450-DP-KaTP

MISSION SERVICES PROGRAM OFFICE

Ka-Band Transition Product High Data Rate Demonstration Plan

November 2002

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

Ka-Band Transition Product High Data Rate Demonstration Plan

November 2002

Prepared by:

David T. Miller, ITT Industries — Date 1/9/03
Ka-Band Transition Product Test Director
CSOC GSFC

Approved by:

Yen F. Wong — Date 1/9/03
Ka-Band Transition Product Design Lead
Code 567, Microwave And Communications Systems Branch

Goddard Space Flight Center
Greenbelt, Maryland

Preface

This Ka-Band Transition Product (KaTP) High Data Rate Demonstration Plan describes the overall plan to demonstrate that the Space Network (SN) and Ground Network (GN) can support customers with data rates up to 600 Mbps at Ka-Band frequencies. Separate test procedure documents will also be written to state the exact SN and GN step-by-step procedures that will be taken to meet the demonstration objectives stated in this demonstration plan.

This document is under the internal configuration management of the Ka-Band Transition Product Design Lead. Proposed changes to this document should be submitted to the Ka-Band Transition Product Design Lead along with supportive material justifying the change. Changes to this document shall be made by complete revision. Questions and proposed changes concerning this document shall be addressed to:

Ka-Band Transition Product Design Lead
Code 567, Microwave And Communications Systems Branch
Building 12
Goddard Space Flight Center
Greenbelt, Maryland 20771

Change Information Page

List of Effective Pages	
Page Number	**Issue**
All	Original

Document History			
Document Number	**Status/Issue**	**Publication Date**	**CCR Number**
450-DP-KaTP	Original	November 2002	N/A

Table Of Contents

SECTION 1. OVERVIEW 1-1

1.1 Introduction 1-1
1.2 Objectives 1-1
1.3 Approach and Configurations 1-1

SECTION 2. GROUND NETWORK DEMONSTRATION 2-1

2.1 GN Demonstration Overview and Configuration 2-1
2.2 BER Demonstrations 2-1
2.3 Antenna Acquisition/Tracking Demonstrations 2-2

SECTION 3. SPACE NETWORK DEMONSTRATION 3-1

3.1 SN Demonstration Overview and Configuration 3-1
3.2 SN Demonstration Approach 3-1

SECTION 4. DEMONSTRATION DOCUMENTATION 4-1

SECTION 5. DEMONSTRATION SCHEDULE 5-1

SECTION 6. ACRONYMS 6-1

Tables

Table 2-1. GN BER And Antenna Acquisition Test Equipment 2-5

Table 3-1. SN BER Test Equipment 3-5

Table 5-1. Ka-Band Demonstration Schedule 5-1

Figures

Figure 1-1. Demonstration Configurations 1-2

Figure 2-1. GN Demonstration End-To-End Test Configuration 2-3

Figure 2-2. GN Loop-Back Test Configuration 2-4

Figure 3-1. SN Demonstration Configuration (End-To-End Tests) 3-3

Figure 3-2. SN Loop-Back Test Configuration 3-4

Section 1. Overview

1.1 Introduction

Space Network (SN) customers are currently supported at data rates up to 300 Mbps using the TDRSS K-band single access (KSA) service, which operates at Ku-band. The Ground Network (GN) currently supports customers at frequencies no higher than X-band and at data rates up to 300 Msps (rate ½ coded). The Ka-Band Demonstration will show that the SN and GN can support customers with data rates up to 600 Mbps at Ka-band frequencies. The high rate capabilities required for the Ka-band demonstration are fundamentally equivalent for both the SN and GN due to the common intermediate frequency (IF) interface design in both networks.

1.2 Objectives

The main objective of the Ka-Band Transition Product (KaTP) demonstration is to establish that Ka-band return communications is feasible at data rates up to 600 Mbps using both the GN and the SN.

More specifically, the objectives of the demonstration are to:

1. Characterize the performance of the Ka-band physical return links at data rates up to 600 Mbps
   a. GN: Direct-to-Earth downlink
   b. SN: KaSA return link relayed via TDRS H, I, or J
2. Characterize the acquisition and tracking performance of the GN Ka-band antenna
3. Assess the effects of hardware distortion on the overall links
4. Characterize the GN and SN system designs
5. Provide end-to-end systems i.e., “reference link” or test capability, to help characterize new high rate Ka-band hardware.

1.3 Approach and Configurations

The key objective of the demonstration will be to assess the RF link performance via measurements of implementation losses and the signal spectra. These measurements, in addition to receiver threshold tests with the SN, will be performed at various data rates and simulated customer Effective Isotropic Radiated Powers (EIRPs). For the GN, antenna autotrack acquisition of a moving source will also be demonstrated.

Figure 1-1 is a high-level block diagram of the GN and SN demonstration configurations. A high-rate data transmitter will provide the Ka-band signal source for the demonstrations. The SN demonstration will use the TDRS H or I spacecraft to relay the signal to a White Sands Complex (WSC) ground station. The GN demonstration ground station at the Wallops Flight Facility (WFF) will be used to receive the signal for the GN demonstration.

