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Joint Polar Satellite System 1 (JPSS-1) Spacecraft High Rate Data (HRD) to Direct Broadcast Stations (DBS) Radio Frequency (RF) Interface Control Document (ICD)

For Public Release

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

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Goddard Space Flight Center
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Preface

This document is under JPSS Flight configuration control. Once this document is approved, JPSS approved changes are handled in accordance with Class I and Class II change control requirements as described in the JPSS Configuration Management Procedures, and changes to this document shall be made by complete revision.

Any questions should be addressed to:

JPSS Configuration Management Office
NASA/GSFC
Code 472
Greenbelt, MD 20771

Change History Log

Revision	Effective Date	Description of Changes
Rev -	05/30/2012	Initial Release. See CCR 472-CCR-12-0173.
Rev A	02/05/2015	Rev A released per 472-CCR-15-0822 (2/5/15). Updated to include data from I&T and CPTs. Some minor corrections are included as well.

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1. Introduction

1.1 Purpose

This Interface Control Document (ICD) establishes performance requirements and defines and controls technical aspects of the High Rate Data (HRD) communications subsystem interfaces between the Joint Polar Satellite System-1 (JPSS-1) Spacecraft and Direct Broadcast Users worldwide within line-of-sight view. The HRD provides real-time mission data (which includes instrument science data, instrument engineering data, and instrument telemetry data), and real-time Spacecraft housekeeping data via X-Band downlink transmission.

1.2 Interface Responsibilities

Ball Aerospace and Technologies Corporation (BATC), under contract to Goddard Space Flight Center (GSFC) JPSS-1 Project Office, is responsible for the JPSS-1 Spacecraft portion of the interface. Users of the Direct Broadcast Stations are responsible for meeting the requirements laid out in this ICD. Design requirements and parameters in this ICD are controlled by the GSFC JPSS-1 Project Office Change Control Board (CCB), with inputs from GSFC JPSS-1 Project Personnel, Raytheon, and BATC as appropriate.

1.3 Interface Identification

1.3.1 RF Link Definition

The communications subsystem interface defined and controlled by this ICD is the HRD Radio Frequency (RF) transmission link between the JPSS-1 Spacecraft and the Direct Broadcast Users as defined in Section 3. This ICD does not apply to the RF links of any other spacecraft/vehicle, tracking system, or dedicated ground terminal. Figure 1-1 depicts the RF links between the Spacecraft and its various interfaces.

1.3.2 Link Calculations

The RF link calculations contained in Appendix A for the Spacecraft modes of operation are included only as supporting data and do not constitute a formal part of the RF ICD agreement. The Earth-coverage antenna patterns and downlink spectrum provided in Appendix B and Appendix C, respectively, are included for information purposes and are also not part of this RF ICD agreement.

1.3.3 Other RF Interfaces

The RF interfaces between the JPSS-1 Spacecraft and the Space Network (SN), the JPSS-1 Spacecraft and the S-Band Ground Stations, and the JPSS-1 Spacecraft and the Ka-Band Ground Stations are included in separate RF ICDs. This ICD provides the definition of the HRD links between the JPSS-1 Spacecraft and the X-Band Direct Broadcast Users.

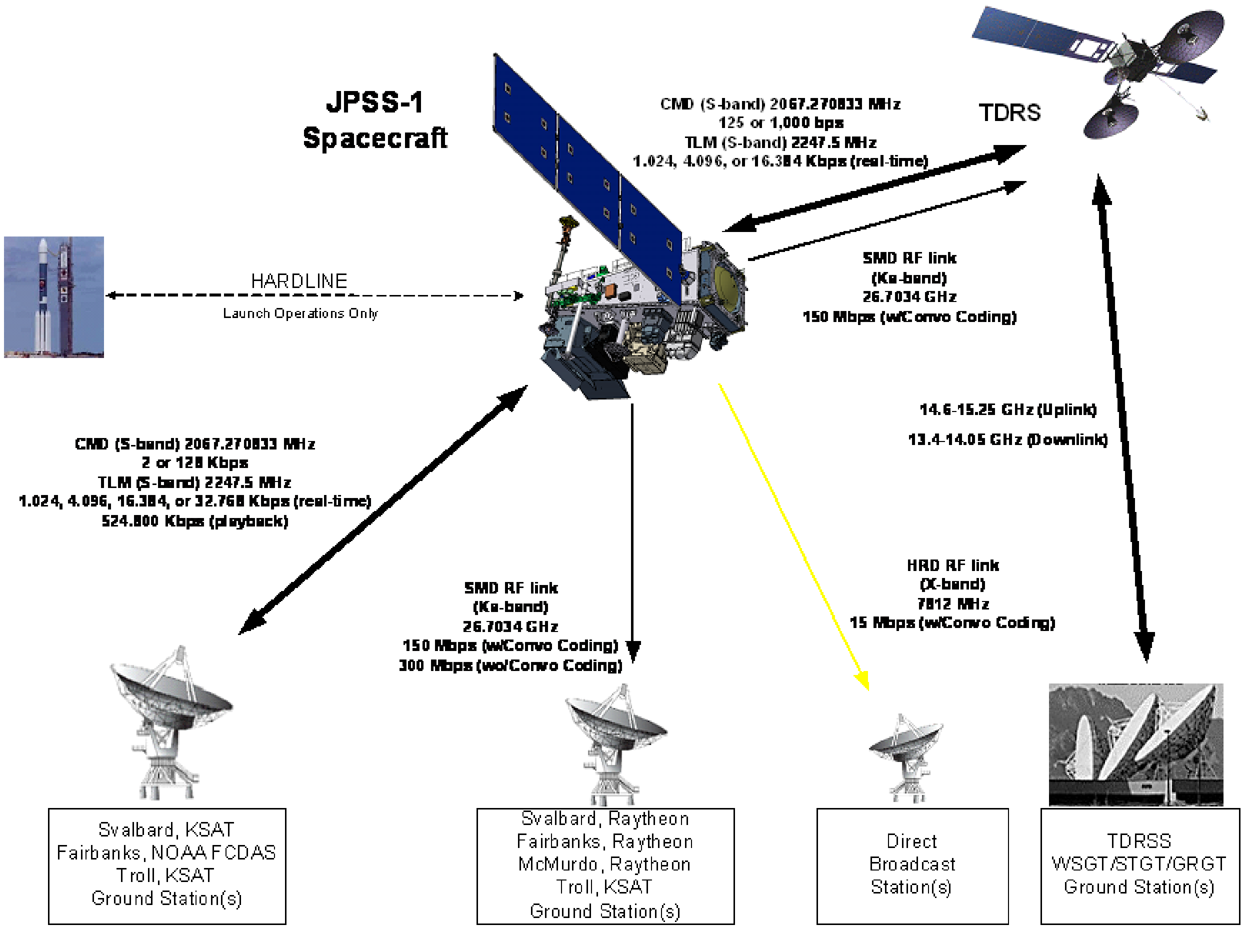


Figure 1-1. Spacecraft Communications Links

2. Documents

2.1 Applicable Documents

The following documents are applicable to the JPSS-1 Spacecraft.

GSFC 472-00009	JPSS-1 Satellite Requirements Specification

National Telecommunications and Information Administration (NTIA), Manual of Regulations and Procedures for Federal Radio Frequency Management (Redbook)

2.2 Reference Documents

The following documents are reference documents applicable to the RF interface being controlled. These documents do not form a part of this ICD and are not controlled by their reference herein.

CCSDS 131.0-B-2	Consultative Committee for Space Data Systems (CCSDS) Recommendations for TM Synchronization and Channel Coding
CCSDS 133.0-B-1	Consultative Committee for Space Data Systems (CCSDS) Recommendations for Advanced Orbiting Systems – Networks and Data Links: Architectural Specification
CCSDS 732.0-B-2	Consultative Committee for Space Data Systems (CCSDS) Recommendations for Advanced Orbiting Systems (AOS) Space Data Link Protocol
GSFC 429-01-02-19	IRD for NPP Mission System to Direct Broadcast Users Interface
ITU-R SA 1157	Protection Criteria for Deep-Space Research
GSFC 472-00163	JPSS-1 Mission Data Format Interface Control Document (ICD)

2.3 Other Related Documents

The following documents are listed for the convenience of the user. These documents do not form a part of this ICD and are not controlled by their reference herein.

INTENTIONALLY REMOVED

3. Communications Interface Requirements

3.1 HRD Link Overview

3.1.1 General

The Spacecraft will use an Earth-coverage pattern antenna to provide downlink for Direct Broadcast Users. It provides real-time mission data (which includes instrument science data, instrument engineering data, and instrument telemetry data), and real-time Spacecraft housekeeping data. The data rate is 15 Mbps at a nominal downlink frequency of 7812 MHz. In normal operations broadcast data will operate continuously providing real-time data to the Direct Broadcast Users.

