



CGMS-39 NOAA-WP-27  
Prepared by NOAA  
Agenda Item: IV/1  
Discussed in WG IV

**BROADCAST SERVICES FOR NOAA'S NPP/JPSS**  
In response to CGMS action 38.47

In response to CGMS action 38.47, NOAA presented information on the direct readout services from the NPP and JPSS satellites. High Rate Data (HRD) and Low Rate Data (LRD) are both direct broadcast services provide by NOAA, the data is freely available to international users as long as they have the proper receiving equipment. The HRD service will be available on NPP and JPSS satellites. JPSS-1 will only have HRD and may have LRD, along with HRD, contingent upon budget. JPSS-2 will have both LRD and HRD.

Recommendation proposed: None.

## Broadcast Services for NOAA's NPP/JPSS

### 1 INTRODUCTION

JPSS spacecraft will also simultaneously broadcast two types of real-time data to suitably equipped ground stations. These direct broadcast/real-time ground stations (or field terminals) will be capable of processing RDRs into EDRs by utilizing the FTS processing software appropriate for the type of field terminal.

The High Rate Data (HRD) broadcast will be a complete, full resolution data set containing sensor data and a subset of auxiliary/ancillary data necessary to generate EDR's and is intended to support users at fixed, regional hubs. A complete set of auxiliary/ancillary data will also be available at an on-line server for field terminal real-time processing. The HRD broadcast will be transmitted at X-band frequencies in the 7750-7850 MHz band (carrier frequencies of 7812 MHz and 7830 MHz), at a data rate of 20 Mbps, and will require a bandwidth of 30.8 MHz, with a tracking receive antenna aperture not to exceed 2.0 meters in diameter. The HRD continuity is expected from NPP through JPSS

The Low Rate Data (LRD) broadcast will be a subset of the full sensor data set and is intended for U.S. and worldwide users of field terminals. Some data compression (lossy or lossless) may be employed for the LRD link. The LRD (L-band) broadcast will provide data at a rate of about 4.0 Mbps (nominally 3.88 Mbps) at 1706 MHz, using a bandwidth of 8 MHz, with full Consultative Committee for Space Data Systems (CCSDS) convolutional coding, Viterbi decoding, and Reed Solomon encoding/decoding into a tracking receive antenna aperture not to exceed 1.0 meter diameter. The LRD parameters (frequency, bandwidth, data rate, and data content) have been selected to satisfy U.S. requirements for low-rate, real-time direct broadcast, as well as be closely compatible with (but not identical to) the broadcast parameters for the Advanced High Resolution Picture Transmission (AHRPT) format that has been accepted and approved by the Coordinating Group on Meteorological Satellites (CGMS) and will be used on the EUMETSAT MetOp spacecraft.

The LRD broadcast will include data required to satisfy the U.S. user-specified, eight highest priority EDRs for real-time broadcast: imagery (from VIIRS) at 800 m HSI from at least one visible and one infrared channel and night time imagery at 2.7 km HSI from the day/night band; atmospheric vertical temperature and moisture profiles (from CrIS, ATMS, and CMIS); global sea surface winds (from CMIS); cloud base height, cloud cover/layers; pressure (surface/profile), and sea surface temperature. Additional lower priority EDRs will also be included in the LRD broadcast on a priority basis and as bandwidth permits. Future communications capabilities (e.g., rebroadcast of processed imagery/data and delivery via the Internet or "commercial" services) may allow other-than-direct satellite-to-ground data transmission to follow-on field terminal systems.

The JPSS LRD broadcast parameters (frequency, bandwidth, data rate, and data content) have been selected to satisfy NOAA requirements for low-rate, real-time direct broadcast, as well as be closely compatible with the broadcast parameters for the Advanced High Resolution Picture Transmission (AHRPT) format that has been accepted and approved by the Coordinating Group on Meteorological Satellites (CGMS) and will be used on the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Metop spacecraft.

## **1.1 Direct Broadcast Users**

The Direct Broadcast users are an external entity to the JPSS Project. The HRD Direct Broadcast users are capable of receiving real-time direct broadcast data if they have the minimum equipment for receipt of the data as specified in Section 5. The Direct Broadcast users also receive broadcast data from other missions such as Metop, DMSP, POES, and EOS.

