DRL JPSS-1 HRD Commissioning Report

October 2018

Phase 1 (DRAFT)

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GREENBELT, MARYLAND

Purpose

This report was prepared by the NASA GSFC Direct Readout Laboratory (DRL) for the Joint Polar Satellite System (JPSS) Mission. This report describes the methodology used and results obtained during the commissioning of High Rate Data (HRD) for the JPSS-1 satellite.

Objectives

JPSS-1 HRD commissioning objectives were as follows:

- receive the HRD broadcast from the JPSS-1 satellite utilizing commercially-available equipment;
- analyze the received HRD using the Real-time Software Telemetry Processing System (RT-STPS);
- document the spectral characteristics of the JPSS-1 HRD broadcast;
- compare reception of the JPSS-1 HRD to reception of the Aqua satellite direct broadcast data and the Suomi National Polar-orbiting Partnership (SNPP) HRD;
- report unexpected and/or anomalous observations regarding the JPSS-1 HRD broadcast.

Assumptions

It was assumed that reception performance would conform to the specifications cited in the Joint Polar Satellite System 1 (JPSS-1) Spacecraft High Rate Data (HRD) to Direct Broadcast Stations (DBS) Radio Frequency (RF) Interface Control Document (ICD). GSFC 422-00165.

It was assumed that the JPSS-1 HRD would conform to structural specifications contained in the JPSS Common Data Format Control Book - External Volume VII - Part I - JPSS Downlink Data Formats. GSFC 474-00380-B0200 Rev 0200A.

It was assumed that the received data would conform to the structural specifications contained in the National Polar-Orbiting Operational Environmental Satellite System Preparatory Project Mission Data Format Control Book. GSFC 429-05-02-42 (Revision I).

Environment

The environment (Figure 1) that was used to receive and analyze the HRD consisted of the DRL's standard production configuration utilizing the following equipment:

- Orbital Systems 2.4XLSA (2.4 meter) antenna system utilizing Two-line Element (TLE) data provided by the Field Terminal Support (FTS) System;

- Orbital Systems EOS-FES front end servers;
- Orbital Systems HRD-200 series receivers;
- Tektronix RSA 5106B RF Spectrum Analyzer.

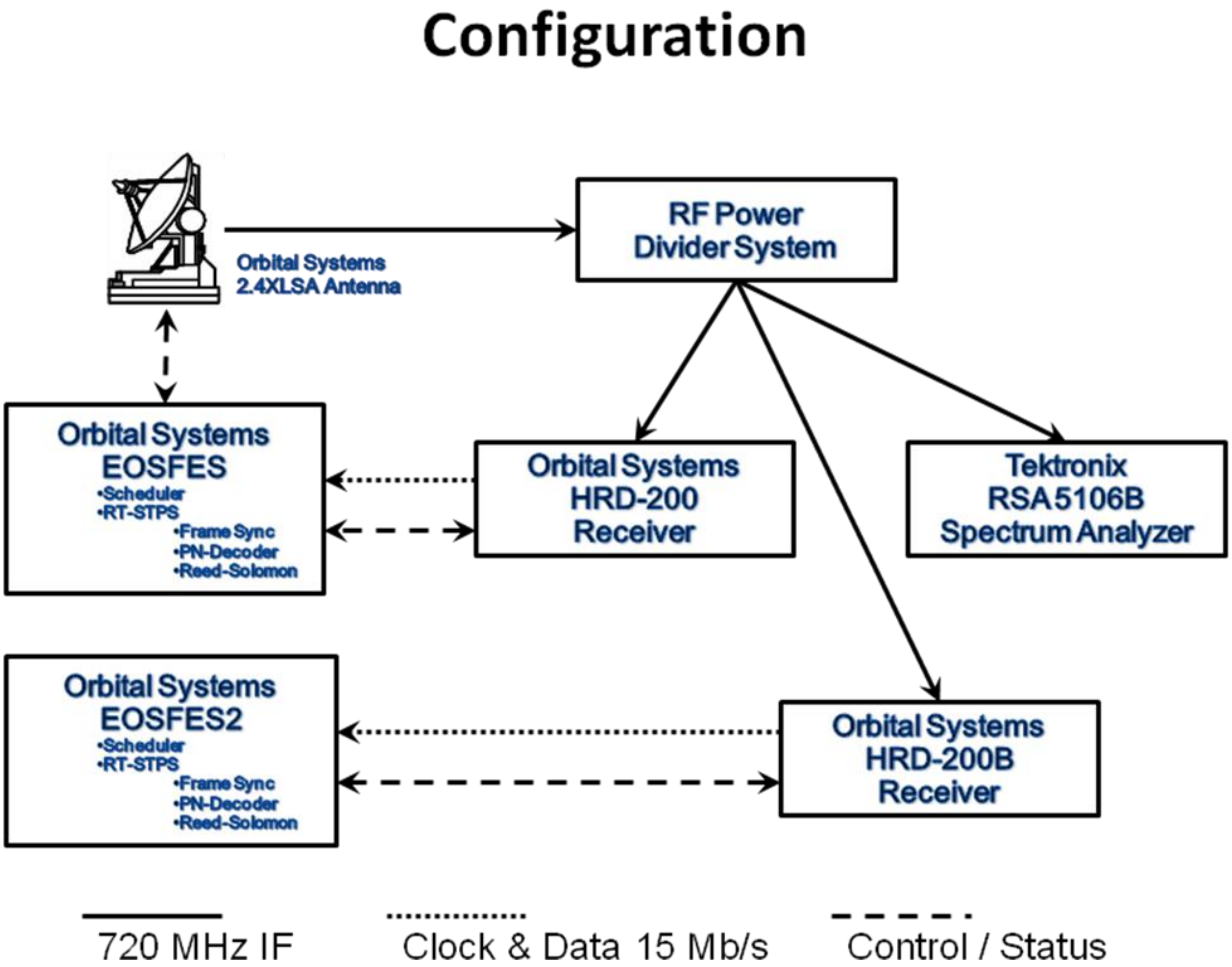

Figure 1. Configuration

System RF Noise Floor

The noise floor typically ranges between -50 and -52 dBm. The noise floor is measured by the HRD-200 series receiver when the receiving antenna is pointed towards cold sky in stow position.

Gain over Temperature (G/T)

The JPSS-1 HRD RF ICD document states that the Ground Station G/T for a 3 meter antenna should have the following characteristics; 22.7 dB/K at 5 degrees elevation, and 23.66 dB/K at 90 degrees elevation.

The receiving system's G/T was measured using vendor-provided software. The measurement on 04/03/2018 was 24.784 dB/K.

Data

The DRL has confirmed the following:

- RF Spectrum Analysis:
  - Amplitude variations up to 13.7 dB have been observed during medium to high (45 – 90 degrees) maximum elevation passes.
  - Significant multipath has been observed during medium to high (45 – 90 degrees) maximum elevation passes.
  - Passes with low (5 – 45 degrees) maximum elevation angles tend to exhibit less multipath and amplitude fluctuation.
- The JPSS-1 HRD transmission is Viterbi encoded.
- The data are PN and Reed-Solomon encoded.
- Channel Access Data Units (CADUs) are present in the data stream.
- Science & Engineering data were detected.
- The results for the data acquired during a typical pass are as follows:
  - VCID0, VCID1, VCID6, VCID11, and VCID16 CADUs were detected;
  - No VCID13 or VCID24 CADUs were detected;
  - ATMS, CrIS, OMPS, and VIIRS packets were detected;
  - No CERES packets were detected;
  - ENG Apid 0, 8, and 11 were detected;
  - 980,000 frames detected;
  - 1,100,469 output CADUs;
  - 222,407 Fill CADUs;
  - 28,618 ATMS packets;
  - 82,919 CrIS packets;
  - 20,124 OMPS packets;
  - 169,782 VIIRS packets;
  - 2,166 ENG/Sci packets.