3.1.2 Interface RF Links

The required RF communication links are as follows:

a. Mission data from Spacecraft-to-Direct Broadcast Users
b. Pseudo Random Bit Stream (PRBS) for Bit Error Rate (BER) measurements

3.2 Interface Functional Requirements

3.2.1 General

Paragraphs 3.2.2 to 3.2.5 describe the X-Band interface functional requirements that exist between the Spacecraft and the Direct Broadcast Users.

3.2.2 Overview

The HRD system hardware onboard the Spacecraft consists of two transmitters, one transfer switch, and one shaped reflector antenna. The antenna is designed to give Earth-coverage radiation pattern. Antenna patterns are shown in Appendix B for reference. The system is designed to always be on, with the ability to be turned off indefinitely. Figure 4-6 shows the architecture for the HRD system and the interface to the Mission Data Formatter (MDF). The Direct Broadcast User Terminal demodulates and decodes the RF received from the Spacecraft communication subsystem. The Spacecraft to Earth station link distance ranges from 2835 Km at a ground station elevation angle of 5°, to 824 Km at a ground station elevation angle of 90°. Direct Broadcast Station support is dependent on favorable radio line-of-sight conditions when Direct Broadcast Station antenna elevation angle is greater than 5° (above the local horizon).

3.2.3 Mission Data

Transmission of real-time payload data from the Spacecraft to Direct Broadcast Users of HRD occurs at 15 Mbps. Mission data will be formatted in accordance with Spacecraft requirements outlined in paragraph 4.3. The 15 Mbps is the Channel Access Data Unit (CADU) bit rate, measured after Reed-Solomon coding and pre-pending the Attached Sync Marker. After rate 1/2 convolutional coding is applied, the in-phase (I)- and quadrature-phase (Q)-channels are each Quadrature Phase Shift Key (QPSK) modulated with 15 Msps (30 Msps total). Data from the

HRD is selectable by Application Identification (APID) via table load. In all cases, fill frames are added in order to maintain the 15 Mbps downlink rate.

3.2.4 Pseudo-Random Bit Stream (PRBS)

The satellite will generate pseudo-random bit stream test data as a test mode used for the purpose of BER checking, as required. It is not a normal X-Band spacecraft operation. The satellite shall reset upon command back to the default configuration from the pseudo-random output.

NOTE:
The link analysis for the PRBS is not shown since the Mission Data link analysis is worst case.

3.2.5 Doppler Tracking and Ranging

The Direct Broadcast Stations must be able to handle a maximum Doppler shift of ± 171.0 kHz at an elevation angle of 5°, and a Doppler shift rate of 1.55 kHz/sec at an elevation angle of 90°. This link does not provide a ranging capability.

3.3 Communications Performance Characteristics

3.3.1 General

RF link performance requirements for the communications functional capability described in paragraph 3.2 are defined in this section. Direct Broadcast Station communications performance requirements are based on the presumption that the Spacecraft and Direct Broadcast Station each perform in accordance with the system performance parameters defined in Section 4.

3.3.2 Mission Data Channel BER

The maximum HRD downlink information BER for the mission data channel will be 1.83×10^{-3}, referenced to the input of a Reed Solomon (RS) Decoder on the ground. With RS decoding at the Direct Broadcast terminal, the effective output mission data BER will be 10^{-8}. The HRD Interface Requirements Document (IRD) requires an E_b/N_o of 4.4 dB, which is more stringent than the 10^{-8} BER requirement. Therefore the link analysis is performed using the E_b/N_o requirement of 4.4 dB.

3.3.3 PRBS Test Channel BER

The maximum HRD downlink information BER for the PRBS test channel will be 1×10^{-4}, referenced to the output of the Viterbi decoder on the ground per the HRD IRD. Actual performance will be better than 10^{-5} based on the E_b/N_o requirement of 4.4 dB.

3.4 Spacecraft/Direct Broadcast Station Communication Link (X-Band Downlink Modes)

The Spacecraft X-Band downlink modes are shown in Table 3-1.

Table 3-1. Spacecraft HRD Communication Modes

Service	Data Mode	Rate (Mbps)	Antenna (Polarization)	Modulation	I:Q Power Ratio
Direct Broadcast Users	HRD (mission data)	15	Earth-coverage antenna (RHCP)	QPSK	1:1
Direct Broadcast Users	PRBS	15	Earth-coverage antenna (RHCP)	QPSK	1:1

4. HRD Link Interface Characteristics

4.1 Purpose

This section specifies the functional design of the RF HRD link. Pertinent Spacecraft and Direct Broadcast Station communications signal designs and system performance requirements are also specified.

4.2 Link Functional Designs: Spacecraft-to-Direct Broadcast Stations HRD Downlink

4.2.1 General

The HRD transmitter will be used to transmit the data for this link. Baseband characteristics will be in accordance with Table 4-1. The Earth-coverage antenna provides 15 Mbps data to the Direct Broadcast Users. The HRD system is designed to transmit data at all times, however, it can be turned off indefinitely if the need arises.

4.2.2 Functional Description

The functional interface of the Mission Data link will be as shown in Figure 4-1, and the functional interface of the PRBS test bit stream link will be as shown in Figure 4-2.

a. Spacecraft mission data or PRBS data are sent from the MDF board within the Command and Data Processor (CDP) to the HRD transmitters. The signal from the CDP is Low Voltage Differential Signal (LVDS) in a Non-return to Zero Level (NRZ-L) format.
b. The data are then converted from NRZ-L to Non-return to Zero Mark (NRZ-M) format and is then convolutionally encoded.
c. The convolutional encoder outputs are split with G1 on the I-channel and G2 (inverted) on the Q-channel. The I-channel and Q-channel data is QPSK modulated onto the X-Band carrier with an I/Q-channel power ratio of 1:1 as shown in Figure 4-1 and Figure 4-2. The X-Band carrier is derived from a Temperature Compensated Crystal Oscillator (TCXO).
d. These data streams QPSK modulate onto a 7812 MHz carrier. The resulting Transmitter RF output is amplified to 7 watts minimum, over full specified unit temperature range, 8 watts minimum at maximum flight allowable temperature range. The link uses the Earth-coverage antenna to transmit to Direct Broadcast Users.

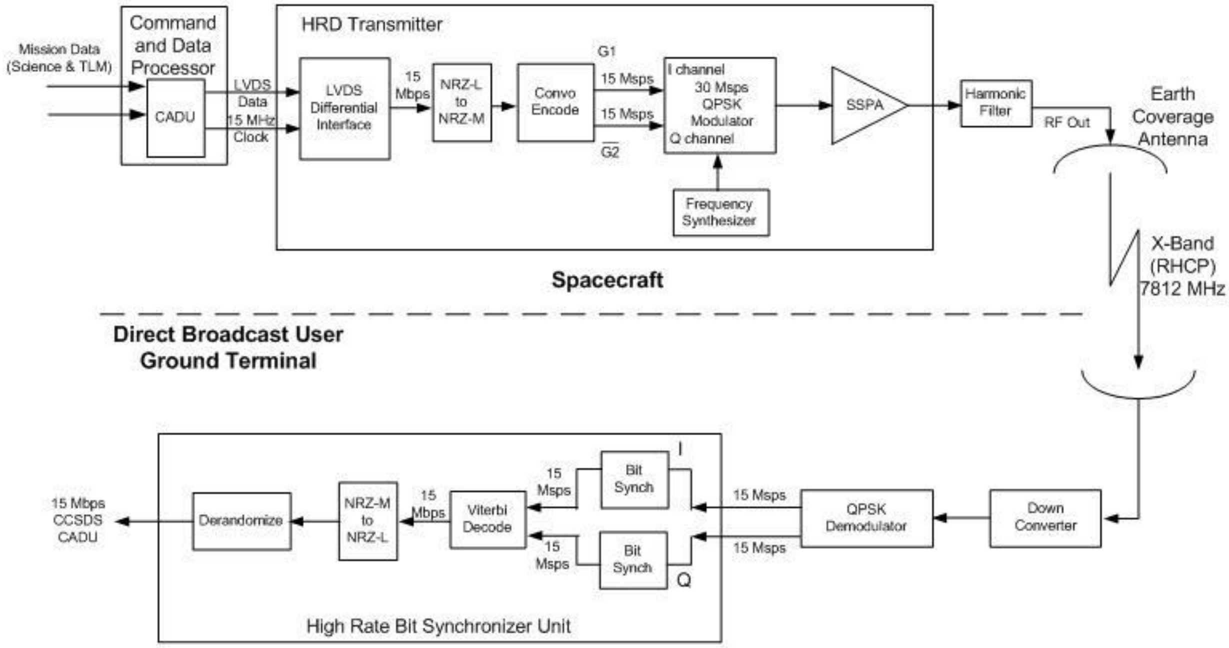


Figure 4-1. Spacecraft-to-Direct Broadcast Station Downlink Configuration (Mission Data)