The intent for the JPSS HRD is to utilize the same RF link characteristics as NPP HRD (described in the reference documents) to maintain compatibility with user ground stations and pre-processors.

## **1.2 Data Flow Descriptions**

The interface between JPSS and the Direct Broadcast users supports the following data flows:

- High Rate Data (HRD)
- Test Bit Stream
- Mission Status Data (via the internet)

## **1.3 High Rate Data**

The HRD produced by the Space Segment consists of real-time science and engineering data. The instrument data included in the HRD are selected packets received by the spacecraft from the instruments. This consists of science data, instrument status data, and instrument diagnostic data. Spacecraft data in the HRD consists of spacecraft status data (i.e., housekeeping data) and the spacecraft diary. The packets selected for inclusion are ground specified by Application Process Identifier (APID). The ground will exclude certain APIDs, such as instrument diagnostic data, if the data rates cannot be supported by the HRD downlink. The HRD will nominally be sent 100% of the time, including times of SM playback. HRD may be disabled for periods of testing and non-nominal conditions.

## **1.4 TEST Bit Stream**

The satellite will generate pseudo-random bit stream test data as a test mode used for the purpose of bit error rate (BER) checking, as required. It is not a normal X-band downlink service.

## **1.5 MISSION STATUS DATA**

The Mission Support Data is provided by the C3S and includes updated JPSS orbit vectors, status information such as scheduled outages of the HRD service, as well as any auxiliary or ancillary data required to process the instrument data contained within the HRD into EDRs. It is available via the internet, and is not part of the HRD data stream coming from the satellite.

## **2 FUNCTIONAL AND PERFORMANCE REQUIREMENTS**

### **2.1 HRD BASEBAND REQUIREMENTS**

#### **2.1.2 HRD Data Content**

The Spacecraft shall broadcast the HRD consisting of ground selectable (specified by APID) real-time instrument science data (including engineering data), real-time spacecraft and instrument housekeeping data, and S/C diary.

#### **2.1.2 HRD Data Rate**

The Spacecraft shall format the HRD Broadcast for transmission at a total data rate of 15 Mbps over the X-band link.

#### **2.1.3 HRD Availability**

The Spacecraft shall continuously broadcast the HRD while the spacecraft is in normal science mode. Note: The intent is to provide broadcast with no guarantee of meeting link margins during non-nominal operations.

#### **2.1.4 HRD CADU Format**

See Figure 5- 1 for example downlink CADU format which consists of an AOS Transfer Frame, Reed-Solomon Check Symbols and an Attached Sync Marker (ASM).

#### **2.1.5 AOS Transfer Frame**

The spacecraft shall format the HRD stream in accordance with required fields of the AOS Transfer Frame Protocol, with the data field comprised of Multiplexing Protocol Data Units, as defined in CCSDS 732.0-B, AOS Space Data Link Protocol.

#### **2.1.6 CADU Generation**

The spacecraft shall generate CADUs by appending an ASM and Reed-Solomon Check Symbols to AOS Transfer Frames as defined by CCSDS 131.0-B, TM Synchronization and Channel Coding.

#### **2.1.7 HRD Bit Error Rate**

The Spacecraft shall provide the HRD to the Direct Broadcast Users with an effective bit error rate after all decoding of less than  $10^{-8}$  under the following conditions:

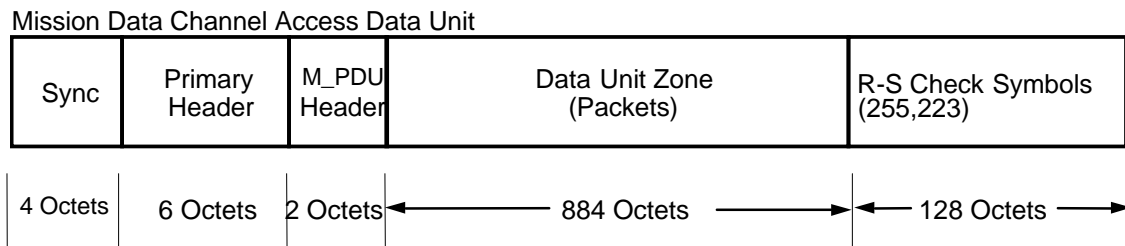
The ground receive station meets the minimum requirements stated in section 2.6

The spacecraft is in view of the ground receive station with a minimum elevation of 5 deg.