Analysis

JPSS-1 RF Signal

Signal amplitude typically approaches -38 dBm, or better, during a pass. The carrier-to-noise ratio is typically about 18 dB. Figure 2 depicts an example of the JPSS-1 RF spectrum. Figure 3 depicts a low elevation angle JPSS-1 pass showing a plot of the elevation and signal level.

Pass Data Plots

The acquired signal level, and elevation data plots for the spacecraft shown in this document were generated using vendor supplied software with a sample rate of approximately 2 seconds. Because of the sample rate, signal strength extrema may not have been captured in the pass plots. However, a spectrum analyzer was used to observe a number of passes and find signal strength extrema.

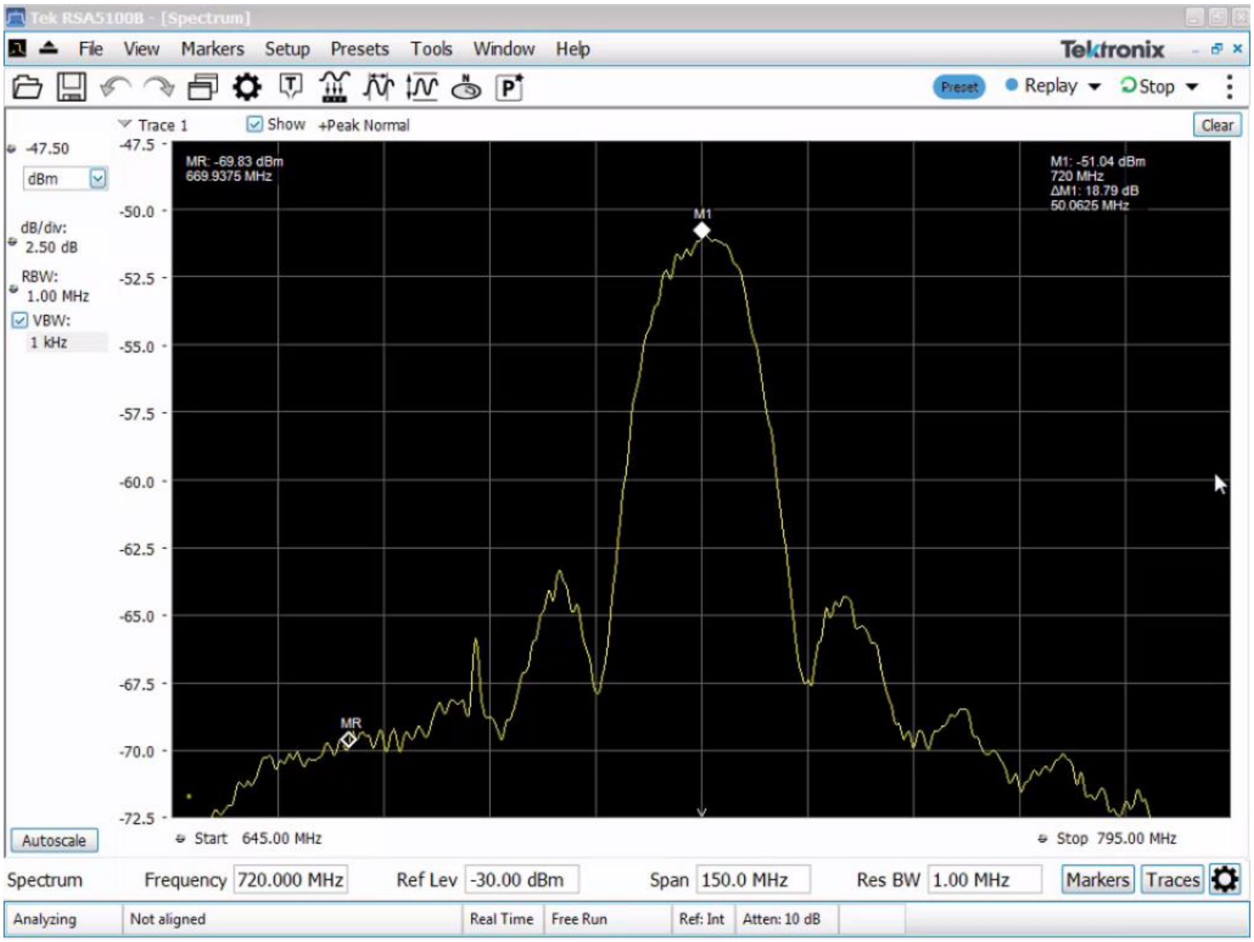

Figure 2. JPSS-1 RF Spectrum During 2018-03-15 06:51 UTC Pass

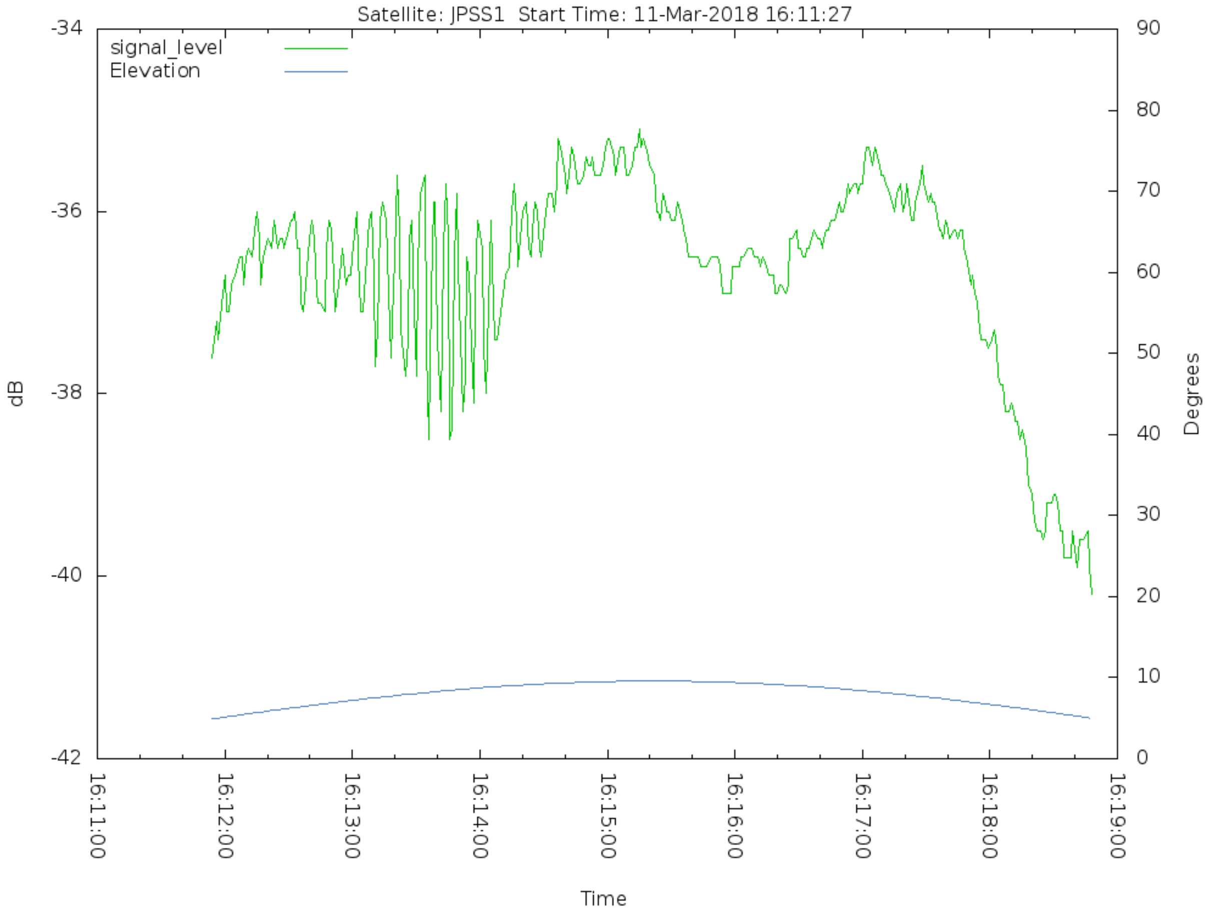

Figure 3. Elevation & Signal Plot for Low Elevation JPSS-1 Pass 2018-03-11 16:11 UTC

Comparison with the SNPP and Aqua Spacecraft

The DRL compared reception of JPSS-1 HRD to the reception of SNPP and Aqua Direct Broadcast data because the three spacecraft are in similar orbits, as well as to rule out any environmental factors at the DRL. The Aqua and SNPP spacecraft's characteristics are widely documented and understood by the Direct Broadcast community.

Table 1. X-band RF

	Aqua	**SNPP**	**JPSS-1**
Transmitter Power (watts)	25	9.1	8
Maximum Antenna Gain	6.8 dBi	9.37 dB	9.5 DBi
Minimum Antenna Gain	-7.2 dBi	-6.0 dB	-5.44 DBi