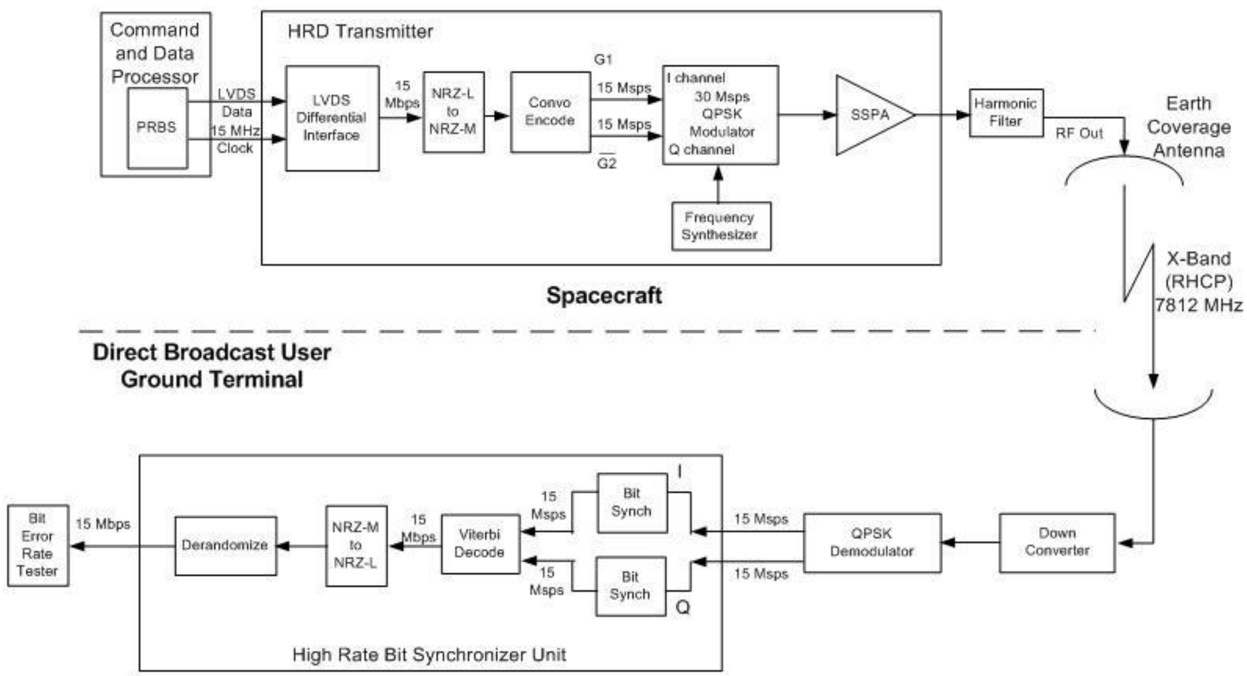


Figure 4-2. Spacecraft-to-Direct Broadcast Station Downlink Configuration (PRBS Mode)

4.2.2.1 Data Formatting

Data formatting for Mission Data is as follows (see Figure 4-1):

a. CCSDS format into coded Advanced Orbiting Systems (AOS) Transfer Frames (TF), (formerly referred to as Coded Virtual Channel Data Units (CVCDU's)) with Reed Solomon (RS) (255,223), I=4
b. Randomize coded AOS transfer frames (see Section 4.3.4)
c. CCSDS format into Channel Access Data Units (CADU's) by adding sync (see Section 4.3.4)
d. Differential encode
e. Convolutional encode (as described in paragraph 4.3.6)—the G1 output will be routed to the I channel, and the G2 (inverted) output will be routed to the Q channel of the HRD transmitter.

Data formatting for PRBS mode is as follows (see Figure 4-2):

a. All zeroes input
b. Randomize the input by using the following bit transition generation function (refer to CCSDS 131.0-B-2 Recommendations for TM Synchronization and Channel Coding, Section 9):

$$h(x) = x^8 + x^7 + x^5 + x^3 +1$$

c. Differential encode
d. Convolutional encode (as described in paragraph 4.3.6)—the G1 output will be routed to the I channel, and the G2 (inverted) output will be routed to the Q channel of the HRD transmitter.

When operating in the PRBS mode, the CADU sync pattern is disabled. See also Figure 4-6.

Details of data formatting are further covered in the JPSS-1 Mission Data Format ICD.

4.2.2.2 Direct Broadcast User Ground Station Functionality

At the Direct Broadcast Users Receive Ground Station, the input signal from the receive antenna is down converted before being input to the QPSK receiver/demodulator. The QPSK receiver/demodulator demodulates the down converted signal into separate I and Q channel data streams with NRZ-M format. Following QPSK demodulation, the bit synchronizers recover symbol clock, the data are Viterbi decoded, and converted to NRZ-L format. After conversion to NRZ-L the data will be de-randomized. Table 4-1 contains minimum performance requirements for the Direct Broadcast capability of the spacecraft and the Users Ground Stations.

Table 4-1. HRD Downlink Baseband and RF Signal Parameters vs Capability

Parameter	Requirement	Capability	Comply
Transmit Center Frequency	7812 ±0.03 MHz	7812 ±0.03MHz	Yes
Data Rate	15,000,000 bps +/- 6 Kbps	15,000,000 bps +/- 6 Kbps	Yes
Polarization	RHCP	RHCP	Yes

Axial Ratio	Ground Elevation Angle (deg)	Angle from Spacecraft Antenna Boresight (deg)	Axial Ratio (dB)	Angle from Spacecraft Antenna Boresight (deg)	Axial Ratio (dB)	NA
	5 40 70 90	61.9 42.7 17.6 0	None	61.9 42.7 17.6 0	6.0	
Coverage	±62°			±62° (1)		Yes
Minimum EIRP (dBm)	Ground Elevation Angle (deg)	Angle from Spacecraft Antenna Boresight (deg)	EIRP (dBm)	Angle from Spacecraft Antenna Boresight (deg)	EIRP (dBm)	
	5 40 70 90	61.9 ±0.1 42.7 ±0.1 17.6 ±0.1 0 ±0.1	42.8 33.6 30.8 30.3	61.9 ±0.1 42.7 ±0.1 17.6 ±0.1 0 ±0.1	43.1 35.2 33.6 31.2	Yes
Data Modulation	QPSK			Compliance		Yes
Data Format, Modulator Output	NRZ-M output			Compliance		Yes
Assigned Bandwidth (-20 dB)	≤30 MHz			30 MHz		Yes
Gain Slope over f_c ±15 MHz	≤0.2 dB/MHz			Angle from Spacecraft Antenna Boresight (deg)	Gain Slope	
				61.9 43.6 17.9 0	0.001 0.001 0.001 0.001	Yes
Gain Flatness over f_c ± 15MHz	<2.0 dB p-p			<2.0 dB p-p		Yes
Phase Non-linearity over f_c ± 15 MHz	<6 degrees p-p			<6 degrees p-p		Yes
I/Q Power Ratio (Nominal)	1:1			1:1		Yes
I/Q Power Ratio Tolerance	≤0. 5 dB			≤0. 5 dB		Yes
QPSK Phase Imbalance	≤4.5°			≤4.5°		Yes
QPSK Gain Imbalance	≤1 dB p-p			≤1 dB p-p		Yes
Data Asymmetry	≤3%			≤3%		Yes
Data Bit Jitter	≤1%			≤1%		Yes
Phase Noise (Offset from Carrier) 100 Hz – 40 MHz Spurious Phase Modulation	≤2.0 degrees RMS ≤2.0 degrees RMS			≤2.0 degrees RMS ≤2.0 degrees RMS		Yes
AM/PM	≤10°/dB			<10°/dB		Yes
I/Q Data Skew	< ±5% of bit period			< ±5% of bit period		Yes
Operational Duty Cycle, Science Mode	100%			100%		Yes
Service Interruption	HRD shall have the ability to be turned ON or OFF			HRD can be commanded ON or OFF		Yes
Frequency Stability Over all conditions	$\pm 1x10^{-5}$			$\pm 1x10^{-5}$		Yes
HRD System BER	$1x10^{-8}$ (link margin ≥1 dB)			$1x10^{-8}$		Yes
Untracked Spurious PM (100 Hz to 40 MHz)	≤2°			≤2°		Yes
Carrier Suppression	≤ -30 dBc			< -30 dBc		Yes
Spurious Emissions (out-of-band)	≤ -60 dBc			< -60 dBc		Yes

Ground Station Pointing Loss	≤1 dB		≤1 dB		Yes
Ground Station Implementation Loss	≤2.5 dB		≤2.5 dB		Yes
Ground Station Multipath Loss at 5° Elevation angle	<0.2 dB		<0.2 dB		Yes
Ground Station G/T (dB/K) 3 meter antenna	Ground Elevation	G/T (dB/K) (2)	Ground Elevation	G/T (dB/K) (2)	Yes
Reference: IRD for NPP Mission System to Direct Broadcast Users Interface	5° 40° 70° 90°	22.7 23.59 23.65 23.66	5° 40° 70° 90°	22.7 23.59 23.65 23.66	

NOTE
1. Allows for +/-0.3 degree pointing uncertainty
2. The link availability is dependent upon actual location of the User Terminal. Reference the Link Analysis in Appendix A.