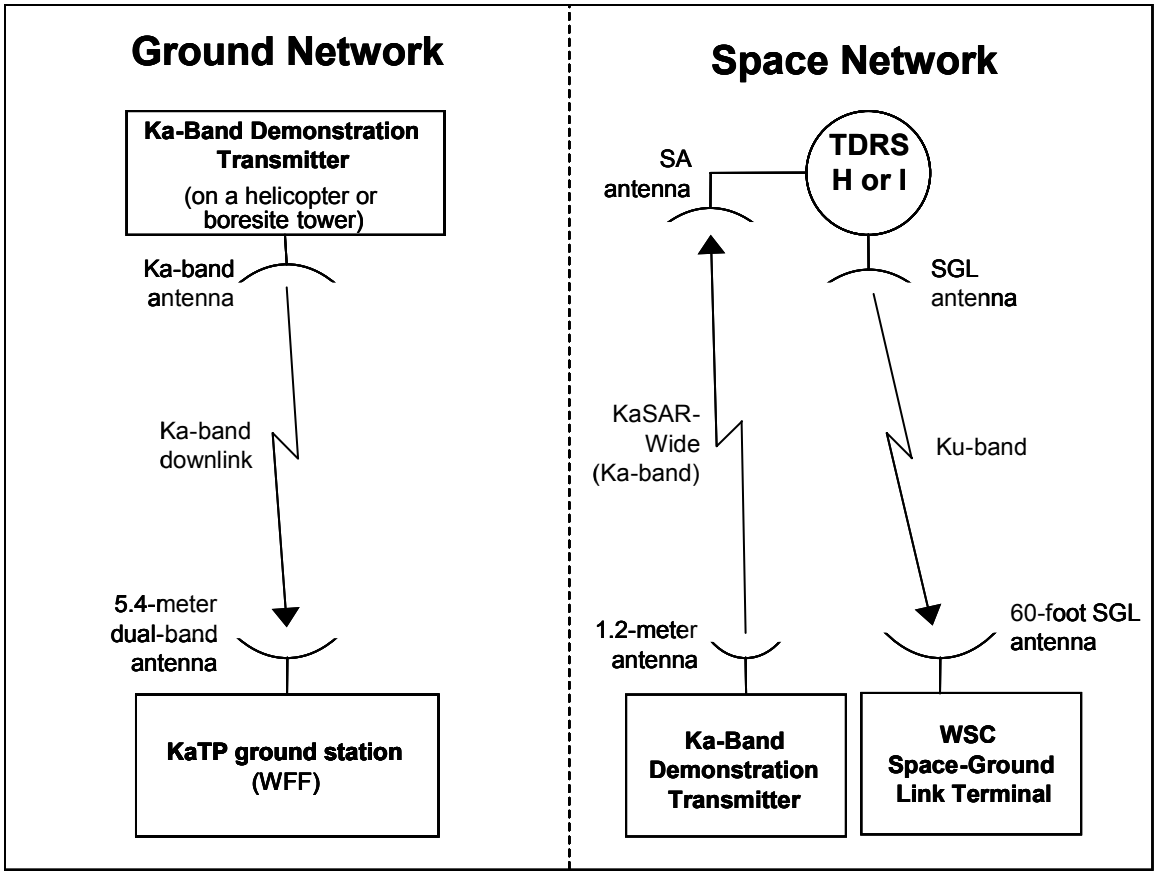

Figure 1-1. Demonstration Configurations

The SN and GN Ka-band demonstrations will be performed sequentially (one after the other) by NASA and support contractor personnel. These demonstrations will maximize the use of existing NASA test equipment in order to minimize the cost associated with procuring new test equipment. The SN demonstrations will utilize on-site test equipment and the existing TDRS H, I, and J KaSA Test Antenna System to simulate a high rate Ka-band Single Access Return (KaSAR) customer.

The GN will utilize a boresite antenna in conjunction with a high rate signal source for bit error rate (BER) testing, and a NASA helicopter will be used for antenna acquisition and tracking tests. The KaTP project will also investigate the use of potential targets of opportunity such as the ENVIronmental SATellite (ENVISAT) spacecraft for the Ka-band demonstrations. Demonstration equipment that is not available in-house will be procured. Equipment procured for the demonstrations will be used at the SN and GN ground stations, but will not be installed permanently for demonstrations or end-to-end testing beyond those performed for the KaTP. If a SN or GN customer requires Ka-band end-to-end testing (reference link) or loop-back testing, the customer will need to make special arrangements with the SN or GN to temporarily configure the ground stations for testing (objective #5).

The current plan is to restrict the modulation scheme of the “reference link” to staggered quadrature phase shift keying (SQPSK) and data rates up to 600 Mbps. For modulation schemes other than SQPSK (e.g., 8PSK/TCM), and data rates higher than 600 Mbps, the customer must provide the compatible transmitter and ground receiver for testing and demonstration.

Section 2. Ground Network Demonstration

2.1 GN Demonstration Overview and Configuration

The key objective of the test will be to assess the RF link performance via measurements of implementation losses, signal spectra, and antenna autotrack parameters. These measurements will be performed at various data rates and simulated customer EIRPs.

Figure 2-1 is a high-level block diagram of the GN test configuration.

The GN demonstration will be conducted at WFF. The WFF Ka-band ground station is a stand-alone, non-operational system; therefore formal scheduling is not required. Two signal sources will be used for the GN demonstration: A boresite tower to demonstrate BER capabilities with a Ka-band transmitter and a helicopter with a Ka-band transmitter to demonstrate autotracking capabilities.

During BER tests, the boresite tower will transmit a SQPSK Ka-band signal that will be received by the 5.4 meter antenna at WFF. The Ka-band ground station will downconvert the signal to a 1.2-GHz IF, and will send it to a high data rate receiver (HDRR). The NASA/GSFC Code 564 Receiver and TSI Receiver will both be used to demodulate the signal and recover the I- and Q- channel data and clock signals for BER measurements.

