SPACE AND NAVAL WARFARE SYSTEMS CENTER

CHARLESTON, SOUTH CAROLINA

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS (E^3) SURVEY OF SITES IN THE SOUTH POLE AREA, ANTARCTICA FINAL REPORT

E^3 TASK NO. E02050

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Prepared By:
Dr. Peder Hansen
SPAWARSYSCEN San Diego
Code 28505

Frederic Duffy
SPAWARSYSCEN Charleston
Code 323FD

Reviewed By:
Katherine S. Khalil
SPAWARSYSCEN Charleston
Code 323

EXECUTIVE SUMMARY

The Space and Naval Warfare Systems Center (SPAWARSYSCEN), Charleston, South Carolina, was tasked to perform an Electromagnetic Interference (EMI) / Electromagnetic Compatibility (EMC) survey in Antarctica during the summer operating season of 2002-2003. The task involved monitoring the effects of electromagnetic radiation on selected electronic equipment and systems under the cognizance of the National Science Foundation. The efforts took place at both McMurdo Station and Amundsen-Scott South Pole Station. SPAWARSYSCEN Charleston tasked a SPAWARSYSCEN San Diego engineer to participate in the South Pole Station portion of this effort. Only the South Pole efforts are reported here.

The following items were accomplished at the South Pole Station.

(1) Investigate the intermittent interference to South Pole Marisat/Goes Terminal (SPM/GT) downlinks. This interference has not been observed in over a year. Nevertheless, these downlink frequencies were monitored for a 24-hour period at the Radio Frequency (RF) building. One possible low-level interfering signal was present at least 80% of the time in the Goes band at 1687.5 MHz.

(2) The magnitude of the South Pole Marisat/Goes Terminal, and TDRS satellite uplink signals was measured at the MAPO building. The signal strengths vary as the dish moves to track the satellite. The Marisat signal is the strongest with a maximum observed level equal to +80 dBuV/m, in close agreement with the level predicted.

(3) Other signals were examined within the 1-2.5 GHz band at MAPO. In this frequency range, TACAN, on 1.19 GHz, is the strongest signal at +85 dBuV/m. The second harmonic of TACAN was also observed. Intermittent low-level signals were observed in the range just above 1 GHz and in the Industrial Scientific and Medical (ISM) band between 2.4 and 2.5 GHz. The shuttle van generates strong impulsive interference when it is nearby. Snowmobiles and possibly LC-135s also generate impulsive interference to a lesser extent.

(4) The spectrum from 10 kHz to 22 GHz was recorded over a 24-hour period at both the RF building and the MAPO building. The results were analyzed to display spectrograms showing the signals present during that period. A brief snapshot of this same spectrum was taken at SPRESO site, and spectrum plots are given showing signals observed.

(5) The spectrum from 1 Hz to 850 Hz was recorded at several locations including 7 sites where Stanford University personnel had previously made measurements from 500 Hz and up. Unfortunately, the magnetometer cable was discovered to be broken upon return to the states. Comparison with the Stanford data and other tests were not conclusive, but indicate the data may be okay and it is included as an appendix.

(6) The out-of-band emissions from the University of Colorado Meteor Radar were measured at the RF building close to the Radar site. A large number of harmonics were observed up to the 23^{rd} harmonic, corresponding to 1.018 GHz. Many of the even harmonics were stronger than the odd harmonics.

(7) The issue of RADHAZ in the vicinity of the TCI antenna located near summer camp was examined. Measurements were not taken due to equipment difficulties on site. Upon return, the manufacturer identified the antenna from pictures as a TCI-566-7N and provided a written email indicating that based on IEEE C95.1-1999, RADHAZ does not exist for distances greater than 20 feet from the tower with 1 kW input power for frequencies below 16 MHz. The nearest summer camp building is well beyond that.

(8) Two additional items not in the Statement of Work (SOW)- are discussed briefly. The first is interference to the AMANDA neutrino detector array by the new Stanford

University VLF transmitter, which was being activated at the time we were on station. The second issue, brought up only after the survey team returned, involves broadband HF noise that had been observed near Summer Camp during the summer season of 2001-02.

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1 Introduction

1.1 Background

1.1.1 Space and Naval Warfare Systems Center (SPAWARSYSCEN) Charleston was tasked to complete an Electromagnetic Interference (EMI) / Electromagnetic Compatibility (EMC) survey in Antarctica during the Austral summer of January 2003 (reference 1.2.1). This survey was conducted under the Navy's Shore E^3 program as Task Number E02050.

1.1.2 The survey was assigned the technical event number T-Z980 by the National Science Foundation (NSF). This technical event included tasks performed both at McMurdo Station and South Pole Station. This report addresses only the South Pole Station tasks.

1.1.3 The original South Pole Station task list consisted of 7 items in priority order (1.2.1, Appendix A). This task list was clarified and modified based on communications sited in the references (1.2.2, 1.2.3, 1.2.4). The task list for South Pole Station (1.3) was finalized during the kick-off meeting with Raytheon Polar Services Corporation (RPSC) personnel Nick Powell, Bill McAfee, and Dan Brooks on 10 January 2003 following the arrival of the SPAWAR Systems Center team at the South Pole Station.

1.1.4 Part of the motivation for this task stems from the planned upgrade of the Antarctic communications (reference 1.2.5). There are two other relevant documents containing previous EMC/EMI surveys in Antarctica (references 1.2.6, 1.2.7), both are included in reference 1.2.5.

1.2 References:

1.2.1 Statement of Work (SOW), Code 323 EMI/EMC Technical Event, Antarctica FY03 (Final 7-17-02), (Prioritized) Annotated with code 323 questions and requested information denoted in red. (Appendix A)

1.2.2 E-mail message from Nick Powell to Mike Peebles, dated 20 Nov 02, Response to questions about SOW (Appendix B).

1.2.3 E-mail message from Professor Umran Inan to Peder Hansen dated 22 Nov 2002, indicating that a Stanford University graduate student would be conducting an ELF survey, but an additional ELF survey below 100 Hz would be desirable (Appendix A).

1.2.4 E-mail message from Dr. Weatherwax to Peder Hansen, dated 13 Nov 2002, with guidance for the ELF survey (Appendix B).

1.2.5 "United States Antarctic Program – South Pole High Frequency Radio User Questionnaire Response and Radio Noise Characterization," Raytheon Technical Services Company (RPSC), January 2002.

1.2.6 Lawandowaki, Gary, "EMI Site Survey at Amundsen-Scott Station," Hewlett Packard Report, 1992.

1.2.7 Results of measurements made in December 2001.

1.2.8 South Pole Frequency Assignments, Excerpted from USAP Band Plan (Appendix C).

1.2.9 Institute of Electrical and Electronics Engineers (IEEE) C95.1-1999, "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz" of 16 Apr 1999

1.2.10 NAVSEA/NAVAIR/SPAWAR OP3565, Volume 1, Sixth Revision, "Electromagnetic Radiation Hazard (Hazards to Personnel, Fuel and other Flammable Material)" of Dec 2002

1.2.11 Sandusky, Donald E, "MARISAT SATELLITE EARTH STATION PREDICTED MAIN BEAM AND SIDELOBE POWER DENSITIES AT THE SOUTH POLE'S DARK SECTOR," SPAWAR Systems Center Charleston, E3 Task Number E00096 Report Date: August 2000

1.2.12 Rockway, J., J. Logan, "Expert MININEC for Windows, EM Scientific, Inc., Carson City, NV, 1999

1.2.13 E-mail from TCI indicating RADHAZ zones for TCI 566-7N HF conical monopole antenna (Appendix B).

1.2.14 E-mail from Nick Powell dated March 12, 2003 indicating an EMI/EMC issue that had been observed during summer 2002/03 (Appendix B).

1.3 South Pole Station Tasks

1.3.1 **MARISAT Interference**: Find the source of L band interference in the South Pole Marisat/Goes Terminal downlink passband. The approach agreed upon at the kick off meeting was to record the spectrum in the two downlink bands for a 24-hour period and examine these recordings for evidence of interference. This corresponds to task 1 of the original SOW.

1.3.2 **MARISAT Signal Level at MAPO**: Measure at the MAPO building the absolute level of all signals in the band between 1 GHz and 2.5 GHz including the Satellite uplink signals. This is an expansion of task 2 of the original SOW.

1.3.3 **Wide Band RF Spectrum Record**: Document the radio signal levels from on-site sources so they can be compared to signal levels following the planned South Pole Station communications upgrade. The approach agreed upon at the kick off meeting was to record the Radio Frequency spectrum from 10 kHz to 22 GHz over a 24-hour period at three locations on station. The locations were to be the RF building, the MAPO building and the South Pole Remote Earth Seismic Observatory (SPRESO) site approximately 8 km distant from the main station. This is a combination of tasks 3 and 6 of the original SOW.

1.3.4 **Low Frequency Spectrum**: Document electromagnetic signals from on-site sources between 1 Hz and 10 kHz. Prior to the survey Stanford University personnel had recorded the spectrum above 500 Hz at 9 locations (reference 1.2.3). Consequently this task was modified to record the spectrum from 1 Hz to 850 Hz at the MAPO building and at as many of the Stanford Sites as possible to complement the Stanford measurements. This corresponds to task 4 of the original SOW.

1.3.5 **University of Colorado meteor Radar Spectrum:** Measure and identify VHF/UHF out-or-band emissions from the U. of Colorado meteor radar located at the RF building. This corresponds to task 5 of the original SOW.

1.3.6 **Conical Monopole RADHAZ Zone:** Chart RADHAZ zones for the TCI conical monopole antenna located near Summer Camp. This antenna is a back up that could be used for transmitting voice communications. The maximum transmitter power is 1000 Watts PEP. This corresponds to task 7 of the original SOW.

1.3.7 Each of the above items is addressed in turn in the report below.

2 South Pole Marisatt/Goes Terminal Interference

2.1 Introduction

2.1.1 The SOW tasking was to find the source of the L-band interference to the South Pole Marisat/Goes Terminal (SPM/GT) satellite downlink. The downlink frequencies for these satellites are 1537.0 – 1541.5 MHz (Marisat), and 1682.1 – 1694.2 MHz (Goes). During the kick off meeting, it was pointed out that the interference had not been observed in over a year. However, Nick Powell had recently observed a signal at 1554.55 just above the Marisat downlink pass band.

2.1.2 One candidate for the interference source is the weather balloon telemetry transmitters that are listed at 1680 MHz in the frequency list (reference 1.2.8). However, on-site personnel thought that frequency was no longer being used for the weather balloons.

2.1.3 The result of the meeting was that Nick Powell requested that both downlink pass bands be recorded at the RF building over a 24-hour period with the antenna pointed in the direction of the satellites. The records were to be examined for the presence of potential interfering signals. The frequency bands selected were 1535 -1545 MHz for Marisat and 1680-1700 MHz for Goes, both being somewhat wider than the satellite downlink pass bands.

2.2 Objective

The objective of this task was to record spectrums of both SPM/GT downlink pass bands over a 24-hour period and examine them for interfering signals.

2.3 Equipment Configuration

The equipment was set up in the RF building. The log periodic antenna covering L-band was located on the roof as shown in Figure 2-1. Note the SPM/GT antenna in the background on the left in the figure. The log periodic antenna was configured for vertical polarization. The antenna was connected to a Low Noise Amplifier (LNA), which can be seen attached to the upper part of the tripod in the figure. The power supply for the LNA can also be seen in the figure sitting on the roof.

