IIP RFI Survey: Version 2

Steven W. Ellingson*

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1 Summary

This report describes an updated survey of radio frequency interference (RFI) made in support of ESL's IIP radiometer project. This report updates [1], which was a crude first attempt to survey the RFI environment, especially around 1420 MHz where IIP field measurements are to be done. New features of this survey are as follows:

- The RF switch in the front end box has been made operational. Now, measurements can be made in pairs: once through the antenna, followed by a look at a matched terminator at ambient temperature. This is useful in improving sensitivity and identifying internal interference.
- PC control over the spectrum analyzer has been extended to allow the averaging and max-holding of traces to occur on the spectrum analyzer, as opposed to the PC. This speeds up measurements by reducing the amount of data that must be transferred.
- A script language has been developed to allow simpler and more flexible control of the experiment. Now, the user simply provides a text file containing the script, which is then read and executed by the PC.

As a result of the current survey, one new "interesting" RFI source is identified in near IIP band of interest: A strong intermittent signal around 1250 MHz.

*The Ohio State University, ElectroScience Laboratory, 1320 Kinnear Road, Columbus, OH 43210, USA. Email: ellingson.1@osu.edu.

2 Instrumentation

Except for the items noted above, instrumentation used in this survey was essentially the same as that used in [1]. For the convenience of the reader, a brief description follows.

The instrumentation consisted of an antenna, some ESL-built mast-mounted electronics (primarily, an LNA), a spectrum analyzer, and a PC for experiment control and data collection. The antenna used for this study was an AOR Model DA3000 discone, which is claimed by the manufacturer to be useable from 25 MHz to 2000 MHz. The discone was mounted on a temporary mast about 2.5 m above the main roof of ESL such that the antenna was about 10 m above the ground. A utility structure exists on the roof to the north of the antenna, which may have attenuated signals arriving from that direction.

The antenna was connected via about 2 m of coaxial cable to an aluminum box containing front end electronics. An internal view of the box is shown in Figure 1. The signal from the antenna enters from left and is routed to the RF switch in the upper right. The switch connects either this input or a 50Ω terminator to a 20 dB directional coupler. The coupled input is via a (currently unused, terminated) SMA jack on the right side of the box. Next is a 1200-1800 MHz bandpass filter (the black cylinder), followed by a low-noise amplifier (LNA). The LNA is an AVCOM Model RFP-24, which is specified to have 22 dB gain, 2.2 dB noise figure, and 2 GHz lowpass bandwidth. The measured gain of the LNA by itself was found to be about 29 dB (significantly higher than specified), and the gain rolls off slowly such that the LNA is still useable (albeit, with degraded performance) to 3 GHz and beyond. The noise figure of the LNA was not measured.

The measured response the front end is shown in Figure 2. The 1 dB compression point was measured to be −30 dBm at the input. Power consumption is 11 mA at 12V.

The front end box is connected to an Agilent Model E4407B spectrum analyzer using a long section of RG-58 coaxial cable. The length of the cable was not measured

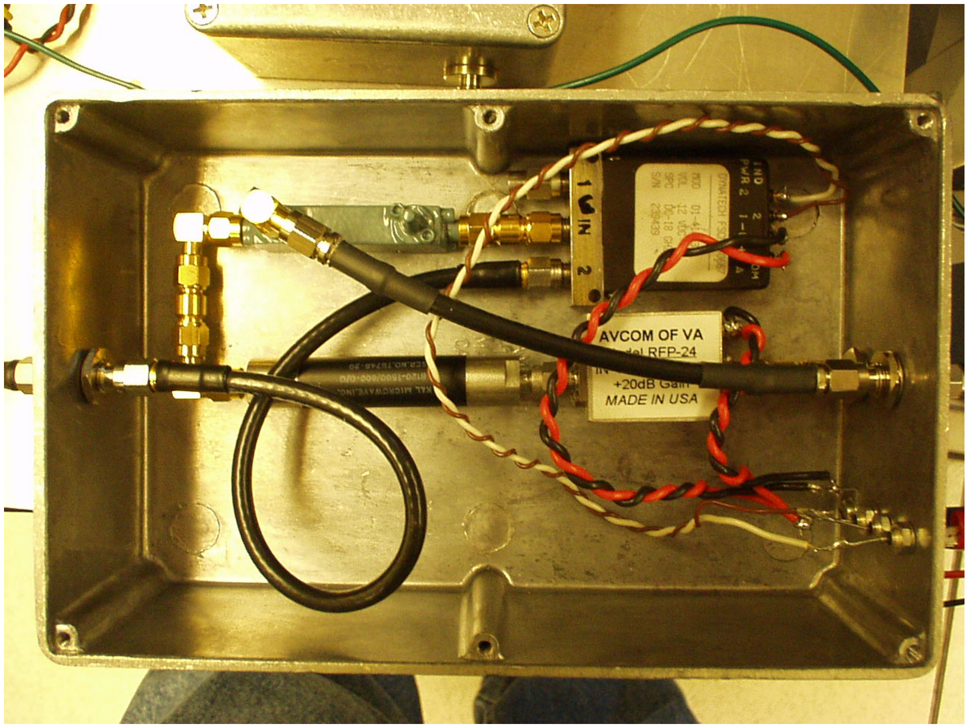

Figure 1: Internal view of front end box.

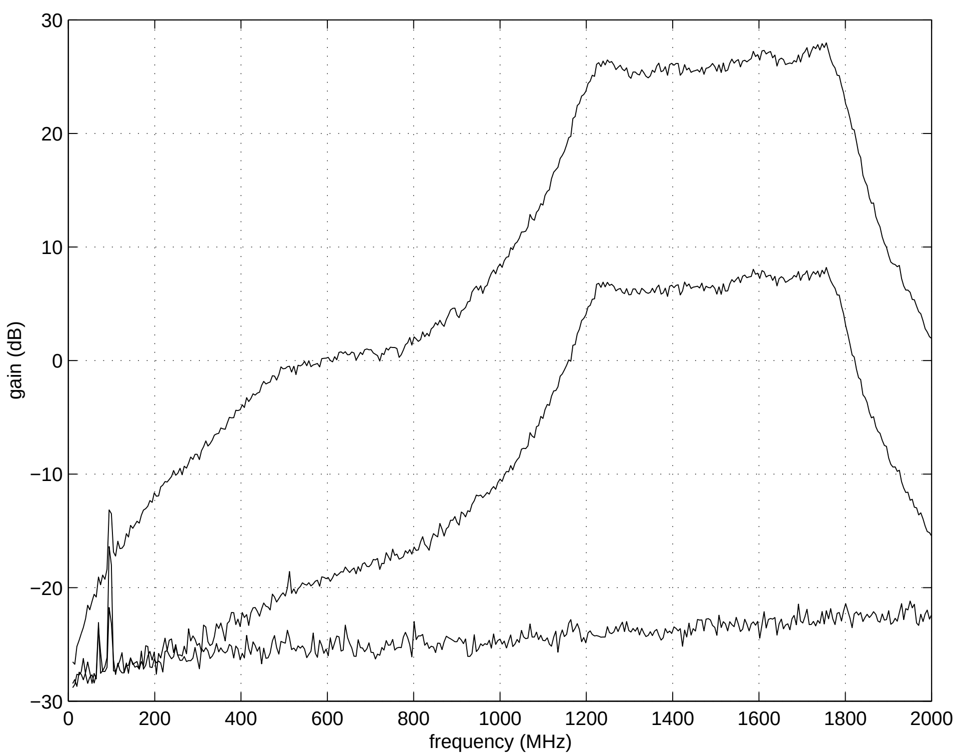

Figure 2: Frequency response of the front end box. *Top:* RF input to RF output. *Middle:* Coupled (calibration) input to RF output. *Bottom:* RF input to RF output, when switched to internal terminator.

but was on the order of 30 m. A 6 dB fixed attenuator was inserted between the front end box and the long coax to improve the match and mitigate reflections. Neglecting the antenna, the estimated gain in front of the spectrum analyzer was about −1 dB (cable) + 27 dB (front end box) − 6 dB (attenuator) − 8 dB (RG-58) = +12 dB. (The losses in the directional coupler and filter are less than 1 dB.)