Total Antenna Gain	14 dBi	15.37 dB	14.94 dB

Table 2. X-band G/T Requirements

	Ground Station G/T (dB/K)				
Elevation (degrees)	**Aqua**	**SNPP**	**JPSS-1**	**Δ between Aqua & JPSS-1 (dB/K)**	**Δ between SNPP & JPSS-1 (dB/K)**
5	21.0	22.7	22.7	1.7	0
40	22.5	23.59	23.59	1.09	0
70	22.7	23.65	23.65	0.95	0
90	23.4	23.66	23.66	0.26	0

NOTES:

1. Aqua RF characteristics were obtained from the Interface Description Document (IDD) for EOS X-band Direct Broadcast document (GSFC-422-11-19-11).
2. SNPP RF characteristics were obtained from the NPP – HRD / SMD Antennas End Item Data Analysis (SER NO. 3257-WBL118 dated 10/13/2005).
3. JPSS-1 RF characteristics were obtained from the JPSS-1 Spacecraft High Rate Data (HRD) to Direct Broadcast Stations (DBS) Radio Frequency (RF) Interface Control Document (ICD) (470-REF-00184 dated 02/09/2015).

Figure 4 depicts a high elevation angle Aqua pass showing a plot of the elevation and signal level.

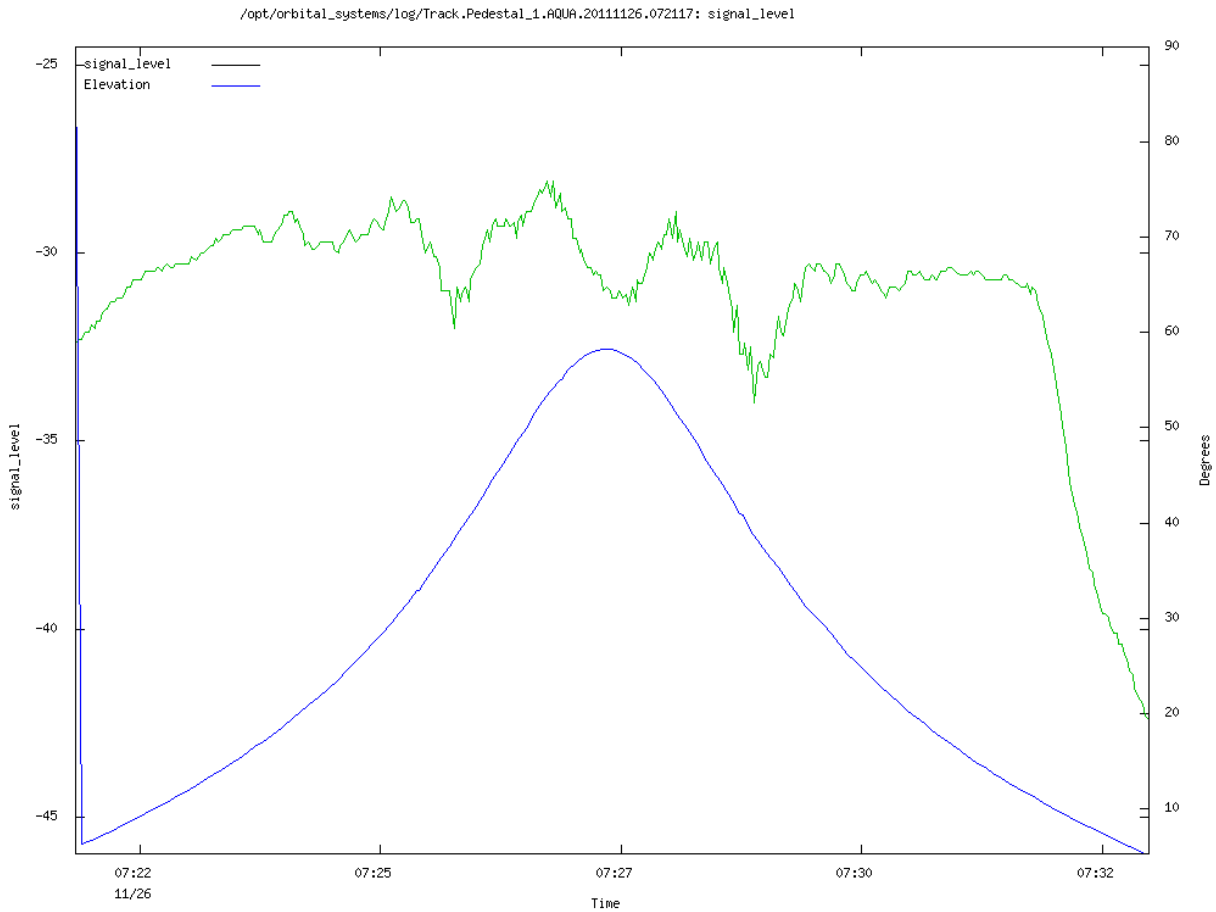

Figure 4. Elevation & Signal Plot for Aqua Pass 2011-11-25 07:21 UTC, Max Elevation=58°

The signal strength extrema in the Aqua signal level plot are not as severe as those seen in the SNPP and JPSS-1 pass plots.

The transmitter power of SNPP/JPSS-1 is 4.4 dB less than the transmitter power of Aqua. The antenna gain of the SNPP and JPSS-1 transmitter chains are greater than that of Aqua. Note that for the listed elevation angles, the G/T requirement for SNPP/JPSS-1 HRD reception is greater than that of Aqua.