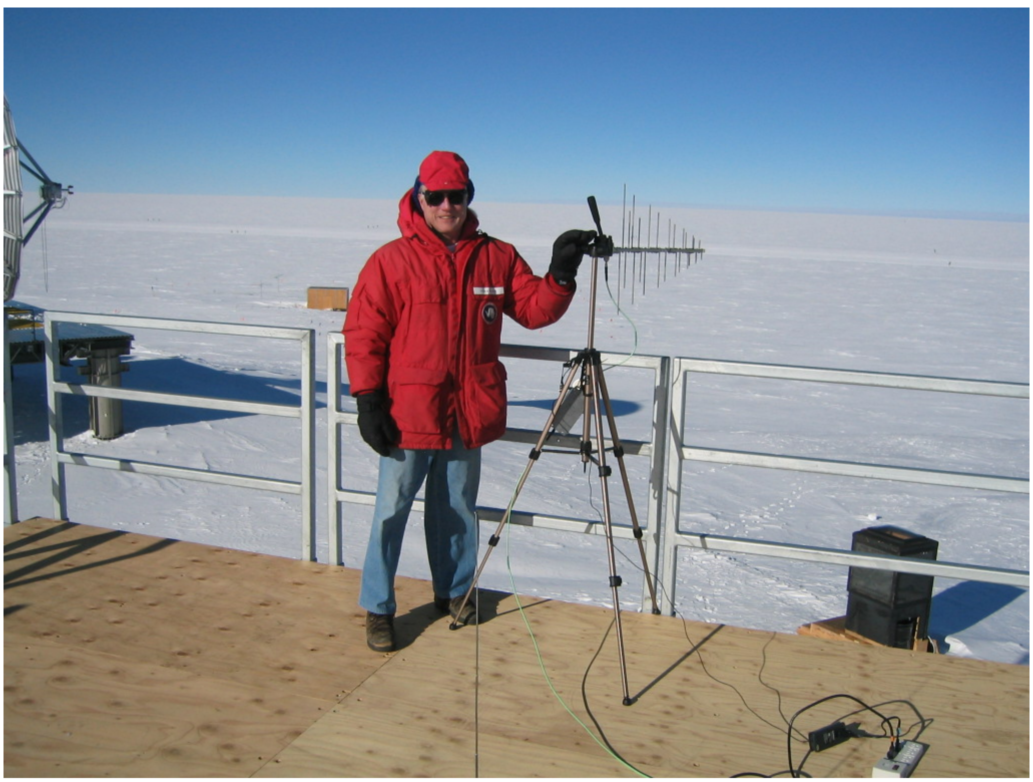

Figure 2-1 Antenna setup on roof of RF building.

2.3.1 The gain of the SPM/GT dish antenna is considerably more than the gain of the log periodic antenna used for this task. Even with the LNA, the satellite downlink signals are not expected to be above the noise level. This configuration could detect fairly strong local signals that interfere with the satellite by coming in through the side lobes of the SPM/GT antenna, but not weak interfering signals that occur within the main beam of the SPM/GT antenna.

2.3.2 There were two general directions that the SPM/GT antenna pointed corresponding to the positions of the Marisat and Goes satellites. The direction shown in the picture above corresponds to the Goes satellite. The direction for the Marisat satellite is about 30 degrees to the west (left). The SPM/GT antenna direction changed to the appropriate direction depending upon which satellite was available above the horizon. If no satellite was above the horizon, the antenna was positioned to catch the next available satellite. The direction of the log periodic antenna was changed to match the direction of the SPM/GT antenna during the times that the survey team was present at the RF building; however, the team was not present during the entire 24-hour period, so sometimes the two directions were different.

2.3.3 The output of the LNA was connected to the HP-8563A spectrum analyzer located inside the RF building using low-loss cable (green cable in picture). A LabView computer program developed by SPAWARSYSCEN Charleston operated the analyzer automatically. The computer program was resident in a notebook computer connected to the spectrum analyzer. This is the standard test setup used for most of the measurements taken at the South Pole station. A block diagram of this setup is shown in Figure 2-2. The list of equipment taken to the South Pole Station is given in Appendix D.

2.3.4 The notebook computer operated the spectrum analyzer and automatically recorded the trace data from the spectrum analyzer as comma delimited Excel files. Two frequency bands (1535 -1545 MHz and 1680-1700 MHz) were recorded. The spectrum analyzer frequency resolution bandwidth was set to 30 kHz. The amount of time in each band was set to be approximately 2 minutes. The analyzer alternated between the two bands with a 2-minute dwell time in each band. There is a small amount of overhead time for the analyzer to set up the band switch. Thus, each band is recorded slightly less than 50% of the time, resulting in slightly less than a 50% chance of observing short duration signals. The analyzer was operated in maximum hold mode so that the maximum signal observed at each frequency over the 2-minute time period was recorded. This gives a 100% chance of catching signals with duration greater than 2 minutes. One problem with the maximum hold mode is that any noise spike will be recorded and appears to be a narrowband signal at the frequency the analyzer was sweeping through at the time the spike occurred.

2.4 Data

2.4.1 There were a total of 640 files recorded by the notebook computer. These files consist of 320, approximately 2-minute records on each of the two frequencies, taken over the period from January 11, 4:09 PM to January 12, 4:14 PM.

2.4.2 A Matlab computer program was developed to expedite viewing these files. The program sequentially steps through the data, plotting each in turn and pausing until a keystroke is input. With this viewing technique, most of the files appeared to contain noise only. The level of the maximum signal in these files averaged about -80.0 dBm. There were only 5 files that contained points 3.0 dB or more above that level. Table 2-1 below contains pertinent information about these 5 files.

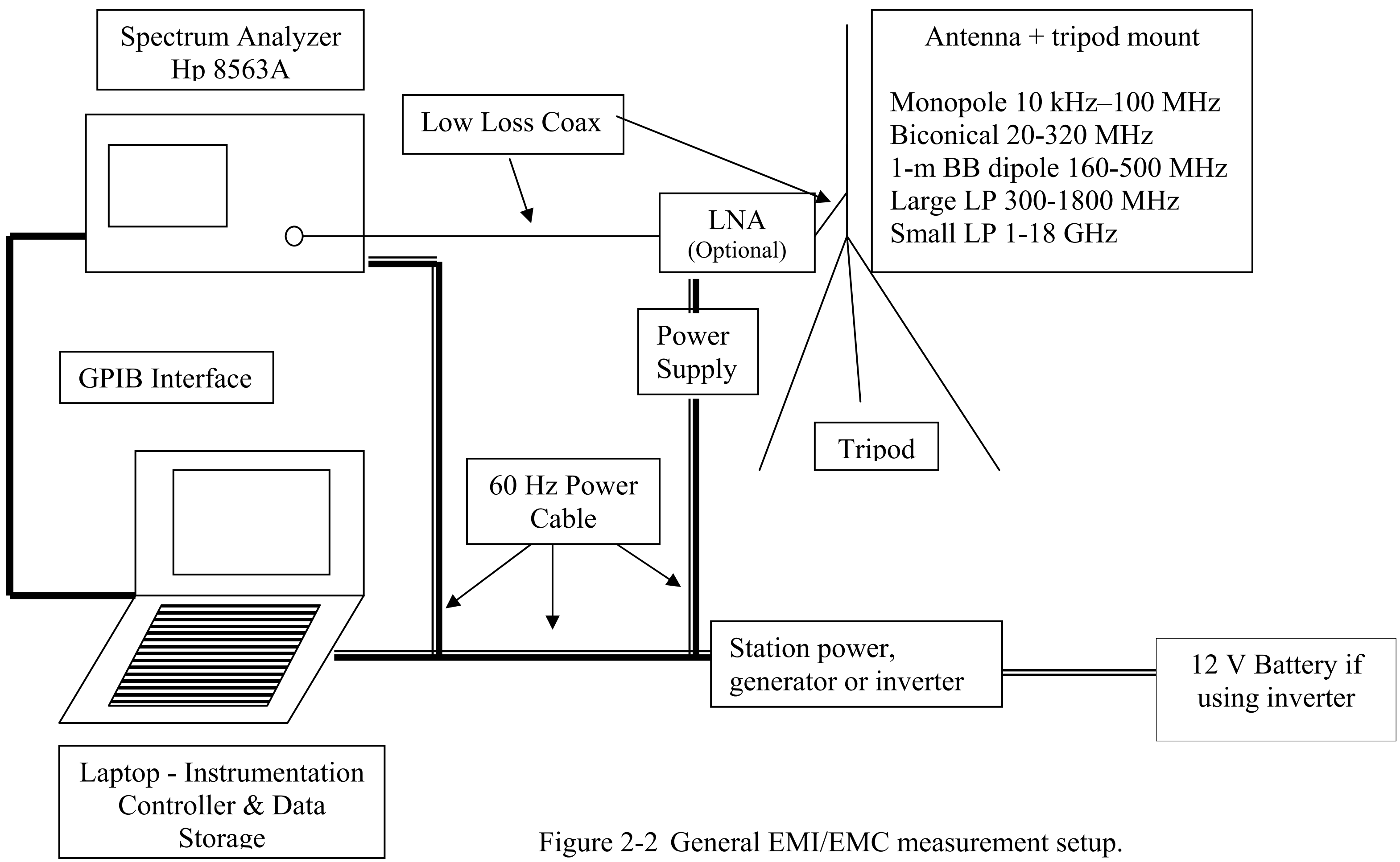

Figure 2-2 General EMI/EMC measurement setup.

Table 2-1 Marisat/Goes 24 Hour Data Files with points 3 dB or more above -80 dBm (* indicates points at contiguous frequencies)					
Date	Time	Band	Frequency (MHz)	Level (dBm)	Above -80dBm dB
1/11/03	16:20-16:22	Marisat	1538.216667 1540.016667* 1540.033333* 1549.966667	-74.0 -76.0 -75.67 -78.83	6.0 4.0 4.33 1.17
1/11/03	16:30-16:32	Marisat	1535.300000 1540.366667	-77.33 -75.99	2.67 4.01
1/11/03	16:36-16:38	Goes	1692.533333	-75.83	4.17
1/12/03	11:35-11:37	Marisat	1535.166666* 1535.183333* 1535.400000	-76.83 -74.0 -75.0	3.17 6.0 5.0
1/12/03	15:55-14:57	Goes	1688.300000	-75.83	4.17

2.4.3 Note that none of the files in the above table is contiguous in time. Some of these files had more than one point above -77 dBm. Of these, there are two cases, indicated by an asterisk in the table above, where points meeting this criterion were contiguous in frequency and formed part of a peak. Both of these cases were in the Marisat downlink band and contained the two highest peaks in the Marisat data. They are plotted in Figure 2-3 and Figure 2-4.

2.4.4 In these two figures, note that, other than the two peaks, the maximum level (noise floor) is about -80.0 dBm. The fact that the peaks shown in these two curves are not persistent in time or frequency means that they are probably the result of a local noise spike, perhaps a switching transient. The 24-hour data recorded at the RF building (section 4.6) indicates that intermittent noise spikes were observed there. The peaks of 3 dB or less above the average maximum noise level could also be due to statistical variation in the noise since it was observed over a 24-hour period. The conclusion of the analysis by viewing the files is that there is no clear evidence of man made interference signals in these two bands.

2.4.5 These same data have also been analyzed statistically using the Amplitude Probability Distribution (APD) technique. Statistical methods are useful to analyze large amounts of data. The APD is commonly used in radio engineering to describe signal amplitude statistics. Generally an APD is a curve of probability versus level giving the probability (or percent of the time) that the amplitude exceeds a given level. SPAWARSYSCEN Charleston has developed a computer program that calculates Amplitude Probability Distributions (APD) of large numbers of data files taken over long periods of time. This program can be used to help quantify the level and duty cycle of intentional signals and man made noise.

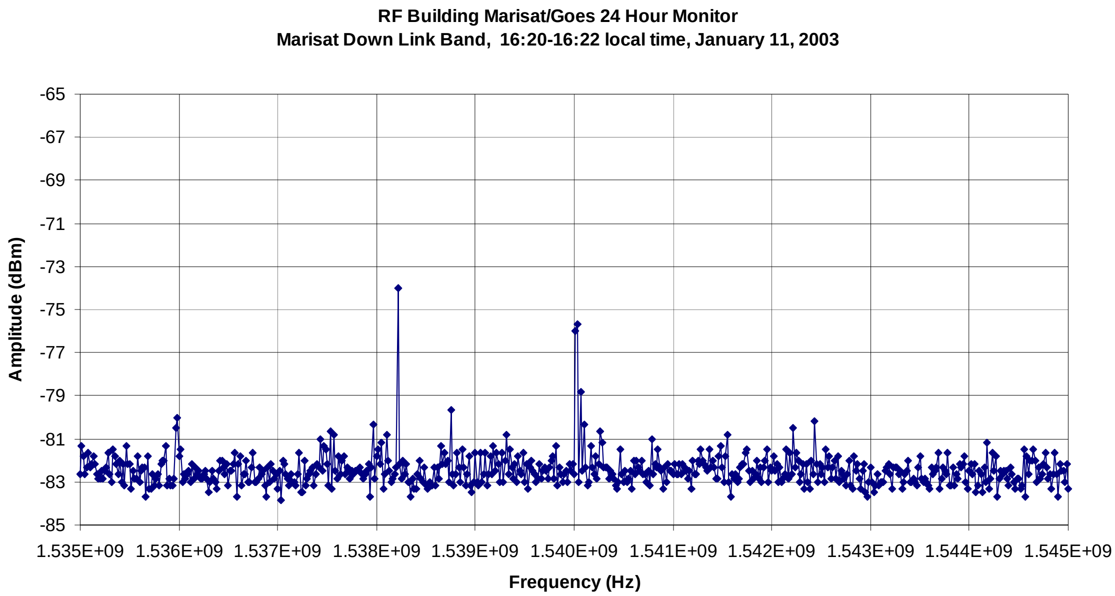

Figure 2-3 Marisat downlink, 16:20–16:22 local, January 11, 2003.

