A High-Resolution Survey of RFI at 1200-1470 MHz as Seen By Argus

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October 29, 2002

1 Summary

This document reports on a survey of radio frequency interference (RFI) in the band 1200-1470 MHz. The survey was conducted during nighttime hours from the roof of the Satellite Communication Facility (SCF) of the Ohio State University (OSU) ElectroScience Laboratory (ESL), using a single planar spiral antenna and RF front end from the Argus project [1]. The resolution of the survey is 30 kHz and the receiver temperature $T_R \sim 140°$K, resulting in a nominal "snapshot" sensitivity of about -132 dBm/(30 kHz) against measured antenna temperatures T_A ranging from $\sim 75°$K (in the region of the 1420 MHz protected astronomy band) to $\sim 131°$K. Thus, the instantaneous ΔT (sensitivity) was in the range 215°K to 271°K. After 16 hrs of observation, ΔT was reduced to about 1°K, allowing detection of signals as weak as -154 dBm/(30 kHz) provided that they are stationary. A "max hold" technique is also used to enhance sensitivity to strong, low-duty cycle signals, such as pulsed-CW radars.

A number of known RFI sources – both strong and weak – are identified. The region of the 1420 MHz radio astronomy allocation was found to be both RFI-quiet and very "cold". In fact, it also appears that the 21-cm line of Galactic H-I was detected, although this is difficult to confirm given the limitations of the experimental setup.

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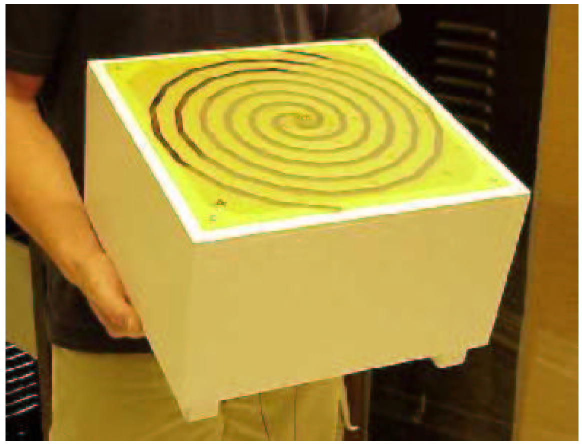

Figure 1: Spiral antenna. The antenna consists of a planar spiral printed on a circuit board substrate, above a system of three ground planes, enclosed in the box.

2 Instrumentation

The instrumentation consisted of the antenna, a single channel filter + LNA + line amplifier combination borrowed from the Argus project [1], a long cable from the roof to a room within SCF, a spectrum analyzer, and a PC for experiment control and data collection. These components are explained in more detail below.

The planar spiral antenna used for this study was a custom design developed for our omnidirectional radio telescope project, Argus [1]. The antenna is shown in Figure 1. This antenna has a pattern which is uniform in azimuth, with maximum gain at the zenith and very low gain toward the horizon.

The output of the antenna was connected via a short cable to a front end consisting of a filter, an Argus LNA [2], and an Argus line amplifier [3]. The bandpass filter was K&L Model 4B120-1500/600-0/0 (1200-1800 MHz), and was added to ensure that strong VHF-band signals could not create linearity problems for the front end. The frequency response of the front end is shown in Figure 2. The length of the cable was not measured but was on the order of 30 m.

In a laboratory within SCF, the other end of the long cable is connected to an Agilent Model E4407B spectrum analyzer. Neglecting the antenna, the gain in front of the spectrum analyzer was about +25 dB (as shown in Figure 2). The spectrum analyzer was interfaced to a PC via RS-232 at 115.2 kb/s. A C-language program