4.3 Baseband Signal Characteristics

4.3.1 General

This paragraph provides a description of the baseband signal characteristics of the HRD downlink signal to the Direct Broadcast Users. The formatting process is illustrated in Figure 4-7.

4.3.2 Mission Data Baseband Signal Parameter

The Spacecraft HRD downlink baseband signal parameters for the mission data are contained in Table 4-1, along with the modulation and RF signal parameters.

4.3.3 HRD Formatter

The MDF within the CDP shall provide a HRD Formatter function that allows CCSDS CADUs to be generated from CCSDS AOS transfer frames provided by the CDP flight software (FSW). The HRD Formatter shall apply Reed-Solomon coding to create Coded AOS transfer frames. The Reed Solomon code used shall be standard CCSDS 255,223 with interleave depth 4 as defined in CCSDS 131.0-B-2, Section 4. The addition of Reed-Solomon coding to the incoming AOS transfer frames was previously defined as CCSDS Grade 2 telemetry service (historically defined in CCSDS 701.0-B-3, Paragraphs 2.3.3 and 2.4.1.2.f) but this terminology is no longer used in the recommendations. A block diagram of the HRD Formatter and transmitter is shown in Figure 4-6. Fill frames with Virtual Channel 63 are added as necessary at the AOS transfer frame level in order to maintain a constant 15 Mbps formatted downlink rate as shown in the diagram. In order to perform BER tests, an all 0's input may be switched into the system prior to the randomizer as shown in Figure 4-6. Additionally, the PRN stream has the CADU Sync Marker turned off.

4.3.4 HRD Randomizer

The HRD Formatter shall provide a function to randomize telemetry data contained in AOS transfer frames. The randomization process shall be Enable/Disable selectable by command.

The data shall be randomized in compliance with CCSDS 131.0-B-2, Section 9, when the HRD data randomizer is enabled. The HRD Randomizer configuration is illustrated in Figure 4-3. The Logic for the HRD data randomizer is shown in Figure 4-4. The data shall bypass this process when the HRD data randomizer is disabled. The 32-bit synchronization marker is added to each Data Unit in order to complete the CADU format.

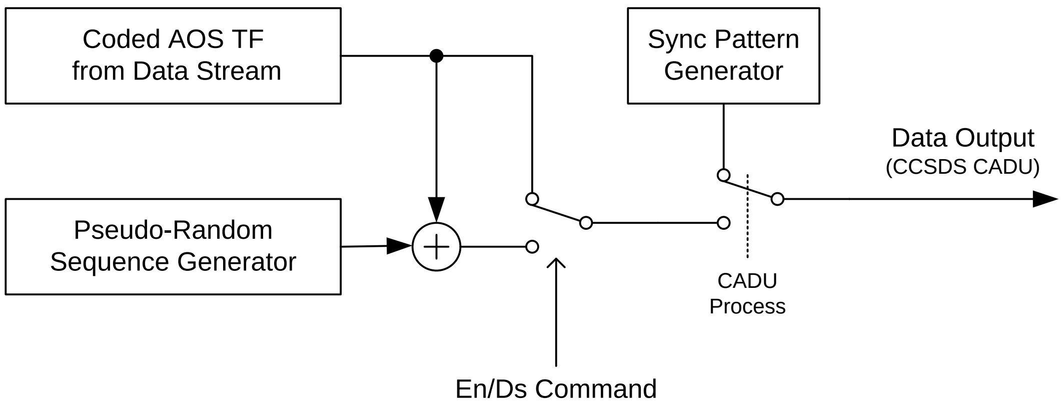


Figure 4-3. HRD Randomizer Configuration

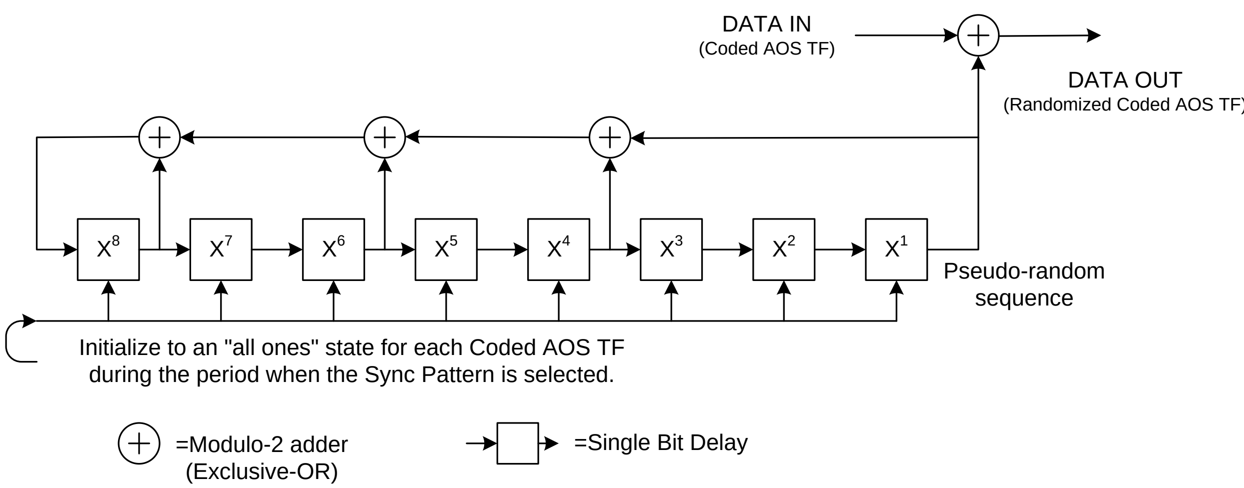


Figure 4-4. HRD Randomizer Logic Diagram

4.3.5 Data and Symbol Signal Formats

After randomization and insertion of the frame synchronization marker, the signal is serially converted from NRZ-L to NRZ-M.

4.3.6 Convolutional Coding

The Spacecraft will encode the HRD stream with a rate ½, constraint length 7 convolutional coding as defined in CCSDS 131.0-B-2, Section 3. Figure 4-5 shows the encoder block diagram. The convolutional encoder outputs are routed with G1 to the I channel and G2 (inverted) to the Q channel of the modulator.