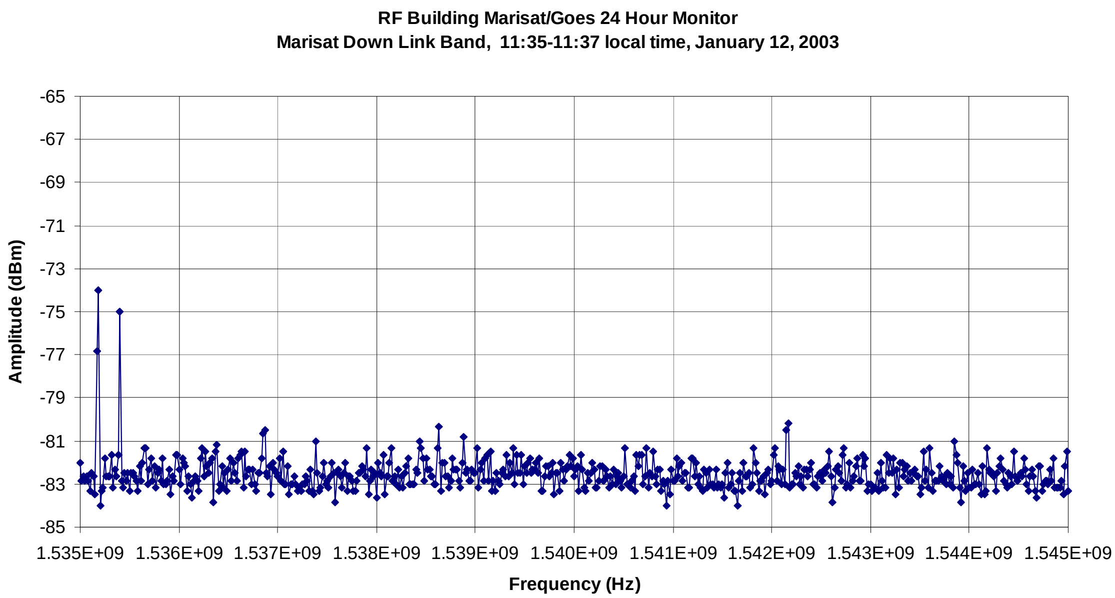

Figure 2-4 Marisat downlink, 11:35–11:37 local, January 12, 2003.

2.4.6 The APD program reads the selected spectral data files and calculates the APD for each frequency. There are 601 frequency points in each band. If only one band is selected, the program calculates the corresponding 601 APDs. Following these calculations, the user interactively selects a threshold and the program outputs a plot of the probability that the signal level was above that threshold versus frequency.

2.4.7 A series of these plots with different thresholds can help to analyze and profile the percentage of time that any signal or noise activity has occurred at a given frequency during the sample period. By using several thresholds, these plots can even indicate if the signal of interest had a variation in amplitude. Generally, a number of these plots are required to represent the statistical activity of a single frequency or group of frequencies.

2.4.8 The Marisat/Goes passband data were processed using the APD program. Curves for the Marisat band with 4 different thresholds are shown in Figure 2-5. These curves are flat across the frequency range for all thresholds and are typical of white noise. Note that as the threshold is lowered, the probability that the signal exceeds that level increases. For example the probability that the signal exceeds -81 dBm is very low at all frequencies, while the probability that the signal exceeds -84 dBm is close to 1. Also, the possible interference signals shown in Figure 2-3 and Figure 2-4 do not show up in the APD plot. This is because those signals (probably noise impulses) were only present in one data file out of 320, so their probability is less than 0.01, which does not show on this plot.

2.4.9 Probability curves for the Goes passband with four different thresholds are shown in Figure 2-6. In this case there is a persistent possible interfering signal that occurs significantly more often than the level of the noise when the threshold is -82 dBm and -81 dBm, 2 and 1 dB respectively below -80 dB. This illustrates the --fact that the APD analysis under certain conditions can detect signals that are below the noise. In this case, the APD program helped to find a possible interfering signal that is not obvious in the individual data plots because it is below the noise. This signal has a narrow spectral peak at about 1687.5 MHz could be interference or the Goes downlink. Note that the frequency for this peak is different than the peaks listed in Table 2-1. Those peaks do not show up in the probability curves because their probability is less than 0.01 (1/330).

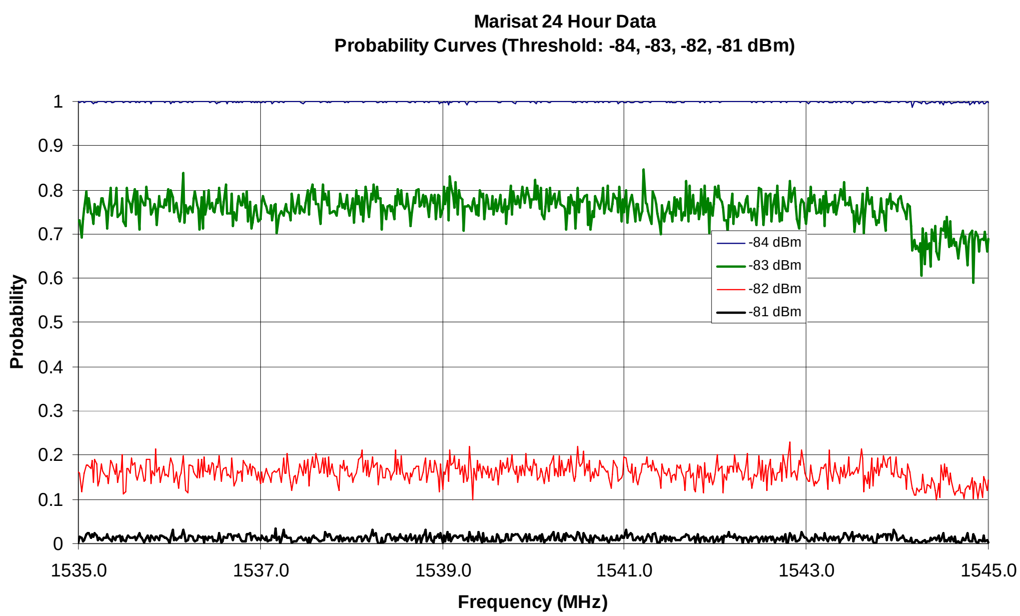

Figure 2-5 Probability curves for Marisat Band, 24 hour data

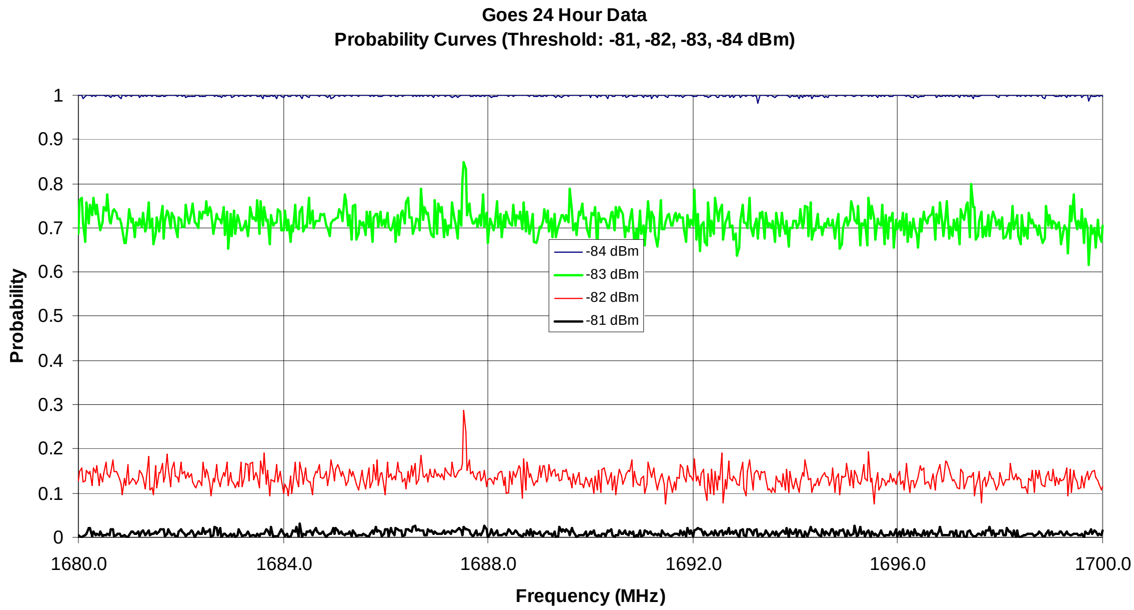

Figure 2-6 Probability curve for Goes band, 24 hour data.

2.5 Discussion

2.5.1 The table lists possible signals observed in the individual spectrum plots that occurred during the 24 hour time period. All of these signals appear to be very narrow band (1 or at most 2 frequency bins) with bandwidths of 30 KHz or less. These signals could have arisen from (1) some local narrow band signal source, (2) a local switching transient (e.g. light switch) resulting in the false appearance of a narrow band signal, or (3) although unlikely, random fluctuations of the amplifier noise can result in the false appearance of a narrow band signal.

2.5.2 Some characteristics that man made narrow band interfering signals would be expected to exhibit are finite bandwidth, time persistence, and multiple occurrences at the same frequency. None of the apparent signals observed by viewing the files had these characteristics and it is suspected that they were the result of noise spikes (1 or 2 of the previous paragraph). The files containing the apparent signals are nearly evenly distributed between the two bands (3 Marisat, 2 Goes, which is consistent with them being the result of some random process.

2.5.3 A locally generated interfering signal might also be expected to be considerably above the noise of the LNA. The table indicates that the largest peak observed was -74 dBm, only 6.0 dB above the average maximum noise level and this level occurred twice, both in the Marisat downlink band. The maximum in the other 3 data sets was only about 4.0 dB above the average maximum. Again this is an indication that the apparent signals may be the result of statistical noise variation, i.e. impulsive noise from a broadband noise source.

2.5.4 The probability curves given in Figure 2-5 and Figure 2-6 do not confirm the peaks listed in the table. However, they do indicate the presence of a low level signal at 1687.5 MHz that was present as much as 80% of the time.

2.6 Conclusions

2.6.1 Using individual spectrum plots there is no clear evidence for interfering signals to the SPM/GT terminal during the 24-hour period January 11/12 2003. The apparent signals observed by this method were not strong or persistent in frequency or time and have therefore been attributed to local switching transient noise or statistical noise variation. However, the APD analysis did indicate a persistent low-level signal in the Goes band at 1687.5 GHz. This signal was present about 80% of the time with a level of -83 dBm and could be an interfering signal or the Goes downlink signal.

3 Satellite Uplink Signal Strength at MAPO

3.1 Background

3.1.1 The original SOW requested measurement of the South Pole Marisat / Goes Terminal (SPM/GT) uplink signal strengths at the MAPO (Martin A. Pomerantz Observatory) building in the dark sector. This was expanded to include the signal strengths of all radiations within the 1–2.5 GHz band at the MAPO building.

3.1.2 SPAWAR Systems Center Charleston previously performed an analysis to predict the main beam and sidelobe power densities created by the MARISAT satellite earth station in the South Pole's Dark Sector where there is an array of sensitive scientific equipment (reference 1.2.11). The analysis provides predicted power densities at various distances and azimuths from the MARISAT antenna indicating that the sidelobe energy drops off rapidly a few degrees away from the axis of the main beam and continues to decrease as the azimuth angle separates from the main beam.