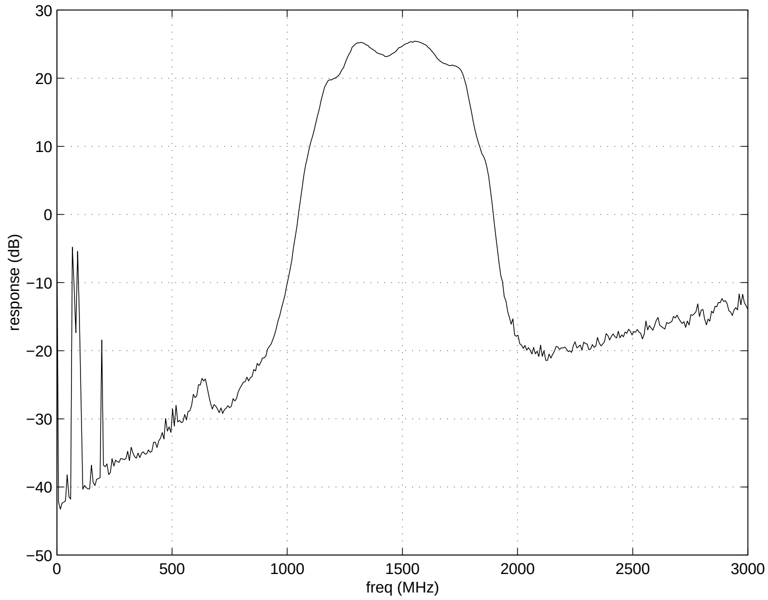

Figure 2: *Top:* Frequency response of the Filter + LNA + Line Amplifier + Long Cable chain, measured *in situ*. Note the break-through of broadcast FM, which gives some indication as to how strong these signals are at the experiment site.

controls the spectrum analyzer and collects data using the techniques described in [4]. For this work, the following spectrum analyzer settings are held constant throughout the experiment: Input attenuation: 5 dB; Internal preamp: ON; Resolution bandwidth (RBW): 30 kHz; Detection method: SAMPLE (as opposed to PEAK (the default for this spectrum analyzer)). The PC directs the spectrum analyzer to take measurements in the following sequence:

1. *Max Hold.* 100 sweeps from 1200-1290 MHz are taken. Each sweep samples the spectrum at 3001 points (that is, every 30 kHz). The output is a "max hold" over the 100 sweeps; that is, the result is a power spectrum where each bin indicates the maximum value observed in that bin. This procedure takes about 26 seconds.

2. *Power Average.* Same as max hold, except the 100 sweeps are linearly averaged. This procedure takes about 26 seconds.

3. Steps 1 and 2 are repeated for the 1290-1380 MHz band.

4. Steps 1 and 2 are repeated for the 1380-1470 MHz band.

5. Go to Step 1.

The max hold and power average measurements are different, but complementary measurements. Power averaging is most effective for characterizing weak, stationary signals. Max hold, on the other hand, is essential for detecting low-duty cycle signals, such as radar pulses or irregularly-timed (possibly one-time) bursts.

In addition, an observation was made using the same script, but with the antenna replaced by a matched load at ambient temperature (assumed 290°K). This was a much shorter observation (700 sweeps for each band and mode), made immediately following the the main observation. This measurement facilitates a rudimentary temperature calibration of the observation.

Using this procedure, data were collected for about 16 hrs during the evening hours of Oct 16, 2002, starting at about 4:00 PM local time. In each case, a total of about 36,600 sweeps were performed for each band and mode. For linear averaging, this amounts to about 14 s effective integration time per 30 kHz frequency bin. All data presented in the following section were calibrated to remove the seperately-measured transfer function of the front end. Thus, the indicated power spectral density (PSD) is that measured at the terminals of the antenna.

3 Results

The results for the 1200-1290 MHz segment are summarized by Figure 3. This figure shows the max hold and power average results computed for the entire observation time. In other words, the max hold result is the max hold over all 36,600 sweeps; similarly the power average result is the average over all sweeps. A summary of the RFI detected is shown in Figure 4.

A detail of the average power results is shown in Figure 5. Note that the ambient-temperature matched load is measured at about -127.5 dBm/(30 kHz), which infers a receiver temperature $T_R \sim 140$°K. Note also that the noise power from the antenna is about 2 dB less, which infers an antenna temperature $T_A \sim 131$°K. The system temperature T_{sys} is therefore ~ 271°K in this band.