Total rain loss is less than 3dB. Note: Rain loss includes attenuation, scintillation, and degradation of G/T.

### 2.1.8 HRD Reed-Solomon Encoding

The Spacecraft shall use Reed-Solomon (255,223) code with an interleave depth of 4 for error correction of the CADUs.



**Figure 2-1 Example Channel Access Data Unit (Sync + coded AOS Frame)**

### 2.1.9 HRD Constant Rate

The Spacecraft shall maintain a constant HRD broadcast rate by using using Idle (a.k.a (fill) Transfer Frames using format as defined in CCSDS 732.0-B.

### 2.1.10 HRD Randomization

The Spacecraft shall randomize the HRD stream compliant with CCSDS 131.0-B, Section 7

### 2.1.11 HRD Convolutional Code

The Spacecraft shall encode the HRD stream with a rate 1/2, constraint length 7 convolutional code as defined in CCSDS 131.0-B.

## 2.2 TEST BIT STREAM BASEBAND REQUIREMENTS

### 2.2.1 Test Bit Stream Data Rate

The Spacecraft shall be capable of providing a Test Bit Stream formatted for transmission at 15 Mbps over the X-band link

### 2.2.2 Test Bit Stream Data Content

The Spacecraft shall generate the Test Bit Stream using the following bit transition generation function (refer to CCSDS 131.0-B):

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

### 2.2.3 Test Bit Stream Bit Error Rate

The Spacecraft shall provide the Test Bit Pattern to the ground with a bit error rate of less than  $10^{-4}$  after convolutional decoding under the following conditions:

- (a) The ground receive station meets the minimum requirements stated in section 2.6
- (b) The spacecraft is in view of the ground receive station with a minimum elevation of 5 deg.
- (c) Total rain loss is less than 3dB. Note: Rain loss includes attenuation, scintillation, and degradation of G/T.

## **2.3 Signal Characteristics**

The HRD signal characteristics are defined in the following paragraphs, and summarized in Appendix C. The HRD broadcast is expected to include virtually all collected mission data.

### **2.3.1 RF Data Modulation**

The Spacecraft shall modulate the X-band RF using Quadrature Phase Shift Keying (QPSK).

### **2.3.2 RF Center Frequency**

The Spacecraft shall transmit the X-band RF on a center frequency of 7812 MHz.

### **2.3.3 RF Data Encoding**

The Spacecraft shall format the data on the X-band RF using NRZ-M.

### **2.3.4 RF Link Margin**

The spacecraft shall provide a link margin for X-band RF of at least 1.0 dB at 5 degrees ground elevation angle.

### **2.3.5 RF encoding order**

The Spacecraft shall generate the HRD and Test Bit Stream using the following order of processing following randomization and CADU construction:

- a) differential encode
- b) convolutional encode
- c) split convolution code symbols onto I & Q channels such that the first convolutional symbol (G1) is placed on I and the second symbol (G2) is placed on Q
- d) modulate I and Q onto the carrier simultaneously.

### **2.3.6 Minimum Received Eb/No**

The spacecraft shall provide a minimum Eb/No of 4.4 dB at the ground receive station for conditions provided in section 2.6 and requirement 2.1.7. Note: Minimum Eb/No is required to guarantee all ground receive sites will be capable of maintaining lock on the signal.

## **2.4 Spectrum Occupancy Compliance**

### **2.4.1 NTIA Compliance**



The Spacecraft X-Band HRD RF link shall comply with the *National Telecommunications and Information Administration (NTIA) Manual of Regulations & Procedures for Federal Radio Frequency Management, Table 8.2.36, 8025-8500 MHz*, for maximum allowed power spectral density at the ground and spectral emission masks for stateside downlinks.