Figure 5 shows the JPSS-1 X-band antenna radiation pattern.

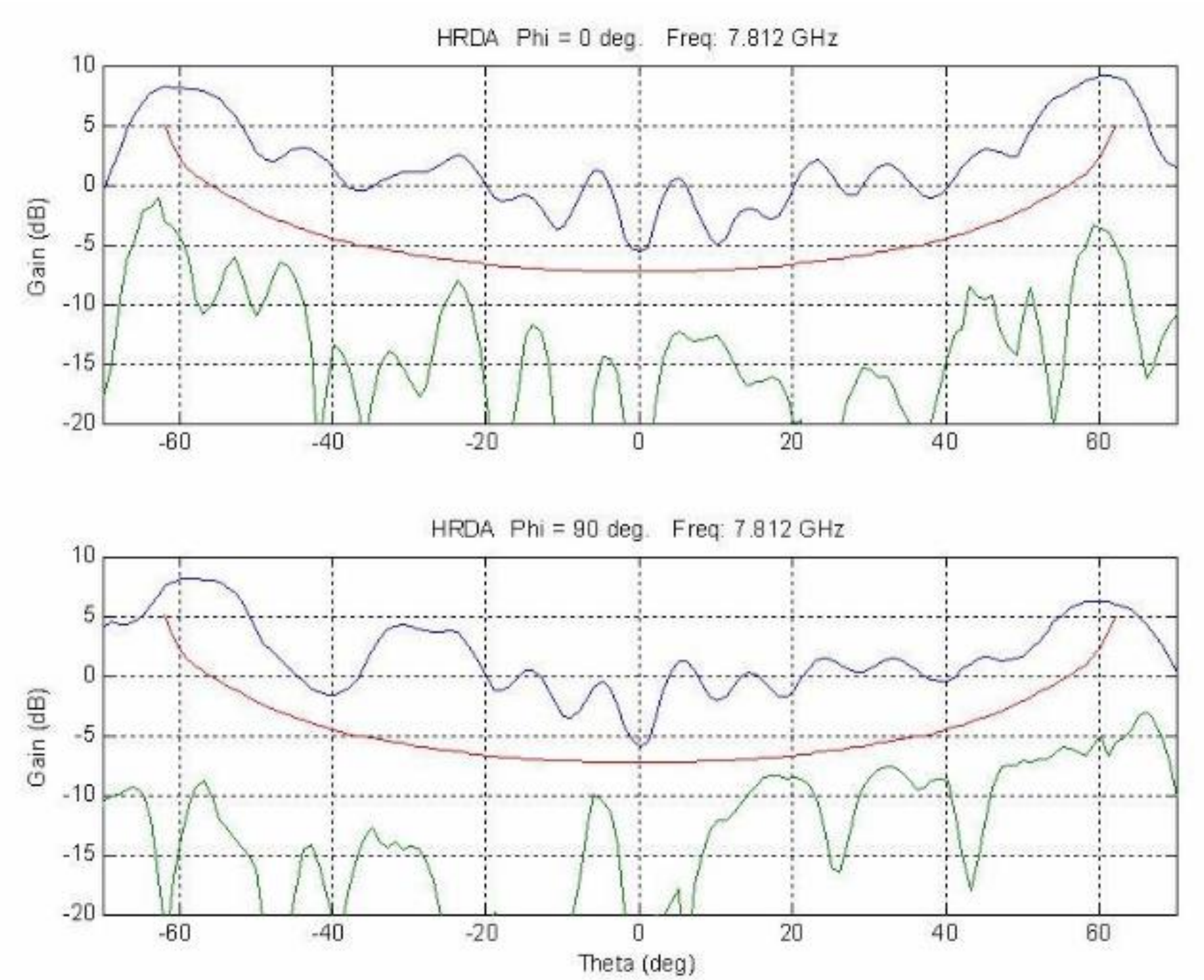

Figure 5. X-band Radiation Pattern Excerpted from the JPSS-1 HRD RF ICD

Figure 6 shows the SNPP X-band antenna radiation pattern.

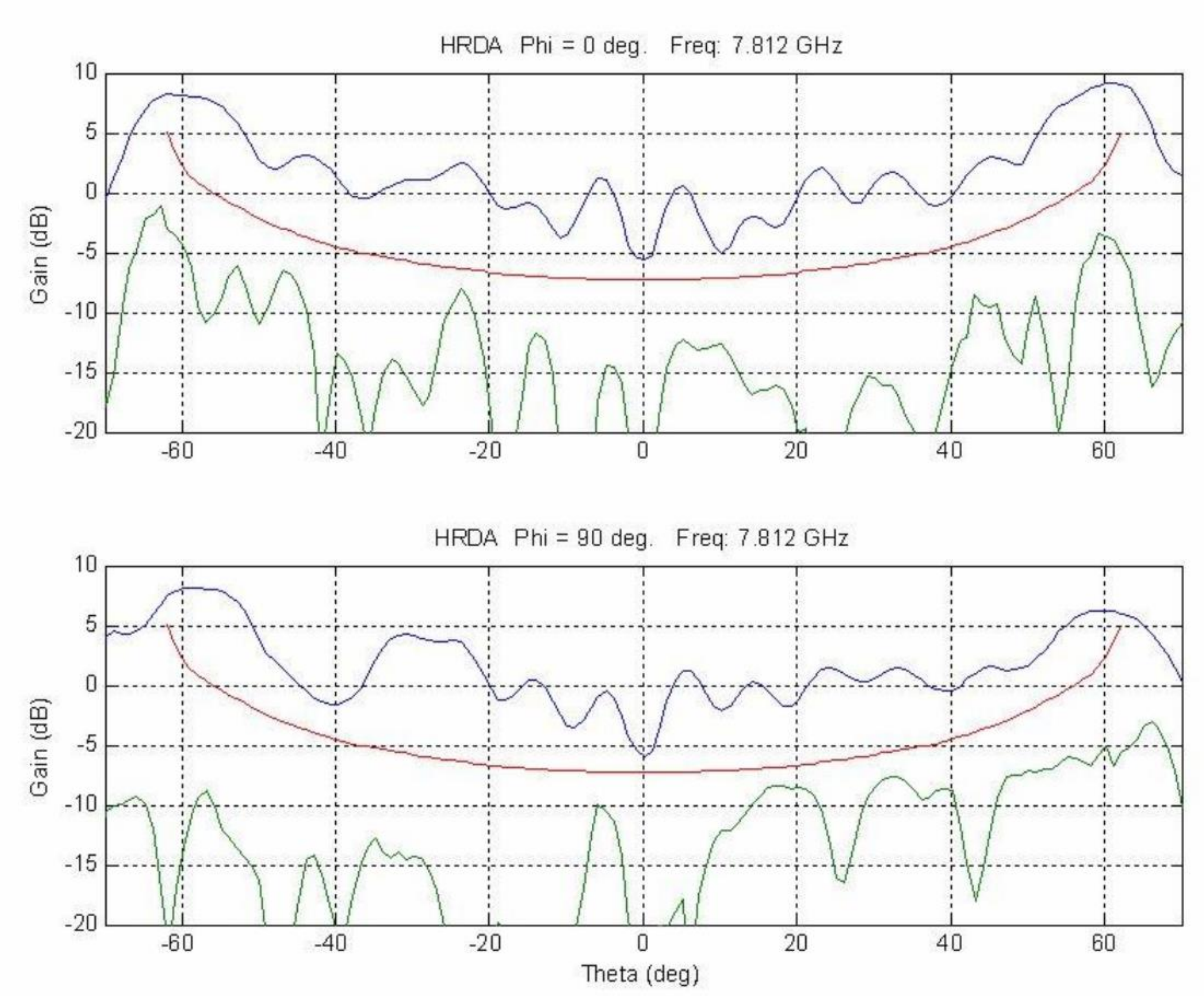

Figure 6. X-band Radiation Pattern Excerpted from the NPP HRD RF ICD

Figure 7 shows the Aqua X-band antenna radiation pattern.

