC client workstations.

P.2.5 SNAS MOC Client Workstation

The SNAS MOC client workstation is considered an external interface because the platform is not part of the SNAS product. Multiple SNAS MOC client workstations can simultaneously access the SNAS servers in any combination of Internet, Open IONet, Restricted IONet and Closed IONet connections.

P.3 SNAS Features and Operations

P.3.1 MOC Client Features

P.3.1.1 MOC Configuration

The user will be able to display, edit and save individual interface configuration settings and user preferences. The MOC user will be able to set applicable thresholds for UPD parameters and alerts.

SNAS will provide the capability for the MOC user to setup, enable, disable and maintain log files on the local client platform for each type of message.

SNAS will provide a default directory structure for the exchange of files between a SNAS MOC Client and an EPS. This directory structure and other characteristics of the interface between a MOC Client and an EPS will be incorporated into the default configuration file. The MOC Client GUI will provide the capability for modifying the default directory structure and other aspects of the interface and interactions between a MOC Client and an EPS.

P.3.1.2 MOC Human Computer Interface

The display for operational mode will be distinctive from the display for Engineering Interface (EIF) mode. Textual displays and graphical display can be shown individually or mixed. Scheduled service information for NCCDS and for DAS can be shown individually or mixed.

Graphical timelines will display NCCDS schedule requests, DAS resource allocation messages, scheduled events, TSWs, TDRS view/orbital constraints, User-specified TDRSS resource constraints, User-specified orbital constraints, including day/night portions of the customer platform's orbit and the most recently retrieved TUT. The graphical display will be capable of presenting timelines for at least five (5) TDRSs or TDRS Sets simultaneously within a single viewable area. The MOC users can determine which TDRSs or TDRS set(s) are displayed on a given timeline. The timelines will be configurable.

Schedule requests and resource allocation message can be saved, modified, and cloned from a timeline. Filtering criteria for timelines can be saved for future use.

The interface will be constructed with a main menu for selecting and initiating actions and panels for displaying information that the user will be able to view and manipulate. The user's login role will determine which actions may be selected from the main menu. Items which are not appropriate for the user's role will be grayed out to indicate that they cannot be selected.

Several panels may be open on the interface screen at any given time but the user may only interact with one panel at a time. All of the open panels will be updated whenever the underlying information changes. Each panel will have a default configuration. User specified preferences will override the default settings.

A panel will be provided for displaying the NCCDS and DAS UPD messages. This panel will also be capable for displaying or replaying of UPD messages from a log file saved in local storage.

A panel will be provided for displaying alerts from a log file saved in local storage. The log file and the display will be updated as alerts are received from the SNAS server. The size of the log file will be determined by a user configurable setting. An alert log file that contains a history of alerts received over a rolling 24 hour period will be maintained on the SNAS database. A user specific alert history can be downloaded and saved to local storage to create a baseline log file on the SNAS Client.

The user will be able to print either individual display panels or the entire display.

The status of the communication links with the NCCDS, the ANCC and DAS will be displayed.

P.3.1.3 MOC User Interactions

General

At login, the user will be able to select either operational or EIF mode and select the SIC or SICs to be used in messages. The UserId at login will determine the SNAS user's role and associated access privileges.

The MOC user will be able to enable and disable local logging of messages received from either the SNAS Server or from the EPS.

The MOC user will be able to turn on saving of the latest TUT information to a file on the client workstation. The MOC user will also be able to save TUT retrieval criteria (filter) for TDRS and service types. The saved criteria will be used as the defaults when a TUT retrieval is performed.

The MOC user will be able to delog or retrieve messages and other information stored on the SNAS Database using pre-defined queries provided by the SNAS SN O&M personnel.

The user will be able to view alerts and messages, current active events and previously transmitted schedule requests and store this information in files on the local work station. The user will be able to tailor the Schedule Request Summary and Active Events Summary panels. The MOC user will also be able to view information such as logs and messages received from the NCCDS/ANCC and DAS that have been saved in local storage.

The SNAS will allow the MOC user to specify various levels of limits (e.g., high and low) for the alarms and triggers for UPD messages. For example: (high) if the demodulator lock status changes from lock to unlock; (Low) if the data quality parameter changes.

The user will be able to set four (4) alarm ranges for any numeric type parameter in the UPD message. These ranges will correspond to lower critical, lower warning, upper warning and upper critical. When a parameter falls within a defined range it will be shaded on the UPD detail panel display.

The MOC user will be able to view Customer data including SIC(s), SSCs, prototype events, Predicted Site Acquisition Tables (PSATs), User Antenna Views (UAVs) and TDRS Communication Windows (TCWs).

Recurrent Scheduling (RS)

MOC users will have a RS capability as described briefly in Section 10.2.4.1. The SNAS RS capability will allow MOC users to generate a series of SARs and associated Alternate Schedule Add Requests (ASARs) controlled by pre-defined patterns, which consist of schedule request prototypes, and based on confirmed events, TSW information, and TUT information. All respecifiable parameters and service-level

flexibility options including service start and stop times, minimum service duration, coupled services and bounded services will be supported.

A user in the Mission Planner role will be able to select RS, establish the input parameters, initiate the SAR/ASAR generation process, monitor progress, generate, save, print a report and terminate the recurrent scheduling activity. The user will also be able to abort the rescheduling process with the effect that all SARs/ASARs generated up to the time of the abort will be saved and available for submission to the NCCDS.

Recurrent scheduling prototypes will be updated when there is a change to a SUPIDEN that is referenced by one or more of the prototypes.

Switch User

A new user is able to logon and continue coverage of an event in progress through the switch user capability. The new user must be either a user with the same SNAS MOC client privileges as the current user or a Mission Manager. This process logs in the new user without closing the connection or changing the state of the current client user application. No user initiated actions will be allowed during the switch user process.

If the new user does not have the correct client privileges then the switch user fails and SNAS sends alerts and logs the error. For successful logins, the switch user capability causes the logout of the original user and the login of the new user to be logged as the current user. All subsequent client actions will be logged with the current user id.

Mission Management

As a support for maintenance of Mission and User data, the SNAS will provide mechanisms for a MOC Mission Manager to transmit updates to the SN O&M personnel and receive responses from the SN O&M personnel. Generally, responses and notifications from the SN O&M personnel to the MOC Mission Manager will be displayed in a specialized panel called a “squawk box.” The SNAS will also provide tools for editing User Data, SICs, SSCs and PEs in the MOC Client.

P.3.1.4 NCCDS Service Support

The user will be able to create, save, print, import, display, edit, duplicate and delete any of the MOC to NCCDS messages for Scheduling and Planning and Real-time monitor and control defined in the 452-ICD-SN/CSM.

The user will be able to select a stored individual schedule request or a stored group of schedule requests to transmit to the NCCDS. The user will be able to create a GCMR populated from parameters based on a user-selected active service.

The SNAS will be able to display the most current values for individual service parameters of each active service.

The MOC user will be able to enable or disable local logging of UPD messages. The user can elect to display UPD information in several formats. All parameters of most recently received UPD messages can be displayed or dynamic updates as new messages are received can be displayed, or a summary display can be selected. The

SNAS MOC user will be able to specify the level as high, medium or low for alerts and for each UPD parameter. The SNAS will generate visual and audible alarms based on the user defined levels.

P.3.1.5 DAS Service Support

The user will be able to create, save, print, import, display, edit, duplicate and delete any of the MOC to DAS messages for Scheduling and Planning and Real-time monitor and control defined in the 452-ICD-DAS/SNAS.

The MOC user will be able to enable or disable local logging of UPD messages. The user can elect to display UPD information in several formats. All parameters of most recently received UPD messages can be displayed or dynamic updates as new messages are received can be displayed, or a summary display can be selected.

P.3.2 O&M Client Features

P.3.2.1 O&M Configuration

The user will be able to display, edit and save individual interface configuration settings and user preferences.

SNAS will provide the capability for the O&M user to setup, enable, disable and maintain log files on the local client platform.

P.3.2.2 O&M Human Computer Interface

The display for the O&M Client will be distinctive from the display for the MOC Client in either the operational mode or the EIF mode. Textual displays and graphical display can be shown individually or mixed.

The interface will be constructed with a main menu for selecting and initiating actions and panels for displaying information that the user will be able to view and manipulate. The user's login role will determine which actions may be selected from the main menu. The initial implementation of the O&M client will only support Data Base Administrator (DBA) functions.

Several panels may be open on the interface screen at any given time but the user may only interact with one panel at a time. All of the open panels will be updated whenever the underlying information changes. Each panel will have a default configuration. User specified preferences will override the default settings.

The user will be able to print either individual display panels or the entire display.

P.3.2.3 O&M User Interactions

The O&M Client supported user interactions are those that will make the client a useful, cost effective tool in day-to-day operations. These restrictions put the focus for the O&M client on DBA functions in support of MOC users. Many of the Systems Administrator (SA) and Information Systems Security Officer (ISSO) functions and

activities deal with elements of the SNAS system that are outside of the SNAS application. Support for these functions and activities cannot be readily incorporated into the SNAS application. Support for SA and ISSO functions may be provided when that support is a cost-effective alternative to other solutions.

The UserId at login will determine the SNAS user's role and associated access privileges. The SNAS O&M client will display the alerts received over the last 24 hours. The alerts displayed will be determined by the user's O&M role.

The SNAS O&M client will provide tools to allow O&M personnel to perform database functions. An O&M user will be able to retrieve alert messages stored in the SNAS database using time of creation, alarm level (information, warning and/or critical), SIC and UserId as selection criteria.

As a support for maintenance of Mission and User data, the SNAS will provide a "squawk box", which is a panel for communications between the O&M user and the SN MOC Mission Managers. The MOC Managers will be able to submit changes and updates to Mission data. The O&M user will be able to respond and provide status including accepted, rejected or pending for the various requests.

The SNAS will also support manual broadcast messaging initiated by the O&M personnel from the O&M Client to send out alerts (e.g., TDRSS outages) to either a MOC User account or users who have selected a specific SIC. This mechanism will reduce the need for person to person interactions (e.g., phone calls, faxes). In addition, the SNAS will provide O&M Client with panel for viewing SIC alerts to increase visibility into the SNAS operations (i.e., display of the alert stream filtered by SIC selection).

SNAS panels exist to monitor string status, support the SSC approval process and monitor user log on/off activity.

P.3.3 Operations

P.3.3.1 SNAS Interactions with NCCDS

The SNAS will provide a 452-ICD-SN/CSM compliant interface with the NCCDS to perform service scheduling, service planning real-time operations, and service performance monitoring.

SNAS will transport all messages received from NCCDS to the MOC Clients in native format as defined in the 452-ICD-SN/CSM.

P.3.3.1.1 Scheduling/Planning

Schedule requests including Schedule Add Request (SAR), Schedule Delete Request (SDR), Replace Requests (RR), Alternate Schedule Add Requests (ASARs) and Wait List Request (WLR) can be created in interactive mode. SNAS will accept and process externally generated batch (bulk) schedule requests consisting of any of these message types.

The SNAS will allow a minimum duration value that is between the nominal service duration and one (1) minute for each service within the SAR and ASAR requests, and prevent the user from specifying a minimum duration value that is out of range.

The SNAS will allow a priority level and the service start time plus and minus tolerances to be specified in the SAR, ASAR and RR messages.

SNAS will allow the generation of coupled services and bound services as defined in the 452-ICD-SN/CSM.

TSWs, PSATs, UAVs, and TCWs can be imported. The SNAS will generate TSWs based on PSATs or UAV and PSAT, or TCWs. The SNAS will also support time-shifting of TSWs by accepting user-entered time interval parameters and regenerating the TSWs based on those parameters.

Mission Prototype Events and scheduling patterns are supported. Users can generate a series of schedule requests using the SNAS RS capability.

When either a USM or SRM is received, the SNAS notifies the user of the message and uses the message content to update status information for display.

P.3.3.1.2 Real-Time Operations

The SNAS fully supports the creation of GCMRs to be transmitted to the NCCDS. When either a GCM Status Message or GCM Disposition message is received, the SNAS notifies the user of the message and uses the message content to update status information for display.

Data monitoring messages including UPD, RCTD, Time Transfer Message (TTM) and Acquisition Failure Notification (AFN) are fully supported. The SNAS uses the SUPIDEN to insure that these messages are only delivered to authorized users. The UPD request message will be automatically transmitted for each event.

P.3.3.2 SNAS Interactions with DAS

The SNAS will provide a 452-ICD-DAS/SNAS compliant interface with the DAS to perform service planning, service allocation, real-time operations, service performance monitoring and data retrieval.

SNAS will transport all messages received from DAS to the MOC Clients in native format as defined in the 452-ICD-DAS/SNAS.

P.3.3.2.1 Scheduling/Planning

Users may request a list of all currently planned events for the mission, the details of a specified planned event, allocation of a specified resource, modification of a pending resource allocation, or deletion of a pending or ongoing resource allocation.

P.3.3.2.2 Real-Time Operations

Users may request reconfiguration of an on-going event or reacquisition of the return service signal. The UPD request message will be automatically transmitted for each event.

P.3.3.2.3 Data Retrieval

Users may request a search for archived data within a specified time window, playback of specific archived data, deletion of a previous playback request, modification of a previous playback request, and the details of a specified planned playback event.

P.3.3.3 SNAS interactions with an EPS

A MOC Customer has the option of providing and using an EPS for enhanced processing and automation of scheduling/planning and real-time monitor and control activities and processes through the interface provided by the SNAS MOC Client application.

The EPS interface is disabled by default. The MOC Mission Manager must enable the EPS interface as part of the MOC Client configuration if MOC operations require use of an EPS.

The interface mechanism will be message exchange. The messages and protocols will be defined in 452-ICD-SNAS/EPS. All of the messages in the 452-ICD-SN/CSM and 452-ICD-DAS/SNAS will be supported as messages encapsulated in either Blocked Message format or Unblocked Message format.

If message pass-through has been enabled by the user, messages from the NCCDS and/or from the DAS will be made available in native format at the EPS interface as they are received by the SNAS MOC client.

The SNAS MOC client will maintain a log of all messages exchanged with the EPS.

Two interface protocols will be offered by the SNAS MOC Client. For the file sharing interface messages will be exchanged either interactively or automatically. The designation of either interactive or automatic will be set for each message in the user configuration file.

For the TCP/IP interface, the user will register SUPIDENS to be supported when the session is initiated. The MOC Client will filter messages to be forwarded to the EPS based on the registered (selected) SUPIDENS.