#### **2.4.2 ITU Compliance**

International downlinks shall comply with the International Telecommunications Union – Radiocommunication Sector (ITU-R) Radio Regulations, RR Article 21.16, Table 21-4, 25.25-27.5 GHz.

#### **2.4.3 DSN Compliance**

The Spacecraft spectral power flux density falling within the Deep Space Research band of 8400 MHz to 8450 MHz shall be less than  $-255.1$  dBW/m<sup>2</sup> Hz

### **2.5 JPSS status information**

#### **2.5.1 Positions Vectors**

The C3S shall make available to the Direct Broadcast users JPSS position vectors of sufficient accuracy to allow Ground Station tracking of the JPSS satellite, via the internet.

#### **2.5.2 Satellite Status**

The C3S shall make available to the Direct Broadcast users current status of the JPSS satellite, via the internet.

#### **2.5.3 HRD Predicted Outages**

The C3S shall make available to the Direct Broadcast users scheduled outages of the HRD, via the internet.

#### **2.5.4 Instrument Predicted Outages**

The C3S shall make available to the Direct Broadcast users scheduled outages of any instrument data, via the internet.

#### **2.5.5 JPSS Auxiliary and Ancillary Data**

The C3S shall make available to the Direct Broadcast users any auxiliary and ancillary data required to process the received instrument data into EDRs, via the internet.

### **2.6 Direct Downlink User Ground Station Characteristics**

#### **2.6.1 User Stations G/T**

The Direct Downlink User Station G/T shall be better than or equal to G/T values shown in Table 2-1. Note: Assumes the User Ground Station has an Antenna Gain of 44.9 dBi or better (3 meter antenna with an efficiency of 55%) with surface tolerance loss of 0.3 dB or better.

**Table 2-1: Ground Station Minimum G/T**



Elevation [deg.]	Ground Station G/T [dB/K]
5°	22.70
40°	23.59
70°	23.65
90°	23.66

### **2.6.2 User Station Pointing Loss**

The Direct Downlink User station degradation due to pointing loss shall not exceed 1.0 dB.

### **2.6.3 User Station Implementation Loss**

The Direct Downlink User station implementation loss shall not exceed 2.5 dB.

### **2.6.4 User Station Multipath Loss**

The Direct Downlink User station shall have a multipath loss of less than 0.2 dB at a 5 degree elevation.



### **3 DIRECT BROADCAST USERS**

The Direct Broadcast Users are an external entity to the JPSS Project. The LRD Direct Broadcast Users are capable of receiving real-time direct broadcast data if they have the minimum equipment for receipt of the data as specified in Section 5. The Direct Broadcast Users also receive broadcast data from other missions such as Metop, DMSP, POES, and EOS.

The intent for the JPSS LRD is to utilize the similar RF link characteristics as Metop-HRPT (described in the reference documents) to maintain compatibility with user ground stations and pre-processors

#### **3.1 Data Flow Descriptions**

The interface between JPSS and the LRD Direct Broadcast Users supports the following data flows:

- Low Rate Data (part of LRD broadcast stream)

- Test Bit Stream (part of LRD broadcast stream)

- Mission Status Data (available via internet)

#### **3.2 Low rate data**

The LRD produced by the Space Segment consists of real-time science and engineering data. The instrument mission data included in the LRD are selected packets received by the spacecraft from the instruments. LRD also includes selected instrument and spacecraft housekeeping telemetry. The packets selected for inclusion are ground specified by Application Process Identifier (APID). The LRD will nominally be sent 100% of the time, including times of SMD playback (i.e., LRD is "full time", and is independent of SMD playbacks). LRD may be disabled for periods of testing and non-nominal conditions.

#### **3.3 TEST Bit Stream**

The satellite will generate, upon command, pseudo-random bit stream test data as a test mode used for the purpose of bit error rate (BER) checking, as required. It is not a normal L-band downlink service.

#### **3.5 MISSION Support DATA**

The Mission Support Data is provided by the C3S and includes updated JPSS orbit vectors, status information such as scheduled outages of the LRD service, as well as any auxiliary or ancillary data required to process the instrument data contained within the LRD into EDRs. It is available via the internet, and is not part of the LRD data stream coming from the satellite.