3.1.3 The MAPO location is well outside of the main beam of the satellite dish so that the signal there is determined by the sidelobe pattern of the dish. As the transmitting antenna moves to follow the satellite, the sidelobe pattern moves causing the signal received at MAPO to vary with time. The analysis in the reference indicates that typical power densities expected at the MAPO building in the Dark Sector range from 8 to 14 picowatts per square centimeter (pW/cm^2). This corresponds to 73.8 to 79.8 dBuV/m.

3.2 Objective

The objective of this task was to make calibrated field strength measurements of all the signals present in the band from 1 to 2.5 GHZ at the MAPO building.

3.3 Approach

3.3.1 The equipment was moved to the Jamesway tent in the MAPO area. The antenna was set up on the roof of the Jamesway heater enclosure (Figure 3.1). The antenna and tripod can be seen on the roof of the wooden structure next to the stovepipe chimney. The amplifier can also be seen on the roof. The remaining equipment was set up in the interior of the tent (Figure 3.2).

3.3.2 The test set up is similar to that shown in Figure 2-2. The antenna used was the 1-meter Log Periodic model SAS-200/518 1-18(+) GHz. The amplifier used was the HP8449B. An initial check with and without the amplifier verified that the strong signal sources from the satellite ground stations did not saturate the amplifier. None of the signals observed saturated the amplifier, so all successive measurements included the amplifier.

3.3.3 The laptop computer was used to operate a Hewlett Packard "Benchlink" computer program to record individual sweeps of the spectrum analyzer on command. The spectrum analyzer was set to the maximum hold mode so that it would record the maximum signal observed on each frequency. The spectrum analyzer data is in terms of dBm vs. frequency. For presentation here, this was converted to dBuV/m using the appropriate factors for the antenna, amplifier and cables. The method for this conversion is given in the first part of Appendix E.

Figure 3-1 External setup at MAPO building.

Figure 3-2 Equipment setup at MAPO building.

3.4 Results

Measurements were taken starting before midnight local time on 14 January and continuing through until about 8:30 local time on 15 January in order to catch a complete cycle of all the satellites. Some spectrum analyzer data was taken over the entire band from 1-2.5 GHz (Wideband). Some sweeps were taken with the spectrum analyzer adjusted to examine the details of a particular signal (Narrowband). There are 3 satellite uplinks at the South Pole, Marisat, Goes, and TDRS. The polarization of these uplinks differs and so, measurements were made with the antenna in both vertical and horizontal positions. The results shown below are divided into the categories, Wideband Vertical, Wideband Horizontal, and Narrowband (Vertical and Horizontal).

3.4.1 Wideband Vertical

3.4.1.1 The maximum resolution bandwidth available for the spectrum analyzer (1 MHz) was used for the wideband sweeps (1-2.5 GHz). However there are only 601 points displayed by the spectrum analyzer, so the resolution displayed in the sweeps presented below is 2.5 MHz. Sweeps of this type at two different times with the antenna in the vertical position are shown in Figure 3-3 and Figure 3-4. The two sweeps are similar, the first one containing 5 signals and the second one containing 4 of the same signals. The strongest signal in this band is TACAN at 1187 MHz. The transmitter for TACAN is located in the Aircraft Taxiway Loop about 2000 feet away from the MAPO building. TACAN is operated continuously during the summer flight season, but is turned off for the winter. This signal was observed continuously at a level of approximately +85 dBuV/m (vertical).

3.4.1.2 The transmitters associated with the signals shown in the figures have been identified by comparison to the master frequency list (Appendix C). The signal at 1630 MHz is the Marisat uplink. The signal at 2035 MHz is the first TDRS uplink. The signal at 2220 MHz is probably the second TDRS uplink, although the frequency listed for that is 2215 MHz. The signal at 2380 MHz is the second harmonic of TACAN.

3.4.1.3 The magnitudes of the signals in the two figures above are given in Table 3-1 below. These spectrums were taken 10 minutes apart. Note that the magnitude of the satellite uplink signals was different over that time frame corresponding to the movement of the transmitting antenna.

Table 3-1 Vertical Polarization Signal Strengths (dBuV/m) at MAPO, Jan 15 03

Time/Freq	1.19 GHz TACAN	1.63 GHz Marisat	2.03 GHz TDRS	2.22 GHz TDRS?	2.39 GHz TACAN 2^{nd}?
6:37 AM	85.2	58.4	52.0	48.2	53.35
6: 47 AM	84.12	-	48.5	45.8	51.35

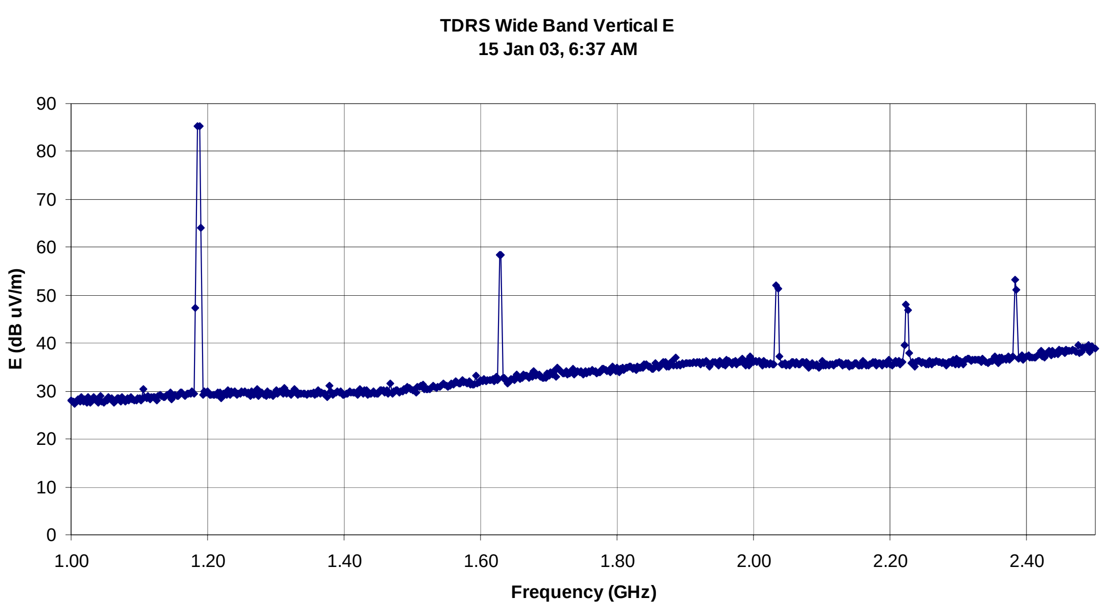

Figure 3-3. MAPO Vertical 1-2.5 GHz at MAPO, 15 Jan 03, 6:37 AM.

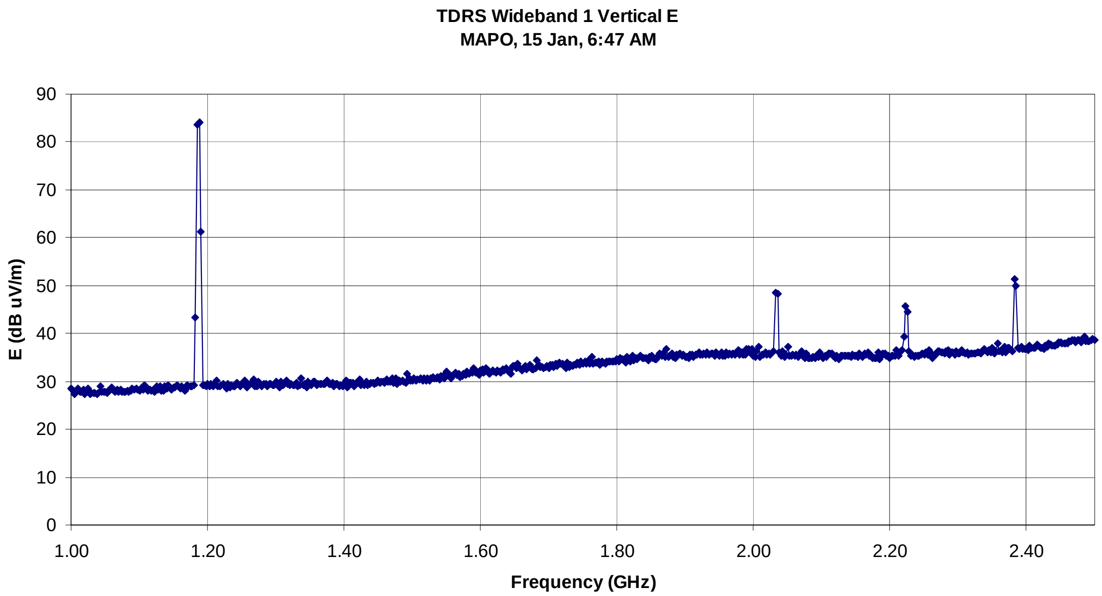

Figure 3-4 MAPO Vertical 1-2.5 GHz at MAPO, 15 Jan 03, 6:47 AM.

3.4.2 Wideband Horizontal

3.4.2.1 Several records of the band from 1-2.5 GHz were taken with the antenna in the horizontal position. These spectrums have been converted to electric field strength in dBuV/m and are given below in Figure 3-5 to Figure 3-8.

3.4.2.2 The first spectrum shown (Figure 3-5) was taken at 5:48 AM and contains 3 signals, which correspond to (1) TACAN, (2) the Marisat uplink and (3) the first TDRS uplink. In addition to these signals, there are a series of weak signals in the frequency range just above 1 GHz. The source of these signals is unknown.

3.4.2.3 The second spectrum shown was taken at 6:21 AM (Figure 3-6). This spectrum contains an additional signal at 2.22 GHz, which is probably the second TDRS uplink. The Marisat signal is weaker in this figure than in the previous figure. Note the weak signals in the region above 2.4 GHz corresponding to the ISM band. There are also a couple of week signals in the region just above 1 GHz.

3.4.2.4 The third spectrum shown was taken at 7:02 AM (Figure 3-7). This is similar to the others, but the ISM band signals show up clearer in this example. There is also a possible weak signal that appears at 2.18 GHz. The source of this signal is not known, and it could be the result of a noise spike.

3.4.2.5 The signal magnitudes from the horizontal data are given in Table 3-2 below. Comparison with Table 3-1 for vertical polarization shows that the TACAN signal is about 17 dB weaker for horizontal polarization, indicating this signal is vertically polarized. Both the Marisat and TDRS signals are stronger for horizontal polarization, indicating they are horizontally polarized. The Marisat signal varied from 52.8 to +81.6 dBuV/m. This corresponds very well to the levels predicted (reference 1.2.11). The strongest level observed for Marisat (horizontal) is slightly less than the vertical TACAN signal. The 2.39 GHz second harmonic of TACAN did not appear in any of the horizontally polarized measurements.

Table 3-2 Horizontal Polarization Signal Strengths (dBuV/m) at MAPO, Jan 15 03					
Time/Freq	1.19 GHz TACAN	1.63 GHz Marisat	2.03 GHz TDRS	2.22 GHz TDRS?	2.39 GHz TACAN 2^{nd}
5:48 AM	62.1	81.6	59.8	-	-
6:22 AM	59.6	67.3	62.8	43.6	-
7:02 AM	64.6	52.8	59.3	38.5	-

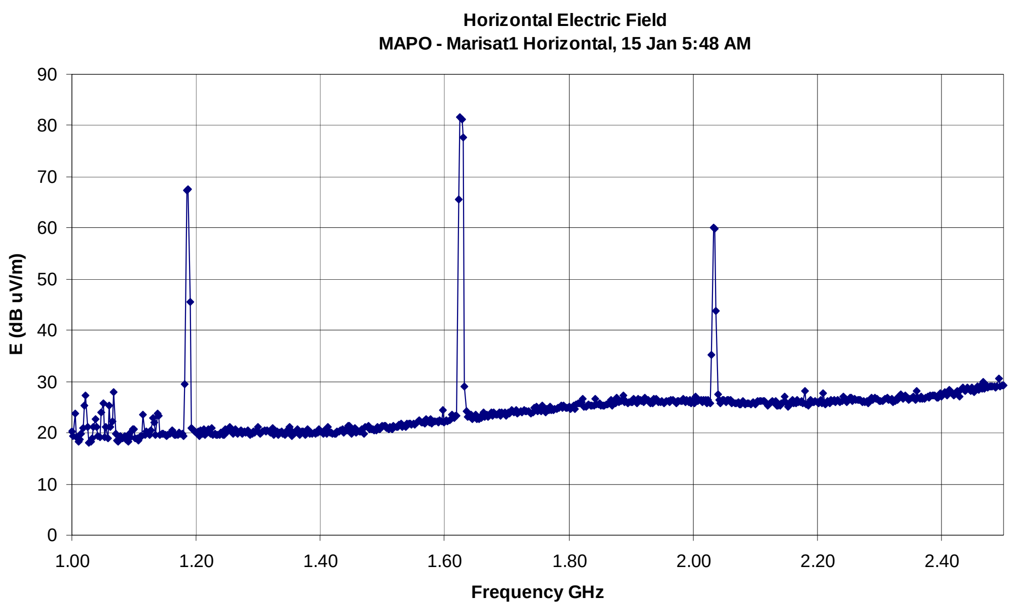

Figure 3-5 MAPO Horizontal 15 Jan 03, 5:48 AM.