P.3.3.3.1 Scheduling/Planning

The block formatted schedule request messages used by the bulk scheduling, as developed by SNAS, are supported. The EPS transmits either one or more block formatted schedule request messages or a bulk schedule file in a Bulk Schedule Coordination Message. These messages can contain one or more of the NCCDS schedule request messages including SARs, ASARs, RRs and SDRs, or one or more of

the DAS Resource Allocation Request messages. They are described in detail in the 452-ICD-SNAS/EPS.

The SNAS MOC client breaks out the individual schedule requests and validates each request. Each valid request is forward to the NCCDS, ANCC, or DAS. The MOC Client also sends the appropriate status messages to the EPS.

SRMs and USMs from the NCCDS and scheduling response messages from DAS will be forwarded to the EPS if two conditions are satisfied. The MOC Client must be set to receive the unmodified messages and the MOC Client must be set in the automatic mode for these messages.

TUT will be available as described in Section P.1.2.4. In addition TUT request and response messages that will allow the EPS to request TUT reports on demand are defined in the 452-ICD-SNAS/EPS. DAS planning messages are supported.

P.3.3.3.2 Real-Time Operations

The EPS transmits GCMRs in the format defined by the 452-ICD-SN/CSM. The SNAS MOC client responds with a GCMR Import Status message for each GCMR. The SNAS MOC client can make messages from the NCCDS and DAS available at the EPS interface. The MOC Client must be set to receive the unmodified messages and the interface must be set in an automatic message forwarding mode.

P.3.3.3.3 Orbital Data Operations

The EPS transmits a PSAT file using message 97/04 or a UAV file using message 97/05 or a TCW file using message 97/10. The SNAS MOC client responds with an Orbital Data Status message (97/09). These messages are discussed in Section 5.1.3 of 452-ICD-SNAS/EPS.

P.3.3.3.4 Reports

The EPS requests a report using the Report Request message. The SNAS MOC client replies with a Report Response message and the requested report:

a. Rejected/Declined Events
b. Confirmed Events Listing
c. Confirmed Schedule
d. Confirmed Events Details.

P.4 Performance Characteristics

The SNAS is designed to operate unattended 24 hours-per-day, 7 days-per-week under normal conditions.

P.4.1 Data Capacity

The SNAS has the capability to store data for a minimum of 100 customer platforms to include at least 250 MOC clients. There will be no limit to the number of SIC ID's that SNAS will support. It allocates resources for one set of operational data and for at least one set of test data for each platform.

P.4.2 Communications Capacity

For any combination of Internet, Open IONet, Restricted IONet and Closed IONet SNAS MOC clients, the SNAS servers are capable of supporting simultaneous connections with a minimum of 250 SNAS MOC clients.

P.4.3 Response Times

In general, actual SNAS response times depend on factors that are beyond the control of the SNAS product. Response times are dependent on delays due to factors such as IONet traffic volume and the performance of the infrastructure supporting the SNAS MOC clients. The SNAS servers will take no more than 2 seconds from the receipt of a message to the transmission of that message. This applies both to MOC to NCCDS/DAS messages and NCCDS/DAS to MOC messages. The SNAS server will retrieve data from the database within 5 seconds of receiving a request from a MOC client.

P.4.4 Availability

The SNAS servers are designed for an availability of 0.9999.

P.4.5 Maintainability

Routine maintenance of the servers and routine system administration can be performed off-line without taking the SNAS out of service. In the event of a failure, the MTTR is less than one hour.

P.5 Provisions for Safety and Security

P.5.1 Security Protocols

SNAS security is based on the defense in depth concept. While SNAS is categorized as a low-impact system based on FIPS Publication 199, Standards for Security Categorization of Federal Information and Information Systems, directions and requirements, a superset of the controls called out for low impact systems in NIST 800-53A, Recommended Controls for Federal Information Systems, is implemented because Internet access is allowed and because SNAS has only limited control over user workstations.

The Closed IONet server and the database function as the core SNAS system. These components reside on the Closed IONet. The Open IONet server functions as a

gateway and a proxy for the Closed IONet server. Communications between the Open IONet server and the Closed IONet server are initiated by the Closed IONet server.

The MOC Client further restricts user access from the Open IONet, the Restricted IONet and the Public Internet. Only users with a registered User ID and password can log onto the SNAS through the SNAS MOC Client. The MOC Client menu provides a limited set of actions that a user can perform. The MOC Client menu is tailored to the role and SIC that the user selects during login.

Passwords and data communicated between a MOC Client and a SNAS Server are encrypted. The communication links between the MOC Clients and the SNAS Servers use TCP/IP, which guarantees delivery of data in the order it was transmitted.

Separation of duties is supported by two mechanisms. The SNAS MOC Client menu options are completely different from the menu options offered on the SNAS O&M Client, even though both clients have the same basic design and look and feel. A SNAS MOC Client user cannot be granted privileged access to a SNAS Server and cannot perform any of the O&M functions. A SNAS O&M user cannot perform any of the MOC Planning/Scheduling or Real Time Control functions.

The SNAS MOC Client provides 5 user roles, which are described in Section 5.5.1 of the Space Network Access System Operations Concept Document, 452-OCD-SNAS.DCN003. The SNAS O&M Client only provides the Database Administrator (DBA) role as described in Section 5.5.2 of the Space Network Access System Operations Concept Document, 452-OCD-SNAS.DCN003.

The SNAS ISSO and SA play a central role in maintaining the SNAS Security Posture. The ISSO is responsible for all of the duties described in Sections 2.3.5.2 and 2.3.5.3 of NPR 2810.1. The SA is responsible for all of the duties described in Section 2.3.6 and 11.3.8 of NPR 2810.1. The SA can also take on all or part of the functions of the ISSO.

MOC Users are responsible for the security of the SNAS MOC Client workstations subject to agreed to Rules of Behavior and the Memo of Understanding (MOU). MOC users are subject to the requirements for background checks as set forth in NPR 2810.1, Section 11.3.2 and security training set forth in Chapter 18 of NPR 2810.1. SNAS MOC Client workstations are subject to the conditions set forth in Section 11.3.5 of NPR 2810.1.

Appendix Q. WSC Transmission Control Protocol (TCP)/Internet Protocol (IP) Data Interface Service Capability (WDISC) System

Q.1 General

This appendix describes the capabilities provided by the WDISC system. The WDISC system was delivered into operations on May 1, 1999. It allows Space Network (SN) customers to send command data and receive telemetry data using TCP/IP.

Support is provided via the NASA Integrated Services Network (NISN) Closed IP Operational Network (IONet) using a defined set of authorized addresses. WDISC simultaneously supports up to six forward data channels and six return data channels at both STGT and WSGT. WDISC customers who use GRGT are supported by the WDISC located at WSGT. The Customer MOC interfaces with WDISC via the IONet. The WDISC sends real-time, IP-encapsulated telemetry and playback data files to the MOC via the IONet.

The SN Gateway, described in Appendix R, also provides WDISC services while supporting additional functionality not available on the WDISC; a comparison between the two systems is given in Appendix R.

Q.2 Capabilities

The WDISC Functional Capabilities include the following:

- Receive encapsulated forward service data from a customer MOC via the Closed IONet, convert data to serial form, and present it to a WSC Local Interface (LI) port. (Please refer to Appendix I for a discussion of Closed versus Open IONet.)
- Receive serial return service data from a WSC LI port, encapsulate it, and present it to a customer MOC via the Closed IONet.
- Monitor data, including computing CCSDS statistics, for forward and return data processed.
- Provide for data recording.
- Allow data playback.
- Provide real-time status on forward and return service data at WSC and/or GSFC.

Please see Figure Q-1 for an overview on WDISC.

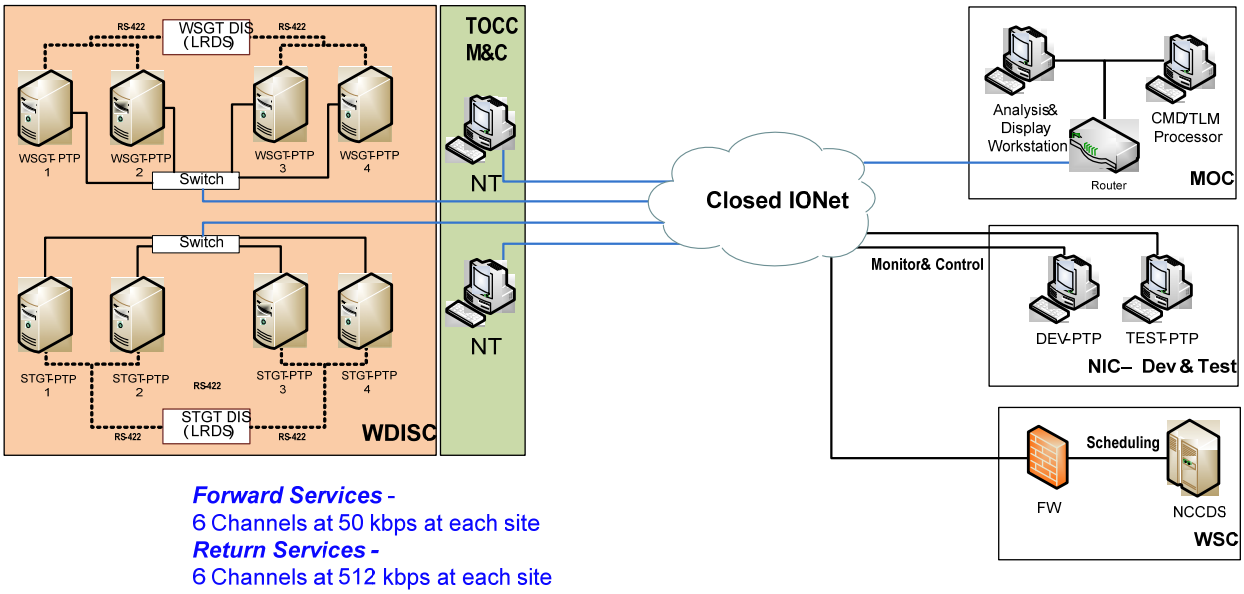

Figure Q-1. WDISC Overview

Q.2.1 IP Routed Data Services

WDISC utilizes a defined set of authorized IP addresses. The TCP/IP protocol used by WDISC allows for reliable delivery of data packets, whereas UDP/IP does not.

WDISC is compatible with the Consultative Committee for Space Data Systems (CCSDS) Telemetry and Telecommand services via use of Programmable Telemetry Processors (PTPs). PTPs are a Commercial Off-the-Shelf (COTS) product. The WDISC PTP vendor has interpreted CCSDS recommendations and coded the PTP software to match their interpretation of customer needs. The WDISC PTP software version excludes any CCSDS SLE functionality but does include Type 1 and 2 CCSDS telemetry frame Virtual Channel processing, randomization, and some types of SFDU headers. CCSDS Command CLTU frames ('Command Link Transmission Unit' frames are the format for command data packets recommended by the CCSDS.) are routinely passed through the computers without manipulation. (Note: CCSDS documents can be found at their website: http://www.ccds.org)

WDISC provides CCSDS compatability that is unavailable from the MDM, such as Reed-Solomon (RS) decoding of telemetry data. WDISC also provides customers with some of the CCSDS space link functions, such as frame synchronization, as well as RS decoding.

The WDISC IP interface is supported via Closed IONet interface (see **Figure Q-2Error! Reference source not found.** and the IONet Access Protection Policy and Requirements (http://www.nisn.nasa.gov/DOCUMENTS1/IONet_Access_Policy_Rev3.doc)). **Because this interface is Unicast IP, it is possible to interface to it via the IONet Secure Gateway System from the Restricted IONet, the Open IONet, or a private network. The legacy MDM interface is targeted for End-of-Life in the near future and, therefore, many new customers will utilize the WDISC and the SN Gateway.**

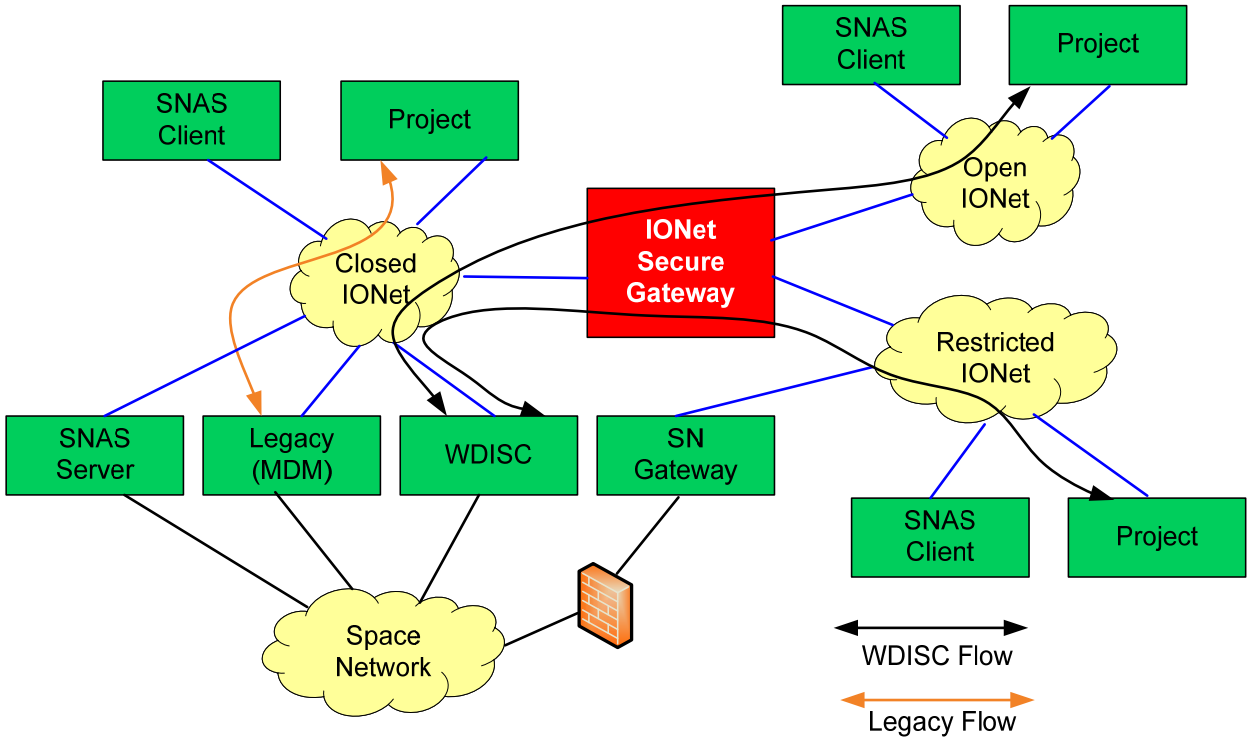

Figure** Q-2. **SN/Customer IP Interfaces

Q.2.2 WDISC and the SN

The WDISC affords TCP/IP customers uniform access to SN services provided by the WSC and Guam ground stations. PTPs provide these capabilities. As with other SN systems, it is scheduled and configured by the NCCDS.