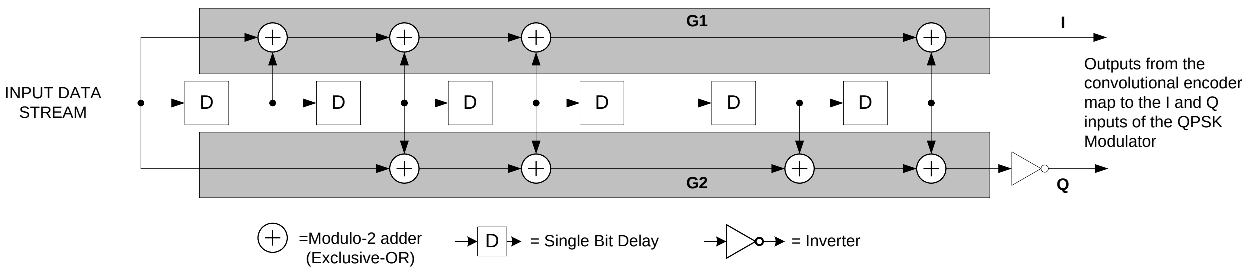


Figure 4-5. CCSDS Recommendation for Telemetry Channel Coding

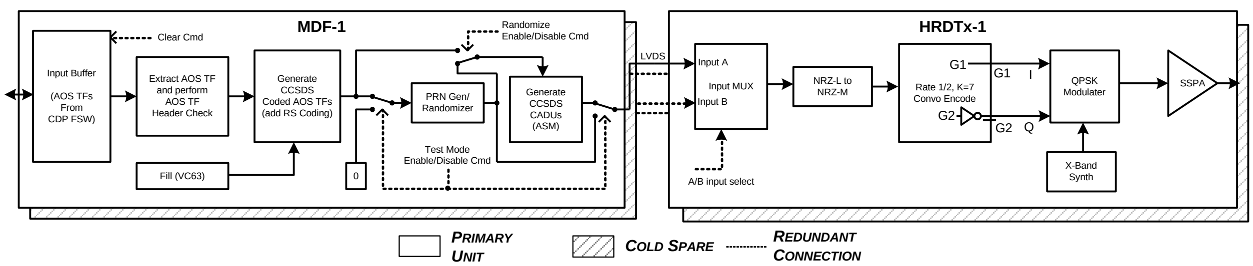


Figure 4-6. HRD Formatter/Transmitter Block Diagram

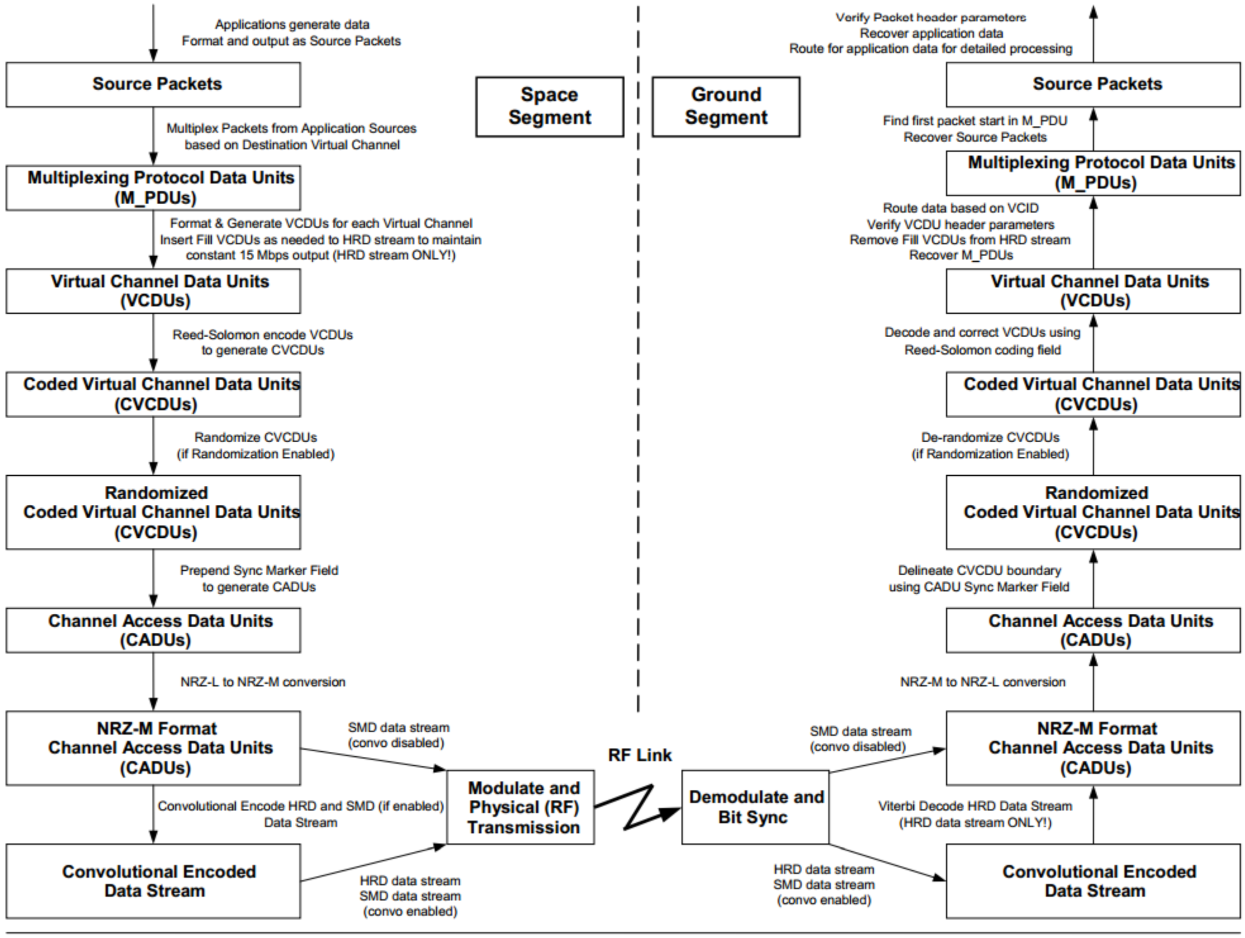


Figure 4-7. CCSDS HRD Formatting

4.4 RF Signal Characteristics

4.4.1 General

For the Spacecraft-to-Direct Broadcast Users HRD 15 Mbps downlink, balanced QPSK modulation (channel power ratio of 1:1) is used.

4.4.2 Signal Characteristics

The signal characteristics of the HRD downlink are in accordance with Table 4-1. QPSK modulation is employed. The X-Band carrier is modulated by the I and Q baseband signals. The HRD downlink uses an Earth-coverage antenna on the Spacecraft.

4.4.2.1 DSN Protection

Deep Space Network (DSN) interference criteria of, –255.1 dBW/m^2 Hz from 8400 to 8450 MHz, is met by filtering the HRD transmitter appropriately in this band.

Table 4-2 shows the DSN power Flux Density Analysis.

Table 4-2. DSN Power Flux Density Analysis

Parameter	Power	Units	Reference
HRDTx Po	14.0	watts	Max Spec Power
Power in dBW	11.46	dBW	
Passive Loss	-2.0	dB	Lowest case loss
Ant Gain (worst case peak)	9.5	dBi	Worst case antenna gain (SC not nadir pointed)
EIRP	18.96	dBW	(sum of above)
RF vs. unmodulated	-71.8	dB	
(Sin X)/X loss	-41.9	dB	Peak 8400 to 8450 MHz
Filter Loss	-56	dB	Tx Filter at 39th sideband
Spectral re-growth (estimate)	10	dB	amplifier in some compression
Spreading factor	-129.3	dB	824 Km distance (S/C directly over DSN)
Total	-270.04	dBW/m^2 per Hz	
Requirement	-255.1	dBW/m^2 per Hz	SA 1157 8400 to 8450 MHz
Margin	**14.94**	dB	Worst Case

4.4.2.2 High Frequency Harmonic Protection

A post HRD transmitter output X-Band Bandpass filter will be employed to best comply with the protection of payload electronics. The passband and stopband filtering characteristics are shown in Figure 4-8.