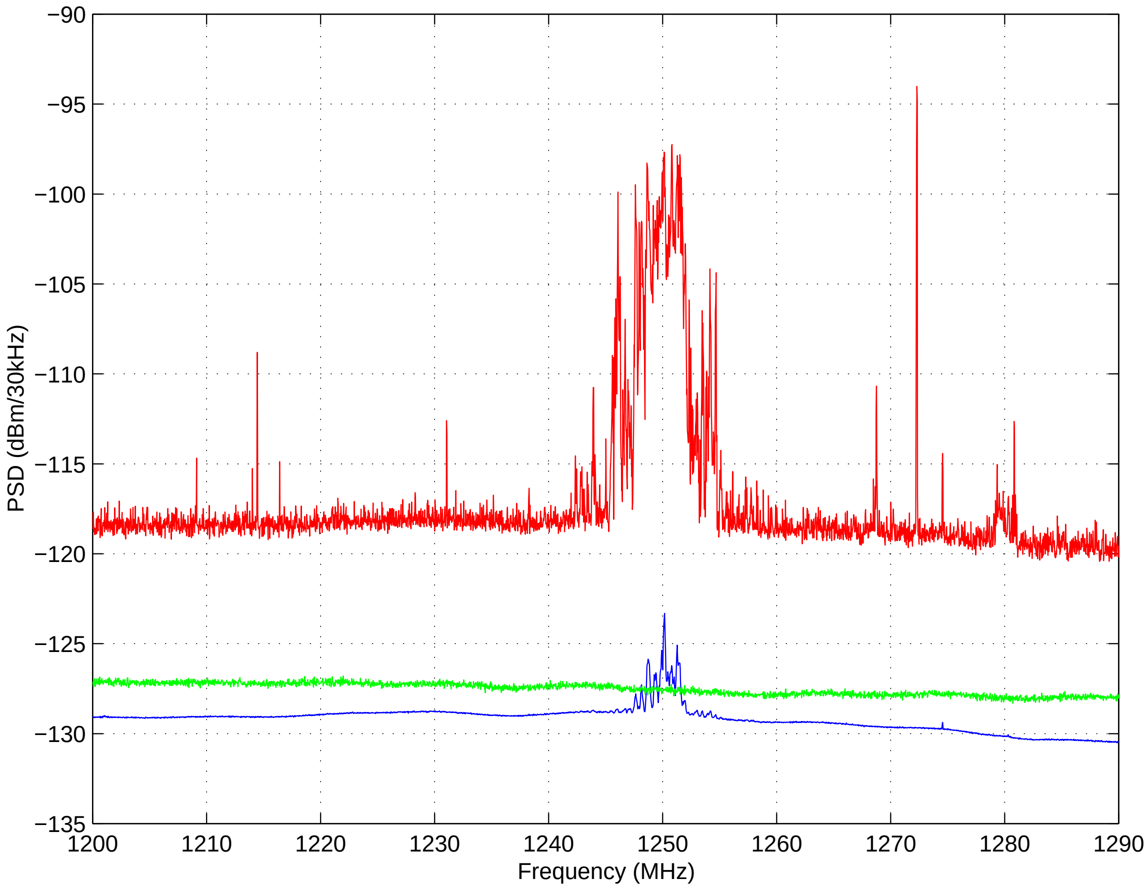

Figure 3: 1200-1290 MHz. *Top/Red:* Max hold, *Middle/Green:* Average, antenna replaced by matched load, *Bottom/Blue:* Average, antenna.

Center Freq. (MHz)	Max. PSD (dBm/30kHz)	Bandwidth (kHz)	Remarks
1209.12	-114	30	
1214.44	-109	60	
1216.41	-115	30	
1231.06	-113	60	
1238.28	-116	30	
1250	-97	∼10000	Local ATV Transmitter
1268.76	-111	30	
1272.31	-94	90	
1274.55	-114	90	Also visible in power average
1280	-113	∼2000	Peaks at 1279.35 & 1280.82

Figure 4: RFI detected in the 1200-1290 MHz band.