The spectrum analyzer was interfaced to a PC via RS-232 at 115.2 kb/s. A C-language program controls the spectrum analyzer and collects data using the techniques described in [2]. For this work, the following settings are held constant throughout the experiment: Input attenuation: 5 dB; Internal preamp: ON; Video bandwidth (VBW): Equal to resolution bandwidth (RBW, which was varied); Detection method: AVERAGE (as opposed to PEAK (the default for this spectrum analyzer)).

A script language was developed to allow simple, flexible control of the experiment. The script used in this experiment is provided in Appendix A. To provide a brief orientation as to the use of the script, an explanation of the first few lines is provided below.

```
// 0-3 GHz
```

Text following a "//" at the beginning of a line is ignored, and available for comments.

```
CD 1                                    # Display 1
```

"`CD`" stands for "change display". In this case, the program is instructed to display subsequent results to display no. 1 (part of the GUI) during execution. A number sign is used to indicate that additional characters on that line are to be ignored (i.e., used for comments).

```
IN 1                                    # Toggle to antenna
```

"`IN`" tells the computer to toggle the RF switch such that the input is either the antenna (1) or the terminator (0).

```
FN 0.0e+0 3.0e+9 1.0e+6 3001 1 100 0 1 # Max hold
```

"`FN`" is a request to obtain a multiple sweeps from the spectrum analyzer. The parameters are the start frequency (0 GHz), stop frequency (3 GHz), RBW (1 MHz), number of points per sweep (3001), enable max hold (1; 0 would mean enable averaging instead), number of sweeps (100), measurement ID number (0), and display color (1). "Max hold" means that the result will be a single trace in which each point is the maximum value for that frequency across all sweeps. "Averaging" means the average of the traces in linear power units (e.g., mW). A "measurement ID number" is a unique number that identifies the requested measurement and is also used to label data files associated with that measurement. The "display color" applies to the GUI.

The control program executes the script from beginning to end, and then returns to the beginning, following an endless loop until the program is manually terminated. Data files associated with each requested measurement are saved to disk using the measurement ID, iteration number, and date/time to construct a filename.

3 0−3 GHz Observations

Figure 3 shows the results summarizing Measurement ID 0, which is a max hold with a span of 0−3 GHz. Each pixel column here represents the max hold of 100 sweeps taken in quick succession. Each measurement takes on the order of 10 s to complete, and the time between measurements (equal to the time required to execute one iteration of the script) is about 3.4 min. Therefore, this spectragram is a little misleading since there are large time gaps between the measurements; e.g., the duty cycle of observation is actually very low. The frequency resolution (equal to the RBW here) is 1 MHz.

Figure 4 shows a "max hold over the max holds"; i.e., a max hold over the 47 measurements shown in Figure 3.

Figure 5 compares this result with the averages over the average-antenna measurement (Measurement ID 1) and average-terminator measurement (ID 2). This plot makes it clear that most of the variation in the noise baseline is due to the system, which implies that the system temperature is large compared to the antenna

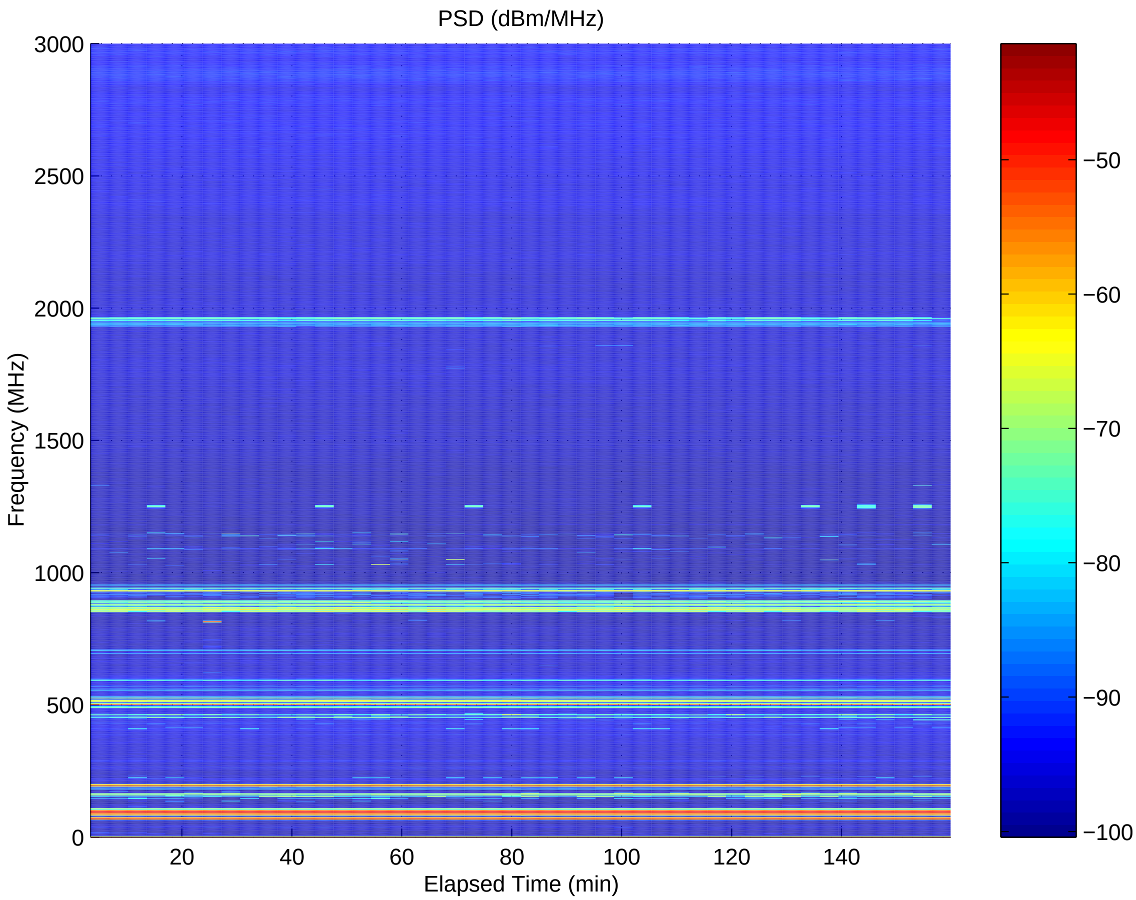

Figure 3: 0−3 GHz: Spectragram of max-hold results.