Two main categories of GN demonstrations will be conducted: BER tests and antenna acquisition/tracking demonstrations. Each of these is discussed in detail below.

2.2 BER Demonstrations

The BER tests will be used to meet demonstration objectives #1, #3, #4, and #5 listed in Section 1.2 above. End-To-End BER tests, which are depicted in Figure 2-1, will be performed using a boresite tower equipped with a Ka-band transmitter. The boresite tower will be located approximately two kilometers from the Ka-band ground station. The Ka-band demonstration transmitter will consist of a pseudo-noise (PN) data generator, high-rate TSI modulator, variable attenuators, a Ka-band upconverter, and antenna. BER tests will also be performed for short loop and medium loop configurations at the ground station to aid in the assessment of the system design and ground station hardware distortion effects.

The short loop test will consist of connecting the 1.2 GHz IF output of the test modulator to the 1.2 GHz IF input of the receiver. This will allow the characterization of the high rate receiver without the distortions induced by other components in the demonstration system. The medium loop test will consist of connecting the output of the Ground Station Ka-band upconverter to a test coupler that is present directly in front of the low noise amplifier (LNA) in the Ka-band ground station. This test will be used to measure the performance degradation associated with the Ground Station Ka-Band upconverter and the ground station front-end components. The short loop and medium loop test configurations are illustrated in Figure 2-2.

When using either receiver, the Ka-band demonstration transmitter will use the TSI modulator which will be configured for dual-channel, uncoded SQPSK modulation with a NRZ-L data format on each channel. The TSI modulator will generate the same Psuedo Random Bit Stream (PRBS) on each channel with a ½ bit offset (SQPSK) after a single PRBS is injected into the I-channel input of the TSI modulator. The receiver will be configured for QPSK and individual I and Q channel BER measurements will be performed. If unexpected BER performance occurs, the demonstration team will be able to better characterize the system performance by isolating the BER performance on the I channel from the BER performance on the Q channel which can not be done if the channels are combined prior to BER measurements.

Multiple data rates will be demonstrated to characterize the system design and performance. The data rates demonstrated will be 50 Mbps, 300 Mbps, 450 Mbps, and 600 Mbps. For each of the above data rates, the output power from the Ka-band demonstration transmitter will be varied in steps in order to vary the E_b/N_0 for BERs between 10^{-4} and 10^{-9}. BER vs. E_b/N_0 curves will be estimated from at least three data points. The E_b/N_0 will be calculated from the measured C/N_0.

The spectrum analyzer display will be stored electronically to document the signal spectra at the input of the receiver. Also, the minimum Prec in dBi will be calculated from the End-To-End BER tests by using the BER and E_b/N_0 results along with the G/T that was calculated by the antenna vendor, ViaSat. During the medium loop tests, the antenna will be put in motion to verify that the motor system does not degrade the BER. Also, eye pattern measurements will be made during the tests when using the TSI receiver. Eye pattern measurements are not possible with the Code 564 receiver.

2.3 Antenna Acquisition/Tracking Demonstrations

The antenna acquisition/tracking demonstrations will be used to meet demonstration objective #2 listed in Section 1.2 above. The antenna acquisition/tracking demonstrations are designed to show that the ground Ka-band antenna can successfully acquire and autotrack a customer spacecraft with Low Earth Orbit (LEO) range dynamics. In addition, the acquisition thresholds of the antenna will be characterized, for both initial and loss-of-lock points. It is anticipated that a Ka-band LEO spacecraft will not be available to support the GN demonstration. Therefore, a helicopter configured with a Ka-band transmitter will be used to simulate the range dynamics of a Ka-band spacecraft as best as possible. Ka-band missions such as ENVISAT will be investigated for use as a potential target of opportunity for the GN demonstrations.

For this demonstration, “user range dynamics” refers to only angular velocity and angular acceleration parameters; Doppler will not be changed intentionally (although Doppler shifts may occur as an unintended byproduct of the angular dynamics). User range dynamics will be simulated by flying a helicopter along a route known to create the desired range dynamics as best as possible.

A wide-beamwidth Ka-band antenna on the helicopter will be pointed in the general direction of the ground antenna at WFF. A QPSK signal will be transmitted from the helicopter. All of the autotrack acquisition times and performance will be recorded.

In order to thoroughly characterize the antenna autotrack performance, additional antenna autotrack demonstrations will also be conducted with the boresite tower. As the signal level from the boresite tower is increased and decreased in steps, the signal-to-noise ratio (SNR) during antenna autotrack acquisition lock and loss-of-lock will be measured.

Table 2-1 lists the equipment required for the GN BER and Antenna Acquisition/Tracking demonstrations.