In general, to obtain SN services, please refer to the process provided in Section 4 of this document. However, to obtain WDISC services, in particular, a customer would coordinate with the network integration group at GSFC to start the process. In coordination with the network integration group, WSC operations (which include

database management, testing, trouble shooting, and scheduling) would update the PTP data, update NCCDS databases, and request NISN gateway updates as needed. After customer/WDISC testing, the customer would use the NCCDS scheduling system to get routine WDISC services.

Based on the WSGT and STGT schedules, the NCCDS controls the PTPs at each ground terminal for events that specify WDISC support. The MOC requests playbacks verbally or via email with WSC operations. For playbacks, a special file name (typically corresponding to a date of recording) is put in a PTP desktop and the desktop is activated manually to connect to the MOC and send data.

Customer access to the WDISC is via TCP/IP connection for forward and return services. For forward services, the customer sends data via TCP/IP to the PTP at WSC. The PTP then sends that data to the WSC Local Interface (LI) via one of its PTP boards. The particular LI port to be used is identified by User Interface Channel (UIFC) ID. For return data, the PTP receives the data from the WSC LI via one of its PTP boards. It frame-syncs to the data and performs processing on it, if necessary. The data is then shipped to the customer via a TCP/IP connection. Mission-specific port numbers are assigned to each customer as required for control, as well as for data ports for forward and return services.

Appendix R. WSC SN Gateway System

R.1 General

This appendix describes the capabilities provided by the SN Gateway system. The SN Gateway system became operational in early 2012. It allows SN customers to send command data and receive telemetry data using TCP/IP in a manner similar to the WDISC, but at much higher data rates (up to 6 Mbps). In addition, it provides Space Link Extension (SLE) services. The SN Gateway system is composed of 4 Programmable Telemetry Processors (PTPs) at each WSC ground terminal; PTPs are a Commercial Off-the-Shelf (COTS) product. Each ground terminal group of 4 PTPs has a Redundant Array of Independent Disks (RAID)-based recording system for up to 10 days of network line outage return link data storage. See Figure R-1 for an overview of the SN Gateway.

R.2 SN Gateway

The SN Gateway affords TCP/IP customers uniform access to SN services provided by the WSC and Guam ground stations. As with other SN systems, the SN Gateway is scheduled and configured by the NCCDS. Network connectivity support is provided via the NISN Restricted IONet. Figure R-2 illustrates the SN Gateway system context.

The SN Gateway is fully redundant and consists of 8 PTPs and supporting hardware. Each PTP hosts four processor boards, two each for forward and return services. The four PTPs at each site operate as two redundant pairs of logical PTPs. Forward signals are A/B selected via a forward RS-422 switch controlled by “last socket connected” method, and return signals are distributed from 4 return LRDS ports per ground station to pairs of PTP ports (see Figure R-3).

The SN Gateway utilizes a defined set of authorized IP addresses which are assigned to the PTPs by the CSO. The SN Gateway supports up to 8 simultaneous forward data channels and 8 simultaneous return data channels (4 of each at STGT and WSGT). SN Gateway customers who use GRGT are supported by the SN Gateway located at WSGT. The Customer MOCs interface with the SN Gateway via the Restricted IONet to send IP-encapsulated command data, receive IP-encapsulated telemetry, and download playback data files.

The SN Gateway is compatible with the Consultative Committee for Space Data Systems (CCSDS) Telemetry and Telecommand services. The SN Gateway PTP supports all WDISC operating modes; Table R-1 provides a comparison between the the two systems. The SN Gateway PTP software version includes some CCSDS SLE functionality and supports Type 1 and 2 CCSDS telemetry frame Virtual Channel processing, randomization, and some types of Standard Format Data Unit (SFDU) headers. It should be noted that the SN Gateway may not support a given CCSDS protocol in the fullest sense. Customers are encouraged to discuss protocol implementation details with the SN to determine whether the SN Gateway is able to support specific customer requirements.

In general, to obtain SN services, please refer to the process provided in Section 4 of this document. However, to obtain SN Gateway services, in particular, a customer would coordinate with the network integration group at GSFC to start the process. In coordination with the network integration group, WSC operations (which include database management, testing, troubleshooting, and scheduling) would update the PTP data, update NCCDS databases, and request NISN gateway updates as needed. After customer/SN Gateway testing, the customer would use the NCCDS scheduling system to get routine SN Gateway services. The SN Gateway translates and transports customer-provided forward and return data between the Restricted IONet and RS-422 baseband serial interfaces. The customer MOC resides on the Restricted IONet and the customer spacecraft (via TDRS) communicates on one or more serial interfaces.

Customer events (forward and return channel communications with the spacecraft) are scheduled via NCCDS or SNAS, as mentioned previously. PTPs within the SN Gateway are scheduled as hot redundant pairs; when a customer event starts, both PTPs in the redundant pair are activated. At the discretion of the customer MOC, one or both PTPs may provide return data, allowing best source selection to be performed at the MOC. This capability must be accounted for when budgeting bandwidth during the customer commitment process. In order to avoid duplication of commands during forward links, only a single PTP may provide forward service.

Return data is recorded on the PTPs supporting a customer event and on the SN Gateway's Return Service Data Recorder (RSDR). Recorded data is typically retrieved from the RSDR; recording on the PTP is a backup in the event of an RSDR failure. Recorded data on the RSDRs is synchronized via the IFL at WSC (Figure R-4). PTP recordings are not synchronized to prevent the propagation of erroneous data in case a single PTP malfunctions.

Monitor and control of the SN Gateway PTPs can be accomplished either from the TDRSS Operations Control Center (TOCC) at WSC or from the Network Integration Center (NIC) at GSFC (Figure R-2). TOCC personnel perform monitor and control under typical operations. The NIC is intended as a backup operations site and as a location from which new customer configuration files can be uploaded to the SN Gateway.

The Goddard Space Flight Center (GSFC) Network Interface Center (NIC) located in Building 13 also has Restricted IONet network connectivity to the the SN Gateways at WSC. This is where the network integration group is located. Prior to operational data flows through the SN Gateway, the NIC Network Operations Manager (NOM) can test with various PTP desktop configurations to determine the best PTP settings for the user data during user data flow tests prior to the mission operations phase. The NOM has the capability of changing the SN Gateway PTP configuration to best handle the user data for both forward and return link data. This configuration is finalized with the WSC TOCC operator and after testing completes, the configuration created by the NOM is used by the NCCDS and TOCC to schedule support for that user's operational data for the duration of the user mission.

R.2.1 SN Gateway RSDR

As described previously, the SN Gateway PTPs record return service data to the RSDR (Figure R-4 illustrates the RSDR context). A customer must elect this configuration during the mission commitment process. Unlike previous systems, which relied on either schedule or ad hoc file playback which had to be coordinated so as to not interfere with realtime telemetry, recorded return data can be retrieved from the SN Gateway RSDR at any time using standard file transfer software. The RSDR provides an SSH File Transfer Protocol (SFTP) server that customer MOCs can connect to using standard tools such as cURL, FileZilla, and WinSCP, among others.

The RSDR subsystem is composed of a RAID5 storage device and a COTS server. Each WSC ground termina features an RSDR systeml. The RSDRs synchronize with one another using the IFL so that all recorded files are available from both RSDRs regardless of the ground terminal through which the customer event was supported. Files will be kept on the RSDR for 10 calendar days after recording, after which time they will be automatically deleted.

Files on the RSDR are segregated into different directories by customer, and authentication via username and password prevents MOCs from accessing files belonging to other customers. The file name format for recorded return data is

<Mission>_<SCID>_<terminal>_<Host_PTP>_<Board_ID>_Aos_<doy>_<hh>_<mm>_<ss>_Los_<doy>_<hh>_<mm>_<ss>.bin

All times are in GMT. For example, return data for an RBSP WSGT event recorded from 11:58:01pm on February 18th, 2001 to 12:16:02am on February 19th on WSGT PTP5 would be named

RBSP_01_WSGT_WSGTPTP5_1_Aos_49_23_58_01_Los_50_00_16_02.bin

The RSDR enforces file throttling of customer data transfers to ensure that offline data transfers do not impact realtime telemetry delivery for customers on the Restricted IONet. Any customer wishing to use the RSDR will need to negotiate offline delivery bandwidth during the customer commitment process. The SN Gateway customer is responsible for funding or managing any increase in bandwidth on the Restricted IONet to the SN Gateway PTPs or RSDR.

R.3 SN Gateway Services

The following subsections provide brief descriptions of the SN Gateway services. In some instances a CCSDS service available on the SN Gateway may not be fully compatible with the associated CCSDS recommendadtion, and the customers need to contact the SN Project to obtain implementation details.

R.3.1 Scheduling Services

- The SN Gateway is scheduled through the NCCDS at WSC exactly the same way as WDISC. The user submits SNAS requests to the NCCDS for

scheduling of SN Gateway services and receives responses back from the NCCDS for confirmation of these requests. NCCDS handles all conflicts for the SN Gateway user.

- The SN Gateway activates at T-5 seconds before the scheduled event start.
- The SN Gateway will deactivate and close all TCP/IP connections at T+3 seconds after scheduled completion of the event.
- Return data recordings may be retrieved from the SN Gateway by the user MOC using SFTP. File retrieval is unscheduled, and neither the NCCDS nor the TOCC is involved in this activity.

R.3.2 Forward Link Services

- Receives TCP/IP forward service data from a customer MOC via the Restricted IONet, performs processing on forward service data if requested, converts the forward data to RS-422 synchronous serial data, and inputs the data to a WSC ground terminal LRDS port for continued WSC ground terminal transmission through TDRS to the user spacecraft.
- Supports forward service data rates from 100 bps to 6 Mbps for SLE FCLTU and non-SLE services.
- Supports IPDU, LEO-T, or 4800-bit block de-encapsulation of forward data.
- Supports forward non-SLE IP frame size of 16 bytes to 2048 bytes (not including encapsulation header).
- Acts as an SLE Provider for FCLTU service.
- Supports SLE FCLTU frame sizes of 16 bytes to 2044 bytes not including SLE headers. CLTUS of varying length can be accommodated within a single command session.
- Data processing functions supported in the forward direction include data format conversion, forward error correction encoding, and randomization.
- Monitors data, including computing CCSDS statistics, for forward data processed.

R.3.3 Return Link Services

- Receives synchronous serial RS-422 data from the LRDS at each ground terminal, performs processing on return service data if requested, and converts that data into IP encapsulated or SLE return data for distribution to the MOC user via the Restricted IONet.
- Data processing functions supported in the return direction include frame synchronization, de-randomization, forward error correction decoding, and SLE processing.
- Return service frame synchronization is Performed using CCSDS attached sync markers (ASMs), which are configurable up to 32 bits.

- Supports non-SLE return frame sizes of 128 to 2048 bytes (not including encapsulation).
- If requested, return service data can be IPDU, LEO-T, or 4800-bit block encapsulated prior to forwarding to the MOC.
- Acts as an SLE Provider for RAF and RCF services.
- Supports SLE Complete Online Delivery and Timely Online Delivery modes. Offline delivery is supported through SFTP.
- Supports return service data rates from 1 kbps to 6 Mbps for SLE RAF, SLE RCF and non-SLE services.
- Supports RAF and RCF frame sizes of 256 bytes to 4096 bytes not including SLE headers.
- Can perform Grade 2 Reed-Solomon decoding of data with interleave level 1, 2, 3, 4, 5, or 8.
- Monitors data, including computing CCSDS statistics, for return data processed.
- Timetags return frame data to 100 microsecond accuracy.
- Records return link data per customer, at the customer's request, for up to 10 days to protect against NISN line outages between the WSC and the user facility.

R.3.4 Return Link Line Outage Recording Services

- The Return Service Data Recording (RSDR) equipment records return link data per customer, at the customer's request, for up to 10 days. This option serves as a safeguard in the event of a NISN line outage between the WSC and the user facility.
- The customer retrieves the line outage recorded data via SFTP from the SN Gateway RSDR equipment.
- The SN Gateway RSDR equipment is duplicated across the two WSC ground terminals so that if a failure occurs to one ground terminal RSDR, the other ground terminal's RSDR still retains the data. The two RSDR systems are synchronized with each other using Windows Distributed File System (DFS). See Figure R-4.
- The RSDR supports throttling of NISN line bandwidth to match the customer's line bandwidth requested through the CSO for this service.
- The SN Gateway customer is responsible for arranging and funding file retrieval bandwidth with the CSO during the mission commitment process prior to using the RSDR services from the SN Gateway on the Restricted IONet.