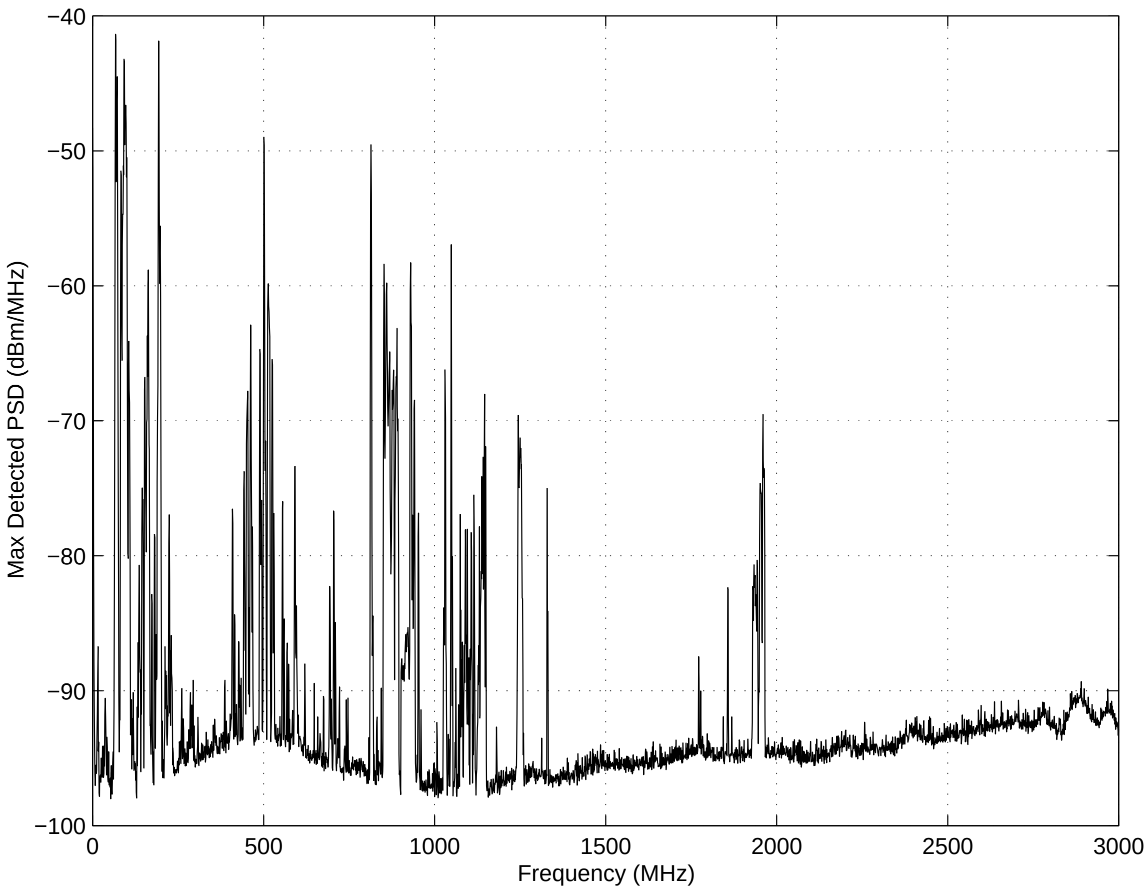

Figure 4: 0−3 GHz: Max hold over all measurements.

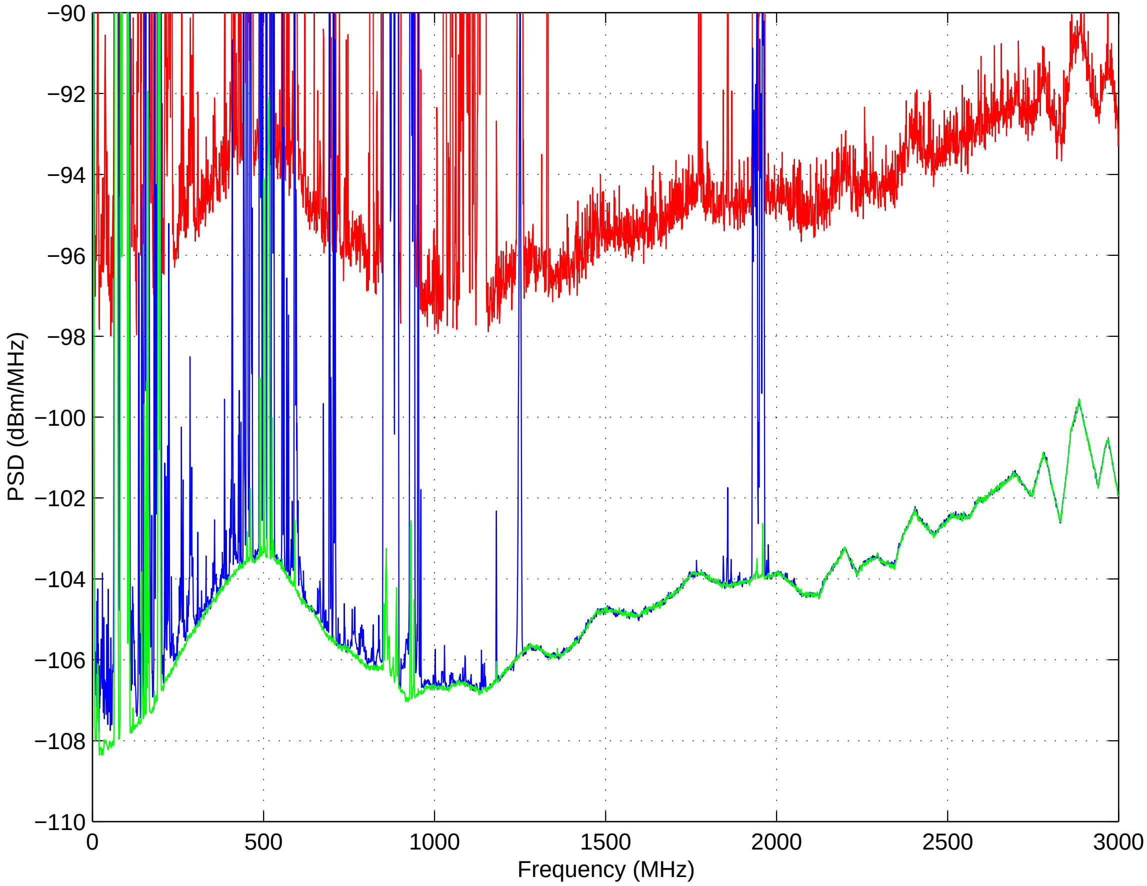

Figure 5: 0−3 GHz: *Red:* Max hold, antenna (ID 0); *Blue:* Average, antenna (ID 1); *Green:* Average, terminator (ID 2).

temperature. To improve the sensitivity of the measurement, we can subtract the "terminator" trace from the "antenna" trace. The result is shown in Figure 6. This figure suggests that the antenna temperature dominates over the system temperature below 1 GHz, whereas the reverse is true above 2 GHz. Between 1 GHz and 2 GHz, Figure 6 reveals some fine structure in the noise baseline. This will be discussed further below.

It is possible to reformat Figure 6 in log units for greater dynamic range, as shown in Figure 7. Interpretation of this plot requires some caution since the some points in Figure 6 have "negative" values since they may be less than the baseline noise values near the limit of sensitivity. To bypass this issue, one can simply take the absolute value before converting to dB, as is done here. Nevertheless, the result shows that this technique is quite effective in removing the system-imposed response