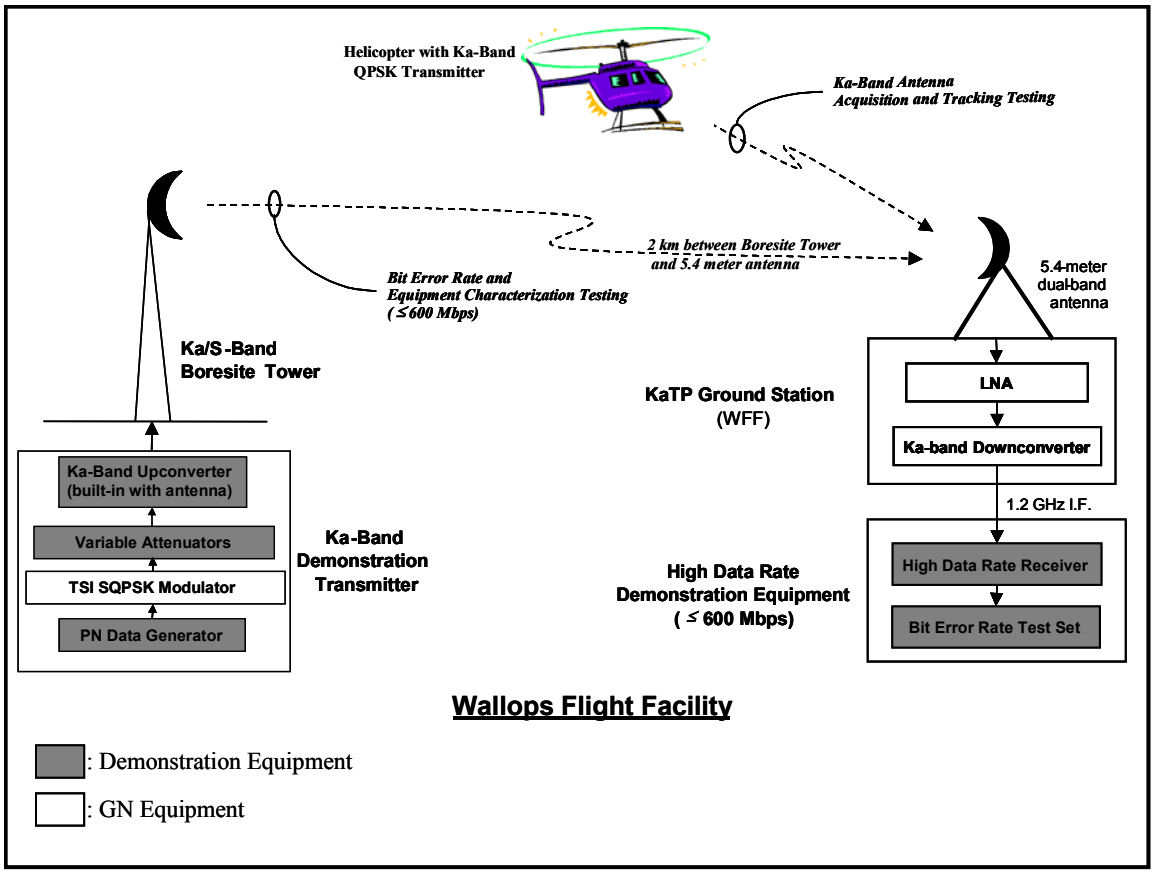

Figure 2-1. GN Demonstration End-To-End Test Configuration

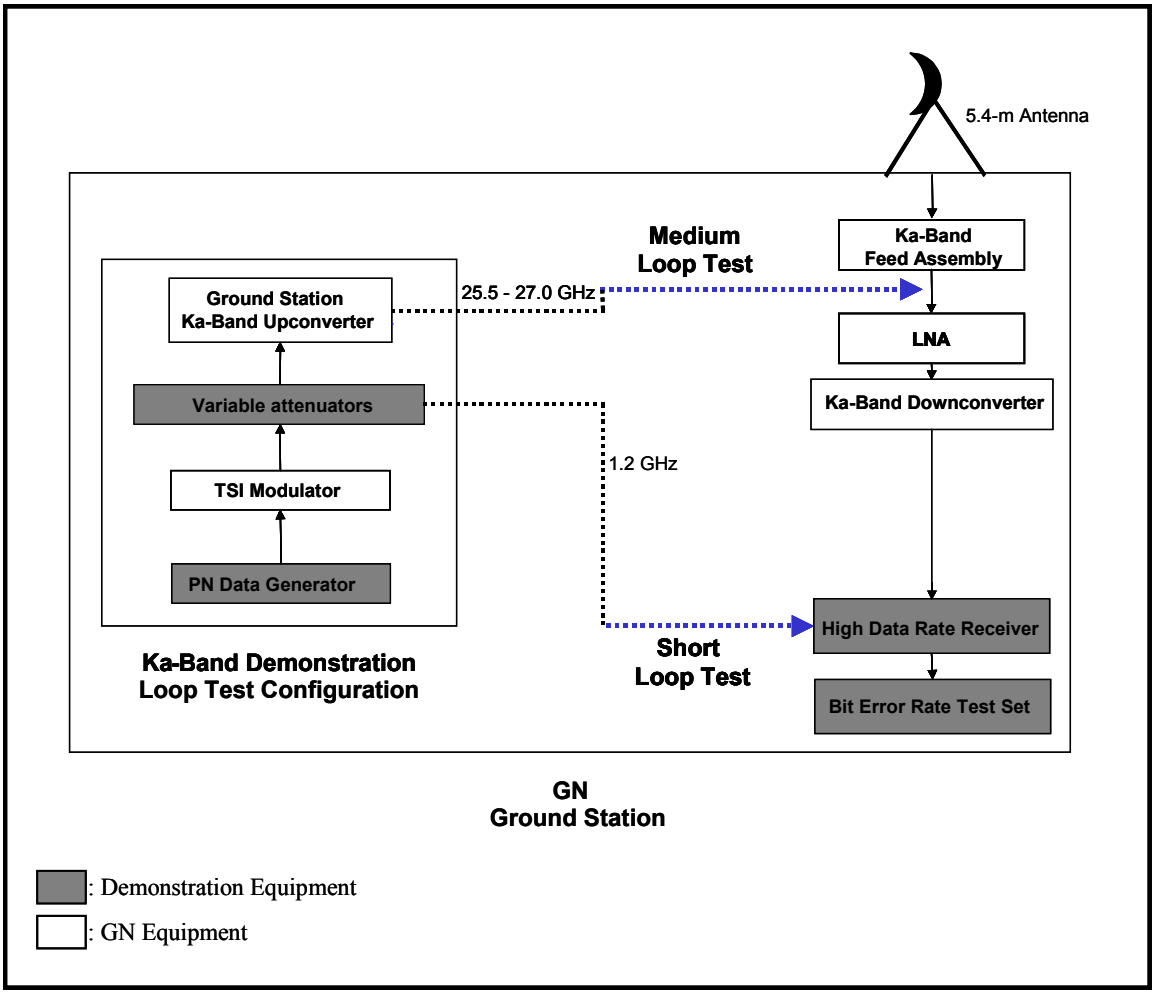

Figure 2-2. GN Loop-Back Test Configuration

Table 2-1. GN BER And Antenna Acquisition Test Equipment

Equipment Nomenclature	Characteristics
TSI and Code 564 High Data Rate Receivers	a. 1.2 GHz IF input b. QPSK demodulation and bit synchronization c. Separate I and Q channel outputs (data and clock) d. Receivers can operate between 50 Mbps and 600 Mbps
Spectrum Analyzer	1.2 GHz center frequency capability for C/N_0 measurements
Bit Error Rate Test Set (BERTS)	a. Capability to handle data rates from 25 Mbps to 600 Mbps b. PRBS NRZ-L bit stream compatible
PN Data/Signal Generator	a. Generate data rates from 25 Mbps to 600 Mbps for each I and Q channel b. PRBS NRZ-L bit stream compatible with BERTS
TSI SQPSK Modulator	a. SQPSK modulation b. Single channel input for 50 Mbps to 600 Mbps NRZ-L data input c. Provide $0.5xT_b$ channel offset prior to modulation d. 1.2 GHz output e. Output Level: -15 to +5 dBm
Ground Station Ka-Band Upconverter (for medium loop-back testing, see Figure 2-2)	a. 1.2 GHz to Ka-Band frequency translation (25.5 – 27.0 GHz tunable) b. 1.2 GHz bandwidth, maximum
Ka-Band Upconverter (built-in with antenna) (for boresite tower, see Figure 2-1)	a. 1.2 GHz to 25.7 GHz Ka-Band frequency translation b. 1.2 GHz bandwidth, maximum
1.2 GHz Variable Attenuators	Vary IF signal level to achieve required E_b/N_0 if needed
Noise/Com AWGN Generator	a. Has signal combiner b. Has 110 dB attenuator in 1 dB steps
GSFC developed Ka-Band Modulator that will be inside Helicopter	a. QPSK modulation b. 300 Mbps
Ka-Band antenna on helicopter	25.5 – 27.0 GHz

Section 3. Space Network Demonstration

3.1 SN Demonstration Overview and Configuration

