

DRL NPP HRD Commissioning Report

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Phase 1 (DRAFT)



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GREENBELT, MARYLAND**

Purpose

This report was prepared by the NASA GSFC Direct Readout Laboratory (DRL) for the NPOESS Preparatory Project (NPP) Mission. This report describes the methodology used and results obtained during the commissioning of NPP High Rate Data (HRD).

Objectives

NPP HRD commissioning objectives were as follows:

- receive the HRD broadcast from the NPP 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 NPP HRD broadcast;
- compare reception of the NPP HRD to reception of the Aqua satellite direct broadcast data;
- report unexpected and/or anomalous observations regarding the HRD broadcast.

Assumptions

It was assumed that reception performance would conform to the specifications cited in the NPOESS Preparatory Project (NPP) Spacecraft High Rate Data (HRD) Radio Frequency (RF) Interface Control Document (ICD) to the Direct Broadcast Stations. GSFC 429-03-02-24 (Original CH-02).

It was assumed that the NPP HRD would conform to structural specifications contained in the NPOESS Common Data Format Control Book - External Volume VII - Part I - NPOESS Downlink Data Formats. D34862-07-01 Rev C.

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 A – CH-02).

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 Mission Support Data Server (MSDS);
- Orbital Systems EOS-FES front end servers;
- Orbital Systems HRD-200 series receivers;
- Tektronix RSA 6106A RF Spectrum Analyzer.

Configuration

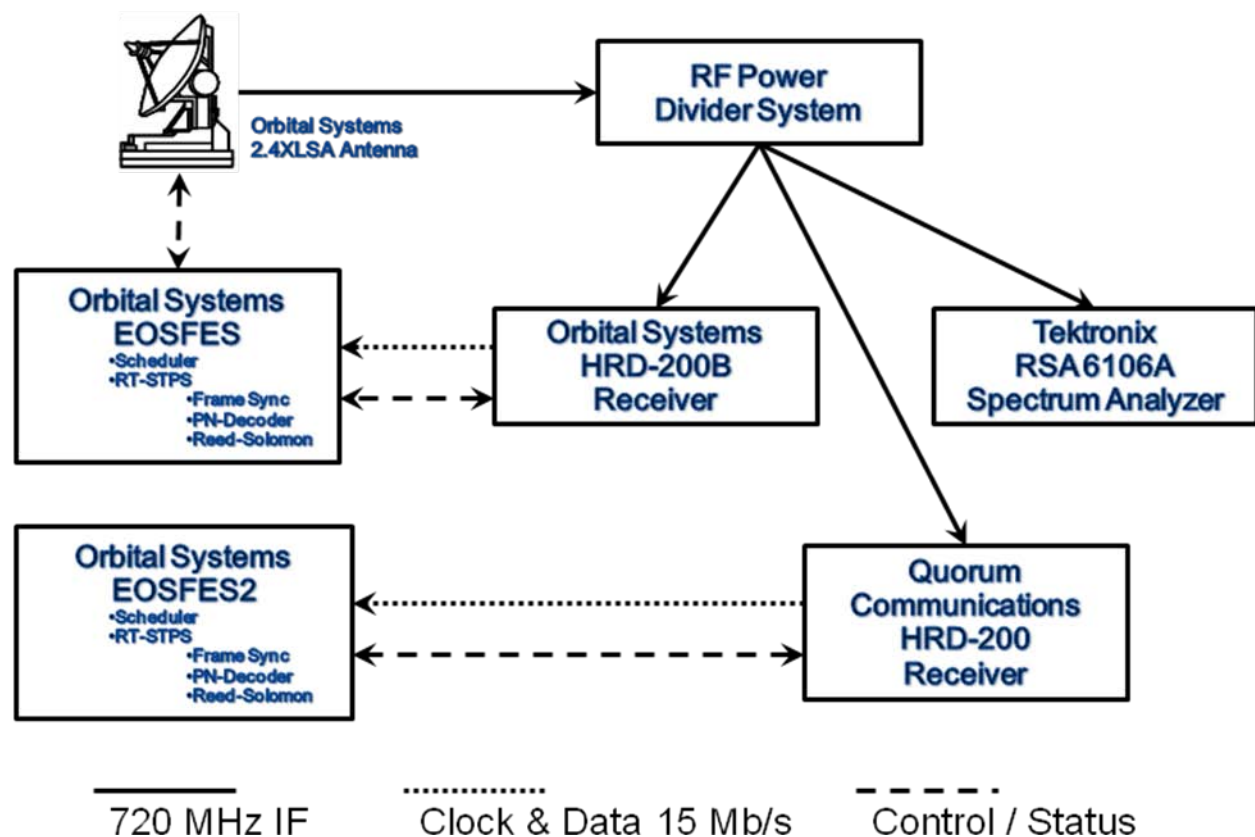


Figure 1. Configuration

System RF Noise Floor

The noise floor typically ranges between -54 and -56 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 NPP 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 11/30/2011 was 24.56 dB/K.

Data

The DRL has confirmed the following:

- RF Spectrum Analysis:
 - Amplitude variations up to 15.14 dB have 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 amplitude fluctuation.
- The NPP 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:
 - Only VCID0 CADUs were detected;
 - No VCID1, VCID6 or VCID16 were detected;
 - No ATMS, CrIS, or VIIRS packets detected;
 - ENG Apid 0, 8, and 11 were detected;
 - 980,000 frames detected;
 - 6,000 VCID0 CADUs;
 - 970,000 Fill CADUs;
 - 1600 ENG/Sci packets.

[This section to be expanded once instrument data are received.]

Analysis

NPP 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

NPP RF spectrum. Figure 3 depicts a low elevation angle NPP pass showing a plot of the elevation and signal level.

Pass Data Plots

The acquired signal level, and elevation data plots for the NPP 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 number of passes were observed using a spectrum analyzer and recorded using a digital video recorder. Signal strength extrema were captured from the video recordings.

