530-SNUG

MISSION OPERATIONS AND DATA SYSTEMS DIRECTORATE

Space Network (SN) Users' Guide

Revision 7

November 1995

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

Space Network (SN)
Users' Guide

Revision 7

November 1995

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SECTION 1. INTRODUCTION

1.1 PURPOSE AND SCOPE

1.1.1 PURPOSE

The National Aeronautics and Space Administration (NASA) Spaceflight Tracking and Data Network (STDN) consists of a Space Network (SN) and a Ground Network (GN). The various elements of the STDN are engineered, maintained, and under the operational control of the Mission Operations and Data Systems Directorate (MO&DSD) of the Goddard Space Flight Center (GSFC) with the objective of providing telemetry, command, and tracking support to low Earth-orbiting spacecraft. This document is intended as a guide to the user community for obtaining communication support from the SN. The SN is composed of the Space Segment, consisting of the Tracking and Data Relay Satellites (TDRS), and the Ground Segment, consisting of the White Sands Complex (WSC) and all of the supporting subsystems. The Tracking and Data Relay Satellite System (TDRSS) is defined as the TDRS constellation and the WSC. This document covers the basic TDRS program, Flight 1 (F1) through Flight 6 (F6), and the replacement program, Flight 7 (F7). Appendix J discusses the future TDRS capabilities. If an SN user needs more information than is described within this document and the referenced documents, the point of contact is the MO&DSD Flight Mission Support Office (FMSO).

1.1.2 SCOPE

The emphasis in this guide is on the interfaces between the user ground facilities and the SN. Other topics covered include the following:

a. Radio Frequency (RF) interface between the user spacecraft and the Tracking and Data Relay Satellite (TDRS).

b. Procedures for working with the GSFC MO&DSD, which has the management and operational responsibility for the SN, to establish user interfaces.

c. SN capabilities and service characteristics.

d. General information pertaining to the operational aspects of the SN.

e. Generalized capabilities and technical characteristics of other MO&DSD elements which support the SN user.

1.2 ORGANIZATION OF THE DOCUMENT

Section 1 describes the general concept of the SN, user flight project procedures for defining and obtaining SN support, and how the user flight project interfaces with the functional elements of the GSFC MO&DSD. This section also provides policy information, which ensures that the user obtains the best possible service from the SN. Section 2 summarizes TDRSS capabilities, and Section 3 contains a detailed description of the individual TDRSS telecommunications services

from which these capabilities are derived. Section 4 describes user/SN operations philosophy and characterizes the operations data traffic between the user ground segment and the SN control entity, the Network Control Center (NCC).

Section 4 also describes the user interfaces with other SN elements, including supporting elements such as the Flight Dynamics Facility (FDF). Section 5 discusses SN-related segments of the NASA Communications (NASCOM) Network and the characteristics of the interface between the user ground segment and NASCOM across which user spacecraft data traffic flows. Appendices are provided to supplement information contained in the body of this document. All references to other documents refer to latest versions available at the time of publication of this revised document.

1.3 SN OVERVIEW

1.3.1 GENERAL

The purpose of this section is to provide an overview of the SN and other supporting elements, and a brief functional description of SN operations.

1.3.2 ELEMENTS OF THE SN

The SN consists of a space segment and a ground segment, under the operational control of the Networks Division of the MO&DSD, with functional support from other supporting ground elements.

1.3.3 SPACE SEGMENT

The space segment of the SN consists of up to four operational TDRSs in geostationary orbit at allocated longitudes. Additional spare TDRS may be in geostationary orbit. All TDRSs (F1-F7) carry functionally identical payloads.

1.3.4 GROUND SEGMENT

1.3.4.1 TDRSS Dedicated Ground Elements. The SN ground elements used in support of or as part of the TDRSS are as follows:

a. WSC:
   (1) Cacique Ground Terminal (also referred to as the White Sands Ground Terminal Upgrade (WSGTU)).
   (2) Danzante Ground Terminal (also referred to as the Second TDRSS Ground Terminal (STGT)).

b. Merritt Island Launch Area (MILA) TDRSS Relay.

c. Bilateration Ranging Transponder System (BRTS).

d. Gamma Ray Observatory Remote Terminal System (GRTS).

1.3.4.2 Supporting Ground Elements. Ground elements of the SN that support the TDRSS are as follows:

a. NCC.

b. NASCOM.

c. FDF.

d. RF Simulation Operation Center (RF SOC)/Simulation Operation Center (SOC).

e. Compatibility Test Vans (CTV).

1.3.4.3 Other Supporting Ground Elements. Ground elements not part of the SN that support the TDRSS are as follows:

a. GN.

b. Deep Space Network (DSN).

1.3.5 SN FUNCTIONAL DESCRIPTION

Figure 1-1 depicts an example operational TDRSS configuration with up to four TDRS. The operational space segment element clusters, TDRS-East and TDRS-West, shown in Figure 1-1, consist of satellites located at 41 and 46 degrees west longitude for the east cluster and 171 and 174 degrees west for the west cluster. There may also be one or more TDRS-Spares in geostationary orbit. These TDRSs provide two-way data communications relay between user spacecraft and the WSC, located at White Sands, NM. Data is transmitted between ground locations (i.e., GSFC) and the WSC using Domestic Communications Satellites (DOMSATs), the ground segment of the SN, and other supporting elements. The SN provides tracking and data acquisition with more than 85 percent coverage for orbit altitudes of 200 to 1,200 km, 100 percent coverage for orbit altitudes of 1,200 to 3,000 km through the Multiple Access (MA) services, and 100 percent coverage for orbital altitudes of 1,200 to 12,100 km through Single Access (SA) services. Geometric coverage decreases above 3,000 km for MA services and above 12,100 km for SA services. Return data rates of up to 300 Megabits per second (Mbps) from user spacecraft are supported, as are a number of other services as described in paragraph 1.4.

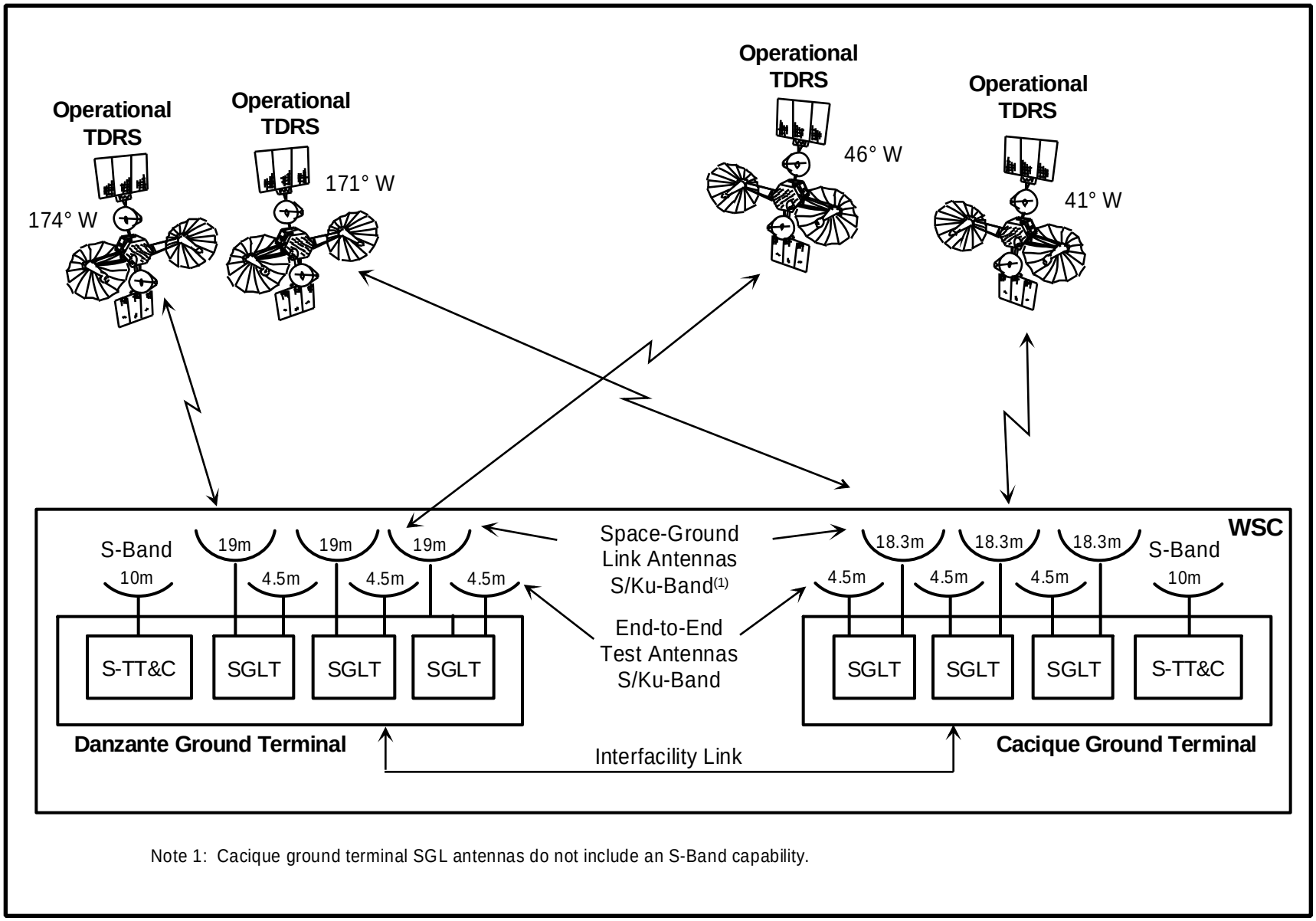

Figure 1-1. Example Operational TDRSS Configuration

1.3.6 ELEMENT FUNCTIONAL DESCRIPTIONS

1.3.6.1 General. Network elements and interfaces are shown in Figure 1-2 and described in paragraphs 1.3.6.2 and 1.3.6.3.

1.3.6.2 Space Segment. Each operational TDRS provides a relay for TDRSS forward and return service signals to and from user spacecraft for data transfer and tracking. Figure 1-3 identifies the pertinent communications components and associated parameters of the TDRS.

1.3.6.3 Ground Segment:

a. TDRSS Dedicated Ground Elements:

(1) WSC. The WSC, consisting of the Cacique and the Danzante, provides the communications equipment necessary for transmitting and receiving data and tracking information relayed via each TDRS. A data link exists between the Cacique and the Danzante for the exchange of user data and tracking information. Additionally, the WSC provides the TDRS Tracking, Telemetry, and Command (TT&C) functions for each TDRS through the TDRSS Operations Control Center (TOCC). Note that the TOCC1 is located in the Cacique and the TOCC2 is located in the Danzante. Equipment is available at both sites to provide the users with end-to-end system testing capabilities. The WSC also provides the interface between the TDRSS and the NASCOM common carrier communications equipment. Additional WSC functions include both data handling and unique support for Shuttle.

(2) MILA Relay. The MILA Relay provides RF signal routing between the TDRS and payloads or satellites under test prior to launch in support of Kennedy Space Center (KSC), Payload Operations Control Centers/Mission Operations Centers (POCC/MOCs), or Johnson Space Center (JSC). MILA also provides a relay between payloads and NASCOM facilities for the POCC/MOCs during the prelaunch period, when needed.

(3) 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 in-orbit TDRS. The BRTS transponders are presently located at the WSC, central Australia, Ascension Island, and American Samoa.

(4) GRTS. The GRTS consists of the Extended TDRSS Ground Terminal (ETGT) located at WSC, the Remote Ground Relay Terminal (RGRT) located at Tidbinbilla, Australia, and a workstation located in the NCC. The GRTS system is used to provide extended coverage for the Compton GRO spacecraft. A TDRS located in the Zone of Exclusion (ZOE) links the Compton GRO to the RGRT. The TDRS is remotely controlled and monitored from the WSC via the ETGT,

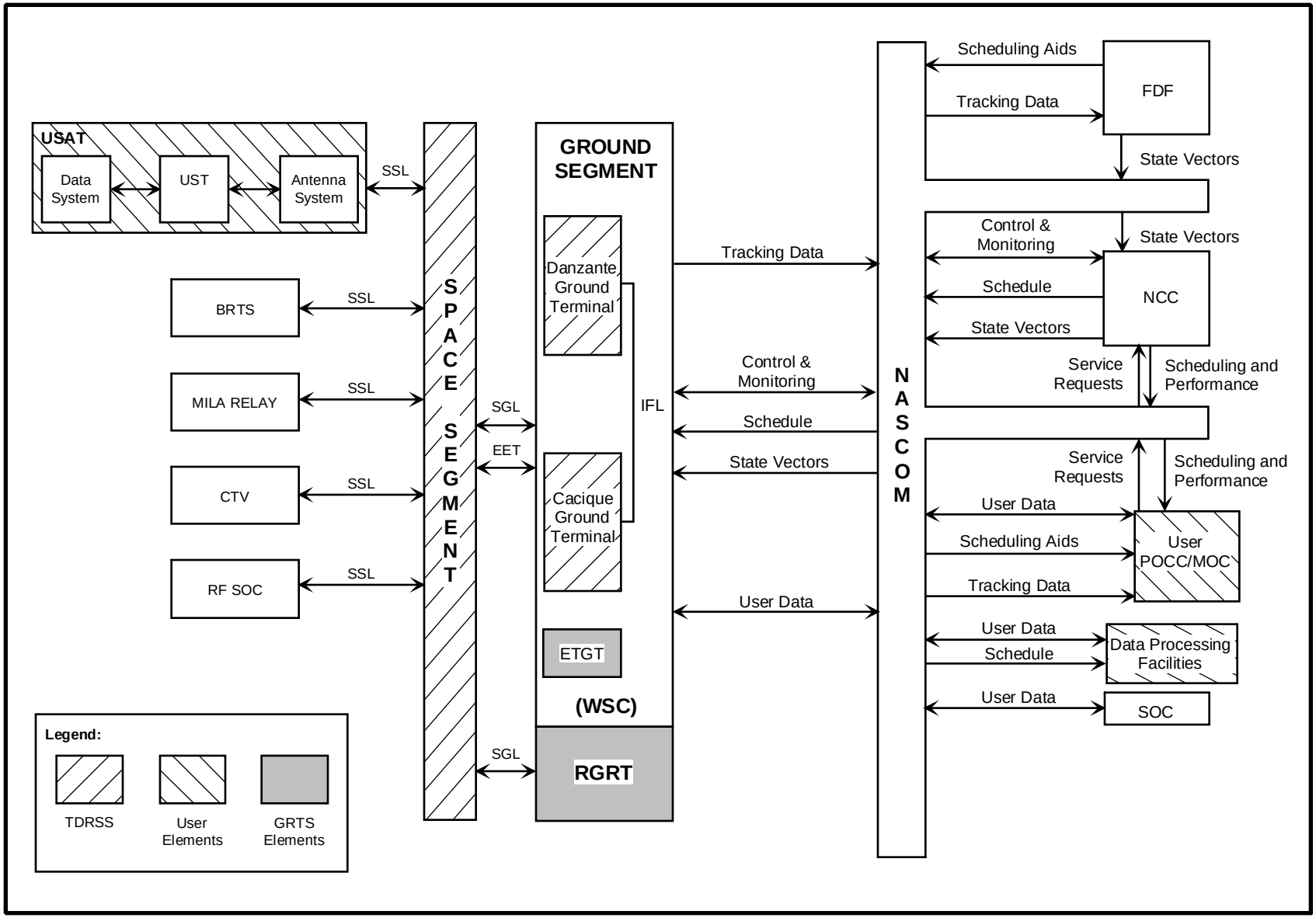

Figure 1-2. Space Network Elements and Interfaces

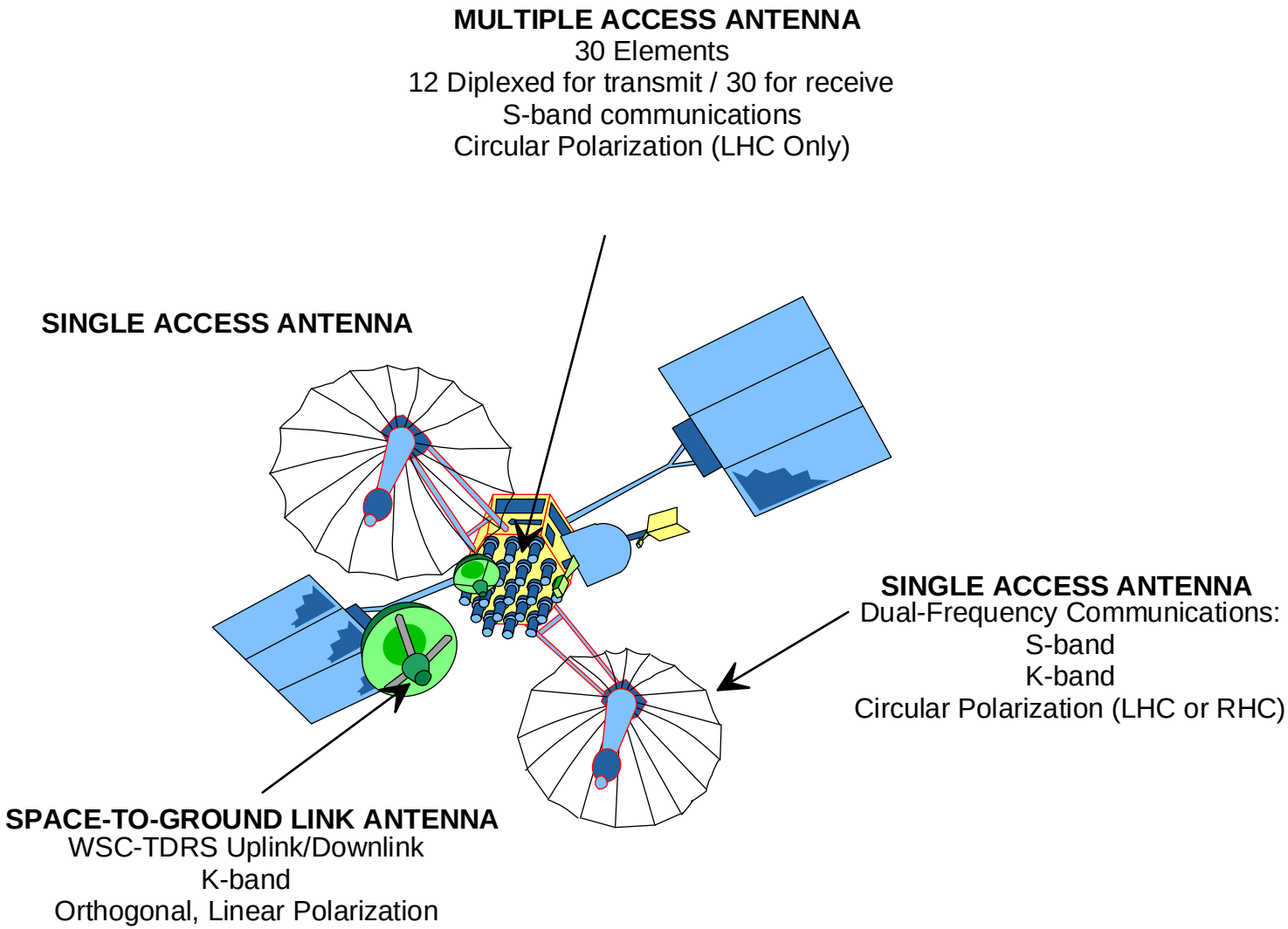

Figure 1-3. Tracking and Data Relay Satellite

and the customer data is relayed to the customer POCC/MOC. Refer to Appendix I and section 2.1.2.4 for additional information on GRTS.

b. Supporting Ground Elements:

(1) NCC. Located at GSFC, the NCC is the operations control facility for the SN and provides the operational management of the STDN. It schedules all SN elements and supporting elements and provides interfaces for planning, acquisition, control, and status of the SN.

(2) NASCOM. The NASCOM network is a global system of communications transmission, switching and terminal facilities that provide NASA with long-haul communications services. NASCOM services which support the SN include circuits between White Sands and GSFC for transmission of user real-time and stored data, and video for manned mission air/ground voice, and also for SN control and status communications.

(3) FDF. Located at GSFC, the FDF provides support to the SN and NASA approved user spacecraft missions for orbit determination, acquisition data generation, attitude determination, and orbit and attitude maneuver support. The FDF also controls and schedules the BRTS for TDRS tracking and monitors the BRTS status.

(4) RF SOC/SOC. The RF SOC and SOC, located at GSFC, provides facilities for conducting user flight project mission simulations for SN users. It can monitor SN performance during these mission simulations, simulate a mission-unique user spacecraft, verify SN/user POCC/MOC compatibility, and simulate a user POCC/MOC in support of fault isolation.

(5) Compatibility Test Van (CTV). Home-based at GSFC, two CTVs provide the means to test user spacecraft at remote locations for data transfer and tracking compatibility with the SN. Each CTV can provide both line-of-sight and cabled RF interfaces to a user spacecraft.

c. Other Supporting Ground Elements:

(1) GN. The GN stations are currently located at Merritt Island, FL (MIL); Ponce de Leon, FL (PDL); Bermuda (BDA). Wallops Island, VA (WPS) also supports high-inclination Space Transportation System (STS) missions. The former GN station at Santiago, Chile (AGO), now under contract from the University of Chile, provides support for some orbital spacecraft. These stations provide prelaunch, launch, orbital, and landing communications support for orbiting spacecraft and launch vehicles, including the Space Transportation System (STS).

(2) DSN. Managed by the Jet Propulsion Laboratory (JPL), Pasadena, CA, the DSN provides telecommunications and tracking support during TDRS launch and

the subsequent transfer operations. In addition, the DSN provides backup support to the SN.

1.4 SERVICES AVAILABLE TO USER FLIGHT PROJECTS

1.4.1 SPACE NETWORK OPERATIONAL SERVICES

1.4.1.1 General. As scheduled through the NCC, the SN (via a TDRS, WSC, and NASCOM) provides forward and return telecommunications services between low Earth-orbiting user spacecraft and user control and data processing facilities at GSFC, or to a NASCOM or user communications service interface at WSC or GSFC. In addition, scheduled tracking services in support of orbit determination are available. The SN provides transport of user data including error control and service accounting information internal to the SN. No link control or higher level functions of the open system interconnection model (ISO document IS7498) are provided. That is, no value-added functions such as flow control, message-by-message routing, or those functions delineated within IS7498 are provided.

1.4.1.2 Forward Services. Forward services may include separate command and tracking channels relayed to the user spacecraft. Forward services are provided in both S-band and K-band. A range of forward service data rates can be accommodated.

1.4.1.3 Return Services. Return services available include simultaneous reception of two Telemetry (TLM) channels and provision of related tracking data. Return services are provided in both S-band and K-band. A range of return service data rates can be accommodated.

1.4.1.4 Service Types. Several types of telecommunications service are simultaneously available to users. The type of telecommunications service selected is determined by the data rate required, duration of service period, and user spacecraft telecommunications system design. The two primary telecommunications services are termed MA and SA and are distinguished, as indicated, by the manner in which a user spacecraft accesses the TDRSS as follows:

a. The MA service operates on a fixed frequency (2106.4 Megahertz (MHz) forward/2287.5 MHz return) in the S-band and is designed to support concurrent return service low data rate users ($\leq$100 kilobits per second (kbps)) requiring near continuous telecommunications service. In this service, each user spacecraft transmitted signal is uniquely coded using a Pseudorandom Noise (PN) sequence to allow unique acquisition and detection of the desired telemetry signal. The SA service is available simultaneously in both S-band (2025-2120 MHz forward/2200-2300 MHz return) and K-band (13.775 Gigahertz (GHz) forward/15.003 GHz return) and is intended for support of medium to very high data rate users (up to 300 Mbps). Refer to sections 2 and 3 for detailed discussions of these services.

b. In addition, a tracking service is available. The tracking service provides for user spacecraft two-way-range and/or range-rate measurements or one-way range-rate measurements.

c. End-to-End Testing services are also available and schedulable. They enable the user to obtain a quick end-to-end checkout of SN services without the use of an actual user spacecraft.

1.4.2 ANALYSIS, TEST, AND SIMULATION SUPPORT

The MO&DSD performs analysis, testing, and simulation which are of direct benefit to the user flight project. Some are mandatory to validate compatibility and to meet launch readiness requirements. For projects that are in the advanced study phase and are not yet approved as new starts by NASA Headquarters (HQ), the MO&DSD will designate a Data Systems Operations Study Manager (DSOSM), who will be a focal point for the project to obtain relevant SN information and analysis. This analysis will address such preliminary questions as projected SN loading, RF link margins, geometric coverage analyses, and MO&DSD preliminary funding and manpower requirements. The results of such analyses will enable an early assessment of the project's compatibility with the SN, and other analyses or information pertaining to other SN elements.

1.4.2.1 Network Loading Analysis. To ensure that sufficient SN resources are available to meet commitments to current and future users, the MO&DSD provides a representative (either a DSOSM or a Data Systems Operations Project Manager [DSOPM]) to each user flight project as early as possible during mission planning to assist in the definition of user flight project needs for MO&DSD services. Typical of the information needed are the projected requirements for communications timeline, data rates, and number of data channels. Although this information may initially be of a preliminary nature, the best available information is needed for projecting SN loading.

1.4.2.2 RF Link Margin and Coverage Analysis. Information exchange for the RF link margin and coverage analysis begins during the initial flight segment Mission Analysis phase and continues until firm coverage requirements and flight segment design are finalized in the Mission Execution phase. The four mission phases are described in section 1.5.2. The Communications Link Analysis and Simulation System (CLASS) analysis tool is used to help achieve a flight segment telecommunications design which is compatible with the TDRSS, and will achieve the desired level of performance. Design deficiencies and possible trade-offs are defined during these analyses. The results of CLASS are used early in the Mission Analysis phase to aid in the development of the RF Interface Control Document (ICD), which is a controlling input to the flight segment telecommunications specifications (refer to paragraph 1.6.1 for further details). Interim and final results of these analyses are published in the mission-specific Geometric Support Analysis and Predicted Signal Margins, 531-GSA-XXX (commonly called the 717). Completion of these analyses is required prior to the MO&DSD readiness-for-launch decision.

1.4.2.3 Compatibility Testing. Compatibility testing is performed as early as possible after fabrication of the user spacecraft (either the flight model, which is preferred, or the prototype model) is completed. Compatibility tests are normally rerun following resolution of significant problems encountered during the original test or following posttest flight segment design modification. Results of these tests are formally published in the mission-specific Compatibility Test Report, 515-2CTR/XXX (formerly called the 713 document). Satisfactory completion of this testing and certification is required to meet the MO&DSD readiness-for-launch criteria.

1.4.2.4 SN Interface Testing and Operational Simulations. Mutually agreed upon end-to-end tests are conducted to validate all telecommunications system functions, as defined in the applicable ICDs. In addition, operational exercises (i.e., simulations, data flows) are conducted to ensure that operations will satisfy requirements and timelines. Guidelines for this support appear in the STDN Tests and Simulations Handbook, STDN No. 413, and the STDN No. 403 series document for a particular user.

1.4.2.5 Orbit Support Analysis. Prelaunch orbital error analyses are performed to determine the frequency with which user spacecraft state vectors are needed to achieve the orbital accuracies required by the user flight project.

1.4.3 OTHER MO&DSD INFORMATION SYSTEM SERVICES AVAILABLE TO USER FLIGHT PROJECTS

The MO&DSD can provide mission and data operations information system services for user spaceflight programs when approved by NASA HQ/Office of Space Communications (OSC)/Code O. This support provides the tools and systems necessary to determine user spacecraft position and orientation, to control the user spacecraft and its scientific instruments, to process the engineering and scientific data, and to disseminate the data to end users. Further information concerning these services is available from the MO&DSD Flight Mission Support Office.

1.5 DEFINING AND OBTAINING SN SERVICES AND MO&DSD SUPPORT

1.5.1 GENERAL

The information in this section is very general in nature and only briefly describes the process for obtaining SN services. In the future, specific information will be available in the MO&DSD User's Guide.

1.5.2 SUPPORT DEFINITION

The MO&DSD approach for supporting user flight projects depends on two factors. The first factor is whether the user is a GSFC or a non-GSFC user flight project. The second factor is based on user impact to existing MO&DSD institutional capabilities. Support is provided through four typical phases of a user flight project: Mission Analysis, Mission Definition, Mission Execution and Mission Operations.

1.5.3 PROCEDURES FOR OBTAINING SN SUPPORT

Initially the user flight project must obtain formal approval from NASA Headquarters for SN support. Then SN loading studies and preliminary analysis of the capability of the SN to provide support are done by the MO&DSD. A determination is made as to whether the mission requires major implementation within the MO&DSD and whether it is a GSFC or non-GSFC project. After these determinations are made, project managers are assigned, support teams are formed,

and proper documentation is prepared. Figure 1-4 illustrates the MO&DSD users flight project support.

1.5.4 SYSTEM REVIEWS

The MO&DSD will conduct system review of all user flight projects in order to ensure readiness for support prior to launch. In addition, GSFC flight projects will have additional reviews conducted by the GSFC System Review Office/Code 301.

1.5.5 OBTAINING INFORMATION AND ASSISTANCE

1.5.5.1 General. The information necessary to understand STDN capabilities as they relate to support of a user flight project can be found in references a through c. References d through h provide information relating to GSFC support policies:

a. Ground Spaceflight Tracking and Data Network (GSTDN) Users' Guide, STDN No. 101.3.

b. Space Network Synoptic Description, STDN No. 134.

c. Portable Simulations System and Simulation Operations Center Guide for TDRSS and GSTDN Users, STDN No. 101.6.

d. Mission Operations and Data Systems Directorate Systems Management Policy, DOD-8YMP/0485.

e. Mission Operations and Data Systems Directorate Software Development Policy, MODSD-8YDP/0186.

f. Mission Operations and Data Systems Directorate Systems Documentation Guidelines, MODSD-8YMP/0286.

g. Goddard Space Flight Center Project Management Handbook, December 1986. GSFC Projects Directorate (Code 400).

h. STDN Operations Concepts 1996, 530-OCD-STDN.

1.5.5.2 Ground Networks. Users who have specific need for GN documents should provide a written request to the Flight Mission Support Office.

1.5.5.3 Technical Assistance. Technical assistance is available to GSFC projects through the DSOPM. Technical assistance is available to non-GSFC projects through the Mission Support Manager (MSM). A DSOSM provides assistance while the project is still under study.

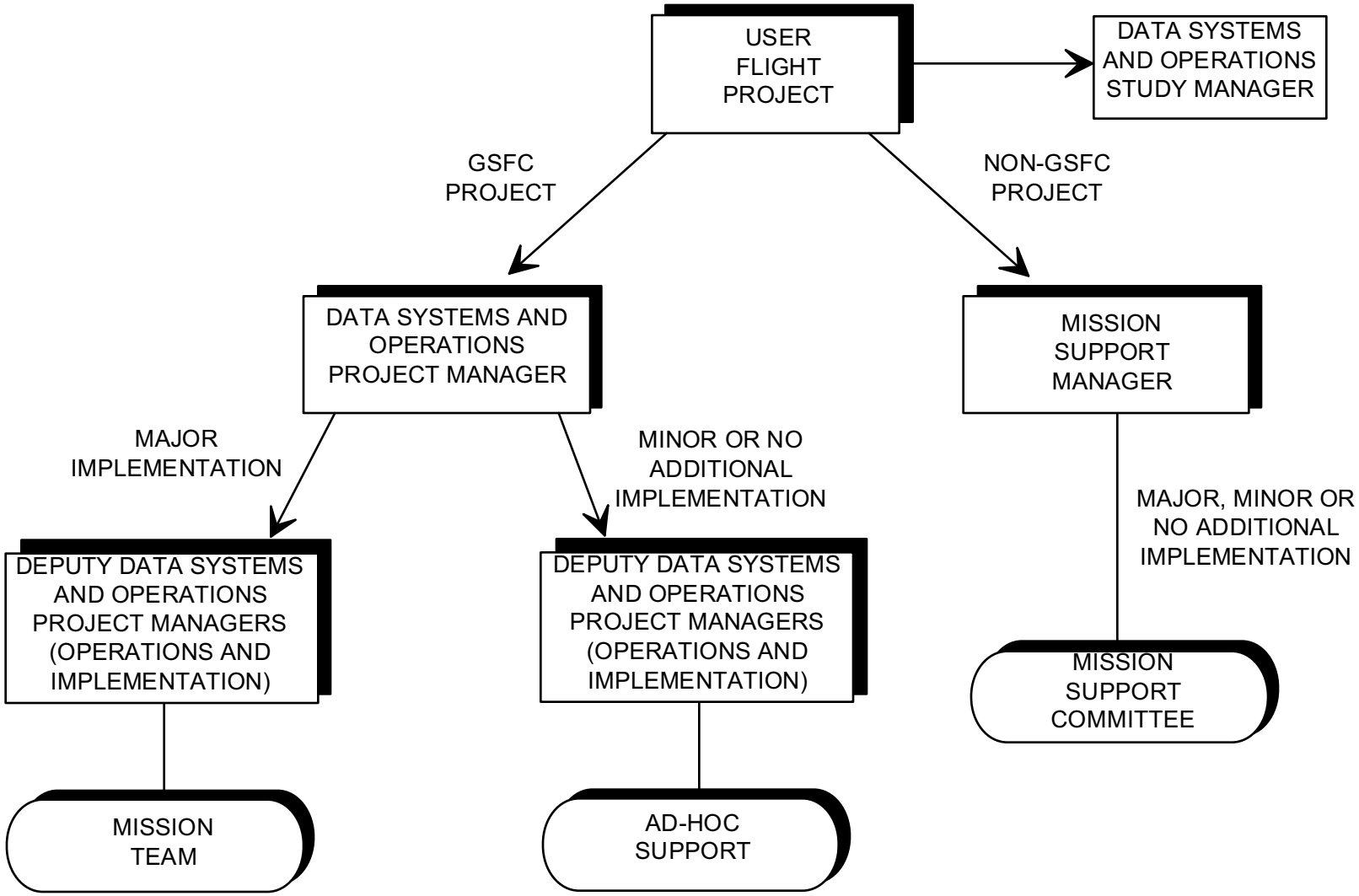

Figure 1-4. MO&DSD User Flight Project Support Definition

1.5.5.4 Mission Support Teams. Two teams are available to assist user flight projects in obtaining SN support. For GSFC flight projects, a Mission Team, chaired by a DSOPM, is available. For non-GSFC flight projects, a Mission Support Committee (MSC), chaired by an MSM, is available to provide assistance. The Mission Team and MSC are multidisciplinary groups, consisting of representatives of appropriate line organizations within the MO&DSD.

1.5.6 NASA POLICY ON DEFINING AND OBTAINING SN SERVICES

1.5.6.1 Policy Documents. The user of any SN capability requires formal approval by NASA HQ/OSC/Code O, as follows:

a. Published policy pertaining to procedures and responsibilities involved in obtaining support from OSC operating elements and the method of documenting requirements (refer to paragraph 1.6.1) is contained in the following NASA Management Instructions (NMI):

(1) NMI 8430.1C describes policy, procedures, and responsibilities for planning, managing, and documenting tracking and data acquisition support for unmanned spaceflight projects.

(2) NMI 8610.10B describes the procedures and documentation involved in entering requirements for manned space flight projects.

b. For further information concerning specific NASA HQ/OSC/Code O policy, contact the MO&DSD Flight Mission Support Office or:

NASA Headquarters
Code O (OSC)
Washington, DC 20546

1.5.6.2 Policy on Use and Reimbursement by Non-NASA Users of the SN. NASA has an SN use and reimbursement policy which may apply to non-NASA users of MO&DSD services. Non-NASA projects desiring SN service may contact the OSC SN Program Office at NASA HQ/Code OX to obtain the details of the policy. The policy is contained in NMI 8410.2, Use and Reimbursement Policy for non- NASA, U.S. Government users of TDRSS; and NMI 8410.3, Use and Reimbursement Policy for non-U.S. Government users of TDRSS. Charges are based on the type and extent of SN services used.

1.6 SN SERVICES AND MISSION SUPPORT DOCUMENTATION

1.6.1 NASA DOCUMENTATION

The NASA documentation system for providing space-communication services to users recognizes four basic documents as follows:

a. Mission Requirements Request (MRR): documents a timely determination of the user's basic requirements.

b. Detailed Mission Requirements (DMR): documents the user's detailed requirements and the MO&DSD response to the stated requirements.

c. ICD: describes the specific interface details. ICDs will be written for each element interface.

d. Mission Operations Support Plan (MOSP): provides operational procedures and configurations information required by MO&DSD elements to support the mission.

There are other documents produced such as a mission support analysis and compatibility test reports. These are the launch readiness documents. Figure 1-5 shows the documentation hierarchy and interrelationships.

1.6.2 SPACE TRANSPORTATION SYSTEM DOCUMENTATION

Support requirements for the STS and payloads embedded within the STS are published by JSC and KSC. Because of the nature of the STS hardware and procedural interfaces, the STS launch phase ground system utilization is characterized by both standardized and optional space-to-ground and ground-to-ground services. These services are negotiated and documented between the STS user and JSC and KSC, directly, via the Payload Integration Plan (PIP) documentation system. JSC and KSC, in turn, formally negotiate with the MO&DSD on behalf of the manifested STS user (or users) for each STS flight. This process is carried out by using the Program Requirements Document (PRD) and the associated methodology for integrating Orbiter and composite payload requirements for SN and ground system services before submitting these requirements for implementation by the MO&DSD.

1.7 CONFIGURATION MANAGEMENT

Configuration control over the SN service and user flight project mission support documentation will be maintained through MO&DSD Configuration Control Board (CCB) at the directorate level; Division and Office level and ad hoc CCBs are established at the branch and project level. Ad hoc CCBs are established in cases of large projects requiring substantial CCB activity. A Security Impact Evaluation Board (SIEB) has been established for the SN to manage all security-related activities. The MO&DSD Configuration Change Request (CCR) form, which can be obtained from the System Interface Manager, is used to introduce and control changes to MO&DSD systems.

1.8 POLICY

1.8.1 STANDARDS OF SERVICE

Support furnished by a GSFC facility, including the SN, must conform to the latest revision of Data Encryption Standard Document, The Federal Information Processing Standard 46-2, December 1993. According to Goddard Management Instruction 8070.1A, which establishes policies and procedures with respect to Consultative Committee for Space Data Systems (CCSDS), any project making use of GSFC facilities must either follow the CCSDS or obtain a

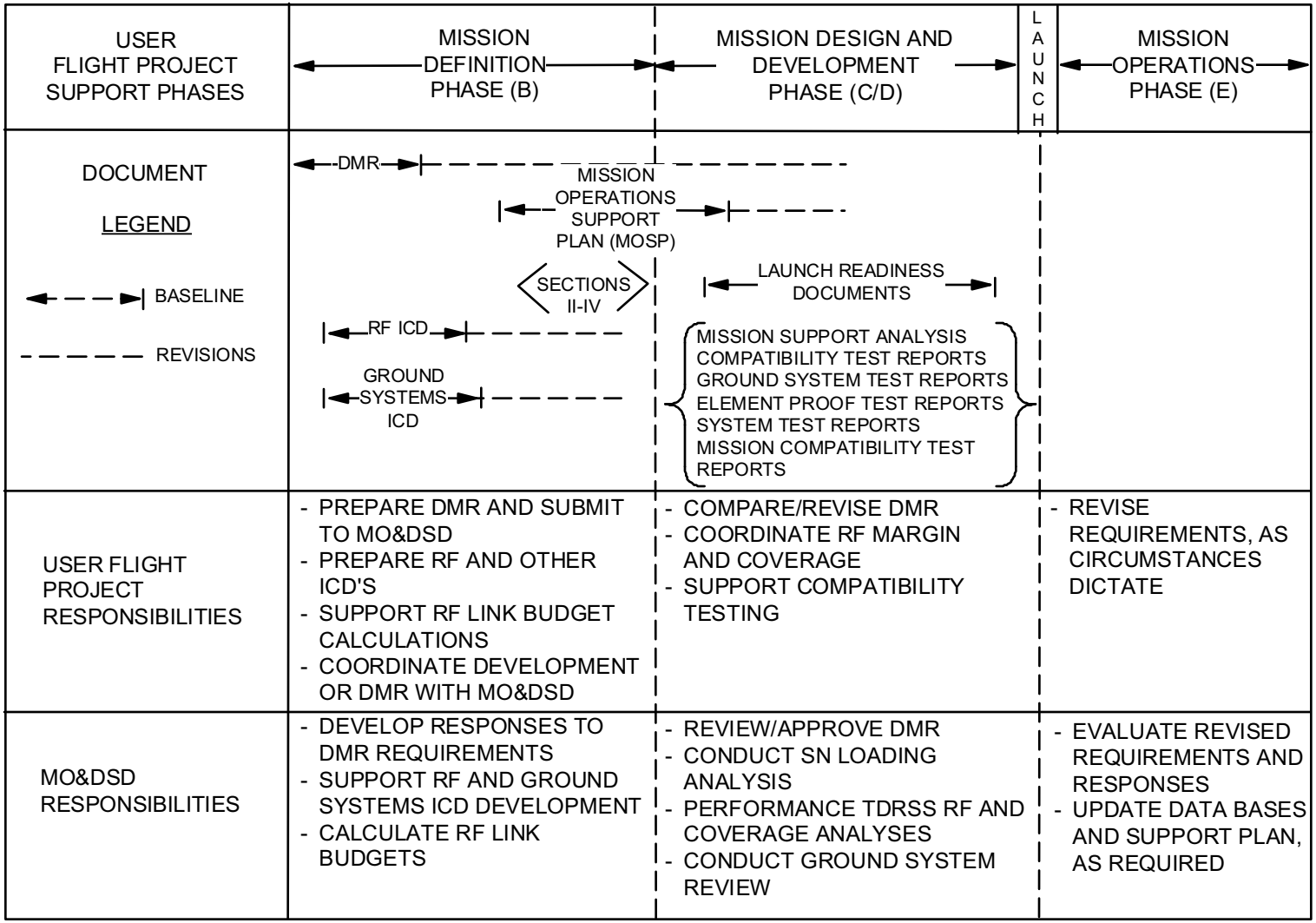

Figure 1-5. SN User's Documentation Timeline

waiver from the Data Systems Requirements Committee (DSRC). If a waiver is needed, the project asks the DSOPM, who in turn requests a waiver from the DSRC. In practice, these standards have provided a common basis for efficient and reliable interchange of data and represent systems and procedures which currently are feasible in the SN. The standards encompass most of the range of support functions which can be furnished by the SN.

1.8.2 USER SPACECRAFT SIGNAL INTERFACE COMPLIANCE

1.8.2.1 Absolute Compliance Requirements. Certain characteristics of the user spacecraft transmitted RF signal require absolute adherence to TDRSS return service characteristics defined in this document. The user spacecraft transmit signal characteristics must conform to these absolute-compliance characteristics to obtain TDRSS return and tracking services. These absolute-compliance characteristics of the user spacecraft signal are designated in this document as the return service signal parameters and TDRSS service characteristics, which are defined in section 3.

1.8.2.2 Partial Compliance Requirements. Other characteristics of the user spacecraft transmitted RF signal allow partial compliance, defined as follows:

a. Parameters. Partial-compliance parameters are those signal characteristics for which degradations in TDRSS return and tracking service performance are incurred if the requirements for parameters in this document are not met. These degradations must be offset by additional user spacecraft transmit Effective Isotropic Radiated Power (EIRP). The user spacecraft transmit signal characteristics that can be partially complied with are the user spacecraft constraints defined in section 3. The user flight project must accept responsibility for technical performance degradations due to partial compliance. Increasing user spacecraft EIRP must be done with care, because in some cases such an increase may affect other users. Also, such an increase may not be a direct solution to the original problem.

b. MO&DSD Evaluation. The values of those user spacecraft transmit signal parameters which will be only partially met will be evaluated by the MO&DSD which will use the CLASS facility to predict the resultant performance degradation. This performance degradation assessment will determine the additional user spacecraft EIRP required to provide acceptable performance throughout the lifetime of the mission. Submission of the partial-compliance parameters values for evaluation and approval is expected to be an iterative process.

c. User Options. The user flight project may elect, after receiving the initial predict performance degradations, to improve the compliance of some parameters in order to reduce the amount of required user spacecraft EIRP. Thus, the user flight project can perform system tradeoffs, trading compliance, either partial or total, against increased user spacecraft transmit EIRP within the user flight project's technical and economic constraints.

d. Incorporation in ICD. The final partial-compliance values and the resulting predicted performance degradations will be incorporated in the RF ICD between the user flight

project and the MO&DSD. The predicted performance degradations should also be included as a degradation line item in the user flight project's link calculations. An example of how CLASS is used for the evaluation of partial compliance with the constraints defined in section 3 is given in Appendix H.