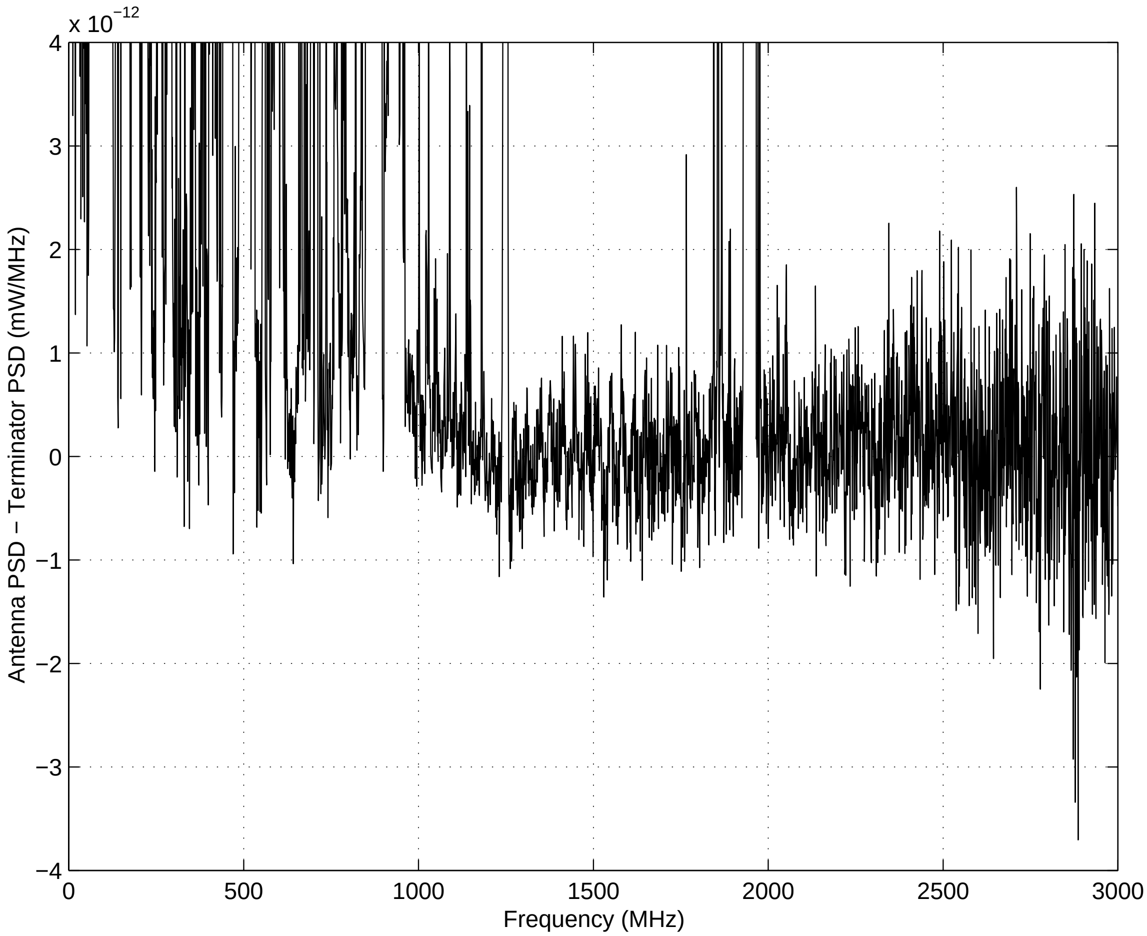

Figure 6: 0−3 GHz: Antenna minus Terminator (linear power units).

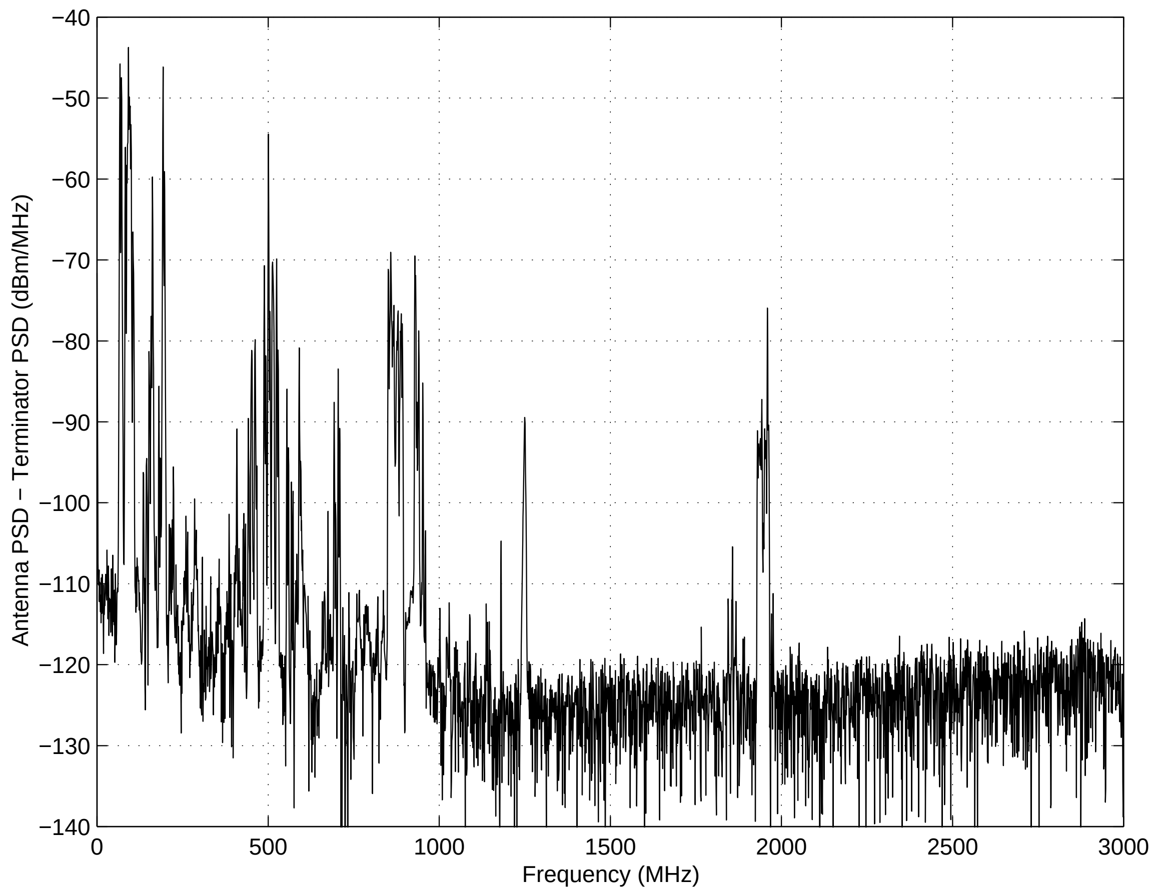

Figure 7: 0−3 GHz: Antenna minus terminator (linear average, expressed in dBm).

(i.e., straightening out the baseline) and improving the sensitivity of the measurement (i.e., lowering the noise floor).

4 1200−1800 MHz Observations

In this section, the span 1200−1800 MHz – the passband of the front end box – is examined in more detail. Figure 8 shows the results summarizing Measurement ID 3, which is a max hold comparable to Figure 3. There are only two notable features. First, a very strong and intermittent source is visible near 1250 MHz. Second, we catch a single occurance of our “favorite” RFI signal, the London ATC radar at 1331 MHz. It is not surprising that more activity is not visible (e.g., for the 1331 MHz radar), since the duty cycles for both the measurement and the radar are so low.

