Preliminary RFI Survey for IIP

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1 Introduction

This report describes a preliminary survey of radio frequency interference (RFI) made in support of ESL's IIP radiometer project. This was a crude first attempt to survey the RFI environment, especially around 1420 MHz where IIP field measurements are to be done.

2 Instrumentation

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. The box is shown in Figure 1. An internal view is shown in Figure 2. The signal from the antenna enters from left and is routed to

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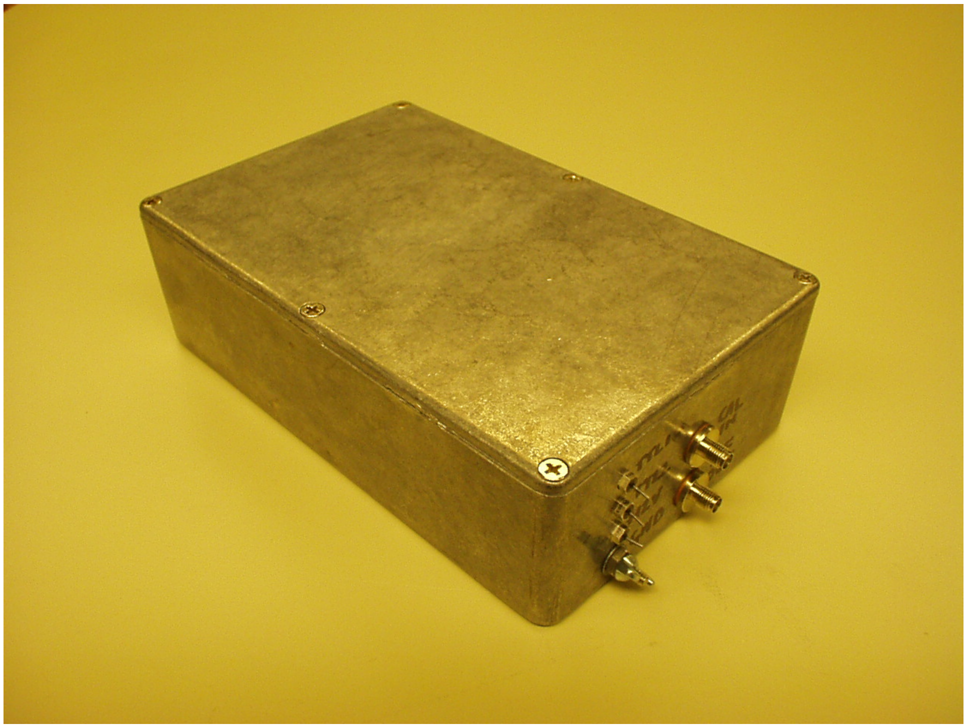

Figure 1: External view of front end box.

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 an 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 3. 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 but was on the order of 30 m. A 6 dB fixed attenuator was inserted between the front

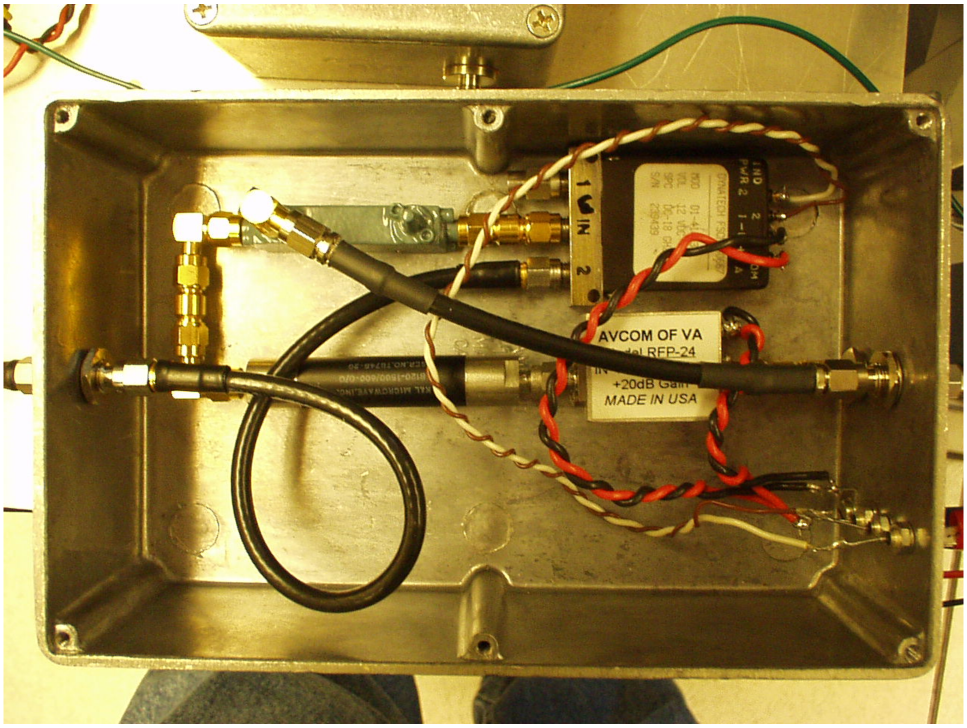

Figure 2: Internal view of front end box.