1.8.3 USER SPACECRAFT/TDRSS RF LINK CIRCUIT MARGINS

1.8.3.1 General. User margin is the risk factor the user flight project must include in its user spacecraft/TDRSS RF communication link design to account for degradations in the user spacecraft communication terminal during the life of the mission. The example link calculations in this guide include a 3 dB Beginning of Life (BOL) user margin to account for such degradations. The user should ensure a 3 dB margin when designing the spacecraft communication system, since most parameters measured by the user are for BOL. The 3 dB margin will take into account user degradations. This 3 dB BOL margin should not be interpreted as a MO&DSD margin requirement to account for any TDRSS degradation.

1.8.3.2 User Options. If the user flight project has performed an analysis which predicts a degradation greater than the suggested 3 dB margin value during the life of the mission, the following options are available:

a. The user flight project could change the user spacecraft design to provide the necessary BOL margin which compensates for the predicted life degradation, thus providing a satisfactory End of Life (EOL) margin.

b. The user flight project could accept additional operational constraints if the incurred degradation exceeds the BOL margin (a condition of negative link margin). An example of an additional operational constraint is reduced coverage due to a reduced maximum user spacecraft/TDRS operating range and/or due to restricting link operation to a better (less degrading) portion of the user spacecraft antenna radiation pattern.

c. The user flight project could use an operational alternative if the link margin became negative. Examples of operational alternatives include:

(1) Use of the TDRSS S-band Single Access (SSA) return service for a link normally supported by an MA return service.

(2) A reduction in the user spacecraft transmitted data rate.

1.8.3.3 Responsibilities. The MO&DSD commitment to provide SN support to a user spacecraft is based on compliance with the performance parameters in the user spacecraft/TDRSS RF ICD. The performance parameters in the ICD are defined for each RF link with a zero dB user margin factor. The user flight project has the total responsibility of establishing the magnitude of the BOL margin for each RF link, except for emissions in the TDRSS MA return service band. The MO&DSD becomes involved in establishment of the magnitude of a user BOL margin only for an RF link with user spacecraft emission in the TDRSS MA return service band. The MO&DSD negotiates with each user flight project, on a case-by-case basis, an upper-limit BOL margin to minimize self-interference to other users of the TDRSS MA return service. The magnitude of

this margin depends on the current and projected EIRP emissions in the TDRSS MA return service band for all user spacecraft. Management of the magnitude of the TDRSS MA return service margin should be accomplished early in the user flight project life cycle, preferably at the time of preparation of the RF ICD, so that the user flight project can include the correct TDRSS MA return service margin in the user spacecraft design specification.

1.8.4 TESTING FOR COMPLIANCE WITH USER CONSTRAINTS

Testing to determine whether user spacecraft constraints are met or to determine the value of a non-compliant constraint is not an explicit requirement for establishing the performance of the user spacecraft/TDRSS RF interface. It is the user flight project responsibility to ascertain how compliance is demonstrated by using measurement, analysis, or a combination of analysis and measurement. As such, MO&DSD does not grant any waivers for user spacecraft constraint testing, but assists user flight projects in assessing the applicability of user spacecraft constraint parameters or portions of user spacecraft parameters which apply to the user spacecraft communications system design.

1.8.5 USER-UNIQUE REQUIREMENTS/EQUIPMENT

In their requirements documents, user flight projects must plan to use existing SN capabilities as defined herein. Any proposed modification to the SN ground data-handling system unique to a specific user must be funded by that user flight project, and be negotiated with NASA Headquarters (Code O).

1.8.6 SA SYSTEM OFFLOADING

1.8.6.1 General. To preclude potential future overloading of the TDRSS SA system (S-band and K-band services) and to support as many users as possible with this system, it is necessary for user flight projects to make maximum use of the TDRSS MA service and minimize use of the TDRSS SA services. Use of TDRSS SA services should be limited to relatively short periods; e.g., use of a data record and dump mode of operation with the dump rates as high as technically and economically feasible.

1.8.6.2 Available Options. To minimize TDRSS SA service times, the TDRSS MA service should be used for command data, tracking data generation, and low data rate telemetry operations, such as spacecraft engineering data and low data rate science data. Consideration should also be given to use of the very high data rate capability of the TDRSS K-band Single Access (KSA) return service for high data rate dumps. Since no significant Radio Frequency Interference (RFI) exists within the TDRSS KSA service frequency band (refer to paragraph 2.2.2 for a discussion of the RFI problem at S-band), there are no pointing restrictions (other than sun pointing constraints or WSC pointing constraints) on the TDRS when using the TDRSS KSA return service.

1.9 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. STDN Tests and Simulations Handbook, STDN No. 413.

2. Requirements Specification for the Danzante Ground Terminal, 530-RSD-DANZANTE.

3. NASA Management Instructions (NMI) 8430.1C.

4. NASA Management Instructions (NMI) 8610.10B.

5. Use and Reimbursement Policy for non-NASA U.S. Government Users of TDRSS, 8410.2.

6. Use and Reimbursement Policy for non-U.S. Government Users of TDRSS,8410.3.

7. Ground Spaceflight Tracking and Data Network (GSTDN) Users' Guide, STDN No. 101.3.

8. Space Network Synoptic Description, STDN No. 134.

9. Portable Simulations System and Simulation Operations Center Guide for TDRSS and GSTDN Users, STDN No. 101.6.

10. Mission Operations and Data Systems Directorate Systems Management Policy, DOD-8YMP/0485.

11. Mission Operations and Data Systems Directorate Software Development Policy, MODSD-8YDP/0186.

12. Mission Operations and Data Systems Directorate Systems Documentation Guidelines, MODSD-8YMP/0286.

13. Goddard Space Flight Center Project Management Handbook, December 1986, GSFC Projects Directorate (Code 400).

14. GSFC STDN Operations Concepts 1994 Briefing Book, January 1988.

15. Data Encryption Standard Document, The Federal Information Processing Standard 46-2, Dec. 1993.

16. Goddard Management Instruction 8070.1A.

17. TDRS & GSTDN Compatibility Test Van Functional Description & Capabilities, STDN No. 408.

18. PN Codes for Use with the Tracking & Data Relay Satellite System (TDRSS), STDN No. 108.

19. JSC Doc. 07700, Vol. XIV, Space Shuttle Payload System, Payload Accommodations, Attachment 1, ICD 2-19001, Shuttle Orbiter/Cargo Standard Interfaces, Revision G, Sept. 26, 1980.

20. Avionics Interfaces

21. CLASS ACRS/TLAS Operator's Manual & Reference Version 94.1

22. Interface Control Document Between the Network Control Center Data System and the Network Control Center User Planning System, 530-ICD-NCCDS/UPS.

23. Interface Control Document Between the Network Control Center Data System (NCCDS) and the Mission Operations Center (MOC), 530-ICD-NCCDS/MOC.

24. Space Network Operations Policy, STDN No. 119.

25. Interface Control Document (ICD) Between the Network Control Center (NCC)/Flight Dynamics Facility (FDF) and the White Sands Complex (WSC), 530-ICD-NCC-FDF/WSC.

26. NASCOM System Development Plan (NSDP), 540-030.

27. NASA Communications (NASCOM) Space Network Ground Segment Data Book (542-016)

28. POCC Capabilities Document, Volume II, MCC/Remote POCC Interface Capabilities Description, JSC-14433.

29. NGT/NASCOM/POCC Interface Control Document, MDOD-1 (ICD/0180)

30. NASCOM Interface Standard for Digital Data Transmission (NISDDT), 542-003.

31. NASCOM-TDRSS Multiplexer/Demultiplexer Data Systems User Interface Manual, GSFC OM-841-80126.

32. Functional and Performance Requirements and Specfication for the TDRSS/STDN User Transponder, STDN No. 203.7.

33. User's Guide for the NASA Standard TDRSS User Transponder, Motorola 68-P02889L.

34. Performance and Design Requirements and Specfication for the Second Generation TDRSS User Transponder, STDN No. 203.8.

35. User's Guide for the NASA Standard TDRSS User Transponder (The Second Generation), Motorola.

36. Design Evaluation Report for the Second Generation TDRSS User Transponder, Motorola.

37. Performance Specification: S-band Transponder for EOS-AM Spacecraft (SP-402), Martin Marietta, PS20008584B.

38. Space Station Freedom Program Communications and Tracking System: B2 Critical Item Development Specification, Standard TDRSS Transponder (Rev. E), GE Spec No. 10033011.

39. Performance and Design Requirements and Specification for the Fourth Generation TDRSS User Transponder, 531-RSD-IVGXPDR.

40. Performance and Design Requirements and Specification for the Balloon-Class TDRSS User Transponder, STDN No. 203.64.

41. Final Report for the Balloon Class TDRSS Transponder, Volume 1: Design Verification Report, STEL-TR-95203.

42. Performance Specification: S-band Transponder for L7 Spacecraft, Martin Marietta, PS23007659B.

SECTION 2. TDRSS CAPABILITIES SUMMARY

2.1 OVERVIEW

2.1.1 GENERAL

The purpose of this section is to provide an overview of the telecommunications services provided to users by the SN and to discuss the TDRSS in terms of user-related functions. The TDRSS is composed of the TDRS constellation and the WSC. There will be up to four operational TDRSs communicating with the Space-to-Ground Link Terminals (SGLTs) at the WSC. Both the Cacique and Danzante have three SGLTs each. SGLT1, SGLT2, and SGLT3 support TDRSS services at Danzante and SGLT4, SGLT5, and SGLT6 support TDRSS services at Cacique. It should be noted that SGLT3 and SGLT6 provide backup support for all Single Access (SA) services. User services are referenced in terms of TDRS-SGLT pairs, where a pair is defined to be the combination of 1 TDRS and 1 SGLT.

2.1.2 AVAILABLE SERVICES

2.1.2.1 Telecommunications Services. The TDRSS provides the users with MA and SA services. The SA services are available for S-band and K-band frequencies.

a. Multiple Access Service. The MA service provides dedicated return service to low Earth-orbiting user spacecraft with real-time, playback, and science data rates up to 100 kbps. Return service support can be provided simultaneously for up to 5 user spacecraft per TDRS-SGLT pair during that portion of each user spacecraft orbit that is visible to any of the TDRSs (i.e., 85 percent or more of a user spacecraft orbit). Forward service operations are time-shared with a maximum individual user spacecraft received bit rate of 10 kbps and will support one user spacecraft per TDRS at a time. The MA service will operate at S-band (fixed frequency and polarization).

b. Single Access Service. Four single access services are available through each TDRS SA antenna: S-band Single Access Forward (SSAF), S-band Single Access Return (SSAR), K-band Single Access Forward (KSAF), and K-band Single Access Return (KSAR). Forward service operation provides data rates up to 300 kbps at S-band and up to 25 Mbps at K-band. Return service operation provides total data rates up to 6 Mbps (rate 1/2 coded) at S-band and up to 300 Mbps (uncoded) at K-band. By definition in this document, all rates are information rates (i.e., prior to encoding) unless specified otherwise. Symbol rates are understood to be after encoding.

c. Cross-support Service. Any mission that is compatible with the MA service can use forward or return service 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. Guidelines and restrictions on using cross-support are found in STDN No. 119.

2.1.2.2 Tracking Services. The TDRSS provides spacecraft tracking data and the data required for clock updates to the user spacecraft.

a. Range and Range Rate (R&RR) Data. Tracking data (R&RR) may be provided with the services discussed in section 2.1.2.1. This data provides tracking accuracies comparable to those currently available from the GN for the MA, SSA, and KSA services.

b. User Time Transfer. The time transfer function provides a method to acquire the data necessary to update a user spacecraft clock. It gives the user POCC/MOC the ability to determine the time difference between the on-board spacecraft clock and Universal Time, Coordinated (UTC). To facilitate the time transfer measurement, the user must cause the spacecraft to note and store the spacecraft clock reading at the time of arrival of the epoch portion of the PN range code. The clock reading must be included in the spacecraft telemetry for processing by the POCC/MOC. It is the POCC/MOC's responsibility to make the necessary adjustment to the user clock using the TDRSS-supplied data and the WSC capability.

2.1.2.3 End-to-End Test Services. The TDRSS provides user End-to-End test services through the functional capabilities of the following SN elements: WSC, CTV, and RFSOC/SOC.

a. TDRSS End-to-End Test Services. The TDRSS End-to-End Test services are provided within each SGLT at WSC. The EET provides user projects the capability of testing the end-to-end SN data communications through a ground-based simulation of the user spacecraft to POCC/MOC link via TDRSS thus eliminating the need for the actual user spacecraft. 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 K-band (KSA) user.

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

(1) Compatibility Testing. Before launch, a TDRSS CTV is used to validate user spacecraft/TDRS RF interface compatibility. The TDRSS CTV emulates the TDRSS in data modulation/demodulation capabilities and provides an RF relay between the user spacecraft and a TDRS. Information about TDRSS compatibility testing is contained in TDRS and GSTDN Compatibility Test Van Functional Description and Capabilities, STDN No. 408.

(2) SN Simulation Testing. User/SN simulation testing is performed before launch, using the user ground facilities (user POCC/MOC and/or data processing facility), TDRSS, and the RFSOC/SOC. The purpose of simulation testing before launch is to validate SN performance. Validation includes operations checkout, end-to-end Bit Error Rate (BER) tests, and fault simulation tests. SN simulation testing is also provided during the user's mission operations. Information for users about the RFSOC/SOC is contained in STDN No. 101.6.

2.1.2.4. Additional Capabilities. Services other than those specifically identified in this document are available to users of the SN on a case-by-case basis. Network commitment to provide these services will be based upon detailed analysis of the requirements and operating conditions during which the service is to be provided. These agreements will be documented in the RF ICD for the SN user and will be valid only for the conditions specified. A partial listing of these services is given below along with their potential applicability. Performance specifications for these services are not, in general, directly related to the standard SN services specified in section 3 of this document.

a. GRO Remote Terminal System (GRTS). In order to alleviate the Zone of Exclusion (ZOE) impact on the Compton GRO spacecraft resulting from its failed flight recorders, NASA relocated a spare TDRS to 275 degrees west longitude. NASA implemented the GRTS Remote GRO Relay Terminal (RGRT) in Tidbinbilla, Australia to perform a bent-pipe relay function between the TDRS at 275 degrees west longitude and the WSC. Because GRTS was designed specifically to meet the needs of the Compton GRO project, the capabilities of this ground facility do not necessarily meet the specifications given in this document. Forward link services are not available through GRTS. Use of the GRTS relay is subject to negotiations with GSFC Code 530. Refer to Appendix I for additional information on GRTS.

b. Intermediate Frequency (IF) Services. TDRSS S-band and K-band telemetry support is available to non-TDRSS compatible users on a short term basis. These users include expendable launch vehicles, upper stages, and spacecraft during various mission phases. The telemetry signals would require the use of the 370 MHz IF port, coupled with GN type receivers. All special purpose equipment used for processing data at the return IF ports and the unmodulated IF forward ports shall be manually configured. Any Doppler compensation required for acquisition and tracking of the user signal or the forward link would be provided by the user equipment. This type of support can be requested by contacting Code 530.

c. SSA Post-Detection Combining. The TDRSS can post-detection combine the signals received from a single user spacecraft through both SSA return services using the same TDRS, thus providing a user spacecraft which has degraded EIRP with a nominal 2.5 dB increase in return service performance (increasing the achievable data rate when the user spacecraft signal is above the WSC receiver threshold). Use of SSA post-detection combining is restricted to emergency-only support for total data rates less than 3 Msps and its use must be coordinated with the SN.

d. SSA Support of DG1 Mode 4. The TDRSS can provide support of DG1 Mode 4 signals through the SSA return service. DG1 Mode 4 signal characteristics are equivalent to DG1 Mode 3 with the exception that periodic convolutional interleaving is not required for DG1 Mode 4 when symbol rates are above 300 ksps. Use of DG1 Mode 4 signals must be coordinated with the SN and the SN cannot guarantee a BER of 10^{-5}.

2.1.3 TDRSS/USER SPACECRAFT FREQUENCY PLAN

Figure 2-1 summarizes the forward and return service frequency plan for the space-to-space links. Figure 2-1 does not show the TDRS-to-WSC and WSC-to-TDRS link channelization because this does not affect the TDRS/user spacecraft interface. Note, until the NCC Service Planning Segment Replacement, which is expected in the 1998 time-frame, the S-band frequency range which is available for user scheduling is 2041.0 to 2117.9 MHz (forward) and 2216 to 2300 MHz (return).

2.1.4 SERVICE OPERATIONS

2.1.4.1 Relational Operations. Figure 2-2 shows the user POCC/MOC/Data Processing Facility (DPF) functional traffic interfaces (command, telemetry, and R&RR data) with the SN and the functional operational interfaces with the NCC for user utilization of the TDRSS telecommunications services. Because the TDRSS is capable of providing extended user spacecraft contact time to many user spacecraft simultaneously, the SN provides sufficient communications facilities to accommodate real-time data transfer between the user spacecraft and the user POCC/MOC and/or data processing facilities. The SN does not store forward service (command) or return service (telemetry) data except for temporary storage (line outage protection), buffering, and later playback of return service (science) data that exceeds the NASCOM data transport system capabilities. Operational control of the SN is the responsibility of the Networks Division, Code 530, at GSFC and is performed by the NCC. The NCC is responsible for scheduling TDRSS services, for real-time configuration control of TDRSS services, for monitoring the performance of scheduled TDRSS services, and for monitoring the availability of TDRSS services. The NCC uses the performance monitoring data from WSC for coordinating fault isolation and subsequent corrective action at all SN elements that support user spacecraft related services.

2.1.4.2 Operational Messages. The user POCC/MOC requests scheduling of SN services and initiates real-time configuration change requests to SN services as a result of user spacecraft real-time configuration changes. The user POCC/MOC receives service related operations monitor and service performance data through the operational interfaces with the NCC if these items are included in the ground facilities ICD.

2.1.4.3 TDRSS Scheduling. Section 4 provides further details on requirements for the user POCC/MOC to schedule TDRSS services and to effect a real-time configuration change of a scheduled service in response to a real-time user spacecraft configuration change.

2.1.5 USER TRANSPONDER OPTIONS AND OPERATIONS

2.1.5.1 General. The user has several options for transponder use during the design of the spacecraft. Transponder options are either the NASA S-band standard transponder or a unique design that meets TDRSS requirements. If the operation permits, the user may elect to use direct transmission and reception in lieu of a transponder. In this case, however, use of a highly accurate and updatable onboard clock to obtain tracking service measurements of the desired accuracy should be considered.

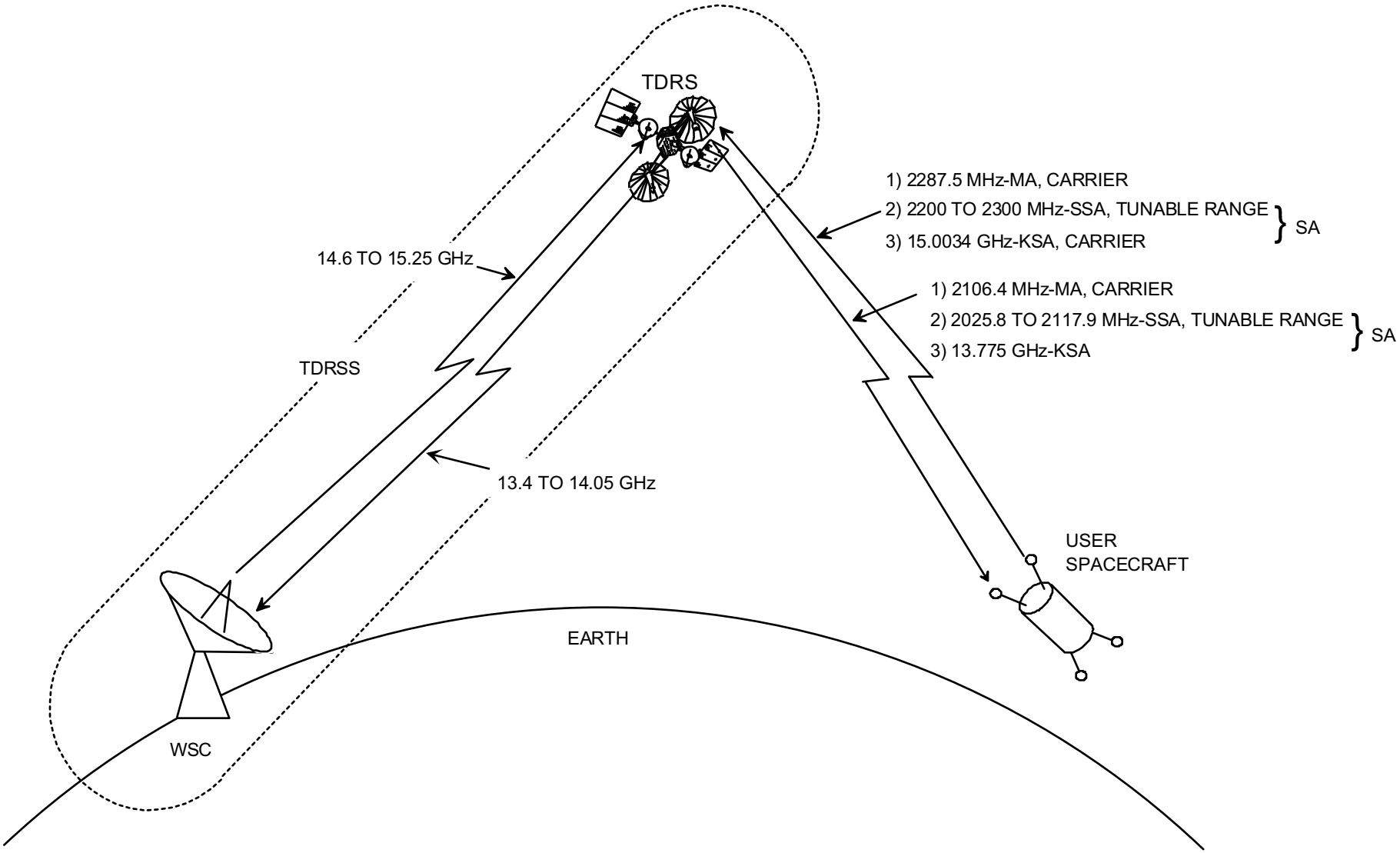

Figure 2-1. TDRSS Forward and Return Service Frequency Plan

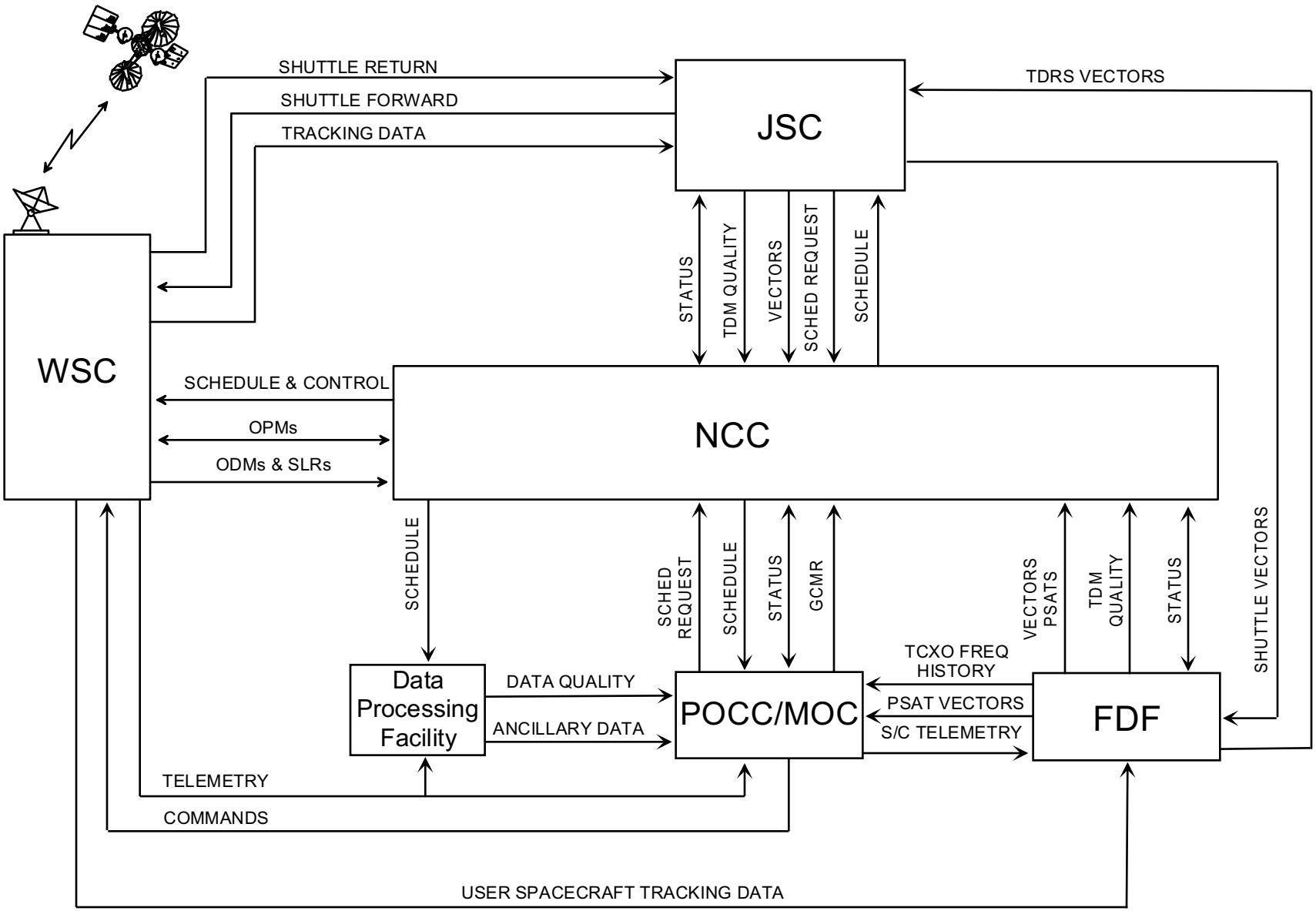

Figure 2-2. User/SN Operational Functional Configuration

2.1.5.2 Available Standard. The NASA S-band standard transponders are listed in paragraph 1.9.

2.1.5.3 Multiple transponder requirements. When a user spacecraft contains multiple transponders for redundancy, each transponder must use the same PN-code assignment. The user spacecraft transponder functional configurations for all TDRSS return link services (MA, SSA, and KSA) are shown in Appendix B, paragraph B.3.

2.2 TDRSS/USER SPACECRAFT ORBITAL COVERAGE CAPABILITIES

2.2.1 GEOMETRIC COVERAGE CAPABILITIES

2.2.1.1 General. The TDRSS, with up to four operational TDRSs, provides the potential for near-global real-time geometric coverage (at least 85 percent of each orbit) for most user spacecraft. This geometric coverage can be provided to all MA services and to some high-priority users of SA services. Paragraphs 2.2.2 and 2.2.3 discuss additional nongeometric coverage constraints. Figure 2-3 is an example of the geometric ZOE, the area in which geometric coverage cannot be provided for a user spacecraft. In this example, the ZOE is for a user spacecraft at a 600 km altitude and TDRSs with a 0 degree inclination at 41 degrees, 46 degrees, 171 degrees and 174 degrees West longitude. The geometric ZOE represents the lower altitude geometric coverage constraint for user spacecraft. For orbital altitude greater than 1200 km, 100-percent geometric coverage can be provided: up to 3000 km for the MA service and 10,000 km for the SA service. In summary, the following coverage is provided:

a. Minimum geometric coverage of 85 percent at 200 km.

b. Geometric coverage at 100 percent between 1200 and 3000 km for the MA service and between 1200 and 10,000 km for the SA service.

c. Geometric coverage decreases above 3000 for MA services and above 10,000 km for SA services.

2.2.1.2 User specific geometric coverage. The amount of geometric coverage which can be provided to a user spacecraft is a function of the user spacecraft altitude and inclination. A user spacecraft at low altitudes and low inclinations passes through the geometric ZOE during each orbit and receives the least coverage. A user spacecraft at high altitudes and high inclinations passes through the geometric ZOE only periodically (e.g., a user spacecraft at 1000 km and 99 degree inclination passes through the geometric ZOE once per day or less, although the duration of this passage is greater than that of a lower inclination mission). The geometric coverage as a function of altitude for various inclinations is summarized in Figure 2-4.

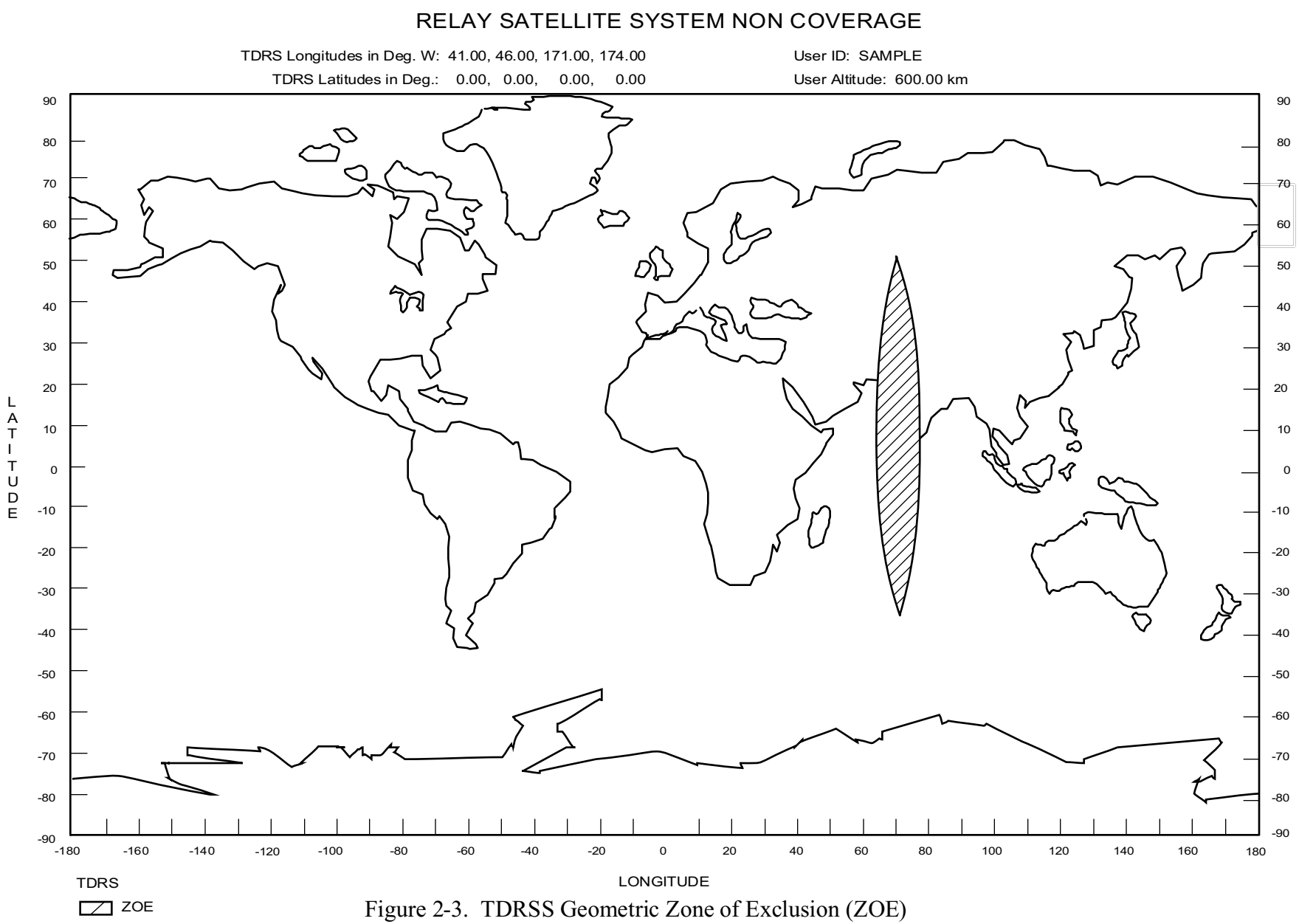

Figure 2-3. TDRSS Geometric Zone of Exclusion (ZOE)

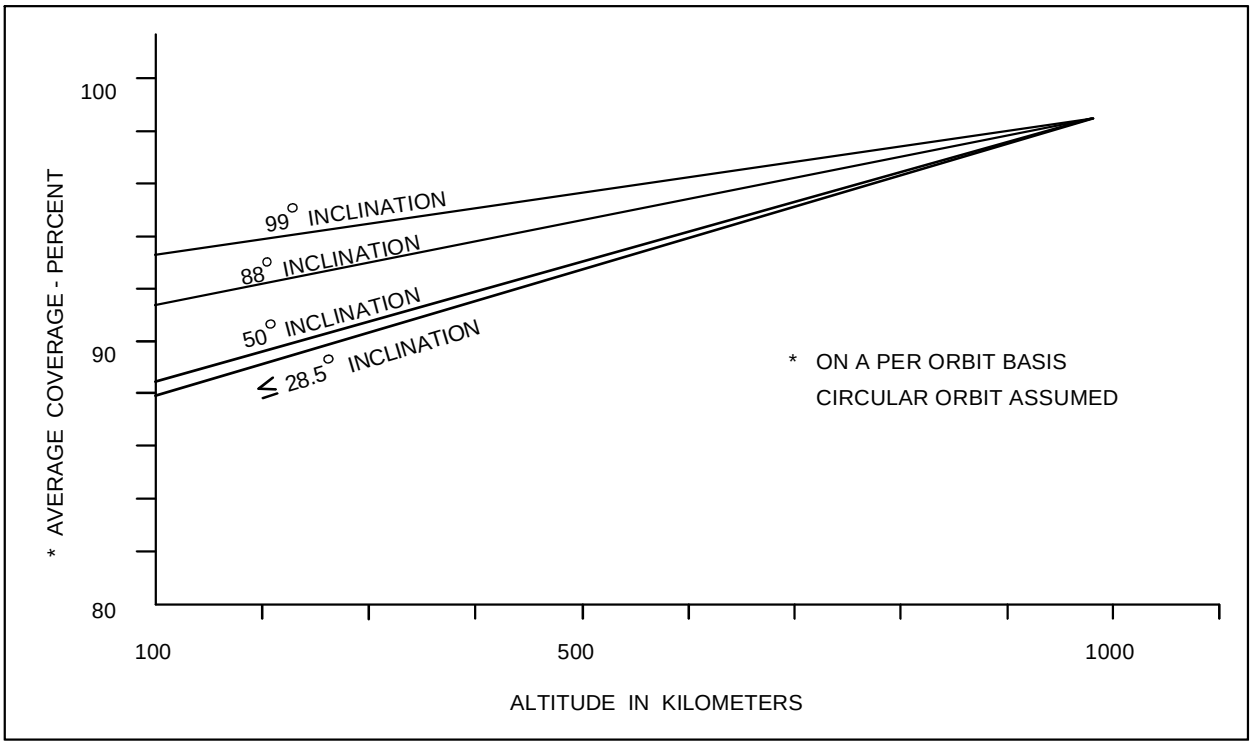

Figure 2-4. Average Geometric Coverage Versus User Spacecraft Altitudes at Various Inclinations

2.2.2 RFI COVERAGE CONSTRAINTS

SSA and MA user spacecraft forward service and TDRS return service receptions are subject to RFI from terrestrial emitters. Actual performance degradation to user spacecraft forward and TDRS return service receptions due to RFI is a complex function of user spacecraft and TDRS transmission/reception characteristics (e.g., frequency, data rate, signal format, convolutional encoding rate 1/2 or 1/3, symbol interleaving), subsatellite point, user spacecraft MA or SSA receiving antenna pattern and boresight pointing location, and the TDRS SSA return service antenna boresight pointing location. Appendix G discusses performance degradations attributable to RFI. More specific information on the performance degradation to a user's particular S-band service operations will be provided by the Communications and Mission Analysis Section, Code 531.1, at the appropriate time during preparation of the RF ICD.

2.2.3 OTHER COVERAGE CONSTRAINTS

The following constraints also reduce available TDRSS telecommunications coverage and should be considered during user mission planning stages:

a. Flux Density Restrictions (User Spacecraft Transmit). User spacecraft transmitted energy in the direction of the Earth during any part of the user spacecraft orbit may not

exceed the specified flux density. Refer to Appendix D for S-band and K-band flux density restrictions and a typical flux density analysis.

b. Flux Density Restrictions (TDRS Transmit). TDRS-transmitted energy in the direction of the Earth during any part of the user spacecraft orbit may not exceed the applicable flux density. The use of high-power SA transmission modes for user spacecraft are restricted to emergency situations only. For STS missions, high-power SA transmission modes are the baseline support modes.

c. Restricted User Spacecraft Antenna Gimbal or Steering Angles. Due to user spacecraft orientation, geometry, or user spacecraft terminal characteristics.

d. Service Limitations. Resource conflicts, sun interference, and scheduling constraints due to higher priority users may preclude service to another user.

2.3 FORWARD SERVICE

2.3.1 GENERAL

The forward services provided by the TDRSS are summarized in paragraphs 2.3.2 through 2.3.5. Details of the forward services, signal design, salient characteristics, and performance appear in section 3 and related appendices. Each forward service uses a single RF link containing a command channel and a range channel.

2.3.2 SERVICE CHARACTERISTICS

2.3.2.1 General. A TDRS can provide one MA forward service, two SSA forward services, and two KSA forward services simultaneously. An SSA and a KSA forward service are provided through each of two TDRS SA antennas. Each SA antenna can support forward service to two different user spacecraft when both users are in the same SA beam and one user is operating at S-band and the other at K-band.

2.3.2.2 MA Forward Service. The MA forward service through a TDRS can support only one user spacecraft at a time. The TDRSS provides the capability for continuous support of MA forward service for each user per TDRS-SGLT pair. These services are time-shared by all users of the MA forward service. The MA forward service transmits the same frequency and polarization to all users. All user spacecraft using the MA service operate at the same frequency and receiving antenna polarization and are discriminated by unique PN codes and TDRS antenna beam pointing. Forward service to an MA user can also be provided by an SSA forward service.

2.3.2.3 SSA Forward Service. Each TDRS can provide two simultaneous SSA forward services via the Single Access antennas. The TDRSS provides the capability for continuous support of SSA forward services for two users per TDRS-SGLT pair. These services are time-shared by all users of the SSA forward service. User spacecraft are discriminated by frequency, polarization, unique PN codes, and TDRS antenna beam pointing. An SSA forward service can also be used

to provide forward service with increased signal EIRP to a user spacecraft that normally uses the MA forward service.

2.3.2.4 KSA Forward Service. Each TDRS can provide two simultaneous KSA forward services via the SA antennas. The TDRSS provides the capability for continuous support of KSA forward services for two users per TDRS-SGLT pair. These services are time-shared by all users of the KSA forward service. User spacecraft are discriminated by polarization, unique PN codes (for forward data rates of less than 300 kbps), and TDRS antenna beam pointing.

2.3.3 SIGNAL CHARACTERISTICS

A forward service (MA, SSA, or KSA) signal includes separate but simultaneous command and range channels for data rates 300 kbps or less. The command channel includes a rapidly acquirable PN code and contains the forward service data. The user spacecraft must use the command channel PN code for signal acquisition. Command data greater than 300 kbps is transmitted only via the KSA forward service. This data Binary Phase Shift Key (BPSK) modulates the KSA forward service carrier. The range channel is not transmitted for forward data rates greater than 300 kbps. The maximum available forward service data rates are 10 kbps (MA), 300 kbps (SSA), and 25 Mbps (KSA).

2.3.4 PERFORMANCE

The performance of the various forward services is summarized in Figure 2-5 and is based on the example link calculations given in Appendix A. Figure 2-5 gives the performance without any user-provided Forward Error Correction (FEC).

2.3.5 OPERATIONS

2.3.5.1 Configuration. Forward service can be provided through any one or any combination of the three services, depending on the user data requirements. Forward service data is handled only in real time through the telecommunications path between the user POCC/MOC and the user spacecraft. Data destined for user spacecraft is expected to be transmitted from user POCC/MOCs in the exact formats required by the user spacecraft. Data acknowledgments from the user spacecraft may be derived by the user POCC/MOC from real-time user spacecraft return service data. Although not normally utilized in this manner, user spacecraft forward service support periods can be scheduled on the basis of required forward service coverage intervals, independent of return service and tracking requirements except for KSA forward service that requires a simultaneous KSA return service when a closed-loop autotrack system is used between the TDRSS and the user spacecraft.

2.3.5.2 General Restrictions. Operational restrictions on the use of the forward services, which are independent of the TDRS forward service transmit power mode, are as follows:

a. KSA Non-User Specific Sun Outage. There is no KSA forward service when the center of the sun is within 1 degree of the TDRS SA antenna KSA boresight (sun outage).

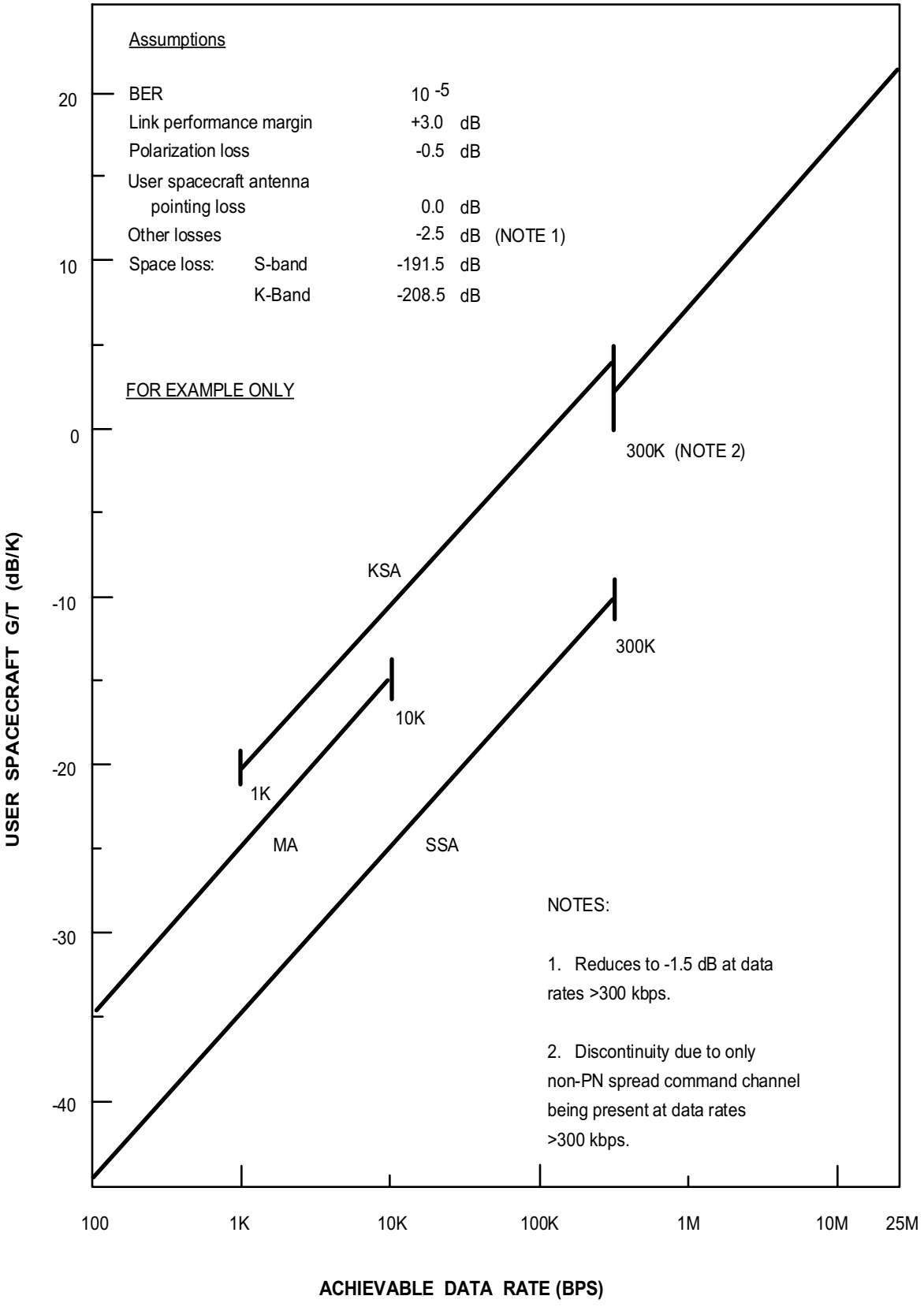

Figure 2-5. Typical User Spacecraft G/T versus Achievable Data Rate Forward Services

b. User-Defined Sun Outage. There is no MA, SSA, or KSA forward service when the center of the sun is within X degrees of the user spacecraft antenna boresight (sun outage) where X is a function of the user spacecraft antenna beamwidth as determined by the user POCC/MOC. A user POCC/MOC may schedule service during the sun interference at his option, but performance may be degraded. To prevent undue delays in user spacecraft reacquisition of KSA forward service due to user spacecraft KSA antenna autotrack system capture by the sun, the user POCC/MOC should schedule KSA forward service support periods that bracket the sun transit. Alternatively, the user POCC/MOC could request that the KSA return service autotrack mode be inhibited during this service support period.

c. S-Band RFI. Degradation to MA and SSA forward service performance may occur due to terrestrial users of the S-band frequency spectrum (refer to Appendix G for a discussion of S-band RFI).

d. K-Band RFI. Very infrequent, sporadic outages may occur on KSA forward services due to RFI.

e. Autotrack Inhibit. The KSA forward service EIRP, in the direction of the user spacecraft, may be reduced when the KSA return service autotrack mode is inhibited.