### **4 FUNCTIONAL AND PERFORMANCE REQUIREMENTS**

#### **4.1 LRD BASEBAND REQUIREMENTS**

#### **4.1.2 LRD Data Content**

The Spacecraft shall broadcast the LRD consisting of ground selectable (specified by APID) real-time instrument science data (including engineering data), as well as selected real-time spacecraft and instrument housekeeping telemetry. Table 4-1 shows examples of instrument data which could be identified by the ground for inclusion in LRD

The content of tables and the point (time) of switching between tables will be controlled by stored command loads of APIDs from the ground. The priority order is the order identified in the ground-provided table, in the event the data associated with the APIDs identified exceeds the link rate.

#### **4.1.3 LRD Data Rate**

The Spacecraft shall format the LRD Broadcast for transmission at a total data rate of 4.0 Mbps over the L-band link.

#### **4.1.4 LRD Availability**

The Spacecraft shall continuously broadcast the LRD while the spacecraft is in normal science mode. Note: The intent is to provide broadcast with no guarantee of meeting link margins during non-nominal operations.

### **4.2 Deleted/Reserved**

#### **4.2.1 LRD CADU Format**

See Figure 4-1 for example downlink CADU format which consists of an AOS Transfer Frame, Reed-Solomon Check Symbols and an Attached Sync Marker (ASM).

#### **4.2.1 AOS Transfer Frame**

The spacecraft shall format the LRD stream in accordance with required fields of the AOS Transfer Frame Protocol, with the data field comprised of Multiplexing Protocol Data Units, as defined in CCSDS 732.0-B, AOS Space Data Link Protocol.

#### **4.2.3 CADU Generation**

The spacecraft shall generate CADUs by appending an ASM and Reed-Solomon Check Symbols to AOS Transfer Frames as defined by CCSDS 131.0-B, TM Synchronization and Channel Coding.

**Table 4-1 Sample LRD Content**



Data Type	Band	Case 1 day	Case 1 night	Case 2 day	Case 2 night
VIIRS	DNB		x		
	I01				
	I02				
	I03				
	I04				
	I05				
	M01				
	M02				
	M03				
	M04	x		x	
	M05			x	
	M06	x			
	M07			x	x
	M08				
	M09				
	M10			x	x
M11					
M12	x	x	x	x	
M13	x	x	x	x	
M14					
M15	x	x	x	x	
M16	x	x	x	x	
CrIS		x	x		x
ATMS		x	x	x	x
OMPS		x	x	x	x
CERES					
Hskpg -16k 15.837%		x	x	x	x
CCSDS overhead		x	x	x	x
TOTAL (Mbps)		3.874	3.478	3.236	3.826

\* Overhead of 15.837 % based on Figure 4-1

#### 4.2.4 LRD Bit Error Rate

The Spacecraft shall provide the LRD to the Direct Broadcast Users with an effective bit error rate after all decoding of less than  $10^{-8}$  under the following conditions:

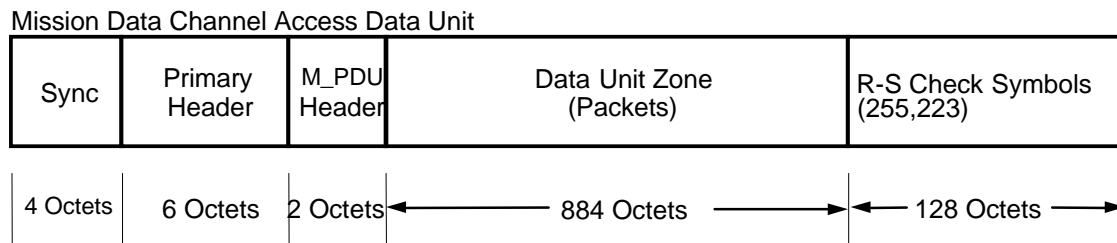
The ground receive station meets the minimum requirements stated in section 4.7

The spacecraft is in view of the ground receive station with a minimum elevation of 5 deg.