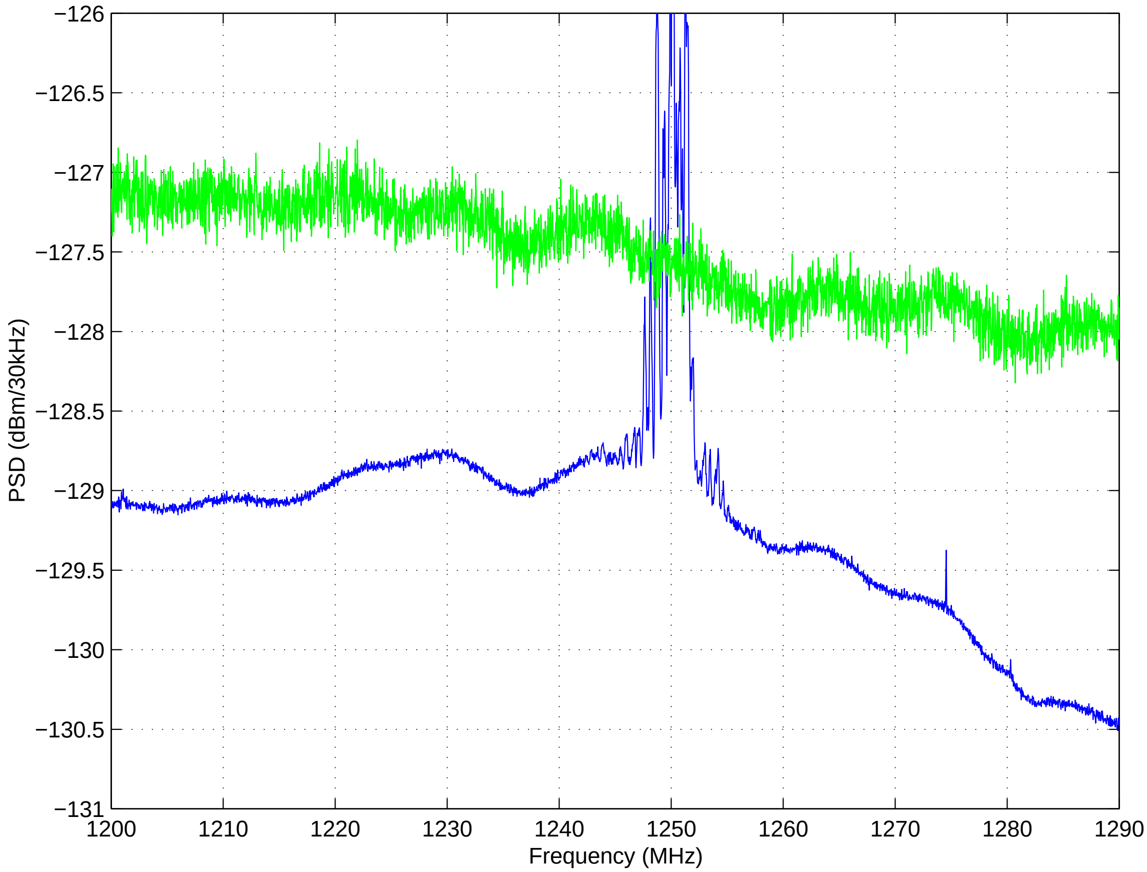

Figure 5: 1200-1290 MHz. *Top/Green:* Average, antenna replaced by matched load, *Bottom/Blue:* Average, antenna.