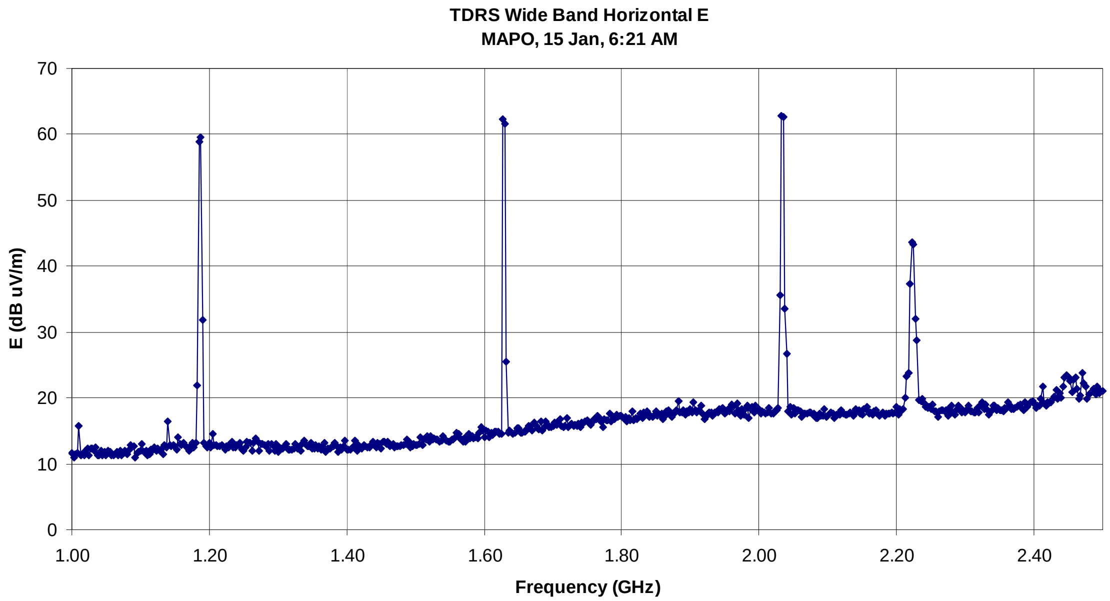

Figure 3-6 MAPO Horizontal 15 Jan 03, 6:21 AM.

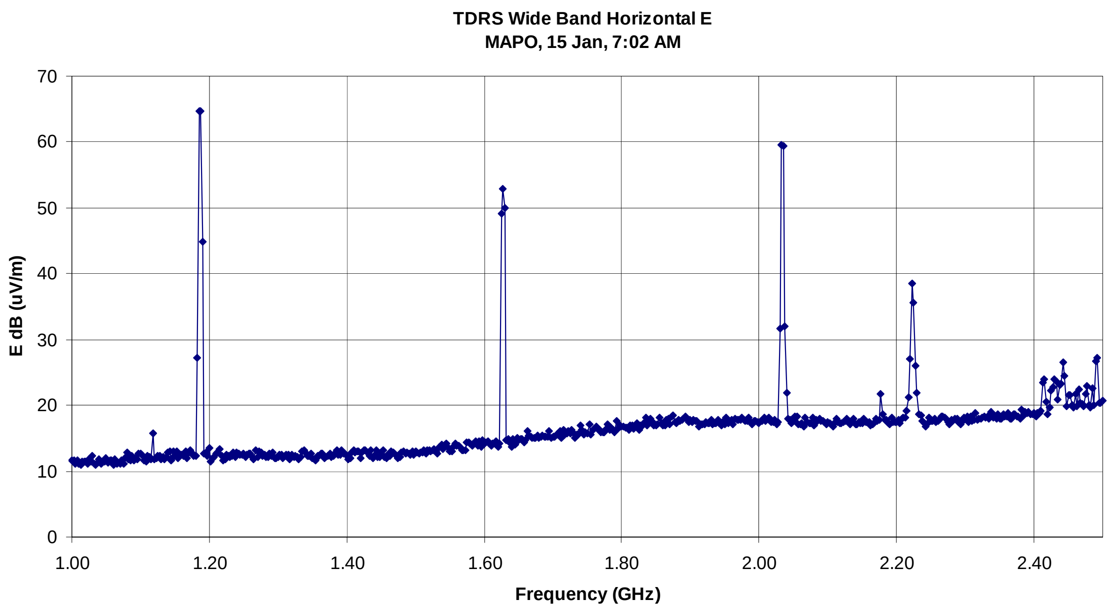

Figure 3-7 MAPO Horizontal 15 Jan 03, 7:02 AM.

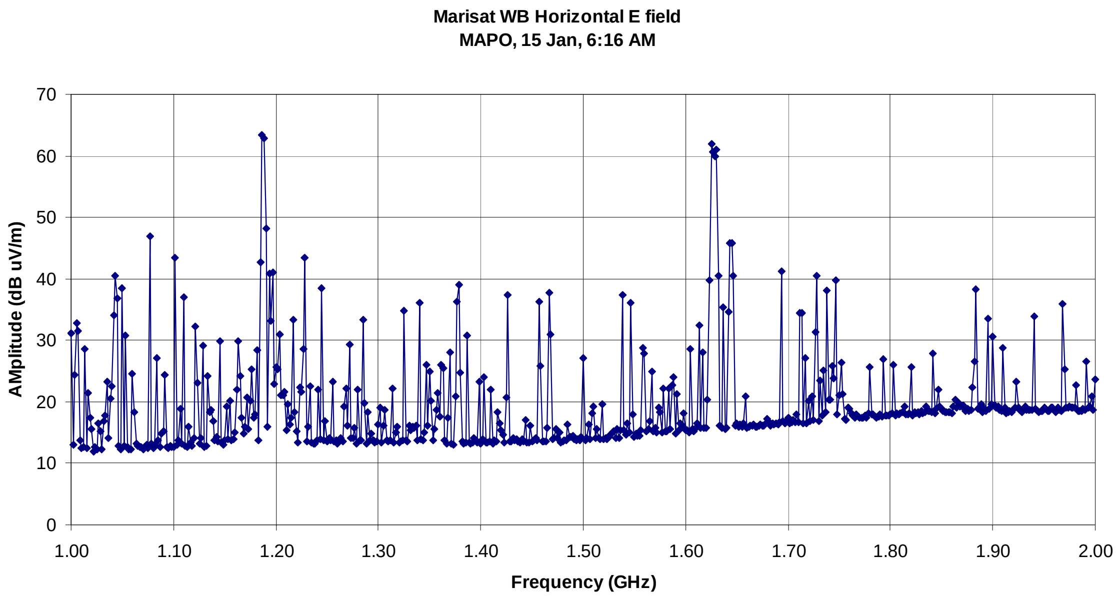

Figure 3-8 MAPO Horizontal 15 Jan 03, 6:16 AM.

3.4.2.6 Figure 3-8 is another spectrum taken with the antenna horizontally polarized, but only over the frequency range from 1-2 GHz. This figure shows the effect of local ignition noise. At the time this sweep was taken, the shuttle van was parked in front of the MAPO building directly in line with the log periodic antenna beam. Obviously the shuttle van generates significant amounts of ignition noise at frequencies up to 2 GHz and above. The data in the figure above was from a single sweep with the spectrum analyzer in maximum hold mode. When several sweeps were taken in that mode, the whole screen was filled with the impulse noise. The motor pool personnel indicated the shuttle van did not have a noise suppression ignition. However, the shuttle van does not run during the winter.

3.4.2.7 There was also ignition noise associated with passing snowmobiles, although not nearly as strong as the shuttle van. Some of the time there was low-level impulse noise that we thought was associated with the LC-31s sitting in the taxiway with their engines running. This noise was intermittent, so the origin is uncertain.

3.4.3 Narrowband Measurements

3.4.3.1 Narrowband spectrums were recorded to examine the spectral details of the TACAN signal and the Marisat uplink.

3.4.3.2 The strongest signal in the band between 1 and 2.5 GHz was the TACAN signal. It is vertically polarized, and it was always present. Narrowband sweeps of this signal with the antenna in both horizontal and vertical position are shown in Figure 3-9. Note that these measurements were taken without the amplifier. The resolution and video bandwidth was 30 kHz.

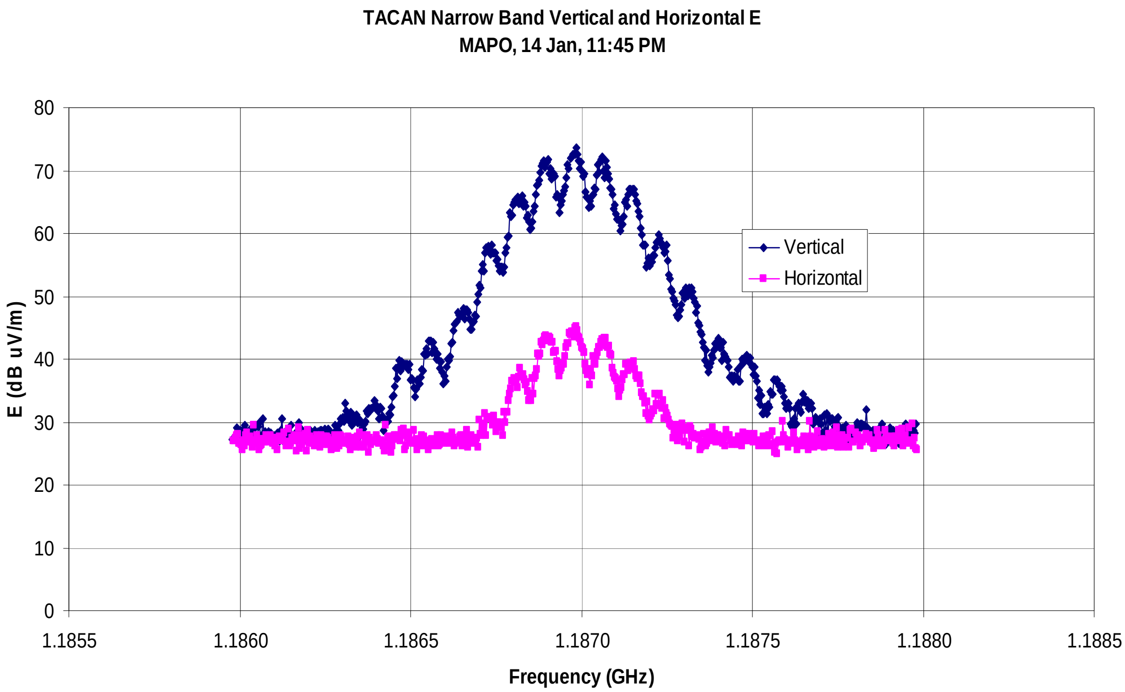

Figure 3-9 TACAN narrowband, vertical and horizontal.

3.4.3.3 A spectrum of the Marisat uplink signal in narrowband mode is shown in Figure 3-10. The Marisat uplink is horizontally polarized, which was the antenna polarization used for this figure. Note the Marisat beacon tone at 1.64 GHz. This tone was always present when the satellite was available. The uplink data is contained between 1.62 and 1.63 GHz. If there is no data to send, this band goes to zero. When the uplink first became available, this band was filled out completely (not shown) corresponding to dumping the stored email traffic. At the hour this spectrum was recorded (nearly 01:00 AM), there was no data to send, and that band went to zero. In order to get this plot, one member of the team went to the MAPO building and used the internet phone in order to activate the satellite information uplink. Unfortunately, the duty cycle for voice is quite low, and the sweep did not catch the full spectrum, which appeared as full lobe between 1.62 and 1.63 GHz, with a peak about 10 dB above that shown in the figure.