The SN demonstration will be conducted at the NASA White Sands Complex (WSC) using the TDRS H or I spacecraft. Since the ground stations at WSC and TDRS spacecraft are operational systems, formal scheduling and Data Service Management Center (DSMC) coordination is required using a SN Scheduling Order (SHO). Figure 3-1 is a high-level block diagram of the SN test configuration.

The TDRS H, I, and J KaSA Test Antenna System at the White Sands Ground Terminal (WSGT) will transmit a KaSAR-wideband (650 MHz bandwidth) signal to the TDRS H or I spacecraft. The TDRS H or I spacecraft will receive the KaSAR-wideband signal using its KSAR1 Single Access (SA) antenna. The Ka-band signal will be downconverted to Ku-band and relayed to WSC via the TDRS Space-Ground Link (SGL) antenna dedicated Downlink. The KaSAR-wideband signal will be received at Ku-band by a 19 meter SGL antenna at a WSC space-ground link terminal (SGLT). The signal will be downconverted (by the new "Ka-band Infrastructure") to a 1.2-GHz IF, and sent to a high data rate (HDR) receiver via the new IF switch.

Two high data rate receivers will be available for the demonstration. Both the TSI receiver and NASA/GSFC developed (Code 564) high data rate receiver will be used/tested during the demonstrations.

These tests will also demonstrate that the SN KaTP modifications provide the SN with a new fully capable 650 MHz IF service, therefore, these demonstrations will be coordinated and scheduled using normal SN SHOs. WSC operations personnel will assist demonstration test personnel in producing the required SHOs.

3.2 SN Demonstration Approach

The BER tests will be used to meet demonstration objectives #1, #3, #4, and #5 listed in Section 1.2 above. End-To-End BER tests, which are depicted in Figure 3-1, will be performed using the existing TDRS H, I, and J KaSA Test Antenna System located at WSGT, the TDRS H or I spacecraft, and a SGLT located at WSC. The KaSA Test Antenna will be pointed at a TDRS H or I using current TDRS H or I state vector information. The TDRS H or I KSAR-1 SA antenna will be pointed at the KaSA Test Antenna using the WSGT state vector.