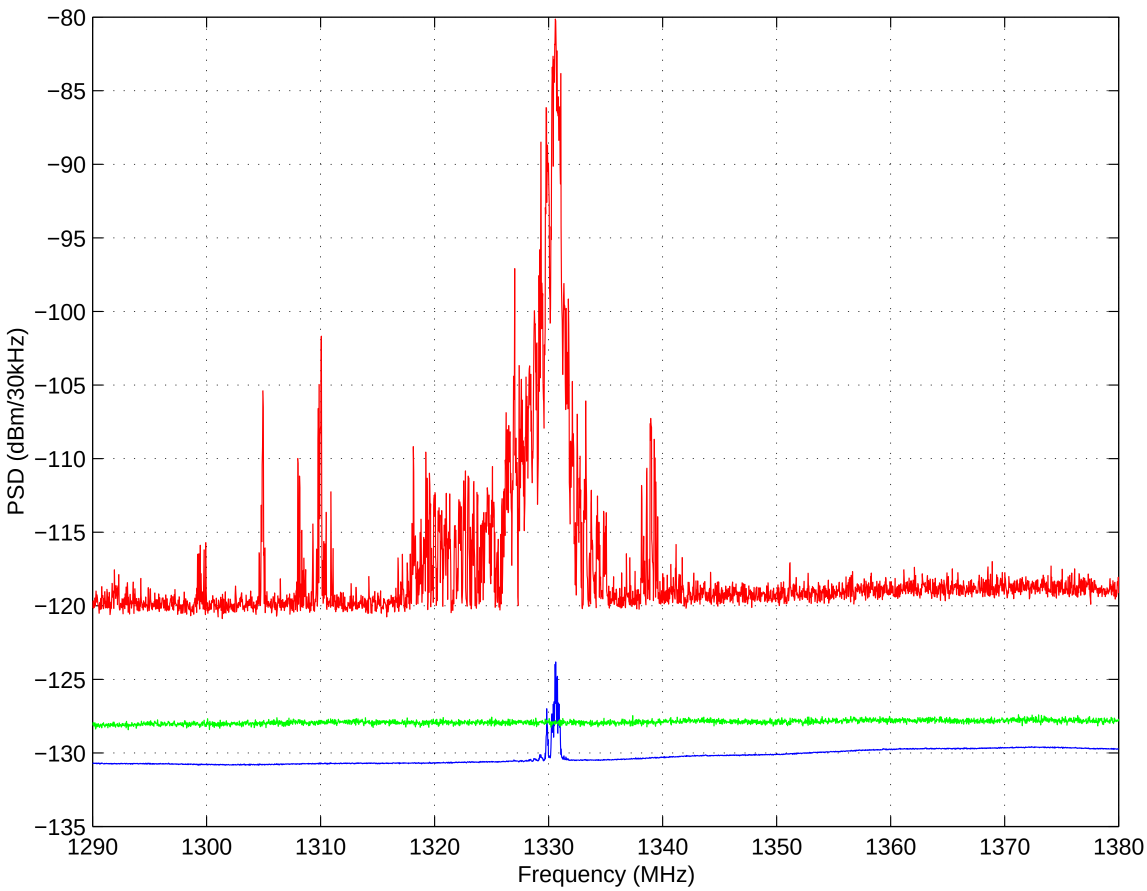

Figure 6: 1290-1380 MHz. *Top/Red:* Max hold, *Middle/Green:* Average, antenna replaced by matched load, *Bottom/Blue:* Average, antenna.

The results for the 1290-1380 MHz segment are summarized by Figure 6. A summary of the RFI detected is shown in Figure 7 and a detail of average power results is shown in Figure 8.

The results for the 1380-1470 MHz segment are summarized by Figure 9 and a detail of average power results is shown in Figure 10. Note that the noise power from the antenna is now about 3 dB less, which infers $T_A \sim 75°$K and $T_{sys} \sim 215°$K. In other words, the sky in this band is significantly colder than the sky in the other two bands examined. The minimum near 1420 MHz suggests that this may be associated with the presence of the protected radio astronomy band.

No RFI was detected in the 1380-1470 MHz band, but Figure 10 indicates a narrow spectral feature about 200 kHz wide centered at 1420.47 MHz. A detail of this feature is shown in Figure 11. The feature is not seen in the max hold trace in Figure 9, and

Center Freq. (MHz)	Max. PSD (dBm/30kHz)	Bandwidth (kHz)	Remarks
1299.5	-116	∼1000	∼ 5 tones, 30 kHz each
1305	-105	∼500	Probable radar
1308	-110	∼700	∼ 5 tones, 60 kHz each
1310	-102	∼500	Probable radar
1331	-80	∼1000	London, OH ATC radar
1339	-107	∼1500	∼ 5 tones, 120 kHz each

Figure 7: RFI detected in the 1290-1380 MHz band.