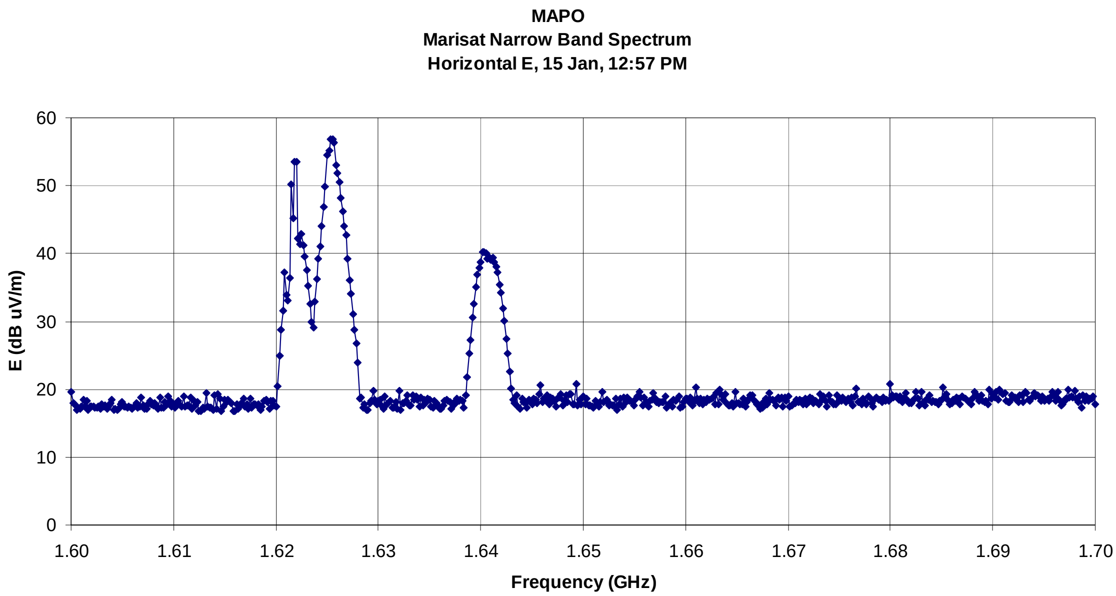

Figure 3-10 Marisat narrowband spectrum at MAPO, horizontal.

3.5 Conclusions

3.5.1 The Marisat signal at MAPO corresponds very well with the predicted levels of the reference given in 1.2.11. This signal is horizontally polarized, and the signal strength varies as the dish follows the satellite. The maximum level observed was 81.6 dBuV/m. The other satellite uplink signals were typically somewhat weaker than the Marisat signal.

3.5.2 The strongest signal in the 1-2.5 GHz band at MAPO was the TACAN signal at 1187 MHz. This signal is vertically polarized, and the level at MAPO was nearly constant at +85 dBuV/m. This transmitter is turned off during the winter months.

3.5.3 The second harmonic of TACAN appeared only in the vertical polarization records at a 2.39 GHz.

3.5.4 There were some unknown weak signals that appeared in the region just above 1 GHz.

3.5.5 There were some persistent weak signals in the ISM band between 2.4 and 2.5 GHz.

3.5.6 The shuttle van puts out significant ignition noise. A noise suppression ignition system should be installed on this van. However, the shuttle van does not run during the winter months. There is also some ignition noise due to the snowmobiles, but it is not as strong and only lasts a short time as they pass by.

4 Wide Band RF Spectrum Record

4.1 Introduction

As discussed in paragraph 1.3.3, during the on-site kick off meeting, the spectral survey items number 3 and 6 in the original SOW (reference 1.2.1, Appendix A) were combined into a task to take 24-hour records of the RF spectrum from 10 kHz to 22 GHz. These records were to be taken at the RF building, MAPO, SPRESO and halfway to SPRESO.

4.2 Objective

The objective of this task was to document the radio frequency signal levels from on-site sources so they could be compared to levels measured later, specifically after completion of the planned communications upgrade.

4.3 Approach

4.3.1 The standard test setup shown in Figure 2-2 was used to record the 24-hour data. Due to the finite bandwidth of the antennas, the frequency range was divided into 4 sweeps corresponding to the frequency ranges of the antennas. It is desirable for the spectrum analyzer resolution bandwidth be less than or equal to the frequency range divided by 601, the number of points displayed on the screen, otherwise there may be some errors in the display. The Labview program allows dividing each of these sweeps into up to 30 bands. This allows reasonable frequency resolution in each band over the entire wide band sweep. The band plan is shown in Table 4-1.

Table 4-1 South Pole Wide Band Sweep Frequencies

Wide Band Sweep	Frequency Range	No. bands	Minimum freq resolution	BW	Antenna SAS-200/
=====	=====	=====	=====	===	=====
WB1	10 kHz - 25 MHz	26			550-1 active monopole
1a	10 - 100 kHz	1	149.8	Hz	“
1b	100 kHz - 1 MHz	1	1.498	kHz	“
1c	1 MHz - 25 MHz	24	1.664	kHz	“
WB2	25 MHz - 300 MHz	30	15.25	kHz	542 biconical
WB3	300 MHz - 1 GHz	30	38.82	kHz	510 larger LP
WB4	1 GHz - 22 GHz	30	1.165	MHz	518 small LP
Total bands		116			

4.3.2 The wide band sweeps are designated as WB1, WB2, WB3, and WB4. The Minimum Freq resolution column indicates the resolution of each of the 601 points across the spectrum analyzer screen. Note that WB1 consists of 26 bands. Band 1a is from 10-100 kHz; band 1b is from 100 kHz - 1 MHz. The remaining 24 bands are uniformly spaced over the band from 1 MHz to 25 MHz. In this way the resolution bandwidth of each band is kept on the order of the signal bandwidth expected in those frequency ranges. Also, note that sweeps WB2, WB3, and WB4 each have 30 bands uniformly distributed over their respective frequency ranges.

4.3.3 The dwell time for each of these bands was approximately ½ minute out of 15 minutes for WB1 and ½ minute out of 17.5 minutes for WB2, WB3, and WB4. This means that each band was recorded for approximately ½ minute. It took 15 to 17 ½ minutes to go through all the bands.

4.3.4 The minimum frequency resolution calculated by dividing the bandwidth of each band by the 601 spectrum analyzer points is given in Table 4-1. When possible, the spectrum analyzer resolution bandwidth was set to the next higher bandwidth setting available to eliminate the possibility of display error. However, for WB4, the minimum frequency resolution is slightly greater than the maximum bandwidth setting for the HP-8563A, which is 1 MHz. This violates the criteria but the impact is minimal in that the readings remain within 0.7 dB of the actual reading in this frequency range. The selection of the sweeps and bands was a trade off that covered the required frequency range and gave acceptable frequency resolution and recording time.

4.3.5 The noise figure of the spectrum analyzer is specified to be 30 dB. Cable loss adds directly to this noise figure. Instrumentation amplifiers were connected near the antenna to set the system noise figure and counter the effects of the coax loss.

4.3.6 Four antennas were needed to cover these sweeps. The active monopole antenna was used for WB1. This antenna has a built in amplifier and was connected directly to the spectrum analyzer by a single coax. For the other three sweeps, an amplifier was placed near the antenna and connected to the antenna by a short piece of coaxial cable. The amplifier output was fed to the spectrum analyzer by a longer piece of coaxial cable. The configuration of cables and amplifiers used at each site is shown in Table 4-2.

4.3.7 For band WB2, the biconical antenna was used with the HP-8447D amplifier, which has a nominal gain of 26 dB over the band from 100 kHz to 1.36 GHz. For WB3, the larger Log Periodic antenna was used with the same amplifier (HP-8447D). For WB4, the smaller Log Periodic antenna was used with the HP-8449B amplifier, which has a nominal gain of 34 dB over the band from 1 to 26.5 GHz.

4.3.8 Two spectrum analyzers were, so two different sweeps were recorded at the same time. Thus, using the two systems, one 24-hour monitoring period at a site could theoretically be completed in 48 hours as long as WB2 and WB3 were not scheduled together, since they requested the same amplifier. Unfortunately, one of the spectrum analyzers would not work correctly with the computer program, causing the recording program to hang-up, consequently, a spare was sent up from McMurdo, causing considerable delay.

4.4 Measurements

4.4.1 By making use of the two systems as described above, the team was able to complete 24 hour records at the RF building and the MAPO building. The times for all the spectrum recordings at each of the sites are given in Table 4-2. However, at the South Pole Remote Earth Observatory (SPRESO) site, located about 7 km from the station, there was only enough time to take a single spectrum record for each of the sweeps, and there was no time for measurements at halfway to SPRESO.

Table 4-2 Times and Configuration for Wide Band Sweeps									
RF Building									
Sweep	Start Date	Time	Stop Date	Time	Ant	Cable 1	Amp	Cable 2	SA
=====	====	====	====	====	====	=====	=====	=====	====
WB1	12-Jan	4:20 PM	13-Jan	4:21 PM	vert	none	internal	A9	max hold
WB2	13-Jan	5:20 PM	14-Jan	7:12 PM	vert	A6	HP-8447D	A9	max hold
WB3	14-Jan	7:57 PM	15-Jan	9:45 PM	vert	A6	HP-8447D	A9	max hold
WB4	13-Jan	9:26 PM	14-Jan	9:26 PM	vert	A?	HP-8449B	A11	max hold
MAPO									
Sweep	Start Date	Time	Stop Date	Time	Ant	Cable 1	Amp	Cable 2	SA
=====	====	====	====	====	====	=====	=====	=====	====
WB1	17-Jan	11:44 PM	18-Jan	11:47 PM	45	none	internal	A11	avg
WB2	16-Jan	11:18 PM	17-Jan	11:19 PM	vert	A6	HP-8447D	A11	avg
WB3	15-Jan	10:47 PM	16-Jan	1:04 PM	45	A6	HP-8447D	A9	max hold
WB3	16-Jan	1:04 PM	16-Jan	10:50 PM	45	A6	HP-8447D	A9	avg
WB4	15-Jan	9:46 AM	16-Jan	12:09 AM	45	A3	HP-8449B	A11	max hold
SPRESO									
Sweep	Date	Start Time	Stop Time	Ant	Cable 1	Amp	Cable 2	SA	
=====	====	====	====	====	=====	=====	=====	=====	
WB1	17-Jan	4:59PM	5:07 PM	45	none	internal	A11	max hold	
WB2	17-Jan	4:15 PM	4:32 PM	45*	none	none	A11	max hold	
WB3	17-Jan	3:52 PM	4:09 PM	45	none	none	A11	max hold	
WB4	17-Jan	4:38 PM	4:55 PM	45	A3	HP-8449B	A11	max hold	

* Borrowed ETS Biconical Antenna model 3110B 30-300 MHz

4.4.2 The antenna was always vertically polarized at the RF building. However, after moving to MAPO, it was determined that some of the satellite signals were horizontally polarized, and the antennas were set to 45 degrees for most measurements there. The spectrum analyzer was set in max hold mode for the RF building measurements and the WB4 recordings at MAPO. However, part way through WB3, it was discovered that the shuttle vans generated strong impulsive noise when they were nearby, so the spectrum analyzer was changed to average mode for the remainder of WB3 and for all of WB1 and WB2 at MAPO.

4.4.3 The measurements at SPRESO were done without the HP-8447D amplifier for bands WB2 and WB3 because it was still in use at the MAPO building. A borrowed South Pole Station biconical antenna was used for WB2. It was quiet at SPRESO, and the spectrum analyzer was operated in max hold mode. Thus, the parameters were somewhat different at the different sites. Table 4-2 gives the configuration, including the amplifiers and cables, as well as the pertinent spectrum analyzer settings for each site. The table includes ID numbers used for the coaxial cables described in Table 4-3.

Table 4-3 Cables & Filters

A2	HiPass Filter
A4	Short Green Cable 3’ LL-142
A6	Short White Cable 17’ RG-55
A9	Long Black Cable 30’ RG-58
A11	Long Green Cable 50’ LL-142
SB22	Short Black Cable 7’ RG-58

4.4.4 The recorded data have been processed to convert the spectrum analyzer readings into electric field strength in terms of dBuV/m. The method as well as the calibration data used is given in Appendix E, along with plots of all data containing apparent signals. A brief discussion of each of these data sets follows.