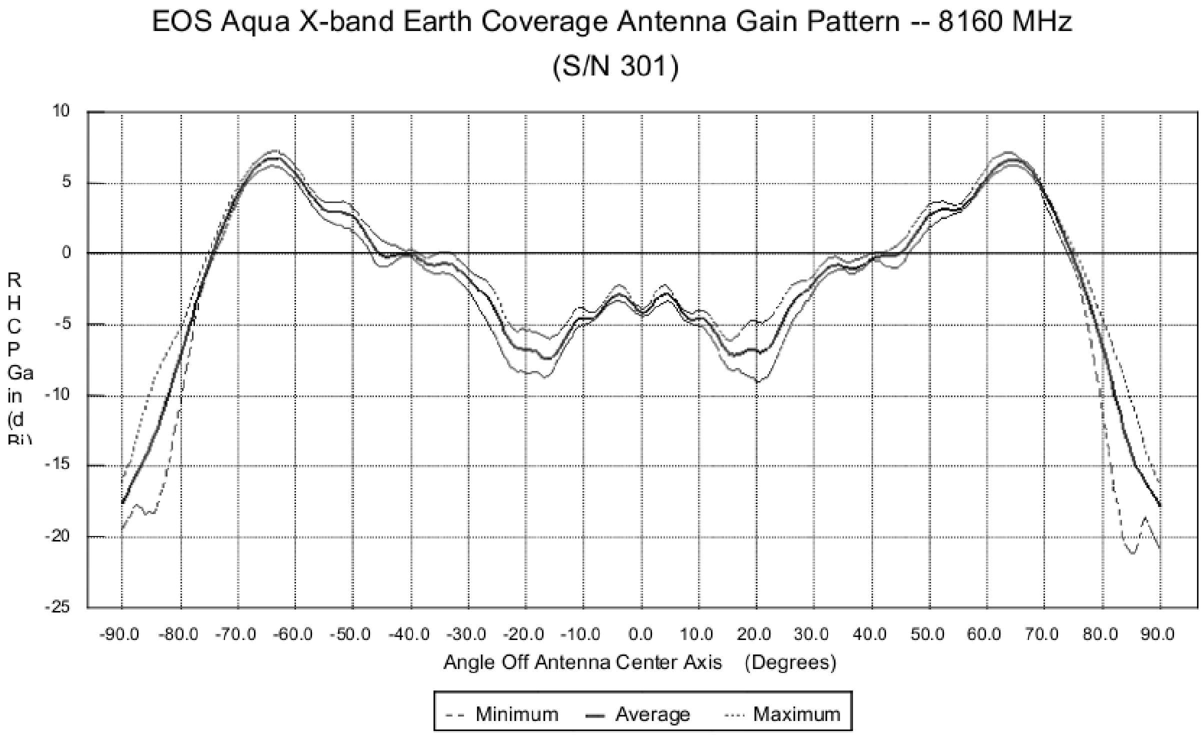

Figure 7. Aqua X-band Radiation Pattern Excerpted from the Aqua IDD X-band Direct Broadcast Document

Based on these antenna radiation patterns, it is apparent that the received signal strength from the Aqua, SNPP, and JPSS-1 spacecraft will vary with elevation angle. In the case of both spacecraft, higher elevation angles produce a greater variation in signal strength, and lower elevation angles produce less variation in signal strength during a pass.

When comparing the signal amplitudes of the Aqua, SNPP, and JPSS-1 spacecraft, the received signal from SNPP and JPSS-1 varies more than that of Aqua for any pass of any elevation angle.

Many Aqua, SNPP, and JPSS-1 passes were analyzed by the DRL as part of the ongoing JPSS-1 HRD commissioning. During high angle JPSS-1 passes, the difference between the maximum and minimum received signal levels is routinely greater than 10 dB. A 13.7 dB difference has been observed.

Table 3 provides the details for four medium to high elevation JPSS-1 passes. The information in the table illustrates the signal strength variations observed during medium to high elevation angle passes.

Table 3. Medium to High Elevation Angle JPSS-1 Pass Data

Pass AOS date/time (UTC)	Max Pass Elevation (deg.)	Max signal Δ captured in EOSFES log and pass plot (dB)	Eb/No at min signal reception point	Elevation at min signal reception point (deg.)
2018-09-13 18:00	84	11.3	8.0	47.54
2018-09-18 18:06	74	10.6	11.5	68.37
2018-09-23 06:51	85	11.1	8.0	34.32
2018-09-28 18:19	56	13.1	6.6	48.53

Figures 8 and 9 show the JPSS-1 signal level extrema as captured by a video recording of the spectrum analyzer during the 2018-09-13 18:00 JPSS-1 pass that had a maximum elevation of 84 degrees. Figure 10 shows the elevation and signal level plot for the 2018-09-13 18:00 JPSS-1 pass.