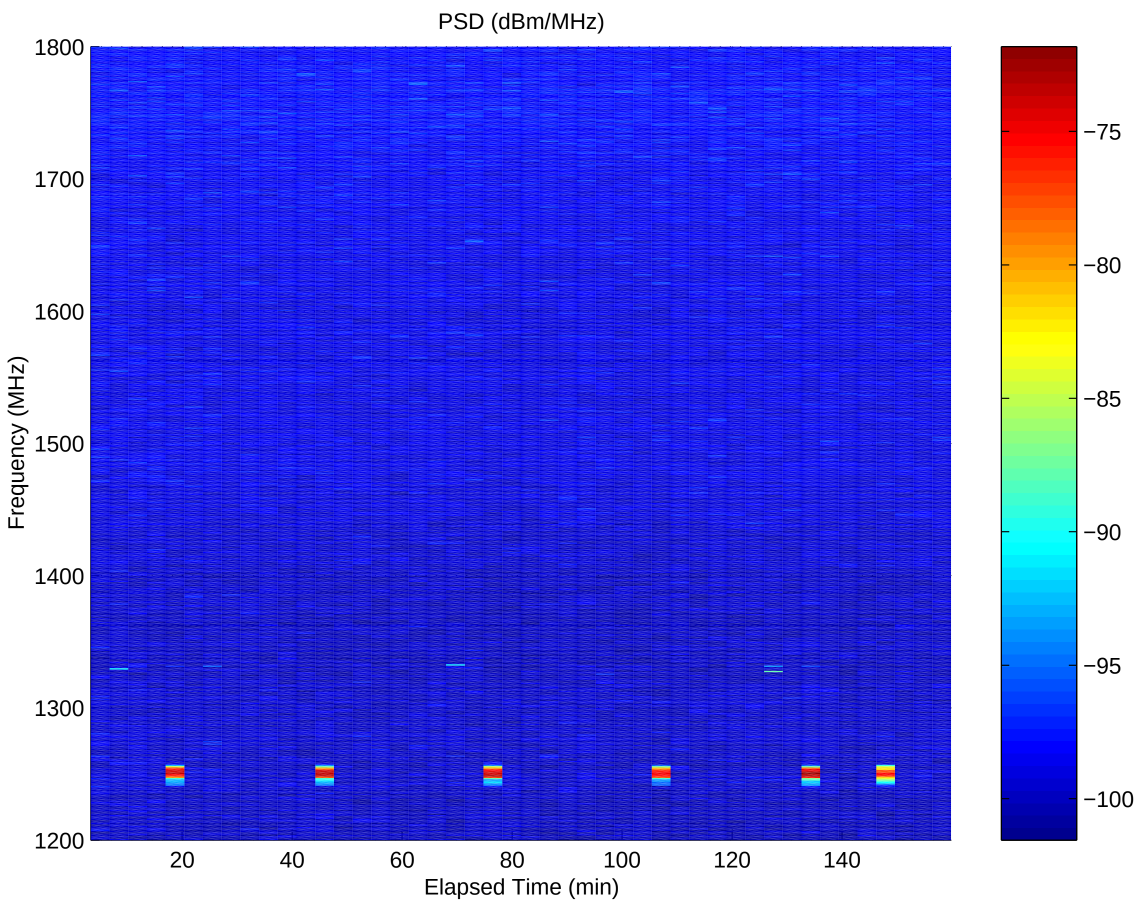

Figure 8: 1200−1800 MHz: Spectragram of max-hold results.

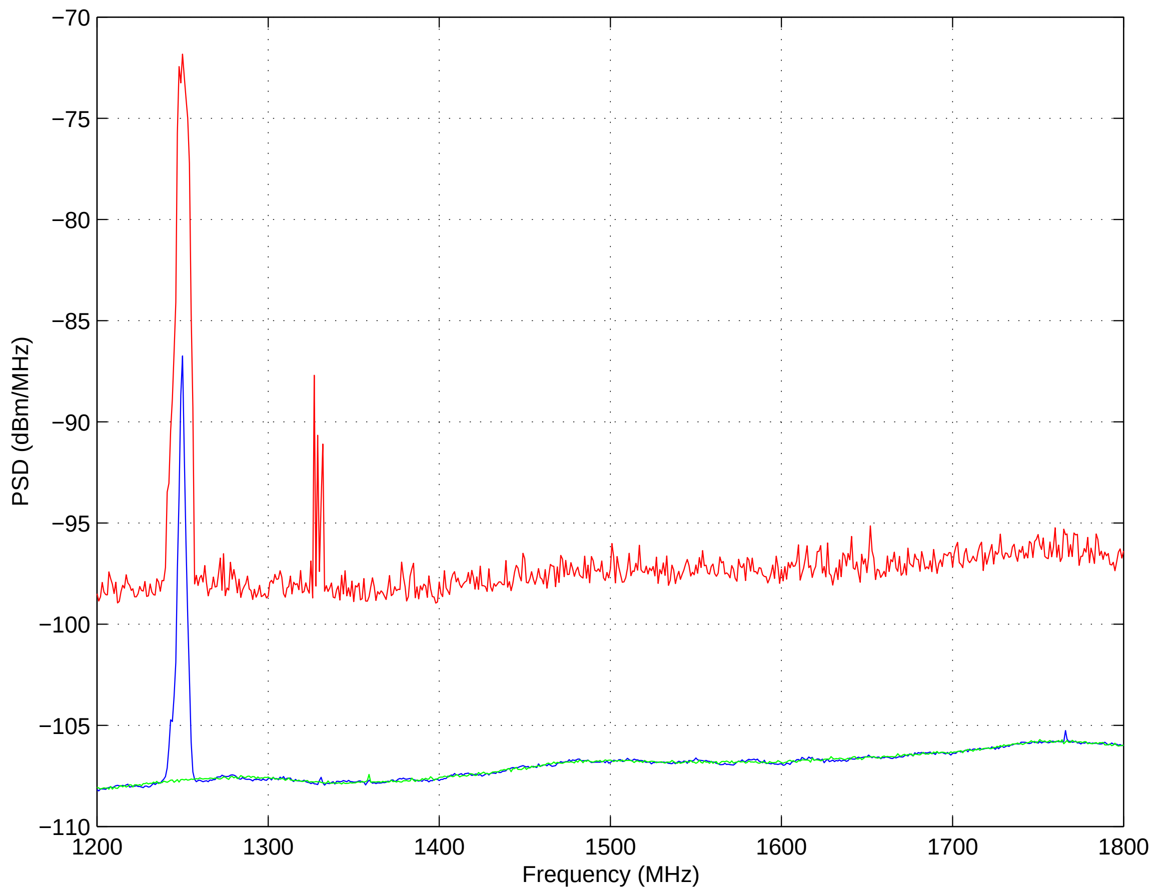

Figure 9: 1200−1800 MHz: *Red:* Max hold, antenna (ID 3); *Blue:* Average, antenna (ID 4); *Green:* Average, terminator (ID 5).

Figure 9 shows the max hold as well as averaged antenna (ID 4) and terminator (ID 5) results for this band. In this view, the 1331 MHz radar is clearly visible in the max hold trace but not in the average trace, which is a good clue that the signal is pulsed with a low duty cycle. Also, we see that the 1250 MHz signal is not at all apparent in the average-terminator trace, confirming that it originates from outside the measurement system.

Figures 10 and 11 are analogous to Figures 6 and 7 respectively. Figure 10 clearly shows the fine ripple in the noise floor previously identified. It is believed that this is the transfer characteristic of the antenna itself, although this could also be due to imperfect impedence match between the antenna and the RF switch.