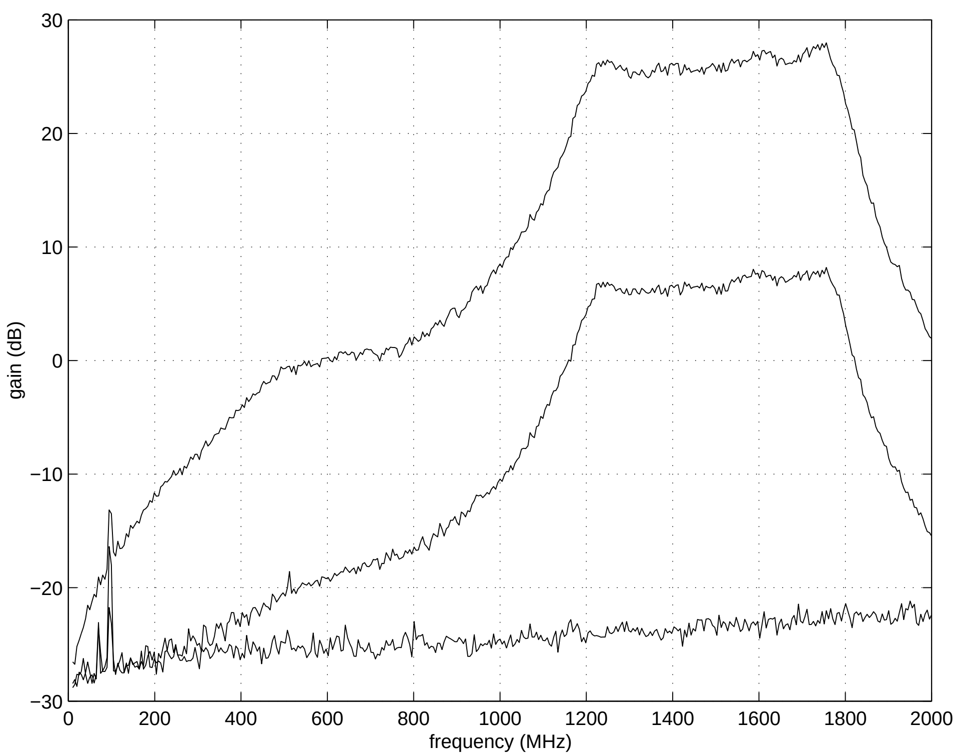

Figure 3: Frequency response of the front end box. *Top:* RF input to RF output. *Middle:* Coupled (calibration) input to RF output. *Bottom:* RF input to RF output, when switched to internal terminator.

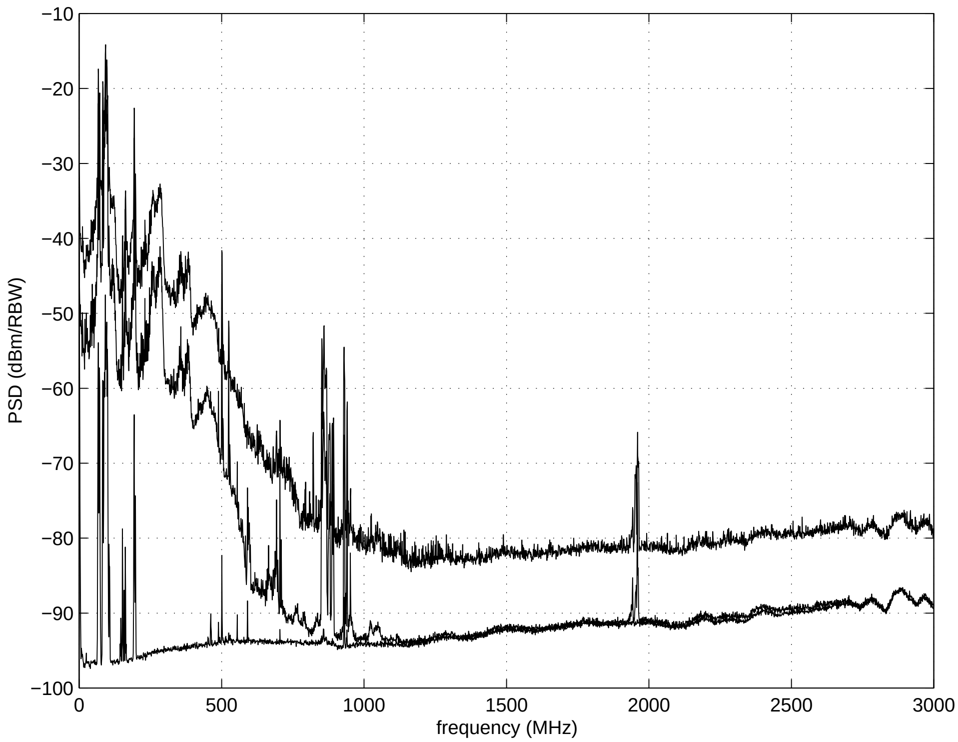

Figure 4: 0−3 GHz *without* front end box. *Top:* Max hold after about 1 minute. *Middle:* Linear average of 100 sweeps. *Bottom:* Linear average of 100 sweeps with antenna replaced by a 50Ω terminator.