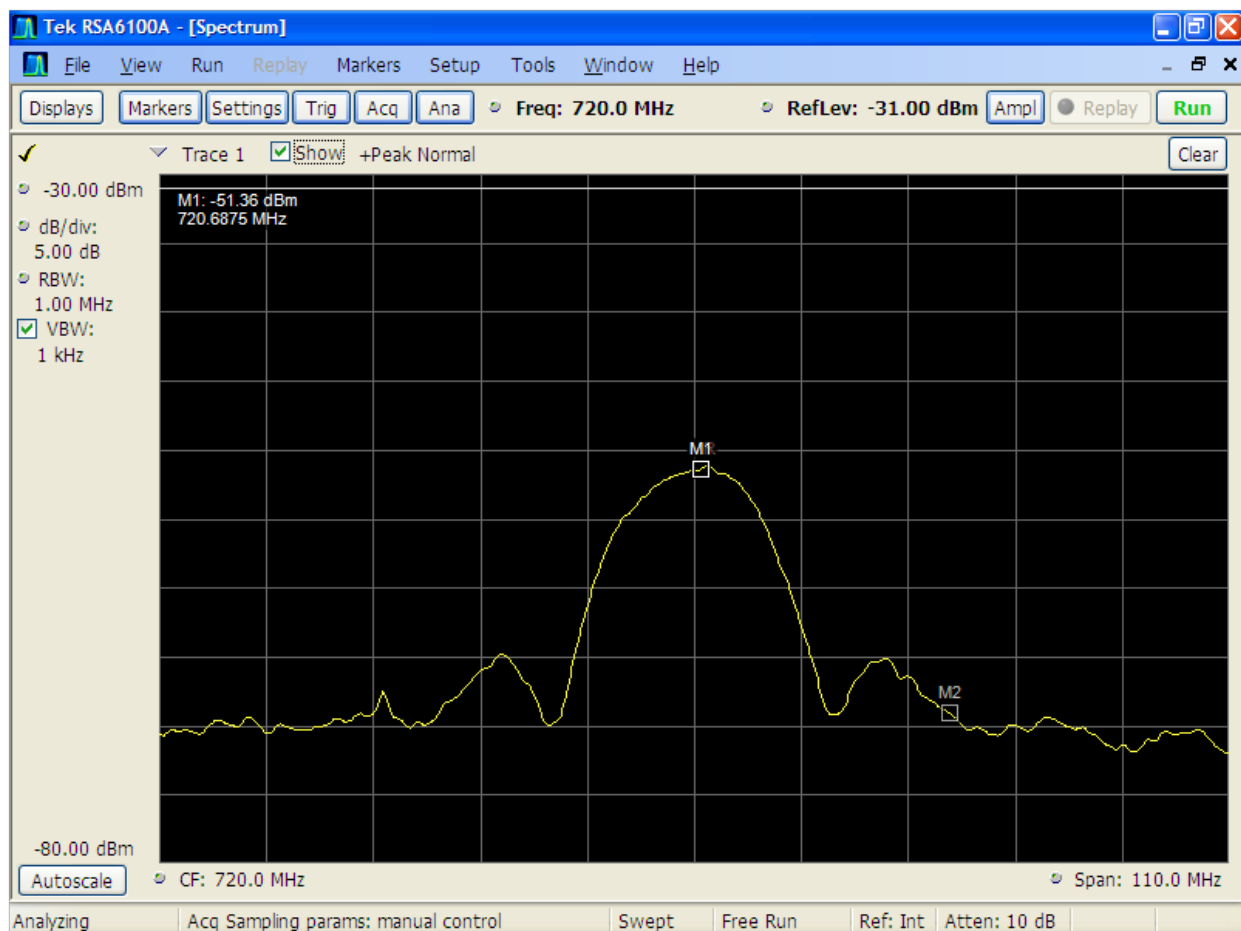


Figure 2. NPP RF Spectrum During 2011-11-11 16:15 UTC Pass

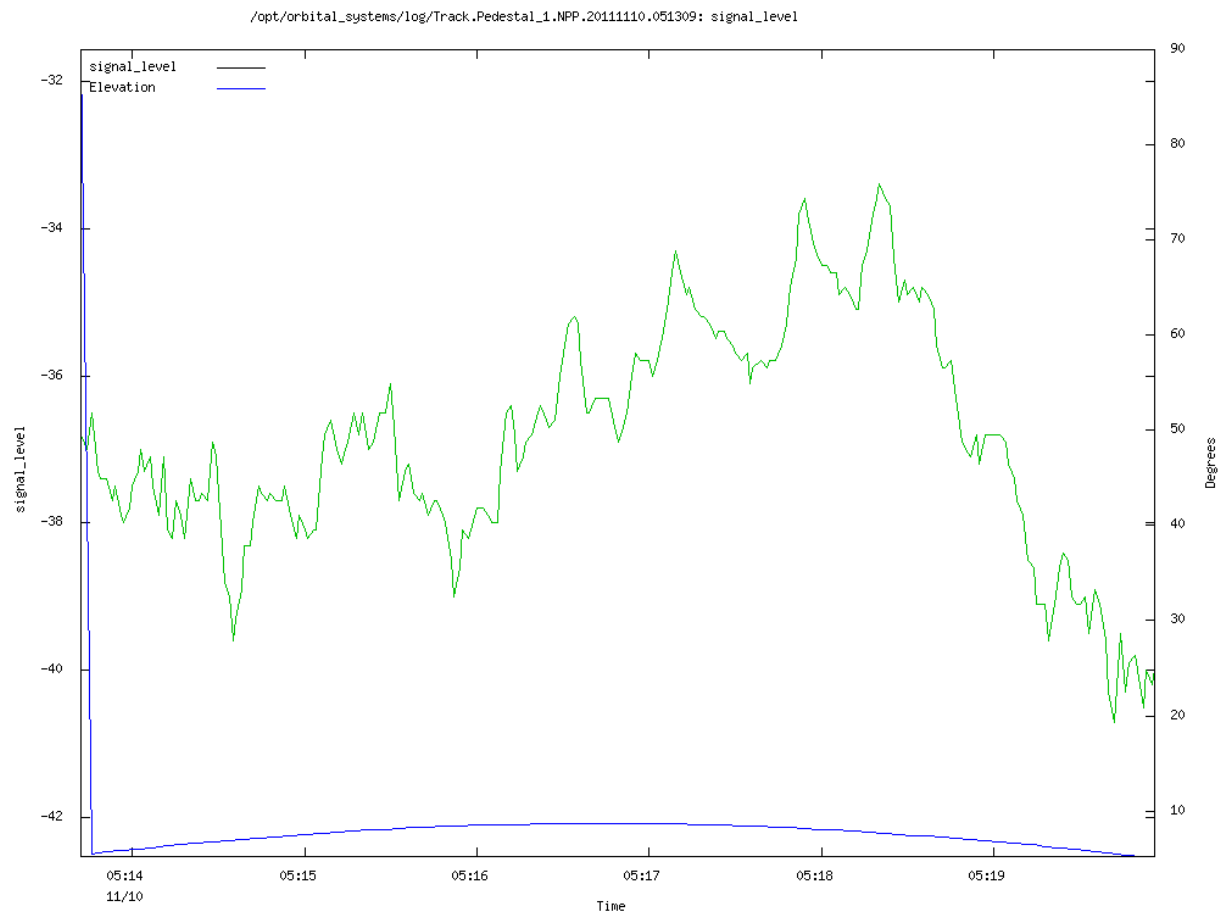


Figure 3. Elevation & Signal Plot for Low Elevation NPP Pass 2011-11-10 05:13 UTC

Comparison with the Aqua Spacecraft

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

Table 1. X-band RF

	Aqua	NPP
Transmitter Power (watts)	25	9.1
Maximum Antenna Gain	6.8 dBi	9.37 dB
Minimum Antenna Gain	-7.2 dBi	-6.0 dB
Total Antenna Gain	14 dBi	15.37 dB

Table 2. X-band G/T Requirements

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

NOTE:

Aqua RF characteristics were obtained from the Interface Description Document (IDD) for EOS X-band Direct Broadcast document (GSFC-422-11-19-11).