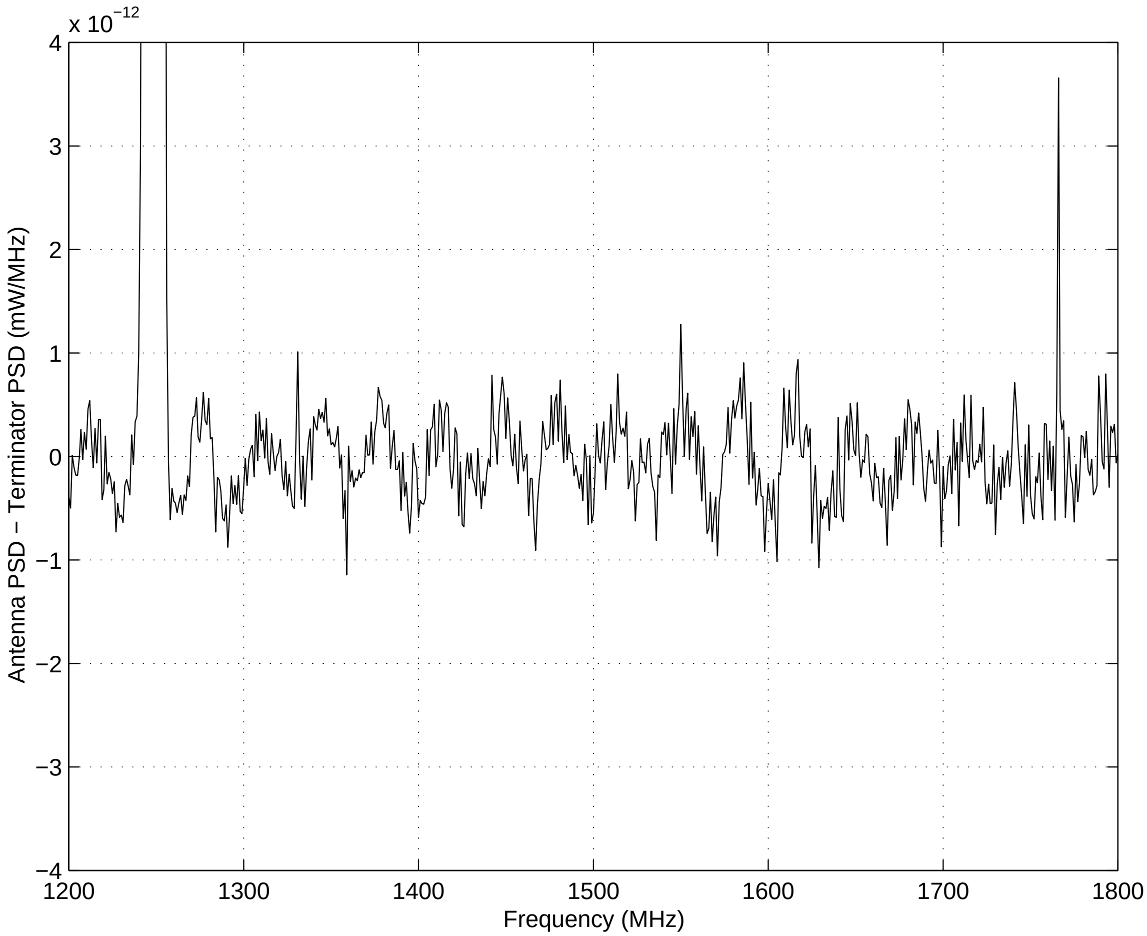

Figure 10: 1200−1800 MHz: Antenna minus terminator (linear power units).

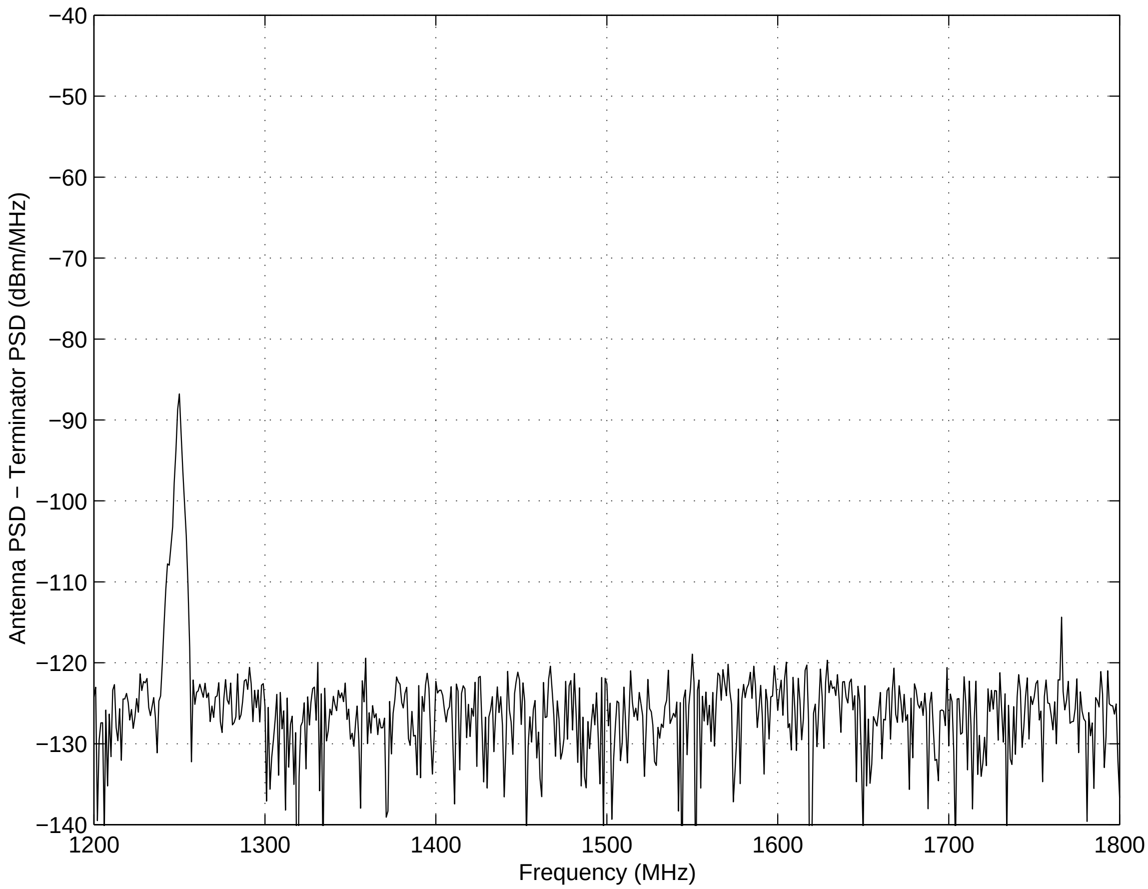

Figure 11: 1200−1800 MHz: Antenna minus terminator (linear average, expressed in dBm).