2.3.5.3 SA High Power Mode Restrictions. Operational restrictions on the use of SSA and KSA forward service in the TDRS forward service transmit high-power mode are as follows:

a. General. For user spacecraft, the high-power mode is used for emergencies only (SSA only).

b. Shuttle. For STS operations, the high-power mode is the baseline mode.

c. Location. The high-power mode is restricted when the user spacecraft is located near the limb of the Earth, as seen from a TDRS.

2.4 RETURN SERVICE

2.4.1 GENERAL

The return services provided by the SN are summarized in paragraphs 2.4.2 through 2.4.5. Details of the return services, signal design, constraints on the user spacecraft transmitted signal, and performance appear in Section 3 and related appendices. Each return link service uses a single RF link.

2.4.2 SERVICE CHARACTERISTICS

2.4.2.1 General. Each TDRS-SGLT pair can support up to five MA return services, two SSA return services, and two KSA return services simultaneously. The total number of MA return services that are available varies with the number of operational TDRSs. TDRSS may

operationally limit the number of user spacecraft utilizing this service during specific time periods to minimize performance degradation due to system self-interference [refer to paragraph 3.2.3.3e]. An SSA and a KSA return service are provided through each of two TDRS SA antennas. SSA and KSA return service can be provided simultaneously to a user spacecraft using the same TDRS SA antenna. Each return service can provide either one or two data channels from a user spacecraft. For example, two data channels can be used to transmit real-time data and recorder playback data or real-time housekeeping data and real-time science data simultaneously.

2.4.2.2 MA Return Service. The TDRSS can simultaneously support five MA return services per TDRS-SGLT pair. Only four of the six SGLTs at WSC provide MA services. MA return service is dedicated to a user spacecraft and can provide support for the entire portion of the user spacecraft orbit that is visible to a given TDRS. All user spacecraft operate at the same frequency and transmitting antenna polarization. They are discriminated by unique PN codes and TDRS antenna beam pointing.

2.4.2.3 SSA Return Service. The single access S-band service is described below:

a. Description. Each TDRS can provide two simultaneous SSA return services via the Single Access antennas. The TDRSS provides the capability for continuous support of SSA return services for two users per TDRS-SGLT pair. These services are time-shared by all users of the SSA return service that are visible to a given TDRS. User spacecraft discrimination includes frequency, antenna polarization, unique PN codes, and TDRS antenna beam pointing.

b. Improvement for MA Users. Users of the MA return service can obtain approximately 8.5 dB of return service performance gain by employing SSA support of a user spacecraft transmitting an MA signal (refer to paragraph 2.1.2.1c). An SSA return service can, therefore, be used to provide return service to a user of the MA return service, providing either increased return service link margin for user spacecraft emergencies or an increased Achievable Data Rate (ADR) equivalent to that for normal users of the SSA return service. If a user is operating at the MA polarization and frequency, that user is still restricted to the maximum allowable MA EIRP.

2.4.2.4 KSA Return Service. Each TDRS can provide two simultaneous KSA return services via the SA antennas. The TDRSS provides the capability for continuous support of KSA return services for two users per TDRS-SGLT pair. These services are time-shared by all users of the KSA return service that are visible to a given TDRS. User spacecraft discrimination includes antenna polarization, unique PN codes for users with data rates less than 300 kbps, and TDRS antenna beam pointing.

2.4.3 SIGNAL CHARACTERISTICS

2.4.3.1 General. The signal characteristics for a TDRSS compatible signal are summarized as follows:

a. Data Group Definitions. The two signal designs available to return service users are defined as either Data Group 1 (DG1) (modes 1, 2, and 3) or Data Group 2 (DG2) signals. The DG1 modes 1, 2, and 3 (I channel) signal design spreads the return service spectrum using PN codes. The DG2 and DG1 mode 3 Q channel signal design does not use spread-spectrum techniques. The DG1 modes 1 and 2 signal design is a spread-spectrum Staggered Quadriphase Pseudorandom Noise (SQPN) signal. The DG2 signal design is a BPSK, Quadrature Phase Shift Key (QPSK), or Staggered Quadriphase Shift Key (SQPSK) signal. The DG1 mode 3 signal design, which is a QPSK-modulated signal, is a hybrid design that contains on one quadrature channel of the carrier (I channel), the same signal design as that of the I channel of DG1 mode 1, and contains the same signal design as DG2 BPSK on the other quadrature channel of the carrier (Q channel). Either signal design can be used for a single return service data channel or for two return service data channels. Each data channel may be uncoded or convolutionally encoded subject to the applicable return service constraints. Return service Non-Return-to-Zero (NRZ) and Bi-Phase (Bi∅) data formats and Bi∅ convolutional encoder output symbol format conversion can be used subject to applicable return service constraints.

b. Data Group 1 Mode Description. DG1 consists of modes 1, 2, and 3. For DG1 modes 1 and 2, the return service data is modulo-2 added asynchronously to specified but related PN codes prior to each of these PN codes BPSK modulating quadrature phases of a carrier. DG1 modes 1 and 3 require a coherent turnaround in the user spacecraft transponder of the received forward service carrier and range channel PN code epoch. DG1 mode 2 uses a noncoherent carrier, which is generated from a local oscillator on the user spacecraft without reference to the forward link frequency, with specified but related short PN codes each BPSK modulating quadrature phases of the carrier. For DG1 mode 3, the I channel is identical to the I channel of DG1 mode 1, and the Q channel is a nonspread-spectrum signal with the return service data directly BPSK modulating the Q channel carrier. For the TDRSS SSA return service, the DG1 mode 3 Q channel data can also be interleaved (refer to Appendix F). DG1 mode 3 is not available for TDRSS MA services.

c. Data Group 2 Description. In DG2, the return service data directly BPSK, SQPSK, or QPSK modulates the carrier. The carrier may be either coherent with the received forward service carrier or noncoherent and generated from a local oscillator on the user spacecraft without reference to the forward link frequency. The type of modulation that can be used is dependent upon the following characteristics of the return service: number of data channels, channel data rates, use of convolutional encoding, use of biphase data formats, and use of the Bi∅-Level (Bi∅-L) format conversion for the convolutional encoder output symbols. BPSK modulation can be used for a single data channel only. SQPSK modulation can be used for a single data channel and for two independent data channels. QPSK modulation can also be used for two independent data channels. For the TDRSS SSA return service, interleaving can also be used with a BPSK single data channel on either or both data channels of a dual data channel (refer to Appendix F).

2.4.3.2 MA Return Service. A user spacecraft must use convolutional encoding for all return service data and may use only DG1 modes 1 and 2 signal designs. Code 530 will coordinate with the user community to ensure an acceptable level of self-interference. The maximum

individual user spacecraft return service data rate for DG1 mode 1 and 2 operations is 100 kbps. Each user spacecraft EIRP is restricted to the minimum required for transmission of the return service data rate (plus a reasonable EIRP margin) to minimize interference with the signals of other user spacecraft using the MA return service.

2.4.3.3 SA Return Service. A user spacecraft can use DG1 modes 1, 2, and 3, and DG2 signal designs depending upon the user spacecraft return service data requirements. The maximum return service data rate is 6 Mbps (rate 1/2 coded) for DG2 SSA return service and 300 Mbps (uncoded) for DG2 KSA return service. The maximum data rate for a user spacecraft operating at the MA return service frequencies with a DG1 mode 3 signal design supported by the SSA cross-support return service is 1.65 Mbps. This is to prevent interference with the adjacent DSN Band.

2.4.4 PERFORMANCE

Performance of the return services in an Additive White Gaussian Noise (AWGN) environment for the various services is given in Appendix A and is based on the ADR versus the signal power received isotropically at a TDRS from a user spacecraft (Prec) relationships presented in section 3. Figures A-5, A-6, and A-7 depict the Ideal Required Prec relationship to ADR for support through the TDRSS MA, SSA, and KSA return services, respectively. The predicted performance degradation for the MA and SSA return services in an RFI environment are not included in these figures (refer to Appendix G). Refer to Appendix A for a complete description of link calculations.

2.4.5 OPERATIONS

2.4.5.1 Nominal Return Service Operations. Return service can be provided through any one or any combination of three services dependent upon the users' data requirements. Data is channeled in real time through the SN telecommunications path between the user spacecraft and user POCC/MOC/data processing facilities. No provisions for user data formatting are provided. Limited data store and forward capabilities are available. PN code despreading (if required), carrier demodulation, data detection, symbol synchronization, Viterbi decoding (if required), and data format conversion (if required) are performed by the TDRSS. All return service data (except certain multimegabit data, refer to paragraph 5.3) is time-tagged by the WSC, blocked into the standard NASCOM TDRSS 4800-bit blocks (refer to paragraph 5.9.2), and transmitted (via the NASCOM data transport system, refer to paragraph 5.1) to the designated user POCC/MOC/data processing facilities. In addition, the measurement of WSC return service time delay is available for channel symbol rates $\leq$6 Megasymbols per second (Msps) to an accuracy of $\pm$25 percent of the data bit period for data rates <250 kbps or $\pm$ 1 microsecond (μsec) for data rates $\geq$250 kbps. Return service user spacecraft support periods are scheduled by the NCC on the basis of required return service coverage intervals as requested by the user POCC/MOC.

2.4.5.2 Return Link Operational Restrictions. Users of the return service must follow the following restrictions:

a. MA Degradation. Degradation in MA return service performance may occur because of self-interference from other user spacecraft transmissions (however, the SN may operationally limit the number of user spacecraft utilizing this service during specific time periods to minimize this performance degradation due to system self-interference [refer to paragraph 3.2.3.3e]).

b. SSA Degradation. Degradation in SSA return service performance may occur because of mutual interference between two user spacecraft transmissions (refer to paragraph 3.3.3.3g). The NCC has the predictive capability to forecast the conflicts, and the user POCC/MOC can request its conflict data.

c. KSA Degradation. Degradation in KSA return service performance may also occur because of mutual interference between two user spacecraft transmissions (refer to paragraph 3.4.3.3e).

d. MA Sun Interference. MA return service is not normally available when the center of the sun is either within three degrees of the TDRS MA return service antenna beam boresight or within one degree of the boresight of the WSC antenna supporting that TDRS (sun outage) [refer to paragraph 3.2.3.3f(6)].

e. SA Sun Interference. No SSA or KSA return service is available when the center of the sun is within four or one degrees of the TDRS SA antenna SSA or KSA boresight, respectively, or within one degree of the boresight of the WSC antenna supporting that TDRS (sun outage) [refer to paragraphs 3.3.3.3e(6) and 3.4.3.3d(6), respectively].

f. S-Band RFI. Degradation in MA and SSA return service performance may occur due to terrestrial users of the S-band frequency spectrum (refer to Appendix G for a discussion of S-band RFI).

g. K-Band RFI. Very infrequent, sporadic short-time duration outages may occur on KSA return services due to RFI. No specific performance degradation estimates have been made or included herein.

h. Weather Interference. Very infrequent, short-term duration weather related outages may occur at the WSC that would preclude TDRSS support. These outages typically do not exceed sixteen hours per year.

2.5 TRACKING SERVICES

2.5.1 GENERAL

The TDRSS can provide user spacecraft and TDRS tracking data for user spacecraft orbit determination (refer to paragraphs 3.2.4 [MA], 3.3.4 [SSA], and 3.4.4 [KSA] for details of the TDRSS tracking services). The TDRS tracking data is obtained by the NCC scheduling tracking services to NASA ground-based BRTS transponders. The TDRS tracking data is used by the FDF in determining precise positioning of the TDRSs as required, user spacecraft orbit

determinations, and for tracking service evaluations. The FDF/BRTS POCC/MOC is responsible for generating BRTS scheduling requests, and for transmitting these scheduling requests to the NCC (refer to paragraph 4.2.5). Error analysis has shown that, for orbit maintenance, one TDRS is capable of tracking user spacecraft to the same accuracy as did the GN.

2.5.2 NORMAL TRACKING SERVICE

The TDRSS can provide two-way R&RR (Doppler) measurements and one-way Doppler measurements for S-band (MA and SSA) and KSA user spacecraft. Range measurements require use on the return service of a PN range code which is coherent with the forward service range channel PN code. Two-way Doppler measurement requires use of a carrier on the return service which is coherent with the forward service carrier. Normal tracking service requires establishment of a forward service and/or a return service to a user spacecraft using either the MA, SSA, or KSA services. The TDRSS can also provide a Time Transfer function to users who have a requirement to update an on-board clock.

2.5.3 SSA CROSS-SUPPORT TRACKING SERVICE

The TDRSS can provide two-way range and Doppler measurements to S-band users supported by one service (MA or SSA) on the forward service and supported by the other service (SSA or MA) on the return service.

2.5.4 TRACKING OPERATIONS

Tracking services can be provided through any of the three (MA, SSA, or KSA) forward and return services depending upon the user's tracking requirements. Sampled range and Doppler data for all user spacecraft is provided at WSC for real-time delivery to the FDF (or to a user Orbit Determination Facility [ODF] for a non-GSFC user). The tracking data is formatted in accordance with the NASA Universal Tracking Data Format (UTDF). For optimum efficiency of TDRSS services, support periods for tracking service should be coincident with either forward service and return service support or return service only support. The time transfer service must be scheduled in conjunction with coherent forward and return support.

SECTION 3. TDRSS TELECOMMUNICATIONS SERVICES

3.1 INTRODUCTION

3.1.1 GENERAL

a. This section defines the TDRSS telecommunications services between the RF interface with the user spacecraft and the SN data interface with the user ground facilities (user POCC/MOC and/or user data processing facility). The RF interface with the user spacecraft is defined in terms of signal parameters, RF characteristics, and field of view. The SN data interface with the user ground facilities is defined in terms of the number and characteristics of the data channels available to the user ground facility at the user ground facility/NASCOM data transport system interface.

b. Forward services represent a data interface between the user POCC/MOC and the NASCOM data transport system and the transmission of an appropriately modulated signal at a minimum signal EIRP in the direction of the user spacecraft by a TDRS.

c. Return service defines an ADR at the NASCOM data transport system/user ground facility interface as a function of P_{rec}, the user spacecraft signal power received at a TDRS antenna input. The ADR equations produce the minimum data rate for all possible signal characteristics as a function of P_{rec}. CLASS analysis (refer to Appendix H) will produce accurate performance projections based upon desired signal characteristics: data rate, data type, and jitter values. The ADR equations are based upon TRW TDRS F1 through F7 “as built” characterization, Danzante implementation, and a required 10^{-5} BER. SN support may be possible for users whose P_{rec} is less than the required P_{rec} for 10^{-5} BER performance as long as the user is willing to accept some risk and significantly less than 100 percent coverage. Any user interested in receiving this marginal SN coverage shall be required to negotiate all support with the Networks Division (Code 530). Additionally, Appendix K discusses the use of Reed-Solomon coding in conjunction with SN user services. Autotrack is assumed for KSA service.

d. The frequency allocations for all RF services between the TDRSs and the user spacecraft are defined in the respective paragraphs for MA, SSA, and KSA forward and return services.

Note

> The term user POCC/MOC, as opposed to the term user ground facility, is used generically hereafter without regard to its specific use (as a user POCC/MOC or as a user data processing facility) or location.

3.1.2 FORWARD SERVICE FLUX DENSITY RESTRICTIONS

All TDRSS forward services incorporate (when necessary) spread spectrum modulation techniques to satisfy flux density restrictions imposed by the National Telecommunications and Information Agency (NTIA).

3.1.3 END-TO-END TEST (EET) SERVICES

End-to-end test services will be provided by the TDRSS using the NASCOM data transport system, FDF, and NCC. The user POCC/MOC will have the capability to use the TDRSS communications services for end-to-end SN data flow simulations without the need for the actual user spacecraft.

3.1.4 TELECOMMUNICATIONS AND TRACKING SERVICES

The following telecommunications services are provided to the users:

a. The MA forward, return, and tracking services described in paragraph 3.2.

b. The SSA forward, return, and tracking services described in paragraph 3.3.

c. The KSA forward, return, and tracking services described in paragraph 3.4.

d. The TDRSS-related Space Shuttle payload services summarized in paragraph 3.5.

e. The EET services described in paragraph 3.6.

3.1.5 INTERFACE DEFINITIONS

Interfaces are defined as follows in this section:

a. Data interfaces are defined between the user POCC/MOC and the NASCOM data transport system (refer to section 5 for specific details of these interfaces).

b. RF interfaces are defined between the user spacecraft and the TDRSs. These include performance requirements, signal parameters, and RF characteristics.

3.2 MA SERVICES

3.2.1 GENERAL

3.2.1.1 Available Services. TDRSS MA services include forward and return telecommunications services, and tracking services. These services are described in terms of the data interface between a user POCC/MOC and the NASCOM data transport system and the RF interfaces between its user spacecraft and a TDRS. These interfaces are characterized by the technical requirements imposed and the operational capabilities provided by the TDRSS. This section describes the RF interfaces between the user spacecraft and TDRS; the data interfaces

between the user POCC/MOC and the NASCOM data transport system are described in section 5.

3.2.1.2 Interface Definition. The RF interface between the TDRS and a user spacecraft is defined in terms of signal parameters, RF characteristics, and field of view. The user POCC/MOC/NASCOM data transport system data interface is defined in terms of the number and characteristics of data channels. Forward service represents a user POCC/MOC data interface with the NASCOM data transport system and 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 user spacecraft. Return service defines an ADR at the WSC receiver output as a function of P_{rec} and a NASCOM data transport system data interface with the user POCC/MOC in terms of the number and distribution of data channels. The frequency allocations for all RF links between the TDRSs and the user spacecraft are defined in paragraphs 3.2.2 and 3.2.3.

3.2.1.3 User Acquisition Requirements. Acquisition and reacquisition by the WSC/user spacecraft of the user spacecraft/TDRS transmitted signal requires prediction by the user POCC/MOC of the user spacecraft transponder/transmitter local oscillator frequency over various projected time periods. The frequency predictions are ultimately incorporated in the NCC Scheduling Order (SHO) message sent to the WSC as a user spacecraft transmitted/received frequency for the specific service support periods. The following discussion applies to user spacecraft transponder designs (e.g., the NASA first and second generation standard transponders; refer to STDN 203.7 for the first generation transponder and STDN 203.8 for the second generation transponder) for which the received center frequency for forward service signal acquisition, and the noncoherent transmitter frequency for return service operations, are derived from a Temperature Compensated Crystal Oscillator (TCXO). Of major concern to the user POCC/MOC is its ability to predict both the user spacecraft TCXO frequency and the thermal profile of the TCXO as a function of the operational scenario and sun position relative to the user spacecraft. The FDF can provide the user POCC/MOC with a history of the TCXO frequency based on TDRSS tracking service one-way Doppler data at intervals to be agreed to by the FDF and the user POCC/MOC. The user POCC/MOC must therefore plan its missions and request the required TDRSS services from the NCC for WSC to obtain the tracking data for FDF. Prior to launch, the user POCC/MOC should also obtain TCXO frequency versus temperature data, including profiles for various operational scenarios as a function of time, i.e., based on thermal vacuum chamber tests and integration tests with the STS when applicable. The user POCC/MOC should then model the predicted TCXO frequency shifts for various operational scenarios and time periods and use them to implement its selected frequency acquisition strategies. These strategies are a function of user spacecraft TCXO frequency uncertainty, vehicle dynamics, and coherent or noncoherent operation. For example, the user POCC/MOC can request, via the NCC, that the TDRSS sweep the forward service frequency or use an expanded frequency uncertainty limit on the return service. In addition, the user POCC/MOC, if feasible, can plan the particular service support period of interest such that at service support period start time, the user spacecraft is in a part of its orbit where the Doppler dynamics are minimal, and the user spacecraft transponder has been previously commanded to remain in the noncoherent mode even upon receipt of a TDRSS forward service signal.

3.2.1.4 TDRSS Acquisition Support to Users. For each scheduled TDRSS service support period, the user requirements for signal acquisition/reacquisition and the TDRSS capabilities to

aid acquisition/reacquisition are as follows (user-related values are for the NASA first and second generation standard transponders; refer to STDN 203.7 for the first generation transponder and STDN 203.8 for the second generation transponder):

a. User Epoch Uncertainty. The maximum epoch uncertainty of the user spacecraft ephemeris supplied to the TDRSS shall be ±9 seconds.

Note

The WSC software will round-off the user receive frequency contained in the SHO to the nearest multiple of 221 Hz for MA forward service. This quantization, under worst case conditions, may increase the predicted user receive frequency uncertainty up to 110 Hz. This results in a reduced maximum user spacecraft ephemeris uncertainty of ±7.6 seconds for the NASA first generation standard transponder and ±7.8 seconds for the NASA second generation standard transponder.

b. User Frequency Uncertainty. The user POCC/MOC must know the operating frequency of the user spacecraft TCXO to within ±700 Hz. For the FDF to be able to provide a user POCC/MOC with a history of its user spacecraft TCXO frequency based upon TDRSS tracking service one-way Doppler data, the user POCC/MOC must plan to schedule enough TDRSS tracking service support periods involving one-way Doppler measurements.

c. User Transponder Characteristics. The NASA first and second generation standard transponders are specified to have an acquisition bandwidth of ±1400 Hz and ±1500 Hz, respectively. Both transponders can acquire a signal with a Doppler rate up to 70 Hz/sec.

d. Forward Frequency Sweep. The TDRSS has a forward service frequency sweep capability of ±3 kHz.

e. Return Frequency Sweep. The TDRSS has a return service expanded frequency search capability of ±3 kHz.

3.2.2 MA FORWARD SERVICES

3.2.2.1 General. The characteristics of the data provided by the user POCC/MOC to the NASCOM data transport system and the RF signals provided by the TDRS to the user spacecraft during TDRSS MA forward services are outlined in paragraphs 3.2.2.2 through 3.2.2.6 (refer to section 5 for additional details of the user POCC/MOC/NASCOM data transport system interface).

3.2.2.2 Signal Parameters. The TDRSS MA forward service signal parameters are defined in Table 3-1. The center frequency (f_o) of the user spacecraft receiver must be defined by the user POCC/MOC in its request to the NCC for TDRSS MA forward service. The features inherent in the signal parameters listed in Table 3-1 are as follows:

a. Spread Spectrum. All TDRSS MA forward services incorporate spread spectrum modulation techniques to satisfy flux density restrictions imposed upon the TDRSS forward services by the NTIA.

b. Doppler Compensation. The TDRSS MA forward service carrier frequency (F) transmitted by a TDRS will be compensated by the WSC for Doppler so that the carrier, F_R, arrives at the user spacecraft receiving system within a predictable tolerance (E) of f_o as defined in Table 3-1. This feature minimizes the Doppler resolution requirements of the user spacecraft receiver and is available continuously to facilitate reacquisition by the user spacecraft in the event of loss of lock of the TDRSS MA forward service signal. Doppler compensation will be inhibited by the WSC during tracking service periods requiring coherent two-way Doppler measurement (refer to paragraph 3.2.4.3) and may otherwise be inhibited by the WSC at the user POCC/MOC's request to the NCC; e.g., if the user spacecraft has an onboard navigation capability and/or a wideband receiver.

c. Coherent Relationship Between the PN Code Clock and the Carrier Frequency. The PN code chip rate is coherently related to F in all cases. This feature permits the user spacecraft receiver to use the receiver PN code clock to predict the received carrier frequency, thereby minimizing receiver complexity and reducing acquisition time.

d. Simultaneous Command and Range Channels. The TDRSS MA forward service signal includes separate but simultaneous command and range channels. This feature provides a solution to the conflicting requirements for range ambiguity resolution, minimum Time to Acquire (T_{acq}), and multipath protection (refer to paragraph f). 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.

e. Unbalanced QPSK Modulation. The command channel/range channel (power) for all TDRSS MA forward service signals is +10 dB. This unbalanced QPSK modulation minimizes the power in the range channel to a level adequate for user spacecraft 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 user spacecraft receiver complexity, increasing user spacecraft command channel acquisition time, or decreasing TDRSS range tracking accuracy.

f. Time Synchronization of Command and Range Channel PN Codes. Prior to transmission from the WSC, the epoch (the all-1's condition) of the range channel PN code is time synchronized to one of the periodic epochs of the command channel PN code generator (refer to paragraph 3.2.2.3a). Because user spacecraft command channel acquisition must precede user spacecraft range channel acquisition, this feature limits the range channel PN code search to only 256 chip positions while the range channel PN code itself contains 261,888 chips. This feature also permits rapid detection of time spread on the received range channel signal identifying acquisition of a diffuse multipath signal. By the user spacecraft transferring the PN code tracking loop to the range channel after range channel acquisition, subsequent multipath interference can be prevented.

Table 3-1. TDRSS MA Forward Service Signal Parameters

Parameter	Definition
TDRS transmit carrier frequency (Hz)	F
Carrier frequency arriving at user spacecraft (Hz) (Note 1)	F_R
$\frac{\text{Command channel radiated power}}{\text{Range channel radiated power}}$	+10 dB
Command Channel	
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 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)	NRZ
Data rate restrictions	0.1 - 10 kbps
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	$(2^{10} - 1) \times 256$
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 3-1. TDRSS MA Forward Service Signal Parameters (cont)

Note
1. 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 user spacecraft receiver as defined by the user POCC/MOC and $E = (70 \times \ddot{R}) + C$; $\ddot{R} \leq 15$ m/sec^2 and $C \leq 110$ Hz (see paragraph 3.2.1.4.a). Forward service Doppler compensation will not increase the peak phase error of a receiver (with a second-order Costas loop, B_L = 36 Hz, at C/N_o = 33 dB-Hz in the command channel) more than 2.4 degrees relative to the phase error for a Doppler-free carrier. This calculation assumes the loop bandwidth for a Second Generation NASA Standard Transponder. The increase in peak phase error due to Doppler compensation will differ based upon transponder characteristics. 2. The SN and the TDRSS are transparent to the data format of the forward service data. The particular format (NRZ-L, NRZ-M, NRZ-S) to be used will be established in the user POCC/MOC.

g. Short-cycled Linear Shift Register PN Code Sequence for Range Channel. The use of a short-cycled PN code for the range channel allows optimization of the command channel PN code. This feature permits use of Gold codes for the command channel to allow generation of a code library with good cross-correlation properties. The TDRSS PN code library (refer to paragraph 3.2.2.3a) is sufficiently large to allow a unique code assignment for each user spacecraft.

h. Asynchronous Data Modulation. The forward service data received at WSC from the NASCOM data transport system is directly modulo-2 added by the WSC to the command channel PN code sequence. Because the PN code clock and the carrier are Doppler compensated by the WSC, the forward service data will be asynchronous with the carrier and the PN code. The forward service data is not processed in any other manner by the WSC.

3.2.2.3 Communications Services. The TDRSS MA forward services available are listed in Table 3-2. Table 3-3 lists their salient characteristics. The definitions for the parameters listed in Table 3-3 are contained in Appendix E. The features inherent in the TDRSS MA forward services listed in Table 3-2 are as follows:

a. PN Code Assignment. The forward service data ultimately received by the user spacecraft from its user POCC/MOC via the supporting elements of the SN will have been asynchronously modulo-2 added to the TDRSS MA forward service command channel PN code by the WSC. A user spacecraft-unique PN code assignment for the range and command channels will be made by the Frequency Manager of the MO&DSD from the library of PN codes defined in PN Codes for Use with the Tracking and Data Relay Satellite System (TDRSS), STDN No. 108.

b. Acquisition Scenarios. MA forward service acquisition times for the NASA first and second generation transponders are listed in Table 3-4. T_{acq} in the user spacecraft receiver is a function of the user spacecraft receiver design and signal-to-noise density ratio. The T_{acq} values listed in Table 3-4 are contingent on the user POCC/MOC defining the user spacecraft receiver center frequency, f_o, to an accuracy of $\pm$700 Hz in each service support request (refer to paragraphs 3.2.1.2 through 3.2.1.4). The acquisition performance of the NASA first generation standard transponder is described in STDN 203.7 and the acquisition performance of the NASA second generation standard transponder is described in STDN 203.8. If the user POCC/MOC is unable to accurately define f_o, the NCC can request the WSC to frequency sweep the TDRSS forward service signal (refer to paragraph 3.2.2.5e) to aid the user spacecraft receiver acquisition process. This real-time NCC action can either be at the user POCC/MOC's real-time request (via a Ground Control Message Request [GCMR]) or based on NCC operational procedures relative to that user spacecraft mission. The forward service signal sweep is initiated 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 forward service signal sweep is independent of simultaneously scheduled Doppler compensation.

c. Acquisition Time Determination. The user spacecraft forward service acquisition time must be considered in determining the overall return service acquisition time for user spacecraft with a coherent mode of operation (refer to paragraph 3.2.3.5c).

d. Link Margins. Example link calculations are provided in Appendix A.

e. Transmit Power. The TDRS will maintain a signal EIRP as defined in Table 3-2 in the direction of the user spacecraft for the duration of the scheduled TDRSS MA forward service to that user spacecraft. There is no requirement for user spacecraft transmission to initiate or maintain TDRSS MA forward service.

f. Functional Characteristics. The functional characteristics of the TDRSS MA forward services are shown in Appendix B, paragraph B.2.

g. Phase Ambiguity. The forward service data phase ambiguity resolution required in the user spacecraft is discussed in Appendix B, paragraph B.2.2.

3.2.2.4 Data Interfaces. The TDRSS MA forward service data interfaces with the user POCC/MOC are as follows:

a. Data Rate Definition. The user POCC/MOC/NASCOM data transport system data channel interface and the user spacecraft data rate are initially defined in the user POCC/MOC service schedule request to the NCC and the resulting SHO to the WSC.

Table 3-2. TDRSS MA Forward Service

Parameter	Description
Field of view (each TDRS)	±13 degrees conical
TDRS antenna polarization	Left-hand Circular (LHC)
TDRS antenna axial ratio (maximum)	1.5 dB over 3-dB beamwidth
TDRS signal EIRP (minimum)	+34 dBW
Transmit frequency (nominal) (refer to note)	$[2287.5 \pm 0.1] \times \frac{221}{240}$ MHz
RF bandwidth (3 dB minimum)	6 MHz
Duty factor	100 percent

Note

The user POCC/MOC must include the best estimate of the user spacecraft receiver center frequency at the start time of each scheduled service support period in its service request to the NCC, which then includes this parameter value in the SHO. The TDRSS MA forward service carrier frequency is then implemented by the WSC to the accuracy of the WSC frequency standard except during Doppler compensation. Following Doppler compensation, the TDRSS MA forward service carrier frequency will meet the frequency requirements of paragraph 3.2.4.3c. The user POCC/MOC must predict the frequency of the user spacecraft local oscillator using frequency drift history provided by the FDF and accounting for thermal profiles as described in paragraphs 3.2.1.3 and 3.2.1.4.

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

Parameter	Description
$\frac{\text{Command channel radiated power}}{\text{Range channel radiated power}}$	+10 ± 0.5 dB
Modulator phase imbalance (BPSK only) (peak)	±3 degrees
Modulator gain imbalance (peak)	±0.25 dB
Relative phase between command and range channels	90 ±3 degrees
Data asymmetry (peak) (note)	±3 percent
Data rise time (90 percent of initial state to 90 percent of final state) (Note)	≤5 percent of data bit duration
Phase nonlinearity (peak)	±0.12 radian over ±2.1 MHz
Gain flatness (peak)	±1.2 dB over ±2.1 MHz
Gain slope (peak)	±0.1 dB/MHz
AM/PM	≤13 degrees/dB
PN code chip jitter (rms) (including effects of Doppler compensation)	≤1 degree
Data bit jitter (peak) (note)	≤1 percent
Spurious PM (rms)	≤1 degree
Spurious outputs	≥27 dBc
Incidental AM (peak)	≤2 percent

Table 3-3. Salient Characteristics for TDRSS MA Forward Services (cont)

Parameter	Description
Phase noise (rms):	
1 Hz - 10 Hz	≤1.5 degrees
10 Hz - 32 Hz	≤1.5 degrees
32 Hz - 1 kHz	≤4.0 degrees
1 kHz - 3 MHz	≤2.0 degrees
Command/range channel PN code chip skew (peak)	≤0.01 chip
PN code chip asymmetry (peak)	≤0.01 chip
PN code chip rate (peak) relative to absolute coherence with carrier rate	≤0.01 chips/sec at PN code chip rate

Note

These values are the TDRSS contributions for data asymmetry, data transition time, and bit jitter, assuming perfect forward service data is provided to the WSC. The actual contributions by the NASCOM data transport system are negligible compared to those contributed by the TDRSS, since the WSC reclocks the data before it is processed by the WSC into the forward service signal.

b. NASCOM Data Format. The user POCC/MOC transmits forward service data to the NASCOM data transport system that is either serial bit-contiguous or in 4800-bit blocks at the user POCC/MOC's option (refer to paragraph5.2.4.3b). The NASCOM data transport system processes this data so that a continuous stream of forward service data and logical clock signals is sent to the WSC at the scheduled user spacecraft data rate.

Note

During the scheduled service support period intervals when there is no forward service data from the user POCC/MOC, the data signal sent by the WSC is clamped to a logical 1.

c. Transmitted Signal. The NRZ format forward service data signal will be modulo-2 added by the WSC to the command channel PN code for retransmission by the TDRS to the user spacecraft. 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.

Table 3-4. MA Forward Service Example Acquisition Times for the First and Second Generation NASA Standard Transponders (Note 3)

Spacecraft S/N_0 (note 1)	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 (note 4)	$\leq$ 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 user spacecraft 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 First and Second Generation user transponders, reference should be made to STDN 203.7 and STDN 203.8, respectively.

4. Applies only to the Second Generation transponder.

d. Operational Data Rates. During a scheduled service support period, a user POCC/MOC may change the TDRSS MA forward service data rate to any data rate value from 0.1 kbps to 10 kbps. However, the operational restrictions of paragraph 3.2.2.5f apply.

3.2.2.5 Operational Characteristics. Changes to the operating conditions or configuration of a TDRS MA forward service during a scheduled service support period are usually initiated by a GCMR from the user POCC/MOC to the NCC. The NCC then transmits these to the WSC as Operations Messages (OPM). The requested changes will be implemented at the WSC and the NCC will be notified of completion of initiation of the requested changes. All changes will be implemented within 35 seconds after receipt of the OPM at the WSC. Additional information concerning WSC response times for OPMs is provided in section 4. The following changes can be made:

a. Center Frequency. The user spacecraft MA receiver center frequency can be changed during a scheduled service support period.

b. Doppler Compensation Inhibit. During periods of TDRSS two-way range and Doppler measurements, the TDRSS will transmit a fixed frequency MA forward service carrier and PN code chip rate (refer to paragraph 3.2.4.6).

c. Doppler Compensation Reinitiation. After a period of two-way range and Doppler measurements, the forward service Doppler compensation can be reinitiated; e.g., to allow for subsequent reacquisition by the user spacecraft of the forward service signal if MA forward service signal tracking is lost by the user spacecraft (refer to paragraph 3.2.4.6).

d. Forward Service Reacquisition. The MA forward service signal can be reinitialized by requesting forward service reacquisition. The WSC will continually apply the PN codes, as well as forward service Doppler compensation (if Doppler compensation is not being inhibited).

e. Forward Service Sweep Request. If a user POCC/MOC is unable to accurately define f_o (the nominal center frequency of the user spacecraft receiver), the forward service carrier frequency can be swept. The MA forward service frequency sweep will be initiated by the WSC 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 WSC Doppler compensation of the MA forward service carrier and PN code rate.

f. Data Rate. During a scheduled service support period, the user POCC/MOC can change the data rate from that initially defined in the SHO.

(1) If the data rate change is not the only change being made to the TDRSS MA forward service parameters at that time, the user POCC/MOC must request the data rate change as part of a reconfiguration GCMR to the NCC. When WSC implements the reconfiguration OPM from the NCC, the TDRSS MA forward service signal to the user spacecraft may be interrupted. If the forward service signal is interrupted, the user spacecraft will have lost signal lock and must then reacquire the TDRSS MA forward service signal (refer to Appendix C). During the time period commencing with notification by the NCC that the GCMR has been accepted (refer to Table 4-2) and ending with reacquisition of the TDRSS MA forward service signal by the user spacecraft, the user POCC/MOC cannot transmit any forward service data to the NASCOM data transport system.

(2) If the data rate change is the only change being made to the TDRSS MA forward service parameters at that time, it is possible for the user POCC/MOC to implement the data rate change using the procedure described in paragraph (1). However, the TDRSS MA forward service signal to the user spacecraft will not be interrupted.

g. User Antenna. During a scheduled service support period, the user POCC/MOC can initiate, terminate, or change the type of user spacecraft despun antenna (included as an OPM only to provide information to WSC) (refer to paragraph 3.2.3.7b).

Note

1. Changes a, c, f, and g are implemented by the NCC via a reconfiguration OPM and their use (individually or collectively) may cause the WSC to interrupt the TDRSS MA forward service signal to the user spacecraft. Change d will cause the WSC to interrupt the forward service because it is implemented by the NCC via a reacquisition OPM. Change g is for WSC information only. If this change is the only change being made at this time to the user spacecraft configuration, it is advisable for the user POCC/MOC to formulate its procedures to preclude generation of a reconfiguration GCMR to the NCC.

2. The WSC implements Doppler compensation inhibit by using a "slow-and-hold" process (refer to paragraph 3.2.4.6b). There is no TDRSS MA forward service signal interruption.

3. Change e is an acquisition aid, and it is implemented by the NCC via a forward service sweep request OPM. Its use will not cause a TDRSS MA forward service signal interruption.

3.2.2.6 Acquisition Scenarios. The following acquisition scenarios identify only the technical aspects of TDRSS MA forward service signal acquisition by the user spacecraft and do not include operational procedures related to acquisition (refer to Appendix C):

a. The user spacecraft signal acquisition of the TDRSS MA forward service signal will be independent of the user spacecraft return service mode or mode status.

b. The spatially formed TDRS MA forward service antenna beam will be open-loop pointed in the direction of the user spacecraft.

c. At the start of the TDRSS MA forward service as defined by the SHO, the TDRS will radiate, in the direction of the user spacecraft, a signal compatible with the TDRSS MA forward service signal parameters listed in Table 3-1, at the TDRS signal EIRP listed in Table 3-2. The carrier and PN code clock will include Doppler compensation as scheduled.

d. The user spacecraft receiving system will search for and acquire the command channel PN code and carrier. Normally, a user POCC/MOC will not be transmitting forward service data to the NASCOM data transport system until the forward service signal has been acquired by the user spacecraft and the acquisition verified by the user POCC/MOC from the user spacecraft return service telemetry. If either the NASA first or second generation standard transponders are used, their design implementation requires that there be no data transitions during the signal acquisition process. For other user spacecraft transponder implementations, if there are data transitions, the user spacecraft receiving system acquisition time may be different from the times listed in Table 3-4.

e. The user spacecraft receiving system will search for and acquire the range channel PN code upon acquisition of the command channel PN code and carrier. Depending upon user spacecraft receiving system design, upon completion of command channel PN code and carrier acquisition, range channel PN code acquisition, and subsequent user spacecraft receiving system transition to signal tracking, the user spacecraft transmitting system may either switch to a coherent transponding mode or remain in a noncoherent mode until commanded by the user POCC/MOC to switch.

f. The WSC will continue Doppler compensation of the TDRSS MA forward service signal unless requested by the user POCC/MOC, via the NCC, to inhibit the Doppler compensation.

3.2.3 MA RETURN SERVICES

3.2.3.1 General. The RF signals provided by the user spacecraft to the TDRS and the characteristics of data provided by the NASCOM data transport system to the user POCC/MOC are defined in paragraphs 3.2.3.2 through 3.2.3.7 (refer to section 5 for additional details of the NASCOM data transport system/user POCC/MOC interface).

3.2.3.2 Signal Parameters

a. General. The TDRSS MA return service signal parameters are listed in Table 3-5. The user spacecraft transmit frequency for DG1 mode 2 service must be defined by the user POCC/MOC to the NCC to an accuracy of ±700 Hz when requesting TDRSS MA return service (refer to paragraphs 3.2.1.3 and 3.2.1.4).

b. Features. The general features inherent in the user spacecraft signal parameters are as follows:

(1) SQPN Modulation. SQPN modulation must be used for DG1 modes 1 and 2. With this feature, the spectral characteristics of a user spacecraft 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 adjacent frequency channels on the TDRS to WSC downlink.

(2) Use of Identical Phase-shifted PN Codes on the I and Q channel. 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. User-unique PN code assignments (refer to STDN No. 108) include shift register tap connections for generating the assigned PN codes. The offset between the I and Q channel PN code epochs is defined in STDN No. 108 for each PN code.

(3) Asynchronous Data Modulation. The return service data stream in each channel will be modulo-2 added asynchronously to the channel PN code (DG1 modes 1 and 2). This prevents the forward service Doppler on the PN code from affecting the return service data stream data rate during DG1 mode 1 operation. In general for DG1 operation, it eliminates the need for synchronizing the user spacecraft data clock with the user spacecraft transmitter PN code clock.

(4) Coherent Relationships Between the PN Code Clock and the Carrier Frequency. The PN code clock must be coherently related to the transmitted carrier frequency in all cases of DG1 mode 1 and 2 operation. This feature permits the user spacecraft transmitter to use a common source for generating the carrier and the PN code clock and permits the WSC to use the PN code clock to aid return service carrier acquisition.

Table 3-5. TDRSS MA Return Service Signal Parameters (Notes 1, 2, 3, 7)

Parameter	Definition
Transmit carrier frequency (Hz)	F_1
Carrier (F_1) reference (Hz)	
DG1 mode 1	$\frac{240}{221} \times F_R$
DG1 mode 2	User spacecraft transmitter oscillator
PN code modulation	SQPN (note 3)
PN code chip rate (chips/sec)	$\frac{31}{[240 \times 96]} \times F_1$
PN code length (chips)	
DG1 mode 1	$(2^{10} - 1) \times 256$
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 4)	Epoch delayed x + 1/2 PN code chips relative to I channel PN code epoch
DG1 mode 2	
I channel	User spacecraft oscillator
Q channel	Epoch delayed 1/2 PN chip period relative to I channel PN code epoch

Table 3-5. TDRSS MA Return Service Signal Parameters (Note 1, 2, 3, 7) (cont)

Parameter	Definition
PN code family	
DG1 mode 1	Truncated 18-state shift register sequences
DG1 mode 2	Gold codes
Data modulation, DG1 modes 1 and 2	Modulo-2 added asynchronously to PN code
Symbol Format	NRZ, Bi∅-L (note 5)
Data Format	NRZ-L, NRZ-M, NRZ-S
DG1 mode 1 data rate restrictions	
Total (note 6)	0.1 - 100 kbps
I channel	0.1 - 100 kbps
Q channel	0.1 - 100 kbps
DG1 mode 2 data rate restrictions	
Total (note 6)	1 - 100 kbps
I channel	1 - 100 kbps
Q channel	1 - 100 kbps

Table 3-5. TDRSS MA Return Service Signal Parameters (Note 1, 2, 3, 7) (cont)

Note

1. User spacecraft data configurations are defined in paragraph 3.2.3.4 for TDRSS MA return service (refer also to Appendix B).