NPP RF characteristics were obtained from the NPP – HRD / SMD Antennas End Item Data Analysis (SER NO. 3257-WBL118 dated 10/13/2005).

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

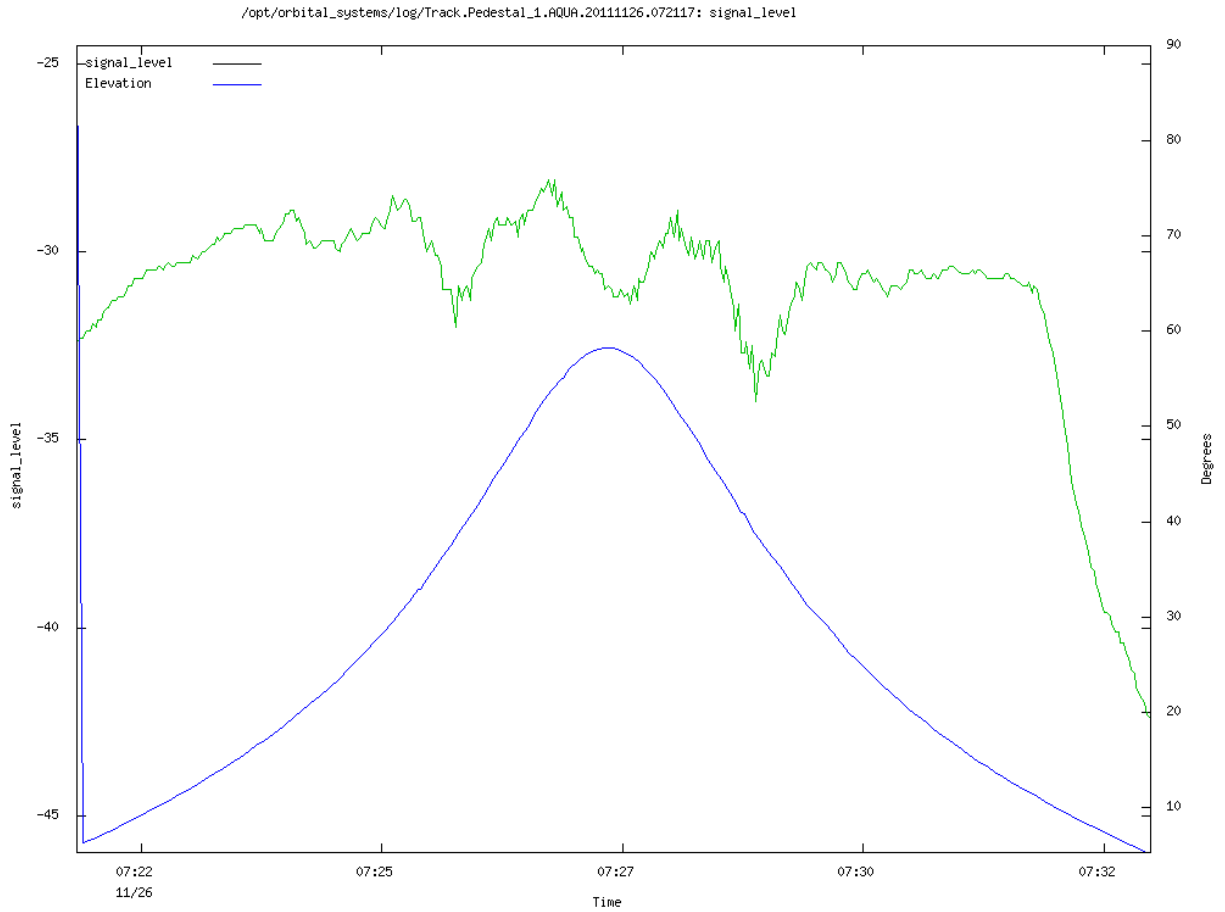


Figure 4. Elevation & Signal Plot for Aqua Pass 2011-11-25 07:21 UTC, Max Elevation=58°

The signal strength extrema in the Aqua signal level plot are not as severe as those seen in the NPP pass plots.

The transmitter power of NPP is 4.4 dB less than the transmitter power of Aqua. The antenna gain of the NPP transmitter chain is greater than that of Aqua. Note that for the listed elevation angles, the G/T requirement for NPP HRD reception is greater than that of Aqua.

Figure 5 shows the NPP X-band antenna radiation pattern.