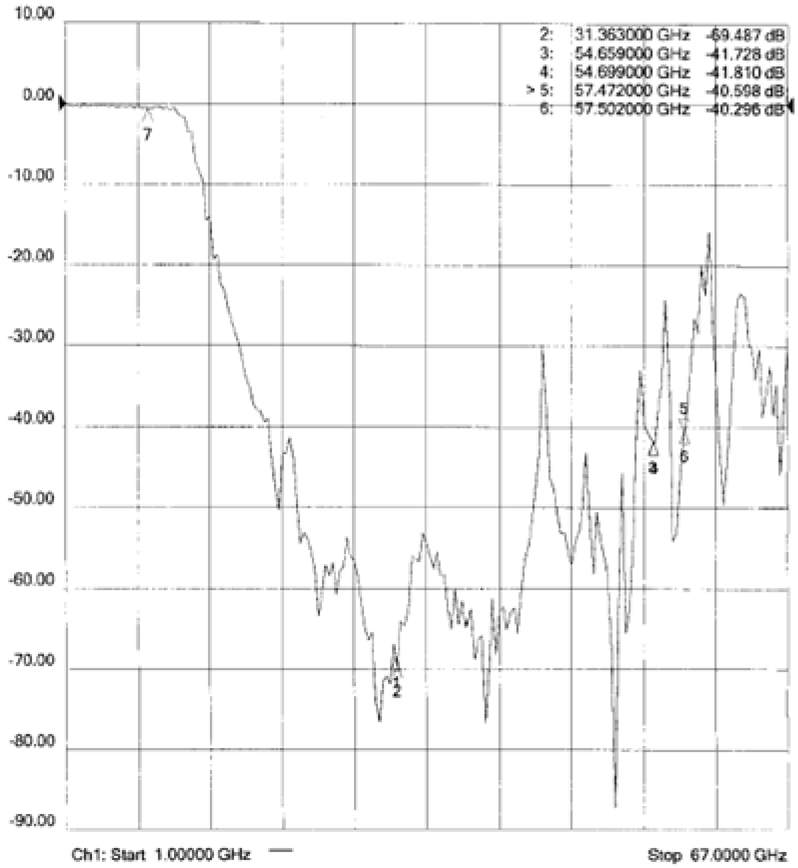
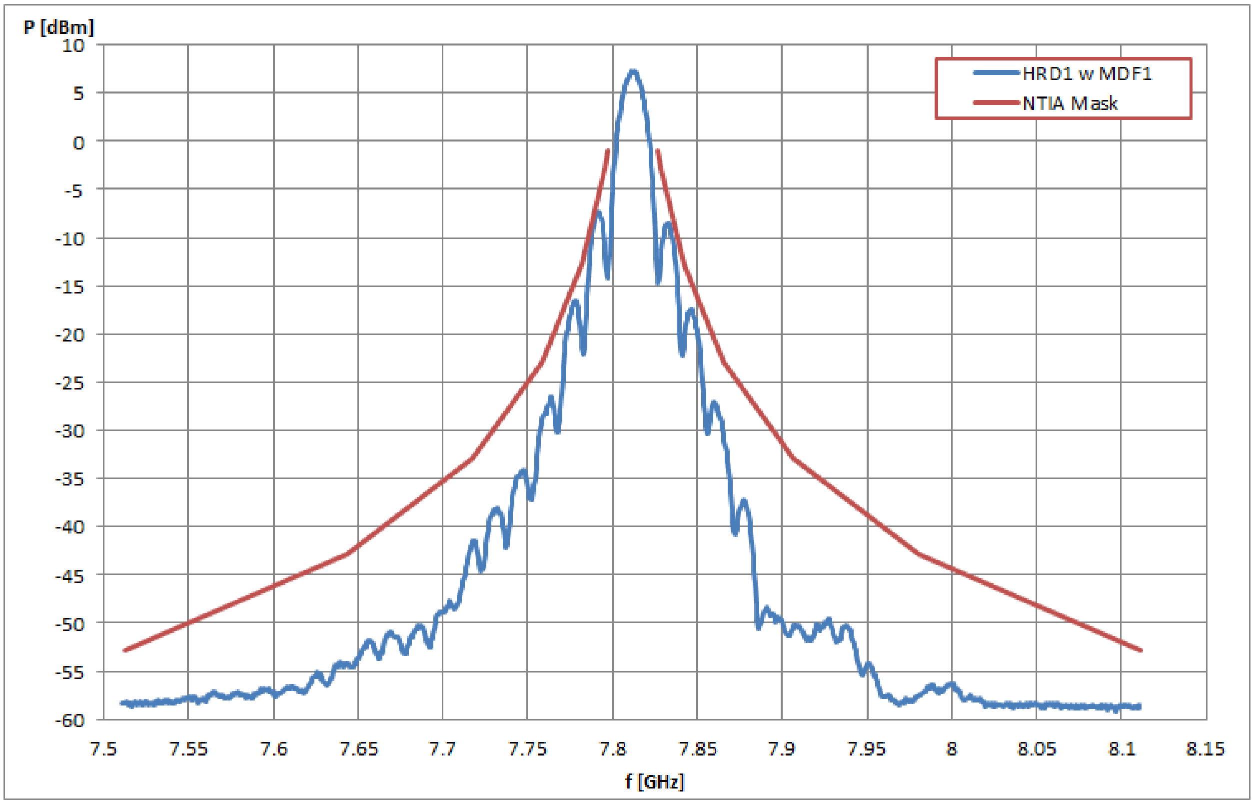


Figure 4-8. HRD Harmonic Filter, Passband and Stopband response

4.4.2.3 NTIA Bandwidth

The filtering of the HRD downlink will be within the NTIA bandwidth mask as shown in Figure 4-9.



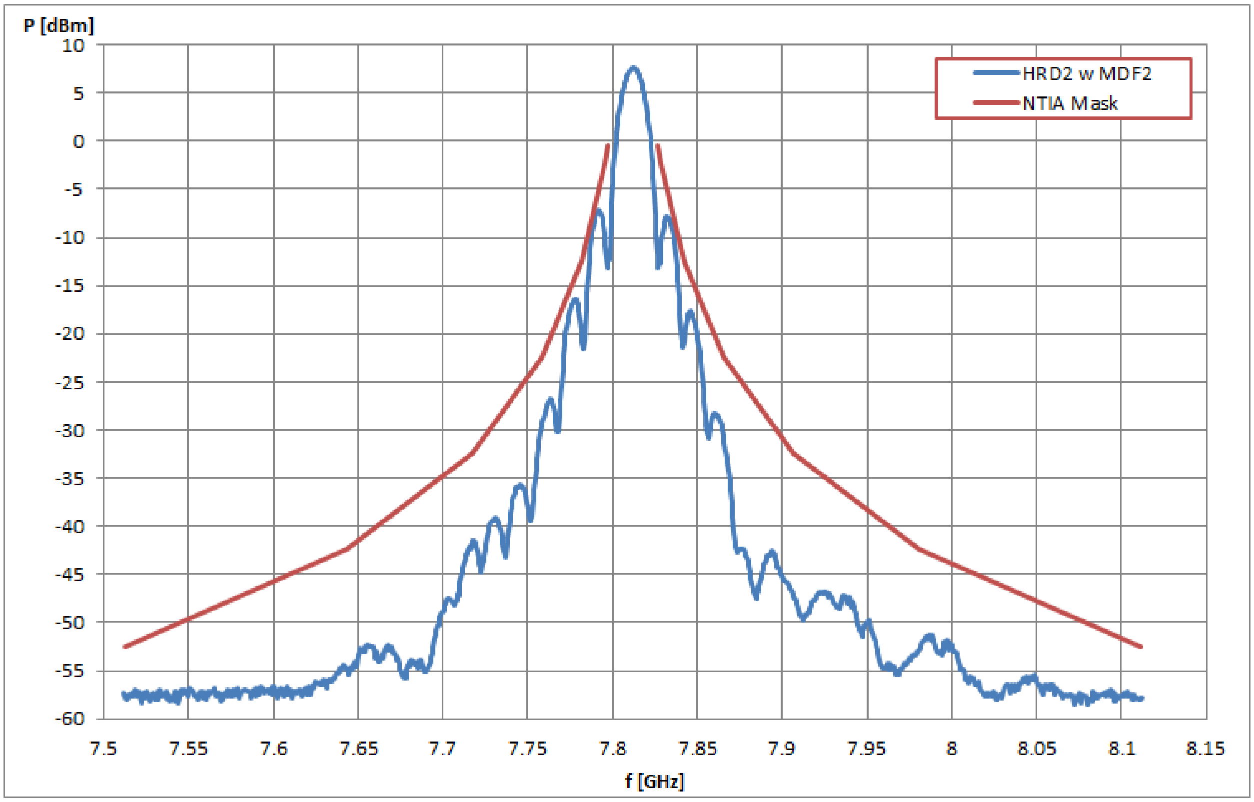


Figure 4-9. NTIA Bandwidth Requirement

4.4.2.4 Filter Characteristics

A pre-final amplifier filter is employed to meet the requirement of 4.4.2.1 and 4.4.2.2. The filter characteristic is shown in Figure 4-9. The spectral output is shown in Appendix C.

4.4.2.5 Doppler Shift

The Spacecraft will be traveling at a velocity of ~7.44 Km/sec at an altitude of 824 Km, this results in a maximum Doppler shift of ±171.0 kHz at an elevation angle of 5°. Figure 4-10 shows the Doppler shift rate as the Spacecraft travels over the different elevation angles. The max rate of change of 1.55 kHz/sec occurs at an elevation angle of 90°.