end box and the long coax to improve the match and control 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 configured for 5 dB input attenuation and the internal preamp was turned ON. The resolution bandwidth (RBW) was varied as indicated below, but video bandwidth (VBW) was always set equal to RBW.

3 0−3 GHz Observations

The first measurements made were made *without* the front end box. Figure 4 shows the results of sweeps from 0−3 GHz in 1 MHz steps with RBW= 1 MHz.

Figure 5 shows the same measurement, now with the front end box in use. **Note that since there is about 12 dB gain in front of the spectrum analyzer, the**

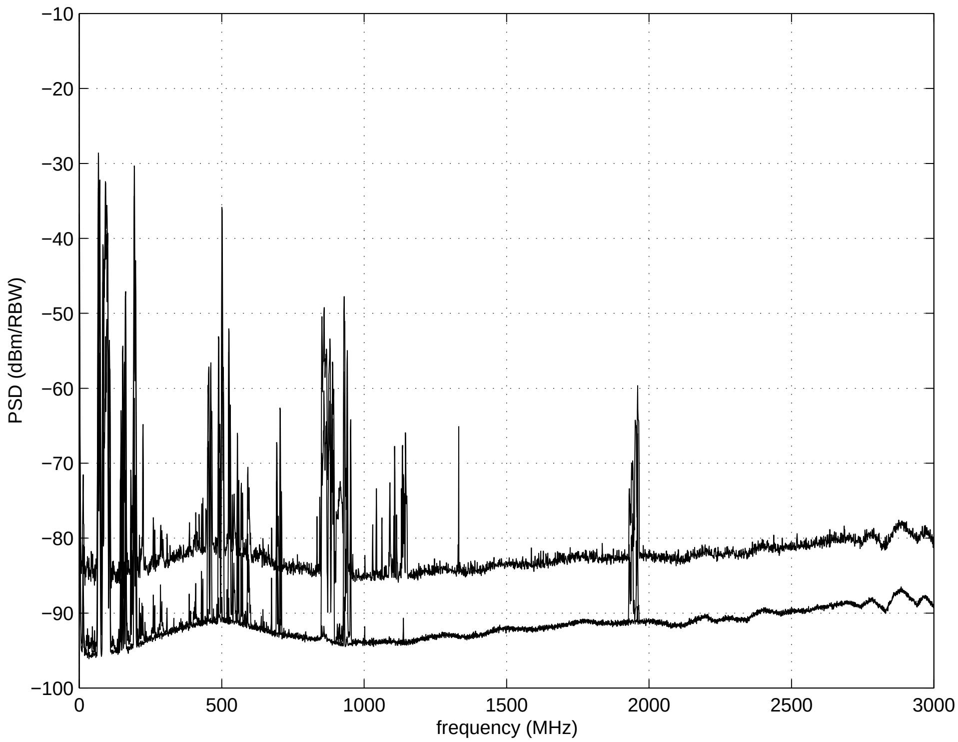

Figure 5: 0−3 GHz using front end box. *Top:* Max hold after about 1 minute. *Middle:* Linear average of 100 sweeps. *Bottom:* Linear average of 100 sweeps with antenna replaced by a 50Ω terminator.

actual power spectral densities (PSD) measured at the antenna terminals are probably about 12 dB less than indicated. (This will be true also for all subsequent results in this report.) Note that the bandpass filter in the front end box is quite effective in suppressing signals below 1 GHz, which is important in preserving the linearity of the LNA and the spectrum analuzer. In fact, the LNA would be operating in compression if this filter were not used.

4 1−2 GHz Observations

In this section, the span 1−2 GHz is examined in detail. For these measurements, RBW=1 MHz and samples are taken every 1 MHz. First, consider the response of the measurement system when the antenna is replaced by a matched terminator. The resulting "baseline" is shown in Figure 6. The ripple is attributed to the filter in the front end box, whereas the slope (increasing from left to right) is attributed to