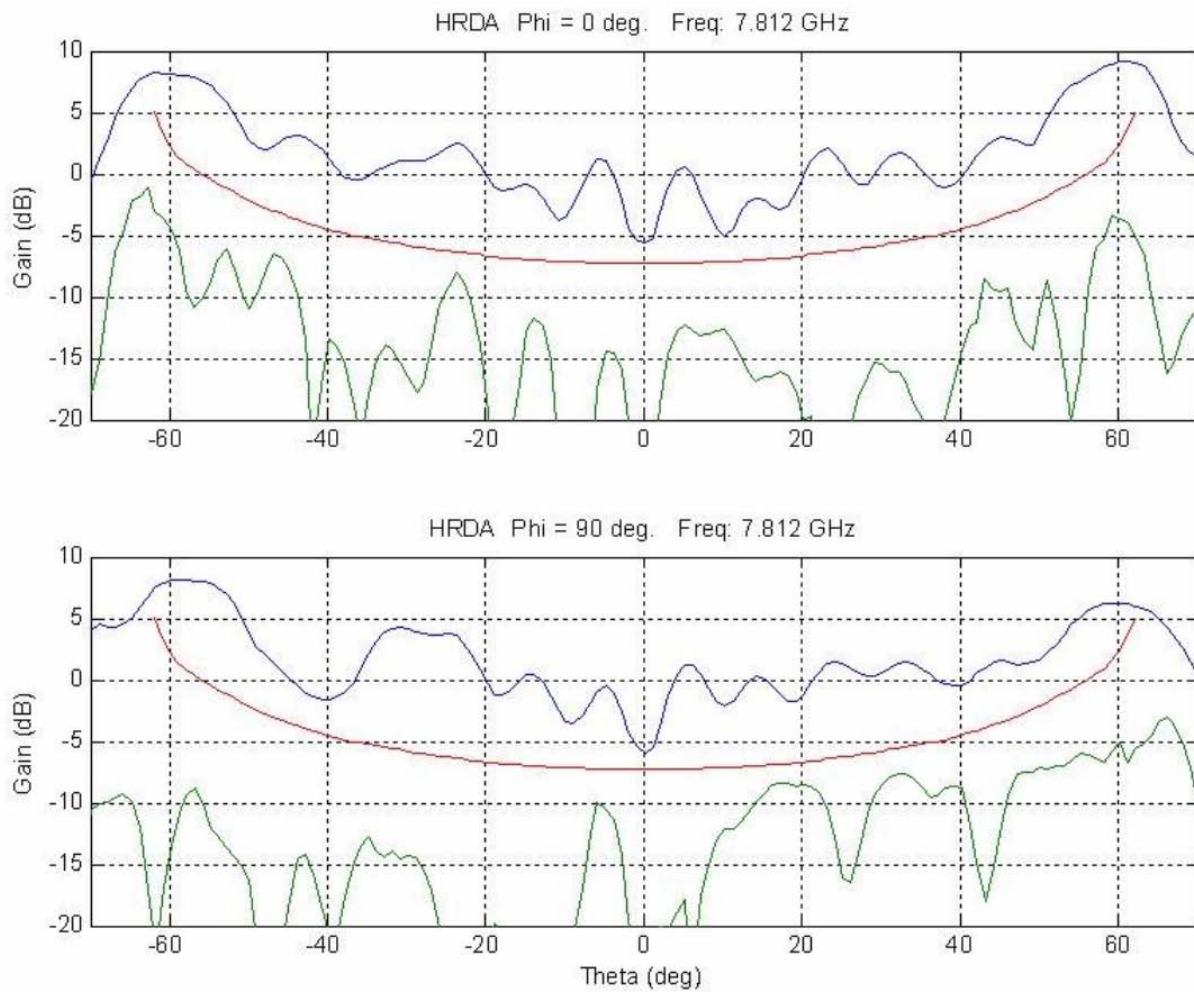


Figure 5. X-band Radiation Pattern Excerpted from the NPP HRD RF ICD

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

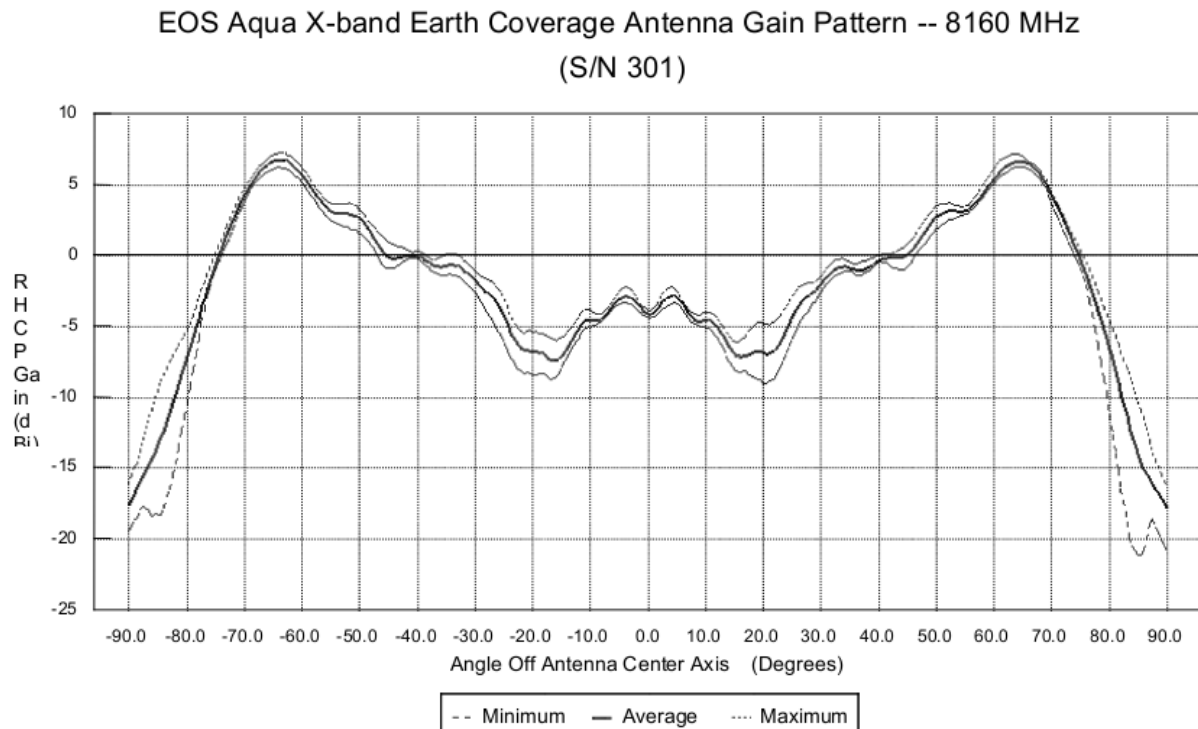


Figure 6. Aqua X-band Radiation Pattern Excerpted from the Aqua IDD X-band Direct Broadcast Document

Based on these antenna radiation patterns, it is apparent that the received signal strength from the Aqua and NPP 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 and NPP spacecraft, the received signal from NPP varies more than that of Aqua for any pass of any elevation angle.

Many Aqua and NPP passes were analyzed by the DRL as part of the ongoing NPP HRD commissioning. During high angle NPP passes, the difference between the maximum and minimum received signal levels is routinely greater than 12.5 dB. A 15.14 dB difference has been observed.

Table 3 provides the details for three medium to high elevation NPP 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 NPP Pass Data

Pass AOS date/time (UTC)	Max Pass Elevation (deg.)	Max signal Δ captured in EOSFES log and pass plot (dB)	Max signal Δ captured in spectrum analyzer video recording (dB)	Eb/No at min signal reception point	Elevation at min signal reception point (deg.)	Spectrum Analyzer video recording time stamp maximum, minimum (min:sec)
2011-11-22 17:42	66	13.1	15.14	5.0	34.69	4:33, 4:20
2011-12-01 18:13	64	12.0	12.51	11.7	46.49	7:39, 8:01
2011-12-02 1754	85	11.0	12.78	8.6	35.13	7:39, 8:51

Figures 7 and 8 show the NPP signal level extrema as captured by a video recording of the spectrum analyzer during the 2011-11-22 17:42 NPP pass that had a maximum elevation of 66 degrees. Figure 9 shows the elevation and signal level plot for the 2011-11-22 17:42 NPP pass.