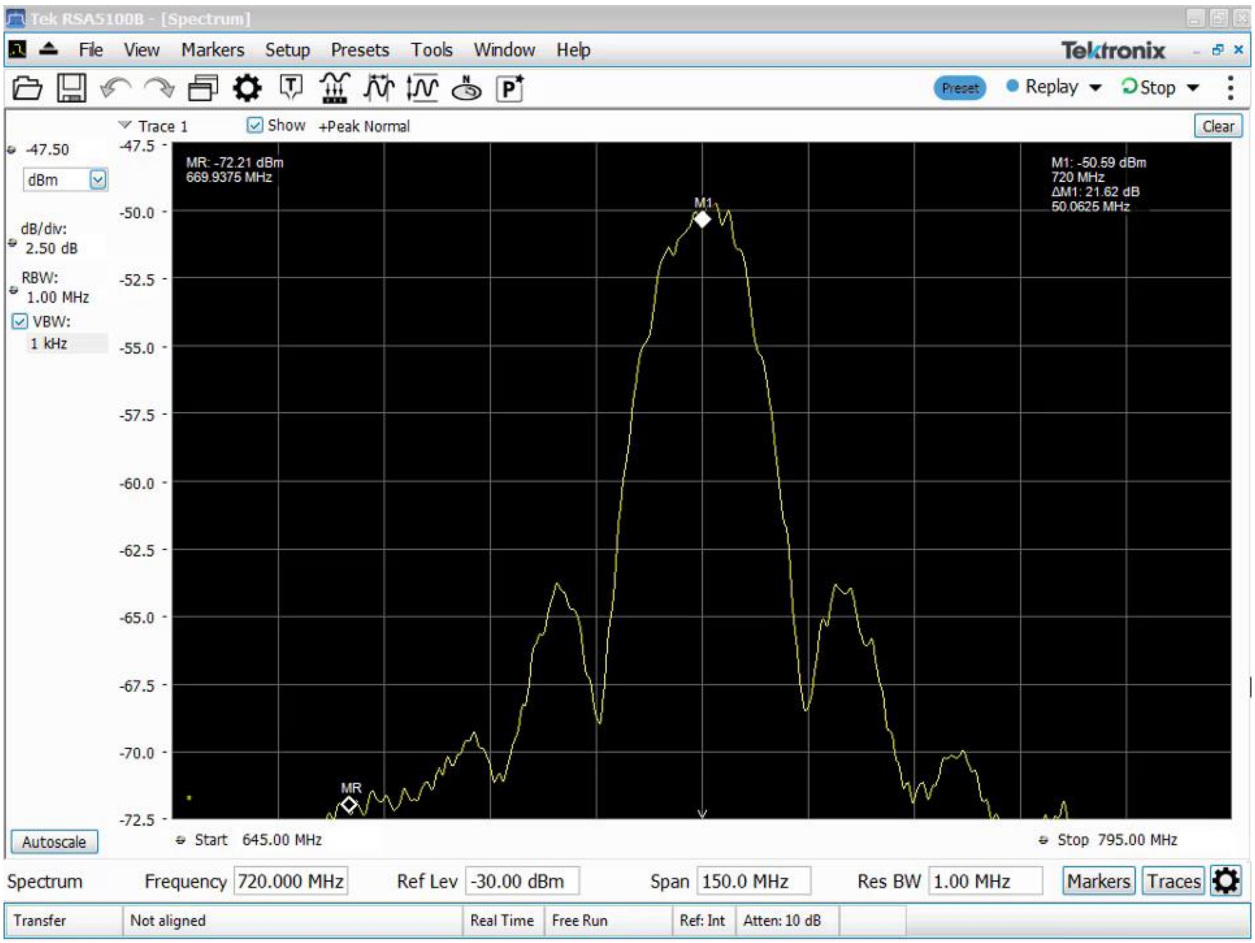

Figure 8. JPSS-1 RF Spectrum (Max Signal) During 2018-09-13 18:00 UTC Pass, Max Elevation=84˚

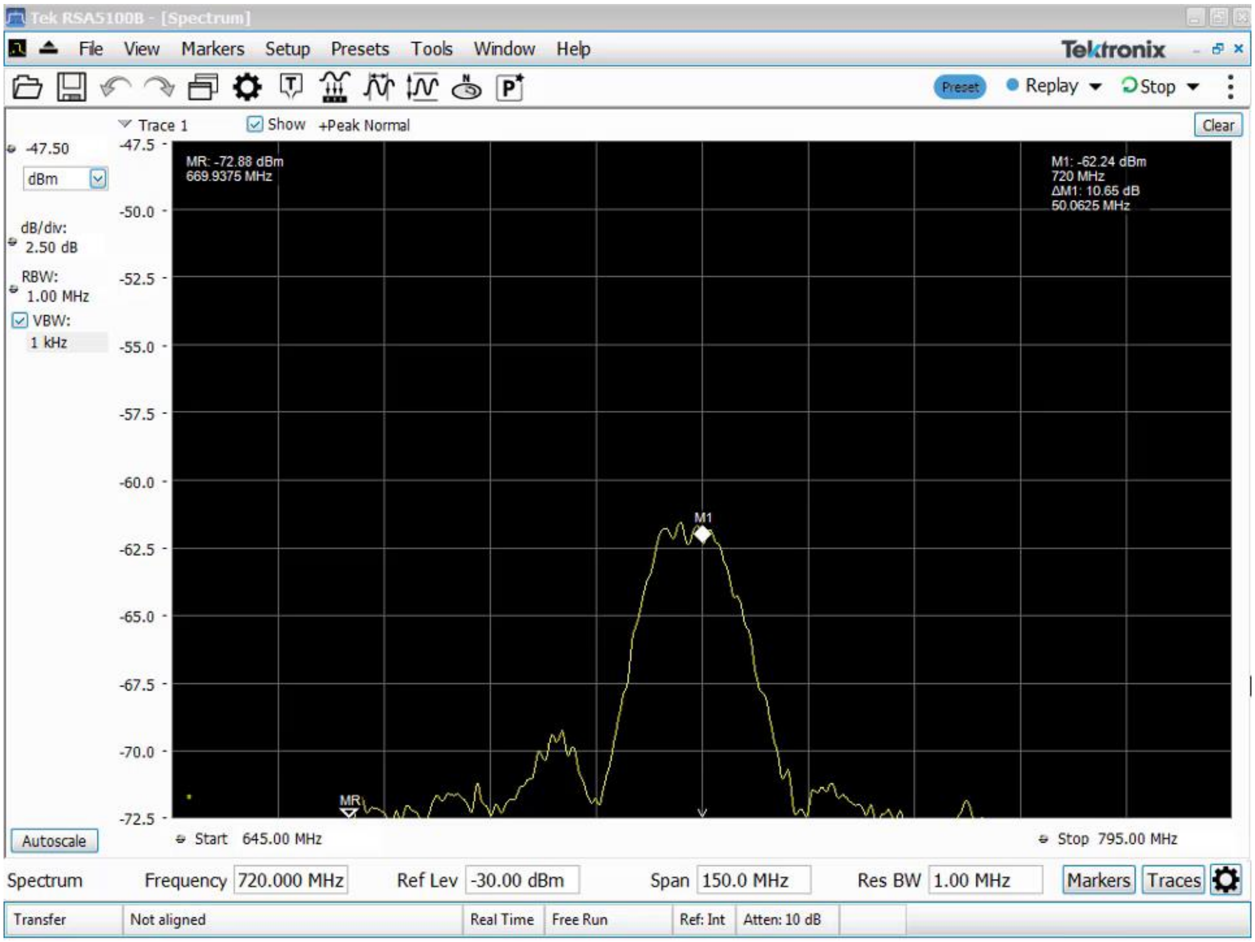

Figure 9. JPSS-1 RF Spectrum (Min Signal) During 2018-09-13 18:00 UTC Pass, Max Elevation=84˚