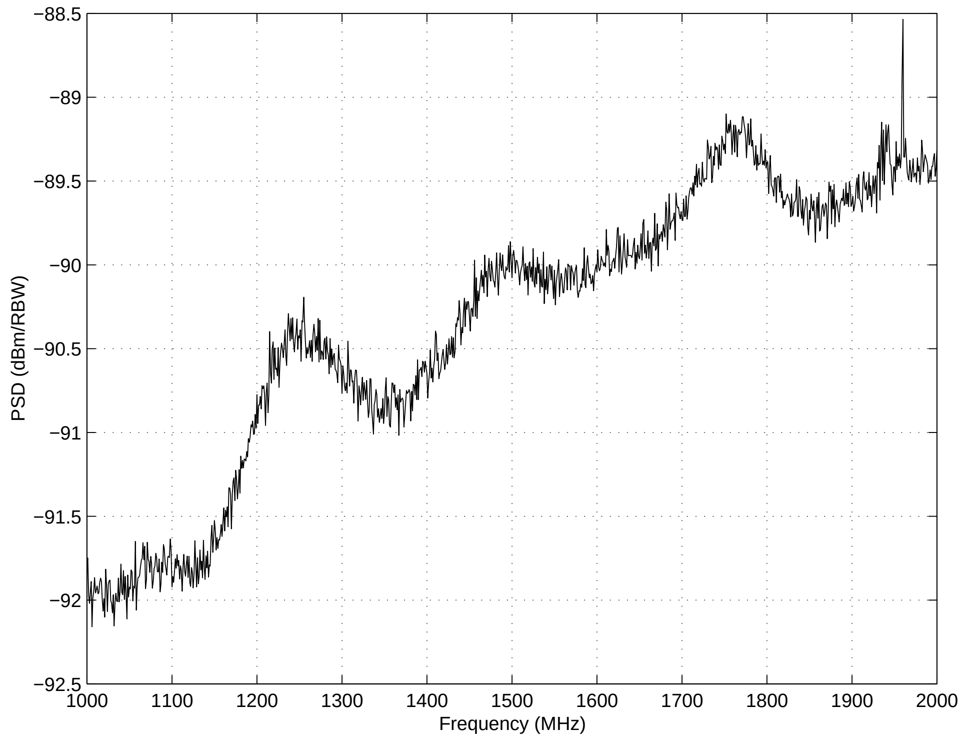

Figure 6: 1−2 GHz with antenna replaced by matched terminator. Linear average of 274 sweeps.

the fact that the noise figure of the system (both the LNA and spectrum analyzer) increases with increasing frequency. However, both effects are quite small compared to the magnitudes of the signals of interest in this report. Thus, no attempt was made to remove this baseline from the following results.

Figure 7 shows the on-air results. Note that the spectrum in the 1200−1800 MHz bandpass of the front end seems to be very quiet, although a signal is visible at 1331 MHz. This will be shown later to be a radar. Also prominent in this figure is the PCS mobile communications band in 1800−2000 MHz, which is very strong and only suppressed by about 15 dB by the front end.

Figure 8 zooms in on the noise floor of the on-air result of Figure 7. Comparing to Figure 6, it is clear that the antenna is responsible for some additional ripple in the noise baseline.

Figure 9 is the same measurement as Figure 7, except now the “max hold” values after about 1700 sweeps (about 15 minutes real time) are shown.

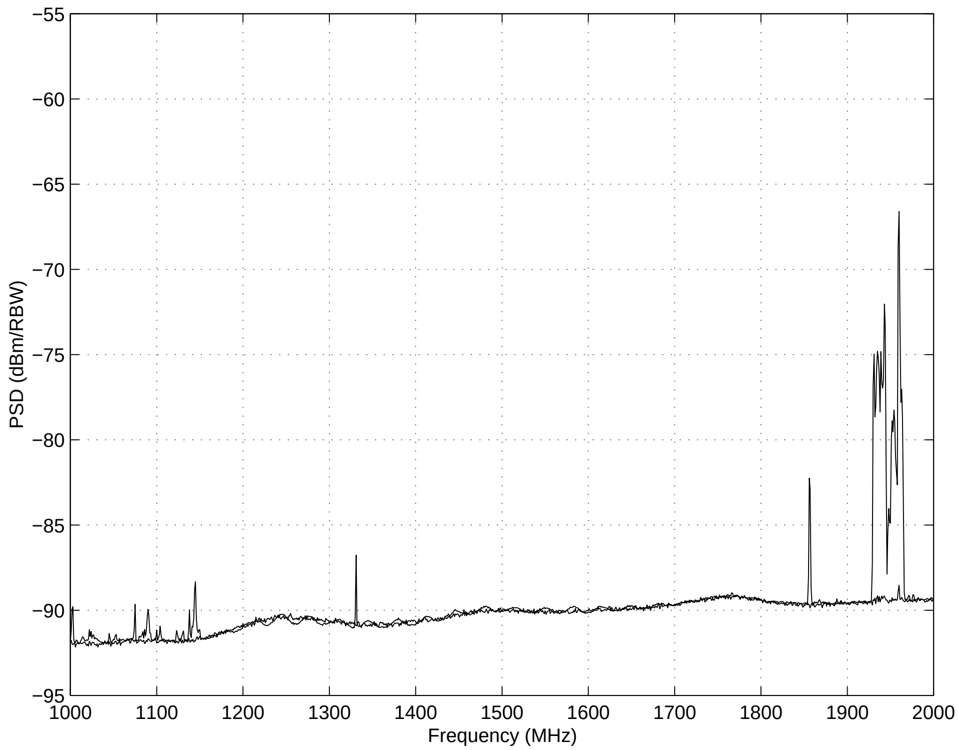

Figure 7: 1−2 GHz. Linear average of about 1700 sweeps. Trace from Figure 6 is also shown but is very close to the other trace.