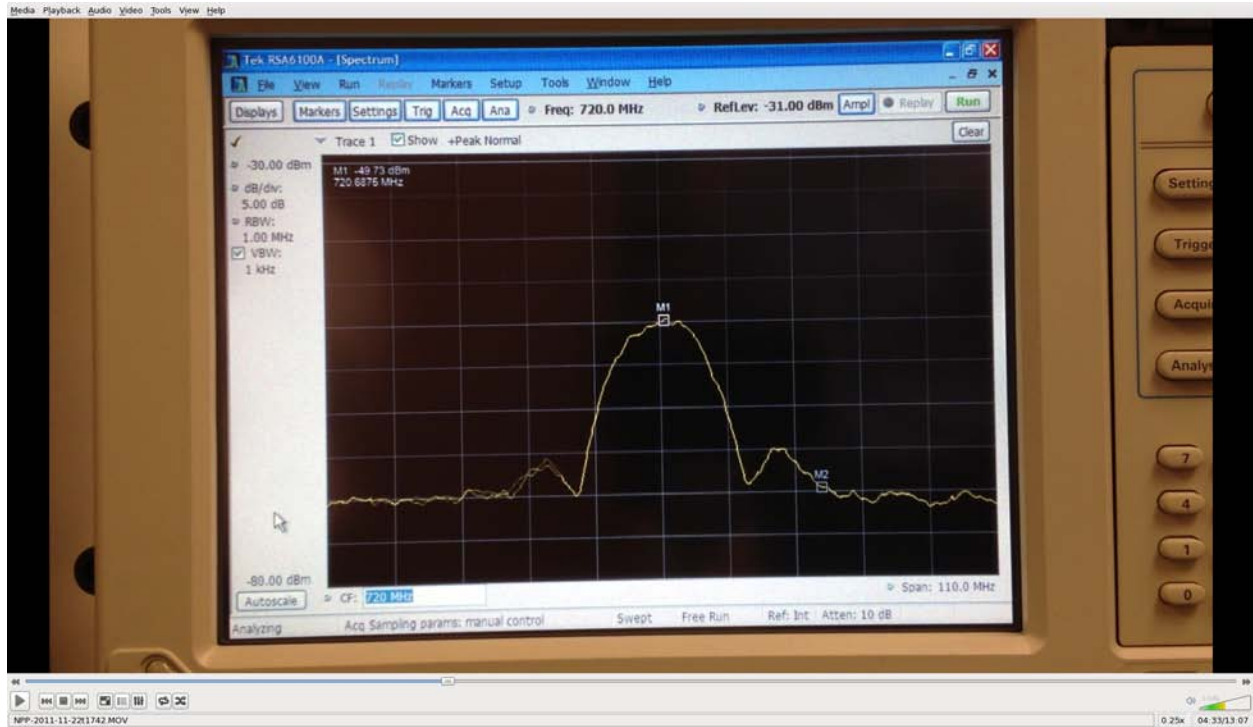


Figure 7. NPP RF Spectrum (Max Signal) During 2011-11-22 17:42 UTC Pass, Max Elevation=66°

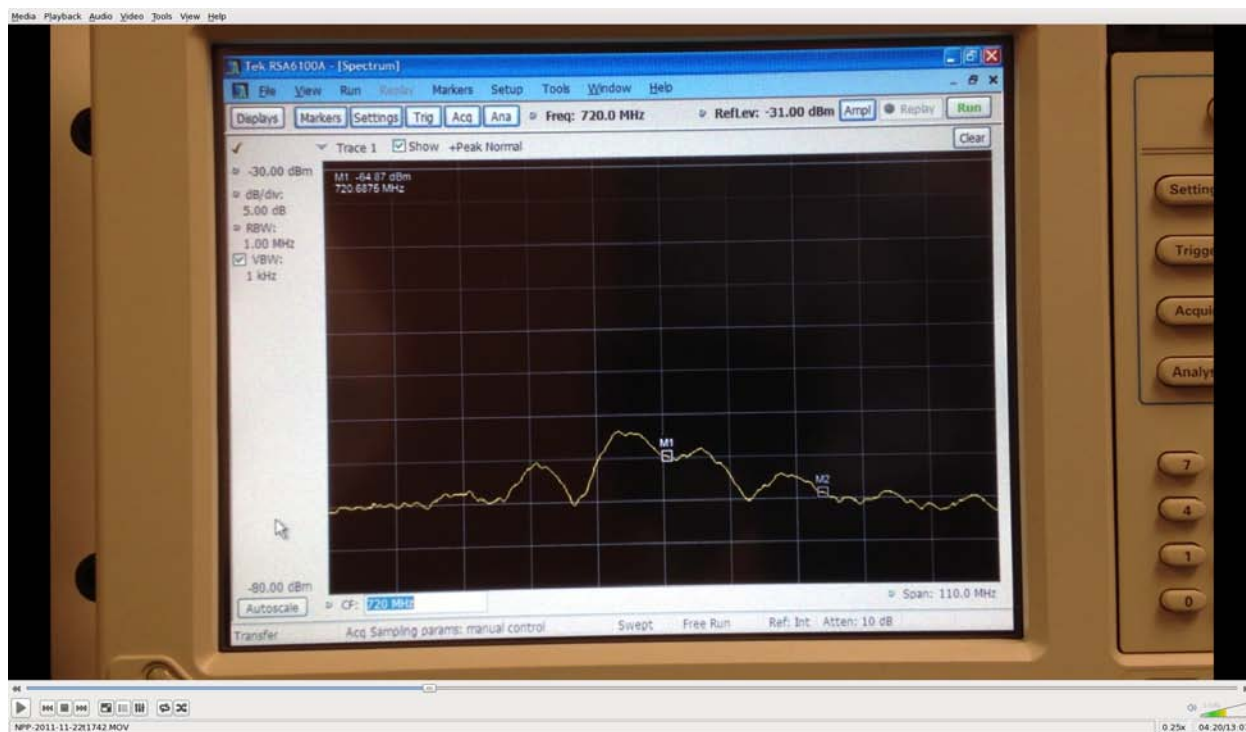


Figure 8. RF Spectrum (Min Signal) During 2011-11-22 17:42 UTC Pass, Max Elevation=66°

The full video file from which the images in Figures 7 and 8 were captured is available at:

<ftp://drl-fs-1.sci.gsfc.nasa.gov/PRODUCTS/data/gsfsc/npp/NPP_Pass_Spectrum_Analyzer_Videos/NPP-2011-11-22t1742.MOV>

The video file is H.264 and AAC encoded and may be played back using either VLC or QuickTime.