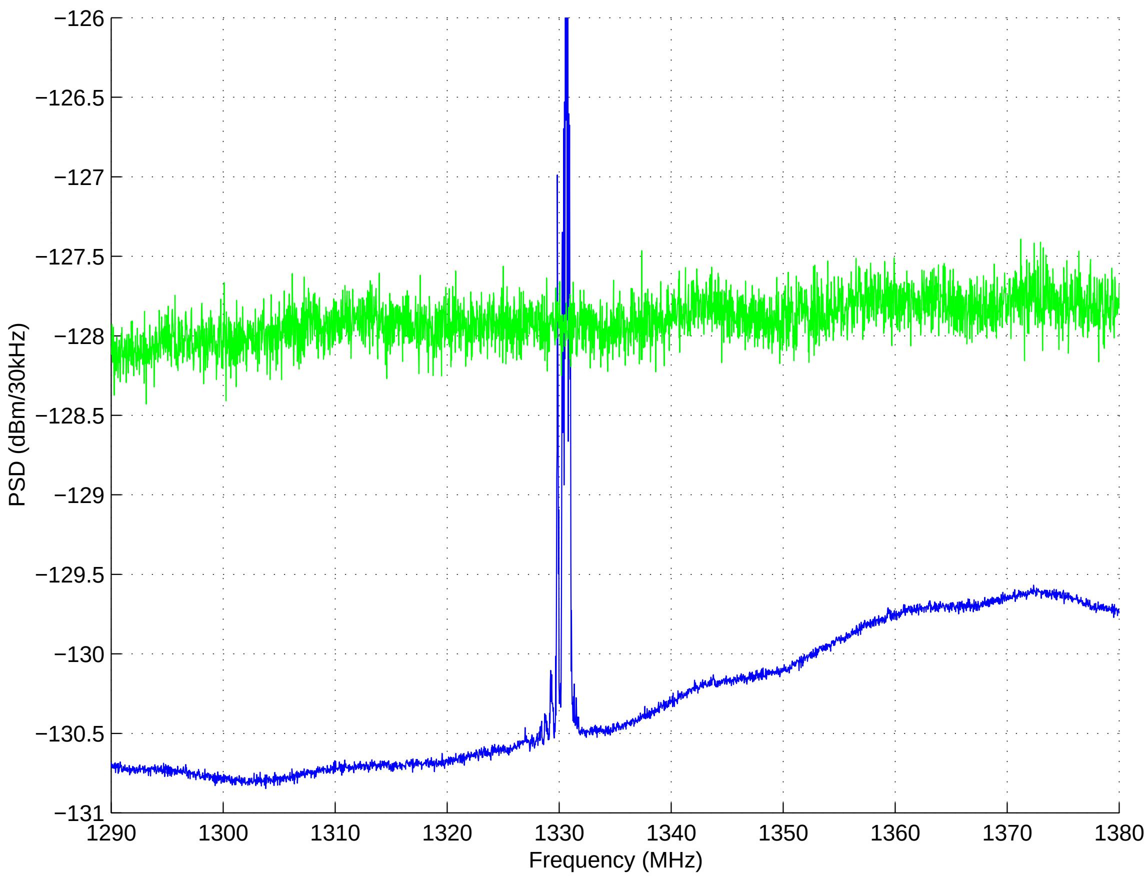

Figure 8: 1290-1380 MHz. *Top/Green:* Average, antenna replaced by matched load, *Bottom/Blue:* Average, antenna.