The TDRS H, I, and J KaSA Test Antenna System, which is owned by Boeing, consists of a 1.2 meter antenna mounted on the roof of the WSGT building and a 100 watt Ka-band traveling wave tube amplifier (TWTA). The Demonstration Ka-band Transmitting System, which is depicted in Figure 3-1, will consist of the TDRS H, I, and J KaSA Test Antenna System, a PN data generator, high-rate test modulator, and the GN Ka-band test upconverter.

In addition to the End-To-End Tests above, BER tests will also be performed for medium loop and long loop configurations to aid in the assessment of the system design and WSC and TDRS hardware distortion effects. The medium loop and long loop test configurations are illustrated in Figure 3-2.

To perform a medium loop test as shown in Figure 3-2, an additional Ku-band upconverter rather than a Ka-band upconverter will be used to upconvert the 1.2 GHz modulator output to an output frequency identical to the TDRS space-ground link dedicated wideband signal (13.725 GHz for a Space Network Interoperability Panel (SNIP) frequency). The medium loop test will consist of connecting the output of the Ku-band upconverter to the input of the equalizer. This medium loop test will be used to measure the performance degradation associated with the new Ka-band infrastructure when the equalizer is in Bypass Mode.

To perform a long loop test as shown in Figure 3-2, the Ku-band upconverter will be used again to upconvert the 1.2 GHz modulator output to an output frequency identical to the TDRS space-ground link dedicated wideband signal (13.725 GHz). The long loop test will consist of connecting the output of the Ku-band upconverter to the input of a SGLT LNA. This long loop test will be used to measure the performance degradation associated with the LNA, tunnel cabling, and equalizer when the equalizer is set in its normal operational mode.

Two data rates will be demonstrated to characterize the system design and performance. The data rates demonstrated will be 300 Mbps and 600 Mbps, but if the 600 Mbps tests have anomalies, 450 Mbps tests will be conducted. The Demonstration Ka-band Transmitting System will use the TSI modulator which will be configured for uncoded SQPSK modulation with a NRZ-L data format on each channel. The TSI modulator will generate the same PRBS on each channel, with a ½ bit offset (SQPSK) after a single PRBS is injected into the I-channel input of the TSI modulator. The receiver will be configured for QPSK and individual I and Q channel BER measurements will be performed. If unexpected BER performance occurs, the demonstration team will be able to better characterize the system performance by isolating the BER performance on the I channel from the BER performance on the Q channel which can not be done if the channels are combined prior to BER measurements.

For each of the above data rates, the output power from the Demonstration Ka-band Transmitting System will be varied in steps in order to obtain E_b/N_0 values for BERs at 10^{-5}, 10^{-6}, 10^{-7}, 10^{-8}, and 10^{-9} (assuming enough EIRP is available during the test for lower BERs). BER vs. E_b/N_0 curves will be estimated from the data points. The E_b/N_0 will be calculated from the measured C/N_0. A spectrum analyzer will be placed in parallel with the receiver input. One hard copy of the spectrum analyzer display will be made for each data rate using a plotter. Also, the minimum Prec in dBWi, that a user needs to present at the TDRS SA antenna for a given data rate, will be calculated after the End-To-End BER tests by using the EIRP, BER, and E_b/N_0 results.

In addition to BER tests, the test team will measure the carrier tracking threshold and carrier acquisition threshold during the medium loop tests, long loop tests, and end-to-end tests.

Also, the following Legacy 300 Mbps test scenarios will be conducted in order to determine any performance differences between the Ku-Band and Ka-Band return links for 300 Mbps channel services:

a. Ka-Band, 300 Mbps, TDRS HIJ 225 MHz Narrowband Channel, Dedicated or Composite Link
b. Ku-Band, 300 Mbps, TDRS HIJ 225 MHz Narrowband Channel, Dedicated or Composite Link

Table 3-1 lists the equipment required for the SN BER demonstrations.