5 1325−1425 MHz Observations

In this section, the span 1325−1425 MHz is examined in detail. For these measurements, RBW=100 kHz and samples are taken every 100 kHz. As a result, the sensitivity is a factor of 10 better than in the above observations. Figure 10 shows the on-air measurement. Note that no signals are apparent except for the 1331 MHz radar previously identified.

6 1331 MHz Radar Observations

In this section, we take a closer look at the 1331 MHz radar signal. In these measurements, the span is 10 MHz around 1331 MHz, RBW=10 kHz, and samples are taken every 10 kHz. The results are shown in Figures 11 and 12. The bandwidth of the signal appears to be about 700 kHz, with some splatter outside this range. Also,

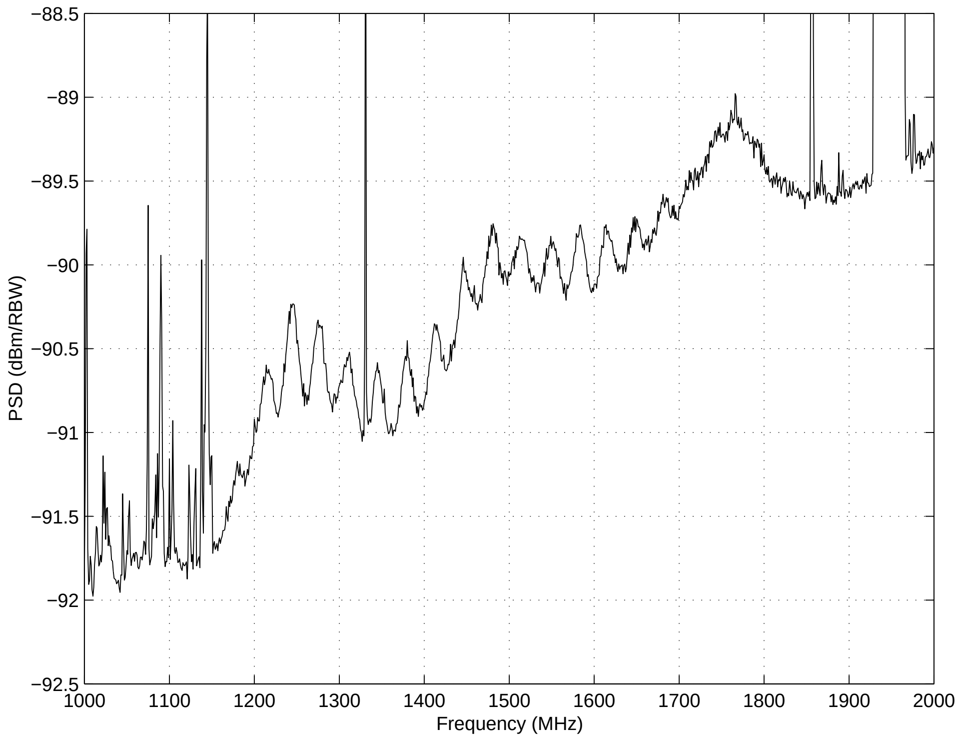

Figure 8: Same as Figure 7, zooming in on noise floor. (Input-terminated result not shown in this figure.)

it clear that the signal has a very low duty cycle since the average values are much smaller than the max-hold values.

For positive identification of this signal, some time domain measurements were made. These were done using the "zero span" configuration of the spectrum analyzer with RBW=3 MHz. It was observed that the signal strength oscillates with a period of 10 s, suggesting a rotating transmit antenna with a narrow beamwidth. Figures 13 and 14 show the results over time scales of 1 s and 50 ms respectively, in each case measured during a peak in the 10 s cycle. From Figure 14 it is clear that the signal consists of pulses of length on the order of 1 μs separated by about 3 ms. The center frequency, bandwidth, rotation rate, pulse length, and pulse period are all consistent with an air traffic control radar known to be operating in London, OH (approximately 43 km distant) with 3 MW transmit power.