2. The DG1 $\frac{\text{Q channel power}}{\text{I channel power}}$ can vary only from 1:1 to 4:1. Although the parameter range available during user spacecraft design is continuous between these two limits, at this time the user POCC/MOC may request this parameter, in scheduling messages to the NCC (refer to Table 4-5), only as the ratio of two small integers.

3. When identical data is being transmitted on balanced I and Q channels (Q/I [power] = 1:1) (single data channel configuration for DG1 modes 1 or 2), the I channel carrier phase must lead the Q channel phase by $\pi/2$ radians.

4. The Q channel PN code must be identical to the I channel PN code offset x + 1/2 PN chips, where x $\geq$20,000. The value of x is defined by the PN code assignment for a particular user spacecraft (refer to STDN No. 108).

5. The output of the user spacecraft convolutional encoder may be NRZ-to-Bi∅-L converted at the option of the user. No G_2 symbol inversion within the convolutional encoder, as defined in paragraph 3.2.3.3f(1)(f), may occur when the output of the convolutional encoder is converted to Bi∅-L format. However, it is recommended that the user spacecraft design use G_2 inversion to obtain symbol transitions, rather than NRZ-to-Bi∅-L conversion.

6. Data signals on the I and Q channels may be independent and asynchronous. If the I and Q channel data signals are independent, the sum of the data rates on the I and Q channel must not exceed 100 kbps. For single data channel operation, the I and Q channel signals must be identical and synchronous and the data rate must not exceed 100 kbps. The maximum data rates for the I channel, the Q channel, and the total are reduced by a factor of 2 when the Rate 1/2 convolutional encoder output signal is biphase formatted.

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.

c. DG1 Signal Parameters. DG1 signal parameters are subdivided into two modes of operation which are distinguished as follows:

(1) DG1 Mode 1. DG1 mode 1 must be used when TDRSS two-way range and Doppler measurements (coherent transponder operation) are required concurrently with return service data transmission. The PN code length is identical to the length of the forward service range channel PN code received from the TDRS. Its epoch is synchronized with the epoch of the forward service range channel PN code (refer to Table 3-5). Return service signal acquisition by the WSC for DG1 mode 1 is possible only when the scheduled TDRSS (MA or SSA) forward service signal is acquired by the user spacecraft and the PN code and carrier transmitted by the user spacecraft are coherently related to the forward service signal from the TDRS. If the TDRSS forward service signal becomes unavailable to the user spacecraft (the forward service is time-shared with other user spacecraft), the user spacecraft transmitter must switch to noncoherent transmitter operation (DG1 mode 2) (refer to paragraph 3.2.3.5.b.(2)). TDRSS (MA or SSA) forward and TDRSS MA return services may not be able to be scheduled simultaneously for a user spacecraft because all users of the TDRSS (MA or SSA) forward services must time-share the single TDRSS MA forward service or the two TDRSS SSA forward services available from each TDRS.

(2) DG1 Mode 2. DG1 mode 2 will be used when WSC return service signal acquisition is necessary without the requirement for prior user spacecraft signal acquisition of the TDRSS (MA or SSA) forward service (noncoherent transponder operations). The carrier frequency transmitted by the user spacecraft must be defined by the user POCC/MOC to a tolerance of $\pm$700 Hz prior to initiation of WSC signal acquisition process for DG1 mode 2; i.e., in the service schedule request to the NCC that results in the SHO to the WSC for the service support period (refer to paragraphs 3.2.1.3 and 3.2.1.4).

(3) DG1 Mode 1 and 2 Data Channel Parameters. The user spacecraft return service signal can have either a single data channel or two independent data channels for both DG1 mode 1 and mode 2 operation (refer to paragraph 3.2.3.4). For a single data channel, the identical data must appear simultaneously on the I and Q channels. For two independent data channels (dual data channels), one independent data stream will appear on the I channel, the other on the Q channel. The I and Q channel power division in the user spacecraft transmitter can be weighted up to a maximum of 4:1 ($Q \geq I$) for either a single data channel or dual data channels.

d. User Transmitter Configurations. The user spacecraft transmitter functional configurations for the TDRSS MA return services (DG1 modes 1 and 2) are shown in Appendix B.

3.2.3.3 Communication Services

a. Available Services. The TDRSS MA return service parameters are listed in Table 3-6. User spacecraft transmitted signal characteristics required to obtain the TDRSS MA return

service performance defined in this paragraph are specified in paragraph 3.2.3.7. 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.

b. PN Coding. A user spacecraft-unique PN code assignment for the DG1 mode 1 and 2 PN codes will be made by the Frequency Manager of the GSFC MO&DSD from the library of PN codes in STDN No. 108. These PN codes will be from the same PN code library assignments as the PN codes for the forward service command and range channels (refer to paragraph 3.2.2.3a).

c. Phase and Channel Ambiguity. Data phase ambiguity (except for NRZ-L) and data channel ambiguity are resolved by the WSC (refer to Appendix B, paragraph B.3).

d. Data Encoding. Convolutional encoding (rate 1/2) is required on all user spacecraft MA transmissions to minimize the P_{rec} requirements and thereby minimize the interference a user spacecraft MA transmission will represent when it appears within the TDRS MA receiving antenna main beam supporting other user spacecraft MA signals. Because all user spacecraft MA signals are modulated with a PN code sequence, each user spacecraft MA signal has the processing gain advantage over other user spacecraft MA signals appearing within the TDRS MA receiving antenna beamwidth. The processing gain is defined by the ratio of the PN code chip rate to the desired user spacecraft symbol rate.

e. Self Interference. Despite the use of user spacecraft convolutional encoding and PN code modulation, there is a probability that the interference caused by other user spacecraft MA signals will degrade the TDRSS MA return service performance for that user spacecraft. The amount of this TDRSS MA return service self interference degradation will be managed by the SN based upon the population of actual/planned users, and minimized by SN/user community coordination.

Note

The TDRSS MA return service performance margin calculations require that individual user spacecraft MA signals be supportable at specified P_{rec} values and data rates in the presence of self interference from other user spacecraft MA signals. Due to the existence of this self interference, the GSFC Networks Division (Code 530) performs user spacecraft MA P_{rec} management during mission planning with each impacted user POCC/MOC to minimize the effects of self interference to all users. Code 530 can predict on a statistical basis the self interference degradation using various loading scenarios for the TDRSS MA return service. This capability is used during the SN's interface with the user project in the mission planning phase to assess the self interference to existing TDRSS MA return service users as well as the planned user project.

Table 3-6. TDRSS MA Return Service (Note 4)

Parameter	Description
Field of view (each TDRS)	$\pm$13 degrees conical
TDRS antenna polarization	LHC
TDRS antenna axial ratio (maximum)	1.5 dB over 3-dB beamwidth
Receive frequency (nominal)	2287.5 $\pm$0.1 MHz
ADR (dB relative to 1 bps) (notes 1, 2, 3)	221.8 + P_{rec} (dBW)
PN Code and Carrier Acquisition	
Orbital Dynamics	$\dot{R} \leq$ 12 km/sec, $\ddot{R} \leq$ 15 m/sec^2, jerk $\leq$ 0.02 m/sec^3
Ephemeris Uncertainty	$\leq \pm$9 sec
P_{rec}	$\geq$-193.5 dBW or consistent with the P_{rec} for ADR, whichever is greater
Acquisition Time ($P_{acq} \geq$ 90%)	
for Frequency Uncertainty $\leq \pm$ 700 Hz	$\leq$ 1 sec
for Frequency Uncertainty $\leq \pm$ 3 kHz	$\leq$ 3 sec
Decoder/Symbol Synchronization Acquisition	
Ephemeris Uncertainty	$\leq \pm$ 9 sec
Minimum data bit transition density	$\geq$ 64 data 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 ADR
Synchronization acquisition time (in seconds) with > 99% probability	Biphase: $\leq$ 1100/(Data Rate in bps) NRZ: $\leq$ 6500/(Data Rate in bps)
Signal Tracking	refer to paragraph 3.2.3.3.f.(11)
Duty factor	100 percent

Table 3-6. TDRSS MA Return Service (Note 4) (cont)

Note

1. The ADR is for a user spacecraft transmitting a signal on an AWGN channel which complies with the constraints defined in paragraph 3.2.3.7 (also refer to Appendix H). 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. Refer to Appendix A, paragraph A.4, for a definition of P_{rec}. For QPSK signals (balanced or unbalanced) with nonidentical data on the I and Q channels (dual data channels), the P_{rec} value specified is to be interpreted as the minimum required P_{rec} per channel.

   For balanced QPSK signals with identical data (synchronous and at the same data rate) on the I and Q channels (i.e., a DG1 single data channel), the minimum required <u>total</u> (I + Q) P_{rec} is equal to the minimum required P_{rec} of <u>either</u> an I or Q channel of a dual data channel with the same data rate.

   For unbalanced QPSK signals with identical data on the I and Q channels (single data channel), the minimum required P_{rec} is to be interpreted as the P_{rec} of the stronger channel.

3. The required user P_{rec} must meet the P_{rec} for ADR or signal acquisition, whichever is greater.

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.

f. <u>ADR Equation Conditions</u>. The ADR indicated in Table 3-6 is based on the following conditions:

(1) <u>Data Encoding</u>:

Note

The WSC Viterbi decoder cannot synchronize correctly to a data signal which does not contain any input data signal transitions prior to convolutional encoding. Sufficient data transitions are necessary during the WSC Viterbi decoder synchronization process to ensure correct branch synchronization.

(a) Code: convolutional, nonsystematic, transparent.

(b) Rate: 1/2.

(c) Constraint length: K = 7.

(d) Generator functions:

1. G_1 = 1111001.

2. G_2 = 1011011.

(e) Symbols generated from G_1 must precede symbols generated from G_2 relative to the data bit period.

(f) Symbols generated from G_2 should be complemented. G_2 symbol inversion provides an increased symbol transition density for a convolutional encoder input data signal with low transition density. Increased symbol transition density will aid WSC clock (symbol) synchronization.

Note

WSC can support symbols generated from G_2 that are either true or complemented and will be defined in the SHO to the WSC. However, G_2 symbol inversion is not supported with NRZ to Biphase-L symbol conversion.

(2) Format Description. The data and symbol format for each data channel are independently selectable by the user spacecraft. Achievable data rate parameters are based on a 10^{-5} BER for all data formats measured at the WSC receiver output. As the NASCOM data transport system BER is $\leq 10^{-7}$, the BER at the NASCOM data transport system/user POCC/MOC interface is basically established by the BER at the WSC receiver output.

(3) Received Power. P_{rec} is in units of dBW. The user project, in determining its design requirements for minimum user spacecraft EIRP, must take into account user spacecraft transmit antenna pointing losses, the space loss between the user spacecraft and the TDRS, and the mismatch loss incurred by a deviation from 0 dB user spacecraft transmit antenna axial ratio. The maximum TDRS receive antenna axial ratio is given in Table 3-6 (also refer to Appendix A).

(4) User Degradations. Further reductions in TDRSS MA return service performance identified in Table 3-6 can occur. For TDRSS MA return service where the user spacecraft employs electronically switchable or selectable antennas, the reduction in TDRSS MA return service performance is defined in paragraph 3.2.3.7b as a function of the user spacecraft transmitting antenna induced AM and PM and switching rate. TDRSS MA return service performance can be degraded if the MA return service self interference exceeds that included in the TDRSS design (refer to paragraph e). The TDRSS MA return service can also be degraded due to RFI (refer to Appendix G). User spacecraft parameters exceeding the constraints of paragraph 3.2.3.7 can also degrade TDRSS MA return service performance (refer to Appendix H).

(5) Acquisition. The MA return service T_{acq} (refer to Table 3-6) for all DG1 modes of operation does not include user spacecraft forward service signal acquisition time. The MA return service T_{acq} also assumes that the user POCC/MOC-defined user spacecraft transmit frequency for DG1 mode 2 is accurate to $\pm$700 Hz (refer to paragraphs 3.2.1.1 through 3.2.1.4) and assumes that the user spacecraft return service signal is present at the WSC at the scheduled start time of the return service support period. For DG1 mode 2, the WSC will be capable of acquiring on NCC request a user spacecraft transmitted signal with a frequency uncertainty of $\pm$3 kHz with TDRSS MA return service signal acquisition times that are increased by a factor of 3.

Note

This is in addition to the WSC being able to accommodate the frequency uncertainty caused by the $\pm$9-second user spacecraft ephemeris uncertainty.

(6) Sun Interference. The TDRSS MA return service will normally not be available when the center of the sun is either within 3 degrees of the TDRS MA receiving antenna beam boresight or within 1 degree of the boresight of the WSC receiving antenna supporting that TDRS. Currently, the NCC cannot use the Predicted Site Acquisition Table (PSAT) message; therefore, it does not know the sun's transit periods. Sun interference checking is a user POCC/MOC responsibility. The NCC does not check, nor does it inhibit, a user POCC/MOC from scheduling events subject to sun interference. Based on this, the user POCC/MOC is responsible for obtaining and using the PSAT information in its mission planning. If the user POCC/MOC requests support through sun transits, TDRSS MA return service performance (signal acquisition and/or tracking, BER) is not guaranteed during the sun transit. The NCC will always verify the absence of WSC antenna sun interference for all service support period requests.

(7) Received Power Considerations. The following conditions apply:

(a) Balanced Single Data Channels. For a user spacecraft synchronously transmitting identical data on the I and Q channels (single data channel) with a balanced I and Q channel power division, the total P_{rec} must be consistent with the ADR listed in Table 3-6 (refer also to note 2 of Table 3-6).

(b) Unbalanced Single Data Channels. For a user spacecraft synchronously transmitting identical data on the I and Q channels (single data channel) having unbalanced I and Q channel power division, the strong channel P_{rec} must be consistent with the ADR listed in Table 3-6. The weak channel P_{rec} need not be consistent with the ADR listed in Table 3-6. The Q/I (power) must not exceed 4:1.

(c) Dual Data Channels. For a user spacecraft transmitting independent data on the I and Q channels (dual data channels), the fraction of total P_{rec} devoted

to the I (or Q) channel will be consistent with the ADR of Table 3-6 for the I (or Q) channel data rate. The Q/I (power) must not exceed 4:1 regardless of the ratio of data rates on the I and Q channels.

(d) Transponder Failure. If the user spacecraft fails to transmit one quadrature carrier channel (I or Q) or that channel does not include data modulation, the ADR capability of the remaining channel is unaffected as long as the remaining channel's P_{rec} is consistent with the ADR listed in Table 3-6.

(8) Multipath. The WSC will provide lockup and interference protection from multipath signals reflected from the Earth.

(9) False Lock Protection. The WSC will protect against false lock to interfering user spacecraft PN codes, false lock to user spacecraft PN code sidelobes, and false lock in carrier recovery during acquisition and subsequent normal TDRSS MA return service.

(10) 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 WSC symbol synchronization loop will not unlock for a P_{rec} that is 3 dB less than the minimum P_{rec} required consistent with the ADR of Table 3-6. For NRZ symbol transition densities between 25% and 40%, the WSC symbol synchronizer loop will not unlock for a P_{rec} that is 2 dB less than the minimum P_{rec} required to for the ADR. However, BER performance may be degraded when the P_{rec} is less than the minimum P_{rec} required to be consistent with the ADR.

(11) Cycle Slips. The mean-time-between-cycle slip in the WSC carrier tracking loop for each TDRSS MA return service is 90 minutes, minimum. This value applies at carrier tracking threshold (i.e., 3 dB less than the minimum P_{rec} required for ADR listed in Table 3-6) and increases exponentially as a function of linear dB increases in P_{rec}. A single cycle slip may invert the signal polarity at the WSC receiver output for either single or dual data channels.

(12) Bit Slippage. For each TDRSS MA return service operating with a minimum P_{rec} required consistent with the ADR of Table 3-6 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 WSC symbol clock recovery loop is either 90 minutes or 10^{10} clock cycles, whichever is greater. For an MA return service operating with 1 dB more than the minimum P_{rec} required for the ADR, and NRZ symbol transition densities between 25% and 40%, the minimum mean time between slips is either 90 minutes or 10^{10} clock cycles, whichever is greater.

g. Frequency and Polarization. The TDRSS MA return service requires a user spacecraft to transmit at 2287.5 MHz with LHC polarization.

h. TDRS Beam Forming. As a part of the TDRSS MA return service, a TDRS antenna beam is continuously formed by the TDRSS in the direction of the user spacecraft being supported. There is no requirement for user spacecraft transmission to initiate or maintain TDRS antenna beam pointing during scheduled TDRSS MA return service support periods.

3.2.3.4 Data Interfaces. The TDRSS MA return service data interfaces are as follows:

a. Data Rates Definition. The user spacecraft data rates for a specific service support period are initially defined by the NCC in the SHO to the WSC for that service support period.

b. NASCOM Operations. The user spacecraft transmits data signals to the TDRS in a continuous symbol stream as scheduled. The data signals may consist of an idle pattern or actual data. After WSC return service signal acquisition, the NASCOM data transport system processes these data streams and provides the user POCC/MOC with each of the individual data streams in the 4800-bit block format or in a bit-contiguous serial data stream as previously agreed to by the user POCC/MOC and the SN (refer to section 5).

c. Single Data Channel Configurations. A single data channel (refer to Appendix B) can be used to support any of the following spacecraft configurations:

(1) Transmitting a balanced QPSK signal configured for synchronous transmission of the identical convolutionally encoded (rate 1/2) data signal on both the I and Q channels.

(2) Transmitting an unbalanced QPSK signal configured for synchronous transmission of the identical convolutionally encoded data signal on both the I and Q channels.

(3) Transmitting a BPSK signal due to either the I or the Q channel of the user spacecraft QPSK modulator being inoperative.

d. Dual Data Channel Configurations. Dual data channels (refer to Appendix B) can be used to support a user spacecraft configured to transmit two independent convolutionally encoded data signals; one on the I channel and one on the Q channel. For TDRSS MA return service from a user spacecraft with dual data channels, the WSC will resolve the data channel ambiguity.

e. Data Loss Detection. The data provided by the user spacecraft on a particular channel must be at the scheduled data rate for that user spacecraft channel (before convolutional encoding). This TDRSS MA return service will be processed by the WSC so that loss of the received data in each channel will be detected. The data stream in that channel sent to the user POCC/MOC by the NASCOM data transport system will be clamped to a logical 1 during this lost data period.

f. Phase Ambiguity Resolution for Differential Encoding. The WSC will resolve the data phase ambiguity for user spacecraft data channels with differentially encoded (NRZ-M/-S) data formats (refer to Appendix B, paragraph B.3).

3.2.3.5 Operational Characteristics. TDRSS MA return services have the following operational characteristics:

a. Service 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 user POCC/MOC to the NCC. The NCC then transmits these to the WSC as an OPM. The requested changes will be implemented at the WSC and the NCC will be notified of the completion of initiation of the requested changes. All changes will be implemented within 35 seconds after receipt of the OPM at the WSC. Additional information concerning WSC response times for OPMs is provided in section 4. The following changes can be made:

(1) Return Service Reacquisition.

(a) In case of loss of lock (PN Code and/or Carrier), the WSC will automatically initiate reacquisition using pre-drop-lock data to aid in the reacquisition. Reacquisition will be based on the assumption that the time difference between the actual user frequency dynamics and the predicted dynamics remains unchanged from the pre-drop-lock difference. If the user spacecraft continues to transmit the minimum P_{rec} for acquisition, reacquisition time typically will not exceed one-half of the initial acquisition times given in Table 3-6.

(b) Reacquisition will continue for up to 10 seconds until lock is achieved or until a reacquisition OPM is received at WSC. If lock is not achieved within 10 seconds of loss of lock, an acquisition failure OPM will be sent to the NCC and WSC will reinitiate the initial service acquisition process.

(2) Expanded User Spacecraft Frequency Uncertainty. If the user POCC/MOC is unable to accurately predict the user spacecraft transmit frequency within $\pm$700 Hz for DG1 mode 2, the WSC can reconfigure to accommodate a $\pm$3 kHz user spacecraft transmit frequency uncertainty during the TDRSS MA return service acquisition/reacquisition process.

Note

This is in addition to the WSC being able to accommodate the frequency uncertainty caused by the $\pm$9 second user spacecraft ephemeris uncertainty.

(3) Data Rate. Change in the I and/or Q channel data rate.

(4) Frequency. Change in the user spacecraft transmit center frequency (noncoherent operation only).

(5) Received Power. Redefinition of maximum and minimum P_{rec} (delineated as user spacecraft EIRP in the SHO [refer to Appendix A]; the difference must not exceed 12 dB) during the scheduled TDRSS MA return service support period.

(6) Power Ratio. Change in the I/Q (power).

(7) Data Format. Change in the I and/or Q channel data format.

(8) Data Bit Jitter. Change in the I and/or Q channel data bit jitter.

(9) Mode. Change in DG1 mode (1 or 2).

(10) User Antenna. Initiation, termination, or type change of user spacecraft despun antenna (included as an OPM only to provide information to the WSC) (refer to paragraph 3.2.3.7).

(11) Data Channel Configuration. Change between a single or dual data source.

Note

These changes to the TDRSS MA return service during a scheduled TDRSS MA return service support period may cause the WSC to interrupt return service for that user spacecraft, requiring reacquisition by the WSC of the user spacecraft signal. Item (10) is for WSC information only. If this change is the only change being made at this time to the user spacecraft configuration, it is advisable for the user POCC/MOC to formulate its procedures to preclude generation of a reconfiguration GCMR to the NCC.

b. Coherent/Noncoherent Operation

(1) Doppler Correction. The WSC corrects the received user spacecraft signal for Doppler to allow for WSC implementation of receivers with narrow acquisition and tracking bandwidths. The Doppler correction used by the WSC is either one-way or two-way, depending on the user spacecraft mode of operation (noncoherent or coherent) and on whether WSC Doppler compensation of the related TDRSS (MA or SSA) forward service signal (coherent operation only) is inhibited. For noncoherent operation, the Doppler correction is based on the user spacecraft transmission frequency stated in the SHO and any subsequent OPMs. Noncoherent operation requires one-way WSC Doppler correction. For coherent operation, Doppler correction is based upon the forward service frequency. Coherent operation with WSC forward service Doppler compensation also requires one-way Doppler correction. Coherent operation with WSC forward service Doppler compensation inhibited (fixed TDRS forward service transmit frequency) requires two-way WSC Doppler correction.

(2) DG1 Mode 1 to DG1 Mode 2 Transitions Due to Loss of Forward Signal. User spacecraft transponders which switch, when the TDRSS MA/SSA forward service signal is lost, from a coherent transponder mode (transmit frequency derived from the received carrier tracking Voltage Controlled Crystal Oscillator [VCXO] and other DG1 mode 1 signal parameters) to a noncoherent mode (transmit frequency derived from the TCXO and other DG1 mode 2 signal parameters), will cause the WSC to drop TDRSS MA return service signal lock. The user spacecraft return service signal cannot be reacquired by WSC unless the WSC is reconfigured from the coherent mode to the noncoherent mode by an appropriate GCM from the NCC to the WSC (initiated by a GCMR from the user POCC/MOC to the NCC).

(3) Maintaining Coherency. For a user spacecraft with a special-design transponder, alternatives are available to the user POCC/MOC to minimize loss of return service data due to user spacecraft short-term tracking loss of the TDRSS (MA or SSA) forward service signal. To bridge these short-term forward service signal dropouts when using coherent operation, the user spacecraft could remain in the coherent mode if it incorporates a frequency memory technique to ensure that the MA return service carrier frequency remains related to the TDRSS (MA or SSA) forward service signal frequency as it was prior to loss of (MA or SSA) forward service signal lock.

c. Service Acquisition Time. The total TDRSS MA return service signal acquisition time is the sum of the following:

(1) PN and carrier acquisition time
(2) Symbol/Decoder synchronization time

The acquisition and synchronization times are given in Table 3-6. Symbol/Decoder Synchronization time will be measured from the time carrier acquisition is achieved to the time 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). Requirements for bit error probability and symbol slipping take effect at the time decoder synchronization is achieved.

Note

Data and symbol transition densities and P_{rec} values higher than the minimums required will reduce these acquisition times.

d. Time Delay Measurement. The WSC can determine the value of the WSC time delay for each TDRSS MA return service channel prior to and following each scheduled support period and at reconfigurations during the support period. The reported value is the time delay from the WSC antenna input to the WSC output to an accuracy of $\pm$25 percent of a data bit period. The time delay measurement may be requested in the SHO and will be available to the user POCC/MOC from the NCC after termination of the scheduled service.

3.2.3.6 Acquisition Scenarios. The following acquisition scenarios identify only the technical aspects of TDRSS MA return service signal acquisition by WSC and do not include operational procedures related to acquisition (refer also to Appendix C):

a. DG1 Mode 1

(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 P_{rec} for each user spacecraft channel must be compatible with the user spacecraft channel data rate and the other TDRSS MA return service signal parameters listed in Table 3-5.

(3) The WSC will adaptively point the spatially formed TDRSS MA receive antenna beam in the direction of the user spacecraft.

(4) At the service start time specified by the SHO, the WSC will begin the search for the user spacecraft signal based upon predicted range and Doppler.

(5) After the forward service has been acquired, the WSC will acquire the user spacecraft signal (PN code and carrier) within the time listed in Table 3-6 and, upon WSC symbol and Viterbi decoder synchronization, establish DG1 mode 1 service at the WSC receiver output.

b. DG1 Mode 2

(1) This mode of user spacecraft operation does not require that a TDRSS (MA or SSA) forward service signal be received by the user spacecraft.

(2) The P_{rec} for each user spacecraft channel must be compatible with the user spacecraft channel data rate and the other TDRSS MA return service signal parameters listed in Table 3-5.

(3) The WSC will adaptively point the spatially formed TDRS MA receive antenna beam in the direction of the user spacecraft.

(4) The WSC will acquire the user spacecraft signal (PN code and carrier) within the time limits listed in Table 3-6, and upon WSC symbol and Viterbi decoder synchronization, establish DG1 mode 2 return service at the WSC receiver output.

c. DG1 Mode Transitions. User POCC/MOCs which plan to operate their spacecraft in both DG1 modes 1 and 2 during a single service support period are advised that TDRSS MA return service mode transitions via reconfiguration OPMs must take into account the requirement of scheduling a corresponding TDRSS (MA or SSA) forward service for this service support period. The following conventions apply:

(1) DG1 Mode 2 to DG1 Mode 1 Transition. The TDRSS (MA or SSA) forward service on the user spacecraft should be established prior to user POCC/MOC transmission of the GCMR to the NCC requesting that the NCC reconfigure the TDRSS for DG1 mode 1 operations (refer to paragraph 3.2.3.6.a(1)).

(2) DG1 Mode 1 to DG1 Mode 2 Transitions. Refer to paragraph 3.2.3.5.b(2) for a discussion on DG1 Mode 1 to Mode 2 transitions.

Note

Failure to observe these conventions may result in WSC rejection of reconfiguration OPMs from the NCC, excessive times for the WSC to reacquire the user spacecraft signal after the WSC reconfiguration, and unnecessary loss of user spacecraft return service data.

3.2.3.7 TDRSS MA Return Service Constraints/Restrictions

a. General. The TDRSS MA return services and tracking services will be provided without degradation for user spacecraft transmitted signal characteristics within the constraints specified in paragraphs b through d and in Table 3-7. Refer to paragraph 1.8 for guidelines if the constraints in this paragraph cannot be met. The definitions of user spacecraft constraints are given in Appendix E.

b. Performance Degradation of TDRSS MA Return Service for a User Spacecraft with Antenna Induced Modulation. User spacecraft antenna-induced Amplitude Modulation (AM) and Phase Modulation (PM) (either from electronic switching or mechanical step motion) on its transmitted signal may result in degraded TDRSS MA return service performance if the AM exceeds 3 dB and/or the PM is greater than 10 degrees.

c. DG1

(1) The individual user spacecraft channel data rates must each be defined by the user POCC/MOC to the NCC to within $\pm$0.1 percent.

(2) The Q/I (power) must be defined by the user POCC/MOC to the NCC to within $\pm$0.4 dB.

d. Symbol Transition Restriction. Within any sequence of 512 symbols, the number of transitions in each user spacecraft channel symbol stream must be $\geq$128 and the maximum number of consecutive symbols without a transition must be $\leq$64.

3.2.4 MA TRACKING SERVICES

3.2.4.1 General. The TDRSS will provide user spacecraft one-way Doppler measurements, two-way range and Doppler measurements, and two-way time transfer measurements. The user spacecraft one-way Doppler measurements will be available for DG1 mode 2 operations. The

Table 3-7. TDRSS MA Return Service User Spacecraft Signal Constraints (Note 3)

Parameters	Description
Symbol transition density (average)	$\geq$ 25 percent
Consecutive symbols without a symbol transition	$\leq$ 64 symbols
Symbol asymmetry (peak)	$\leq \pm$ 3 percent
Symbol rise time (90 percent of initial state to 90 percent of final state)	$\leq$5 percent of symbol duration
Symbol jitter and jitter rate (note 1)	$\leq$ 0.1 percent
QPSK phase imbalance	$\leq \pm$ 3 degrees
Gain imbalance	$\leq \pm$ 0.25 dB
Phase nonlinearity (applies for all types of phase nonlinearities) (peak)	$\leq$3 degrees over $\pm$2.1 MHz
Gain flatness (peak)	$\leq$0.3 dB over $\pm$2.1 MHz
Gain slope (peak)	$\leq$0.1 dB/MHz over $\pm$2.1 MHz
AM/PM	$\leq$12 degrees/dB
Frequency stability (peak)	
1-sec average time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 1 \times 10^{-7}$
48-hr observation time	$\leq 3 \times 10^{-7}$
Incidental AM (peak):	
At frequencies $\geq$10 Hz for data rates <1 kbps; at frequencies >100 Hz for data rates >1 kbps	$\leq$5 percent

Table 3-7. TDRSS MA Return Service User Spacecraft Signal Constraints (Note 3) (cont)

Parameters	Description
Untracked spurious PM (rms)	≤2 degrees
Minimum 3-dB bandwidth prior to power amplifier	≥4.5 MHz
Untracked phase noise (rms) (coherent and noncoherent)	
Data rate ≤3 kbps	≤2 degrees
Data rate ≥3 kbps	≤3 degrees
I/Q symbol skew (relative to requirements of I/Q data synchronization where appropriate) (peak)	≤3 percent
I/Q PN code chip skew (relative to 0.5 chip)	≤0.01 chip
PN code chip rate (peak), DG1 mode 2 (relative to absolute coherence with carrier rate)	≤0.01 chips/sec at PN code chip rate
PN code power suppression (noncoherent and coherent)	≤0.3 dB
Permissible P_{rec} variation without reconfiguration GCMR from user POCC/MOC) (note 2)	≤12 dB
Permissible rate of P_{rec} variation	≤10 dB/sec
Maximum P_{rec}	-161.2 dBW

Table 3-7. TDRSS MA Return Service User Spacecraft Signal Constraints (Note 3) (cont)

Note

1. The symbol jitter and jitter rate are defined as the user transmitted signal peak clock frequency jitter and peak clock jitter rate (sinusoidal or 3σ random) as a percent of the symbol clock rate.

2. The P_{rec} at the low end of the variation range must be $\geq P_{rec}$, minimum (refer to Table 3-6). The allowable variation range of 12 dB is based upon the SHO minimum EIRP value varying from -3 dB to +9 dB relative to the actual user EIRP. An EIRP value less than the -3 dB variation results in a longer acquisition time, while an EIRP exceeding the +9 dB variation may cause false PN lock or nonacquisition.

3. 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.

user spacecraft two-way Doppler, range, and two-way time transfer measurements will be available for DG1 mode 1 operations.

3.2.4.2 Range Tracking

a. General. The TDRSS tracking service will be capable of providing accurate and independent (sample-to-sample) range data as indicated in paragraphs b through f with user spacecraft signal Doppler frequencies to ±230 kHz and Doppler rates to ±1.5 kHz/sec.

b. Range Measurement rms Error. The rms error contribution to range measurement resulting from the TDRSS will not exceed the values listed in Table 3-8 for P_{rec} values consistent with the ADRs listed in Table 3-6.

c. Range Measurement Systematic Error. The systematic range error contribution from a TDRS will be less than ±35 nsec based on prelaunch measurement and predicted on-orbit performance. The systematic range error contribution from the WSC will be less than ±30 nsec.

d. Range Granularity. The range granularity, which is the smallest discrete output of the WSC receiver, is 1 nsec.

e. Range Ambiguity Interval. The minimum unambiguous range measurement is equal to the period (nominally 85 msec) of the TDRSS forward service range channel PN code.

f. TDRSS Delay Compensation. The WSC ranging system will compensate the range measurement for delays internal to the TDRSS (WSC and TDRS).

Table 3-8. TDRSS MA Tracking Service Range Measurement rms Error

ADR	Maximum rms Range Error (seconds x 10^{-9})
<1000 bps	20
≥1000 bps	10
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.	

3.2.4.3 Doppler Tracking

a. General. The TDRSS tracking service will be capable of providing Doppler information with the accuracy and characteristics specified in paragraphs b through d for user spacecraft signal Doppler frequencies to ±230 kHz and Doppler rates to ±1.5 kHz/sec. The Doppler signal is biased and processed so that a signal of 240.0 MHz + 1000 f_d is obtained, where f_d is the Doppler. The Doppler count at the WSC is nondestruct with a WSC capability of maintaining a continuous count for a minimum of 50 minutes. 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.

Note

The definition of 240.0 MHz is 240.0000 MHz, where the magnitude of the fraction portion is the accuracy of the WSC frequency standard.

b. 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 3-9 for P_{rec} values consistent with the ADRs listed in Table 3-6.

c. Reference Frequency

(1) Two-Way Doppler. For two-way Doppler measurements, WSC forward service Doppler compensation is inhibited, and the reference frequency for the WSC receiver is related to the forward service transmit frequency consistent with the appropriate frequency turnaround ratio, assuming no relative motion between the TDRS and WSC. Such inhibition is accomplished by the WSC only when a Doppler compensation inhibit request is received via an OPM from the NCC or if Doppler inhibition is scheduled by the SHO. During this Doppler compensation inhibit mode, the TDRS forward service transmit frequency is held constant so that the reference frequency for the two-way Doppler measurement at the WSC is an integral multiple of 240 Hz. Since the reference frequency is the user spacecraft transmit

Table 3-9. TDRSS MA Tracking Service Doppler Measurement rms Phase Noise

ADR (bps) (note 1)	Maximum rms Phase Noise (radians) (note 2)
≤500	0.4
>500	0.3
≤1000	0.3
>1000	0.2

Note

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 sec measurement time reference.

frequency, which is coherently related to the received TDRS forward service frequency by the coherent turnaround ratio (240/221), this is accomplished by fixing the TDRS forward service transmit frequency at an integral multiple of 221. The reference frequency is therefore given by:

$$f_{ref} = f_T\ (240/221)$$

where f_T is the TDRSS forward service transmit frequency after WSC Doppler compensation has been accomplished.

(2) One-Way Doppler. For one-way Doppler measurements, the reference frequency for the Doppler extractor will be the user spacecraft transmit frequency as defined in the SHO, to the accuracy of the WSC frequency standard.

d. Doppler Granularity. A Doppler granularity of 1×10^{-3} cycle is provided.

3.2.4.4 Time Transfer Measurement

a. General. The TDRSS two-way tracking service will be capable of providing time transfer data as indicated in paragraphs b through e with user spacecraft signal Doppler frequencies to ±230 kHz and Doppler rates to ±1.5 kHz/sec. The WSC will measure the elapsed time between a reference time epoch and the next outgoing forward link range channel PN epoch. The WSC will measure the elapsed time between that reference time epoch and the first return link PN epoch to arrive after the outgoing forward link PN epoch.

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 WSC.

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 will compensate the time transfer measurement for delays internal to the TDRSS (WSC and TDRS).

3.2.4.5 Measurement Timing

a. General. The WSC frequency reference stability is consistent with TDRSS tracking and telecommunications performance capabilities.

b. Timing Accuracy. The WSC epoch times for range, Doppler, and time transfer measurements will be within ±5 μsec of Universal Time, Coordinated (UTC). The WSC epoch times will be traceable to within ±100 nsec of UTC time.

c. Data Sampling. Range and Doppler measurement data are sampled on-time to within ±1 μsec and ±25 nsec, respectively. "On-time" refers to that portion (leading or trailing edge) of the timing signal which is synchronized with UTC at the output of the WSC timing system and is used for sampling the measurement data.

d. Sample Intervals. Sample intervals are available for the range and Doppler measurement data. Data can be sampled at selectable intervals, in sec/sample, of 1, 5, 10, 60, and 300. Intervals between time transfer measurements are 1 second.

3.2.4.6 Operation of Doppler Compensation Inhibit

a. Peak Frequency Dynamics. WSC Doppler compensation inhibit must be initiated by a GCMR from the user POCC/MOC to the NCC prior to all periods of TDRSS two-way range and Doppler measurements. When the Doppler compensation inhibit mode is selected after operating in the Doppler compensation mode, the user spacecraft receiver will see the forward service frequency dynamics. The peak frequency dynamics that can be seen by the user spacecraft receiver (due to relative TDRS-user spacecraft velocities up to 12 km/sec, accelerations up to 15 m/sec^2, and jerks up to 0.02 m/sec^3) are frequency offsets up to ±90 kHz, frequency rates up to ±110 Hz/sec, and frequency accelerations up to ±0.2 Hz/sec^2, respectively. The user flight project must ensure that the user spacecraft receiver signal tracking characteristic is compatible with the peak frequency dynamics experienced or that the Doppler compensation inhibit mode will be selected only over

portions of the user spacecraft orbit where the frequency dynamics are low. Failure to do so can result in forward service, return service, and tracking service outages if the user spacecraft receiver PN code and/or carrier loops unlock.

b. Transition Process. A slow-and-hold process is used by the WSC to establish Doppler compensation inhibit and to reinitiate Doppler compensation. Doppler compensation inhibit will be initiated within 10 seconds of receipt of the appropriate OPM by the WSC and completed within 10 seconds after initiation. Upon reinitiation of Doppler compensation by the WSC, the TDRSS MA forward service carrier frequency will change slowly to the corrected Doppler compensated value.

3.3 SSA SERVICES

3.3.1 GENERAL

3.3.1.1 Available Services. TDRSS SSA services include forward and return telecommunications services, and tracking services. These services are described in terms of the data interfaces between a user POCC/MOC and the NASCOM data transport system and the RF interface between the user spacecraft and a TDRS. These interfaces are characterized by the technical requirements imposed and the operational capabilities provided by the TDRSS. This section describes the RF interfaces between the user spacecraft and TDRS; the data interfaces between the user POCC/MOC and NASCOM are described in section 5.

3.3.1.2 Interface Definition. The RF interface between the TDRS and a user spacecraft is defined in terms of signal parameters, RF characteristics, and field of view. The user POCC/MOC/NASCOM data transport system data interface is defined in terms of the number and characteristics of data channels. Forward service represents a user POCC/MOC data interface with the NASCOM data transport system and the transmission by a TDRS of an appropriately modulated signal at or greater than a minimum signal EIRP in the direction of the desired user spacecraft. Return service defines an ADR at the WSC receiver output as a function of P_{rec} and a NASCOM data transport system data interface with the user POCC/MOC in terms of number and distribution of data channels. The frequency allocations for all RF links between the TDRSs and user spacecraft are defined in paragraphs 3.3.2 and 3.3.3.

3.3.1.3 User Acquisition Requirements. Acquisition and reacquisition by the WSC/user spacecraft of the user spacecraft/TDRS transmitted signal requires prediction by the user POCC/MOC of the user spacecraft transponder/transmitter local oscillator frequency over various projected time periods. The frequency predictions are ultimately incorporated in the NCC SHO to the WSC as a user spacecraft transmitted/received frequency for the specific service support periods. The following discussion applies to user spacecraft transponder designs (e.g., the NASA first and second generation standard transponders; refer to STDN 203.7 for the first generation and STDN 203.8 for the second generation) for which the received center frequency for forward service signal acquisition, and the noncoherent transmitter frequency for return service operations, are derived from a TCXO. Of major concern to the user POCC/MOC is its ability to predict both the user spacecraft TCXO frequency and the thermal profile of the TCXO as a function of the operational scenario and sun position relative to the user spacecraft. The FDF can provide the user POCC/MOC with a history of the TCXO frequency based on TDRSS tracking service one-way Doppler data at intervals to be agreed to by the FDF and the

user POCC/MOC. The user POCC/MOC must therefore plan its missions and request the required TDRSS services from the NCC for the WSC to obtain the tracking data from the FDF. Prior to launch, the user POCC/MOC should also obtain TCXO frequency versus temperature data, including profiles for various operational scenarios as a function of time; i.e., based on thermal vacuum chamber tests and integration tests with the STS when applicable. The user POCC/MOC should then model the predicted TCXO frequency shifts for various operational scenarios and time periods and use them to implement its selected frequency acquisition strategies. These strategies are a function of user spacecraft TCXO frequency uncertainty, vehicle dynamics, and coherent or noncoherent operation. For example, the user POCC/MOC can request, via the NCC, that the TDRSS sweep the forward service frequency or use an expanded frequency uncertainty limit on the return service. In addition, the user POCC/MOC, if feasible, can plan the particular service support period of interest such that at service support period start time, the user spacecraft is in a part of its orbit where the Doppler dynamics are minimal, and the user spacecraft transponder has been previously commanded to remain in the noncoherent mode even on receipt of a TDRSS forward service signal.

3.3.1.4 TDRSS Acquisition Support to Users. For each scheduled TDRSS service support period, the user requirements for signal acquisition/reacquisition and the TDRSS capabilities to aid acquisition/reacquisition are as follows (user-related values are for the NASA first and second generation standard transponders; refer to STDN 203.7 for the first generation and STDN 203.8 for the second generation):

a. User Epoch Uncertainty. The maximum epoch uncertainty of the user spacecraft ephemeris supplied to the TDRSS shall be ±9 seconds.

Note

The WSC software will round-off the user receive frequency contained in the SHO to the nearest multiple of 221 Hz for SSA forward service. This quantization, under worst case conditions, may increase the predicted user receive frequency uncertainty up to 110 Hz. This results in a reduced maximum user spacecraft ephemeris uncertainty of ±7.6 seconds for the NASA first generation standard transponder and ±7.8 seconds for the NASA second generation standard transponder.

b. User Frequency Uncertainty. The user POCC/MOC must know the operating frequency of the user spacecraft TCXO to within ±700 Hz. For the FDF to be able to provide a user POCC/MOC with a history of its user spacecraft TCXO frequency based upon TDRSS tracking service one-way Doppler data, the user POCC/MOC must plan to schedule enough TDRSS tracking service support periods involving one-way Doppler measurements.

c. User Transponder Characteristics. The NASA first and second generation standard transponders are specified to have an acquisition bandwidth of ±1400 Hz and ±1500 Hz, respectively. Both transponders can acquire a signal with a Doppler rate up to 70 Hz/sec.

d. Forward Frequency Sweep. The TDRSS has a forward service frequency sweep capability of $\pm$3 kHz.

e. Return Frequency Sweep. The TDRSS has a return service expanded frequency search capability of $\pm$3 kHz.

3.3.2 SSA FORWARD SERVICES

3.3.2.1 General. The characteristics of the data provided by the user POCC/MOC to the NASCOM data transport system and the RF signals provided by the TDRS to the user spacecraft during TDRSS SSA forward services are described in paragraphs 3.3.2.2 through 3.3.2.6 (refer to section 5 for additional details of the user POCC/MOC/NASCOM data transport system interface).