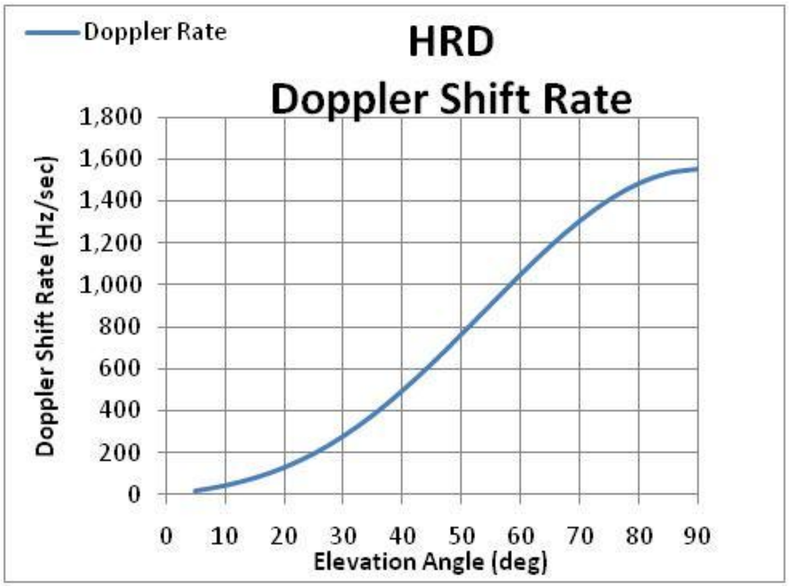


Figure 4-10. Doppler Shift Rate vs Elevation Angle

4.4.2.6 Spurious Emissions

All out-of-band spurious emissions will be less than –60 dBc.

4.5 Ground Interface testing

4.5.1 HRD Compatibility Test

The JPSS-1 Spacecraft will be made available to perform HRD compatibility testing for the purpose of verifying compatibility with the specified HRD ground station. A hard-line RF output from the transmitter and an air link path will be available for this compatibility testing.

4.5.2 End-to-End Test

For End-to-End (ETE) testing during JPSS-1 Compatibility Tests (JCTs), a hardline RF output with the HRD signal will be made available for use with the ground receiver and processor located in the Satellite factory clean room. The RF signal will have the characteristics described above in sections 4.1 through 4.4.

4.6 HRD Scheduling

Mission Support Data (MSD) regarding JPSS-1 scheduling, ephemeris information, predicted outages, and other user messages will be stored on the JPSS Field Terminal Support (FTS) Web-portal. Direct Broadcast Users may retrieve the mission support data from the FTS Web-portal via the internet. The FTS Web-portal access will be granted to the Direct Broadcast User upon registration with the JPSS Program.

Appendix A RF Link Calculations

Figure A-1 summarizes the worst case HRD link margin with a 5° elevation angle. Figure A-2 has been included to show the link margins over various elevation angles.

Link Analysis for HRD Downlink JPSS Payload Science Downlink (5 deg) at 15 Mbps				
Parameter	Symbol	Value	Unit	Source
Frequency	f	7.812	GHz	JPSS RF IRD 472-00173
Transmitter Power	p	7.8	Watt	Tx RF Po @ < 35° C
Total Transmit Power	P	38.92	dBm	P = 10 log(p)+30
S/C Antenna Gain	Gt	5.50	dBi	Ant Gain at ± 62°
Passive Loss	Li	-2.00	dB	Coax Cable, Filter, Switch Losses
Equiv. Isotropic Radiated Power	EIRP	42.4	dBm	EIRP = P+Gt+Li
Propagation Path Length	S	2835	km	Alt=824km, Elev Angle=5°
Free Space Dispersion Loss	Ls	-179.4	dB	Ls = -92.44 - 20log(S) - 20log(f)
Polarization Loss	Lp	-0.26	dB	Tx Ant AR Loss in Gain, Tx AR=3.58dB, Rx AR=2dB
Rain & Atmospheric Loss	La	-3.65	dB	NPP HRD IRD 429-03-02-24, Appendix A
Multipath Loss	Lc	-0.20	dB	JPSS RF IRD 472-00173
Ground Antenna Pointing Loss		-1.00	dB	JPSS RF IRD 472-00173, 3 Meter Ground Antenna
Ground Station G/T	Grp	22.70	dB/K	JPSS RF IRD 472-00173, 3 Meter Ground Antenna
Total Received Power/T		-119.34	dBm/K	
Boltzmann's Constant	k	-198.6	dBm/Hz-K	$k = 10\log(1.38*10^{-23})$
Total Received Power/kT		79.26	dB-Hz	
DATA CHANNEL (QPSK)				
Data Power/kT		79.26	dBm/Hz/KT	
Information Rate		71.18	dB-Hz	15 Mbps with Reed Solomon
Available E_b/N_o		8.08	dB	
Rqd E_b/N_o 10^{-5} BER from Viterbi		4.40	dB	JPSS RF IRD 472-00173
Implementation Loss		-2.50	dB	JPSS RF IRD 472-00173
Available Signal Margin		**1.18**	**dB**	**1 dB Margin Required**

Figure A-1. Link Analysis at 5° Elevation Angle

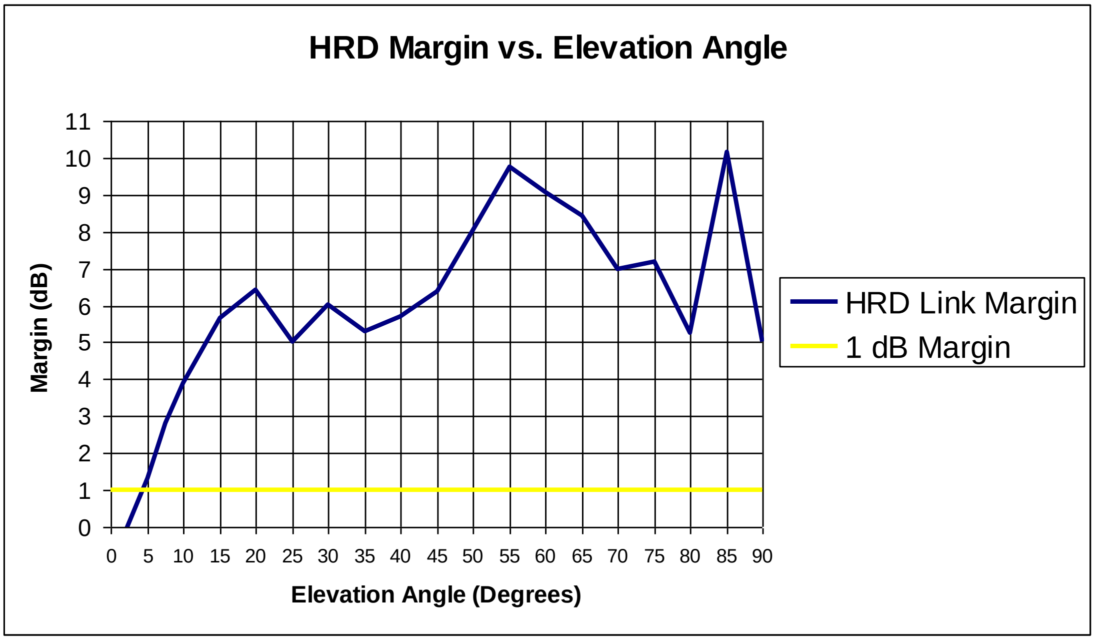


Figure A-2. Typical Link Analysis vs User Terminal Elevation Angle

Appendix B Earth Coverage Antenna Patterns

Figure B-1 shows the Earth Coverage HRD antenna patterns as a function of the offpoint angle. Contained within these plots is the RHCP antenna gain and the minimum antenna gain. As shown in this figure the Earth Coverage antenna maintains the necessary link margin over all angles.