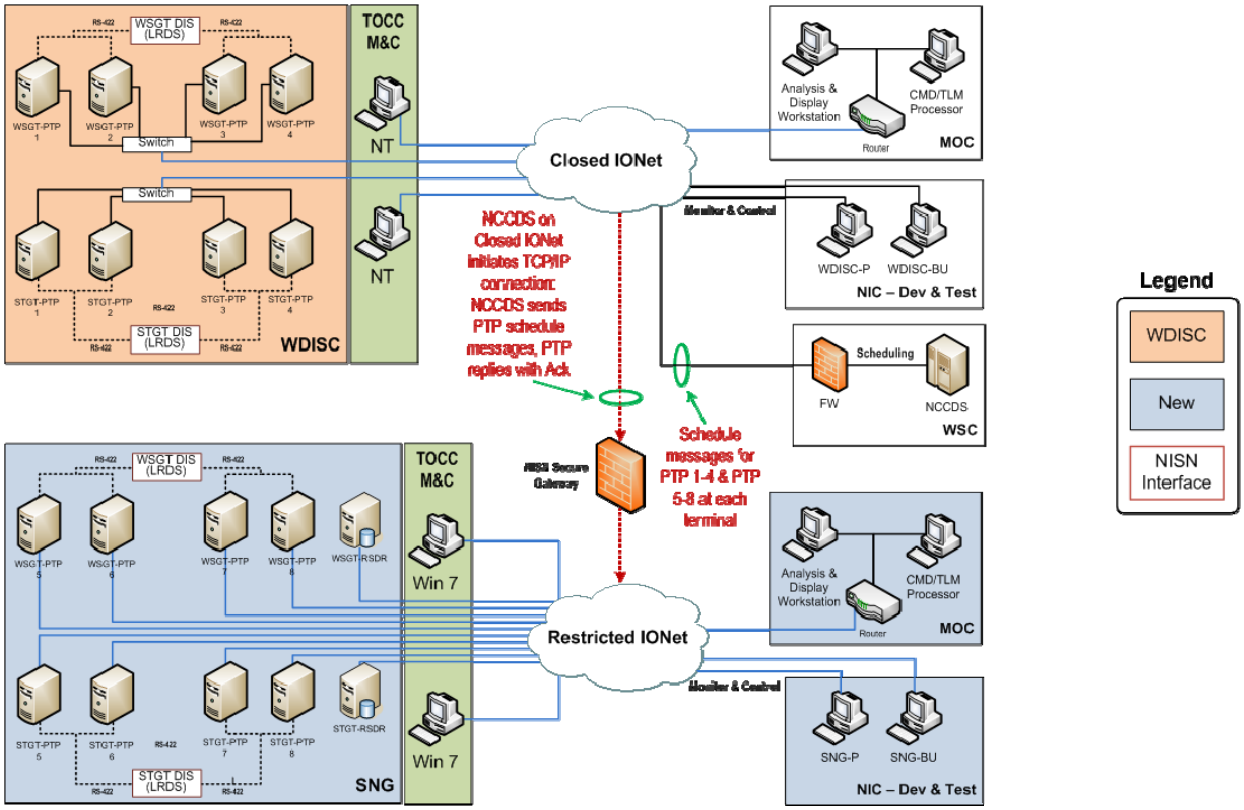

Figure R-1. SN Gateway Overview

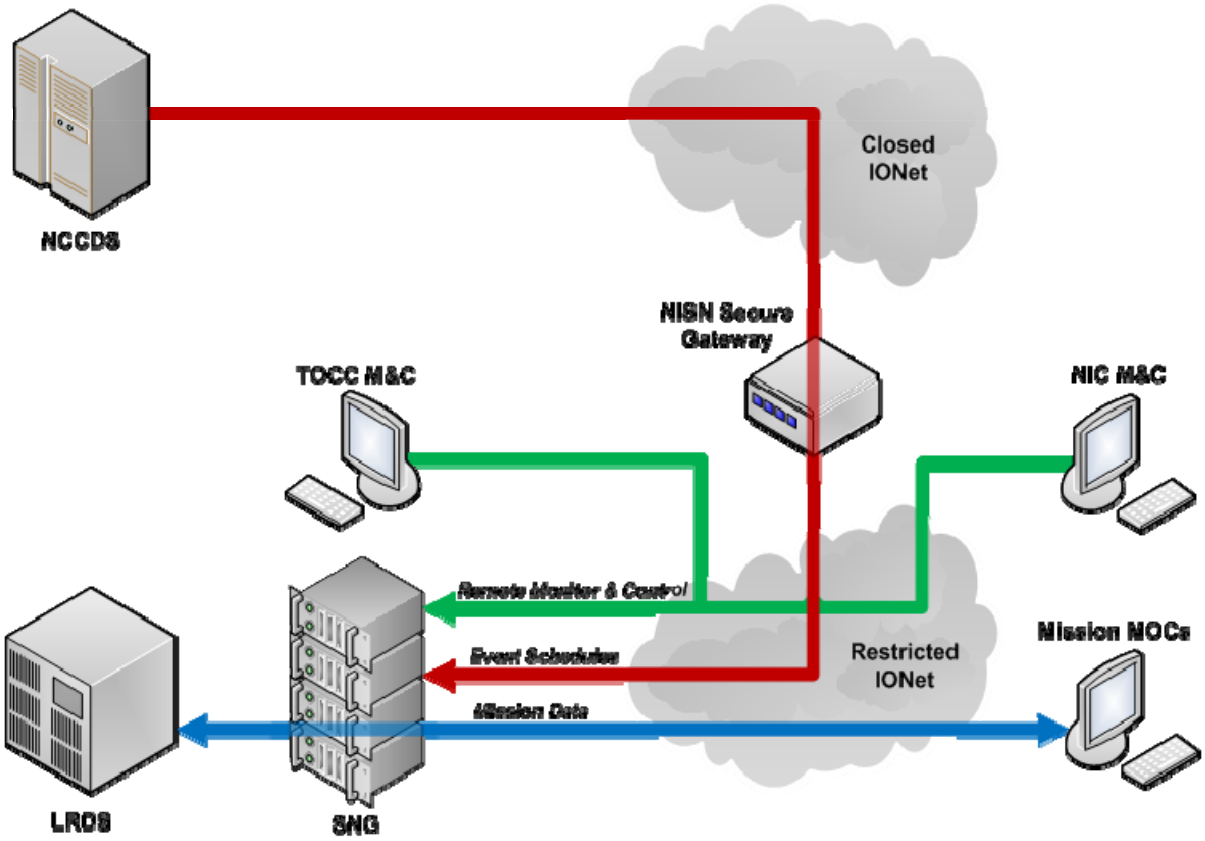

Figure R-2. SN Gateway Context Diagram

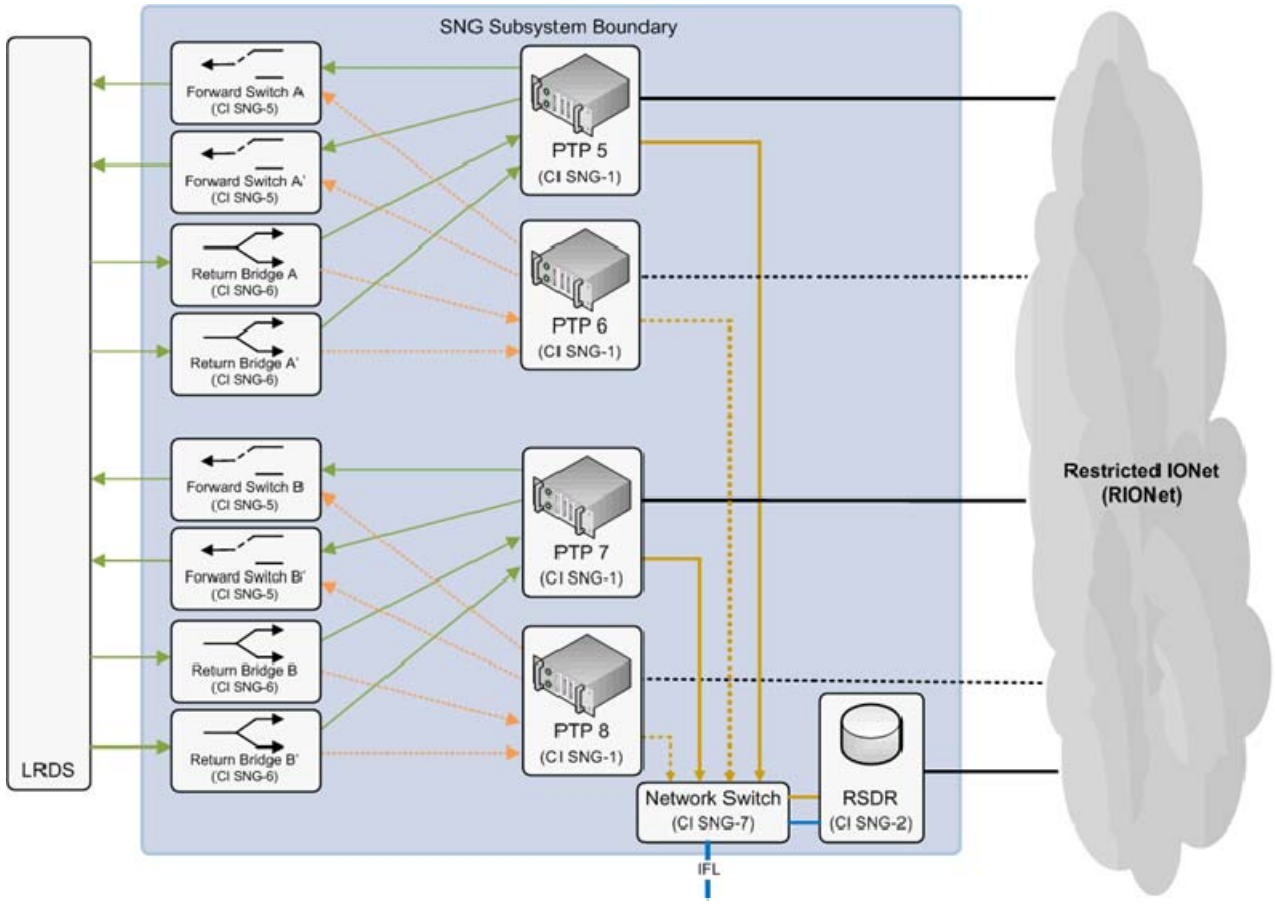

Figure R-3. WSC SN Gateway Interfaces Per Ground Terminal

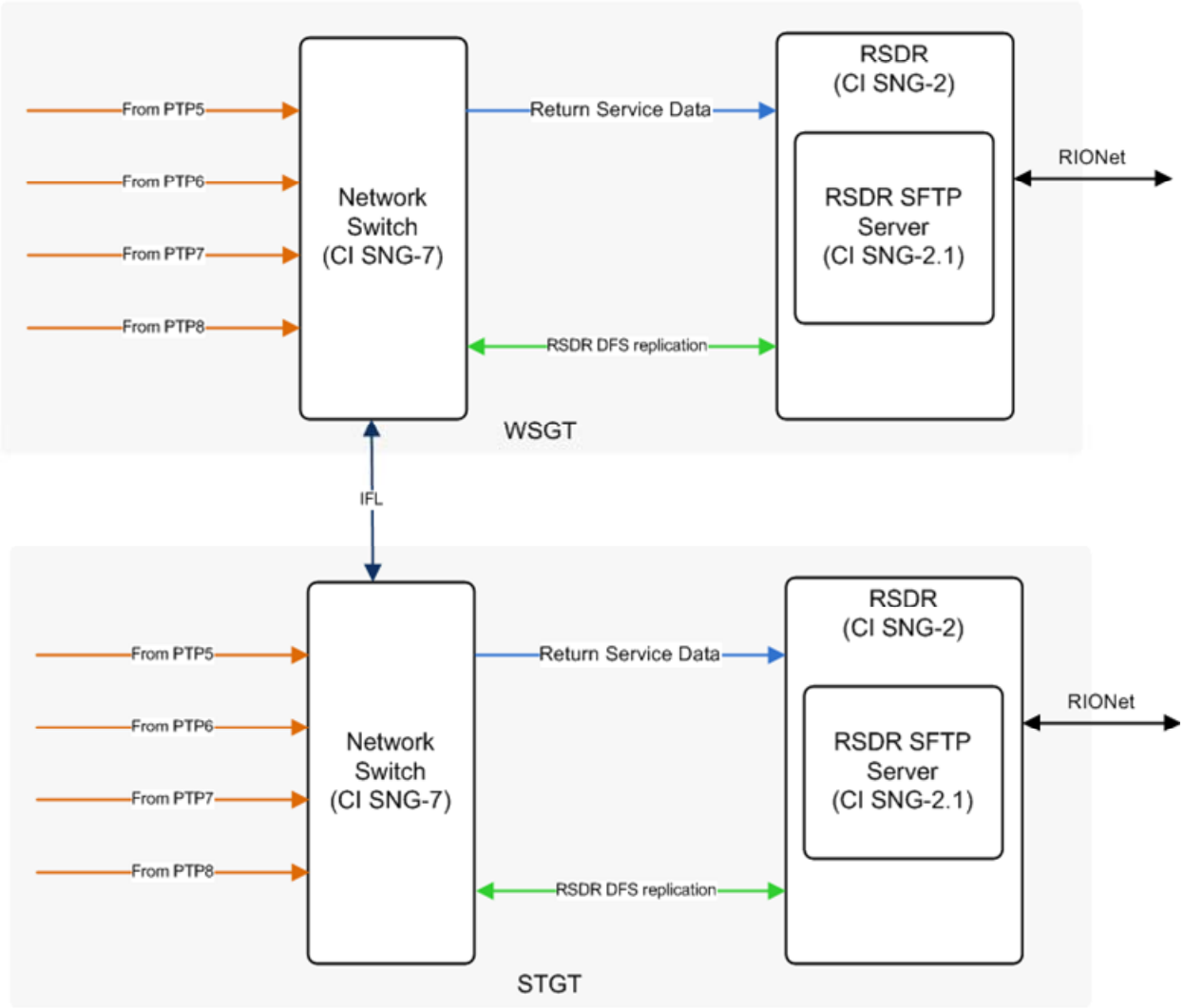

Figure R-4. SN Gateway RSDR Diagram

Table R-1. Comparison of Between WDISC and SN Gateway

Feature	WDISC	SNG
Network Interface	Closed IONet	Restriced IONet
Forward Data Rate	< 50 kbps	100 bps to 6 Mbps
Return Data Rate	< 512 kbps	1 kbps to 6 Mbps
Channels	6 bidirectional per Terminal	4 forward and 4 return per Terminal
Protocols Supported *(partial list)*	• CCSDS Telemetry (TM) • CCSDS Telecommand (TC) • CCSDS AOS • IPDU • LEO-T • 4800 BB	Same as WDISC, plus • CCSDS Space Link Extension (SLE) o FCLTU o RAF o RCF
Data Format Conversion	from NRZ-L to NRZ-M, NRZ-S, BiΦ-L, BiΦ-M, or BiΦ-S	from NRZ-L to NRZ-M, NRZ-S, BiΦ-L, BiΦ-M, or BiΦ-S
Forward Error Correction	Convolutional coding and decoding Reed Solomon decoding	Convolutional coding and decoding Reed Solomon coding and decoding
Post-Realtime Delivery	Scheduled file playback	Unscheduled SFTP file retrieval
Operating System	Windows NT 4	Windows 7 (PTPs, TOCC Workstations) Windows Server 2008 R2 (RSDRs)

Appendix S. SN Future Services

S.1 General

This appendix describes anticipated future SN customer services introduced by the Space Network (SN) Ground Segment Sustainment (SGSS) project expected to be completed by mid-2016. This appendix should be viewed as information only and is not a final commitment for service capability. Significant changes to the capabilities described herein are not anticipated, but are possible. This Users Guide will be updated at the conclusion of the SGSS development effort and will contain a description of the 'as delivered' customer service capabilities.