3.3.2.2 Signal Parameters. The TDRSS SSA forward signal parameters are defined in Table 3-10. The center frequency, f_o, of the user spacecraft receiver must be defined by the user POCC/MOC in its request to the NCC for TDRSS SSA forward service. The features inherent in the signal parameters listed in Table 3-10 are as follows:

a. Spread Spectrum. All TDRSS SSA forward services incorporate spread spectrum modulation techniques to satisfy flux density restrictions imposed on the TDRSS forward services by the NTIA.

b. Doppler Compensation. The TDRSS SSA forward service carrier frequency (F) transmitted by a TDRS will be compensated by the WSC for Doppler so that the carrier, F_R, arrives at the user spacecraft receiving system within a predictable tolerance (E) of f_o as defined in Table 3-10. This feature minimizes the Doppler resolution requirements of the user spacecraft receiver and is available continuously to facilitate reacquisition by the user spacecraft in the event of loss of lock of the TDRSS SSA forward service signal. Doppler compensation will be inhibited by the WSC during tracking service periods requiring coherent two-way Doppler measurement (refer to paragraph 3.3.4.3) and may otherwise be inhibited by WSC at the user POCC/MOC's request to the NCC; e.g., if the user spacecraft has an onboard navigation capability and/or a wideband receiver.

c. Coherent Relationships Between the PN Code Clock and the Carrier Frequency. The PN code chip rate is coherently related to F in all cases. This feature permits the user spacecraft receiver to use the receiver PN code clock to predict the received carrier frequency, thereby minimizing receiver complexity and reducing acquisition time.

d. Simultaneous Command and Range Channels. The TDRSS SSA forward service signal includes separate but simultaneous command and range channels. This feature provides a solution to the conflicting requirements for range ambiguity resolution, minimum T_{acq}, and multipath protection (refer to paragraph f). 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.

Table 3-10. TDRSS SSA Forward Service Signal Parameters

Parameter	Description
TDRS transmit carrier frequency (Hz)	F
Carrier frequency arriving at user spacecraft (Hz) (note 1)	F_R
$\frac{\text{Command channel radiated power}}{\text{Range channel radiated power}}$	+10 dB
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 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)	NRZ
Data rate restrictions	0.1 - 300 kbps
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 3-10. TDRSS SSA Forward Service Signal Parameters (cont)

Note

1. 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 user spacecraft receiver as defined by the user POCC/MOC and $E = (70 \times \ddot{R}) + C$; $\ddot{R} < 50$ m/sec^2 and $C \leq 110$ Hz (see paragraph 3.3.1.4.a).

   Forward service Doppler compensation will not increase the peak phase error of a receiver (with a second-order Costas loop, $B_L = 36$ Hz, at $C/N_o = 33$ dB-Hz in the command channel) more than 2.4 degrees relative to the phase error for a Doppler-free carrier. This calculation assumes the loop bandwidth for a Second Generation NASA Standard Transponder. The increase in peak phase error due to Doppler compensation will differ based upon transponder characteristics.

2. The SN and the TDRSS are transparent to the data format of the forward service data. The particular format (NRZ-L, NRZ-M, NRZ-S) to be used will be established in the user POCC/MOC.

e. Unbalanced QPSK Modulation. The command channel/range channel (power) for all TDRSS SSA forward service signals is +10 dB. This unbalanced QPSK modulation minimizes the power in the range channel to a level adequate for user spacecraft 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 user spacecraft receiver complexity, increasing user spacecraft command channel acquisition time, or decreasing TDRSS range tracking accuracy.

f. Time Synchronization of Command and Range Channel PN Codes. Prior to transmission from WSC, the epoch (the all-1's condition) of the range channel PN code is time synchronized to one of the periodic epochs of the command channel PN code generator (refer to paragraph 3.3.2.3a). Because user spacecraft command channel acquisition must precede user spacecraft range channel acquisition, this feature limits the range channel PN code search to only 256 chip positions while the range channel PN code itself contains 261,888 chips. This feature also permits rapid detection of time spread on the received range channel signal identifying acquisition of a diffuse multipath signal. By the user spacecraft transferring the PN code tracking loop to the range channel after range channel acquisition, subsequent multipath interference can be prevented.

g. Short-cycled Linear Shift Register PN Code Sequence for Range Channel. The use of a short-cycled PN code for the range channel allows optimization of the command channel PN code. This feature permits use of Gold codes for the command channel to allow generation of a code library with good cross-correlation properties. The TDRSS PN code library (refer to paragraph 3.3.2.3a) is sufficiently large to allow a unique code assignment for each user spacecraft.

h. Asynchronous Data Modulation. The forward service data received at WSC from the NASCOM data transport system is directly modulo-2 added by WSC to the command channel PN code sequence. Because the PN code clock and the carrier are Doppler compensated by the WSC, the forward service data will be asynchronous with the carrier and the PN code. The forward service data is not processed in any other manner by the WSC.

3.3.2.3 Communications Services. The TDRSS SSA forward service parameters are listed in Table 3-11. Table 3-12 lists their salient characteristics. The definitions for the parameters listed in Table 3-12 are contained in Appendix E. The features inherent in the TDRSS SSA forward services listed in Table 3-11 are as follows:

Note

Due to current NCC software constraints, the S-Band frequency range which is available for user scheduling is 2041.0 to 2117.9 MHz (forward) and 2216 to 2300 MHz (return).

a. PN Code Assignment. The forward service data ultimately received by the user spacecraft from its user POCC/MOC via the supporting elements of the SN will have been asynchronously modulo-2 added to the TDRSS SSA forward service command channel PN code by the WSC. A user spacecraft-unique PN code assignment for the range and command channels will be made by the Frequency Manager of the MO&DSD from the library of PN codes defined in STDN No. 108.

b. Acquisition Scenarios. SSA forward service acquisition times for NASA first and second generation transponders are listed in Table 3-13. T_{acq} in the user spacecraft receiver is a function of the user spacecraft receiver design and signal-to-noise density ratio. The T_{acq} values listed in Table 3-13 are contingent on the user POCC/MOC defining the user spacecraft receiver center frequency, f_o, to an accuracy of $\pm$700 Hz in each service support request (refer to paragraphs 3.3.1.3 and 3.3.1.4). If the user POCC/MOC is unable to accurately define f_o, the NCC can request the WSC to frequency sweep the TDRSS forward service signal (refer to paragraph 3.3.2.5e) to aid the user spacecraft receiver acquisition process. This real-time NCC action can either be at the user POCC/MOC's real-time request (via a GCMR) or based on NCC operational procedures relative to that user spacecraft mission. The forward service signal sweep is initiated 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 forward service signal sweep is independent of simultaneously scheduled Doppler compensation.

c. Acquisition Time Determination. The user spacecraft forward service acquisition time must be considered in determining the overall return service acquisition time for user spacecraft with a coherent mode of operation (refer to paragraph 3.3.3.5c).

d. Link Margins. Example link calculations are provided in Appendix A.

e. Transmit Power. The TDRS will maintain a signal EIRP as defined in Table 3-11 in the direction of the user spacecraft for the duration of the scheduled TDRSS SSA forward

service to that user spacecraft. There is no requirement for user spacecraft transmission to initiate or maintain TDRSS SSA forward service. The use of TDRSS SSA forward service high-power operation is restricted by flux density restrictions which do not permit operation when the user spacecraft is within ±1.5 degrees of the Earth horizon as seen by that TDRS. TDRSS SSA forward service high-power operation is reserved for user spacecraft contingencies.

f. Functional Characteristics. The functional characteristics of TDRSS SSA forward services are shown in Appendix B, paragraph B.2.2.

g. Phase Ambiguity. The forward service data phase ambiguity resolution required in the user spacecraft is discussed in Appendix B, paragraph B.2.

3.3.2.4 Data Interfaces. The TDRSS SSA forward service data interfaces with the user POCC/MOC are as follows:

a. Data Rate Definition. The user POCC/MOC/NASCOM data transport system data channel interface and the user spacecraft data rate are initially defined in the user POCC/MOC service schedule request to the NCC and the resulting SHO to the WSC.

b. NASCOM Data Format. The user POCC/MOC transmits forward service data to the NASCOM data transport system that is either serial bit-contiguous or in 4800-bit blocks at the user POCC/MOC's option (refer to paragraph5.2.4.3b). The NASCOM data transport system processes this data so that a continuous stream of forward service data and logical clock signals is sent to the WSC at the scheduled user spacecraft data rate.

Note

During the scheduled service support period intervals when there is no forward service data from the user POCC/MOC, the data signal sent by the WSC is clamped to a logical 1.

c. Transmitted Signal. The NRZ format forward service data signal will be modulo-2 added by the WSC to the command channel PN code for retransmission by the TDRS to the user spacecraft. 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.

d. Operational Data Rates. During a scheduled service support period, a user POCC/MOC may change the TDRSS SSA forward service data rate to any data rate value in the range 0.1 kbps to 300 kbps. However, the operation restrictions of paragraph 3.3.2.5f apply.

Table 3-11. TDRSS SSA Forward Service

Parameter	Description
Field of view (each TDRS)	±22 degrees east-west ±28 degrees north-south
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	+46.1 dBW
Transmit frequency (nominal) (notes 2, 3, 4)	Selectable receiver frequency 2025.8 MHz to 2117.9 MHz [based on $\frac{221}{240} \times$ (2200 to 2300) MHz]
RF bandwidth (3 dB, minimum)	20 MHz
Duty factor	100 percent

Note

1. Operational considerations may limit choice of TDRS antenna polarization.

2. The user POCC/MOC must include the best estimate of the user spacecraft receiver center frequency at the start time of each scheduled service support period in his service request to the NCC, which then includes this parameter value in the SHO. The TDRSS SSA forward service carrier frequency is then implemented by the WSC to the accuracy of the WSC frequency standard except during Doppler compensation. Following Doppler compensation, the TDRSS SSA forward service carrier frequency will meet the frequency requirements of paragraph 3.3.4.3c. The user POCC/MOC must predict the frequency of the user spacecraft local oscillator using frequency drift history provided by the FDF and accounting for the thermal profiles described in paragraphs 3.3.1.3 and 3.3.1.4.

3. Interference considerations limit the usefulness of the lower portion of the SSA return service frequency band.

4. Due to current NCC software constraints, the forward S-Band frequency range which is available for user scheduling is 2041.0 to 2117.9 MHz.

Table 3-12. Salient Characteristics for TDRSS SSA Forward Service

Parameter	Description
$\frac{\text{Command channel radiated power}}{\text{Range channel radiated power}}$	+10 ±0.5 dB
Modulator phase imbalance (BPSK only) (peak)	±3 degrees
Modulator gain imbalance (peak)	±0.25 dB
Relative phase between command and range channels	90 ±3 degrees
Data asymmetry (peak) (note)	±3 percent
Data transition time (90 percent of initial state to 90 percent of final state) (note)	≤5 percent of data bit duration
Phase nonlinearity (peak)	±0.15 radian over ±7 MHz
Gain flatness (peak)	±0.8 dB over ±7 MHz
Gain slope (peak)	±0.1 dB/MHz
AM/PM	≤10 degrees/dB
PN code chip jitter (rms) (including effects of Doppler compensation)	≤1 degree
Data bit jitter (peak) (note)	≤1 percent
Spurious PM (rms)	≤1 degree
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 - 6 MHz	≤2 degrees

Table 3-12. Salient Characteristics for TDRSS SSA Forward Service (cont)

Parameter	Description
Command/range channel PN code chip skew (peak)	≤0.01 chip
PN code asymmetry (peak)	≤0.01 chip
PN code chip rate (peak) relative to absolute coherent with carrier rate	≤0.01 chips/sec at PN code chip rate

Note

These values are the TDRSS contributions for data asymmetry, data transition time, and data bit jitter, assuming perfect forward service data is provided to the WSC. The actual contributions by the NASCOM data transport system are negligible compared to those contributed by the TDRSS, since the WSC reclocks the data before it is processed by the WSC into the forward service signal.

Table 3-13. SSA Forward Service Example Acquisition Times for the First and Second Generation NASA Standard Transponders (Note 3)

Spacecraft S/N_0 (note 1)	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 (note 4)	≤ 7 sec	≤ 5 sec	≤ 10 sec	≤ 22 sec

Notes

1. S/N_0 is the signal to noise density ratio (dB-Hz) at the user spacecraft 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 First and Second Generation user transponders, reference should be made to STDN 203.7 and STDN 203.8, respectively.

4. Applies only to the Second Generation transponder.

3.3.2.5 Operations Characteristics. 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 user POCC/MOC to the NCC. The NCC then transmits these to the WSC as OPMs. The requested changes will be implemented at the WSC and the NCC will be notified of completion of initiation of the requested changes. All changes will be implemented within 35 seconds after receipt of the OPM at WSC. Additional information concerning WSC response times for OPMs is provided in section 4. The following changes can be made:

a. Center Frequency. The user spacecraft SSA receiver center frequency can be changed during a scheduled service support period.

b. Doppler Compensation Inhibit. During periods of TDRSS two-way range and Doppler measurements, the TDRSS will transmit a fixed frequency SSA forward service carrier and PN code chip rate (refer to paragraph 3.3.4.6).

c. Doppler Compensation Reinitiation. After a period of two-way range and Doppler measurement, the forward service Doppler compensation can be reinitiated; e.g., to allow for subsequent reacquisition by the user spacecraft of the forward service signal if SSA forward service signal tracking is lost by the user spacecraft (refer to paragraph 3.3.4.6).

d. Forward Service Reacquisition. The SSA forward service signal can be reinitialized by using forward service reacquisition. The WSC will continually apply the PN codes, as well as forward service Doppler compensation (if Doppler compensation is not being inhibited).

e. Forward Service Sweep Request. If a user POCC/MOC is unable to accurately define f_o (the nominal center frequency of the user spacecraft receiver), the forward service carrier frequency can be swept. The SSA forward service frequency sweep will be initiated by the WSC 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 WSC Doppler compensation of the SSA forward service carrier and PN code rate.

f. Data Rate. During a scheduled service support period, the user POCC/MOC can change the data rate from that initially defined in the SHO in the following manner:

(1) If the data rate change is not the only change being made to the TDRSS SSA forward service parameters at that time, the user POCC/MOC must request the data rate change as part of a reconfiguration GCMR to the NCC. When the WSC implements the reconfiguration OPM from the NCC, the TDRSS SSA forward service signal to the user spacecraft may be interrupted. If the forward service is interrupted, the user spacecraft will have lost signal lock and must then reacquire the TDRSS SSA forward service signal (refer to Appendix C). During the time period commencing with notification by the NCC that the GCMR has been accepted (refer to Table 4-2) and ending with reacquisition of the TDRSS SSA forward service signal by the user spacecraft, the user POCC/MOC cannot transmit any forward service data to the NASCOM data transport system.

(2) If the data rate change is the only change being made to the TDRSS SSA forward service parameters at that time, it is possible for the user POCC/MOC to implement the data rate change using the procedure described in paragraph (1). However, the TDRSS SSA forward service signal to the user spacecraft will not be interrupted.

g. User Antenna. During a scheduled service support period, the user POCC/MOC can initiate, terminate, or change the type of user spacecraft despun antenna (included as an OPM only to provide information to the WSC) (refer to paragraph 3.3.3.7b).

h. Polarization. Change in user spacecraft SSA receiving antenna polarization.

i. Spectrum Spreading. Initiation or termination of the command channel PN code (spectrum spreading).

j. Forward Service EIRP Change. The TDRS SSA forward service signal EIRP can be changed between the normal-power mode and the high-power mode (for user spacecraft emergency use only).

Note

1. Changes a, c, f, g, h, and i, are implemented by the NCC via a reconfiguration OPM and their use (individually or collectively) may cause the WSC to interrupt the TDRSS SSA forward service signal to the user spacecraft. Change d will cause the WSC to interrupt the forward service as it is implemented by the NCC via a reacquisition OPM. Change g is for WSC information only. If this change is the only change being made at this time to the user spacecraft configuration, it is advisable for the user POCC/MOC to formulate its procedures to preclude generation of a reconfiguration GCMR to the NCC.

2. The WSC implements Doppler compensation inhibit by using a "slow-and-hold" process (refer to paragraph 3.3.4.6b). There is no TDRSS SSA forward service signal interruption.

3. Changes e and j are acquisition aids, and they are implemented by the NCC via a forward service sweep request OPM and a forward service EIRP change request OPM respectively. Their use (individually or collectively) will not cause a TDRSS SSA forward service signal interruption.

3.3.2.6 Acquisition Scenarios. The following acquisition scenarios identify only the technical aspects of TDRSS SSA forward service signal acquisition by the user spacecraft and do not include operational procedures related to acquisition (refer to Appendix C):

a. The user spacecraft signal acquisition of the TDRSS SSA forward service signal will be independent of the user spacecraft return service mode or mode status.

b. The TDRSS SSA forward service antenna will be open-loop pointed in the direction of the user spacecraft.

c. At the start of the TDRS SSA forward service as defined by the SHO, the TDRS will radiate, in the direction of the user spacecraft, a signal compatible with the TDRSS SSA forward service signal parameters listed in Table 3-10 at a scheduled EIRP consistent with the TDRSS signal EIRPs listed in Table 3-11. The carrier and PN code clock will include Doppler compensation as scheduled.

d. The user spacecraft receiving system will search for and acquire the command channel PN code and carrier. Normally, a user POCC/MOC will not be transmitting forward service data to the NASCOM data transport system until the forward service signal has been acquired by the user spacecraft and the acquisition verified by the user POCC/MOC from user spacecraft return service telemetry. If either the NASA first generation or second generation standard transponders are used, their design implementation requires that there be no data transitions during the signal acquisition process. For other user spacecraft transponder implementations, if there are data transitions, the user spacecraft receiving system acquisition time may be longer than the times listed in Table 3-13.

e. The user spacecraft receiving system will search for and acquire the range channel PN code upon acquisition of the command channel PN code and carrier. Depending upon the user spacecraft receiving system design, upon completion of command channel PN code and carrier acquisition, range channel PN code acquisition, and subsequent user spacecraft receiving system transition to signal tracking, the user spacecraft transmitting system may either switch to a coherent transponding mode or remain in a noncoherent mode until commanded by the user POCC/MOC to switch.

f. The WSC will continue Doppler compensation of the TDRSS SSA forward service signal unless requested by the user POCC/MOC, via the NCC, to inhibit the Doppler compensation.

3.3.3 SSA RETURN SERVICES

3.3.3.1 General. The RF signals provided by the user spacecraft to the TDRS and the characteristics of data provided by the NASCOM data transport system to the user POCC/MOC are defined in paragraphs 3.3.3.2 through 3.3.3.7 (refer also to section 5 for additional details of the NASCOM data transport system/user POCC/MOC interface).

3.3.3.2 Signal Parameters

a. General. The TDRSS SSA return service signal parameters are listed in Table 3-14. The user spacecraft transmit frequency for DG1 mode 2 or DG2 (noncoherent operations) service must be defined by the user POCC/MOC to the NCC to an accuracy of $\pm$700 Hz when requesting TDRSS SSA return service (refer to paragraphs 3.3.1.3 and 3.3.1.4).

b. Features. The general features inherent in the user spacecraft signal parameters are as follows:

(1) SQPN/SQPSK/QPSK/BPSK Modulation. SQPN modulation must be used for DG1 modes 1 and 2, whereas SQPSK, QPSK, or BPSK modulation will be used for DG2, and QPSK must be used for DG1 mode 3. For SQPN and SQPSK modulation, the spectral characteristics of a user spacecraft 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 user spacecraft using adjacent frequency channels on the TDRS links.

(2) Use of Identical Phase-shifted PN Codes on the I and Q Channels. 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. User-unique PN code assignments (refer to STDN No. 108) include shift register tap connections for generating the assigned PN codes. The offset between the I and Q channel PN code epochs is defined in STDN No. 108 for each PN code.

(3) Asynchronous Data Modulation. The return service data stream in each channel will be modulo-2 added asynchronously to the channel PN code [DG1 modes 1, 2, and 3 (I channel)]. This prevents the forward service Doppler on the PN code from affecting the return service data stream data rate during DG1 mode 1 or mode 3 (I channel) operations. In general, for DG1 operation it eliminates the need for synchronizing the PN code user spacecraft data clock with the user spacecraft transmitter PN code clock.

(4) Coherent Relationships Between the PN Code Clock and the Carrier Frequency. The PN code clock must be coherently related to the transmitted carrier frequency in all cases of DG1 modes 1, 2, and 3 (I channel) operation. This feature permits the user spacecraft transmitter to use a common source for generating the carrier and the PN code clock and permits the WSC to use the PN code clock to aid return service carrier acquisition.

c. DG1 Signal Parameters. DG1 signal parameters are subdivided into three modes of operation which are distinguished as follows:

(1) DG1 Mode 1. DG1 mode 1 must be used when two-way range and Doppler measurement (coherent transponder operations) are required concurrently with return service low-rate data transmission. The PN code length is identical to the length of the forward service range channel PN code received from the TDRS. Its epoch is synchronized with the epoch of the forward service range channel PN code (refer to Table 3-14). Return service signal acquisition by the WSC for DG1 mode 1 is possible only when the scheduled TDRSS (SSA or MA) forward service signal is acquired by the user spacecraft and the PN code and carrier transmitted by the user

Table 3-14. TDRSS SSA Return Service Signal Parameters (Note 12)

Parameter	Description
DG1 (notes 1, 2, 3)	
Transmit carrier frequency (Hz)	F_1
Carrier (F_1) reference (Hz)	
DG1 modes 1 and 3	$\frac{240}{221} \times F_R$
DG1 mode 2	User spacecraft transmitter oscillator
PN code modulation	
DG1 modes 1 and 2	SQPN (note 3)
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 4)	Epoch delayed x + 1/2 PN code chips relative to I channel PN code epoch
DG1 mode 2	
I channel	User spacecraft oscillator
Q channel	Epoch delayed 1/2 PN code chip period relative to I channel PN code chip epoch
DG1 mode 3, I channel	Same as DG1 mode 1 (I channel)

Table 3-14. TDRSS SSA Return Service Signal Parameters (Note 12) (cont)

Parameter	Description
DG1 (notes 1, 2, 3) (cont)	
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
Symbol interleaving (note 5)	Refer to paragraph 3.3.3.3e(10)
Data format	NRZ-L, NRZ-M, NRZ-S
Symbol format	NRZ, Bi∅-L (Note 6)
DG1 mode 1 data rate restrictions	
Total (note 7)	0.1 - 300 kbps
I channel	0.1 - 150 kbps
Q channel	0.1 - 150 kbps
DG1 mode 2 data rate restrictions	
Total (note 7)	1 - 300 kbps
I channel	1 - 150 kbps
Q channel	1 - 150 kbps
DG1 mode 3 data rate restrictions	
Total (note 7)	I (max) + Q (max)
I channel	0.1 - 150 kbps
Q channel	1 kbps - 3 Mbps (Note 8)

Table 3-14. TDRSS SSA Return Service Signal Parameters (Note 12) (cont)

Parameter	Description
DG2 (notes 1, 9)	
Transmit carrier frequency	F_2
Carrier (F_2) reference (Hz)	$\frac{240}{221} \times F_R$ or user spacecraft oscillator
Data modulation (notes 10, 11)	SQPSK, BPSK (single data channel), or QPSK (dual data channel) (refer to Appendix B)
Symbol interleaving (note 5)	Refer to paragraph 3.3.3.3e(9)
Symbol format	NRZ, Bi∅-L (note 6)
Data format	NRZ-L, NRZ-M, NRZ-S
Data rate restrictions	
Total (note 7)	I (max) + Q (max)
I channel	1 kbps - 3 Mbps
Q channel	1 kbps - 3 Mbps

Note

1. User spacecraft data configurations are defined in paragraph 3.3.3.4 for TDRSS SSA return service (refer also to Appendix B).

2. The DG1 $\frac{\text{Q channel power}}{\text{I channel power}}$ can vary only from 1:1 to 4:1. Although the parameter range available during user spacecraft design is continuous between these two limits, at this time the user POCC/MOC may request this parameter, in scheduling messages to the NCC (refer to Table 4-5), only as the ratio of two small integers.

3. When identical data is being transmitted on balanced I and Q channels (Q/I [power] = 1:1) (single data channel configuration for DG1 modes 1 or 2), the I channel carrier phase must lead the Q channel phase by $\pi/2$ radians.

4. The Q channel PN code must be identical to the I channel PN code offset 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 user spacecraft (refer to STDN No. 108).

5. For DG1, mode 3 (Q channel) and DG2, symbol interleaving must be used for channel symbol rates above 300 ksps.

Table 3-14. TDRSS SSA Return Service Signal Parameters (Note 12) (cont)

Note (cont)

6. When symbol interleaving is not utilized, the output of the user spacecraft convolutional encoder may be NRZ-to-Bi∅-L converted at the option of the user. No G_2 symbol inversion within the convolutional encoder, as defined in paragraph 3.3.3.3e(1)(a)6, must occur when the output of the convolutional encoder is converted to Bi∅-L format. However, it is recommended that the user spacecraft designs use G_2 inversion to obtain symbol transitions, rather than NRZ-to-Bi∅-L conversion. NRZ-to-Bi∅-L conversion is not allowed for the single data channel configuration with alternate I/Q data bits of both DG1 and DG2. NRZ-to-Bi∅-L is not allowed for the DG2 single data channel configuration with alternate I/Q encoded symbols.

7. Data signals on the I and Q channels may be independent and asynchronous. Unless otherwise stated, the data is Rate 1/2 convolutionally encoded.

   DG1 and DG2 dual data channel operations involve independent data signals on the I and Q channels. These data signals can be asynchronous. The sum of the data rates on the I and Q channels must not exceed the total.

   For DG1 mode 1 or 2 dual data channel operation, the sum of the data rates on the I and Q channel must not exceed 300 kbps. For single data channel operation, the I and Q channel signals are either: (1) identical and synchronous and the data rate must not exceed 150 kbps or (2) alternate bits of the same data signal and the data signal must not exceed 300 kbps.

   For DG2 operations with identical symbol rates on the I and Q channels, the I and Q channels must be offset relative to one another by one half symbol period.

   For DG1 and DG2, maximum data rates for the I channel, and/or the Q channel, and the total are reduced by a factor of 2 when the Rate 1/2 convolutional encoder output signal is biphase formatted.

   If the channel data is to be Rate 1/3 convolutionally encoded, the maximum data rates are reduced by a factor of 1.5 with NRZ formatting.

8. For TDRSS SSA cross-support return service from a user spacecraft which normally uses the TDRSS MA return service, this Q channel upper limit reduces to 1.5 Mbps.
9. For DG2 dual data channel operations, the $\frac{\text{I channel power}}{\text{Q channel power}}$ can be either 1:1 or 4:1. For DG2 single data channel operations with SQPSK modulation, it must be 1:1.

Table 3-14. TDRSS SSA Return Service Signal Parameters (Note 12) (cont)

Note (cont)
10. The DG2 single data channel with SQPSK modulation can be used to support a user spacecraft configured to transmit return service data with either: (1) the two concurrent output symbols of a Rate 1/2 convolutional encoder on the I and Q channels, where the input to the encoder is restricted to a data rate ≤ 300 kbps or (2) the I and Q channels consisting of alternate data bits of the same data signal. Refer to paragraph 3.3.3.4.e for more detail.
11. For DG2 single data channel operations, BPSK may be used for data rates ≤3 Mbps (Rate 1/2 convolutionally encoded data) or ≤2 Mbps (Rate 1/3 convolutionally encoded data).
12. 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.

spacecraft are coherently related to the forward service signal from the TDRS. TDRSS forward and return services must be scheduled to be available simultaneously, either both through the TDRSS SSA (forward and return) service or one through the TDRSS SSA (forward or return) service and the other through the TDRSS MA (return or forward) service. If the former, these services should be requested by the user POCC/MOC to be scheduled to negate the need for using DG1 mode 2 for normal operations. If the TDRSS forward service signal becomes unavailable to the user spacecraft, the spacecraft transmitter must switch to noncoherent transmitter operation (DG1 mode 2) (refer to paragraph 3.3.3.5.b.(2)). TDRSS MA forward and TDRSS SSA return services may not be able to be scheduled simultaneously for a user spacecraft because all users of the TDRSS MA forward service must time-share the single TDRSS MA forward service available from each TDRS.

(2) DG1 Mode 2. DG1 mode 2 can be used when WSC return service signal acquisition is necessary without the requirement for prior user spacecraft signal acquisition of the TDRSS (SSA or MA) forward service (noncoherent transponder operation). The carrier frequency transmitted by the user spacecraft must be defined by the user POCC/MOC to a tolerance of ±700 Hz prior to initiation of the WSC signal acquisition process for DG1 mode 2; i.e., in the service schedule request to the NCC that results in the SHO to the WSC for that service support period (refer to paragraphs 3.3.1.3 and 3.3.1.4).

(3) DG1 Mode 3. DG1 mode 3 can be used when two-way range and 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.

(4) DG1 Mode 1 and 2 Data Channel Parameters. The user spacecraft return service signal can have either a single data channel or two independent data channels for both DG1 modes 1 and 2 operation (refer to paragraph 3.3.3.4). For a single data channel,

the following configurations are supported: (1) the identical data must appear simultaneously on the I and Q channels or (2) the I and Q channels are alternate bits of the same data signal. For two independent data channels (dual data channels), one independent data stream will appear on the I channel, the other on the Q channel. The I and Q channel power division in the user spacecraft transmitter can be weighted up to a maximum of 4:1 ($Q \geq I$) for either a single data channel with identical data on both channels or dual data channels. The Q/I (power) must be equal to 1:1 for a single data channel with alternate I/Q data bits.

(5) DG1 Mode 3 Data Channel Parameters. For DG1 mode 3, the user spacecraft return service signal has two independent data channels (refer to paragraph 3.3.3.4). One independent data stream will appear on the I channel and the other on the Q channel. The I and Q channel power division in the user spacecraft transmitter can be weighted up to a maximum of 4:1 ($Q \geq I$).

d. DG2 Signal Parameters. The following summarizes the DG2 signals:

(1) DG2. DG2 signal parameters must be used when the return service data rate equipment exceeds the capability of DG1 operations. DG2 operation cannot provide TDRSS range tracking because PN code modulation is not used for DG2. The DG2 carrier can be either coherently related to or independent of the TDRSS (SSA or MA) forward service carrier frequency. 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. The carrier frequency transmitted by the user spacecraft must be defined by the user POCC/MOC to a tolerance of $\pm$700 Hz prior to initiation of the WSC acquisition process when the DG2 carrier is independent of the forward service signal (refer to paragraphs 3.3.1.3 and 3.3.1.4).

(2) DG2 Data Channel Parameters. The DG2 return service signal can have either a single data channel or two independent data channels (dual data channels). User spacecraft data configurations for DG2 are defined in paragraph 3.3.3.4. For DG2 dual data channel operations, the I and Q channel power division in the user spacecraft transmitter can be either 1:1 or 4:1 ($I \geq Q$). For DG2 single data channel operations with SQPSK modulation, it must be 1:1.

e. User Transmitter Configurations. The user spacecraft transmitter functional configurations for the TDRSS SSA return services (DG1 and DG2) are shown in Appendix B.

3.3.3.3 Communications Services

a. Available Services. The TDRSS SSA return services available are listed in Table 3-15. User spacecraft transmitted signal characteristics required to obtain the TDRSS SSA return service performance defined in this paragraph are specified in paragraph 3.3.3.7. 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.

Note

Due to current NCC software constraints, the S-Band frequency range which is available for user scheduling is 2041.0 to 2117.9 MHz (forward) and 2216 to 2300 MHz (return).

b. PN Coding. A user spacecraft unique PN code assignment for the DG1 modes 1, 2, and 3 (I channel) PN codes will be made by the Frequency Manager of the GSFC MO&DSD from the library of PN codes in STDN No. 108. These PN codes will be from the same PN code library assignments as the PN codes for the forward service command and range channels (refer to paragraph 3.3.2.3a).

c. Phase and Channel Ambiguity. Data phase ambiguity (except for NRZ-L) and data channel ambiguity are resolved by the WSC (refer to paragraph B.3).

d. Data Encoding. Convolutional encoding (rate 1/2 or rate 1/3) must be used for all user spacecraft SSA transmissions both to minimize P_{rec} and as an RFI mitigation technique.

e. ADR Equation Conditions. The ADR indicated in Table 3-15 is based on the following conditions:

(1) Data Encoding.

Note

The WSC Viterbi decoder cannot synchronize correctly to a data signal which does not contain any input data signal transitions prior to convolutional encoding. Sufficient data transitions are necessary during the Viterbi decoder synchronization process to ensure correct branch synchronization.

(a) The following data encoding parameters apply to these TDRSS SSA return services: DG1 modes 1 and 2 for a single data channel; DG1 modes 1, 2, and 3 for dual data channels; DG2 for a single data channel (BPSK or SQPSK modulation); and DG2 for dual data channels (QPSK modulation):

1. Code 1: convolutional, nonsystematic, transparent.

2. Rate: 1/2.

3. Constraint length: K = 7.

4. Generator functions:

a. G_1 = 1111001.

Table 3-15 TDRSS SSA Return Service (note 8)

Parameter	Description
Field of View (each TDRS)	$\pm$22 degrees east-west $\pm$28 degrees north-south
TDRS antenna polarization (note 5)	RHC or LHC selectable
TDRS antenna axial ratio (maximum)	1.5 dB over 3 dB beamwidth
Receive frequency band (notes 6 and 7)	2200 MHz to 2300 MHz
ADR (dB relative to 1 bps) (rate 1/2 convolutionally encoded) (notes 1, 3, 4)	
DG1 modes 1 and 2	$230.7 + P_{rec}$
DG1 mode 3	
I channel	$230.7 + P_{rec}$
Q channel	$230.4 + P_{rec}$
DG2	$230.4 + P_{rec}$
ADR (dB relative to 1 bps) (rate 1/3 convolutionally encoded) (notes 1 through 4)	
DG1 mode 3, Q channel	$230.7 + P_{rec}$
DG2	$230.7 + P_{rec}$
PN Code (if applicable) and Carrier Acquisition	
Orbital dynamics	$\dot{R} \leq 12$ km / sec, $\ddot{R} \leq 15$ m / sec^2, jerk $\leq .02$ m / sec^3
Ephemeris Uncertainty	$\leq \pm$ 9 sec
P_{rec}	$\geq$ -202.0 dBW or consistent with the P_{rec} for ADR, whichever is greater
Acquisition Time ($P_{acq} \geq 90\%$)	
for Frequency Uncertainty $\leq \pm$ 700 Hz	$\leq$ 1 sec
for Frequency Uncertainty $\leq \pm$ 3 kHz	$\leq$ 3 sec

Table 3-15 TDRSS SSA Return Service (cont) (note 8)

Parameter	Description
Decoder/Symbol Synchronization Acquisition	
Ephemeris Uncertainty	$\leq \pm$ 9 sec
Minimum data bit transition density	$\geq$ 64 data randomly distributed data bit transitions within any sequence of 512 data bits
Number of consecutive data bits without a transition	$\leq$ 64
Prec (dBW)	consistent with the P_{rec} for ADR
Synchronization acquisition time (in seconds) with >99% probability	
Biphase	< 1100/(Data Rate in bps)
NRZ	< 6500/(Data Rate in bps)
Symbol/Deinterleaver/Decoder Synchronization Acquisition	
Ephemeris Uncertainty	$\leq \pm$ 9 sec
Minimum data bit transition density	$\geq$ 64 data randomly distributed data bit transitions within any sequence of 512 data bits
Number of consecutive data bits without a transition	$\leq$ 64
Prec (dBW)	consistent with the P_{rec} for ADR
Synchronization acquisition time (in seconds) with >99% probability	
Rate 1/2 coding	Average: $\leq$ 36000/(Data Rate in bps) Maximum: $\leq$ 66000/(Data Rate in bps)
Rate 1/3 coding	Average: $\leq$ 26000/(Data Rate in bps) Maximum: $\leq$ 46000/(Data Rate in bps)

Table 3-15 TDRSS SSA Return Service (cont) (Note 8)

Parameter	Description
Signal Tracking	
During Free Flight	refer to paragraph 3.3.3.3.e.(13)
During Powered Flight	refer to paragraph 3.3.3.3.j
Duty Factor	100%

Note

1. The ADR is for a user spacecraft transmitting a signal on an AWGN channel which complies with the constraints defined in paragraph 3.3.3.7 (also refer to Appendix H). Refer to Appendix G for a discussion of the additional degradation applicable to TDRSS SSA return service performance due to S-band RFI.

2. Rate 1/3 convolutional encoding can only be used on the Q channel of DG1 mode 3, DG2 BPSK, DG2 single data channel configuration using SQPSK with alternate I and Q data bits, DG2 dual data channel configuration.

3. The required user P_{rec} must meet the P_{rec} for ADR or signal acquisition, whichever is greater.

4. Refer to Appendix A, paragraph A.4, for a definition of P_{rec}. For QPSK signals (balanced or unbalanced) with nonidentical data on the I and Q channels (dual data channels), the P_{rec} value specified is to be interpreted as the minimum required P_{rec} per channel. For balanced SQPSK signals with alternate I/Q data bits and DG2 balanced SQPSK signals with alternate I/Q encoded symbols, the P_{rec} value specified is to be interpreted as the minimum required P_{rec} per channel where the channel data rate is 1/2 the bit rate of the data source. A user with a DG2 SQPSK modulated signal is required to transmit a P_{rec} of $\geq$ -190.0 dBW or consistent with the P_{rec} for ADR, whichever is greater.

   For DG1 balanced QPSK signals with identical data (synchronous and at the same data rate) on the I and Q channels, the minimum required <u>total</u> (I + Q) P_{rec} is equal to the minimum required P_{rec} of <u>either</u> an I or Q channel of a dual data channel with data at this same data rate.

   For unbalanced QPSK signals with identical data on the I and Q channels (DG1 single data channel only), the minimum required P_{rec} is to be interpreted as the P_{rec} of the stronger channel.

Table 3-15 TDRSS SSA Return Service (cont)

Note

5. Operational considerations may limit the choice of TDRS antenna polarization.

6. Interference considerations limit the usefulness of the lower portion of the SSA return service frequency band.

7. Due to current NCC software constraints, the S-Band return frequency range which is available for user scheduling is 2216 to 2300 MHz.

8. 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.

b. G_2 = 1011011.

5. Symbols generated from G_1 must precede symbols generated from G_2 relative to the data bit period.

6. Symbols generated from G_2 should be complemented. G_2 symbol inversion provides an increased symbol transition density for a convolutional encoder input data signal with low transition density. Increaded symbol transition density will aid WSC clock (symbol) synchronization.

Note

WSC can support symbols generated from G_2 that are either true or complemented and will be defined in the SHO to the WSC. However, G_2 symbol inversion is not supported with NRZ to Biphase-L symbol conversion.

(b) The following data encoding parameters will apply to the TDRSS SSA DG2 BPSK single data channel:

Note

These code parameters are available to current users compatible with the NASA Deep Space Network. However, all future users that plan to operate with the DSN should use Code 1.

1. Code 2: convolutional, nonsystematic, transparent.

2. Rate: 1/2.

3. Constraint length: K = 7.

4. Generator functions:

a. G_1 = 1011011.

b. G_2 = 1111001.

5. Symbols generated from G_1 must precede symbols generated from G_2 relative to the data bit period.

6. Symbols generated from G_1 must be complemented.

(c) The following data encoding parameters apply to these TDRSS SSA return services: DG1 mode 3 Q channel (dual data channel configuration), DG2 for a single data channel (BPSK modulation and SQPSK modulation with alternate I/Q data bits), and DG2 for dual data channels (QPSK modulation):

Note

These data encoding parameters cannot be used for the DG2 single data channel (SQPSK modulation with alternate I/Q encoded symbols) configuration of the TDRSS SSA return service.

1. Code 3: convolutional, nonsystematic, transparent.

2. Rate: 1/3.

3. Constraint length: K = 7.

4. Generator functions:

a. G_1 = 1111001.

b. G_2 = 1011011.

c. G_3 = 1110101.

5. The symbol sequence must be generated from G_1, G_2, and G_3 successively relative to the data bit period.

6. Alternate symbols generated from the convolutional encoding must be complemented.

(2) Format Description. The data and symbol format for each data channel are independently selectable by the user spacecraft. Achievable rate parameters are based

on a 10^{-5} BER for all data formats measured at the WSC receiver output. As the NASCOM data transport system BER is $\leq 10^{-7}$, the BER at the NASCOM data transport system/user POCC/MOC interface is basically established by the BER at the WSC receiver output.

(3) Received Power. P_{rec} is in units of dBW. The user project, in determining its design requirements for minimum user spacecraft EIRP, must take into account user spacecraft transmit antenna pointing losses, the space loss between the user spacecraft and the TDRS, and the polarization mismatch loss incurred by a deviation from 0 dB user spacecraft transmit antenna axial ratio. The maximum TDRS receive antenna axial ratio is given in Table 3-15 (also refer to Appendix A).

(4) User Degradations. Further reductions in the TDRSS SSA return service performance identified in Table 3-15 can occur. For TDRSS SSA return service where the user spacecraft employs electronically switchable or selectable antennas, the reduction in TDRSS SSA performance is defined in paragraph 3.3.3.7b as a function of the user spacecraft transmitting antenna-induced AM and PM and switching rate. The TDRSS SSA return service will also be degraded due to RFI (refer to Appendix G). User spacecraft parameters exceeding the constraints described in paragraph 3.3.3.7 can also degrade TDRSS SSA return service performance (refer to Appendix H).

(5) Acquisition. The SSA return service T_{acq} (refer to Table 3-15), for all modes of operation does not include user spacecraft forward service signal acquisition time. The SSA return service T_{acq} also assumes that the user POCC/MOC-defined user spacecraft transmit frequency for DG1 mode 2 or DG2 (noncoherent operations) is accurate to $\pm$700 Hz (refer to paragraphs 3.3.1.3 and 3.3.1.4) and assumes that the user spacecraft return service signal is present at the WSC at the start time of the scheduled return service support period. For DG1 mode 2 and DG2 (noncoherent operations), the WSC will be capable of acquiring, on NCC request, a user spacecraft transmitted signal with a frequency uncertainty of $\pm$3 kHz with TDRSS SSA return service signal acquisition times that are increased by a factor of 3.

Note

This is in addition to the WSC being able to accommodate the frequency uncertainty caused by the $\pm$9-second user spacecraft ephemeris uncertainty.

(6) Sun Interference. The TDRSS SSA return service will not be available when the center of the sun is either within 4 degrees of the TDRS SSA receiving antenna boresight or within 1 degree of the boresight of the WSC receiving antenna supporting that TDRS. Currently the NCC cannot use the PSAT message; therefore, it does not know the sun's transit periods. Sun interference checking is a user POCC/MOC responsibility. The NCC does not check, nor does it inhibit, a user POCC/MOC from scheduling events subject to sun interference. Based on this, the user POCC/MOC is responsible for obtaining and using the PSAT information in its mission planning. If the user POCC/MOC requests support through sun transits, TDRSS SSA return

service performance (signal acquisition and/or tracking, BER) is not guaranteed during the sun transit. The NCC will always verify the absence of WSC antenna sun interference for all service support period requests.

(7) DG1 Received Power Considerations. For DG1 service, the following conditions apply:

(a) Balanced Single Data Channels. For a user spacecraft synchronously transmitting identical data on the I and Q channels (single data channel-identical data) with a balanced I and Q channel power division, the total P_{rec} must be consistent with the ADR listed in Table 3-15 (refer also to note 4 of Table 3-15).

(b) Balanced Single Data Channel-Alternate I/Q Bits. For a user spacecraft transmitting alternate I and Q data bits from the data signal (single data channel-alternate I/Q bits), the fraction of total P_{rec} devoted to the I (or Q) channels must be consistent with the ADR in Table 3-15 for the channel data rate. The Q/I (power) must be equal to 1:1.

(c) Unbalanced Single Data Channels. For a user spacecraft synchronously transmitting identical data on the I and Q channels (single data channel) having unbalanced I and Q channel power division, the strong channel P_{rec} must be consistent with ADR listed in Table 3-15. The weak channel P_{rec} need not be consistent with the ADR listed in Table 3-15. The Q/I (power) must not exceed 4:1.

(d) Dual Data Channels. For a user spacecraft transmitting independent data on the I and Q channels (dual data channels), the fraction of total P_{rec} devoted to the I (or Q) channels must be consistent with the ADR in Table 3-15 for the I (or Q) channel data rate. The Q/I (power) must not exceed 4:1 regardless of the ratio of data rates on the I and Q channels.

(e) Transponder Failure. If the user spacecraft fails to transmit one quadrature carrier channel (I or Q) or that channel does not include data modulation, the ADR capability of the remaining channel is unaffected as long as the remaining channel's P_{rec} is consistent with the ADR listed in Table 3-15.