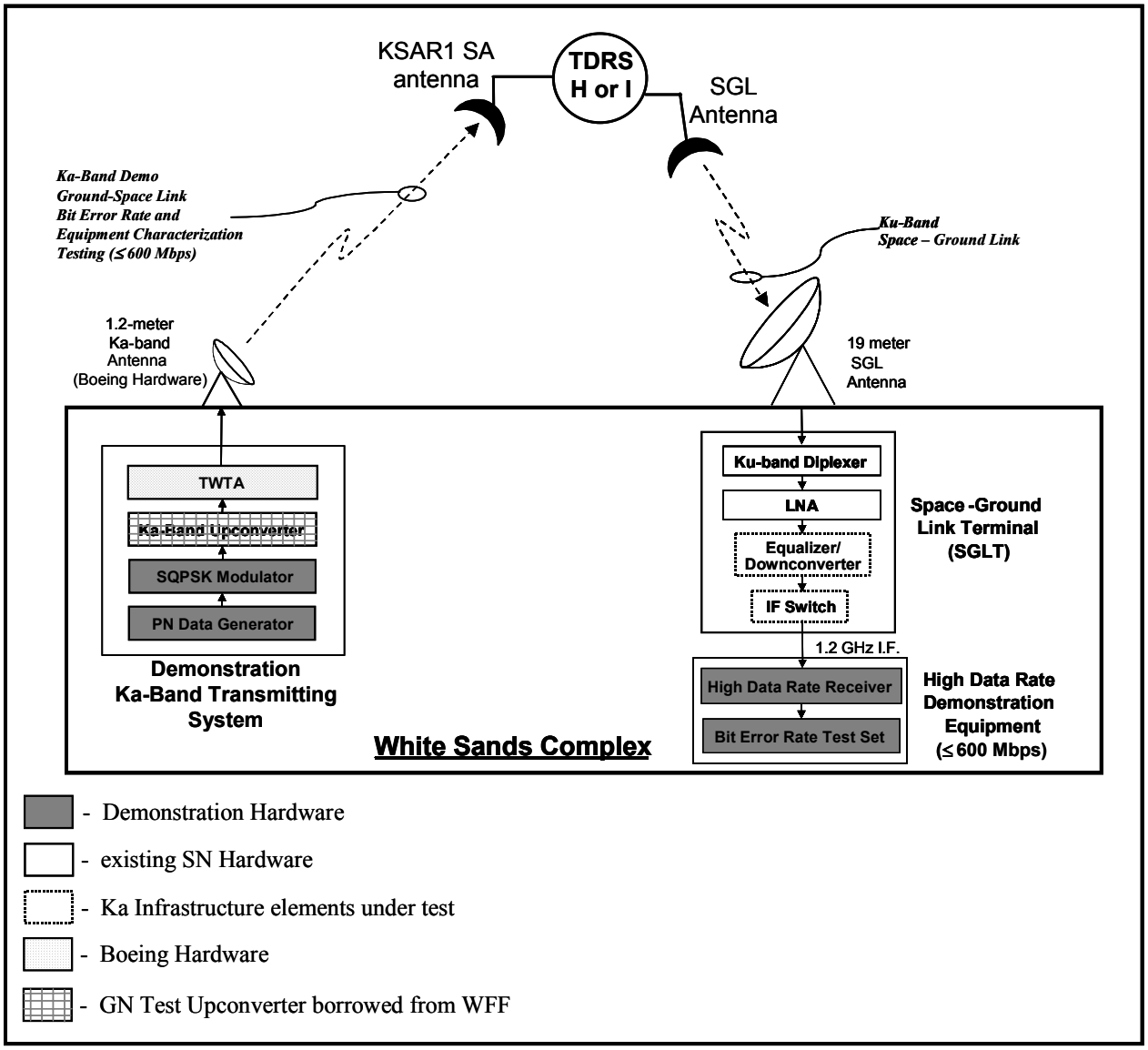

Figure 3-1. SN Demonstration Configuration (End-To-End Tests)