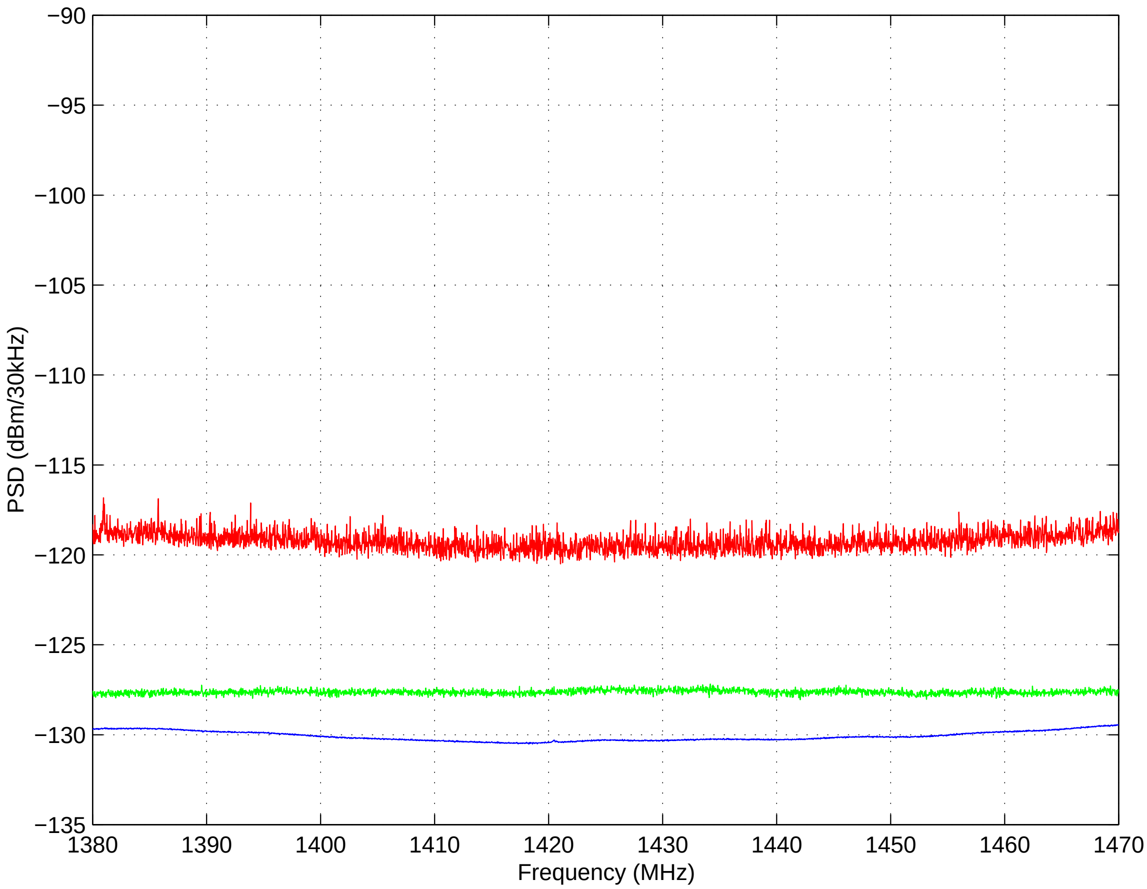

Figure 9: 1380-1470 MHz. *Top/Red:* Max hold, *Middle/Green:* Average, antenna replaced by matched load, *Bottom/Blue:* Average, antenna.

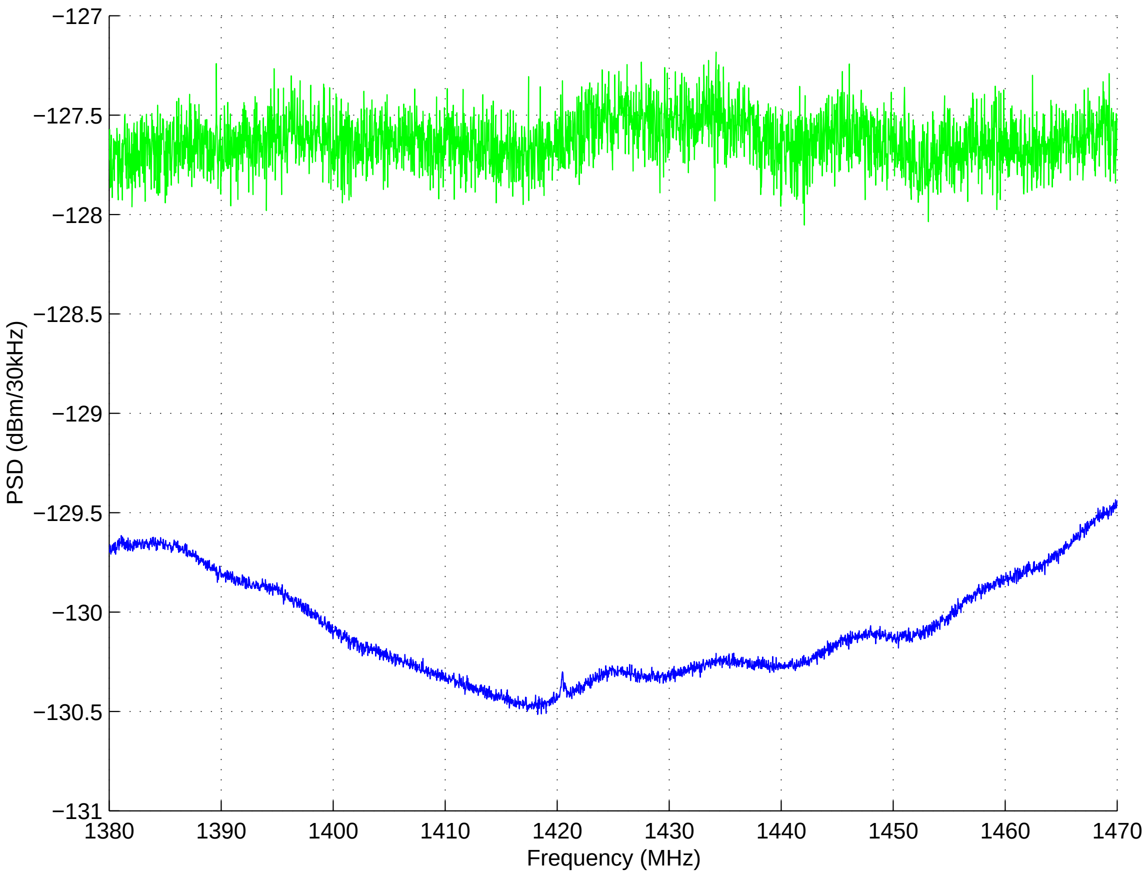

Figure 10: 1380-1470 MHz. *Top/Green:* Average, antenna replaced by matched load, *Bottom/Blue:* Average, antenna.