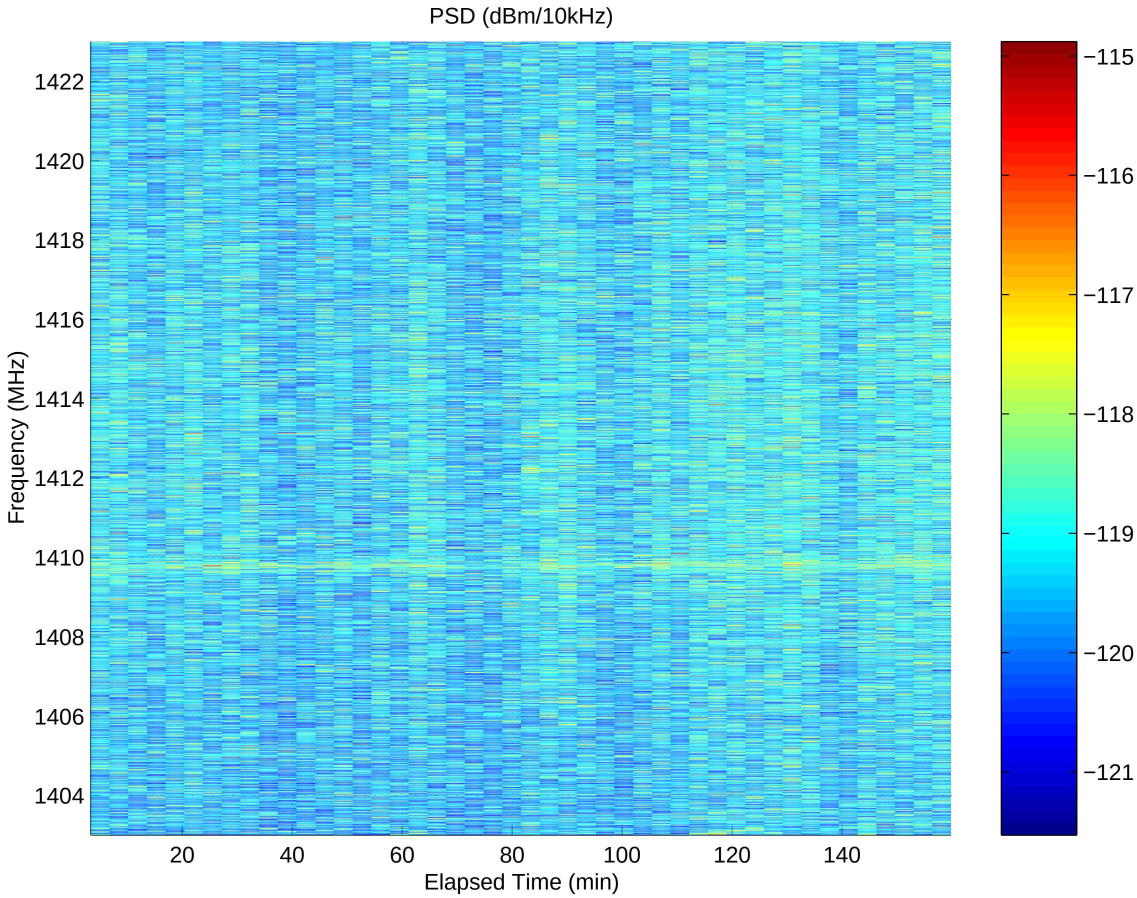

Figure 12: 1403−1423 MHz: Spectragram of max-hold results.

5 1403−1423 MHz Observations

In this section, the span 1403−1423 MHz – the 20 MHz currently of greatest interest in L-band remote sensing – is examined in more detail. For these measurements, RBW=10 kHz and samples are taken every 10 kHz. As a result, the sensitivity is a factor of 100 better than in the above observations. Figure 12 shows the results summarizing Measurement ID 6, which is a max hold comparable to Figures 3 and 8. No signals are discernible except perhaps for a very weak persistant signal around 1410 MHz.

Figure 13 shows the max hold as well as averaged antenna (ID 7) and terminator (ID 8) results for this band. In this view, we see that the 1410 MHz "signal" appears in both the antenna and terminator traces, indicating that it originates from *inside* the measurement system.

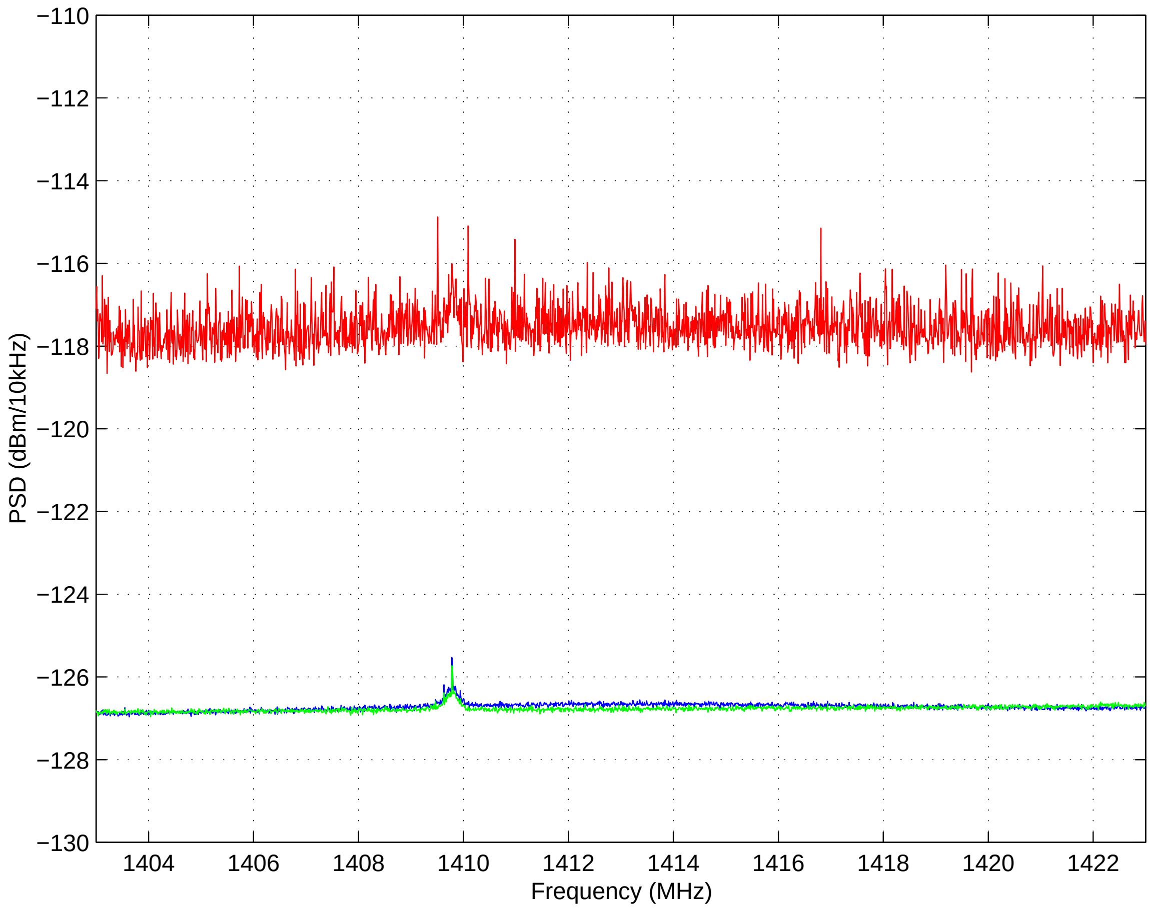

Figure 13: 1403−1423 MHz: *Red:* Max hold, antenna(ID 6); *Blue:* Average, antenna (ID 7); *Green:* Average, terminator (ID 8).