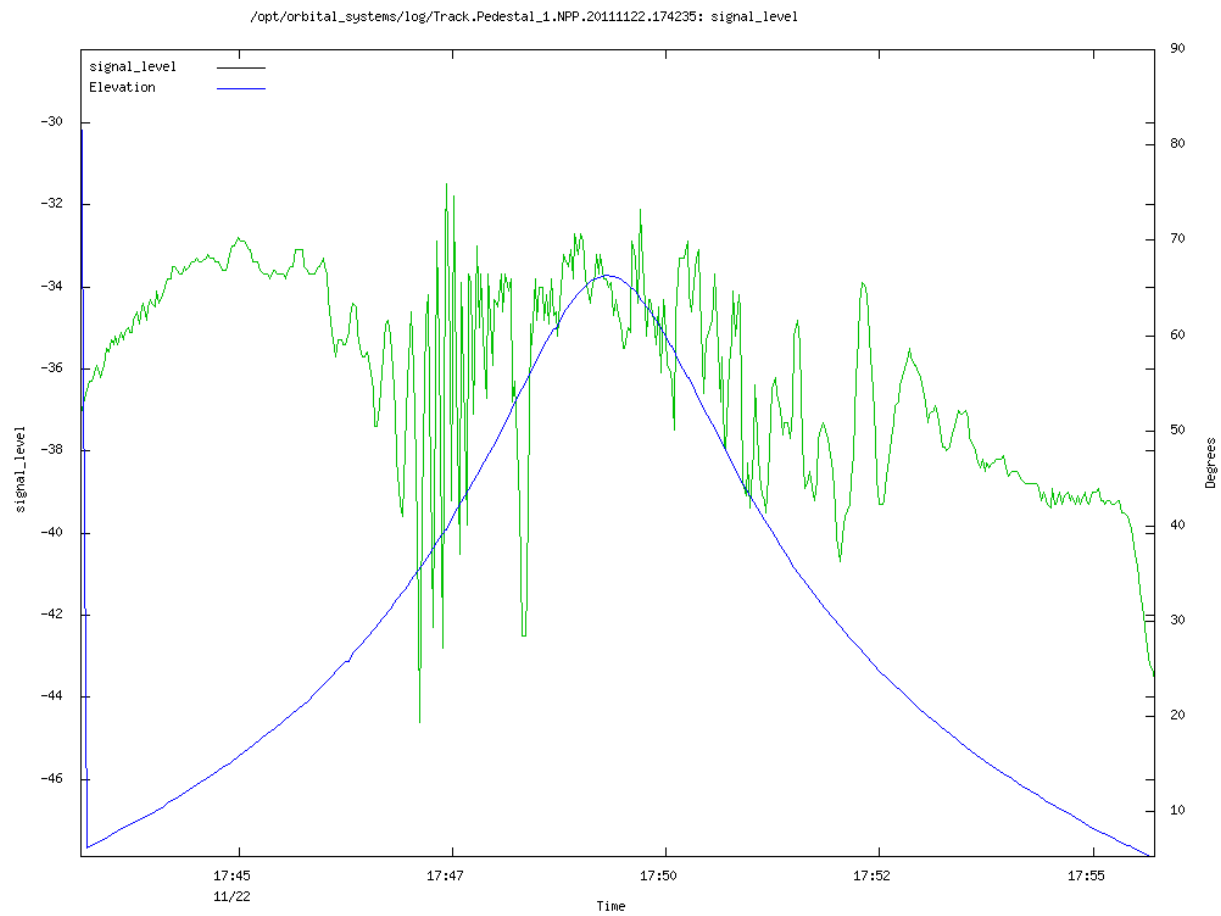


Figure 9. Elevation & Signal Plot for NPP Pass 2011-11-22 17:42 UTC, Max Elevation=66°

Figures 10 and 11 show the elevation and signal level plots for the 2011-12-01 18:13 and 2011-12-02 17:54 passes respectively.