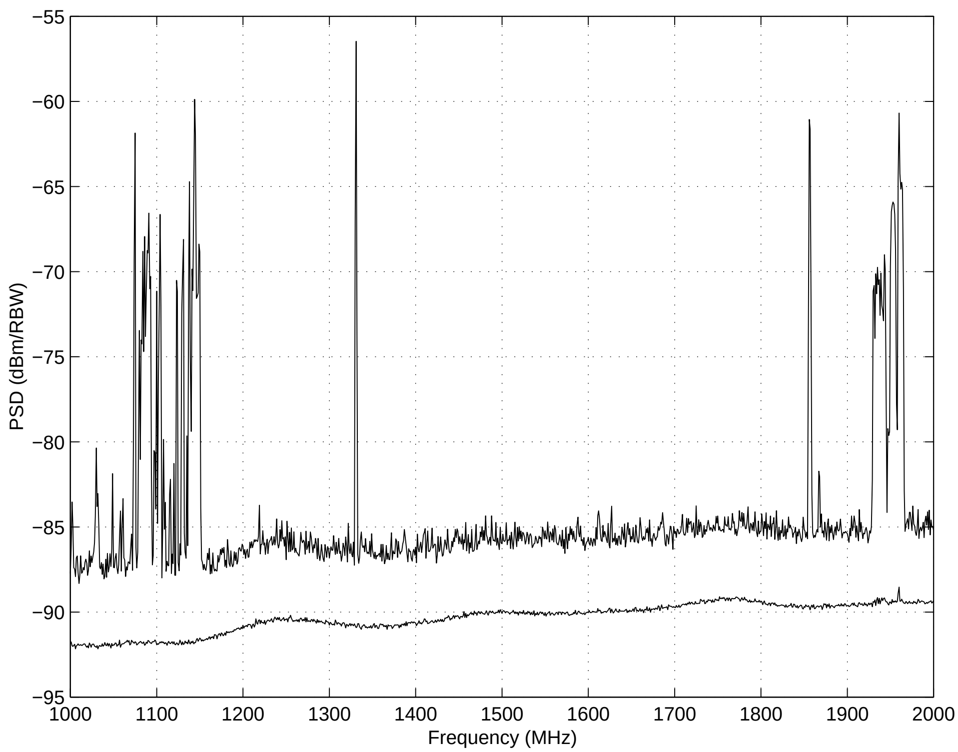

Figure 9: 1−2 GHz. *Top:* Max hold after 1700 sweeps. *Bottom:* Linear average of about 1700 sweeps.

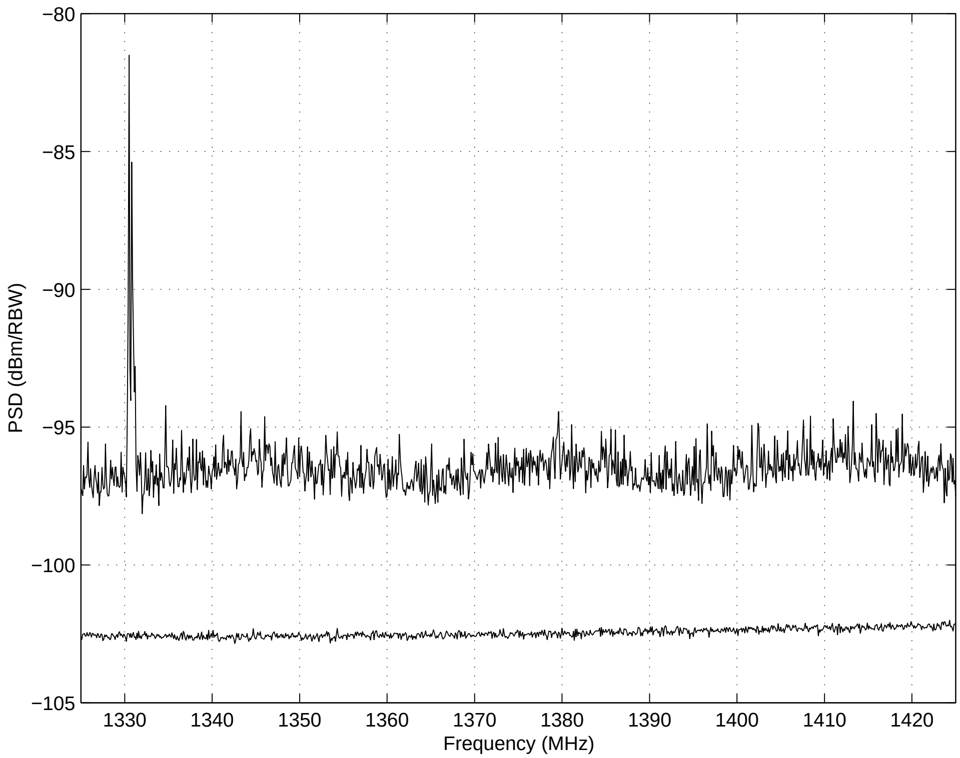

Figure 10: 1325−1425 MHz. *Top:* Max hold after 1424 sweeps. *Bottom:* Linear average of about 1424 sweeps.