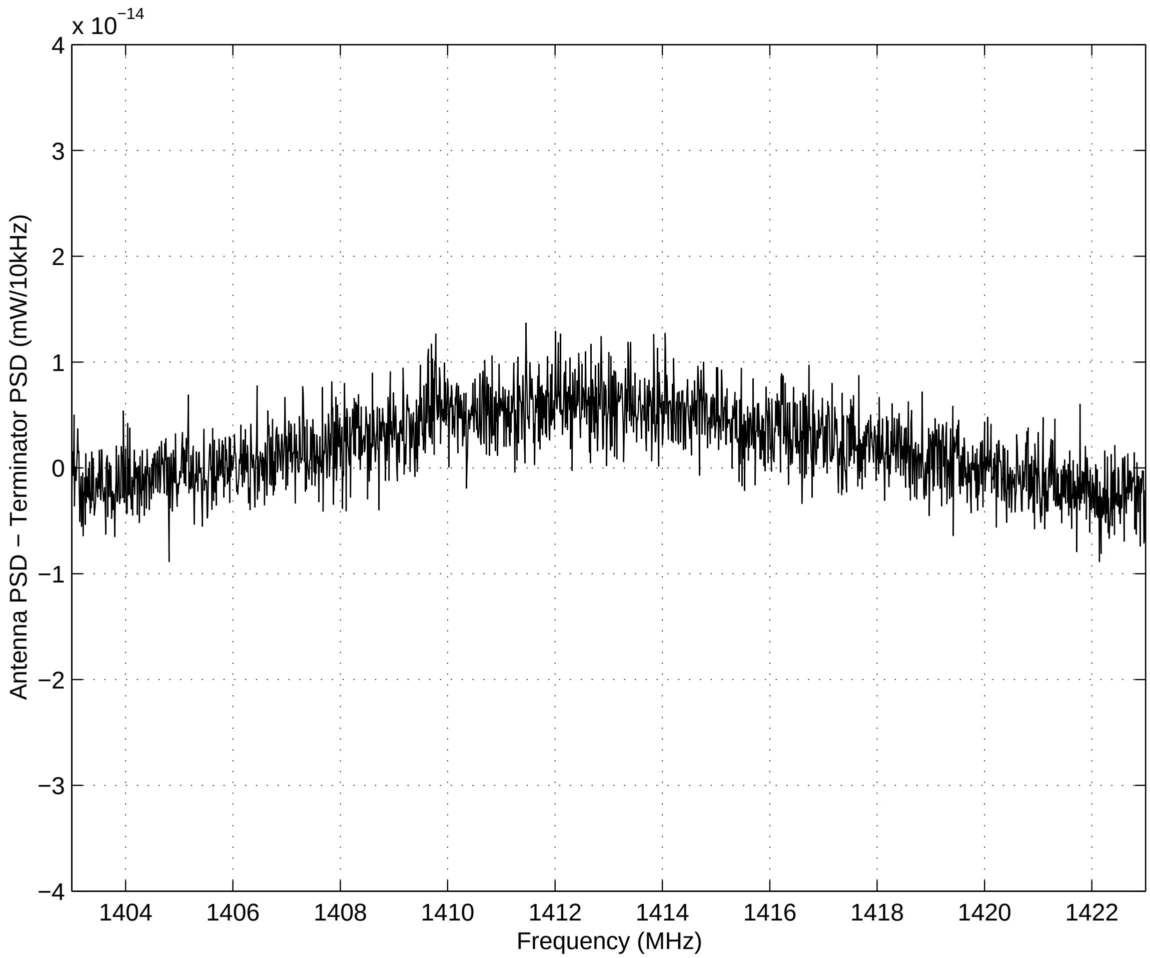

Figure 14: 1403−1423 MHz: Antenna minus terminator (linear power units.

Figures 14 and 15 are analogous to Figures 10 and 11 respectively. Note that the "hump" visible in these plots is part of the slow ripple previously discussed. No external RFI signals are discernible to the level of sensitivity of this measurement.

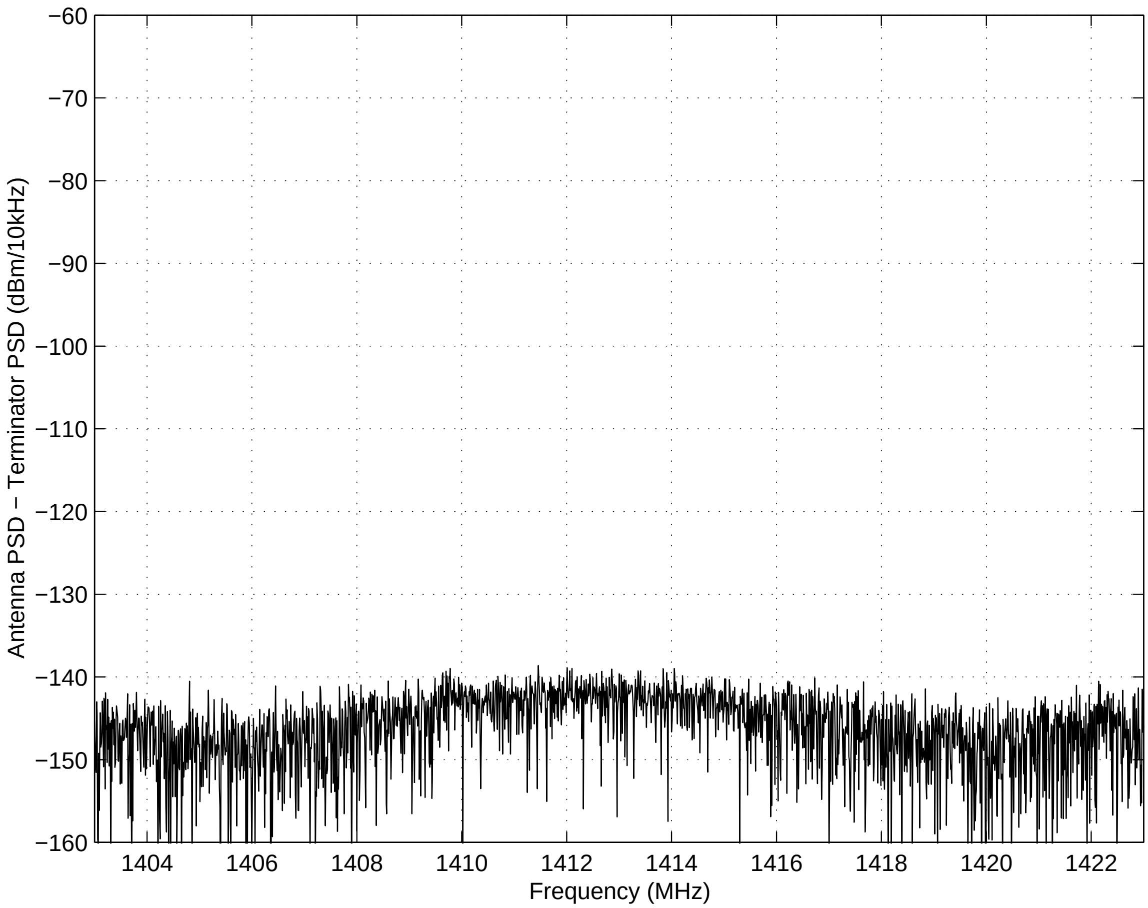

Figure 15: 1403−1423 MHz: Antenna minus terminator (linear average, expressed in dBm).

A Experiment Script

```
// 0-3 GHz
CD 1                                    # Display 1
IN 1                                    # Toggle to antenna
FN 0.0e+0 3.0e+9 1.0e+6 3001 1 100 0 1 # Max hold
FN 0.0e+0 3.0e+9 1.0e+6 3001 0 100 1 2 # Average
IN 0                                    # Toggle to terminator
FN 0.0e+0 3.0e+9 1.0e+6 3001 0 100 2 3 # Average

// 1200-1800 MHz
CD 2                                    # Display 2
IN 1                                    # Toggle to antenna
FN 1.2e+9 1.8e+9 1.0e+6 601 1 100 3 1  # Max hold
FN 1.2e+9 1.8e+9 1.0e+6 601 0 100 4 2  # Average
IN 0                                    # Toggle to terminator
FN 1.2e+9 1.8e+9 1.0e+6 601 0 100 5 3  # Average

// Detection span (1413+/-10 MHz)
CD 3                                         # Display 3
IN 1                                         # Toggle to antenna
FN 1.403e+9 1.423e+9 10.0e+3 2001 1 100 6 1 # Max hold
FN 1.403e+9 1.423e+9 10.0e+3 2001 0 100 7 2 # Average
IN 0                                         # Toggle to terminator
FN 1.403e+9 1.423e+9 10.0e+3 2001 0 100 8 3 # Average

// End of script
EN
```

References

[1] S.W. Ellingson, "Preliminary RFI Survey for IIP", IIP Memo 21, June 11, 2002.

[2] S.W. Ellingson, "Agilent Spectrum Analyzer Computer Control Demo", IIP Memo 20, June 6, 2002.