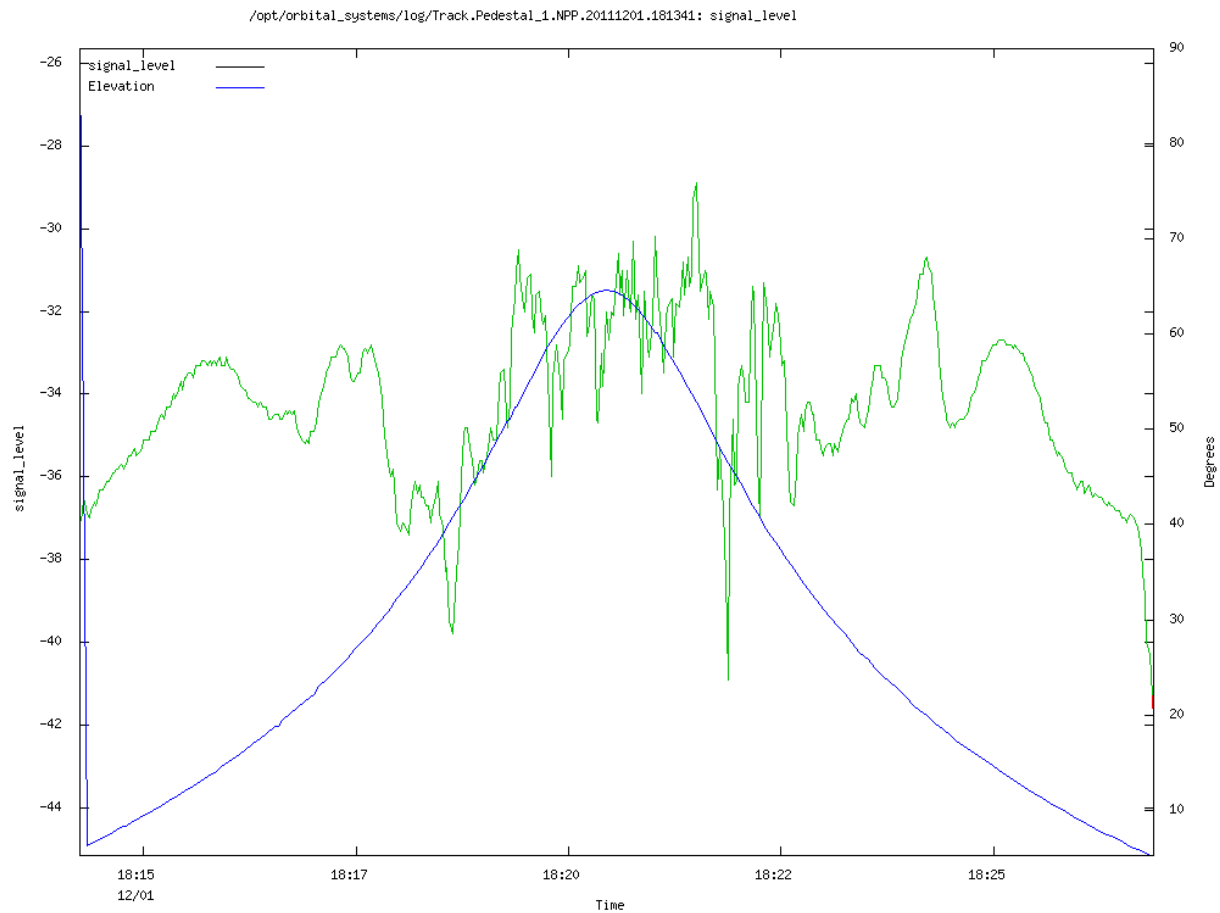


Figure 10. Elevation & Signal Plot for NPP Pass 2011-12-01 18:13 UTC, Max Elevation=64°

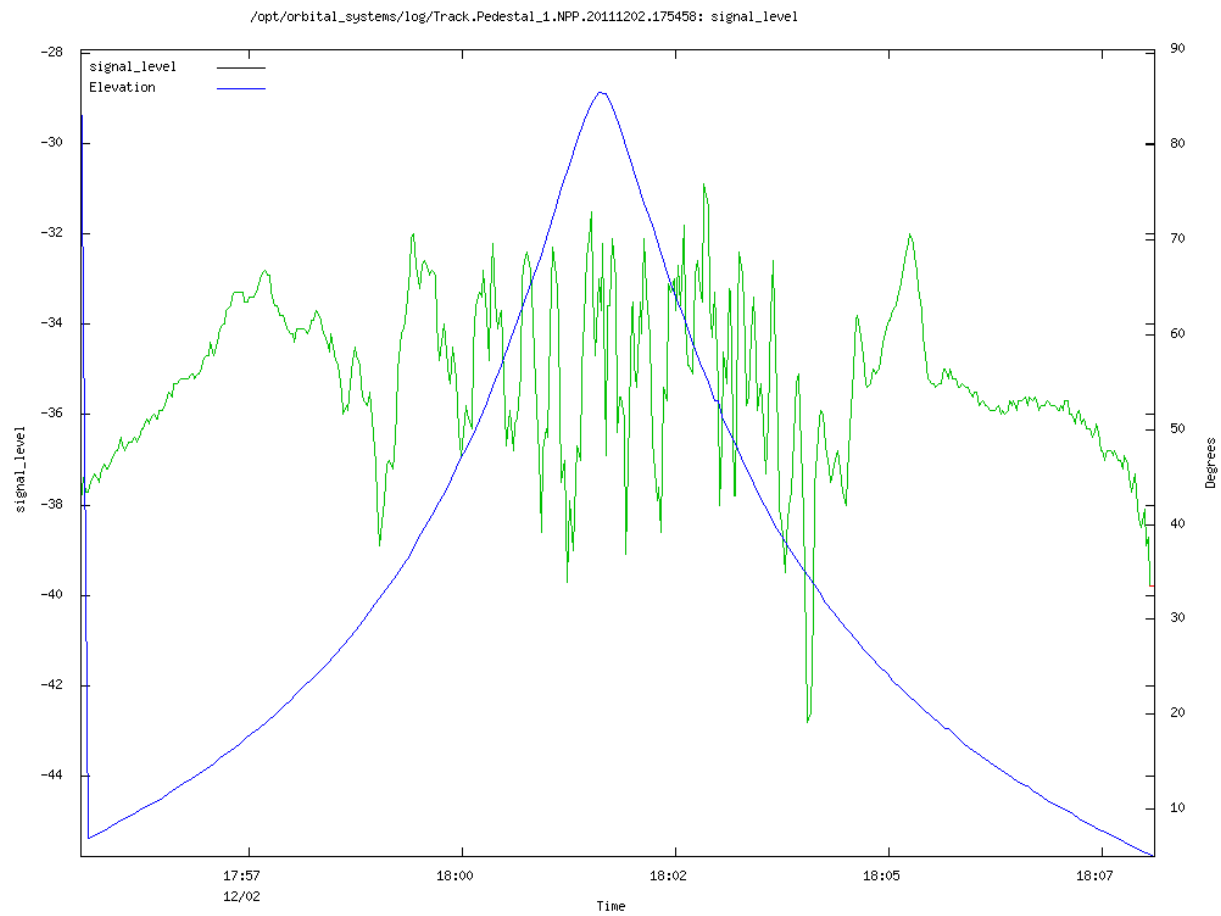


Figure 11. Elevation & Signal Plot for NPP Pass 2011-12-02 17:54 UTC, Max Elevation=85°

HRD reception Eb/No values as low as 5.0 have been measured during NPP passes at the DRL.

The variation in signal strength during high elevation NPP passes was also observed at the Oregon State University (OSU) site. Figures 12 and 13 show behavior similar to that observed at the DRL for high elevation passes, suggesting that the variations in signal strength cannot be attributed to environmental factors unique to the DRL.