(8) Multipath. The WSC will provide lockup and interference protection from multipath signals reflected from the Earth.

(9) DG2 Received Power Considerations. For a user spacecraft using DG2, I/Q (power) will be either 1:1 or 4:1. The fraction of total P_{rec} devoted to the I (or Q) channel data must be consistent with the ADR of Table 3-15 for the I (or Q) channel data rate. For dual data channel operation, if one quadrature carrier channel (I or Q) is not transmitted or that channel does not include data modulation, the ADR capability of the remaining channel is unaffected.

(10) Periodic Convolutional Interleaving. At symbol rates above 300 ksps, symbol interleaving of the user spacecraft transmission must be used for DG1 mode 3 and

DG2 signals. Deinterleaving is not supported for symbol rates $\leq$ 300 ksps. 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. Periodic convolutional interleaving is not supported for code 2 data encoding parameters.

(11) 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 WSC symbol synchronization loop will not unlock for a P_{rec} that is 3 dB less than the minimum P_{rec} required consistent with the ADR of Table 3-15. For NRZ symbol transition densities between 25% and 40%, the WSC symbol synchronizer loop will not unlock for a P_{rec} that is 2 dB less than the minimum P_{rec} required for the ADR. However, the BER performance may be degraded when the P_{rec} is less than the minimum required to be consistent with the ADR.

(12) False Lock. The TDRSS SSA return services will be protected against WSC false lock in carrier recovery during acquisition and subsequent normal TDRSS SSA return service. For DG1 the TDRSS SSA return services will be protected against false lock to user spacecraft PN code sidelobes. TDRSS SSA cross-support return service to user spacecraft normally using the TDRSS MA return service [refer to paragraph (17)] will be protected against false WSC lock to interfering user spacecraft PN codes, WSC false lock to user spacecraft PN code sidelobes, and WSC false lock in carrier recovery.

(13) Cycle Slips. The mean time-between-cycle slip in the WSC carrier tracking loop for each TDRSS SSA return service will be 90 minutes minimum. This value applies at carrier tracking threshold (i.e., 3 dB less than the minimum P_{rec} for ADR listed in Table 3-15) and increases exponentially as a function of linear dB increases in P_{rec}. For DG1, modes 1, 2, and 3 I data channels with spectrum spreading and for nonspread DG1 mode 3 Q or DG2 data channels with either BPSK modulation or unbalanced QPSK modulation, a single cycle slip will invert the signal polarity at the WSC demodulator output. For DG2 data channels with balanced QPSK modulation, a single cycle slip will interchange the I and Q demodulator outputs and invert one of the outputs. For a single data channel with balanced QPSK, the WSC Viterbi decoder may require resynchronization. For the dual data channel configuration with balanced QPSK, for which channel ambiguity resolution will be provided, the time for the WSC to recover will be the time for the WSC to detect an interchange and to resynchronize its bit synchronizers and Viterbi decoders.

(14) Bit Slippage. For each TDRSS SSA return service operating with a minimum P_{rec} required consistent with the ADR of Table 3-15 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 WSC symbol clock recovery loop is either 90 minutes or 10^{10} clock cycles, whichever is greater. For an SSA return service operating with 1 dB more than the minimum P_{rec} required for the ADR, and NRZ symbol transition densities between 25% and 40%, the minimum

mean time between slips is either 90 minutes or 10^{10} clock cycles, whichever is greater.

(15) Rate 1/3 Performance. User spacecraft designs can utilize rate 1/3 convolutional encoding to provide more robust SSA return service performance in the presence of RFI (refer to Appendix G). SSA return service signals that are rate 1/3 convolutionally encoded incur lower RFI degradations for the same RFI environment than signals that are rate 1/2 convolutionally encoded (refer to Table G-1). The performance of the TDRSS SSA return service with user spacecraft signals that are rate 1/3 convolutionally encoded is given in Table 3-15. The performance of the TDRSS SSA return service with rate 1/3 convolutional encoding applies under the following conditions:

(a) With the symbol interleaving as defined in Appendix F, or without symbol interleaving.

(b) Data rates from 1 kbps to 2 Mbps.

(c) User spacecraft designs must not use Bi0-L format conversion of the convolutional encoder output in conjunction with the use of rate 1/3 convolutional encoding.

(16) Simultaneous MA and SSA Services. For a user spacecraft mission that normally uses the TDRSS MA return service for DG1 mode 1 or 2 operations but also has a concurrent requirement to use the TDRSS SSA return service for DG2 operations (using a separate transmitter), TDRSS SSA DG2 return service can be concurrently supported to that user spacecraft along with a TDRSS SSA forward service from the same TDRS antenna. The carrier frequency for the DG2 signal must either be different from the TDRSS MA return service frequency or RHC polarization must be used (refer to paragraphs 3.3.3.3f and g). For noncoherent DG2 operations, the carrier frequency can also be independent of the TDRSS SSA forward service frequency, thereby permitting noncoherent DG2 operations without impacting TDRSS SSA forward service to, or simultaneous TDRSS MA DG1 mode 1 return service from, that same user spacecraft.

(17) SSA Support of an MA User. The TDRSS SSA return service will be capable of supporting user spacecraft, which normally use the TDRSS MA return service, with the ADR and acquisition time performance of normal TDRSS SSA return service (refer to Table 3-15).

f. Frequency and Polarization. The TDRSS SSA return service can support user spacecraft with assigned frequencies anywhere within the 2200 to 2300 MHz band with either RHC or LHC polarization (refer to Table 3-15, notes 6 and 7). The following restrictions apply:

(1) The center frequency of each TDRSS SSA service channel is tunable over the range from 2200.5 to 2299.5 MHz in uniform 0.5 MHz steps.

(2) The TDRS gain flatness and phase linearity are controlled over the entire 2200 to 2300 MHz band.

(3) The ADR relationships of Table 3-15 are satisfied for center frequencies from 2205 to 2295 MHz.

(4) Narrow band user spacecraft, whose bandwidth does not exceed or spill over the edges of the 2200 to 2300 MHz band, should experience acceptable data service as indicated by the TDRS gain flatness and phase linearity performance which is satisfied out to the band edges.

(5) User spacecraft data rates should be constrained so that the first null of the spectrum for BPSK modulation (or the second null for QPSK) falls within the 2200 to 2300 MHz band.

(6) In addition, user spacecraft normally will operate with RHC polarization, regardless of their operating frequency, to minimize the interference generated by user spacecraft normally using the TDRSS MA return service. Finally, users should avoid selection of frequencies in the 2200 to 2220 MHz band to minimize the TDRSS SSA return service performance degradation due to RFI effects (refer to Appendix G).

g. Mutual Interference. It is possible for the mutual interference between SSA user spacecraft operating on the same polarization to become significant. For mutual interference to be significant, all the following conditions must be satisfied:

(1) TDRSS SSA return service operation within the same 10 MHz bandwidth.

(2) Simultaneous TDRSS SSA return service operation.

(3) TDRSS SSA return services for each user spacecraft are provided by the same TDRS.

(4) The user spacecraft are located within 3 degrees of each other as seen from the same TDRS. (This value may need to be increased if the user spacecraft P_{rec} margin [refer to Appendix A] increases beyond 3 dB).

Note

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

h. Restrictions on Received Power. For those situations where TDRSS SSA return service mutual interference can exist (TDRSS SSA return service frequency outside the TDRSS MA return service frequency band of 2285 to 2290 MHz), but avoidance through scheduling is not desirable, LHC polarization can be used. However, when operating LHC polarization, the out-of-band energy radiated by the user spacecraft must not result in a P_{rec} greater than -194.2 dBW within the TDRSS MA return service frequency band.

i. TDRS Antenna Pointing. There is no requirement for user spacecraft transmission to initiate or maintain TDRS antenna pointing during scheduled TDRSS SSA return service support periods.

j. Signal Tracking and Reacquisition During Powered Flight. TDRSS can support signal tracking and reacquisition during powered flight under the following conditions:

(1) Signal Tracking. For a required minimum P_{rec}, TDRSS will provide signal tracking with a probability of more than 0.99 for a user with powered flight dynamics (user spacecraft velocities up to 15 km/sec, accelerations up to 50 m/sec^2, and jerks up to 2 m/sec^3) and an ephemeris uncertainty of $\pm$9 seconds. DG1 signals are required have a minimum P_{rec} of -200.5 dBW or the minimum P_{rec} for ADR, whichever is greater. DG2 signals are required to have a minimum P_{rec} of -194.4 dBW or the minimum P_{rec} for ADR, whichever is greater.

(2) 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 using pre-drop lock tracking data as an aid. The normal reacquisition time for a user with powered flight dynamics and an ephemeris uncertainty of $\pm$9 seconds is a maximum of 1 second with a probability of at least 0.99.

3.3.3.4 Data Interfaces. The TDRSS SSA return service data interfaces are as follows:

a. Data Rate Definition. The user spacecraft data rates for a specific service support period are initially defined by the NCC in the SHO to the WSC for that service support period.

b. NASCOM Operations. The user spacecraft transmits data signals to the TDRS in continuous symbol streams as scheduled. The data signals may consist of an idle pattern or actual data. After WSC return service signal acquisition, the NASCOM data transport system processes these data streams and provides the user POCC/MOC with each of the individual data streams in the 4800-bit block format or in a bit-contiguous serial data stream as previously agreed to by the user POCC/MOC and the SN (refer to section 5).

c. DG1 Single Data Channel Configurations. For DG1, a single data channel (refer to Appendix B) can be used to support any of the following user spacecraft configurations:

(1) Transmitting a balanced QPSK signal configured for synchronous transmission of the identical convolutionally encoded (rate 1/2 only) data signal on both I and Q channels.

(2) Transmitting a balanced SQPSK signal configured such that the I and Q channels consist of alternate bits of the same data signal. Both the I channel and Q channel data signals will be identically but independently 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.

(3) Transmitting an unbalanced QPSK signal and configured for synchronous transmission of the identical convolutionally encoded (rate 1/2 only) data signal on both the I and Q channels.

(4) Transmitting a BPSK signal as a result of either the I or Q channel of the user spacecraft QPSK modulator being inoperative.

d. DG2 BPSK Single Data Channel Configuration. For DG2 with BPSK modulation, a single data channel (refer to Appendix B) can be used to support a user spacecraft configured to transmit a single convolutionally encoded (rate 1/2 or rate 1/3) data signal.

e. DG2 SQPSK Single Data Channel Configurations. For DG2, a single data channel (refer to Appendix B) can be used to support a user spacecraft configured to transmit convolutionally encoded data with SQPSK modulation using one of the following configurations: (1) the I and Q channels consist of the two concurrent output symbols of a rate 1/2 convolutional encoder, where the input to the encoder is restricted to a data rate $\leq$ 300 kbps, or (2) the I and Q channels consist of alternate data bits of the same data signal. For the alternate data bit configuration, each data channel will be identically but independently differentially formatted, rate 1/2 or rate 1/3 convolutionally encoded, and, if required, symbol interleaved.

f. Interleaving Constraint. At symbol rates above 300 ksps, the convolutionally encoded data signal must be interleaved using the technique shown in Appendix F.

g. DG1 and DG2 Dual Data Channel Configurations. For DG1 and DG2, the dual data channels (refer to Appendix B) can be used to support a user spacecraft configured to transmit two independent convolutionally encoded data signals, one on the I channel and one on the Q channel. All channels may use rate 1/2 convolutional encoding. For DG1 mode 3, rate 1/3 convolutional encoding may be used only on the Q channel. For DG2, rate 1/3 convolutional encoding may be used on either or both channels of the dual data channel configuration.

h. Channel Ambiguity Resolution. The WSC will resolve the data channel ambiguity (refer to Appendix B) for all user spacecraft DG1 dual data channels. For user spacecraft DG2 dual data channels, the WSC will resolve the data channel ambiguity if at least one of the following criteria is met:

(1) Unbalanced (I/Q = 4:1) QPSK modulation.

(2) Rate 1/2 convolutional encoding on one channel and rate 1/3 convolutional encoding on the other.

(3) The channel symbol rates are unequal and the higher rate exceeds the lower rate by at least 25 percent.

Note

When a harmonic of the I (or Q) channel clock is within 25 percent of the Q (or I) channel clock frequency, ambiguity resolution cannot be reliably achieved using WSC bit synchronizers set up for operation at the scheduled I and Q channel data rates (refer to Appendix B, paragraph B.3).

i. Data Loss Detection. The data provided by the user spacecraft on a particular channel must be at the scheduled data rate for that user spacecraft channel (before convolutional encoding). This TDRSS SSA return service will be processed by the WSC so that loss of the received data in each channel will be detected. The data stream in that channel sent to the user POCC/MOC by the NASCOM data transport system will be clamped to a logical 1 during this data loss period.

j. Phase Ambiguity Resolution for Differential Encoding. The WSC will resolve the data phase ambiguity for user spacecraft data channels with differentially encoded (NRZ-M/-S) data formats (refer to Appendix B, paragraph B.3)

3.3.3.5 Operational Characteristics. TDRSS SSA return services have the following operational characteristics:

a. Service Changes. Changes to the operating conditions or configuration of a TDRSS SSA return service during a scheduled service support period are initiated by a Ground Control Message Request (GCMR) from the user POCC/MOC to the NCC. The NCC then transmits these to WSC as an OPM. The requested changes will be implemented at the WSC and the NCC will be notified upon completion of initiation of the requested changes. All changes will be implemented within 35 seconds after receipt of the OPM at the WSC. Additional information concerning WSC response times for OPMs is provided in section 4. The following changes can be made:

(1) Return Service Reacquisition.

(a) In case of loss of lock (PN Code and/or Carrier), the WSC will automatically initiate reacquisition using pre-drop-lock data to aid in the reacquisition. Reacquisition will be based on the assumption that the time difference between the actual user frequency dynamics and the predicted dynamics remains unchanged from the pre-drop-lock difference. If the user spacecraft continues to transmit the minimum P_{rec} for acquisition, reacquisition time typically will not exceed one-half of the initial acquisition times given in Table 3-15.

(b) Reacquisition will continue for up to 10 seconds until lock is achieved or until a reacquisition OPM is received at WSC. If lock is not achieved within 10 seconds of loss of lock, an acquisition failure OPM will be sent to the NCC and WSC will reinitiate the initial service acquisition process.

(2) Expanded User Spacecraft Frequency Uncertainty. If the user POCC/MOC is unable to accurately predict the user spacecraft transmit frequency within $\pm$700 Hz

for DG1 mode 2 or for DG2 (noncoherent operations), the WSC can reconfigure to accommodate a ±3 kHz user spacecraft transmit frequency uncertainty during the TDRSS SSA return service acquisition/reacquisition process.

Note

This is in addition to the WSC being able to accommodate the frequency uncertainty caused by the ±9 second user spacecraft ephemeris uncertainty.

(3) Data Rate. Change in the I and/or Q channel data rate.

(4) Frequency. Change in the user spacecraft transmit center frequency (noncoherent operations only).

(5) Received Power. Redefinition of maximum and minimum P_{rec} (delineated as user spacecraft EIRP in the SHO [refer to Appendix A]; difference must not exceed 12 dB) during the scheduled TDRSS SSA return service support period.

(6) Power Ratio. Change in the I/Q (power).

(7) Data Format. Change in the I and/or Q channel data format.

(8) Data Bit Jitter. Change in the I and/or Q channel data bit jitter.

(9) DG1 Mode. Change in DG1 mode (1, 2, or 3).

(10) User Antenna. Initiation, termination, or type change of user spacecraft despun antenna (included as an OPM only to provide information to the WSC) (refer to paragraph 3.3.3.7).

(11) Polarization. Change in user spacecraft transmitting antenna polarization.

(12) Data Group. Change between DG1 and DG2. When changing from Data Group 1 to Data Group 2, the user must also specify the type of DG2 service (non-coherent or coherent) even if the type of DG2 service was specified as desired in the original schedule request. Similarly, when changing from Data Group 2 to Data Group 1, the user must also specify the DG1 mode. If the mode or coherency type is not specified in the reconfiguration request to change Data Group, WSC will reject the reconfiguration.

(13) DG2 Mode. Change in DG2 mode of operation (coherent and noncoherent).

(14) Interleaving. Initiation or termination of symbol interleaving.

(15) DG2 Single Data Channel Modulation. Change in DG2 single data channel modulation (SQPSK or BPSK).

(16) Data Channel Configuration. Change in data source (single or dual).

Note

These changes to the TDRSS SSA return service during a scheduled TDRSS SSA return service support period may cause the WSC to interrupt return service for that user spacecraft, requiring reacquisition by the WSC of the user spacecraft signal. Item (10) is for WSC information only. If this change is the only change being made at this time to the user spacecraft configuration, it is advisable for the user POCC/MOC to formulate its procedures to preclude generation of a reconfiguration GCMR to the NCC.

b. Coherent/Noncoherent Operation

(1) Doppler Correction. The WSC corrects the received user spacecraft signal for Doppler to allow for WSC implementation of receivers with narrow acquisition and tracking bandwidths. The Doppler correction used by WSC is either one-way or two-way, depending on the user spacecraft mode of operation (noncoherent or coherent) and on whether WSC Doppler compensation of the related TDRSS (SSA or MA) forward service signal (coherent operations only) is inhibited. For noncoherent operation, the Doppler correction is based on the user spacecraft transmission frequency stated in the SHO and any subsequent OPMs. Noncoherent operation requires one-way WSC Doppler correction. For coherent operation, the Doppler correction is based upon the forward service frequency. Coherent operation with WSC forward service Doppler compensation also requires one-way WSC Doppler correction. Coherent operation with WSC forward service Doppler compensation inhibited (fixed TDRS forward service transmit frequency) requires two-way WSC Doppler correction.

(2) Coherent to Noncoherent Transitions Due to Loss of Forward Signal. User spacecraft transponders which switch, when the TDRSS SSA/MA forward service signal is lost, from a coherent transponder mode (transmit frequency derived from the received carrier tracking VCXO) to a noncoherent mode will cause the WSC to drop TDRSS SSA return service signal lock. For DG2, during periods of WSC forward service Doppler compensation, the frequency offset of the TCXO causes the WSC to drop TDRSS SSA return service signal lock when the switch is made. During periods of WSC forward service Doppler compensation inhibit, a switch by the user spacecraft from the VCXO to the TCXO will provide an additional frequency offset due to lack of appropriate WSC Doppler correction. For DG1, the switch to the noncoherent mode (DG1 mode 2) also changes other user spacecraft return service signal parameters (e.g., PN codes). Reconfiguration and reacquisition by the WSC is required via an appropriate GCM from the NCC to the WSC (initiated by a GCMR from the user POCC/MOC).

(3) Maintaining Coherency. For a user spacecraft with a special design transponder, alternatives are available to the user POCC/MOC to minimize loss of return service

data due to user spacecraft short term tracking loss of the TDRSS (SSA or MA) forward service signal. To bridge these short term forward service signal dropouts when using coherent operation, the user spacecraft could remain in the coherent mode if it incorporates a frequency memory technique to ensure that the SSA return service carrier frequency remains related to the TDRSS (SSA or MA) forward service signal frequency as it was prior to loss of (SSA or MA) forward service signal lock. For DG2 operation, the user spacecraft design could consider only noncoherent operation by using a highly accurate and stable user spacecraft frequency source. Two-way Doppler tracking service then would not be available.

c. Service Acquisition Time. The total TDRSS SSA return service signal acquisition time is the 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)

The acquisition and synchronization times are given in Table 3-15. 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), and the correct polarity of the input symbols. Requirements for bit error probability and symbol slipping take effect at the time decoder synchronization is achieved.

Note

Data and symbol transition densities and P_{rec} values higher than the minimums required will reduce these acquisition times.

d. Time Delay Measurement. WSC can determine the value of the WSC time delay for each TDRSS SSA return service channel prior to and following each scheduled support period and at reconfigurations during the support period. The reported value is the time delay from the WSC antenna input to the WSC output for each channel to an accuracy of $\pm$25 percent of a data bit period for data rates <250 kbps or $\pm$1 μsec for data rates $\geq$250 kbps. The time delay measurement may be requested in the SHO and will be available to the user POCC/MOC from the NCC after termination of the scheduled service.

3.3.3.6 Acquisition Scenarios. The following acquisition scenarios identify only the technical aspects of TDRSS SSA return service signal acquisition by the WSC and do not include operational procedures related to acquisition (refer also to Appendix C):

a. DG1 Modes 1 or 3

(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 P_{rec} for each user spacecraft channel must be compatible with the user spacecraft channel data rate and the other TDRSS SSA return service signal parameters listed in Table 3-14.

(3) The WSC will open-loop point the TDRS SSA receive antenna in the direction of the user spacecraft.

(4) At the service start time specified by the SHO, the WSC will begin the search for the user spacecraft signal based upon predicted range and Doppler.

(5) After the forward service has been acquired, the WSC will acquire the user spacecraft signal (PN code and carrier) within the time limits listed in Table 3-15 and, upon WSC symbol, deinterleaver (if applicable), and Viterbi decoder synchronization, establish DG1 mode 1 or 3 return service at the WSC/receiver output.

(6) The TDRSS SSA forward and return services are available simultaneously. These services should be requested by the user POCC/MOC to be scheduled simultaneously to negate the need for using DG1 mode 2. The user spacecraft should maintain DG1 mode 1 or 3 operations, thereby eliminating return service data interruptions which occur when changing from DG1 mode 1 or 3 to DG1 mode 2 and vice versa.

b. DG1 Mode 2

(1) This mode of user spacecraft operation does not require a TDRSS (MA or SSA) forward service signal to be received by the user spacecraft. However, the user spacecraft transmitter must be commanded to turn on when DG1 mode 2 transmissions are desired, either by stored commands, on-board configuration settings, or direct commands from its user POCC/MOC.

(2) The P_{rec} for each user spacecraft channel must be compatible with the user spacecraft channel data rate and the other TDRSS SSA return service signal parameters listed in Table 3-14.

(3) The WSC will open-loop point the TDRSS SSA receive antenna in the direction of the user spacecraft.

(4) The WSC will acquire the user spacecraft signal (PN code and carrier) within the time limits listed in Table 3-15 and, upon WSC symbol and Viterbi decoder synchronization, establish DG1 mode 2 return service at the WSC/ receiver output.

c. DG1 Mode Transitions. User POCC/MOCs which plan to operate their user spacecraft in both DG1 modes 2 and 1 (or 3) during a single service support period are advised that

TDRSS SSA return service mode transitions via reconfiguration OPMs must take into account the requirement of scheduling a corresponding TDRSS (MA or SSA) forward service for this service support period. The following conventions apply:

(1) DG1 Mode 2 to DG1 Mode 1 (or 3) Transitions. The TDRSS (MA or SSA) forward service on the user spacecraft must be scheduled to be established prior to user POCC/MOC transmission of the GCMR to the NCC requesting that the NCC reconfigure the TDRSS for DG1 mode 1 (or 3) operations (refer to paragraph 3.3.3.6.a.(1)).

(2) DG1 Mode 1 (or 3) to DG1 Mode 2 Transitions. Refer to paragraph 3.3.3.5.b.(2) for a discussion on DG1 Mode 1 (or 3) to DG1 Mode 2 transitions.

Note

Failure to observe these conventions may result in WSC rejection of reconfiguration OPMs from the NCC, excessive times for the WSC to reacquire the user spacecraft signal after the WSC reconfiguration, and unnecessary loss of user spacecraft return service data.

d. DG2. When the user spacecraft is in a coherent turnaround configuration, the WSC return service signal acquisition will be identical to DG1 mode 1 (refer to paragraph a) except that DG2 signal parameters, T_{acq} capabilities, and acquisition restrictions apply. When the user spacecraft is in a noncoherent configuration, the WSC return service signal acquisition will be identical to DG1 mode 2 (refer to paragraph b) except that DG2 signal parameters, T_{acq} capabilities, and acquisition restrictions apply.

Note

The WSC return service demodulators check on a 1 second cycle whether or not user spacecraft SSA return service signal carrier lock has been lost. When carrier lock is first lost, WSC symbol synchronization and WSC Viterbi decoder lock will also be lost almost concurrently. These loss-of-lock indications appear in the periodically updated (every 5 seconds) ODM for that user spacecraft SSA return service support period. Upon receipt of the loss-of-lock indications in the ODM, the user POCC/MOC may request the NCC to send a TDRSS SSA return service reacquisition OPM to the WSC (refer to paragraph 4.3). It is recommended that the user POCC/MOC delay initiation of the GCMR to the NCC for at least 35 seconds after initial receipt of the loss-of-lock indications in the ODM. An Acquisition Failure Notification OPM is sent from WSC to NCC if the automatic reacquisition process fails to reacquire the user signal within 10 seconds of loss-of-lock.

3.3.3.7 TDRSS SSA Return Service Constraints/Restrictions

a. General. The TDRSS SSA return services and tracking services will be provided without degradation for user spacecraft transmitted signal characteristics within the constraints specified in paragraphs b through e and Table 3-16. Refer to paragraph 1.8 for guidelines if the constraints in this paragraph cannot be met. Definitions of user spacecraft constraints are given in Appendix E.

b. Performance Degradation of TDRSS SSA Return Service for a User Spacecraft with Antenna-induced Modulation. User spacecraft antenna-induced AM and PM (either from electronic switching or mechanical step motion) on its transmitted signal can result in degraded TDRSS SSA return service performance if the AM exceeds 3 dB and/or the PM is greater than 10 degrees.

c. DG1 and DG2.

(1) The individual user spacecraft channel data rates must each be defined by the user POCC/MOC to the NCC to within $\pm$0.1 percent.

(2) The Q/I (power) must be defined by the user POCC/MOC to the NCC to within $\pm$0.4 dB.

d. DG2 Only.For unbalanced QPSK, the I channel must contain the higher data rate. 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.

e. Symbols Transition Restrictions (All Data Groups). Within any sequence of 512 symbols, the number of transitions in each user spacecraft channel symbol stream must be $\geq$128 and the maximum number of consecutive symbols without a transition must be $\leq$64.

3.3.4 SSA TRACKING SERVICES

3.3.4.1 General. The TDRSS will provide user spacecraft one-way Doppler measurements and two-way range and Doppler measurements. The user spacecraft one-way Doppler measurements will be available on return service channels for all DG1 mode 2 and DG2 (noncoherent) operations. The user spacecraft two-way Doppler and time transfer measurements will be available for DG1 modes 1 and 3 and DG2 (coherent) operations. The user spacecraft two-way range measurements will be available for DG1 mode 1 or 3 operations (i.e. PN spread modes).

Table 3-16. TDRSS SSA Return Service User Spacecraft Signal Constraints (Note 4)

Parameter	Description
Symbol transition density (average)	$\geq$25 percent
Consecutive symbols without a symbol transition	$\leq$64 symbols
Symbol asymmetry (peak)	$\leq \pm$3 percent
Symbol rise time (90 percent of initial state to 90 percent of final state)	$\leq$5 percent of symbol duration
Symbol jitter and jitter rate (note 1)	$\leq$ 0.1 percent
BPSK phase imbalance	$\leq \pm$3 degrees
QPSK phase imbalance	$\leq \pm$3 degrees
Gain Imbalance	$\leq \pm$0.25 dB
Phase nonlinearity (applies for all types of phase non-linearities) (peak)	$\leq$3 degrees over $\pm$3.5 MHz
Gain flatness (peak)	$\leq$0.3 dB over $\pm$3.5 MHz
Gain slope (peak)	$\leq$0.1 dB/MHz over $\pm$3.5 MHz
AM/PM	$\leq$12 degrees/dB
Frequency stability (peak)	
1-sec average time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 1 \times 10^{-7}$
48-hr observation time	$\leq 3 \times 10^{-7}$
Incidental AM (peak) At frequencies >10 Hz for data rates <1 kbps; at frequencies >100 Hz for data rates >1 kbps	$\leq$5 percent

Table 3-16. TDRSS SSA Return Service User Spacecraft Signal Constraints (Note 4) (cont)

Parameter	Description
Untracked spurious PM (rms)	
DG1	≤2 degrees
DG2 BPSK	≤2 degrees
DG2 I/Q = 4:1	≤2 degrees
DG2 I/Q = 1:1	≤1 degree
Minimum 3-dB bandwidth prior to power amplifier (note 2)	DG1: ≥4.5 MHz or two times maximum symbol rate, whichever is larger DG2: ≥2 times maximum channel symbol rate
Untracked phase noise (rms) (coherent and noncoherent)	
DG1	
Data rate ≤3 kbps	≤2 degrees
Data rate ≥3 kbps	≤3 degrees
DG2 BPSK	
Data rate ≤3 kbps	≤2 degrees
Data rate ≥3 kbps	≤3 degrees
DG2	
I/Q = 1:1	≤1 degree
I/Q = 4:1	≤1 degree
I/Q symbol skew (relative to requirements for I/Q data synchronization where appropriate) (peak)	≤3 percent
I/Q PN code chip skew (relative to 0.5 chip)	≤0.01 chip
PN code chip rate (peak), DG1 mode 2 (relative to absolute coherence with carrier rate)	≤0.01 chips/sec at PN code chip rate
PN code power suppression (noncoherent and coherent)	≤0.3 dB

Table 3-16. TDRSS SSA Return Service User Spacecraft Signal Constraints (cont)

Parameter	Description
Permissible P_{rec} variation (without reconfiguration GCMR from user POCC/MOC) (note 3)	$\leq$12 dB
Permissible rate of P_{rec} variation	$\leq$10 dB/sec
Maximum P_{rec}	-149.7 dBW -157.7 dBW (SSA cross-support: DG1 mode 3)

Note

1. The symbol jitter and jitter rate are defined as the user transmitted signal peak clock frequency jitter and peak clock jitter rate (sinusoidal or 3σ random) as the percentage of symbol clock rate.

2. For the purpose of minimum bandwidth definition, the symbol rate for the Bi∅-formatted data will be twice the symbol rate prior to NRZ-to-Bi∅ data format conversion of the convolutional encoder output.

3. The P_{rec} at the low end of the variation range must be $\geq P_{rec}$, minimum (refer to Table 3-15). The allowable variation range of 12 dB is based upon the SHO minimum EIRP value varying from -3 dB to +9 dB relative to the actual user EIRP. An EIRP value less than the -3 dB variation results in a longer acquisition time, while an EIRP exceeding the +9 dB variation may cause false PN lock or nonacquisition.

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.

3.3.4.2 Range Tracking

a. General. The TDRSS tracking service will be capable of providing accurate and independent (sample-to-sample) range data as indicated in paragraphs b through f with user spacecraft signal Doppler frequencies to ±230 kHz and Doppler rates to ±1.5 kHz/sec.

b. Range Measurement rms Error. The rms error contribution to range measurement resulting from the TDRSS will not exceed the values listed in Table 3-17 for P_{rec} values consistent with the ADRs listed in Table 3-15.

c. Range Measurement Systematic Error. The systematic range error contribution from a TDRS will be less than ±35 nsec based on prelaunch measurement and predicted on-orbit performance. The systematic range error contribution from the WSC will be less than ±30 nsec.

d. Range Granularity. The range granularity, which is the smallest discrete output of the WSC receiver, is 1 nsec.

e. Range Ambiguity Interval. The minimum unambiguous range measurement is equal to the period (nominally 85 msec) of the TDRSS forward service range channel PN code.

f. TDRSS Delay Compensation. The WSC will compensate the range measurement for the delays internal to the TDRSS (WSC and TDRS).

Table 3-17. TDRSS SSA Tracking Service Range Measurement rms Error

ADR	Maximum rms Range Error (seconds x 10^{-9})
<1000 bps	20
≥1000 bps	10
Note All data rate values (and notes which modify these values, based upon specific signal formal and encoding restrictions) are to be interpreted as data bit rates, and not as data symbol rates.	

3.3.4.3 Doppler Tracking

a. General. The TDRSS tracking service will be capable of providing Doppler information with the accuracy and characteristics specified in paragraphs b through d for user spacecraft signal Doppler frequencies to ±230 kHz and rates to ±1.5 kHz/sec. The Doppler signal is biased and processed so that a signal of 240.0 MHz + $1000 \cdot f_d$ is obtained, where f_d is the Doppler. The Doppler count at the WSC is nondestruct with a WSC capability of maintaining a continuous count for a minimum of 50 minutes. 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.

Note

The definition of 240.0 MHz is 240.0000 MHz, where the magnitude of the fraction portion is the accuracy of the WSC frequency standard.

b. 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 3-18 for P_{rec} values consistent with the ADRs listed in Table 3-15.

Table 3-18. TDRSS SSA Tracking Service Doppler Measurement rms Phase Noise

ADR (bps) (note 1)	Maximum rms Range Error Phase Noise (radians) (note 2)
≤500	0.4
>500	0.3
≤1000	0.3
>1000	0.2

Note

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 sec measurement time reference.

c. Reference Frequency

(1) For two-way Doppler measurements, WSC forward service Doppler compensation is inhibited, and the reference frequency for the WSC Receiver is related to the forward service transmit frequency consistent with the appropriate frequency turnaround ratio, assuming no relative motion between the TDRS and the WSC. Such inhibition is accomplished by the WSC only when a Doppler compensation inhibit request is received via an OPM from the NCC, or if Doppler inhibition is scheduled by the SHO. During this Doppler compensation inhibit mode, the TDRS forward service transmit frequency is held constant so that, at the WSC, the reference frequency for the two-way Doppler measurement is an integral multiple of 240 Hz. Since the reference frequency is the user spacecraft transmit frequency, which is coherently related to the received TDRS forward service frequency by the coherent turnaround ratio (240/221), this is accomplished by fixing the TDRS forward service transmit frequency at an integral multiple of 221. The reference frequency is therefore given by:

$$f_{ref} = f_T\,(240/221)$$

where f_T is the TDRS forward service transmit frequency after WSC Doppler compensation has been accomplished.

(2) For one-way Doppler measurements, the reference frequency for the Doppler extractor will be the user spacecraft transmit frequency as defined in the SHO, to the accuracy of the WSC frequency standard.

d. Doppler Granularity. A Doppler granularity of 1×10^{-3} cycle is provided.

3.3.4.4 Time Transfer Measurement

a. General. The TDRSS two-way tracking service will be capable of providing time transfer data as indicated in paragraphs b through e with user spacecraft signal Doppler frequencies to ±230 kHz and Doppler rates to ±1.5 kHz/sec. The WSC will measure the elapsed time between a reference time epoch and the next outgoing forward link range channel PN epoch. The WSC will measure the elapsed time between that reference time epoch and the first return link PN epoch to arrive after the outgoing forward link PN epoch.

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 WSC.

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 will compensate the time transfer measurement for delays internal to the TDRSS (WSC and TDRS).

3.3.4.5 Measurement Timing

a. General. The WSC frequency reference stability is consistent with TDRSS tracking and telecommunication performance capabilities.

b. Timing Accuracy. The WSC epoch times for range, Doppler, and time transfer measurements will be within ±5 μsec of UTC. The WSC epoch times will be traceable to within ±100 nsec of UTC time.

c. Data Sampling. Range and Doppler measurement data are sampled on-time to within ±1 μsec and ±25 nsec, respectively. "On-time" refers to that portion (leading or trailing edge) of the timing signal which is synchronized with UTC at the output of the WSC timing system and is used for sampling the measurement data.

d. Sample Intervals. Sample intervals are available for the range and Doppler measurement data. Data can be sampled at selectable intervals, in sec/sample, of 1, 5, 10, 60, and 300. Intervals between time transfer measurements are 1 second.

3.3.4.6 Operation of Doppler Compensation Inhibit

a. Peak Frequency Dynamics. WSC Doppler compensation inhibit must be initiated by a GCMR from the user POCC/MOC to the NCC prior to all periods of TDRSS two-way range and Doppler measurements. When the Doppler compensation inhibit mode is selected after operating in the Doppler compensation mode, the user spacecraft receiver will see the forward service frequency dynamics. Peak frequency dynamics are due to the relative TDRS-user spacecraft velocities up to 15 km/sec and 12 km/sec, accelerations up to 50 m/sec^2 and 15 m/sec^2, and jerks up to 2.0 m/sec^3 and 0.02 m/sec^3, respectively for a non-shuttle powered-flight and a free flight user. These dynamics as seen by the user spacecraft receiver are frequency offsets up to 113 and 90 kHz, frequency rates up to 375 and 113 Hz/sec, and frequency accelerations up to 15 and 0.15 Hz/sec^2 for the non-shuttle powered-flight and a free flight user, respectively. Note that Doppler compensation is not required for velocities of 12 km/sec or above. The user project must ensure that the user spacecraft receiver signal tracking characteristic is compatible with the peak frequency dynamics experienced or that the Doppler compensation inhibit mode will be selected only over portions of the user spacecraft orbit where the frequency dynamics are low. Failure to do so can result in forward service, return service, and tracking service outages if the user spacecraft receiver PN code and/or carrier loops unlock.

b. Transition Process. A slow and hold process is used by the WSC to establish Doppler compensation inhibit and to reinitiate Doppler compensation. Doppler compensation inhibit will be initiated within 10 seconds of receipt of the appropriate OPM by the WSC and completed within 10 seconds after initiation. Upon reinitiation of Doppler compensation by the WSC, the TDRSS forward service carrier frequency will change slowly to the corrected Doppler compensated value.

3.4 KSA SERVICES

3.4.1 GENERAL

3.4.1.1 Available Services. TDRSS KSA services include forward and return telecommunications services, and tracking services. These services are described in terms of the data interfaces between a user POCC/MOC and the NASCOM data transport system and the RF interface between its user spacecraft and a TDRS. These interfaces are characterized by the technical requirements imposed and the operational capabilities provided by the TDRSS. This section describes the RF interfaces between the user spacecraft and TDRS; the data interfaces between the user POCC/MOC and the NASCOM data transport system are described in section 5.

3.4.1.2 Interface Definition. The RF interface between the TDRS and a user spacecraft is defined in terms of signal parameters, RF characteristics, and field of view. The user POCC/MOC/NASCOM data transport system data interface is defined in terms of the number and characteristics of data channels. Forward service represents a user POCC/MOC data interface with the NASCOM data transport system and 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 user spacecraft. Return service defines an ADR at the WSC receiver

output as a function of P_{rec} and a NASCOM data transport system data interface with the user POCC/MOC in terms of the number and distribution of data channels. The frequency allocations for all RF links between the TDRSs and the user spacecraft are defined in paragraphs 3.4.2 and 3.4.3.

3.4.1.3 User Acquisition Requirements. Acquisition and reacquisition by the WSC/user spacecraft of the user spacecraft/TDRS transmitted signal requires prediction by the user POCC/MOC of the user spacecraft transponder/transmitter local oscillator frequency over various projected time periods. The frequency predictions are ultimately incorporated in the NCC SHO to the WSC as a user spacecraft transmitted/received frequency for the specific service support periods. The following discussion applies to user spacecraft transponder designs for which the received center frequency for forward service signal acquisition, and the noncoherent transmitter frequency for return service operations, are derived from a TCXO. Of major concern to the user POCC/MOC is its ability to predict both the user spacecraft TCXO frequency and the thermal profile of the TCXO as a function of the operational scenario and sun position relative to the user spacecraft. The FDF can provide the user POCC/MOC with a history of the TCXO frequency based on TDRSS tracking service one-way Doppler data at intervals to be agreed to by the FDF and the user POCC/MOC. The user POCC/MOC must therefore plan its missions and request the required TDRSS services from the NCC for the WSC to obtain the tracking data for the FDF. Prior to launch, the user POCC/MOC should also obtain TCXO frequency versus temperature data, including profiles for various operational scenarios as a function of time; i.e., based on thermal vacuum chamber tests and integration tests with the STS when applicable. The user POCC/MOC should then model the predicted TCXO frequency shifts for various operational scenarios and time periods and use them to implement its selected frequency acquisition strategies. These strategies are a function of user spacecraft TCXO frequency uncertainty, vehicle dynamics, and coherent or noncoherent operation. For example, the user POCC/MOC can request, via the NCC, that the TDRSS sweep the forward service frequency or use an expanded frequency uncertainty limit on the return service. In addition, the user POCC/MOC, if feasible, can plan the particular service support period of interest such that at service support period start time, the user spacecraft is in a part of its orbit where the Doppler dynamics are minimal, and the user spacecraft transponder has been previously commanded to remain in the noncoherent mode even upon receipt of a TDRSS forward service signal.

3.4.1.4 TDRSS Acquisition Support to Users. For each scheduled TDRSS service support period, the user requirements for signal acquisition/reacquisition, and the TDRSS capabilities to aid acquisition/reacquisition, are as follows:

a. Epoch Uncertainty for Autotrack. The maximum epoch time uncertainty of the applicable user spacecraft ephemeris supplied to the TDRSS shall be $\pm$4.5 seconds for user spacecraft operations requiring the TDRSS KSA return service autotrack process. Use of the autotrack inhibit mode is only for spacecraft operational considerations approved by the SN during the approval cycle of the user spacecraft/SN RF ICD. When the autotrack process has been inhibited, the TDRSS KSA return service and forward service performance characteristics stated in this Users' Guide may not be fully realized.

Note

The WSC software will round-off the user receive frequency contained in the SHO to the nearest multiple of 1469 Hz for KSA forward service. This quantization, under worst case conditions, may increase the predicted user receive frequency uncertainty up to 734 Hz.

b. User Frequency Uncertainty. The user POCC/MOC must know the operating frequency of the user spacecraft TCXO to within ±5 kHz. For the FDF to be able to provide a user POCC/MOC with a history of its user spacecraft TCXO frequency based upon TDRSS tracking service one-way Doppler data, the user POCC/MOC must plan to schedule enough TDRSS tracking service support periods involving one-way Doppler measurements.

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

d. Frequency Sweep on Return Link. The TDRSS has a return service expanded frequency search capability of ±20 kHz.

3.4.2 KSA FORWARD SERVICES

3.4.2.1 General. The characteristics of the data provided by the user POCC/MOC to the NASCOM data transport system and the RF signals provided by the TDRS to the user spacecraft during TDRSS KSA forward services are described in paragraphs 3.4.2.2 through 3.4.2.6 (refer to section 5 for additional details of the user POCC/MOC/NASCOM data transport system interface).

3.4.2.2 Signal Parameters. The TDRSS KSA forward service signal parameters are defined in Table 3-19. The center frequency, f_O, of the user spacecraft receiver must be defined by the user POCC/MOC in its request to the NCC for TDRSS KSA forward service. The features inherent in the signal parameters listed in Table 3-19 are as follows:

a. Spread Spectrum. All TDRSS KSA forward services with data rates ≤300 kbps incorporate spread spectrum modulation techniques to satisfy flux density restrictions imposed upon TDRSS forward services by the NTIA.

b. Doppler Compensation. The TDRSS KSA forward service carrier frequency (F) transmitted by a TDRS will be compensated by the WSC for Doppler so that the carrier, F_R, arrives at the user spacecraft receiving system within a predictable tolerance (E) of f_O as defined in Table 3-19. This feature minimizes the Doppler resolution requirements of the user spacecraft receiver and is available continuously to facilitate reacquisition by the user spacecraft in the event of loss of lock of the TDRSS KSA forward service signal. Doppler compensation will be inhibited by WSC during tracking service periods requiring coherent two-way Doppler measurement (refer to paragraph 3.4.4.3) and may otherwise be

inhibited by the WSC at the user POCC/MOCs request to the NCC; i.e., if the user spacecraft has an onboard navigation capability and/or a wideband receiver.

c. Coherent Relationships Between the PN Code Clock and the Carrier Frequency. The PN code chip rate is coherently related to F in all cases. This feature permits the user spacecraft receiver to use the receiver PN code clock to predict the received carrier frequency, thereby minimizing receiver complexity and reducing acquisition time.

d. Simultaneous Command and Range Channels. The TDRSS KSA forward service signal includes separate but simultaneous command and range channels for data rates 300 kbps or less. This feature provides a solution to the conflicting requirements for range ambiguity resolution, minimum T_{acq}, and multipath protection (refer to paragraph f). 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.

e. Unbalanced QPSK Modulation. The command channel/range channel (power) for all TDRSS KSA forward service signals is +10 dB. This unbalanced QPSK modulation minimizes the power in the range channel to a level adequate for user spacecraft 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 user spacecraft receiver complexity, increasing user spacecraft command channel acquisition time, or decreasing TDRSS range tracking accuracy.

f. Time Synchronization of Command and Range Channel PN Codes. Prior to transmission from the WSC, the epoch (the all-1's condition) of the range channel PN code is time synchronized to one of the periodic epochs of command channel PN code generator (refer to paragraph 3.4.2.3a). Because user spacecraft command channel acquisition must precede user spacecraft range channel acquisition, this feature limits the range channel PN code search to only 256 chip positions while the range channel PN code itself contains 261,888 chips. This feature also permits rapid detection of time spread on the received range channel signal identifying acquisition of a diffuse multipath signal. By the user spacecraft transferring the PN code tracking loop to the range channel after range channel acquisition, subsequent multipath interference can be prevented.

g. Short-cycled Linear Shift Register PN Code Sequence for Range Channel. The use of a short-cycled PN code for the range channel allows optimization of the command channel PN code. This feature permits use of Gold codes for the command channel to allow generation of a code library with good cross-correlation properties. The TDRSS PN code library (refer to paragraph 3.4.2.3a) is sufficiently large to allow a unique code assignment for each user spacecraft.