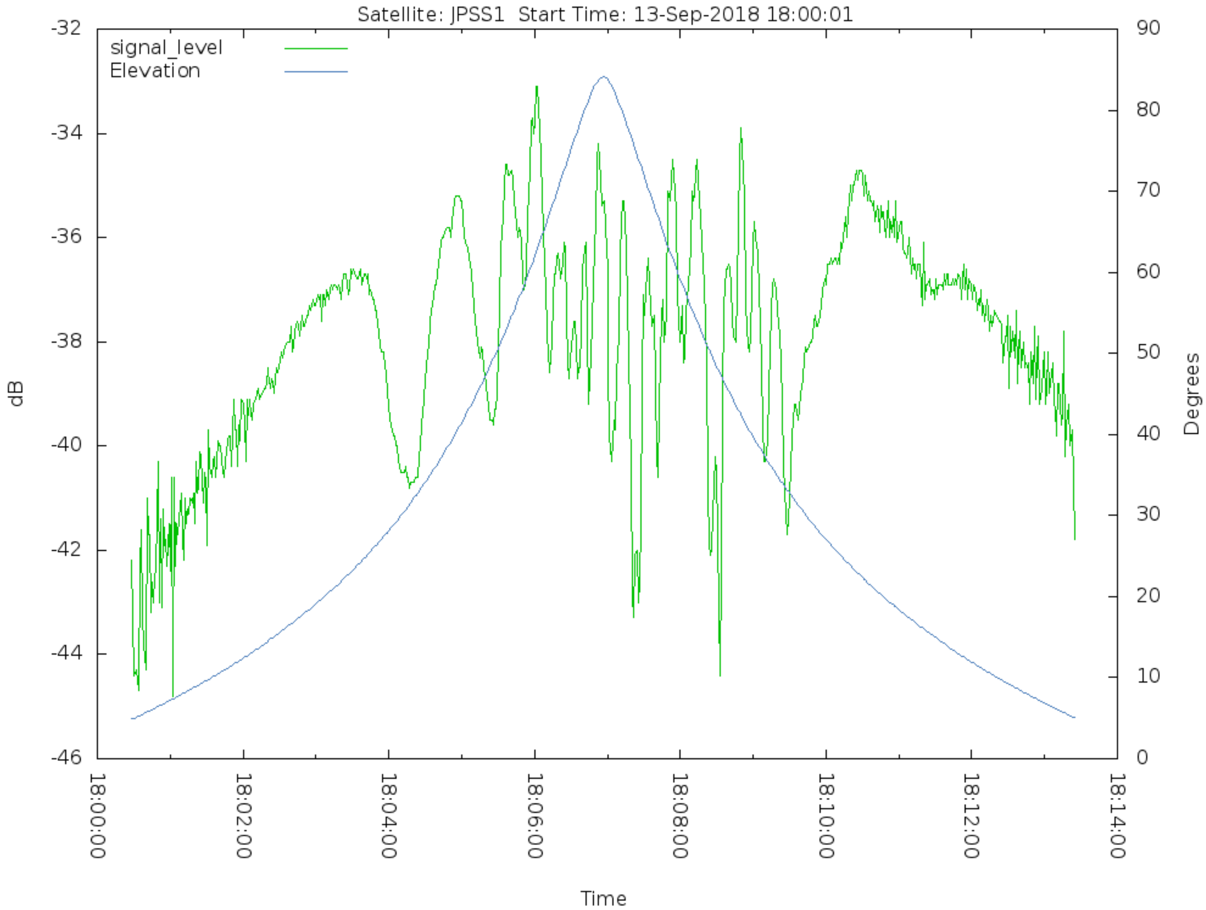

Figure 10. Elevation & Signal Plot for JPSS-1 Pass 2018-09-13 18:00 UTC, Max Elevation=84°

Figures 11, 12, and 13 show the elevation and signal level plots for the 2018-09-18 18:06, 2018-09-23 06:51, and 2018-09-28 18:19 passes respectively.

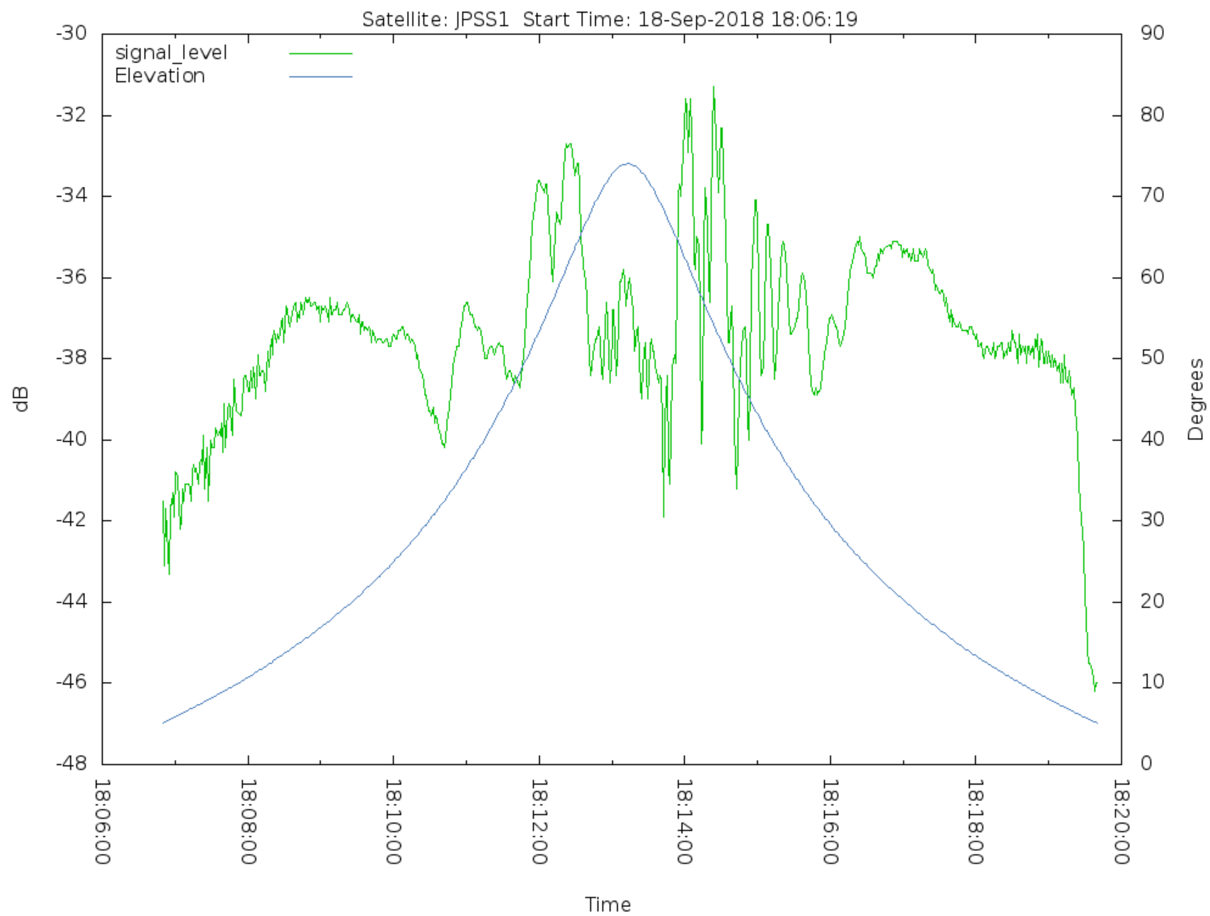

Figure 11. Elevation & Signal Plot for JPSS-1 Pass 2018-09-18 18:06 UTC, Max Elevation=74˚