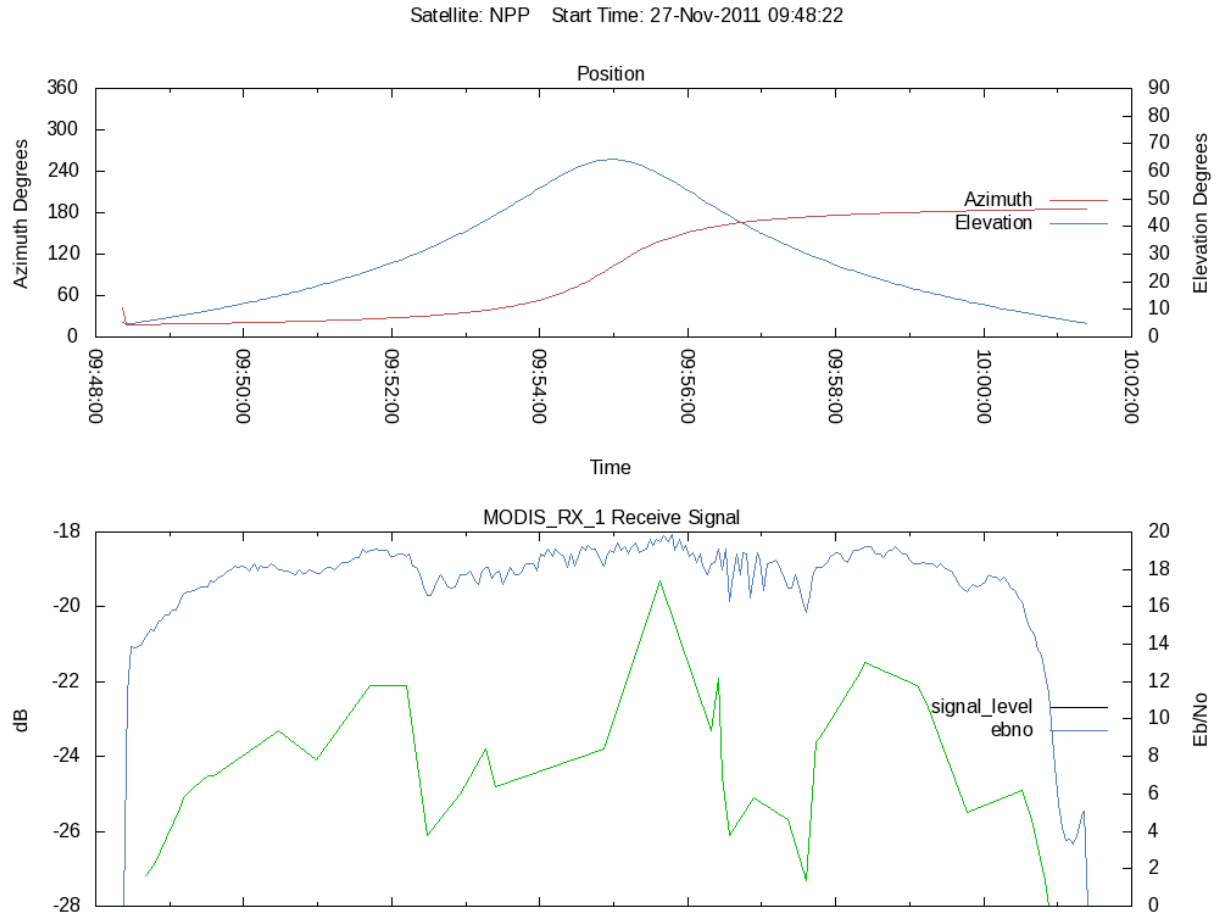


Figure 12. Azimuth, Elevation, & Signal Plot for OSU Acquired NPP Pass 2011-11-27 09:48 UTC

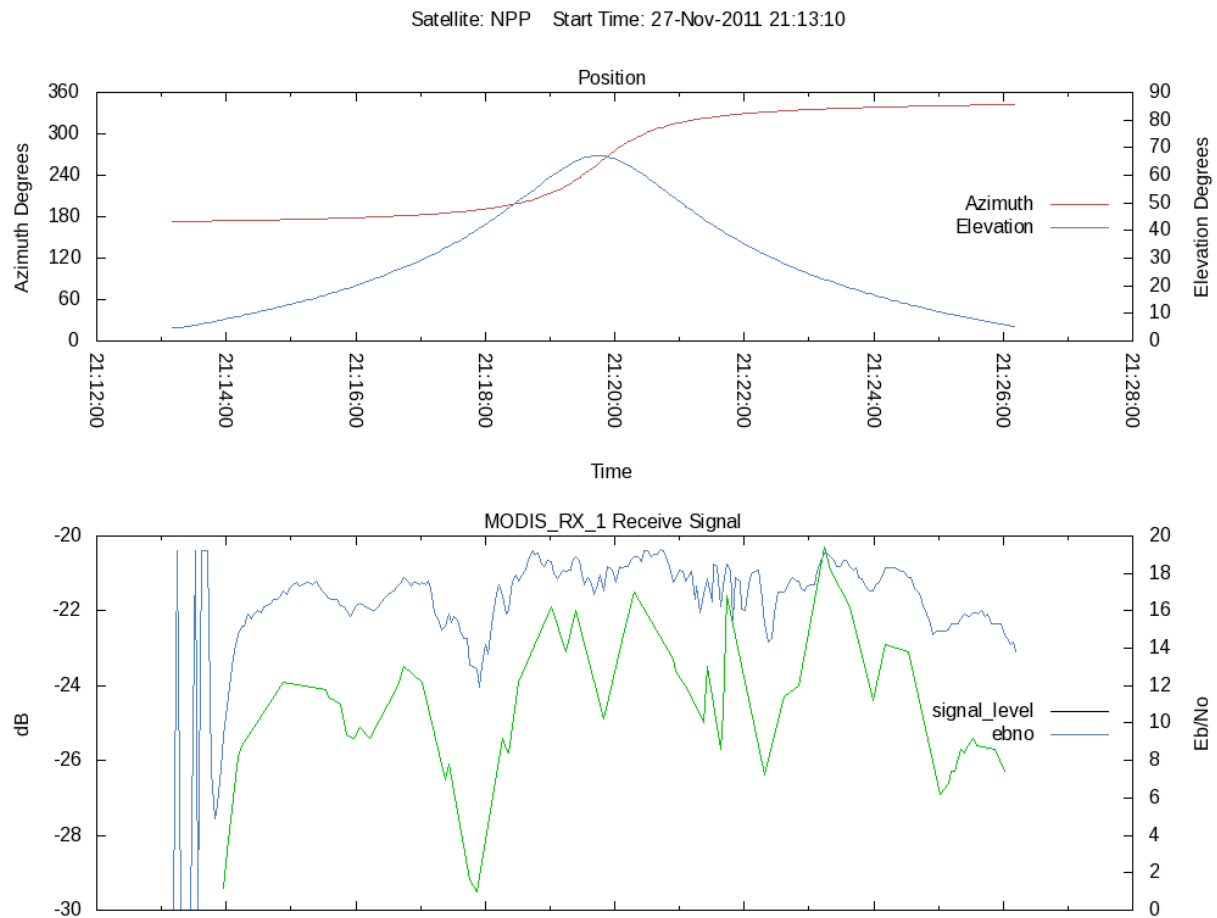


Figure 13. Azimuth, Elevation, & Signal Plot for OSU Acquired NPP Pass 2011-11-27 21:13 UTC

Conclusions

The received NPP HRD signal amplitude variation is large, over 15 dB during medium to high elevation passes. (This value can be corroborated against the measured value for this antenna as stated in the NPP – HRD / SMD Antennas End Item Data Analysis (SER NO. 3257-WBL118 dated 10/13/2005).

The observed RF reception performance suggests that the NPP link budget estimate is inadequate. Signals received at the DRL and OSU sites frequently have been marginal, and deep nulls in signal strength occur regularly under good reception conditions.

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