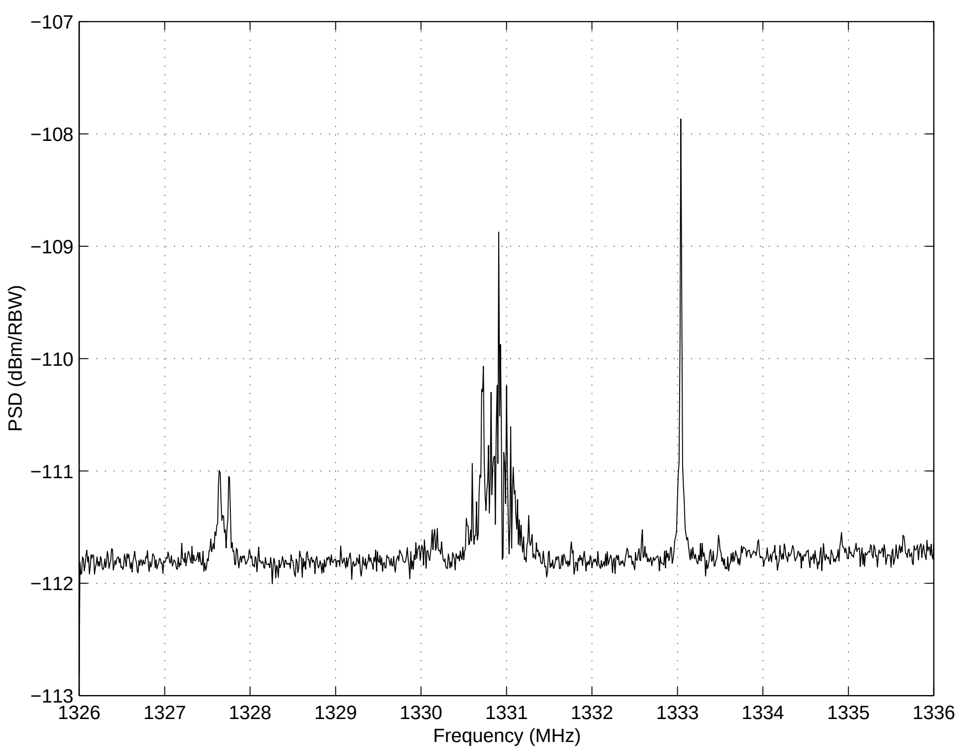

Figure 11: 1331 MHz radar. Linear average of 1529 sweeps.

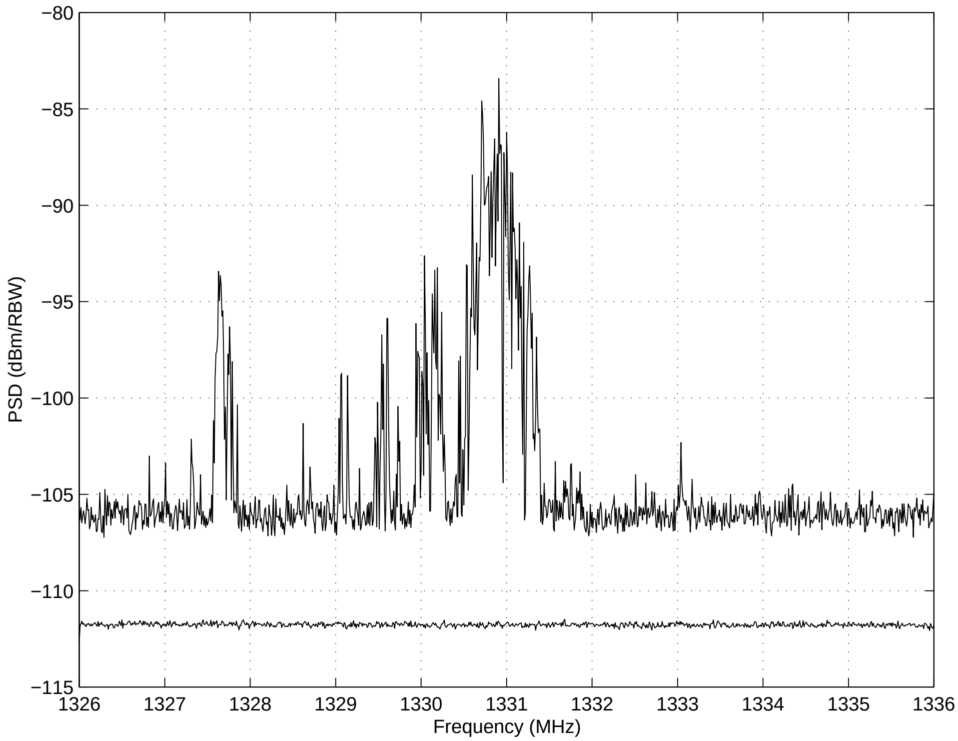

Figure 12: 1331 MHz radar Max hold over 1529 sweeps.