4.5 SPRESO Data

4.5.1 The SPRESO data plots are contained in Appendix E.3. Due to the limited time available at SPRESO, this data consists of single spectrum records for each band of the wide band sweeps. All of the data taken at SPRESO were examined using the Matlab viewing program. There were only 17 bands that contained apparent signals, and only plots of these bands are included in the data in the appendix. The plots are in units of dBuV/m versus frequency.

4.5.2 At SPRESO, the HP8447D amplifier used for the two middle bands (WB2 and WB3) was not available because it was still in service at the MAPO building. Consequently, the sensitivity reduced significantly for the bands in these two sweeps. These bands comprise the frequency range from 25 MHz to 1 GHz.

4.5.3 Three examples of the SPRESO data plots are given below along with some comments on their interpretation.

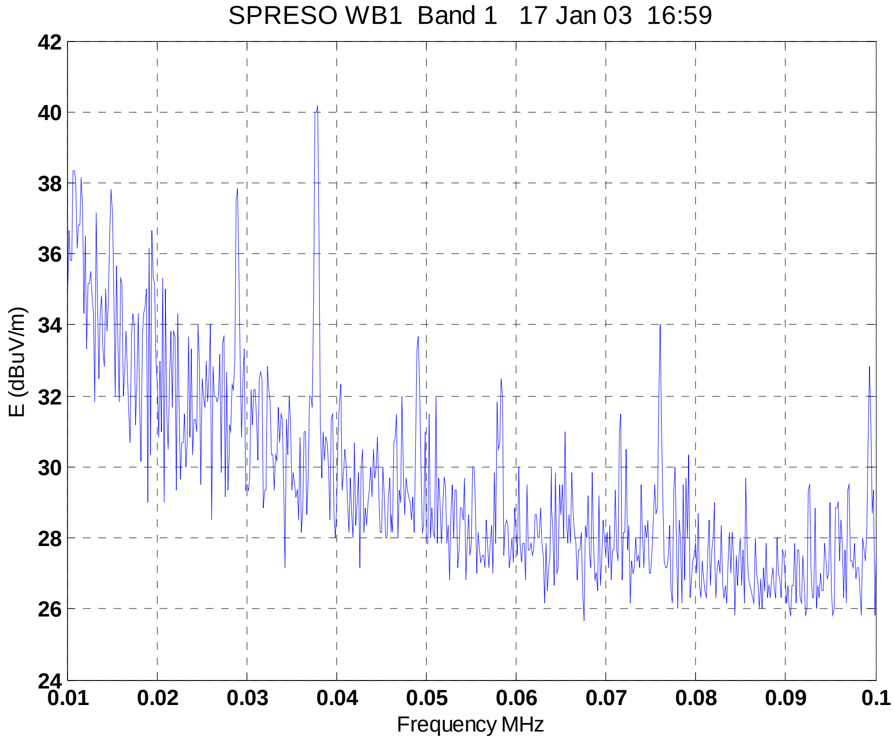

Figure 4-1 SPRESO WB1 Band 1

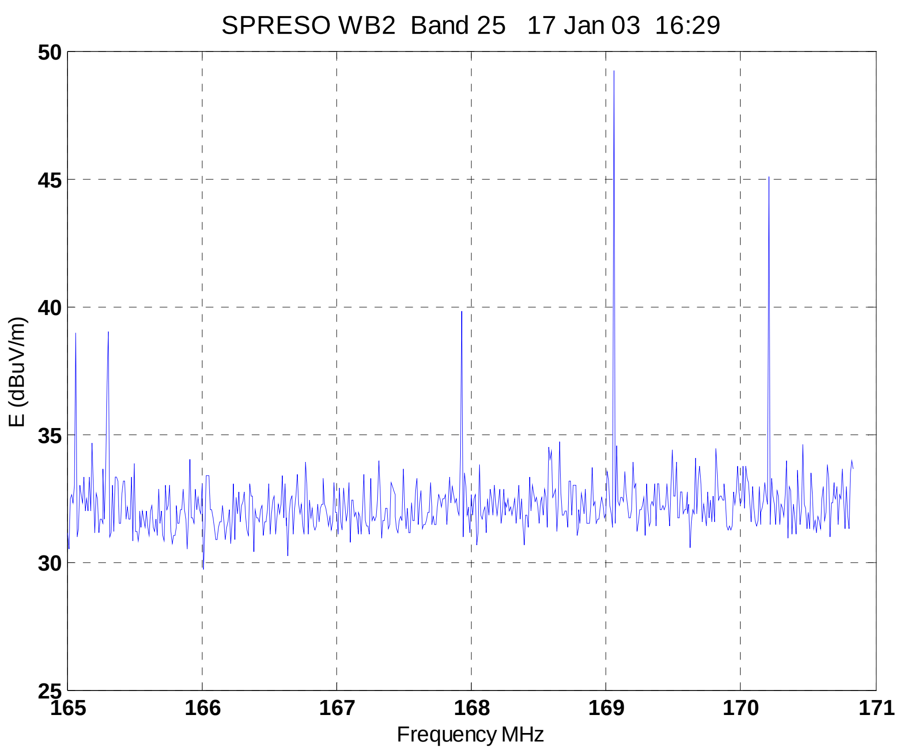

Figure 4-2 SPRESO WB2 Band 25

4.5.4 Figure 4-1 shows the data for SPRESO WB1 Band 1, which covers the frequency range from 10 kHz to 100 kHz. There are some VLF and LF signals shown, but the Stanford VLF signal at 19.2 KHz (section 8.1) was not on the air at the time of this recording. Also, the wide band noise discussed in section 8.2 was not observed at SPRESO. Examination of the plots in Appendix E shows that there are some weak signals throughout the HF band probably due to distant sources. The local sources were apparently not on during the times of this recording.

4.5.5 Figure 4-2 shows data for SPRESO WB2 band 25, which covers the frequency range from 165 to slightly less than 171 MHz. There are several signals that show up in this band. In addition to the signals shown in the figure, there are strong signals at 162.3 MHz, and 175.4 MHz (see plots in Appendix E). All these signals are probably VHF hand held communications, although that frequency range is not listed in the South Pole Frequency List. There are also signals at 404 MHz and 436 MHz that could be hand held communications. There were two other strong signals in WB2 at 64 MHz and 110 MHz, which can be seen in the figures in Appendix E.

4.5.6 Figure 4-1 shows the data for SPRESO WB4 Band 1. This is the only band of WB4 that had any signals present.

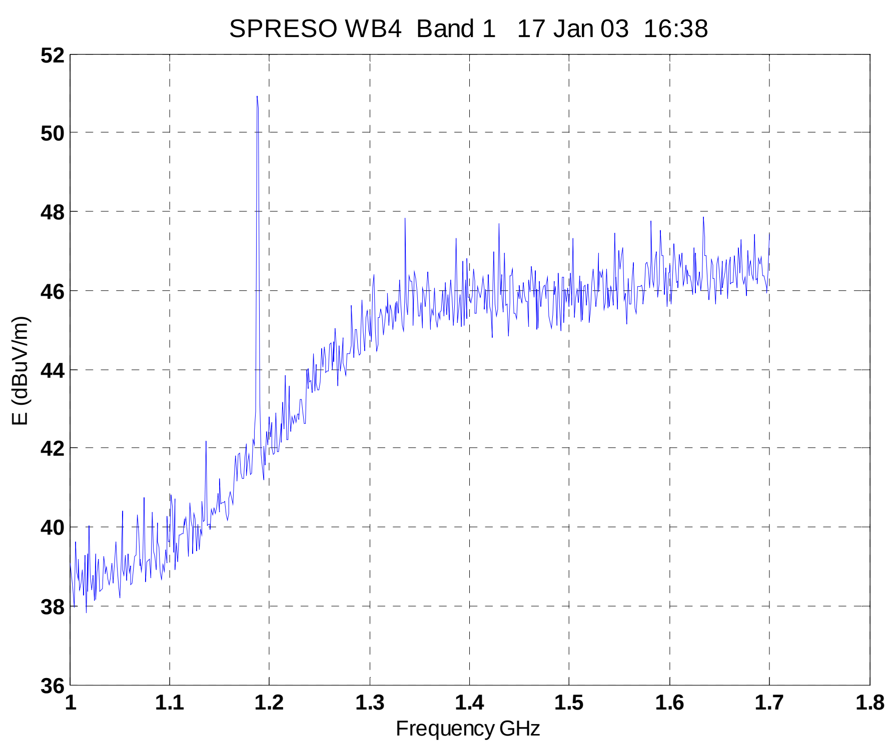

Figure 4-3 RF WB4 Band 1

4.5.7 The signal in Figure 4-3 is identified as the TACAN transmitter at 1187 MHz (see section 3.5.2). Note that the noise floor in the figure appears to increase with frequency. This is due to the fact that the calibration factors for the antenna, amplifier and cables are a function of frequency. In this frequency range, the noise limit for the recording system is internal, either from the amplifier or spectrum analyzer, depending upon the cable losses. The white noise level was corrected to an equivalent electric field using the calibration factors. The result is that the sensitivity (noise floor) in terms of field strength varies with frequency. The system sensitivity in terms of field strength is indicated by the noise floor in the plots.

4.6 RF Building Data

4.6.1 The wide band sweep data at the RF building and the MAPO building were recorded over a 24-hour period. These data have been converted to dBuV/m, and plotted versus both frequency and time using a spectrogram display. All of the data with signals present are given in Appendix E. The spectrograms in the appendix contain many interesting unidentified signals. Some illustrative examples are given below.

4.6.2 An example of a spectrogram for RF WB1 Band 1, corresponding to from 10 kHz to 100 kHz, is shown in Figure 4-4. The spectrogram plots frequency on the x-axis, time on the y-axis and magnitude in the z direction represented by color. The color bar on the right hand side of the figure gives the scaling in units of dBuV/m.

4.6.3 The data in the spectrograms were taken over a 24-hour period during parts of two days. The label at the top of the spectrogram identifies the location, sweep, and band, as well as giving the dates on which the data were taken. The time axis is vertical with the start time at the top and the end time at the bottom.

4.6.4 The vertical orange lines in Figure 4-4 represent spectral tones that were present for the entire 24-hour period of the recording. The RF building was quite noisy, and many tones at various frequencies were observed. The tones in the figure below appear to be harmonics of a signal at approximately 4 kHz. The RF building is powered through a solid state Uninterruptible Power Supply (UPS) that could not be disabled without causing problems. The low frequency harmonic tones were thought to be caused by the UPS. This was not verified since the UPS could not be shut down for a test.

4.6.5 There are many signals and harmonic tones that appear in the RF building data for WB1 and WB2, which are shown in the spectrograms given in the appendix. Also, see section 8.2 for a discussion of some wideband noise that was observed in WB1 at the RF building.

4.6.6 Figure 4-5 corresponds to the frequency range from 42 to 49 MHz recorded at the RF building. This figure shows the fairly wide band signal at the fundamental frequency of the University of Colorado Radar (section 6) that was present for the entire 24 hour period.