Table 3-19. TDRSS KSA Forward Service Signal Parameters

Parameter	Description
TDRS transmit carrier frequency (Hz)	F
Carrier frequency arriving at user spacecraft (note 1)	F_R
$\frac{\text{Command channel radiated power}}{\text{Range channel radiated power}}$	+10 dB
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 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)	NRZ
Data rate restrictions (notes 3, 4)	1 kbps - 25 Mbps
Range Channel (note 5)	
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

Table 3-19. TDRSS KSA Forward Service Signal Parameters (cont)

Parameter	Description
PN code family	Truncated 18-stage shift register sequences

Notes

1. 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 user spacecraft receiver as defined by the user POCC/MOC and $E = (500 \times \ddot{R}) + C$ for $\ddot{R} \leq 15$ m/sec^2 and $C \leq 734$ Hz (see paragraph 3.4.1.4.a).

   Forward service Doppler compensation will not increase the peak phase error of a receiver (with a second order Costas loop, B_L = 110 Hz, at a C/N_o = 41 dB-Hz in the command channel) more than 3 degrees relative to the phase error for a Doppler free carrier.

2. The SN and the TDRSS are transparent to the data format of the forward service data. The particular data format (NRZ-L, NRZ-M, NRZ-S) to be used will be established in the user POCC/MOC.

3. For user spacecraft data rates exceeding 300 kbps, PN code modulation will not be used, and the command channel data will directly PSK modulate the transmitted carrier $\pm\pi/2$ radians (BPSK). No range data is possible if BPSK is used.

4. For data rates of 300 kbps or less, the user POCC/MOC can change the data rate within the constraints of paragraph 3.4.2.4d. For data rates above 300 kbps, the user POCC/MOC, via the NCC must notify the WSC of the data rate in the SHO and of any data rate changes in a reconfiguration OPM.

5. For data rates >300 kbps, the range channel is not transmitted.

h. Asynchronous Data Modulation. For data rates $\leq$300 kbps, the forward service data received at the WSC from the NASCOM data transport system is directly modulo-2 added by the WSC to the command channel PN code sequence. For data rates >300 kbps, there is no PN code modulation and data directly BPSK modulates the carrier by $\pm \pi/2$ radians. Because the PN code clock and the carrier are Doppler compensated by the WSC, the forward service data will be asynchronous with the carrier and the PN code. The forward service data is not processed in any other manner by the WSC.

3.4.2.3 Communications Services. The TDRSS KSA forward services available are listed in Table 3-20. Table 3-21 lists their salient characteristics. The definitions for the parameters listed in Table 3-21 are contained in Appendix E. The features inherent in the TDRSS KSA forward services listed in Table 3-20 are as follows:

a. PN Code Assignment. The forward service data with rates $\leq$ 300 kbps ultimately received by the user spacecraft from its user POCC/MOC via the supporting elements of

the SN will have been asynchronously modulo-2 added to the TDRSS KSA forward service command channel PN code by the WSC. A user spacecraft-unique PN code assignment for the range and command channels will be made by the Frequency Manager of the MO&DSD from the library of PN codes defined in STDN No. 108.

b. Acquisition Scenarios. The following information is general in nature, and is offered in that context. If the user POCC/MOC is unable to accurately define the user spacecraft receiver center frequency f_o to within $\pm$5 kHz, the NCC can request the WSC to frequency sweep the TDRSS forward service signal (refer to paragraph 3.4.2.5e) to aid the user spacecraft receiver acquisition process. This real-time NCC action can either be at the user POCC/MOC's real-time request (via a GCMR) or based upon NCC operational procedures relative to that user spacecraft mission. The forward service signal sweep is initiated 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 forward service signal sweep is independent of simultaneously scheduled Doppler compensation.

c. Acquisition Time Determination. The user spacecraft forward service acquisition time must be considered in determining the overall return service acquisition time for user spacecraft with a coherent mode of operation (refer to paragraph 3.4.3.5c).

d. Link Margins. Example link calculations are provided in Appendix A.

e. Autotrack Scenarios. The TDRSS KSA forward service is defined in Table 3-20. Because of the narrow beamwidth of the TDRS SA antenna supporting the TDRSS KSA forward and return services, when the TDRSS KSA return service autotrack process is enabled, the TDRS normal or high-power KSA forward service EIRP (as appropriate) in the direction of the user spacecraft may not be realized until the TDRSS KSA return service begins autotracking the user spacecraft transmitted KSA return service signal. If the KSA return service autotrack process is inhibited, refer to paragraph 3.4.1.4a. In either case, link acquisition is accomplished through the acquisition scenarios defined in paragraph 3.4.3.6. If the TDRSS KSA return service autotrack process is enabled, transmission by the user spacecraft of a KSA return service signal is required for the WSC to initiate and maintain either normal or high power TDRSS KSA forward service to the user spacecraft.

f. Forward Service Restrictions. The TDRSS KSA forward service will not be provided when the center of the sun is within 1 degree of the TDRS KSA antenna boresight (refer to paragraph 3.4.3.3[d]6).

g. Functional Characteristics. The functional characteristics of TDRSS KSA forward services are shown in Appendix B, paragraph B.2.

h. Phase Ambiguity. The forward service data phase ambiguity resolution required in the user spacecraft is discussed in Appendix B, paragraph B.2.2.

Table 3-20. TDRSS KSA Forward Service

Parameter	Description
Field of view (each TDRS)	±22 degrees east-west ±28 degrees north-south
TDRS antenna polarization (note 1)	RHC or LHC selectable
TDRS antenna axial ratio (maximum)	
Normal or high-power mode	1 dB over 3-dB beamwidth
Acquisition mode	(note 2)
TDRS signal EIRP (minimum)	
Normal power mode	+46.5 dBW (note 5)
High power mode (note 3)	+48.5 dBW (note 5)
Acquisition mode (note 3)	+40 dBW (note 2)
Transmit frequency (nominal) (note 4)	13.775 GHz ±0.7 MHz
RF bandwidth (3dB, minimum)	50 MHz
Duty factor	100 percent (normal and high power)

Note

1. Operational considerations may limit choice of TDRS antenna polarization.

2. The acquisition mode EIRP includes the maximum polarization loss resulting from a user spacecraft receiving antenna axial ratio of 6 dB and the TDRS KSA transmitting antenna axial ratio at the edge of the acquisition beamwidth.

3. The TDRS acquisition mode signal EIRP will be provided at the start of the TDRSS KSA forward service and is independent of K-band signal transmission by the user spacecraft. Within 10 seconds of KSA return service P_{rec} consistent with the ADR or -182.8 dBW, whichever is larger, the appropriate TDRS KSA normal-power or high-power mode signal EIRP will be provided as scheduled.

Table 3-20. TDRSS KSA Forward Service (cont)

Note (cont)
4. The user POCC/MOC must include the best estimate of the user spacecraft receiver center frequency at the time of startup of each scheduled service support period in its service request to the NCC, which then includes this parameter value in the SHO. The TDRSS KSA forward service carrier frequency is then implemented by WSC to the accuracy of the WSC frequency standard except during Doppler compensation. Following Doppler compensation, the TDRSS KSA forward service carrier frequency will meet the frequency requirements of paragraph 3.4.4.3c. The user POCC/MOC must predict the frequency of the user spacecraft local oscillator using frequency drift history provided by the FDF and accounting for the thermal profiles described in paragraphs 3.4.1.3 and 3.4.1.4.
5. EIRP values are for a TDRSS forward service with a TDRSS return autotrack service.

3.4.2.4 Data Interfaces. The TDRSS KSA forward service data interfaces with the user POCC/MOC are as follows:

a. Data Rate Definitions. The user POCC/MOC/NASCOM data transport system data channel interface and user spacecraft data rate are initially defined in the user POCC/MOC service schedule request to the NCC and the resulting SHO to the WSC.

b. NASCOM Data Format. The user POCC/MOC transmits forward service data to the NASCOM data transport system that is either serial bit-contiguous or in 4800-bit blocks at the user POCC/MOC's option (refer to paragraph5.2.4.3b). The NASCOM data transport system processes this data so that a continuous stream of forward service data and logical clock signals are sent to the WSC at the scheduled user spacecraft data rate.

Note

During the scheduled service support period, during intervals where there is no forward service data from the user POCC/MOC, the data signal sent by the WSC is clamped to a logical 1.

c. Transmitted Signal. For data rates 300 kbps or less, the NRZ format forward service data signal will be modulo-2 added by the WSC to the command channel PN code for retransmission by the TDRS to the user spacecraft. 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. For data rates greater than 300 kbps, the NRZ format forward service data signal will be directly BPSK modulated by the WSC for retransmission by the TDRS to the user spacecraft.

Table 3-21. Salient Characteristics for TDRSS KSA Forward Services

Parameter	Value
$\frac{\text{Command channel radiated power}}{\text{Range channel radiated power}}$	+10 ±0.5 dB
Modulator phase imbalance (BPSK only) (peak)	±3 degrees
Modulator gain imbalance (peak)	±0.25 dB
Relative phase between command and range channels	90 ±3 degrees
Data asymmetry (peak) (note)	±3 percent
Data transition time (90 percent of initial state to 90 percent of final state) (note)	≤5 percent of bit duration
Phase nonlinearity (peak)	±0.15 radian over ±17.5 MHz
Gain flatness (peak)	±0.8 dB over ±17.5 MHz
Gain slope (peak)	±0.1 dB/MHz
AM/PM	≤7 degrees/dB
PN code chip jitter (rms) (including effects of Doppler compensation)	≤1 degree
Data bit jitter (peak) (note)	≤1 percent
Spurious PM (rms)	≤1 degree
Spurious outputs	≥27 dBc
Incidental AM (peak)	≥2 percent

Table 3-21. Salient Characteristics for TDRSS KSA Forward Services (cont)

Parameter	Value
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
Command/range channel PN code chip skew (peak)	≤0.01 chip
PN code asymmetry (peak)	≤0.01 chip
PN code chip rate (peak) (relative to absolute coherence with carrier rate)	≤0.01 chips/sec at PN code chip rate
Note These values are the TDRSS contributions for data asymmetry, data transition time, and bit jitter, assuming perfect forward service data is provided to WSC. The actual contributions by the NASCOM data transport system are negligible compared to those contributed by the TDRSS, since WSC reclocks the data before it is processed by WSC into the forward service signal.	

d. Operational Data Rates. During a scheduled service support period, if the initial TDRSS KSA forward service data rate is ≤300 kbps, a user POCC/MOC may change the TDRSS KSA forward service data rate to any other data rate value in the range 1 to 300 kbps. However, the operational restrictions of paragraph 3.4.2.5f apply. If either the initial data rate or the desire data rate are >300 kbps, the user POCC/MOC must use a GCMR as described in paragraph 3.4.2.5f.

3.4.2.5 Operational Characteristics. Changes to the operating conditions or configuration of a TDRSS KSA forward service during a scheduled service support period are usually initiated by a GCMR from the user POCC/MOC to the NCC. The NCC then transmits these to the WSC as OPMs. The requested changes will be implemented at the WSC and the NCC will be notified of completion of initiation of the requested changes. All changes will be implemented within 35 seconds after receipt of the OPM at the WSC. Additional information concerning WSC response times for OPMs is provided in section 4. The following changes can be made:

a. Center Frequency. The user spacecraft KSA receiver center frequency can be changed during a scheduled service support period.

b. Doppler Compensation Inhibit. During periods of TDRSS two-way range and Doppler measurements, the TDRSS will transmit a fixed frequency KSA forward service carrier and PN code chip rate (refer to paragraph 3.4.4.6).

c. Doppler Compensation Reinitiation. After a period of two-way range and Doppler measurement, the forward service Doppler compensation can be reinitiated; i.e., to allow for subsequent reacquisition by the user spacecraft of the forward service signal if KSA forward service signal tracking is lost by the user spacecraft (refer to paragraph 3.4.4.6).

d. Forward Service Reacquisition. The KSA forward service signal can be reinitialized by using forward service reacquisition. The WSC will continually apply the PN codes as well as forward service Doppler compensation (if Doppler compensation is not being inhibited).

e. Forward Service Sweep Request. If a user POCC/MOC is unable to accurately define f_o (the nominal center frequency of the user spacecraft receiver) the KSA forward service carrier frequency can be swept. The KSA forward service frequency sweep will be initiated by the WSC 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 KSA forward service frequency sweep does not impact simultaneous WSC Doppler compensation of the KSA forward service carrier and PN code rate.

f. Data Rate. During a scheduled service support period, the user POCC/MOC can change the data rate from that initially defined in the SHO in the following manner:

(1) If either the initial data rate and/or the desired data rate are >300 kbps, or the data rate change is not the only change being made to the TDRSS KSA forward service parameters at that time, the user POCC/MOC must request the data rate change as part of a reconfiguration GCMR to the NCC. When the WSC implements the reconfiguration OPM from the NCC, the TDRSS KSA forward service signal to the user spacecraft may be interrupted. If the forward signal is interrupted, the user spacecraft will have lost signal lock and must then reacquire the TDRSS KSA forward service signal (refer to Appendix C). During the time period commencing with notification by the NCC that the GCMR has been accepted (refer to Table 4-2) and ending with reacquisition of the TDRSS KSA forward service signal by the user spacecraft, the user POCC/MOC cannot transmit any forward service data to the NASCOM data transport system.

(2) If the initial data rate and the desired data rate are both $\leq$300 kbps and the data rate change is the only change being made to the TDRSS KSA forward service parameters at that time, it is possible for the user POCC/MOC to implement the data rate change using the procedure described in paragraph (1). However, the TDRSS KSA forward service signal to the user spacecraft will not be interrupted.

g. Polarization. Change in user spacecraft KSA receiving antenna polarization.

h. Spectrum Spreading. Initiation or termination of the command channel PN code (spectrum spreading).

i. Forward Service EIRP Change. The TDRS KSA forward service signal EIRP can be changed between the normal power mode and the high-power mode.

Note

1. Changes a, c, f, g, and h are implemented by the NCC via a reconfiguration OPM and their use (individually or collectively) may cause WSC to interrupt the TDRSS KSA forward service signal to the user spacecraft. Change d will cause the WSC to interrupt the forward service as it is implemented by the NCC via a reacquisition OPM.

2. The WSC implements Doppler compensation inhibit by using a "slow-and-hold" process (refer to paragraph 3.4.4.6b). There is no TDRSS KSA forward service signal interruption.

3. Changes e and i are acquisition aids, and they are implemented by the NCC via a forward service sweep request OPM, and a forward service EIRP change request OPM, respectively. Their use (individually or collectively) will not cause a TDRSS KSA forward service signal interruption.

3.4.2.6 Acquisition Scenarios. The user spacecraft signal acquisition of the TDRSS KSA forward service signal is normally part of the overall user spacecraft/TDRSS KSA (forward and return) services acquisition; therefore, user spacecraft KSA forward acquisition is described in paragraph 3.4.3.6 under TDRSS KSA return service acquisition (refer to Appendix C).

3.4.3 KSA RETURN SERVICES

3.4.3.1 General. The RF signals provided by the user spacecraft to the TDRS and the characteristics of data provided by the NASCOM data transport system to the user POCC/MOC are defined in paragraphs 3.4.3.2 through 3.4.3.7 (refer to section 5 for additional details of the NASCOM data transport system/user POCC/MOC interface).

3.4.3.2 Signal Parameters

a. General. The TDRSS KSA return service signal parameters are listed in Table 3-22. The user spacecraft transmit frequency for DG1 mode 2 or DG2 (noncoherent operations) service must be defined by the user POCC/MOC to the NCC to an accuracy of $\pm$5 kHz when requesting TDRSS KSA return service (refer to paragraphs 3.4.1.3 and 3.4.1.4).

b. Features. The general features inherent in the user spacecraft signal parameters are as follows:

(1) SQPN/SQPSK/QPSK/BPSK Modulation. SQPN modulation must be used for DG1 modes 1 and 2, whereas SQPSK, QPSK, or BPSK modulation will be used for DG2 and QPSK must be used for DG1 mode 3. For SQPN and SQPSK modulation, the spectral characteristics of a user spacecraft 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 user spacecraft using adjacent frequency channels on the TDRS services.

(2) Use of Identical Phase-shifted PN Codes on the I and Q Channels. 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. User-unique PN code assignments (refer to STDN No. 108) include shift register tap connections for generating the assigned PN codes. The offset between the I and Q channel PN code epochs is defined in STDN No. 108 for each PN code.

(3) Asynchronous Data Modulation. The return service data stream in each channel will be modulo-2 added asynchronously to the channel PN code (DG1 modes 1, 2, and 3 [I channel]). This prevents the forward service Doppler on the PN code from affecting the return service data stream data rate during DG1 mode 1 or mode 3 (I channel) operation. In general for DG1 operation, it eliminates the need for synchronizing the user spacecraft data clock with the user spacecraft transmitter PN code clock.

(4) Coherent Relationships Between the PN Code Clock and the Carrier Frequency. The PN code clock must be coherently related to the transmitted carrier frequency in all cases of DG1 modes 1, 2, and 3 (I channel) operation. This feature permits the user spacecraft transmitter to use a common source for generating the carrier and the PN code clock and permits the WSC to use the PN code clock to aid return service carrier acquisition.

c. DG1 Signal Parameters. DG1 signal parameters are subdivided into three modes of operation which are distinguished as follows:

(1) DG1 Mode 1. DG1 mode 1 must be used when TDRSS two-way range and Doppler measurements (coherent transponder operations) are required concurrently with return service low-rate data transmission. The PN code length is identical to the length of the forward service range channel PN code received from the TDRS. Its epoch is synchronized with the epoch of the forward service range channel PN code (refer to Table 3-22). Return service signal acquisition by the WSC for DG1 mode 1 is possible only when the scheduled TDRSS KSA forward service signal is acquired by the user spacecraft and the PN code and carrier transmitted by the user spacecraft are coherently related to the forward service signal from the TDRS. To support DG1 Mode 1 service, TDRSS KSA forward and return service must be scheduled to occur simultaneously. If the TDRSS forward service signal becomes unavailable to the user spacecraft, the user spacecraft transmitter must switch to noncoherent transmitter operation (DG1 mode 2) (refer to paragraph 3.4.3.5.b.(2)).

Table 3-22. TDRSS KSA Return Service Signal Parameters (Note 1, 2, 10)

Parameter	Description
DG1 (notes 1, 2)	
Transmit carrier frequency (Hz)	F_1
Carrier (F1) reference (Hz)	
DG1 modes 1 and 3	$\left(\frac{1600}{1469}\right) \times F_R$
DG1 mode 2	User spacecraft transmitter oscillator
PN code modulation	
DG1 modes 1 and 2	SQPN (note 3)
DG1 mode 3 I channel	PSK $\pm\pi/2$ radians
PN code chip rate (chips/sec)	$\left[\frac{31}{1600 \text{ x } 96}\right] \times F_1$
PN code length (chips)	
DG1 modes 1 and 3	$(2^{10}-1)$ 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 4)	Epoch delayed x + 1/2 PN code chips relative to I channel PN code epoch
DG1 mode 2 I channel	User spacecraft oscillator
Q channel	Epoch delayed 1/2 PN code chip period relative to I channel PN code chip epoch
DG1 mode 3, I channel	Same as DG1 mode 1, I channel

Table 3-22. TDRSS KSA Return Service Signal Parameters (Note 1, 2, 10)(cont)

Parameter	Description
DG1 (notes 1, 2)(cont)	
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
Data format	
Without convolutional encoding	NRZ-L, NRZ-M, NRZ-S, Bi∅-L, Bi∅-M, Bi∅-S
With convolutional encoding (note 5)	NRZ-L, NRZ-M, NRZ-S
DG1 mode 1 data rate restrictions Total (note 6)	1 - 600 kbps
I channel	1 - 300 kbps
Q channel	1 - 300 kbps
DG1 mode 2 data rate restrictions Total (note 6)	1 - 600 kbps
I channel	1 - 300 kbps
Q channel	1 - 300 kbps
DG1 mode 3 data rate restrictions	
Total (note 6)	I + Q
I channel	1 - 300 kbps
Q channel	1 kbps - 150 Mbps

Table 3-22. TDRSS KSA Return Service Signal Parameters (note 1, 2,10) (cont)

Parameter	Description
DG2 (notes 1, 8)	
Transmit carrier frequency (Hz)	F_2
Carrier (F_2) reference (Hz)	$\left(\frac{1600}{1469}\right) x F_R$ or user spacecraft oscillator
Data modulation (note 7)	QPSK, BPSK, or SQPSK
Data format	
Without convolutional encoding	NRZ-L, NRZ-M, NRZ-S, Bi∅-L, Bi∅-M, Bi∅-S (note 9)
With Rate 1/2 convolutional encoding (note 5)	NRZ-L, NRZ-M, NRZ-S
Data rate restrictions	
Total (notes 6,7)	1 kbps - 300 Mbps
I channel	1 kbps - 150 Mbps
Q channel	1 kbps - 150 Mbps

Note

1. User spacecraft data configurations are defined in paragraph 3.4.3.4 for TDRSS KSA return service (refer also to Appendix B).

2. The DG1 $\frac{\text{Q channel power}}{\text{I channel power}}$ can vary only from 1:1 to 4:1. Although the parameter range available during user spacecraft design is continuous between these two limits, at this time the user POCC/MOC may request this parameter, in scheduling messages to the NCC (refer to Table 4-5), only as the ratio of two small integers.

3. When identical data is being transmitted on balanced I and Q channels (Q/I [power] = 1:1) (single data channel configuration for DG1 modes 1 or 2), the I channel carrier phase must lead the Q channel phase by $\pi/2$ radians.

4. The Q channel PN code must be identical to the I channel PN code offset 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 user spacecraft (refer to STDN No. 108).

Table 3-22. TDRSS KSA Return Service Signal Parameters (note 1, 2, 10) (cont)

Note (cont)

5. At the option of the user, the output of the user spacecraft convolutional encoder may be NRZ-to-Bi0-L converted. This format conversion capability can be used only with BPSK or QPSK modulation and data rates $\leq$5 Mb/sec. It is recommended that the user spacecraft design use G_2 inversion, as defined in paragraph 3.4.3.3d(1)(f), to obtain symbol transitions, rather than NRZ-to-Bi0-L conversion. When NRZ-to-Biphase conversion is used, the G_2 inversion is not applicable.

6. For dual data channel operations, data signals on the I and Q channels are independent. They can be asynchronous. The sum of the data rates on the I and Q channel must not exceed the total.

   For DG1 mode 1 or 2 single data channel operation, the I and Q channel signals must be identical and synchronous, and the data rate must not exceed 300 kbps.

   For DG2, single data channel operation, symbols on the I and Q channels must be offset relative to one another by one half data period if uncoded or one half symbol period if rate 1/2 convolutionally encoded.

   For DG1 and DG2, maximum data rates for the I channel, the Q channel, and the total are reduced by a factor of 2 when the data is either biphase formatted or Rate 1/2 convolutionally encoded; and when both Rate 1/2 convolutional encoding and biphase format conversions are used, the maximum data rates for the I channel, the Q channel, and the total are reduced by a factor of 4. Biphase data format shall not be used for data rates >5 Mb/sec.

7. For DG2 single data channel operation, BPSK may be used with data rates up to 100 Mb/sec (uncoded data), or up to 50 Mb/sec (Rate 1/2 convolutionally encoded data).

8. For DG2 dual data channel operation, the DG2 $\frac{\text{I channel power}}{\text{Q channel power}}$ can be either 1:1 or 4:1. For DG2 single data channel operation, it must be 1:1.

9. For DG2 single data channel operation with SQPSK modulation and alternate I/Q data bits, only NRZ-L can be used because the I and Q channel data signals must be independently differentially formatted prior to modulation (refer to paragraph 3.4.3.4e). For DG2 single data channel operation with SQPSK modulation and alternate I/Q encoded symbols, only NRZ-L, M, S can be used.

10. 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) DG1 Mode 2. DG1 mode 2 can be used when WSC return service signal acquisition is necessary without the requirement for prior user spacecraft signal acquisition of the TDRSS KSA forward service (noncoherent transponder operation). The carrier frequency transmitted by the user spacecraft must be defined by the user POCC/MOC to a tolerance of $\pm$5 kHz prior to initiation of the WSC signal acquisition process for DG1 mode 2; i.e., in the service schedule request to the NCC that results in the SHO to the WSC for that service support period (refer to paragraphs 3.4.1.3 and 3.4.1.4).

(3) DG1 Mode 3. DG1 mode 3 can be used when two-way range and 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 Mode 3, the Q channel must contain only data and no PN code.

(4) DG1 Mode 1 and 2 Data Channel Parameters. The user spacecraft return service signal can have either a single data channel or two independent data channels for both DG1 mode 1 and DG1 mode 2 operations (refer to paragraph 3.4.3.4). For a single data channel, the identical data must appear simultaneously on the I and Q channels. For two independent data channels (dual data channels), one independent data stream will appear on the I channel, the other on the Q channel. The I and Q channel power division in the user spacecraft transmitter can be weighted up to a maximum of 4:1 ($Q \geq I$) for either a single data channel or dual data channels.

(5) DG1 Mode 3 Data Channel Parameters. For DG1 mode 3, the user spacecraft return service signal has two independent data channels (refer to paragraph 3.4.3.4). One independent data stream will appear on the I channel and the other on the Q channel. The I and Q channel power division in the user spacecraft transmitter can be weighted up to maximum of 4:1 ($Q \geq I$).

d. DG2 Signal Parameters. The following summarizes the DG2 signals:

(1) DG2. DG2 signal parameters must be used when the return service data rate requirement exceeds the capability of DG1 operations. DG2 operation cannot provide TDRSS range tracking because PN code modulation is not used for DG2. The DG2 carrier can be either coherently related to or independent of the TDRSS KSA forward service carrier frequency. TDRSS two-way Doppler tracking can be provided when the DG2 carrier is coherently related to the TDRSS KSA forward service carrier frequency. The carrier frequency transmitted by the user spacecraft must be defined by the user POCC/MOC to a tolerance of $\pm$5 kHz prior to initiation of the WSC acquisition process when the DG2 carrier is independent of the forward service signal (refer to paragraphs 3.4.1.3 and 3.4.1.4).

(2) DG2 Data Channel Parameters. The DG2 return service signal can have either a single data channel or two independent data channels (dual data channels). User spacecraft data configurations for DG2 are defined in paragraph 3.4.3.4. For DG2

dual data channel operations, the I and Q channel power division in the user spacecraft transmitter can be either 1:1 or 4:1 (I≥Q). However, for DG2 single data channel operations with SQPSK modulation, it must be 1:1.

e. User Transmitter Configurations. The user spacecraft transmitter functional configurations for the TDRSS KSA return services (DG1 and DG2) are shown in Appendix B.

3.4.3.3 Communications Services

a. Available Services. The TDRSS KSA return services available are listed in Table 3-23. User spacecraft transmitted signal characteristics required to obtain the TDRSS KSA return service performance defined in this paragraph are specified in paragraph 3.4.3.7. The TDRSS KSA return service performance defined in this paragraph also assumes return service operation in an AWGN environment. Appendix G discusses performance degradations to the TDRSS KSA return service due to RFI. Example link calculations are provided in Appendix A.

b. PN Coding. A user spacecraft-unique PN code assignment for the DG1 mode 1, 2, and 3 (I channel) PN codes will be made by the Frequency Manager of the MO&DSD from the library of PN codes in STDN No. 108. These PN codes will be from the same PN code library assignment as the PN codes for the forward service command and range channels (refer to paragraph 3.4.2.3a).

c. Phase and Channel Ambiguity. Data phase ambiguity (except for NRZ-L and Bi0-L) and data channel ambiguity are resolved by the WSC (refer to Appendix B, paragraph B.3).

d. ADR Equation Conditions. The ADR indicated in Table 3-23 is based on the following:

(1) Data encoding:

Note

The WSC Viterbi decoder cannot synchronize correctly to a data signal which does not contain any input data signal transitions prior to convolutional encoding. Sufficient data transitions are necessary during the WSC Viterbi decoder synchronization process to ensure correct branch synchronization.

(a) Code: convolutional, nonsystematic, transparent.

(b) Rate: 1/2.

(c) Constraint length: K = 7.

Table 3-23. TDRSS KSA Return Service (Note 5)

Parameter	Description
Field of view (each TDRS)	$\pm$ 22 degrees east-west $\pm$ 28 degrees north-south
TDRS antenna polarization (note 1)	RHC or LHC selectable
TDRS antenna axial ratio (maximum)	1 dB over 3 dB beamwidth
Receive frequency (nominal)	$\left(\frac{1600}{1469}\right) \times 13.775 \text{ GHz} \pm 0.7 \text{ MHz}$
ADR without coding (dB relative to 1 bps) (notes 2, 3, 4)	
DG1, modes 1 and 2	239.5 + P_{rec} (dBW)
DG1, mode 3	
I channel	$P_{rec} \geq$ -182.8 (dBW)(note 6)
Q channel	237.8 + P_{rec} (dBW)
DG2	237.8 + P_{rec} (dBW)
ADR with Rate 1/2 convolutional encoding (dB relative to 1 bps) (notes 2, 3, 4)	
DG1, modes 1 and 2	$P_{rec} \geq$ -182.8 (dBW)(note 6)
DG1, mode 3	
I channel	$P_{rec} \geq$ -182.8 (dBW)(note 6)
Q channel	244.7 + P_{rec} (dBW)
DG2	244.7 + P_{rec} (dBW)
Autotrack acquisition	
Orbital dynamics	$\dot{R} \leq 12 \text{ km/sec}$, $\ddot{R} \leq 15 \text{ m/sec}^2$, jerk $\leq .02 \text{ m/sec}^3$
Ephemeris Uncertainty	$\leq \pm$ 4.5 sec
P_{rec} with probability > 99%	$\geq$-182.8 dBW or consistent with the P_{rec} for ADR, whichever is greater
Acquisition Time	$\leq$ 10 seconds

Table 3-23. TDRSS KSA Return Service (Note 5)(cont)

Parameter	Description
PN Code (if applicable) and Carrier Acquisition	
Orbital dynamics	$\dot{R} \leq 12$ km / sec, $\ddot{R} \leq 15$ m / sec^2, jerk ≤ 0.02 m / sec^3
Ephemeris Uncertainty	$\leq \pm$ 4.5 sec
P_{rec}	$\geq$ -182.8 dBW or consistent with the P_{rec} for ADR, whichever is greater
Acquisition Time ($P_{acq} \geq 90\%$)	
for Frequency Uncertainty $\leq \pm$ 5 kHz	$\leq$ 1 sec
for Frequency Uncertainty $\leq \pm$ 20 kHz	$\leq$ 3 sec
Decoder/Symbol Synchronization Acquisition (coded data)	
Ephemeris Uncertainty	$\leq \pm$ 4.5 sec
Minimum data bit transition density	$\geq$ 64 data 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 ADR
Synchronization acquisition time (in seconds) with >99% probability	
Biphase	< 1100/(Data Rate in bps)
NRZ	< 6500/(Data Rate in bps)
Symbol Synchronization Acquisition (uncoded data)	
Ephemeris Uncertainty	$\leq \pm$ 4.5 sec
P_{rec} (dBW)	consistent with the P_{rec} for ADR
Synchronization	Achieved when error rate for next 1000 bits is $\leq 10^{-5}$
Synchronization acquisition time (in seconds) with >99% probability	
Biphase	< 300/(Data Rate in bps)
NRZ	< 3000/(Data Rate in bps)

Table 3-23. TDRSS KSA Return Service (Note 5)(cont)

Parameter	Description
Signal Tracking	refer to paragraph 3.4.3.3.d.(12)
Duty Factor	100 percent

Note

1. Operational considerations may limit choice of TDRS antenna polarization.

2. The ADR is for a user spacecraft transmitting a signal on an AWGN channel which complies with the constraints defined in paragraph 3.4.3.7 (also refer to Appendix H). Refer to Appendix G for a discussion of the additional degradation applicable to the TDRSS KSA return service performance due to K-band RFI.

3. Refer to Appendix A, paragraph A.4, for a definition of P_{rec}. For QPSK signals (balanced or unbalanced) with nonidentical data on the I and Q channels (dual data channels), the P_{rec} value specified is to be interpreted as the minimum required P_{rec} per channel. For balanced SQPSK signals with alternate I/Q data bits and DG2 balanced SQPSK signals with alternate I/Q encoded symbols, the P_{rec} value specified is to be interpreted as the minimum required P_{rec} per channel where the channel data rate is 1/2 the bit rate of the data source.

   For DG1 balanced QPSK signals with identical data (synchronous and at the same data rate) on the I and Q channels, the minimum required <u>total</u> (I + Q) P_{rec} is equal to the minimum required P_{rec} of <u>either</u> an I or Q channel of a dual data channel with data at this same data rate.

   For unbalanced QPSK signals with identical data on the I and Q channels (DG1 single data channel only), the minimum required P_{rec} is to be interpreted as the P_{rec} of the stronger channel.

4. The required user P_{rec} must meet the P_{rec} for ADR or signal acquisition, whichever is greater.

5. 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.

6. Required P_{rec} value is the P_{rec} to meet autotrack/signal acquisition and this P_{rec} can achieve the highest allowable data rate of DG1, mode 3 I channel (both uncoded and rate 1/2 coded) and DG1, modes 1 and 2 (rate 1/2 coded). Refer to Figure A-7 of Appendix A for a graphical representation of the KSA return service required received power at the TDRS versus ADR.

(d) Generator functions:

1. G_1 = 1111001.

2. G_2 = 1011011.

(e) Symbols generated from G_1 must precede symbols generated from G_2 relative to the data bit period.

(f) Symbols generated from G_2 should be complemented. G_2 symbol inversion provides an increased symbol transition density for a convolutional encoder input data signal with low transition density. Increased symbol transition density will aid WSC clock (symbol) synchronization.

Note

WSC can support symbols generated from G_2 that are either true or complemented and will be defined in the SHO to the WSC. However, G_2 symbol inversion is not supported with NRZ to Biphase-L symbol conversion.

(2) Format Description. The data and symbol format for each data channel are independently selectable by the user spacecraft. Achievable data rate parameters are based on a 10^{-5} BER for all data formats measured at the WSC receiver output. As the NASCOM data transport system BER is $\leq 10^{-7}$, the BER at the NASCOM data transport system/user POCC/MOC interface is basically established by the BER at the WSC receiver output.

(3) Received Power. P_{rec} is in units of dBW. The user project, in determining its design requirements for minimum user spacecraft EIRP, must take into account user spacecraft transmit antenna pointing losses, the space loss between the user spacecraft and the TDRS, and the polarization mismatch loss incurred by a deviation from 0 dB user spacecraft transmit antenna axial ratio. The maximum TDRS receive antenna axial ratio is given in Table 3-23 (also refer to Appendix A).

(4) User Degradations. Further reductions in the TDRSS KSA return service performance identified in Table 3-23 can occur. User spacecraft parameters exceeding the constraints described in paragraph 3.4.3.7 can degrade TDRSS KSA return service performance (refer to Appendix H).

(5) Acquisition. The KSA return service T_{acq} (refer to Table 3-23) for all modes of operation does not include user spacecraft forward service signal acquisition time. The KSA return service T_{acq} also assumes that the user POCC/MOC-defined user spacecraft transmit frequency for DG1 mode 2 or DG2 (noncoherent operations) is accurate to $\pm$5 kHz (refer to paragraphs 3.4.1.3 and 3.4.1.4) and assumes that the user spacecraft return service signal is present at the WSC at the start time of the scheduled return service support period. For DG1 mode 2 and DG2 (noncoherent

operation), WSC will be capable of acquiring, on NCC request, a user spacecraft transmitted signal with a frequency uncertainty of ±20 kHz with TDRSS KSA return service signal acquisition times that are increased by a factor of 3.

Note

This is in addition to the WSC being able to accommodate the frequency uncertainty caused by the maximum epoch uncertainty of the applicable user spacecraft ephemeris being ±4.5 seconds whether the TDRSS KSA return service autotrack process is being utilized or inhibited. (Refer also to paragraph 3.4.1.4a.)

(6) Sun Interference. The TDRSS KSA return service will not be available when the center of the sun is either within 1 degree of the TDRS KSA receiving antenna boresight or within 1 degree of the boresight of the WSC receiving antenna supporting that TDRS. Currently, the NCC cannot use the PSAT message; therefore, it does not know the sun's transit periods. Sun interference checking is a user POCC/MOC responsibility. The NCC does not check, nor does it inhibit, a user POCC/MOC from scheduling events subject to sun interference. Based on this, the user POCC/MOC is responsible for obtaining and using the PSAT information in its mission planning. If the user POCC/MOC requests support through sun transits, TDRSS KSA return service performance (autotrack acquisition and/or tracking, signal acquisition and/or tracking, BER) is not guaranteed during the sun transit. It is possible that the TDRSS could autotrack the sun (if autotrack were enabled), in which case it would become necessary for the user POCC/MOC to request the NCC to send an OPM to the WSC to initiate reacquisition of the user spacecraft signal (after the sun transit is over). The NCC will always verify the absence of WSC antenna sun interference for all service support period requests.

(7) DG1 Received Power Considerations. For DG1 service, the following conditions apply:

(a) Balanced Single Data Channels. For a user spacecraft synchronously transmitting identical data on the I and Q channels (single data channel) with a balanced I and Q channel power division, the total P_{rec} must be consistent with the ADR listed in Table 3-23.

(b) Unbalanced Single Data Channels. For a user spacecraft synchronously transmitting identical data on the I and Q channels (single data channel) having unbalanced I and Q channel power division, the strong channel P_{rec} must be consistent with the ADR listed in Table 3-23. The weak channel P_{rec} need not be consistent with the ADR listed in Table 3-23. The Q/I (power) must not exceed 4:1.

(c) Dual Data Channels. For a user spacecraft transmitting independent data on the I and Q channels (dual data channels), the fraction of total P_{rec} devoted to the I (or Q) channel must be consistent with the ADR in Table 3-23 for the I

(or Q) channel data rate. The Q/I (power) must not exceed 4:1 regardless of the ratio of data rates on the I and Q channels.

(d) Transponder Failure. If the user spacecraft fails to transmit one quadrature carrier channel (I or Q) or that channel does not include data modulation, the ADR capability of the remaining channel is unaffected.

(8) Multipath. The WSC will provide lockup and interference protection from multipath signals reflected from the Earth.

(9) DG2 Considerations. For DG2 service, the following conditions apply:

(a) DG2 Power Received. For a user spacecraft using DG2, the I channel to Q channel power ratio will be either 1:1 or 4:1. The fraction of total P_{rec} devoted to the I (or Q) channel must be consistent with the ADR of Table 3-23 for the I (or Q) channel data rate. If one quadrature carrier channel (I or Q) is not transmitted or that channel does not include data modulation, the ADR capability of the remaining channel is unaffected.

(b) DG2 SQPSK Single Data Channel. For a user spacecraft using DG2 single data channel with a data rate $\leq$10 Mbps and SQPSK modulation, G_2 inversion does not increase symbol transition density of either the I or Q channel.

(10) Loss of Symbol Synchronization. For each TDRSS KSA return service with data transition densities greater than 40% for NRZ symbols and any transition density for biphase symbols, the WSC symbol synchronization loop will not unlock for a P_{rec} that is 3 dB less than the minimum P_{rec} required consistent with the ADR in Table 3-23 (refer also to note 3 of Table 3-23). For NRZ symbol transition densities between 25% and 40%, the WSC symbol synchronizer loop will not unlock for a P_{rec} that is 2 dB less than the minimum P_{rec} required for the ADR. However, the BER performance may be degraded when the P_{rec} is less than the minimum required to be consistent with ADR.

(11) False Lock Protection. The TDRSS KSA return services will be protected against WSC false lock in carrier recovery during acquisition and subsequent normal TDRSS KSA return service. For DG1, the TDRSS KSA return services will also be protected against WSC false lock to user spacecraft PN code sidelobes.

(12) Cycle Slips. The mean time-between-cycle slip in the WSC carrier tracking loop for each TDRSS KSA return service will be 90 minutes minimum. This value applies at carrier tracking threshold (i.e., 3 dB less than the minimum P_{rec} for ADR listed in Table 3-23) and increases exponentially as a function of linear dB increases in P_{rec}. For DG1 mode 1, 2, or 3 I data channels with spectrum spreading and for non-spread DG1 mode 3 Q or DG2 data channels with either BPSK modulation or unbalanced QPSK modulation, a single cycle slip will invert the signal polarity at the WSC demodulator output. For DG2 data channels with balanced QPSK modulation, a single cycle slip will interchange the I and Q demodulator outputs and invert one of

the outputs. For a single data channel with balanced QPSK, the WSC Viterbi decoder may require resynchronization. For the dual data channel configuration with balanced QPSK, for which channel ambiguity resolution will be provided, the time for the WSC to recover will be the time for the WSC to detect an interchange and to resynchronize its bit synchronizers and Viterbi decoders.

(13) Protection Against Loss-of-Lock. After TDRSS KSA return service signal acquisition with TDRSS KSA return service autotrack either enabled or inhibited, the TDRSS KSA return service signal or autotrack, if enabled, will not lose lock for fades up to 3 dB below the minimum P_{rec} listed in Table 3-23 or the minimum P_{rec} required for autotrack, whichever is greater.

(14) Bit Slippage. For each TDRSS KSA return service operating with a minimum P_{rec} required consistent with the ADR of Table 3-23 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 WSC symbol clock recovery loop is either 90 minutes or 10^{10} clock cycles, whichever is greater. For a KSA return service operating with 1 dB more than the minimum P_{rec} required for the ADR, and NRZ symbol transition densities between 25% and 40%, the minimum mean time between slips is either 90 minutes or 10^{10} clock cycles, whichever is greater.

e. Mutual Interference. If a TDRS is simultaneously supporting two KSA user spacecraft which are located within 0.5 degree of each other as seen by that TDRS, mutual interference will be significant if both user spacecraft are operating with the same direction of circular polarization. For this reason, the TDRSS KSA return service provides selectable TDRS RHC or LHC polarization. It is anticipated that KSA user spacecraft will be either configured similarly to provide selectable RHC or LHC polarization to allow operation when mutual interference exists or elect not to operate during conditions of mutual interference. Polarization selection is made during the mission planning phase.

f. Restrictions on Received Power Levels. P_{rec} must be ≥ -182.8 dBW or consistent with the ADR as defined in Table 3-23, whichever is greater, to initiate and maintain the TDRSS KSA return service.

3.4.3.4 Data Interfaces. The KSA return service data interfaces are as follows:

a. Data Rate Definition. The user spacecraft data rates for a specific service support period are initially defined by the NCC in the SHO to the WSC for that service support period.

b. NASCOM Operations. The user spacecraft transmits data signals to the TDRS in continuous symbol streams as scheduled. The data signals may consist of an idle pattern or actual data. After WSC return service signal acquisition, the NASCOM data transport system processes these data streams and provides the user POCC/MOC with each of the individual data streams in the 4800-bit block format or in a bit-continguous serial data stream as previously agreed to by the user POCC/MOC and the SN (refer to section 5).

c. DG1 Single Data Channel Configurations. For DG1, a single data channel (refer to Appendix B) can be used to support any of the following user spacecraft configurations:

(1) Transmitting a balanced QPSK signal configured for synchronous transmission of the identical uncoded or convolutionally encoded (rate 1/2) data signal on both the I and Q channels.

(2) Transmitting an unbalanced QPSK signal configured for synchronous transmission of the identical uncoded or convolutionally encoded (rate 1/2) data signal on both the I and Q channels.