S.2 Background

STGT and WSGT upgrades were designed and implemented in the early 1990s and some of the systems are reaching or are close to reaching obsolescence. The current system uses equipment and communications protocols that are becoming obsolete and difficult to operate, maintain, and replace since vendors no longer support a majority of these system hardware and software. Spares inventory on many items are at levels that pose risks to the ability to maintain the system, and some online systems have been cannibalized to repair other failed systems to full function. As new systems are acquired to perform upgrades and implement new requirements, it is becoming increasingly difficult to interface those systems with the older systems already in place. The age of the SN ground segment and the risks associated with operating and maintaining the system led the Office of Space Communications and Navigation (SCaN) to initiate a sustainment effort for the core elements of SNGS. The SGSS Project is tasked with determining the appropriate method of sustaining SN operations for a minimum of 25 additional years of service.

The SGSS system replaces a majority of the existing SN Ground Segment with modern technology. SGSS continues to provide the highly available services that users of the SN have come to expect.

S.3 Overview of TDRSS Non-Legacy Capabilities

This section describes anticipated SN support of forward and return user communication services using Single Access (SA) and Multiple Access (MA) capabilities. Please contact the Space Network (SN) Ground Segment Sustainment (SGSS) project to confirm the actual support capabilities.

S.3.1 Forward Services

Table S-1 provides a summary of the new, non-legacy (new capabilities delivered by SGSS) forward signal characteristics that the modems will support in addition to the legacy signal characteristics in Table 3-1 of this document. The maximum available forward service data rates are 300 kbps, 14 Mbps, 50 Mbps, and 50 Mbps for the MA, SSA, KuSA, and KaSA forward services, respectively.

Table S-1. TDRSS Forward Service Signal Characteristics [1]

Service	Modulation	Coding[2]	Data Rate[3]
MAF	PN-Spread BPSK	R ½ Convolutional	1 – 150 kbps
		R ½ LDPC	1 – 150 kbps
		R 7/8 LDPC	1 – 262.5 kbps
		Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	1 – 131.2 kbps
	Unbalanced QPSK, PN-Spread (Range on Q channel)	R ½ Convolutional	1 – 150 kbps
		R ½ LDPC	1 – 150 kbps
		R 7/8 LDPC	1 – 262.5 kbps
		Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	1 – 131.2 kbps
SSAF	Non-Spread BPSK[5]	R ½ Convolutional	150 kbps – 3.5 Mbps
		R ½ LDPC	150 kbps – 3.5 Mbps
		R 7/8 LDPC	262.5 kbps – 6.125 Mbps
		Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	131.2 kbps – 3 Mbps
	PN-Spread BPSK	R ½ Convolutional	1 – 150 kbps
		R ½ LDPC	1 – 150 kbps
		R 7/8 LDPC	1 – 262.5 kbps
		Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	1 – 131.2 kbps
	Non-Spread SQPSK[5]	Uncoded	600 kbps – 14 Mbps
		R ½ Convolutional	300 kbps – 7 Mbps
		R ½ LDPC	300 kbps – 7 Mbps
		R 7/8 LDPC	525 kbps – 12.25 Mbps
		Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	262.3 kbps – 6.1 Mbps
	Unbalanced QPSK, PN-Spread (Range on Q channel)	R ½ Convolutional	1 – 150 kbps
		R ½ LDPC	1 – 150 kbps

Service	Modulation		Coding[2]	Data Rate[3]
			R 7/8 LDPC	1 – 262.5 kbps
			Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	1 – 131.2 kbps
	PM	Direct	R ½ Convolutional	0.125 kbps – 500 kbps
			Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	0.125 kbps – 437 kbps
		PSK Subcarrier	R ½ Convolutional	0.125 – 4 kbps[4]
			Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	0.125 – 3.5 kbps[4]
KuSAF/ KaSAF	Non-Spread BPSK		R ½ Convolutional	150 kbps – 12.5 Mbps
			R ½ LDPC	150 kbps – 12.5 Mbps
			R 7/8 LDPC	262.5 kbps – 21.875 Mbps
			(255,223) Reed-Solomon	262.3 kbps–21.8 Mbps
			Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	131.2 kbps–10.9 Mbps
	PN-Spread BPSK		R ½ Convolutional	1 – 150 kbps
			R ½ LDPC	1 – 150 kbps
			R 7/8 LDPC	1 – 262.5 kbps
			(255,223) Reed- Solomon	1 - 262.3 kbps
			Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	1 - 131.2 kbps
	Non-Spread SQPSK		Uncoded	600 kbps – 50 Mbps
			R ½ Convolutional	300 kbps – 25 Mbps
			R ½ LDPC	300 kbps – 25 Mbps
			R 7/8 LDPC	525 kbps – 43.75 Mbps
			(255,223) Reed- Solomon	524.7kbps –43.73 Mbps
			Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	262.3kbps–21.8 Mbps
	Unbalanced QPSK, PN-Spread		R ½ Convolutional	1 – 150 kbps

Service	Modulation	Coding[2]	Data Rate[3]
	(Range on Q channel)	R ½ LDPC	1 – 150 kbps
		R 7/8 LDPC	1 – 262.5 kbps
		(255,223) Reed- Solomon	1 – 262.4 kbps
		Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	1 – 131.2 kbps

Notes:

1. Support limited to a single data source. For coded services, only alternating symbols will be supported
2. Encoding performed by WSC.
3. Where data rate is defined as the single stream rate provided by the customer. All data rates stated assuming NRZ symbol formatting. If bi-phase symbol formatting is used, data rate maximums must be reduced by a factor of 2. Note that bi-phase symbol formatting is not necessarily supported for every service configuration stated in this table.
4. The subcarrier to data rate ratio (R), where $R = 2^n$ and n = 1 to 7.
5. Stated data rates for this service mode are based upon a customer frequency allocation of approximately 14 MHz. This 14 MHz allocation is consistent with the precedent set by the current Space Network User's Guide. A customer allocation in excess of 6 MHz requires an NTIA waiver.

S.3.2 Return Services

Table S-2 provides a summary of the new, non-legacy (new capabilities delivered by SGSS) return signal characteristics that the modems will support in addition to the legacy signal characteristics in Table 3-2 of this document. Table S-3 provides a summary of the KaSAR-650 MHz Data Service Customer Signal Distortion Constraints.

Table S-2. TDRSS Return Service Signal Characteristics

Service	Data Group	Mode	Modulation	Coding[1]	Data Rate[2]	Data Source	Alt Bits or Sym[7]
MAR	DG1	Mode 1	PN-Spread BPSK	R ½ LDPC	1 - 150 kbps	Single	--
				R7/8 LDPC	1 – 262.5 kbps	Single	--
				Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	1 – 131.2 kbps	Single	--
			SQPN	R ½ Convolutional	1 - 300 kbps	Single	Bits
				R ½ LDPC	1 - 300 kbps	Single	Sym
				R7/8 LDPC	1 - 525 kbps	Single	Sym
				Concatenated (255, 223) Reed-Solomon + R ½ `Convolutional	1 – 262.4 kbps	Single	Sym
		Mode 2	PN-Spread	R ½ LDPC	1 – 150 kbps	Single	--

Service	Data Group	Mode	Modulation	Coding[1]	Data Rate[2]	Data Source	Alt Bits or Sym[7]
			BPSK	R7/8 LDPC	1 – 262.5 kbps	Single	--
				Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	1 – 131.2 kbps	Single	--
			SQPN	R ½ LDPC	1 – 300 kbps	Single	Sym
				R7/8 LDPC	1 – 525 kbps	Single	Sym
				Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	1 – 262.4 kbps	Singlel	Sym
		Mode 3[3]	QPSK	R ½ LDPC	I: 1 -150 kbps[4] Q: 1 kbps – 1.5 Mbps	Dual	--
				R7/8 LDPC	I: 1 - 262.5 kbps Q: 1 kbps – 3.5 Mbps	Dual	--
				Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	I: 1 -131.2 kbps Q: 1 kbps – 1.31 Mbps	Dual	--
	DG2[3]	Coherent and Noncoherent	SQPSK	R ½ LDPC	1 kbps – 4 Mbps	Single	Sym
				R 7/8 LDPC	1 kbps – 7 Mbps	Single	Sym
				Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	1 kbps – 2.62 Mbps	Single	Sym
SSAR	DG1	Mode 1	PN-Spread BPSK	R ½ LDPC	1 - 150 kbps	Single	--
				R7/8 LDPC	1 – 262.5 kbps	Single	--
				Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	1 – 131.2 kbps	Single	--
			SQPN	R ½ LDPC	1 - 300 kbps	Single	Sym
				R7/8 LDPC	1 - 525 kbps	Single	Sym
				Concatenated (255, 223) Reed-Solomon + R ½ `Convolutional	1 – 262.4 kbps[6]	Single, Dual	Bits,Sym
		Mode 2	PN-Spread BPSK	R ½ LDPC	1 – 150 kbps	Single	--
				R7/8 LDPC	1 – 262.5 kbps	Single	--
				Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	1 – 131.2 kbps	Single	--
			SQPN	R ½ LDPC	1 – 300 kbps	Single	Sym
				R7/8 LDPC	1 – 525 kbps	Single	Sym

Service	Data Group	Mode	Modulation	Coding[1]	Data Rate[2]	Data Source	Alt Bits or Sym[7]
				Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	1 – 262.4 kbps[6]	Single, Dual	Bits,Sym
		Mode 3	QPSK	R ½ LDPC	I: 1 -150 kbps[4] Q: 1 kbps – 4.5 Mbps	Dual	--
				R7/8 LDPC	I: 1 - 262.5 kbps Q: 1 kbps – 7.8 Mbps	Dual	--
				Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	I: 1 -131.2 kbps Q: 1 kbps – 2.62 Mbps	Dual	--
	DG2[5]	Coherent and Noncoherent	BPSK	Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	1 kbps – 2.6 Mbps	Single	--
			QPSK, SQPSK	R ½ LDPC	1 kbps – 9 Mbps	Single	Sym
				R 7/8 LDPC	1 kbps – 15.75 Mbps	Single	Sym
				Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	1 kbps – 5.25 Mbps[6]	Single, Dual	Bits, Sym
			8PSK	R ½ LDPC[8]	6 -12 Mbps	Single	Sym
				R 7/8 LDPC	6 – 23.6 Mbps	Single	Sym
	Phase Modulation (PM)	Coherent and Noncoherent	Direct PM	Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	0.125 kbps – 2.62 Mbps	Single	--
			PSK Subcarrier PM	Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	0.125 kbps – 0.44 Mbps	Single	--
		Coherent	PSK Subcarrier PM	Uncoded	0.125 kbps – 1 Mbps	Single	--
				R ½ Convolutional	0.125 kbps – 0.512 Mbps	Single	--
KuSAR	DG1	Mode 1 and 2	PN-Spread BPSK	R ½ LDPC	1 – 150 kbps	Single	--
				R 7/8 LDPC	1 – 262.5 kbps	Single	--
				(255,223) Reed-Solomon	1 – 262.3 kbps	Single	--
				Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	1 – 131.2 kbps	Single	--
			SQPN	R ½ LDPC	1 – 300 kbps	Single	Sym

Service	Data Group	Mode	Modulation	Coding[1]	Data Rate[2]	Data Source	Alt Bits or Sym[7]
				R 7/8 LDPC	1 – 525 kbps	Single	Sym
				(255,223) Reed-Solomon	1 – 525 kbps	Single	Sym
				Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	1 – 262.4 kbps	Single	Sym
	DG2[5]	Coherent and Noncoherent	QPSK, SQPSK	R ½ LDPC	1 kbps – 200 Mbps	Single	Sym
				R 7/8 LDPC	1 kbps – 410 Mbps	Single	Sym
				R 7/8 TPC	1 kbps – 410 Mbps	Single	Sym
				(255,223) Reed-Solomon	1 kbps - 275 Mbps	Single	Sym
				Concatenated (255, 223) Reed-Solomon + R ½ Convolutional	1 kbps – 131.2 Mbps	Single	Sym
		Noncoherent	8PSK	R ½ LDPC[8]	150 – 300 Mbps	Single	Sym
				R 7/8 LDPC	150 – 600 Mbps	Single	Sym
				R 7/8 TPC	150 – 600 Mbps	Single	Sym
KaSAR-225 MHz	DG2 [5]	Noncoherent	QPSK, SQPSK	R ½ LDPC	1 kbps – 200 Mbps	Single	Sym
				R 7/8 LDPC	1 kbps – 410 Mbps	Single	Sym
				R 7/8 TPC	1 kbps – 410 Mbps	Single	Sym
				(255,223) Reed-Solomon	1 kbps -277.52 Mbps	Single	Sym
				Concatenated(255, 223) Reed-Solomon + R ½ Convolutional	1 kbps – 131.2 Mbps	Single	Sym
			8PSK	R ½ LDPC[8]	150 – 300 Mbps	Single	Sym
				R 7/8 LDPC	150 – 600 Mbps	Single	Sym
				R 7/8 TPC	150 – 600 Mbps	Single	Sym
KaSAR-650 MHz	DG2	Noncoherent	SQPSK	Uncoded	300 – 800 Mbps	Single	Bits
				R ½ LDPC	300 – 575 Mbps	Single	Sym
				R 7/8 LDPC	300 - 1000 Mbps	Single	Sym
				R 7/8 TPC	300 - 1000 Mbps	Single	Sym
			8PSK	R ½ LDPC[8]	300 – 850 Mbps	Single	Sym
				R 7/8 LDPC	300 – 1200 Mbps	Single	Sym
				R 7/8 TPC	300 – 1200 Mbps	Single	Sym

Service	Data Group	Mode	Modulation	Coding(1)	Data Rate(2)	Data Source	Alt Bits or Sym(7)

Notes:

1. Decoding performed by WSC.
2. All data rates stated assuming NRZ symbol formatting. If bi-phase symbol formatting is used, data rate maximums must be reduced by a factor of 2. Note that bi-phase symbol formatting is not necessarily supported for every service configuration stated in this table.
3. Applicable to SMAR only.
4. Equipment will also be capable of supporting an I channel with no data present i.e., just the "long" PN code on the I channel.
5. DG2 maximum supported data rates based upon very full use of a 10 MHz customer allocation for SSAR service, a 300 MHz customer allocation for KuSAR and KaSAR-225 MHz service, and an 800 MHz customer allocation for KaSAR-650 MHz.
6. This is the total data rate when dual data source.
7. Applicable to single data source only.
8. 8PSK with rate 1/2 LDPCC service modes is under consideration for deletion. Contact the SN Project Office to determine its status if this modulation/coding combination is deemed needed by the customer.