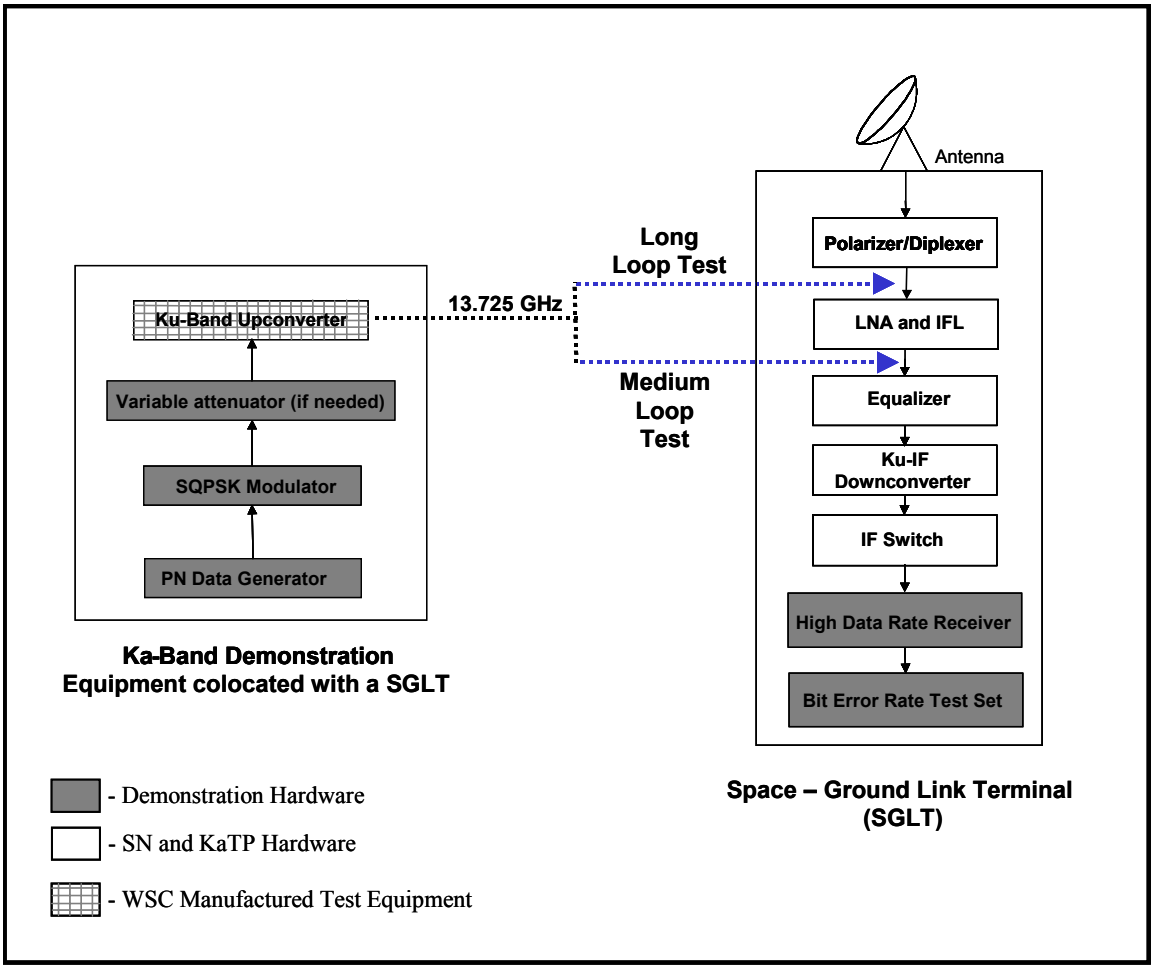

Figure 3-2. SN Loop-Back Test Configuration

Table 3-1. SN BER Test Equipment

Equipment Nomenclature	Characteristics
TSI and Code 564 High Data Rate Receivers	a. 1.2 GHz IF input b. QPSK demodulation and bit synchronization c. Separate I and Q channel outputs (data and clock) d. Receivers can operate between 50 Mbps and 600 Mbps
Spectrum Analyzer	1.2 GHz center frequency capability for C/N_0 measurements
Bit Error Rate Test Set (BERTS)	a. Capability to handle data rates from 150 Mbps to 600 Mbps b. PRBS NRZ-L bit stream compatible
PN Data/Signal Generator	a. Generate data rates from 150 Mbps to 600 Mbps for each I and Q channel b. PRBS NRZ-L bit stream compatible with BERTS
TSI SQPSK Modulator	a. SQPSK modulation b. Single channel input for 300 Mbps to 600 Mbps NRZ-L data input c. Provide $0.5xT_b$ channel offset prior to modulation d. 1.2 GHz output e. Output Level: -15 to +5 dBm
Ka-Band Test Upconverter (Borrow from GN Ground Station at WFF for end-to-end BER tests)	a. 1.2 GHz to Ka-Band SNIP demo frequency translation (26.1 GHz) b. 1.2 GHz bandwidth
Ku-Band Upconverter (for medium loop and long loop tests and manufactured by WSC)	a. 1.2 GHz to 13.725 GHz frequency translation b. 650 MHz bandwidth, maximum
TWTA (Part of KaSA Test Antenna System at WSGT)	a. Ka-Band (25.25 – 27.5 GHz) b. Output Power = 100 W maximum c. Variable output power to provide required E_b/N_0 at receive equipment
Ka-Band Antenna (Part of KaSA Test Antenna System at WSGT)	1.2 meter, 25.25 – 27.5 GHz
1.2 GHz Variable Attenuators	Vary IF signal level to achieve required E_b/N_0 if needed
Noise/Com AWGN Generator	a. Has signal combiner b. Has 110 dB attenuator in 1 dB steps

Section 4. Demonstration Documentation

The following documentation will be written in order to meet the demonstration plan's objectives:

a. KaTP Demonstration Test Procedures for the GN Ground Terminal
b. KaTP Demonstration Test Procedures for the SN Infrastructure
c. KaTP Demonstration Test Report for the GN and SN

The two test procedure documents will define the GN and SN step-by-step test procedures, test equipment, data collection methods, and test set-ups that NASA personnel and their support contractor personnel will use to meet the objectives in the demonstration plan.

A single test report will be written to state the GN and SN test results. The report will include data processing methods and calculations, E_b/N_0 vs BER curve results, signal spectrum plots, GN eye pattern plots, implementation loss calculations, comparison with predictions, and conclusions about the GN's and SN's ability to support high data rate users.

Section 5. Demonstration Schedule

The Ka-Band Demonstration schedule is provided in Table 5-1. The GN and SN demonstrations will be performed to meet all the objectives stated in Section 1.2 of this plan.

Table 5-1. Ka-Band Demonstration Schedule

Activity	Dates
Develop Demonstration Test Procedures	November 2001 - November 2002
Conduct On-site SN Demonstration Review	April 2002
Conduct On-site GN Demonstration Review	May 2002
Conduct Final Demonstration Review	September – October 2002
Conduct SN Demonstration	December 2002
Conduct GN Demonstration	January 2003
Demonstration Report Delivery	February 2003

Section 6. Acronyms

AGC	Automatic Gain Control
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BERTS	Bit Error Rate Test System
CW	Continuous Wave
DSMC	Data Service Management Center
EIRP	Effective Isotropic Radiated Power
ENVISAT	ENVIronmental SATellite
FOTS	Fiber Optic Transmission System
GN	Ground Network
GSFC	Goddard Space Flight Center
HDR	High Data Rate
HDRR	High Data Rate Receiver
IF	Intermediate Frequency
IFL	Intra-Facility Link
KaSAR	Ka-Band Single Access Return
KaTP	Ka-Band Transition Product
KSA	K-Band Single Access
LEO	Low Earth Orbit
LNA	Low Noise Amplifier
NASA	National Aeronautics and Space Administration
PMP	Product Management Plan
PN	Pseudo-noise
PRBS	Psuedo Random Bit Stream
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
RHCP	Right-Hand Circular Polarized

SA	Single Access
SGL	Space-Ground Link
SGLT	Space-Ground Link Terminal
SHO	Scheduling Order
SN	Space Network
SNIP	Space Network Interoperability Panel
SNR	Signal-to-Noise Ratio
SQPSK	Staggered Quadrature Phase Shift Keying
SRD	System Requirements Document
STGT	Second TDRSS Ground Terminal
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TWTA	Traveling Wave Tube Amplifier
WFF	Wallops Flight Facility
WSC	White Sands Complex
WSGT	White Sands Ground Terminal