Total rain loss is less than 0.3 dB. Note: Rain loss includes attenuation, scintillation, and degradation of G/T.

#### 4.2.5 LRD Reed-Solomon Encoding

The Spacecraft shall use Reed-Solomon (255,223) code with an interleave depth of 4 for error correction of the CADUs.



*Figure 4-1: Example Channel Access Data Unit (Sync + coded AOS Frame)*

#### 4.2.6 LRD Constant Rate

The Spacecraft shall maintain a constant LRD broadcast rate by using using Idle (a.k.a (fill) Transfer Frames using format as defined in CCSDS 732.0-B.

#### 4.2.7 LRD Randomization

The Spacecraft shall randomize the LRD stream compliant with CCSDS 131.0-B, Section 7.

### 4.3 TEST BIT STREAM BASEBAND REQUIREMENTS

#### 4.3.1 Test Bit Stream Data Rate

The Spacecraft shall be capable of providing, by command, a Test Bit Stream formatted for transmission at 4.0 Mbps over the L-band link

#### 4.3.2 Test Bit Stream Data Content

The Spacecraft shall generate the Test Bit Stream using the following bit transition generation function (refer to CCSDS 131.0-B):

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

### 4.3.3 Test Bit Stream Bit Error Rate

The Spacecraft shall provide the Test Bit Pattern to the ground with a bit error rate of less than  $10^{-4}$  after convolutional decoding under the following conditions:

- (a) The ground receive station meets the minimum requirements stated in section 4.7
- (b) The spacecraft is in view of the ground receive station with a minimum elevation of 5 deg.
- (c) Total rain loss is less than 0.3 dB. Note: Rain loss includes attenuation, scintillation, and degradation of G/T.

## 4.4 Signal Characteristics

### 4.4.1 RF Data Modulation

The Spacecraft shall modulate the L-band RF using Quadrature Phase Shift Keying (QPSK).

### 4.10.2 RF Center Frequency

The Spacecraft shall transmit the L-band RF on a center frequency of 1707.000 MHz.

### 4.4.3 RF Data Pulse Code Modulation Format

The Spacecraft shall format the data on the L-band RF using NRZ-M.

### 4.4.4 RF Margin

The spacecraft shall provide a link margin for L-band RF of at least 3 dB for all ground elevation angles above 5 degrees.

### 4.4.5 NTIA Compliance

The Spacecraft L-band RF shall comply with the *National Telecommunications and Information Administration (NTIA) Manual of Regulations & Procedures for Federal Radio Frequency Management* for maximum allowed power spectral density at the ground and spectral emission masks.

### 4.4.6 RF encoding order

The Spacecraft shall generate the LRD and Test Bit Stream using the following order of processing following randomization and CADU construction:

- a) differential encode
- b) convolutional encode
- c) split convolution code symbols onto I & Q channels such that the first convolutional symbol (G1) is placed on I and the second symbol (G2) is placed on Q
- d) modulate I and Q onto the carrier simultaneously.

### 4.4.7 Minimum Received Eb/No



The spacecraft shall provide a minimum Eb/No of 4.0 dB at the ground receive station for conditions provided in section 4.7 and requirement 4.2.4. Note: Minimum Eb/No is required to guarantee all ground receive sites will be capable of maintaining lock on the signal.

#### 4.5 Satellite-Controlled Characteristics summary

The RF and modulation characteristics of the LRD signal transmitted from the JPSS satellite shall be as identified in Table 4-2.

**Table 4-2 LRD Link Characteristics**

PARAMETER	VALUE
Signal	LRD, Low Rate Data Transmission
Nominal Carrier Center Frequency	1707.000 MHz
RF bandwidth	6.0 MHz (99 % of the total signal power)
Polarization	RHCP
Data Rate / Channel Data Rate	4.0 Mbps/5.333333 Mbps
Data Modulation	QPSK FEC 3/4
Convolutional encoding	Code rate = 3/4
	Constraint length 7 bits
	Connection vectors: G1= 1111001/ G2=1011011
	Phase relationship: G1 associated with the first symbol
	Symbol inversion: No
	Puncturing: Yes. (see note 1 below)
Satellite Axial Polarization	< 4.5 dB (at nadir)
Power Flux Density evolution during satellite pass	-154 dBW/m <sup>2</sup> 4 kHz (see note 2 below)
Carrier Frequency Deviation	25 x10 <sup>-6</sup>

Note 1:

- The 3/4 rate code is realized by puncturing the output of a 1/2 rate encoder.
- The output streams from the 3/4 rate Viterbi encoder consist of the output streams of the 1/2 rate encoder, with the exception of two out of six bits, which are deleted in a repeating pattern.