Table S-3. KaSAR-650 MHz Data Service Customer Signal Distortion Constraints

Parameter (Note)	Requirement (Note)
Minimum channel state symbol transition density	≥ 128 randomly distributed channel state symbol transitions within any sequence of 512 channel state symbols
Consecutive I-channel or Q-channel channel state symbols without a state transition	≤ 64 channel state symbols
Channel state symbol asymmetry (peak)	≤ ± 3 percent
Channel state symbol jitter and jitter rate	≤ 0.1 percent
Phase imbalance	
a. BPSK/QPSK/SQPSK	≤ ± 3 degrees
b. 8-PSK	≤ ± 2 degrees
Gain imbalance	≤ ± 0.25 dB
Phase nonlinearity (peak)	≤ 6 degrees over ± 230 MHz
Gain flatness (peak)	≤ 0.6 dB over ± 230 MHz
Gain slope	≤ 0.1 dB/MHz over ± 230 MHz
AM/PM	≤ 6 degrees/dB
Noncoherent frequency stability (peak) (± 300 kHz customer oscillator frequency uncertainty)	
1-sec observation time	$\leq 3 \times 10^{-9}$
Lifetime	$\leq 1.1 \times 10^{-5}$
Incidental AM (peak)	
a. For open-loop pointing at frequencies ≥ 100 Hz	≤ 5 percent
b. For autotrack performance	
At frequencies: 10 Hz – 10 kHz	≤ 3 percent
At frequencies: 10 Hz – 2 kHz	≤ 0.6 percent

Parameter (Note)	Requirement (Note)
Spurious PM	≤ 2 degrees
Minimum 3-dB bandwidth prior to power amplifier	≥ 2 times maximum channel baud rate
Phase noise	
1 Hz – 10 Hz	≤ 50.0 degrees rms
10 Hz – 100 Hz	≤ 20.0 degrees rms
100 Hz – 1 kHz	≤ 3.6 degrees rms
1 kHz – 400 MHz	≤ 2.0 degrees rms
In-band spurious outputs, where in-band bandwidth is twice the maximum channel symbol rate	≤ -30 dBc
Out-of-band emissions	See Appendix D of SNUG for allowable levels of customer out-of-band emissions, including spurs
I/Q channel state symbol skew (peak)	≤ 3 percent
Axial ratio	≤ 3 dB
Data rate tolerance	≤ ± 0.1 percent
I/Q power ratio tolerance	≤ ± 0.4 dB
Note: The definitions and descriptions of the customer constraints are provided in SNUG, Appendix E.	

S.3.3 Tracking Services

New tracking services offered by SGSS include Ka-band one-way return Doppler tracking and Demand Access Service (DAS) tracking service.

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Appendix T. User Spacecraft Clock Correlation System

T.1 General

There are several ways of setting or correlating a clock in space with an Earth based time standard. Use of Global Positioning System (GPS) for position and time is becoming very common. But we need to set clocks on near Earth satellites that are outside the GPS constellation, do not have a GPS receiver, or are in deep space. This is commonly done by using either an RF signal that travels one way (spacecraft to Earth or Earth to spacecraft) or for more accurate correlations, a signal that travels two ways (Earth to satellite and back to Earth). These techniques can also be used between any two nodes, such as a space station and another satellite. Setting a clock at one point to agree with another one at a different location is referred to as time transfer. The one way method is referred to as the Return Data Delay (RDD) method or the RCTD method. Some missions use the uplink instead of the down (return) link. The principals are the same but the higher data rate on the down/return link allows for more accurate time correlation. The TDRSS uses PN spread spectrum for ranging, which lends itself to an accurate two way time transfer method called the USCCS. USCCS is outlined here and is more fully described in the USCCS User Guide [452-UG-USCCS] which also covers the RDD methods. In this discussion we do not concern ourselves with the various hardware delays that must be taken into account and are fully covered in the 452-UG-USCCS.

T.2 Overview

The fundamental principal of the USCCS is shown in Figure T-1. A signal, a PN epoch, is sent from the ground to a User spacecraft via a TDRS and back to the ground. When the signal arrives at the User spacecraft, it triggers a reading of the spacecraft clock. We call this the Spacecraft Time and the reading is sent to the ground via the normal spacecraft telemetry. Knowledge of when the signal left the ground, t_1, and when it returned, t_3, is used to accurately calculate when it was at the spacecraft and triggered the reading of the spacecraft clock, t_2. On the ground, the reading on the clock is compared to the time that the reading was triggered by the epoch. This results in a measurement (not a calculation) of the spacecraft clock error from UTC. For each transmitted PN epoch, there is a set of t_1, t_2, t_3 but we have not used notation here to distinguish one set from another.

It is up to the User MOC to manage the spacecraft clock. Some projects adjust the oscillator frequency that drives the clock, some reset the clock, and some just maintain a table of Spacecraft Time vs. UTC.

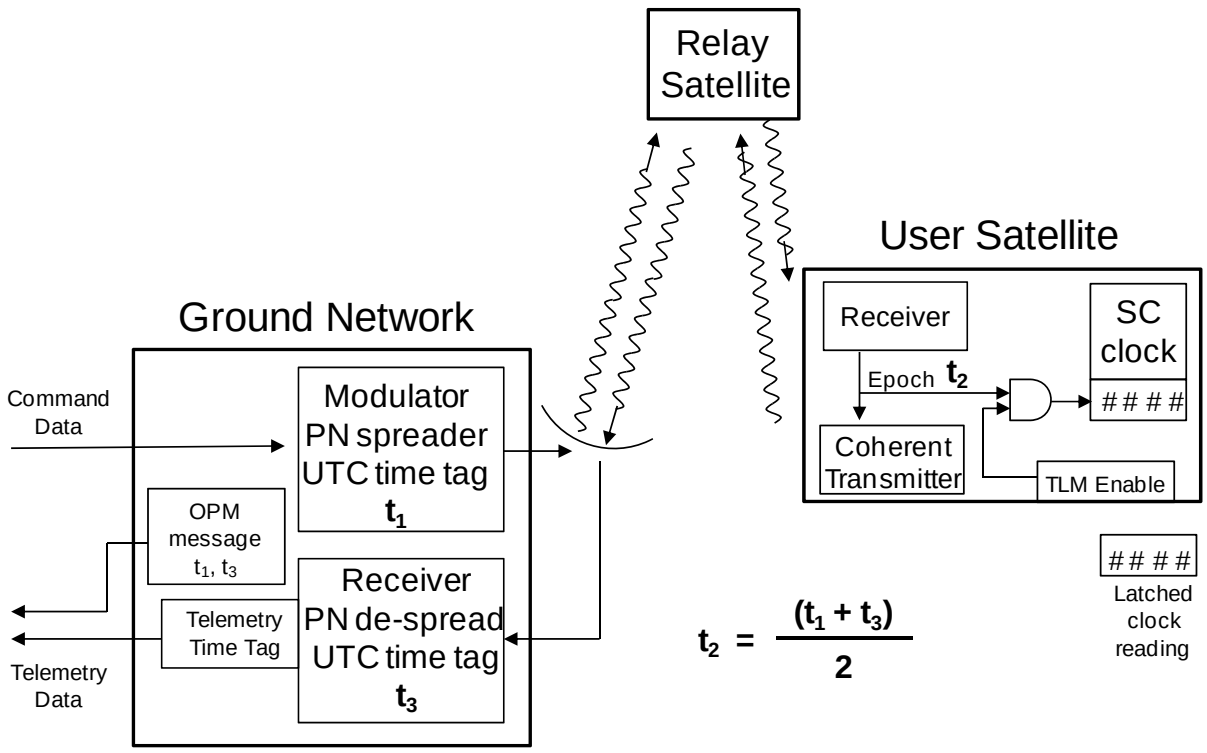

Figure T-1. Block Diagram of Time Transfer Signal and Data Flow

Using the USCCS requires knowledge of details of the TDRSS PN ranging system since the epochs in the PN range code are used as the timing signals. Figure T-2 shows the geometry of the range measurement. The full range that the signal travels from the ground network element (WSC) to the TDRS relay satellite at Geosynchronous Earth Orbit (GEO), to the User satellite and then back to the ground network elements is of the order of 140,000 Km => 0.47 sec. The range channel PN code is 1023 x 256 = 261,888 chips long and is transmitted at approximately 3.08 Mcps, making the period of the code 261888/3.08 Mcps = 0.085 sec. At the speed of light, this will cover a distance of d = c t = 2.9979×10^5 Km x 0.085 sec = 25491 Km. It initially appears that the range cannot be unambiguously measured with range PN patterns of this length. But, since the maximum range variation of a LEO satellite as seen by a GEO relay satellite is only a little more than the Earth's radius of 6378 Km, the required range variation measurement only needs to be about 8000 Km, and the two way variation is thus 16000 Km. The 25,000 Km length PN code is sufficient to unambiguously locate a LEO satellite. It is then also sufficient to be used unambiguously for time transfer for a LEO satellite.

T.2.1 Using Range PN Codes for Spacecraft Clock Correlation

USCCS, being a two way method, requires a coherent spread spectrum link (DG1, modes 1 or 3) and is very similar in concept to a ranging measurement. For a ranging measurement, the difference in the time from when a PN epoch leaves the WSC, t_1, and the time that the epoch returns to the WSC, t_3, is recorded, accurate to a few 10s of

nanoseconds, i.e. 30 ns => 9 m. Of course, we must also know when this difference measurement was made. Since a LEO spacecraft is only moving at about 8 Km/sec, it only moves about 8 m in a millisecond so the absolute UTC time of the ranging measurement need not be to the nanosecond accuracy required by the range measurement, approximately a millisecond will do. On the other hand, in order for clock correlation to be accurate to about 1 microsecond, even though we do not need to know the round trip transit time accurate to 10s of nanoseconds, we do need to know when the signal leaves the ground terminal and when it returns to the ground terminal, accurate to within a microsecond of UTC.

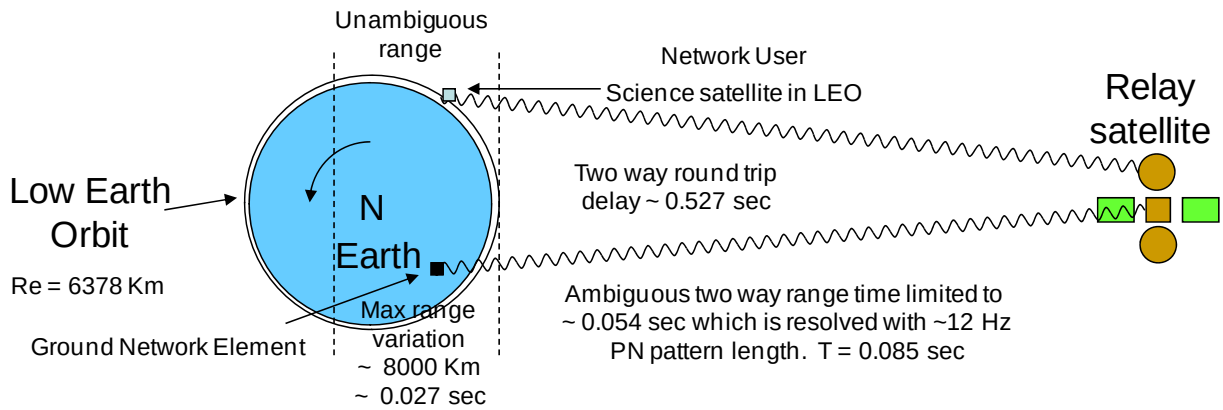

Figure T-2. Block Diagram of Time Transfer Signal and Data Flow

T.2.2 Time Transfer Messages

At the User request, the TDRSS can generate an OPerations Message (OPM66) that contains the time that the epochs left the ground station (t_1s) and the time that the epochs returned to the ground station (t_3s). This information is in PB4 time format which is granulated to a fraction (1/16) of a microsecond. The absolute accuracy with respect to UTC, however, is only as good as the ground station's time keeping with respect to UTC. The requirement has been that the ground station time must be within 5 microseconds of UTC but with GPS time transfer to the Ground station, it is generally kept to within 1 microsecond of UTC. Forward and Return epochs occur every 85 ms. In order to reduce the OPM 66 message size, only the first epoch after the one second roll over is transmitted. The software at the User MOC that processes the time data must use the knowledge that epochs occur approximately every 85 milliseconds and interpolate from the OPM data to evaluate all of the epoch times. Variation due to Doppler from second to second is small enough that the interpolated values will be accurate to better than a microsecond.

T.2.3 User Transponder and Spacecraft Processing

In order to make use of the USCSS service, the User transponder must be capable of coherent PN ranging. In addition, the transponder must output a pulse to the Command

And Data Handling (C&DH), referred to as a Time Transfer Epoch that is synchronized to the simultaneous receipt and transmission of the epoch in the PN range code that is modulated on the RF link. The Spacecraft C&DH system must use that epoch to read the spacecraft clock and the spacecraft processing system must place that clock reading in telemetry that is sent to the ground. When using CCSDS virtual channels, a Time Packet is used that has a specific Application Identification (APID) within the Virtual Channels Identification (VCID) used for real time spacecraft housekeeping.

Epochs occur every 85 ms and using every one over a 5 minute period as an example, would result in far more data than is needed. In 5 minutes, 3529 epochs will occur. It is necessary for the ground processing to be able to figure out which epoch caused which clock reading. To correlate all of the data and limit the over burden, several missions have used a circuit that has the reading of the spacecraft clock generally disabled, and only enables the reading of the clock at some limited interval. For example, every 16th housekeeping Virtual Channel Data Unit (VCDU) is used by several missions. A circuit monitors the sequence count of the housekeeping VCDUs and only when the last 4 bits of the sequence count is all ones (xx…xxx1111) is the epoch circuit enabled. This is indicated in Figure T-1 on the lower right of the User Satellite block by the TLM Enable. As a frame with such a sequence count leaves the C&DH on the way to the transmitter, the t_2 circuit is enabled. Upon arrival of the next Time Transfer Epoch, the spacecraft clock is read and the circuit is again disabled. Both the reading on the spacecraft clock and the sequence count of the VCDU is placed in the Time Packet and sent to the ground. At this point, there is no urgency, the time packet can arrive at the ground in a later VCDU without loss of accuracy.