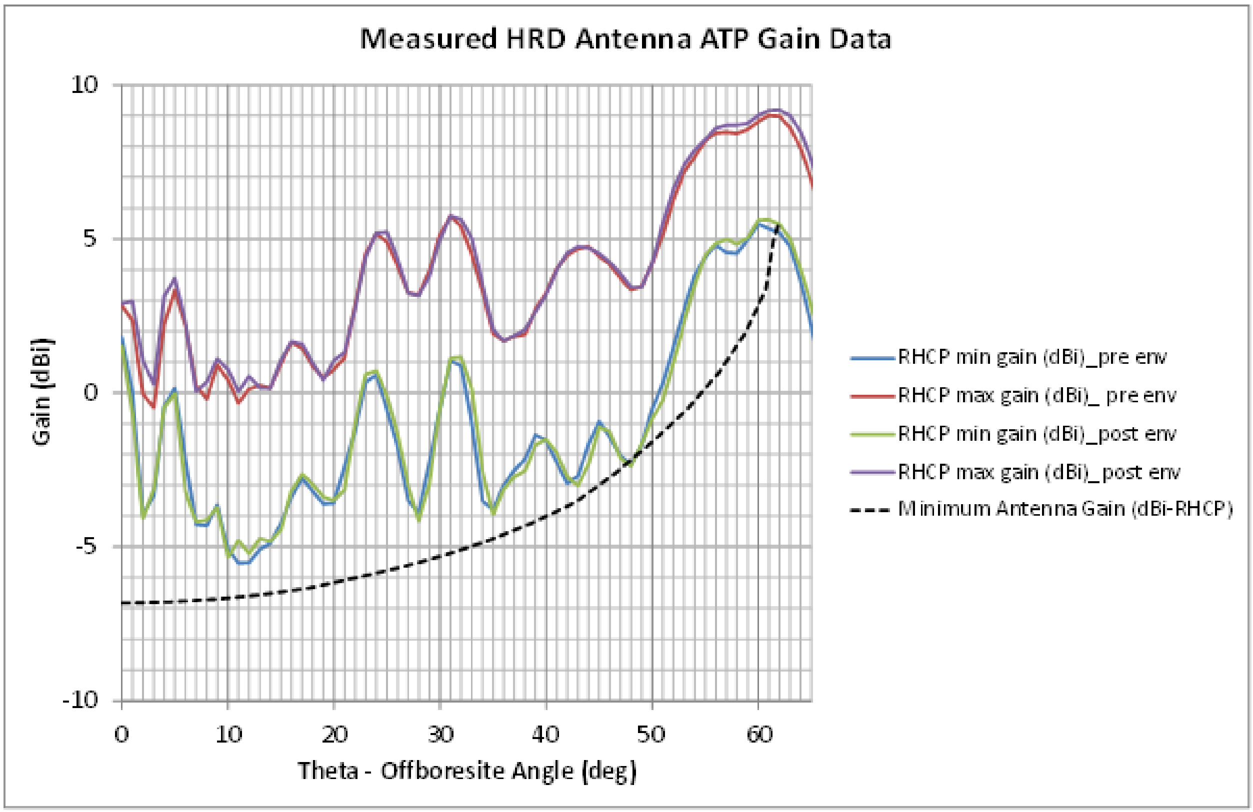


Figure B-1. Single Sided Antenna Pattern Requirement as a Function of Offpoint Angle

Appendix C HRD Spectrum

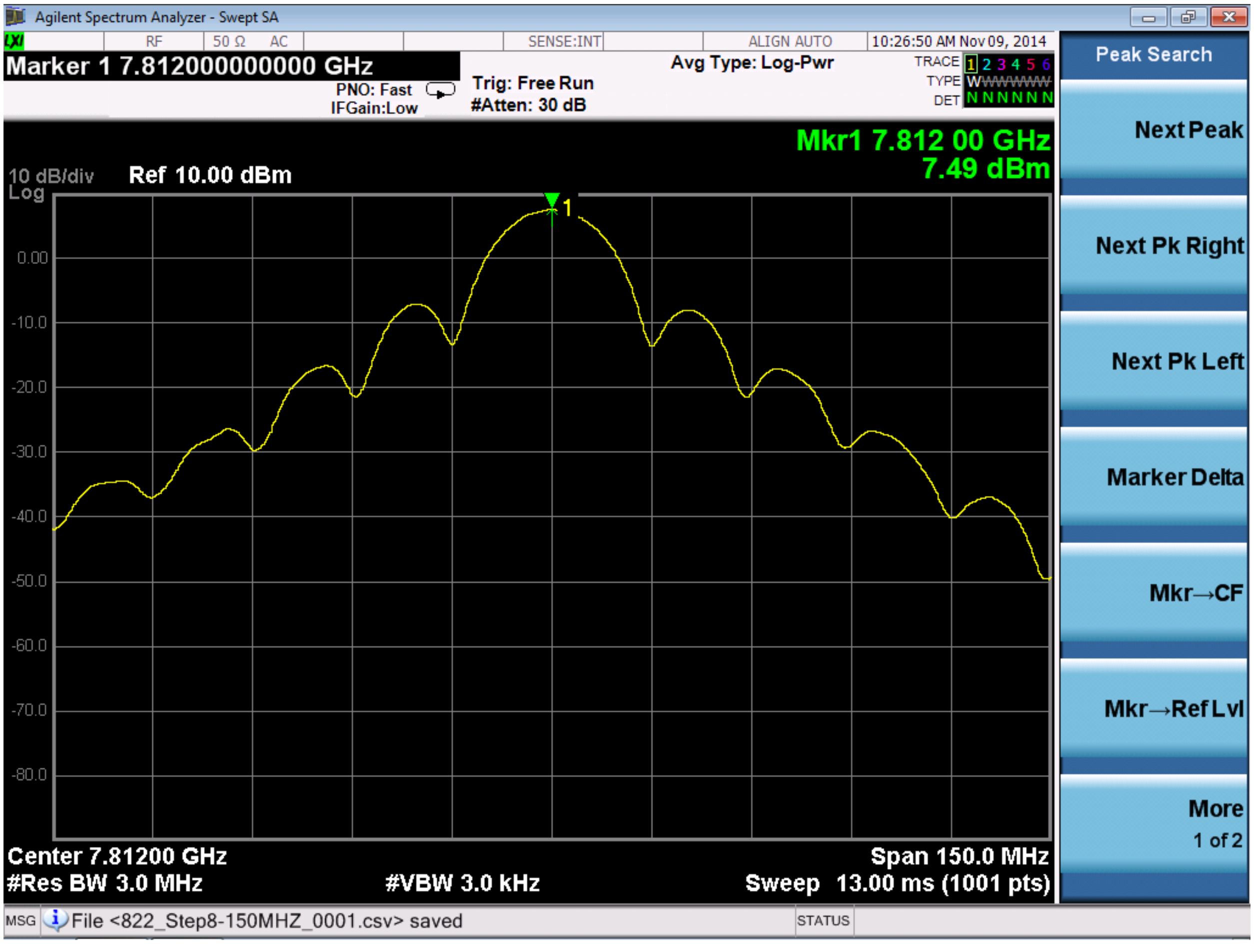


Figure C-1. Spectral Plots

Appendix D Acronyms and Abbreviations

AM	Amplitude Modulation
AOS	Advanced Orbiting Systems
APID	Application Identification
BATC	Ball Aerospace and Technology Corporation
BER	Bit Error Rate
bps	bits per seconds
C	Celsius
CADU	Channel Access Data Unit
CCB	Change Control Board
CCSDS	Consultative Committee for Space Data Systems
CDP	Command and Data Processor
CMD	Command
CVCDU	Coded Virtual Channel Data Unit
dB	Decibel
dBc	Decibel/carrier
dBi	Decibel Isotropic
dB/K	Decibel/Kelvin
dBm	Decibel/miliwatt
DBS	Direct Broadcast Stations
dBW	Decibel/Watt
deg	degrees
Ds	Disable
DSN	Deep Space Network
EIRP	Effective Isotropic Radiated Power
En	Enable
ETE	End-to-End
FSW	Flight Software
GHz	Giga Hertz
GSFC	Goddard Space Flight Center
G/T	Gain-to-Noise Temperature Ratio
HRD	High Rate Data
HRDTx	High Rate Data Transmitter
Hz	Hertz
I	In-phase
ICD	Interface Control Document
IRD	Interface Requirements Document
JCT	JPSS Compatibility Tests
JPSS-1	Joint Polar Satellite System-1
K	Kelvin
Kbps	Kilo bits per second
Km	Kilometer
LVDS	Low Voltage Differential Signal

Mbps	Mega bits per second
MDF	Mission Data Formatter
MHz	Mega Hertz
MSDS	Mission Support Data Server
Msps	Mega symbols per second
NASA	National Aeronautics and Space Administration
NPOES	National Polar-Orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NRZ	Non Return to Zero
NRZ-L	Non Return to Zero-Level
NRZ-M	Non Return to Zero-Mark
NTIA	National Telecommunications and Information Administration
PCM	Pulse Code Modulation
PM	Phase Modulation
PO	Program Office
p-p	peak-peak
PRBS	Pseudo-Random Bit Stream
PRN	Pseudo-Random Noise
Q	Quadrature
QPSK	Quadrature Phase Shift Key
RF	Radio Frequency
RFICD	Radio Frequency Interface Control Document
RHCP	Right Hand Circular Polarization
RMS	Root Mean Square
RS	Reed Solomon
S/C	Spacecraft
sec	second
SER	System Engineering Report
SN	Space Network
SNUG	Space Network Users' Guide
SSPA	Solid State Power Amplifier
synch	synchronizer
TBD	To Be Determined
TBR	To Be Reviewed
TCXO	Temperature Compensated Crystal Oscillator
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TF	Transfer Frame
TLM	Telemetry
URL	Uniform Resource Locator
VCDU	Virtual Channel Data Unit