(3) Transmitting a BPSK signal due to either the I or Q channel of the user spacecraft QPSK modulator being inoperative.

d. DG2 BPSK Single Data Channel Configuration. For DG2 with BPSK modulation, a single data channel (refer to Appendix B) can be used to support a user spacecraft configured to transmit a single uncoded or convolutionally encoded (rate 1/2) data signal. The user spacecraft convolutional encoding configuration will be identical to that for the dual data channel encoding configuration defined in paragraph f.

e. DG2 SQPSK Single Data Channel Configurations. For DG2 with SQPSK modulation, a single data channel (refer to Appendix B) can be used to support a user spacecraft configured to transmit uncoded data on I and Q channels consisting of alternate bits of a single data signal. The I and Q channels data signals must be differentially formatted separately prior to transmission. For a convolutionally encoded (rate 1/2) data signal with a data rate of 10 Mbps or less, the single data channel can be used to support a user spacecraft configured to transmit the two concurrent output symbols of a rate 1/2 convolutional encoder on the I and Q channels. For a convolutionally encoded data signal of greater than 10 Mbps, the user spacecraft must be configured to divide the data signal into an I channel and a Q channel data signal, each channel data signal consisting of alternate bits of the original data signal. The I channel data signal and the Q channel data signal must be differentially formatted separately, then independently rate 1/2 convolutionally encoded prior to transmission on the I and Q channels, respectively. Each rate 1/2 convolutional encoder in the user spacecraft will be an n-parallel encoder consisting of n-branch encoders in parallel. The composite serial symbol output from the n-parallel encoder will consist of the branch encoder output symbols interleaved every nth symbol. The relationship between the user spacecraft data rate and the number of branch encoders is as follows:

$$n = \frac{R_d}{2 \times 10^7} \text{ rounded to the next higher integer if } n \neq \text{integer}$$

where: n = number of branch encoders for the I or Q channel rate 1/2 convolutional encoder

R_d = channel data rate (bps)

f. DG1 and DG2 Dual Data Channel Configurations. For DG1 and DG2, the dual data channels (refer to Appendix B) can be used to support a user spacecraft configured to transmit two independent data signals, one on the I channel and one on the Q channel. Either or both data signals may be either uncoded or rate 1/2 convolutionally encoded. For a convolutionally encoded data signal to be transmitted on either of the data channels, the user spacecraft must be configured to rate 1/2 convolutionally encode the data signal for that channel using an n-parallel encoder prior to transmission. The relationship between the user spacecraft channel data rate and the number of branch encoders is as follows:

$$n = \frac{R_d}{2 \times 10^7} \text{ rounded to the next higher integer if } n \neq \text{integer}$$

where: n = number of branch encoders for the I or Q channel rate 1/2 convolutional encoder

R_d = channel data rate (bps)

g. Channel Ambiguity Resolution. The WSC will resolve the data channel ambiguity (refer to Appendix B) for all user spacecraft DG1 dual data channels. For user spacecraft DG2 dual data channels, the WSC will resolve the data channel ambiguity if at least one of the following criteria is met:

(1) Unbalanced (I/Q = 4:1) QPSK modulation.

(2) Rate 1/2 convolutional encoding on one channel and the other channel uncoded.

(3) The channel symbol rates are unequal and the higher rate exceeds the lower rate by at least 25 percent.

Note

When a harmonic of the I (or Q) channel clock is within 25 percent of the Q (or I) channel clock frequency, ambiguity resolution cannot be reliably achieved using WSC bit synchronizers set up for operation at the scheduled I and Q channel data rates (refer to Appendix B, paragraph B.3).

h. Data Loss Detection. The data provided by the user spacecraft on a particular channel must be at the scheduled data rate for that user spacecraft channel (before convolutional encoding). This TDRSS KSA return service will be processed by the WSC so that loss of the received data in each channel will be detected. The data stream in each channel sent to the user POCC/MOC by the NASCOM data transport system will be clamped to a logical 1 during this data loss period.

i. Phase Ambiguity Resolution for Differential Encoding. The WSC will resolve the data phase ambiguity for user spacecraft data channels with differentially encoded (Bi0-M/-S, NRZ-M/-S) data formats (refer to Appendix B, paragraph B.3).

3.4.3.5 Operational Characteristics. TDRSS KSA return services have the following operational characteristics:

a. Service Changes. Changes to the operating conditions or configuration of a TDRSS KSA return service during a scheduled service support period are initiated by a GCMR from the user POCC/MOC to the NCC. The NCC then transmits these to the WSC as an OPM. The requested changes will be implemented at the WSC and the NCC will be notified of the completion of the initiation of the requested changes. All changes will be implemented in less than 35 seconds after receipt of the OPM at the WSC. The following changes can be made:

(1) Return Service Reacquisition.

(a) In case of loss of lock (PN Code and/or Carrier), the WSC will automatically initiate reacquisition using pre-drop-lock data to aid in the reacquisition. Reacquisition will be based on the assumption that the time difference between the actual user frequency dynamics and the predicted dynamics remains unchanged from the pre-drop-lock difference. If the user spacecraft continues to transmit the minimum P_{rec} for acquisition, reacquisition time typically will not exceed one-half of the initial acquisition times given in Table 3-23.

(b) Reacquisition will continue for up to 10 seconds until lock is achieved or until a reacquisition OPM is received at WSC. If lock is not achieved within 10 seconds of loss of lock, an acquisition failure OPM will be sent to the NCC and WSC will reinitiate the initial service acquisition process.

(2) Expanded User Spacecraft Frequency Uncertainty. In the event the user POCC/MOC is unable to accurately predict the user spacecraft transmit frequency within $\pm$5 kHz for DG1 mode 2 or for DG2 (noncoherent operations), the WSC can reconfigure to accommodate a $\pm$20 kHz user spacecraft transmit frequency uncertainty during the TDRSS KSA return service acquisition/reacquisition process.

Note

This is in addition to the WSC being able to accommodate the frequency uncertainty caused by the maximum epoch uncertainty of the applicable user spacecraft ephemeris being $\pm$4.5 seconds whether the TDRSS KSA return service autotrack process is being utilized or inhibited (refer also to paragraph 3.4.1.4a).

(3) Data Rate. Change in the I and/or Q channel data rate.

(4) Frequency. Change in the user spacecraft transmit center frequency (noncoherent operations only).

(5) Received Power. Redefinition of maximum and minimum P_{rec} (delineated as user spacecraft EIRP in a SHO [refer to Appendix A]; difference must not exceed 12 dB) during the scheduled TDRSS KSA return service support period.

(6) Power Ratio. Change in I/Q (power).

(7) Data Format. Change in the I and/or Q channel data format.

(8) Data Bit Jitter. Change in the I and/or Q channel data bit jitter.

(9) DG1 Mode. Change in DG1 mode (1, 2, or 3).

(10) Polarization. Change in user spacecraft transmitting antenna polarization.

(11) Data Group. Change between DG1 and DG2. When changing from Data Group 1 to Data Group 2, the user must also specify the type of DG2 service (non-coherent or coherent) even if the type of DG2 service was specified as desired in the original schedule request. Similarly, when changing from Data Group 2 to Data Group 1, the user must also specify the DG1 mode. If the mode or coherency type is not specified in the reconfiguration request to change Data Group, WSC will reject the reconfiguration.

(12) DG2 Mode. Change in DG2 mode of operation (coherent and noncoherent).

(13) DG2 Single Data Channel Modulation. Change in DG2 single data channel modulation (SQPSK or BPSK).

(14) TDRSS Autotrack Mode. Change in TDRSS autotrack mode (enable/disable).

(15) Data Channel Configuration. Change in data source (single or dual).

(16) G_2 inversion. Change in encoder configuration (enabled or bypassed).

Note

These changes to the TDRSS KSA return service during a scheduled TDRSS KSA return service support period may cause the WSC to interrupt return service for that user spacecraft, requiring reacquisition by the WSC of the user spacecraft (signal acquisition and, when enabled, autotrack acquisition).

b. Coherent/Noncoherent Operation.

(1) Doppler Correction. The WSC corrects the received user spacecraft signal for Doppler to allow for WSC implementation of receivers with narrow acquisition and tracking bandwidths. The Doppler correction used by the WSC is either one-way or two-way, depending on the user spacecraft mode of operation (noncoherent or coherent) and on whether Doppler compensation of the related TDRSS KSA forward service signal (coherent operation only) is inhibited. For noncoherent operation, the Doppler correction is based on the user spacecraft transmission frequency stated in the SHO and any subsequent OPMs. Noncoherent operation requires one-way WSC Doppler correction. For coherent operation, the Doppler correction is based upon the forward service frequency. Coherent operation with WSC forward service Doppler compensation also requires one-way WSC Doppler correction. Coherent operation with WSC forward service Doppler compensation inhibited (fixed TDRS forward service transmit frequency) requires two-way WSC Doppler correction.

(2) Coherent to Noncoherent Transitions Due to Loss of Forward Signal. User spacecraft transponders which switch, when the TDRSS KSA forward service signal is lost, from a coherent transponder mode (transmit frequency derived from the carrier tracking VCXO) to a noncoherent mode (transmit frequency derived from a TCXO) will cause the WSC to drop TDRSS KSA return service lock. For DG2, during periods of WSC forward service Doppler compensation, the frequency offset of the TCXO causes the WSC to drop TDRSS KSA return service signal lock when the switch is made. During periods of WSC forward service Doppler compensation inhibit, a switch by the user spacecraft from the VCXO to the TCXO will provide an additional frequency offset due to lack of appropriate WSC Doppler correction. For DG1, the switch to the noncoherent mode (DG1 mode 2) also changes other user spacecraft return service signal parameters (e.g., PN codes). Reconfiguration and reacquisition by WSC is required via an appropriate GCM from the NCC to the WSC (initiated by a GCMR from the user POCC/MOC).

(3) Maintaining Coherency. For a user spacecraft with a special-design transponder, alternatives are available to the user POCC/MOC to minimize loss of return service data due to user spacecraft short-term tracking loss of the TDRSS KSA forward service signal. To bridge these short term forward service signal dropouts when using coherent operation, the user spacecraft could remain in the coherent mode if it incorporates a frequency memory technique to ensure that the KSA return service carrier frequency remains related to the TDRSS KSA forward service signal frequency as it was prior to loss of KSA forward service signal lock. For DG2 operation, the user spacecraft design could consider only noncoherent operation by using a highly accurate and stable user spacecraft frequency source. Two-way Doppler tracking service would then not be available.

c. Service Acquisition Time. The total TDRSS KSA return service signal acquisition time is the sum of the following:

(1) PN (DG1 only) and carrier acquisition time

(2) Symbol/Decoder synchronization time (for coded signals) or Symbol Synchronization time (for uncoded signals)

(3) Autotrack acquisition time (when the TDRSS KSA return service autotrack mode is enabled)

The acquisition and synchronization times are given in Table 3-23. Symbol/Decoder Synchronization time will be measured from the time carrier acquisition is achieved to the time 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). Requirements for bit error probability and symbol slipping take effect at the time decoder synchronization is achieved. Symbol synchronization time will be measured from the time carrier acquisition is achieved to the time symbol synchronization is defined as having been achieved when the error rate for the next 1000 bits is 10^{-5} or less.

Note

Data and symbol transition densities and P_{rec} values higher than the minimums required will reduce these acquisition times.

d. Time Delay Measurement. WSC can determine the value of the WSC time delay for each TDRSS KSA return service channel (with symbol rates $\leq$6 Msps for NRZ symbols and $\leq$3 Msps for biphase symbols) prior to and following each scheduled support period and at reconfigurations during the support period. The reported value is the time delay from the WSC antenna input to the WSC output for each channel to an accuracy of $\pm$25 percent of a data bit period for data rates <250 kbps or $\pm$1 μsec for data rates $\geq$250 kbps. The time delay measurement may be requested in the SHO and will be available to the user POCC/MOC from the NCC after termination of the scheduled service. WSC time delay measurements are not available for TDRSS KSA return service channel data rates >6 Mbps per I or Q channel.

3.4.3.6 Autotrack/Signal Acquisition Scenarios. The following acquisition scenario identifies only the technical aspects of TDRSS KSA return service autotrack (if enabled) and signal acquisition by the WSC and does not include operational procedures related to acquisition (refer also to Appendix C):

a. Acquisition Scenario

Note

T_F = Scheduled start time of the TDRSS KSA forward service, and
T_R = Scheduled start time of the TDRSS KSA return service.

(1) KSA Autotrack Description. The TDRSS KSA return service autotrack acquisition process (if enabled) is a noncoherent detection process. The process will acquire and track a user spacecraft KSA return service signal independent of whether that signal is coherent or noncoherent relative to a TDRSS KSA forward service

signal being concurrently transmitted by that TDRS in the direction of that user spacecraft.

(2) Autotrack Power Requirement. For the TDRSS KSA return service autotrack process (if enabled) to acquire a user spacecraft KSA return service signal, the KSA return service P_{rec} must either be at least -182.8 dBW, or consistent with the ADR, whichever is greater (refer to Table 3-23).

(3) Autotrack Operational Process. When the TDRSS KSA return service autotrack process is initiated, or reinitiated by receipt and implementation of an appropriate KSA return service reconfiguration or reacquisition OPM from the NCC (refer to Table 4-2 and Table 4-3), the process starts in its coarse-track mode. In the coarse-track mode, the WSC initially open-loop points the TDRS SA antenna in the calculated direction of the user spacecraft. The WSC then processes error signals derived from the received user spacecraft KSA return service signal to use as a vernier to correct for small error build-ups in moving the TDRS antenna at the calculated angular rate of the user spacecraft. The process will transfer to its fine-track mode (i.e., autotracking the received user spacecraft KSA return service signal) within 15 seconds after the time when the signal is first present at the TDRS with adequate KSA return service P_{rec} [refer to paragraph (2)]. If the user spacecraft KSA return service signal is present when the TDRSS KSA return service autotrack process initially starts or restarts its coarse-track mode [refer to paragraphs (8) and (9)], the WSC will complete its KSA return service signal acquisition processes (refer to paragraph 3.4.3.5c) prior to the autotrack process transferring to its fine-track mode.

(4) TDRS Forward EIRP Level. If the TDRSS KSA return service autotrack process is enabled, then the TDRS KSA forward service signal EIRP, in the calculated direction of the user spacecraft, will initially be at least 40 dBW (TDRSS KSA forward service acquisition mode EIRP, refer to Table 3-20). The TDRS KSA forward service signal EIRP may not reach its scheduled normal or high power level until the TDRSS KSA return service autotrack system (if enabled) has transferred to its fine-track mode. If the TDRSS KSA return service autotrack process is inhibited, refer to paragraph 3.4.1.4a.

(5) Forward and Return Relative Service Start Time for Coherent Channels. For optimal TDRSS KSA return service operations, all coherent services should have the TDRSS forward and return services starting at the same time. If operational conditions 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.

(6) Forward acquisition Prior to T_R. If the user spacecraft design requires user spacecraft autotrack system acquisition of the TDRSS KSA forward service signal prior to T_R in order to provide sufficient KSA return service EIRP in the direction of the TDRS to satisfy the P_{rec} requirements, and if T_F is prior to or at T_R, the user spacecraft KSA autotrack system must be able to acquire the TDRS KSA forward

service signal at a signal level consistent with the TDRS KSA forward service acquisition mode EIRP.

(7) Forward and Return Relative Service Times for Open-Loop Pointing. If the user spacecraft design allows for accurate enough open-loop pointing of its KSA antenna in the direction of the TDRS to ensure adequate KSA return service P_{rec}, then the noncoherent TDRSS KSA return services (DG1 mode 2 and DG2 [noncoherent operations]) can be provided to that user spacecraft independent of the status of the TDRSS KSA forward service, and T_F may be later than T_R. For example, these TDRSS services can be provided even if the TDRSS KSA forward service has not been scheduled, or the user spacecraft KSA forward service autotrack system has failed, or has been inhibited.

(8) Reacquisition Operations. When the WSC receives an appropriate KSA return service reconfiguration or reacquisition OPM from the NCC [refer to paragraph (3) and to paragraph 4.3], the WSC reverts to open-loop pointing the TDRS SA antenna (in the calculated direction of the user spacecraft position) from the time that the WSC terminates the ongoing TDRSS KSA return service support (as a result of receipt and acceptance of the reacquisition or reconfiguration OPM) until the time that the WSC completes its implementation of that OPM. As a result, the TDRSS KSA forward service EIRP may reduce (during this period) from its scheduled, or previously reconfigured, signal EIRP level to the acquisition mode EIRP level. It is recommended that the user spacecraft KSA autotrack system be able to maintain autotrack tracking at received signal levels consistent with the TDRSS KSA forward service acquisition mode EIRP. Depending upon the user spacecraft KSA forward service receiving system design, this latter TDRSS KSA forward service EIRP level may be inadequate to support user spacecraft KSA forward service carrier, range and/or command channel PN code, and/or command channel signal tracking performance requirements.

(9) Drop in Received Power Level. This paragraph discusses WSC procedures when there is a temporary decrease in KSA return service P_{rec} below the minimum level required by the TDRSS KSA return service autotrack process. For a maximum of 60 seconds after the KSA return service P_{rec} has first fallen below the minimum required level, the TDRSS KSA return service autotrack process rate logic causes the TDRS SA antenna to continue moving at the calculated user spacecraft angular rate, but with the off-set biases built up during the preceding coarse- and fine-track mode operations. If, within that 60 seconds, the KSA return service P_{rec} has increased back to or above the minimum level required by the TDRSS KSA return service autotrack process, 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 user spacecraft position. This procedure has been implemented to bridge the gap in normal closed-loop autotracking of the user spacecraft KSA return service signal so as to maintain the TDRSS KSA forward service signal EIRP at its scheduled level in the expected direction of the user spacecraft position. However, if after 60 seconds the KSA return service P_{rec} has not increased back to or above the minimum level required by the TDRSS KSA return service autotrack process, the WSC reverts to open-loop pointing the TDRS

SA antenna in the calculated direction of the user spacecraft position. As a result, the TDRSS KSA forward service EIRP may reduce from its scheduled, or reconfigured, signal EIRP level to the acquisition mode EIRP level. It is recommended that the user spacecraft KSA autotrack system be able to maintain autotrack tracking at received signal levels consistent with the TDRSS KSA forward service acquisition mode EIRP. Depending upon the user spacecraft KSA forward service receiving system design, this latter TDRSS KSA forward service EIRP level may be inadequate to support user spacecraft KSA forward service carrier, PN code, and/or signal tracking performance requirements. The TDRSS KSA return service autotrack process will not restart until the KSA return service P_{rec} has increased back to or above the minimum level required by that process.

(10) Interference Mitigation to S-band Users. An instantaneous P_{rec} increase in the TDRSS KSA return service channel being supported via the TDRS composite downlink Traveling Wave Tube Amplifier (TWTA) can potentially cause BER degradations to other TDRSS SSA and Shuttle S-band return services being concurrently supported via that same TDRS. For a user spacecraft KSA return service signal that results in a P_{rec} greater than -159.2 dBW, it is recommended that the user POCC/MOC plan to use the following operational procedure to minimize return service performance degradations to other ongoing user spacecraft missions due to an instantaneous increase in K-band P_{rec} level caused either by its user spacecraft signal being present at, or prior to, T_R or by its user spacecraft turning on its transmitting system at, or subsequent to, T_R:

(a) Prior to T_R: The P_{rec} (resulting from the user spacecraft KSA 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 user spacecraft KSA 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 user spacecraft KSA 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).

(11) Return Data Loss Minimizations. To minimize loss of desired user spacecraft return service data, and for either coherent or noncoherent KSA return service operations, it is recommended that the user POCC/MOC have its user spacecraft transmit only an idle pattern on each data channel, and not real data, until after it has observed (via the ODM data) that the WSC has completed all of its data channel signal acquisition processes (refer to paragraph 3.4.3.5c).

b. DG1 Mode Transitions. User POCC/MOCs that plan to operate their user spacecraft in both DG1 modes 2 and 1 (or 3) during a single service support period are advised that TDRSS KSA return service mode transitions via reconfiguration OPMs must take into

account the requirement of scheduling a corresponding TDRSS KSA forward service for this service support period. The following conventions apply:

(1) DG1 Mode 2 to DG1 Mode 1 (or 3) Transitions: The TDRSS KSA forward service to the user spacecraft must be scheduled to be established prior to user POCC/MOC transmission of the GCMR to the NCC requesting that the NCC reconfigure the TDRSS for DG1 mode 1 (or 3) operations (refer to paragraph 3.4.3.6.a.(5)).

(2) DG1 Mode 1 (or 3) to DG1 Mode 2 Transitions: Refer to paragraph 3.4.3.5.b(2) for a discussion on DG1 Mode 1 (or 3) to DG1 Mode 2 transitions.

Note

Failure to observe these conventions may result in WSC rejection of reconfiguration messages from the NCC, excessive times for the WSC to reacquire the user spacecraft signal after WSC reconfiguration, and unnecessary loss of user spacecraft return service data.

c. DG2. When the user spacecraft is in a coherent turnaround configuration, the WSC return service signal acquisition will be identical to DG1 mode 1 except that DG2 signal parameters apply. When the user spacecraft is in a noncoherent configuration, the WSC return service signal acquisition will be identical to DG1 mode 2 except that DG2 signal parameters apply. Refer to paragraph a.

Note

The WSC return service demodulators check on a 1-second cycle whether or not user spacecraft KSA return service signal carrier lock has been lost. When carrier lock is first lost, WSC symbol synchronization and WSC Viterbi decoder lock (if encoded) will also be lost almost concurrently. These loss-of-lock indications appear in the periodically updated (every 5 seconds) ODM for that user spacecraft KSA return service support period. Upon receipt of the loss-of-lock indications in the ODM, the user POCC/MOC may request the NCC to send a TDRSS KSA return service reacquisition OPM to the WSC (refer to paragraph 4.3). It is recommended that the user POCC/MOC delay initiation of the GCMR to the NCC for at least 35 seconds after initial receipt of the loss-of-lock indications in the ODM. An Acquisition Failure Notification OPN is sent from WSC to NCC if the automatic reacquistion process fails to reacquire the user signal within 10 seconds of loss-of-lock.

3.4.3.7 TDRSS KSA Return Service Constraints/Restrictions

a. General. The TDRSS KSA return services and tracking services will be provided without degradation for user spacecraft transmitted signal characteristics within the constraints specified in paragraphs b through g and Table 3-24. Refer to paragraph 1.8 for guidelines if the constraints in this paragraph cannot be met. The definitions of user spacecraft constraints are given in Appendix E.

b. DG1 and DG2.

(1) The individual user spacecraft channel data rates must each be defined by the user POCC/MOC to the NCC to within $\pm$0.1 percent.

(2) The Q/I (power) must be defined by the user POCC/MOC to the NCC to within $\pm$0.4 dB.

c. DG2 Only. For unbalanced QPSK, the I channel must contain the higher data rate. 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.

d. Symbol Transition Restrictions. Within any sequence of 512 symbols, the number of transitions in each user spacecraft channel symbol stream must be $\geq$128 and the maximum number of consecutive symbols without a transition must be $\leq$64.

e. User Spacecraft Angular Velocity for Autotrack Acquisition. If the TDRSS return service autotrack mode is enabled, the probability of pointing the TDRS KSA antenna with sufficient accuracy to establish service for any user spacecraft within the field of view of the TDRS is $\geq$99 percent when the user spacecraft's angular velocity does not exceed 0.0135 degree/second. When the user spacecraft's angular velocity exceeds this value, the pointing probability decreases.

f. KSA Autotrack Performance. The following acquisition performance requirements shall apply with a probability > 0.99:

(1) Autotrack acquisition is achieved within 10 seconds for a minimum P_{rec} value of -182.8 dBW or consistent with the ADR, whichever is greater (refer to Table 3-23).

(2) Autotrack acquisition and subsequent autotracking shall be achieved for user incidental amplitude modulation (AM) of $\leq$ 0.6%, 10 Hz to 2 kHz; $\leq$ 3.0%, 2 kHz to 10 kHz; and $\leq$ 5%, $\geq$ 10 kHz.

(3) In the event that autotrack acquisition does not occur within the time specified, the acquisition process will continue until autotrack acquisition occurs, or until a reacquisition is requested, or until the end of scheduled service.

Table 3-24. TDRSS KSA Return Service User Spacecraft Signal Constraints (Note 7)

Parameter	Description
Data bit transition density (average) (note 1)	≥25 percent
Consecutive data bits without a data bit transition (note 1)	≤64 data bits
Data asymmetry (peak) (note 1)	≤ ± 3 percent
Data rise time (note 1) (90 percent of initial state to 90 percent of final state)	≤5 percent of data bit duration
Symbol (data) bit jitter and jitter rate (notes 1 and 2)	≤ 0.1 percent (see paragraph E.1.2.3)
BPSK phase imbalance	≤ ± 3 degrees
QPSK phase imbalance	≤ ± 3 degrees
Gain imbalance	≤ ± 0.25 dB
Phase nonlinearity (applies for all types of phase nonlinearities) (peak)	≤3 degrees over ±80 MHz
Gain flatness (peak)	≤0.3 dB over ±80 MHz
Gain slope	≤0.1 dB/MHz over 80 Mhz
AM/PM	≤12 deg/dB
Frequency stability (peak)	
1-sec observation time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 1 \times 10^{-7}$
48-hr observation time	$\leq 3 \times 10^{-7}$
Incidental AM (peak)	
At frequencies between 10 Hz and 2 kHz	≤0.6 percent (note 3)
At frequencies between 2 kHz and 10 kHz	≤3 percent
At frequencies ≥10 kHz	≤5 percent
Untracked spurious PM	≤2 degrees
Minimum 3-dB bandwidth prior to power amplifier (note 4)	DG1: ≥4.5 MHz or two times maximum symbol rate, whichever is larger DG2: ≥2 times maximum channel symbol rate

Table 3-24. TDRSS KSA Return Service User Spacecraft Signal Constraints (Note 7) (cont)

Parameter	Description
Untracked phase noise (rms) (coherent and noncoherent)	
DG1	≤3 degrees
DG2	
BPSK	≤3 degrees
I/Q = 1	≤2 degrees
I/Q = 4	≤1 degree
I/Q data skew (relative to requirements for I/Q data synchronization where appropriate) (peak) (note 1)	≤3 percent
I/Q PN code chip skew (relative to 0.5 chip)	≤0.01 chip
PN code chip rate (peak) DG1 mode 2 (relative to absolute coherence with carrier rate)	≤0.01 chips/sec at PN code chip rate
PN code power suppression (noncoherent and coherent)	≤0.3 dB
Axial ratio for autotrack	≤3 dB
Permissible P_{rec} variation (without reconfiguration GCMR from user POCC/MOC) (note 5)	≤12 dB
Permissible rate of P_{rec} Variation	≤10 dB/sec
Maximum P_{rec}	-149.2 dBW
Minimum P_{rec} for TDRSS KSA return service autotrack	-182.8 dBW or consistent with ADR value, whichever is greater (note 6)

Table 3-24. TDRSS KSA Return Service User Spacecraft Signal Constraints (Note 7) (cont)

Note

1. When the data is Rate 1/2 convolutionally encoded, these data bit parameters should be interpreted as symbol parameters.

2. The symbol (data) jitter and jitter rate are defined as the user transmitted signal peak clock frequency and peak clock jitter rate (sinusoidal or 3σ random) as a percent of the symbol (data) clock rate.

3. The TDRSS design implementation may not provide the stated TDRSS KSA 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 KSA 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.

4. For the purpose of minimum bandwidth definition, the symbol rate for the Bi∅-formatted data will be twice the symbol rate prior to the NRZ-to-Bi∅ data format conversion of the convolutional encoder output.

5. The P_{rec} at the low end of the variation range must be $\leq P_{rec}$ (minimum) (refer to Table 3-23). For all KSA return service signals with channel symbol rates ≤6 Msps, the allowable variation range of 12 dB is based upon the SHO minimum EIRP value varying from -3 dB to +9 dB relative to the actual user EIRP. An EIRP value less than the -3 dB variation results in a longer acquisition time, while an EIRP exceeding the +9 dB variation may cause false PN lock or nonacquisition.

6. Failure to provide this minimum P_{rec} at the start of service may preclude successful TDRSS autotrack pullin.

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.

3.4.4 KSA TRACKING SERVICES

3.4.4.1 General. The TDRSS will provide user spacecraft one-way Doppler measurements and two-way range and Doppler measurements. The user spacecraft one-way Doppler measurements will be available on return service channels for all DG1 mode 2 and DG2 (noncoherent) operations. The user spacecraft two-way Doppler and time transfer measurements will be available to DG1 modes 1 and 3 and DG2 (coherent) operations. The user spacecraft two-way range measurements will be available for DG1 modes 1 or 3 operations (i.e., PN spread modes).

3.4.4.2 Range Tracking

a. General. The TDRSS tracking service will be capable of providing accurate and independent (sample-to-sample) range data as indicated in paragraphs b through f with user spacecraft signal Doppler frequencies to $\pm$1.6 MHz and Doppler rates to $\pm$10.5 kHz/sec.

b. Range Measurement rms Error. The rms error contribution to range measurement resulting from the TDRSS will not exceed 10 nsec for user spacecraft with a P_{rec} of at least -182.8 dBW or a P_{rec} consistent with the ADRs listed in Table 3-23, whichever is greater.

c. Range Measurement Systematic Error. The systematic range error contribution from a TDRS will be less than $\pm$35 nsec based on prelaunch measurement and predicted on-orbit performance. The systematic range error contribution from WSC will be less than $\pm$30 nsec.

d. Range Granularity. The range granularity, which is the smallest discrete output of the WSC receiver, is 1 nsec.

e. Range Ambiguity Interval. The minimum unambiguous range measurement is equal to the period (nominally 86 msec) of the TDRSS forward service range channel PN code.

f. TDRSS Delay Compensation. The WSC ranging system will compensate the range measurement for the delays internal to the TDRSS (WSC and TDRS).

3.4.4.3 Doppler Tracking

a. General. The TDRSS tracking service will be capable of providing Doppler information with the accuracy and characteristics specified in paragraphs b through d for user spacecraft signal Doppler frequencies to $\pm$1.6 MHz and signal Doppler rates to $\pm$10.5 kHz/sec. The Doppler signal is biased and processed so that a signal of 240. MHz + 100 f_d is obtained, where f_d is the Doppler. The Doppler count at the WSC is nondestruct with a WSC capability of maintaining a continuous count for a minimum of 50 minutes. 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.

Note

The definition of 240. MHz is 240.0000 MHz, where the magnitude of the fraction portion is the accuracy of the WSC frequency standard.

b. Doppler Measurement rms Phase Noise. The rms phase noise contribution to Doppler tracking, resulting from the TDRSS, will not exceed 0.2 radians for user spacecraft with a P_{rec} consistent with the ADRs listed in Table 3-23.

c. Reference Frequency.

(1) For two-way Doppler measurements, WSC forward service Doppler compensation is inhibited, and the reference frequency for the WSC Doppler extractor is coherently related to the forward service transmit frequency consistent with the appropriate frequency turnaround ratio, assuming no relative motion between the TDRS and the WSC. Such inhibition is accomplished by the WSC only when a Doppler compensation inhibit request is received via an OPM from the NCC or if Doppler inhibition is scheduled by the SHO. During this Doppler compensation inhibit mode, the TDRS forward service transmit frequency is held constant so that the reference frequency for two-way Doppler measurement at the WSC is an integral multiple of 1600 Hz. Because the reference frequency is the user spacecraft transmit frequency, which is coherently related to the received TDRS forward service frequency by the coherent turnaround ratio (1600/1469), this is accomplished by fixing the TDRS forward service transmit frequency at an integral multiple of 1469. The reference frequency is therefore given by:

$$f_{ref} = f_T\left(\frac{1600}{1469}\right)$$

where f_T is the TDRS forward service transmit frequency after WSC Doppler compensation has been accomplished.

(2) For one-way Doppler measurements, the reference frequency for the Doppler extractor will be the user spacecraft transmit frequency as defined in the SHO to the accuracy of the WSC frequency standard.

d. Doppler Granularity. A Doppler granularity of 1×10^{-2} cycle is provided.

3.4.4.4 Time Transfer Measurement

a. General. The TDRSS two-way tracking service will be capable of providing time transfer data as indicated in paragraphs b through e with user spacecraft signal Doppler frequencies to $\pm$1.6 MHz and Doppler rates to $\pm$10.5 kHz/sec. The WSC will measure the elapsed time between a reference time epoch and the next outgoing forward link range channel PN epoch. The WSC will measure the elapsed time between that reference time epoch and the first return link PN epoch to arrive after the outgoing forward link PN epoch.

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 WSC.

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 will compensate the time transfer measurement for delays internal to the TDRSS (WSC and TDRS).

3.4.4.5 Measurement Timing

a. General. The WSC frequency reference stability is consistent with TDRSS tracking and telecommunication performance capabilities.

b. Timing Accuracy. The WSC epoch times for range, Doppler, and time transfer measurements will be within ±5 μsec of UTC. The WSC epoch times will be traceable to within ±100 nsec of UTC time.

c. Data Sampling. Range and Doppler measurement data are sampled on-time to within ±1 μsec and ±25 nsec, respectively. "On-time" refers to that portion (leading or trailing edge) of the timing signal which is synchronized with UTC at the output of the WSC timing system and is used for sampling the measurement data.

d. Sample Intervals. Sample intervals are available for the range and Doppler measurement data. Data can be sampled at selectable intervals, in sec/sample, of 1, 5, 10, 60, and 300. Intervals between time transfer measurements are 1 second.

3.4.4.6 Operation of Doppler Compensation Inhibit

a. Peak Frequency Dynamics. WSC Doppler compensation inhibit must be initiated by a GCMR from the user POCC/MOC to the NCC prior to all periods of TDRSS two-way range and Doppler measurements. When the Doppler compensation inhibit mode is selected after operating in the Doppler compensation mode, the user spacecraft receiver will see the forward service frequency dynamics. The peak frequency dynamics that can be seen by the user spacecraft receiver (due to relative TDRS-user spacecraft velocities up to 12 km/sec, accelerations up to 15 m/sec^2, and jerks up to 0.02 m/sec^3) are frequency offsets up to ±570 kHz, frequency rates up to ±740 Hz/sec, and frequency accelerations up to ±1 Hz/sec^2, respectively. The user project must ensure that the user spacecraft receiver signal tracking characteristic is compatible with the peak frequency dynamics experienced or that the Doppler compensation inhibit mode will be selected only over portions of the

user spacecraft orbit where the frequency dynamics are low. Failure to do so can result in forward service, return service, and tracking service outages if the user spacecraft receiver PN code and/or carrier loops unlock.

b. Transition Process. A slow and hold process is used by the WSC to establish Doppler compensation inhibit and reinitiate Doppler compensation. Doppler compensation inhibit will be initiated within 10 seconds of receipt of the appropriate OPM by the WSC and completed within 10 seconds after initiation. Upon reinitiation of Doppler compensation by the WSC, the TDRSS forward service carrier frequency will change slowly to the corrected Doppler compensated value.

3.5 TDRSS SERVICES TO SPACE SHUTTLE PAYLOADS

3.5.1 GENERAL

3.5.1.1 The Space Shuttle uses the SN for its primary communications. The services (telecommunications and others) which the Space Shuttle provides to user spacecraft payloads and the user-Shuttle interface requirements associated with each of these services are described in JSC Document 07700, Volume XIV, Space Shuttle Payload System, Payload Accommodations, Attachment 1, ICD 2-19001, Shuttle Orbiter/Cargo Standard Interfaces, Revision G, September 26, 1980. Section 8.0, Avionics Interfaces, of this document describes specifically the TDRSS forward and return service capabilities and the interface requirements that each TDRSS service imposes on the user spacecraft payload. Data formats and user signal characteristic requirements are defined for each TDRSS service. These Shuttle services are summarized briefly in paragraphs 3.5.2 through 3.5.4. However, user projects should communicate directly with the following office at the JSC:

Manager
JSC/Payload Integration Office: Code LP
Johnson Space Center
Houston, Texas 77058
(713) 483-2343

3.5.1.2 The TDRSS and Shuttle functional configurations for the S-band and K-band forward and return services, respectively, are contained in Appendix B, paragraph B.4.

3.5.2 ATTACHED USER SPACECRAFT PAYLOADS

3.5.2.1 General. Attached user spacecraft payloads can be served by the Payload Data Interleaver (PDI), Multiplexer/Demultiplexer (MDM), Orbiter/Payload Recorder (OPR), K-band processor, payload signal processor, S-band FM signal processor, and Shuttle-to-cargo data bus.

3.5.2.2 Payload Data Interleaver. The Shuttle provides for the acquisition of asynchronous Pulse Code Modulated (PCM) signals for up to five attached payloads. It can accommodate four input data streams simultaneously with a maximum composite on-orbit output of 64 kbps consisting of payload data, PDI status, and Shuttle time tags. Shuttle-standard and Shuttle-nonstandard formats for PDI inputs are described in JSC Document 07700, Volume XIV.

3.5.2.3 MDM. The Shuttle provides data channels for the acquisition and control of attached user spacecraft payloads through the MDMs under control of the Shuttle computers. The following are available:

a. Low-level discrete outputs.

b. High-level discrete outputs.

c. Low-level discrete inputs.

d. High-level discrete inputs.

e. Low-level differential analog inputs.

f. Serial data input/output.

3.5.2.4 Orbiter/Payload Recorder. The OPR provides the capability to record Bi∅-L digital and analog data simultaneously on up to 14 tracks. Standard speeds of 6, 7.5, 38, and 230 in./sec are available and nonstandard speeds of 9.5, 12, 15, 19, 24, 30, 48, 60, 76, and 96 in./sec are available.

3.5.2.5 K-band Signal Processor. The K-band signal processor provides data to and from attached user spacecraft payloads at 2 to 50 Mbps data rates.

3.5.2.6 Payload Signal Processor. The payload signal processor can provide commands to up to five attached payloads, commanding one payload at a time (time shared).

3.5.2.7 S-band FM Signal Processor. The S-band FM signal processor can handle the following attached user spacecraft payload signals:

a. 300 Hz to 4 MHz analog inputs.

b. 200 bps to 5 Mbps digital inputs.

c. 250 bps to 256 kbps Department of Defense data inputs.

3.5.2.8 Audio Central Control Network. This interface can process duplex voice communications to attached manual payloads.

3.5.2.9 CCTV Video Control Unit. This interface can provide video, synch, and control signals to/from an attached user spacecraft payload.

3.5.3 DETACHED USER SPACECRAFT PAYLOADS

3.5.3.1 General. Detached user spacecraft payloads can be served by the Payload Interrogator (PI), via the bent-pipe mode, and through use of the K-band rendezvous radar.

3.5.3.2 Payload Interrogator. The PI provides full-duplex RF communications between the Shuttle and detached user spacecraft payloads and includes the transmission of commands to and receipt of telemetry from these payloads. For standard payloads, commands are modulated on a 16 kHz subcarrier by the PI, while the payload modulates telemetry on a 1.024 MHz subcarrier. For nonstandard payloads, commands can directly modulate the PI transmitter, while all telemetry must be phase modulated by the user spacecraft payload (suppressed carrier modulation is not allowed).

3.5.3.3 Payload Signal Processor. The payload signal processor can provide command data to a single detached user spacecraft payload and can receive payload telemetry from a single detached user spacecraft payload via the PI.

3.5.3.4 Bent-pipe Mode. The Shuttle PI provides a bent-pipe mode for detached user spacecraft payloads to permit remodulation of the received S-band data signal onto the TDRSS K-band return service carrier.

3.5.4 SHUTTLE TRANSMITTER/RECEIVER CONFIGURATIONS

Functional configurations that delineate the data format and data channel ambiguities resolved by the Shuttle and the WSC are delineated in Appendix B, paragraph B.4 for the TDRSS Shuttle S-band and K-band forward and return services.

3.6 TDRSS END-TO-END TEST (EET) SERVICES

3.6.1 GENERAL

3.6.1.1 The TDRSS EET service provides simulation and test of telecommunications services to users without the use of the actual user spacecraft. The TDRSS can provide forward and return EET telecommunications services either in conjunction with or completely independent of one another. EET services for MA forward/SSA return and SSA forward/MA return are also available. The TDRSS functional configuration for forward and return EET services are shown in Appendix B.

3.6.1.2 Two EET service modes are available to users as described below.

a. Local Mode.

(1) Forward EET: Simulated user forward data is generated in a Bit Error Rate (BER) test set or data tape(s) at the WSC. The data is modulated, upconverted, amplified, and uplinked to TDRS. The TDRS relays the uplinked data to the simulated user at the WSC, where it is down converted and switched to the appropriate receiver. The receiver recovers the data and outputs it to the BER test set, where it is compared to the data originally transmitted.

(2) Return EET: For all return service configurations other than K-band Shuttle, two simulated data streams (I and Q) are generated by BER test sets or data tape(s) at the WSC. The data is modulated, upconverted, amplified, and transmitted to the TDRS via the assigned EET antenna. The TDRS relays the data back to the WSC via the

normal return link path. The return service equipment at WSC recovers the data and outputs it to the BER test set, where it is compared to the data originally transmitted.

b. POCC/MOC Mode.

(1) Forward EET: Simulated user forward data is provided by the user POCC/MOC to the WSC via NASCOM. The data is modulated, upconverted, amplified, and uplinked to TDRS. The TDRS relays the uplinked data to the simulated user at the WSC where it is down converted and switched to the appropriate receiver. The receiver recovers the data and delivers it to the user POCC/MOC via NASCOM.

(2) Return EET: The user POCC/MOC provides two simulated return data streams (I and Q) to the WSC via NASCOM. The data is modulated, upconverted, amplified, and transmitted to the TDRS via the assigned EET antenna. The TDRS relays the data back to the WSC via the normal return link path. The return service equipment at WSC recovers the data and delivers it to the user POCC/MOC via NASCOM.

3.6.2 FORWARD END-TO-END TEST SERVICE

3.6.2.1. General. Each WSC TDRS-SGLT pair can simultaneously provide both S-band and K-band EET forward services. The S-band services can be any one of the following: MA, SSA, or S-band Shuttle. Similarly, the K-band service can be either KSA or K-band Shuttle telecommunications service.

3.6.2.2 Forward EET Service Characteristics.

a. Forward EET service signal parameters are defined in Tables 3-1, 3-10, and 3-19 for MA, SSA, and KSA, respectively.

b. The forward EET service data rate for user POCC/MOC generated KSA forward data must be $\leq$ 7 Mbps.

c. The TDRSS is capable of simulating the user G/T, frequency, and polarization as specified in Table 3-25.

Table 3-25. Forward End-to-End Test Service Performance Characteristics

Parameter	S-band	K-band
Nominal frequency	2020 to 2123 MHz adjustable in 10 Hz steps	13,775 MHz $\pm$ 700 kHz
G/T	-50 to -10 dB/K adjustable in 1.0 dB steps	-27 to 21 dB/K adjustable in 1.0 dB steps
Polarization	LHC or RHC, selectable	LHC or RHC, selectable

3.6.3 RETURN END-TO-END TEST SERVICE

3.6.3.1. General. Each WSC TDRS-SGLT pair can simultaneously provide both S-band and K-band EET return services. The S-band services can be any one of the following: MA, SSA, or S-band Shuttle. Similarly, the K-band service can be either KSA or K-band Shuttle telecommunications service.

3.6.3.2 Return EET Service Characteristics

a. Return EET service signal parameters are defined in Tables 3-5, 3-14, and 3-22 for MA, SSA, and KSA, respectively.

b. The total return EET service data rate (I + Q) for user POCC/MOC generated KSA return data must be $\leq$ 10 Mbps. The individual channel return EET service data rate (I or Q) for user POCC/MOC generated KSA return data must be $\leq$ 7 Mbps.

c. The TDRSS is capable of simulating the user frequency, EIRP, and polarization as specified in Table 3-26.

Table 3-26. Return End-to-End Test Service Performance Characteristics

Parameter	S-band	K-band
Frequency	2200 to 2300 MHz adjustable in 10 Hz steps	15,003.4 MHz $\pm$ 1.5 MHz
EIRP	-11 to 45 dBW adjustable in 1.0 dB steps	-3 to 60 dBW adjustable in 1.0 dB steps
Polarization	LHC or RHC, selectable	LHC or RHC, selectable