Note 2:

The gain of the antenna shall be such that the following PFD limitations are met:

- 154 dBW/(m<sup>2</sup>-4 kHz) for elevation angle (delta) lower than 5°
- 154 + 0.5 (delta -5) dBW/(m<sup>2</sup>-4 kHz) for elevation angle (delta) between 5° and 25°
- 144 for elevation angle (delta) greater than 25°

The following assumptions shall be used in the PFD calculation:

- Peak of TX spectrum density including possible residual carrier.
- Typical values for TX power and antenna gain over elevation.
- Average values for antenna gain along azimuth.

As a minimum, the satellite shall radiate LRD at the levels described in Figure 4-2.

Angle w.r.t. nadir	EIRP (dBW)
0	1.46
5	1.49
10	1.61
15	1.8
20	2.07
25	2.44
30	2.9
35	3.48
40	4.2
45	5.1
50	6.25
55	7.8
58	9.1
60	9.1
62	9.1

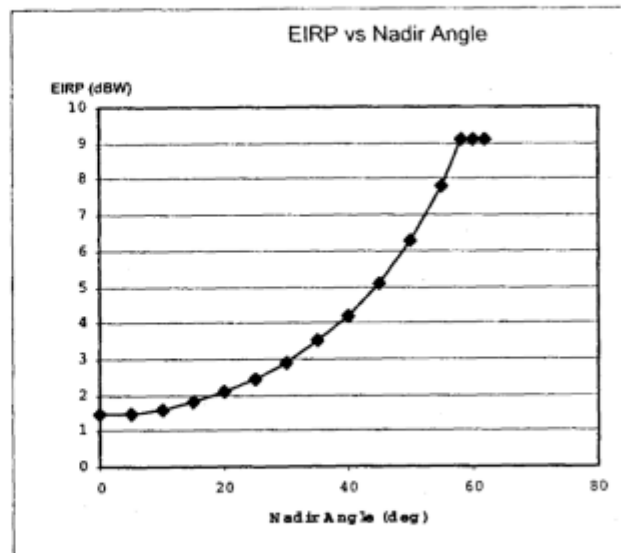


Figure 4-2 Minimum EIRP for LRD



**4.6.1 JPSS Positions Vectors**

The C3S shall make available to the Direct Broadcast Users JPSS position vectors of sufficient accuracy to allow Ground Station tracking of JPSS, via the internet.

**4.6.2 JPSS Satellite Status**

The C3S shall make available to the Direct Broadcast Users current status of the JPSS satellite, via the internet.

**4.6.3 LRD Predicted Outages**

The C3S shall make available to the Direct Broadcast Users scheduled outages of the LRD, via the internet.

**4.6.4 JPSS Instrument Predicted Outages**

The C3S shall make available to the Direct Broadcast Users scheduled outages of any instrument data, via the internet.

**4.6.5 JPSS Auxiliary and Ancillary Data**

The C3S shall make available to the Direct Broadcast Users any auxiliary and ancillary data required to process the received instrument data into EDRs, via the internet.

**4.7 Direct Downlink User Ground Station Characteristics**

The LRD signal reception is based on a 1.8 meter L-band antenna, which will receive the 1707 MHz LRD carrier.

The LRD link shall serve ground stations, which may be located anywhere in the world, and which will have the characteristics identified in Table 4-3.

**Table 4-3 Ground Terminal Characteristics**

G/T @ 5° elevation and clear sky	6 dB/K
Ground Station axial ratio	< 1 dB
Pointing loss	< 0.5 dB