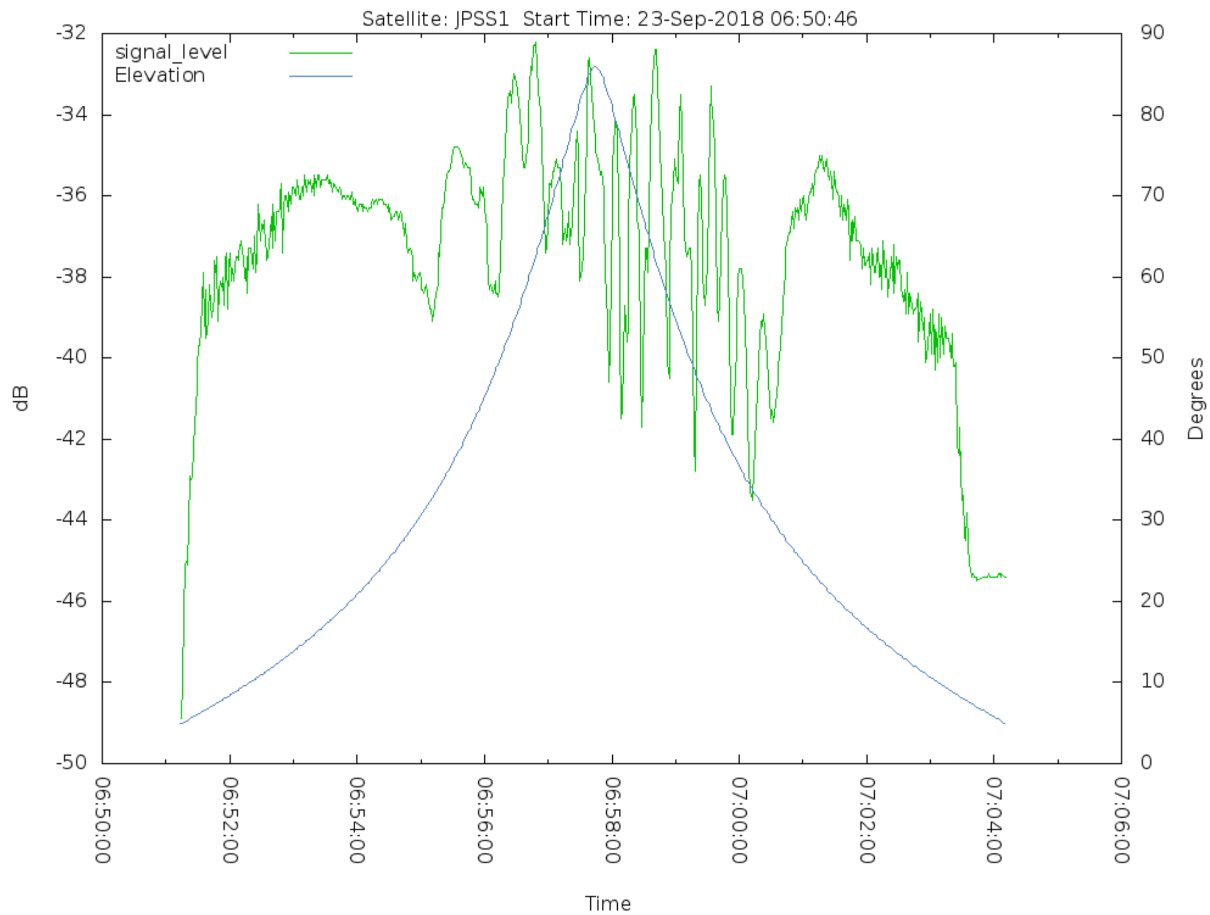

Figure 12. Elevation & Signal Plot for JPSS-1 Pass 2018-09-23 06:51 UTC, Max Elevation=85˚

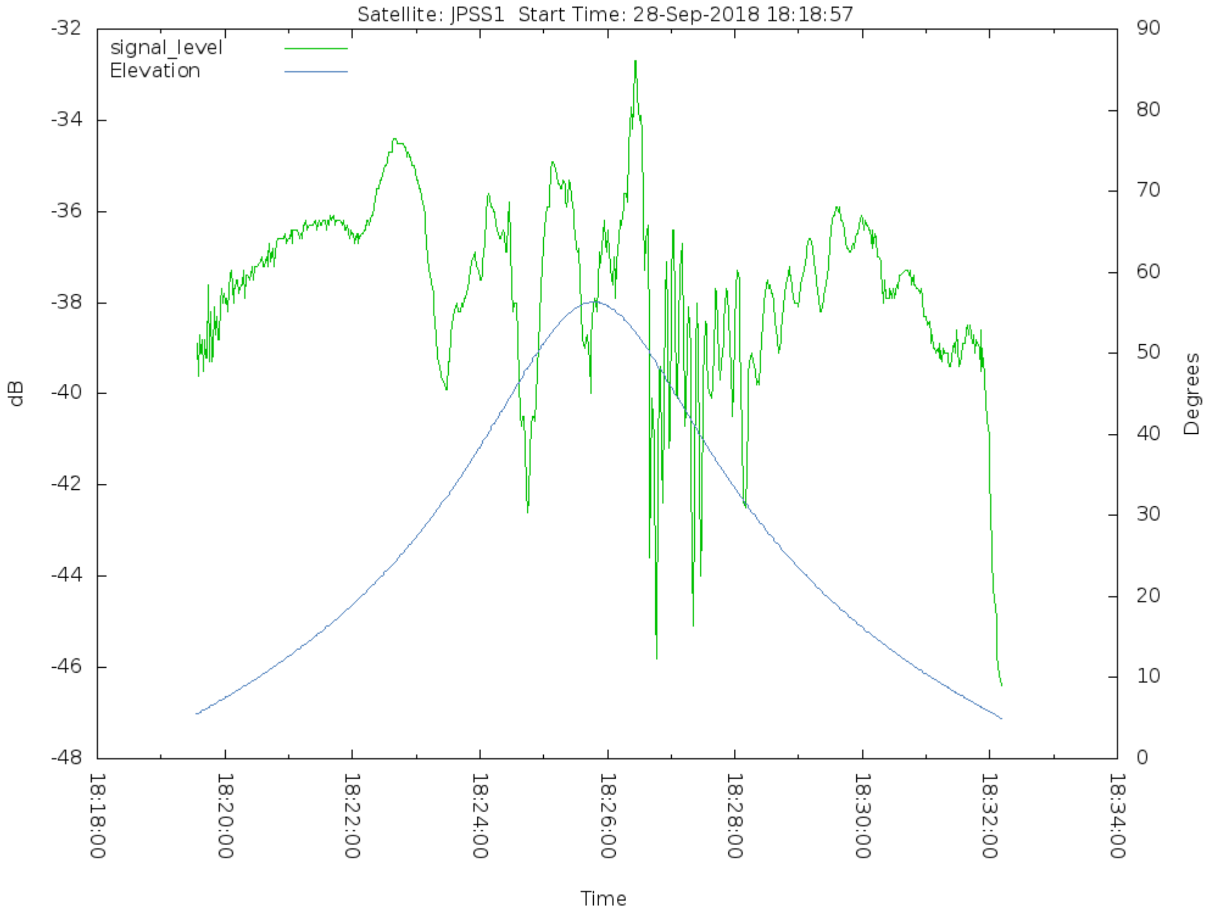

Figure 13. Elevation & Signal Plot for JPSS-1 Pass 2018-09-28 18:19 UTC, Max Elevation=56˚

HRD reception Eb/No values as low as 6.6 have been measured during JPSS-1 passes at the DRL.

Conclusions

The received JPSS-1 HRD signal shows multipath and signal amplitude variation similar to what was observed and reported by the DRL for SNPP in the NPP HRD Commissioning Report. While signal amplitude variations for JPSS-1 are not as severe as for SNPP, and did not result in data loss during spring; once autumn came and orbit geometries shifted data loss due to lows in the these amplitude variations started to occur.

The observed RF reception performance suggests that the JPSS-1 link budget estimate is inadequate. While better than SNPP, signals received at the DRL site frequently have been marginal, and deep nulls in signal strength sometimes occur under good reception conditions, and more frequently under adverse meteorological conditions.

Ground stations that only meet the minimum G/T margin stated in the JPSS-1 HRD RF ICD are likely to experience unreliable JPSS-1 HRD reception during high elevation passes. Furthermore, stations designed to comply with the JPSS-1 HRD link budget may realize limited utility of the HRD broadcast.