T.2.4 Determine the Spacecraft Clock Error

We need to determine which epoch triggered which spacecraft clock reading.

When the User spacecraft telemetry arrives at the ground (WSC) the data is time tagged with a ground receipt time (GRT, also called Earth Receipt Time, ERT). As IP has come to dominate ground data handling, a GRT may not be available to all customers. The MOC time processing software uses the GRT of the frames that enabled the spacecraft clock reading to estimate the time that the enable occurred. This involves a simple calculation similar to that used for the less accurate RDD method of clock correlation. An approximate range time to the satellite must be known in order to subtract the space propagation delay from the GRT in order to estimate when the VCDU enabled the clock reading by the Time Transfer Epoch. As complicated as it may sound, one of the nice things about the USCCS is that the OPM 66 contains a list of t_1 and t_3 times making is almost trivial to determine the spacecraft to ground propagation time. From orbit geometry, we know that the minimum round trip propagation time is at least 0.5 seconds.

The following steps are how the data is processed:

1. Examine a time packet and find the sequence count of the frame that is associated with the clock reading in that time packet.
2. Find that frame and determine the GRT for that frame.

3. Using the list of t_3s, pick the one that is close to the GRT.
4. Using the list of t_1s, find the one that is at least 0.5 sec before the chosen t_3.
5. Take the difference between this t_1 and t_3 to get the round trip light time.
6. Divide by 2 to get the one way light time, the one way range time.
7. Subtract this from the frame GRT to get the approximate epoch enable time.
8. Calculate and make a table of the possible t_2 values. Do this by looking at the t_1 values and then finding the first t_3 that is at least 0.5 seconds later, $t_2 = (t_1+t_3)/2$.
9. Using the table of t_2 values, find the first one after the enable time found in line 7.
10. t_2 is the UTC time that the clock was read. By comparing this to the clock reading in the time packet used in line 1.
11. Define the term Clock Error. For example, True UTC time = clock reading - Clock Error, hence Clock Error = Clock reading – True UTC time = Clock Reading – t_2.
12. Using several time packets, make a table of clock error values. Over about 5 minutes, the errors should be all the same to better than a microsecond accuracy. Delete any outliers that occurred due to the estimate of the epoch enable time.

T.2.5 Clock Correlation Conclusion

The forward range (long code) epoch UTC transmit times, t_1, and the received range epoch UTC times, t_3, are recorded at the WSC network element. These times are made available to the User processing center for the purpose of correlating a spacecraft clock with a ground time standard, UTC, to within about 1 microsecond.

The biggest contributor to inaccuracy in the RDD clock correlation method is the inaccuracy of the spacecraft to ground propagation time which is usually based on a predicted orbit vector. When using the USCCS, the OPM 66 gives that time, measured to a fraction of a microsecond, and eliminates the inconvenience and mistakes that are made when running orbit software to determine the spacecraft to ground propagation time.

By using the received forward epoch to stimulate a reading of the spacecraft clock, and sending that reading to the operation center via spacecraft telemetry, spacecraft clock error may be determined. The calculation of the epoch arrival time at the spacecraft

$$t_2 = (t_1 + t_3)/2$$

is correct independent of the motion of the User spacecraft but is limited to about 1 µs accuracy due to the motion of the relay satellite and ground based network element as the Earth rotates. When microsecond or sub microsecond time correlation is desired, and GPS is not available, the USCCS can be used but there are additional orbit geometry considerations and relativistic effects that the user must consider.

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Appendix U. Recommended Customer Phase Noise Performance for Doppler Tracking Services

This Appendix provides recommended customer phase noise performance for Doppler tracking services. The customer phase noise guidance provided in this appendix will ensure a total Doppler tracking error (system + customer) ≤ 0.2 rad/sec (1σ, channel data rate > 1 kbps) or ≤ 0.4 rad/sec (1σ, channel data rate ≤ 1 kbps) assuming an averaging time of 1 second.

Tables U-1 through U-3, provide recommended customer phase noise performance for Doppler tracking services using MAR, SSAR and KuSAR services, respectively.

Table U-1. TDRSS MAR Service Recommended Customer Phase Noise Performance for Doppler Tracking Services

Parameters	Description
Phase noise (rms) (Notes 1, 4)	
DG1 Mode 1 (Note 2)	
All baud rates	
1 Hz – 10 Hz	≤1.0° rms
10 Hz – 1 kHz	≤1.0° rms
1 kHz – 3 MHz	≤1.5° rms
DG1 Mode 2 (Note 3)	
All baud rates	
1 Hz – 10 Hz	≤ 2.0° rms
10 Hz – 100 Hz	≤ 1.0° rms
100 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 3 MHz	≤ 2.0° rms
DG1 Mode 3 (applicable to SMA only) (Note 2)	
All baud rates	
1 Hz – 10 Hz	≤ 1.0° rms
10 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 6 MHz	≤ 1.5° rms

Table U-1. TDRSS MAR Service Recommended Customer Phase Noise Performance for Doppler Tracking Services (cont'd)

Parameters	Description
Phase noise (rms) (Notes 1, 4) (cont'd)	
DG2 Coherent (applicable to SMA only) (Note 2)	
All baud rates	
1 Hz – 10 Hz	≤1.0° rms
10 Hz – 1 kHz	≤1.0° rms
1 kHz – 3 MHz	≤2.0° rms
DG2 Noncoherent (applicable to SMA only) (Note 3)	
All baud rates	
1 Hz – 10 Hz	≤ 2.0° rms
10 Hz – 100 Hz	≤ 1.0° rms
100 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 3 MHz	≤ 2.0° rms

Notes:

1. Derivation of the phase noise requirements involved making assumptions about the distribution of the phase noise power in each frequency region. Since no phase noise PSD will exactly match the phase noise power distribution assumed for this derivation, phase noise PSDs which are close to violating the phase noise limits or phase noise PSDs which violate the phase noise limits should be evaluated on a case-by-case basis to determine their acceptability.
2. Coherent return link recommended phase noise performance assumes a forward service signal with no phase noise on it. Phase noise created in the user receiver carrier tracking loop by thermal noise on the forward link is a component which must be considered as a contributor to the user coherent return service phase noise.
3. If one-way Doppler tracking is required for orbit determination during customer launch and early orbit, contact NASA/GSFC Flight Dynamics (Code 595) for additional information and guidance about oscillator uncertainty.
4. Users are encouraged to minimize phase noise contributions below 1 Hz as this phase noise has a substantial impact on Doppler tracking error.

Table U-2. TDRSS SSAR Service Recommended Customer Phase Noise Performance for Doppler Tracking Services

Parameter	Description
Phase noise (rms) (Notes 1, 4)	
DG1 Mode 1 (Note 2)	
All baud rates	
1 Hz – 10 Hz	≤1.0° rms
10 Hz – 1 kHz	≤1.0° rms
1 kHz – 6 MHz	≤1.5° rms
DG1 Mode 2 (Note 3)	
All baud rates	
1 Hz – 10 Hz	≤ 2.0° rms
10 Hz – 100 Hz	≤ 1.0° rms
100 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 6 MHz	≤ 1.5° rms
DG1 Mode 3 (Note 2)	
All baud rates	
1 Hz – 10 Hz	≤ 1.0° rms
10 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 6 MHz	≤ 1.5° rms
DG2 Coherent (Note 2)	
All baud rates	
1 Hz – 10 Hz	≤1.0° rms
10 Hz – 1 kHz	≤1.0° rms
1 kHz – 6 MHz	≤2.0° rms
DG2 Noncoherent (Note 3)	
All baud rates	
1 Hz – 10 Hz	≤ 2.0° rms
10 Hz – 100 Hz	≤ 1.0° rms
100 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 6 MHz	≤ 2.0° rms

Table U-2. TDRSS SSAR Service Recommended Customer Phase Noise Performance for Doppler Tracking Services (cont'd)

Notes:

1. Derivation of the phase noise requirements involved making assumptions about the distribution of the phase noise power in each frequency region. Since no phase noise PSD will exactly match the phase noise power distribution assumed for this derivation, phase noise PSDs which are close to violating the phase noise limits or phase noise PSDs which violate the phase noise limits should be evaluated on a case-by-case basis to determine their acceptability.
2. Coherent return link recommended phase noise performance assumes a forward service signal with no phase noise on it. Phase noise created in the user receiver carrier tracking loop by thermal noise on the forward link is a component which must be considered as a contributor to the user coherent return service phase noise.
3. If one-way Doppler tracking is required for orbit determination during customer launch and early orbit, contact NASA/GSFC Flight Dynamics (Code 595) for additional information and guidance about oscillator uncertainty.
4. Users are encouraged to minimize phase noise contributions below 1 Hz as this phase noise has a substantial impact on Doppler tracking error.

Table U-3. TDRSS KuSAR Service Recommended Customer Phase Noise Performance for Doppler Tracking Services

Parameter	Description
Phase noise (rms) (Notes 1, 4)	
DG1 Mode 1 (Note 2)	
All Baud rates	
1 Hz – 10 Hz	≤3.0° rms
10 Hz – 1 kHz	≤3.0° rms
1 kHz – 150 MHz	≤1.4° rms
DG1 Mode 2 (Note 3)	
Channel baud rate < 16 ksps	
1 Hz – 10 Hz	≤ 4.0° rms
10 Hz – 100 Hz	≤ 3.0° rms
100 Hz – 1 kHz	≤ 1.8° rms
1 kHz – 150 MHz	≤ 1.4° rms

Table U-3. TDRSS KuSAR Service Recommended Customer Phase Noise Performance for Doppler Tracking Services (cont'd)

Parameter	Description
Phase noise (rms) (Notes 1, 4) (cont'd)	
DG1 Mode 2 (Notes 3) (cont'd)	
Channel baud rate ≥ 16 ksps	
1 Hz – 10 Hz	≤ 15.0° rms
10 Hz – 1 kHz	≤ 4.0° rms
100 Hz – 1 kHz	≤ 2.0° rms
1 kHz – 150 MHz	≤ 2.0° rms
DG2 Coherent (Note 2)	
All baud rates	
1 Hz – 10 Hz	≤3.0° rms
10 Hz – 1 kHz	≤1.8° rms
1 kHz – 150 MHz	≤1.0° rms
DG2 Noncoherent (Notes 3)	
Channel baud rate < 108.5 ksps	
1 Hz – 10 Hz	≤ 4.0° rms
10 Hz – 100 Hz	≤ 2.5° rms
100 Hz – 1 kHz	≤ 1.4° rms
1 kHz – 150 MHz	≤ 1.4° rms
Channel baud rate ≥ 108.5 ksps	
1 Hz – 10 Hz	≤ 15.0° rms
10 Hz – 100 Hz	≤ 5.5° rms
100 Hz – 1 kHz	≤ 2.0° rms
1 kHz – 150 MHz	≤ 2.0° rms

Notes:

1. Derivation of the phase noise requirements involved making assumptions about the distribution of the phase noise power in each frequency region. Since no phase noise PSD will exactly match the phase noise power distribution assumed for this derivation, phase noise PSDs which are close to violating the phase noise limits or phase noise PSDs which do violate the phase noise limits should be evaluated on a case-by-case basis to determine their acceptability.
2. Coherent return link recommended phase noise performance assumes a forward service signal with no phase noise on it. Phase noise created in the user receiver carrier tracking loop by thermal noise on the forward link is a component which must be considered as a contributor to the user coherent return service phase noise.
3. If one-way Doppler tracking is required for orbit determination during customer launch and early orbit, contact NASA/GSFC Flight Dynamics (Code 595) for additional information and guidance about oscillator uncertainty.
4. Users are encouraged to minimize phase noise contributions below 1 Hz as this phase noise has a substantial impact on Doppler tracking error.

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Glossary

μsec	microsecond
ACE	Advanced Composition Explorer
ACRS	Automated Conflict Resolution System
ADR	achievable data rate
AFN	Acquisition Failure Notification
AM	amplitude modulation
ANCC	Auxiliary Network Control Center
AOS	Advanced Orbiting System
AS	Antenna Subsystem
ASAR	Alternate Schedule Add Request
ASCII	American Standard Code for Information Interchange
ASF	Alaska Satellite Facility
ATF	Australian TDRS Facility
AWGN	Additive White Gaussian Noise
AXAF-I	Advanced X-ray Astrophysics Facility - Imagery
baud rate	rate at which a characteristic (i.e., phase, frequency, amplitude) of a carrier wave is changed by the modulating signal
BCH	Bosc Chaudhuri Hocquenghem
BER	bit error rate
BERTS	bit error rate test system
Biϕ	biphase
Biϕ-L	biphase level
Biϕ-M	biphase mark
Biϕ-S	biphase space
B_L	loop noise bandwidth
BM	Briefing Message
bps	bits per second
BPSK	binary phase shift keying
BRTS	Bilateration Ranging Transponder System

BSR	bit slippage rate
BW	bandwidth
C	increase in the predicted customer frequency uncertainty due to the WSC software rounding off the customer receive frequency contained in the SHO
C&DH	Command and Data Handling
C/N	ratio of carrier power-to-noise power (dB)
C/No	carrier power-to-noise spectral density ratio (dB-Hz)
CCB	Configuration Control Board
CCR	Configuration Change Request
CCS	Communications and Control Segment
CCSDS	Consultative Committee for Space Data Systems
CDS	Comprehensive Discrepancy System
CF	center frequency
channel	link subdivision used for information transfer and/or two-way range measurement
channel BW	6 MHz for MA, 10 MHz for SSA, 225 MHz for KuSA, 225 MHz or 650 MHz, selectable by ground, for KaSA return links
chip	one bit of a PN sequence as opposed to data bits
CLASS	Communications Link Analysis and Simulation System
CLTU	Command Link Transmission Unit
CMD	command
CMO	Configuration Management Office
command channel	forward service data channel
COTS	commercial off-the-shelf
CRC	Cyclic Redundancy Check
CSO	Communications Service Office
CSR	Customer Service Representative
CTL	Compatibility Test Laboratory
CTP	Compatibility Test Plan
CTR	Compatibility Test Report
CTV	Compatibility Test Van
DAS	Demand Access System

data BW	bandwidth in Hz equal to two times the baud rate
data channel	an independent data signal contained within a link
data rate	rate of a digital information data signal before convolutional encoding and/or conversion to biphase format
DBA	Data Base Administrator
dB	decibel
dBc	dB below total signal power
dBi	decibels referenced to an isotropic radiator
dBmi	decibels referenced to one milliwatt isotropically received power
dBW	decibel relative to one watt
dBWi	decibels referenced to one watt isotropically received power
DCE	Doppler compensation enabled
DCI	Doppler compensation inhibited
DCN	Document Change Notice
DG1	Data Group 1
DG2	Data Group 2
DIS	Data Interface System
DMU	Demodulator Unit
DOMSAT	Domestic Communications Satellite
DPM	Data Presence Monitoring
DQM	data quality monitoring
dr	data rate
DSMC	Data Service Management Center
DSN	Deep Space Network
DUT	Device Under Test
E	maximum uncompensated Doppler on the TDRS forward link signal arriving at the customer platform (Hz); East
EBNet	EOS Backbone Network
E_b/N_o	bit energy-to-noise spectral density ratio (dB)
EEFOV	Extended Elliptical field of view (degrees)
EES	Earth-exploration satellite services