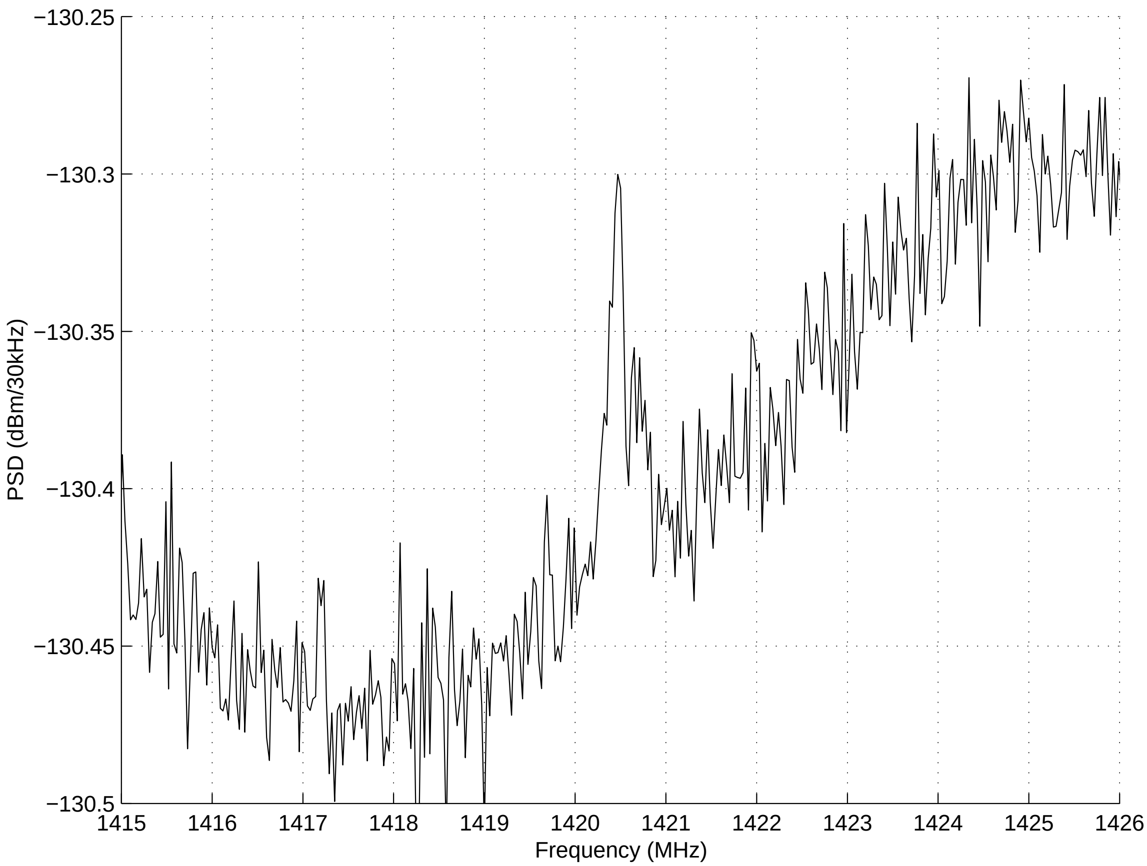

Figure 11: Narrow spectral feature with peak at 1420.47 MHz; possibly associated with Galactic H-I.

so is probably a stationary (always present) signal. Thus, it is possible that this is the 21-cm line of Galactic H-I. This line has a rest frequency of 1420.405 MHz, but is smeared significantly due to doppler; a spread of 200 kHz is on the order of what would be expected for an integration over the entire sky.

References

[1] http://esl.eng.ohio-state.edu/rfse/argus/rfse-argus.html.

[2] S.W. Ellingson, "A 1-GHz Highpass PHEMT Low-Noise Amplifier (Rev. 1)," Design Report, Oct 6, 2002. Available via http://esl.eng.ohio-state.edu/∼swe/argus/docserv.html.

[3] S.W. Ellingson, "A Low-Cost L-Band Line Amplifier (Rev. 1)," Design Report, October 9, 2002. Available via http://esl.eng.ohio-state.edu/∼swe/argus/docserv.html.

[4] S.W. Ellingson, "Agilent Spectrum Analyzer Computer Control Demo", IIP Memo 20, June 6, 2002. (see [5])

[5] ESL's NASA IIP Project Document Server, http://esl.eng.ohio-state.edu/∼swe/iip/docserv.html.