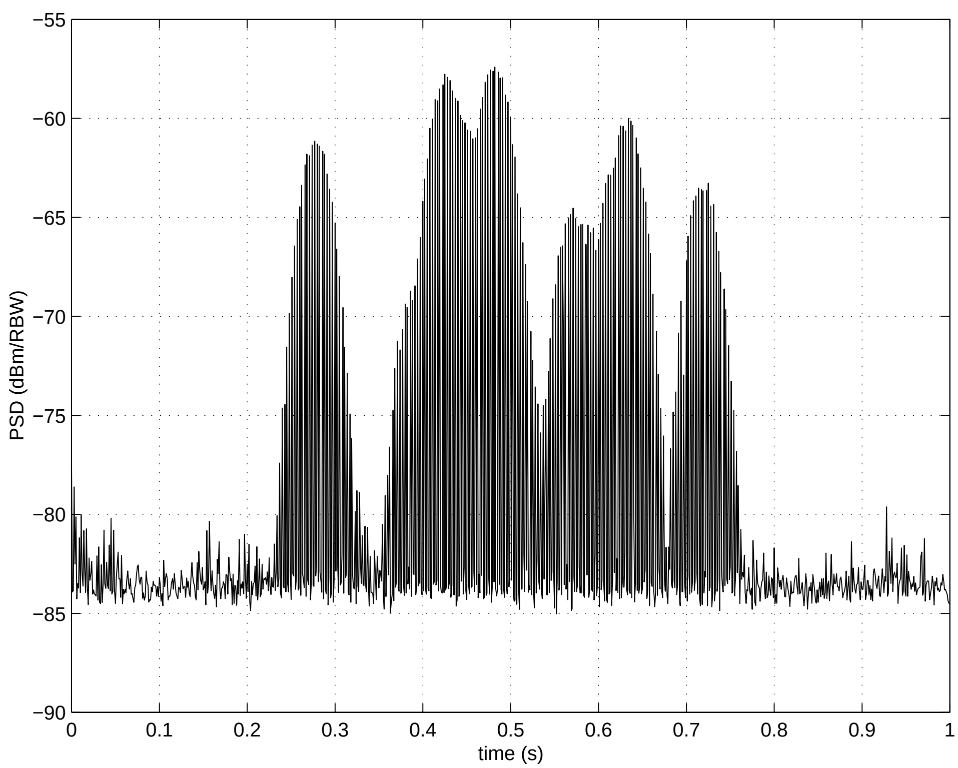

Figure 13: 1331 MHz radar observed near a peak in the 10-s cycle. 1 s span.

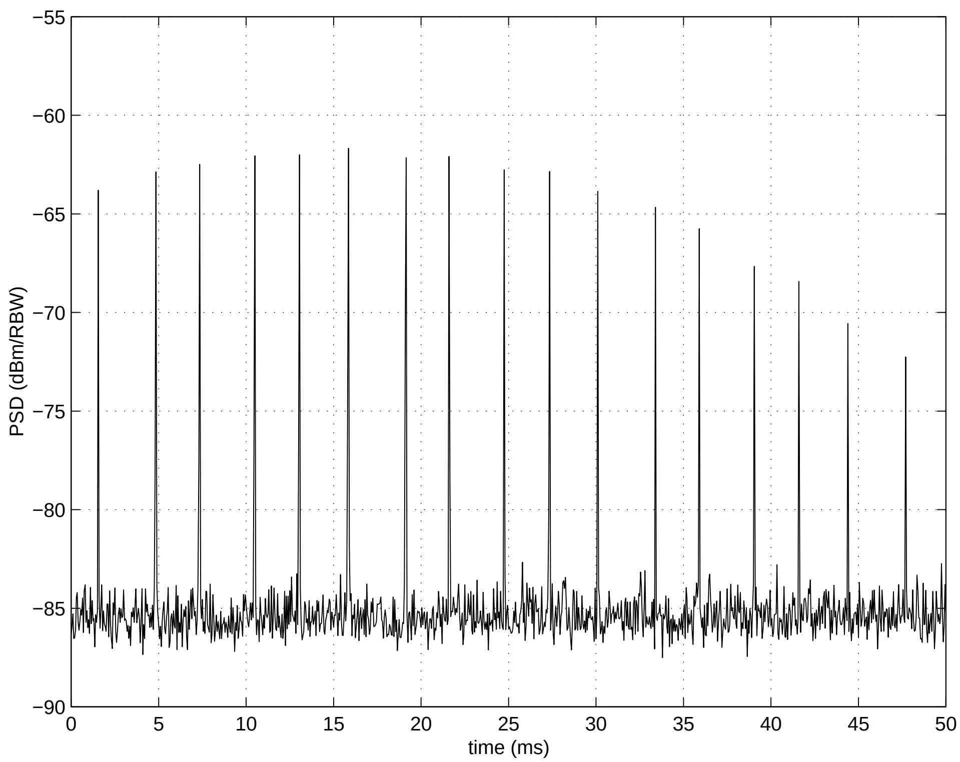

Figure 14: 1331 MHz radar observed near a peak in the 10-s cycle. 50 ms span.