EET	End-to-End Test
EIF	Engineering Interface
EIRP	effective isotropic radiated power (dBW)
ELV	expendable launch vehicle
EMC	Element Multiplexer Correlator
EOS	Earth Observation System
EPS	External Processing System
ES	earth station
ESC	Exploration and Space Communications Projects Division
ESH	EDOS Service Header
EVM	Error Vector Magnitude
F	transmit carrier frequency (Hz)
f	frequency (Hz)
F_1	carrier frequency transmitted by the customer platform (Hz)
F3, F6, F7, F8	TDRS Flight 3, 6, 7, 8
FA	Forecast Analyst (NCCDS)
f_d	Doppler frequency
FCLTU	Forward Command Link Transmission Unit
FDF	Flight Dynamics Facility
FEC	forward error correction
FM	frequency modulation
f_o	nominal center frequency of customer platform receiver (Hz)
forward service	link from the WSC through the TDRS to the customer platform
FOV	field of view (degrees)
F_R	carrier frequency arriving at user spacecraft (Hz)
f_{ref}	user spacecraft transmit frequency (Hz)
f_T	TDRSS forward service transmit frequency after Doppler compensation
FTP	File Transfer Protocol
G	gain
G/T	antenna gain-to-noise temperature ratio (dB/K)

G_1, G_2, G_3	symbol generation functions
GCE	ground control equipment
GCM	Ground Control Message
GCMR	Ground Control Message Request
GDIS	Guam Data Interface System
GEO	Geosynchronous Earth Orbit
GHz	gigahertz
GMT	Greenwich Mean Time
GN	Ground Network
GPR	Goddard Procedural Requirements
GRGT	Guam Remote Ground Terminal (the WSC ground terminal located in Guam)
GRS	Guam Remote Station
GRT	Ground Receipt Time
GSAMS	GSFC Spectrum Allocation and Management Site
GSFC	Goddard Space Flight Center
GT	Ground Terminal
Gu	antenna gain of the customer platform (dB)
GUI	Graphical User Interface
HPA	high power amplifier
HR	high rate
HRDS	High Rate Data System
HRS	High Rate Switch
Hz	Hertz
I channel	data channel supported by 0 degree and 180 degree phase modulation of the reference carrier
ICD	Interface Control Document
IF	intermediate frequency
IFL	interfacility link
IIRV	improved interrange vector
IONet	IP Operational Network
IP	internet protocol

IRAC	Interdepartmental Radio Advisory Committee (part of the NTIA)
ISS	International Space Station
ISSO	Information Systems Security Officer
ITU	International Telecommunications Union
ITU-R	International Telecommunications Union Radiocommunication Sector
jerk	rate of change of range acceleration between TDRS and customer platform (meter/second^3)
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
JVM	Java Virtual Machine
k	Boltzmann's constant, -228.6 dBW/Hz-K; constraint length of convolutional code
K	Kelvin, unit of temperature
Ka-band	22.5 to 27.5 GHz
KaSA	Ka-band Single Access
KaSAF	Ka-band Single Access Forward
KaSAR	Ka-band Single Access Return
K-band	13.40 to 15.25 GHz
kbps	kilobits per second
kHz	kilohertz
km	kilometer
KSC	Kennedy Space Center
KuSA	Ku-band Single Access
KuSAF	Ku-band Single Access Forward
KuSAR	Ku-band Single Access Return
LAN	local area network
LCP	left circular polarization
LDPCC	Load Density Parity Check Conversion
LEO	Low Earth Orbit
LEOFOV	low earth orbit field of view (degrees)
LEOP	launch and early orbit phase/launch and early operations phase

LEO-T	Low Earth Orbiting-Terminal
LHC	Left-hand circular
LHCP	Left-Hand Circular Polarization
LI	local interface
link	Includes either all data and/or range channels provided by a TDRS forward or return service to a customer platform. In the case of SA service, a link is defined relative to a specific antenna on a particular TDRS. In the case of MA service, a link is defined relative to a particular TDRS.
LOS	Line-of-sight
LR	low rate
LRDS	Low Rate Data Switch
LRS	Low Rate Switch
MA	Multiple Access
MAF	Multiple Access Forward
MAR	Multiple Access Return
Mbps	megabits per second
MCC	Mission Control Center
MDM	multiplexer/demultiplexer
MGS	McMurdo Ground Station
MHz	megahertz
MI	mutual interference
MOC	Mission Operations Center
MOCC	Mission Operations Control Center
MORR	Mission Operations Readiness Reviews
MSB	most significant bit
msec	millisecond
Msps	megasymbols per second
MTRS(2)(U)	McMurdo TDRSS Relay System(2)(Upgrade)
N	North
NA	not applicable
NAM	Network Advisory Message
NASA	National Aeronautics and Space Administration

NASCOM	NASA Communications Network
NCC	Network Control Center
NCCDS	NCC Data System
NEC	NASCOM Event Cancel
NEN	Near Earth Network
NES	NASCOM Event Schedule
NEST	NISN/NASA Event Scheduling Terminal
NGIN	Next Generation Integrated Network
NIC	Network Integration Center
NIM	Networks Integration Manager
NIMO	Networks Integration Management Office
NISDDT	NASCOM Interface Standard for Digital Data Transmission
NISN	NASA Integrated Services Network
NOM	Network Operations Manager
NOSP	Network Operations Support Plan
NPAS	Network Planning and Analysis System
NPG	NCC Protocol Gateway
NRD	Network Requirements Document
NRR	NASCOM Reconfiguration Request; Network Requirements Review
NRZ	nonreturn to zero
NRZ-L	nonreturn to zero level
NRZ-M	nonreturn to zero mark
NRZ-S	nonreturn to zero space
nsec	nanosecond
NSF	National Science Foundation
NTIA	National Telecommunications and Information Agency
O&M	Operations and Maintenance
OBO	Output Back-Off
OCXO	Oven Controlled Oscillator
ODM	Operations Data Message (from GTs to NCCDS)

OIP	Operations Interface Procedures
OPM	Operations Message
OOTMS	On orbit test mode system
OPS	operations
OQPSK	Offset quadriphase shift keying
P_{acq}	probability of correct acquisition
PCD	Project Commitment Document
PCI	periodic convolutional interleaving
PCM	Pulse code modulated
PDL	Ponce de Leon Tracking Station
PFD	power flux density
PFOV	Primary field of view (degrees)
PIP	Payload Integration Plan
PM	phase modulation
PN	pseudorandom noise
POCC	Payload Operations Control Center
PP	peak-to-peak
PRD	Program Requirements Document
P_{rec}	signal power received isotropically at a TDRS from a customer platform
P_s	signal power at antenna output
PSAT	Predicted Site Acquisition Tables
PSD	power spectral density
PSK	Phase-shift keying; phase-shift key modulation using differential encoded data
PSLA	Project Service Level Agreement
PTE	Performance Test Equipment
PTP	Programmable Telemetry Processor
Q channel	data channel supported by $\pm$90 degree phase modulation of the reference carrier
QLR	Quick-Look Report
QPSK	quadriphase shift keying
$\dot{R}$	range velocity between a TDRS and the customer platform (meter/second)

$\ddot{R}$	range acceleration between a TDRS and the customer platform (meter/second^2)
$\dddot{R}$	jerk (m/sec^3)
R	ratio between data rate and convolutionally encoded symbol rate; range between TDRS and customer platform (meters)
range channel	forward service channel used for transferring the PN code used for two-way range measurement
RCP	right circular polarization
1.1 RCTD	return channel time delay
R_d	channel data rate (b/sec)
RDD	Return Data Delay
return service	link from the customer platform through the TDRS to the WSC
RF	radio frequency
RFI	radio frequency interference
RFICD	Radio Frequency Interface Control Document
RFSOC	Radio Frequency Simulation Operations Center
RHC	Right-hand circular
RHCP	Right-Hand Circular Polarization
rms	root mean square
RR	Radio Regulations
R_s	channel symbol rate
R-S	Reed-Solomon
RS	Recurrent Scheduling
RSDR	Return Service Data Recording
RSS	root sum square
Rx	receiver
S	South
S/(N+I)	signal-to-(noise plus interference) ratio
S/N_o	signal-to-noise density ratio (dB-Hz)
SA	Single Access; System Administrator
SAR	Synthetic Aperture Radar; Schedule Add Request

SAT_b	forward buffering delay for reserialized output data delivery
SAT_d	return buffering delay for reserialized output data delivery
S-band	2000 to 2300 MHz
SD	sweep duration
SDIF	SNAS-DAS Interface
SDR	Schedule Delete Request
sec	second
service	consists of any of the forward, return, tracking, simulation, or verification services
SF	Standard Format
SFCG	Space Frequency Coordination Group
SFDU	Standard Formatted Data Unit
SFTP	Secure File Transfer Protocol
SGL	Space-Ground Link
SGLT	Space-Ground Link Terminal
SGSS	Space Network Ground Segment Sustainment Project
SHO	Schedule Order (NCCDS to GTs)
SIC	Support Identification Code
SIEB	Security Impact Evaluation Board
Signal EIRP	total EIRP + L_p + L_t (dBW) where: L_p = loss resulting from imperfect antenna pointing (dB) ($L_p \leq 0$ dB) L_t = all tandem link losses including power robbing caused by noise and spurious signals (dB) ($L_t \leq 0$ dB)
SLE	Space Link Extension
SLR	Service Level Report
SMA	S-band Multiple Access
SMAF	S-band Multiple Access Forward
SMAP	Soil Moisture Active Passive
SMAR	S-band Multiple Access Return
SN	Space Network
SNAS	Space Network Access System

SND	Space Network Directive
SNG	SN Gateway
SNIF	SNAS-NCCDS Interface
SNIP	Space Network Interoperability Program
SNR	Signal-to-noise ratio
SNUG	Space Network Users' Guide
SO	spurious outputs; Scheduling Operator (NCCDS); space operations
SORCE	Solar Radiation and Climate Experiment
SoS	Start of Sequence
SQPN	Staggered quadriphase pseudorandom noise
SQPN modulation	a modulation process in which the phase of the PN clock modulating the Q channel is delayed 1/2 chip relative to the phase of the PN clock modulating the I channel
SQPSK	staggered quadriphase shift keying
SQPSK modulation	a quadriphase process in which the data bits (symbols if convolutionally encoded) of the Q channel are delayed one-half bit period (one-half symbol period if convolutionally encoded) relative to the I channel
SR	space research; sweep range
SRM	Schedule Result Message
SS	Spread Spectrum
SSA	S-band Single Access
SSAF	S-band Single Access Forward
SSAR	S-band Single Access Return
SS-BPSK	Spread Spectrum – binary phase shift keying
SSC	service specification code
SS-UQPSK	Spread Spectrum– unbalanced quadriphase shift keying
STAT MUX	statistical multiplexer
STDN	Spaceflight Tracking and Data Network
STGT	Second TDRSS Ground Terminal
SUPIDEN	support identifier

SV	State Vector
symbol rate	rate of the digital information data signal before conversion to biphase format. When convolutional encoding is used, the rate of the digital information data signal out of the convolutional encoder before conversion to biphase format.
systematic	original information bits appear in output data stream
T_a	antenna temperature (K)
T_{acq}	time to acquire
TCP	transmission control protocol
TCW	TDRS Communication Window
TCXO	Temperature Compensated Crystal Oscillator
TDE	TDRS-East (same as TDRS-E)
TDM	time division multiplexing; Tracking Data Message
TDRS(S)	Tracking and Data Relay Satellite (System)
TDRS-E	TDRS-East (same as TDE)
TDRS-W	TDRS-West (same as TDW)
TDRS-Z	TDRS in Zone of Exclusion (same as TDZ)
TFDH	Telemetry Frame Data Header
T_i	noise temperature contribution due to interference from other multiple access users (K)
TILT	TDRSS Internet Link Terminal
TT	Time Tag
TLAS	TDRS Look Angle System
TLM	telemetry
TOCC	TDRSS Operations Control Center
TPC	Turbo Product Code
T_R	time return service begins
TR	Test Report
transparent	I(b) the input to the encoder is mapped into T(b) the output of the encoder, then for transparency to exist, the complement of I(b) must be mapped into the complement of T(b)
TRR	Test Readiness Review

T_s	receiving system noise temperature (K) referenced to the antenna output terminals
TSW	TDRSS Scheduling Window
TT&C	tracking, telemetry, and command
TTM	Time Transfer Message
TURFTS	TDRSS User RF Test Set
TUT	TDRSS Unscheduled Time
TWTA	Traveling Wave Tube Amplifier
Tx	transmitter
UAV	User Antenna View
UDP	User Datagram Protocol
UIFC	User Interface Channel
UPD	User Performance Data (from NCCDS to MOC)
UQPSK	unbalanced quadriphase shift keying
USCCS	User Spacecraft Clock Calibration System
USM	User Schedule Message (from NCCDS to MOC)
USS	User Services Subsystem
UTC	Universal Time Coordinated
VCDU	Virtual Channel Data Units
VIC	Vehicle Identification Code
VID	Vehicle Identification
VOIP	Voice Over Internet Protocol
VSWR	Voltage Standing Wave Ratio
W	West
WAN	wide area network
WDISC	WSC Data Interface Service Capability
WSC	White Sands Complex (consists of WSGT and STGT)
WSGT	White Sands Ground Terminal
www	world wide web
ZOE	zone of exclusion