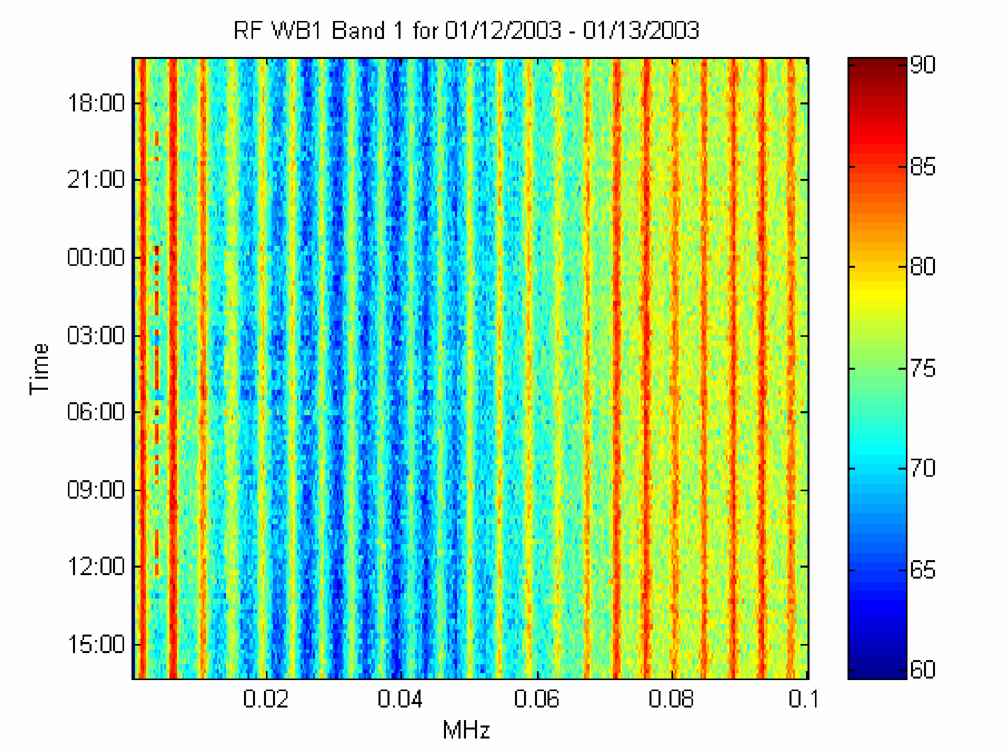

Figure 4-4 RF WB1 Band 1 Spectrogram (dBuV/m)

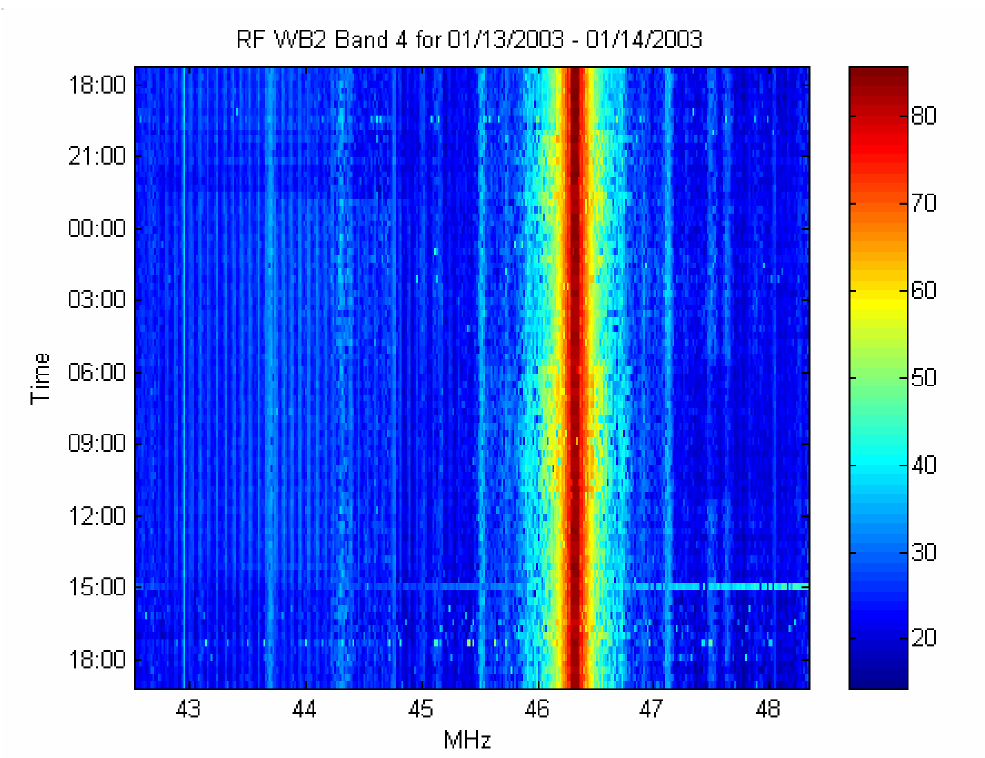

Figure 4-5 RF WB2 Band 4 (dBuV/m)

4.6.7 Figure 4-5 also shows a burst of wide band noise that occurred at about 20:00 on 1/13/2003. The wide band noise appears as a series of white spots forming a horizontal line. This illustrates how the spectrogram display can provide discrimination against intermittent impulsive or wide band noise.

4.6.8 Figure 4-6 is a spectrogram for a band centered at 400 MHz. This figure shows intermittent activity at several frequencies. It also shows several incidences of broadband or impulse noise represented by the horizontal stripes with a magnitude of about 40 dBuV/m. Similarly, Figure 4-7 for a band of frequencies around 500 MHz shows some strong wide band noise.

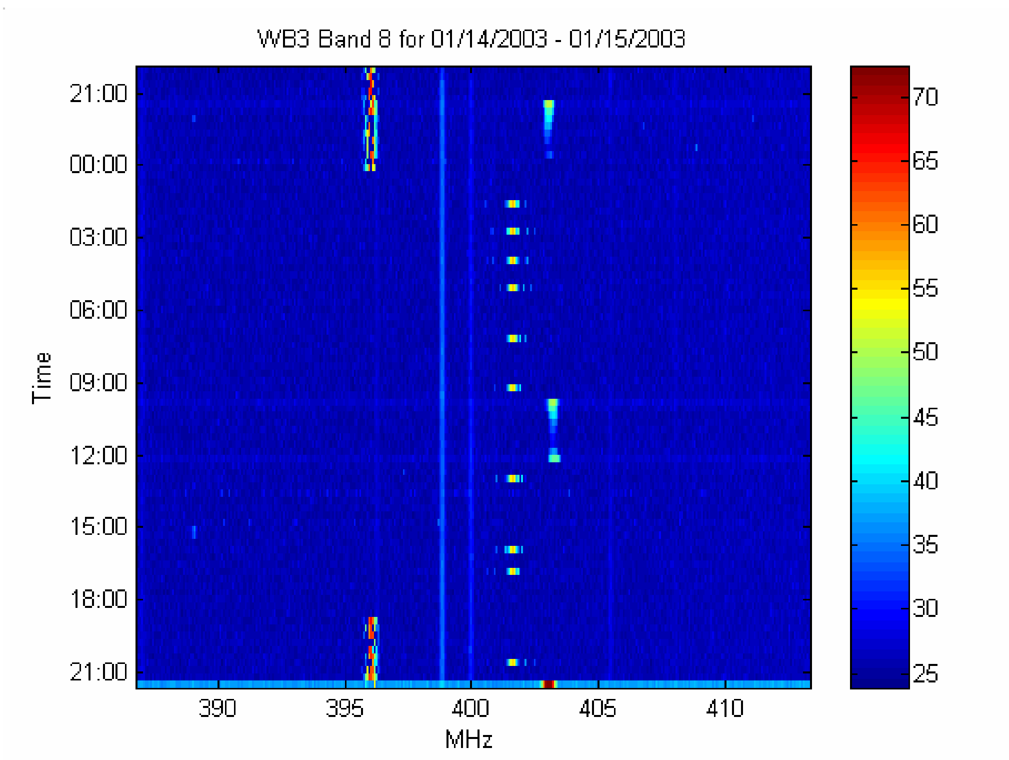

Figure 4-6 RF WB3 Band 8 (dBuV/m)

4.6.9 Figure 4-7 corresponds to the frequency range from 445 to just below 470 MHz. It shows a signal with a level of around 47 dBuV/m that was present for the entire recording period. There was another stronger signal that consisted of several tones centered around 455 MHz that was on for a brief period when the recording started and then again for approximately 2-1/2 hours around midnight.

4.6.10 Figure 4-9 shows the band from 1.0 to 1.7 GHz as measured at the RF building. The TACAN signal can be seen continuously at 1180 MHz (section 3). The satellite uplink signals for Marisat can also be seen, as well as some other intermittent signals. Note that there are quite a number of wideband noise events represented by the horizontal bands. This noise is similar in time occurrence and extent to the wide band noise discussed in section 8.2 and may possibly be due to the same source.

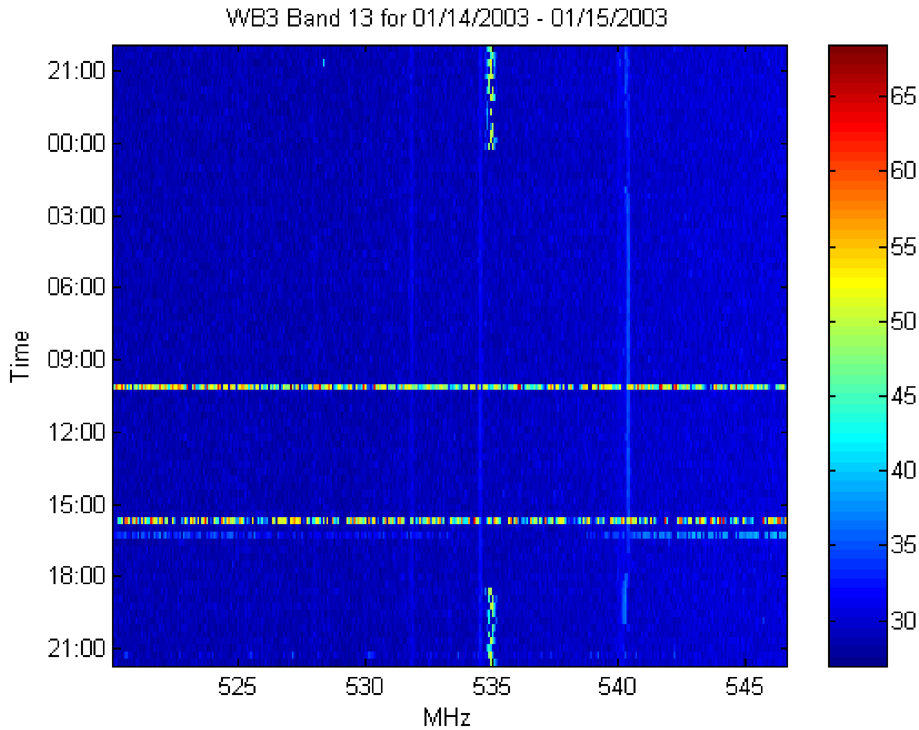

Figure 4-7 RF WB3 Band 13 (dBuV/m)

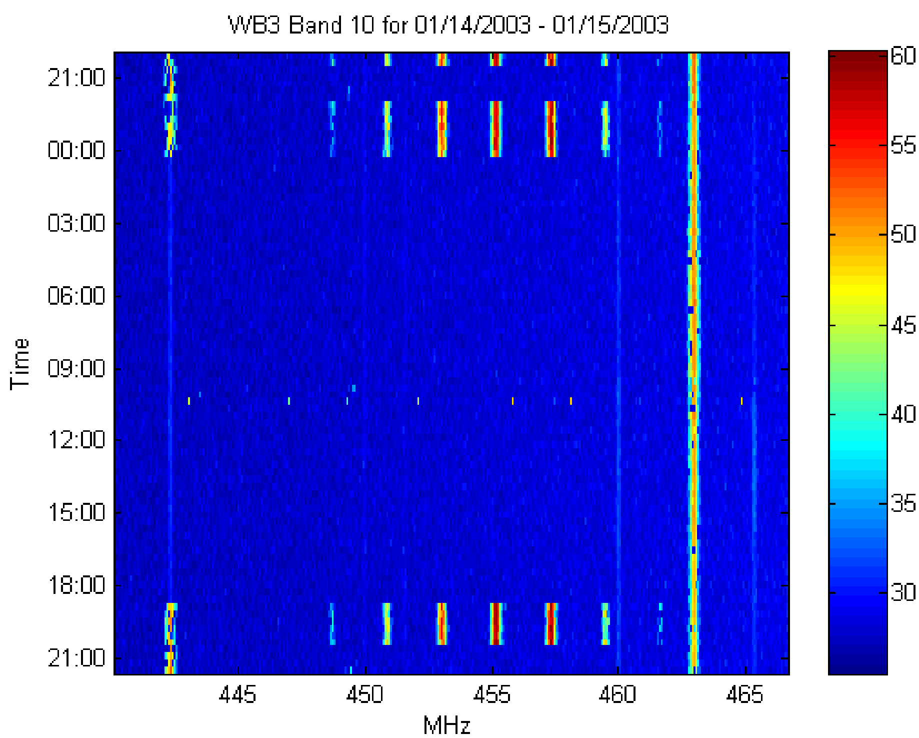

Figure 4-8 RF WB3 Band 10 (dBuV/m)

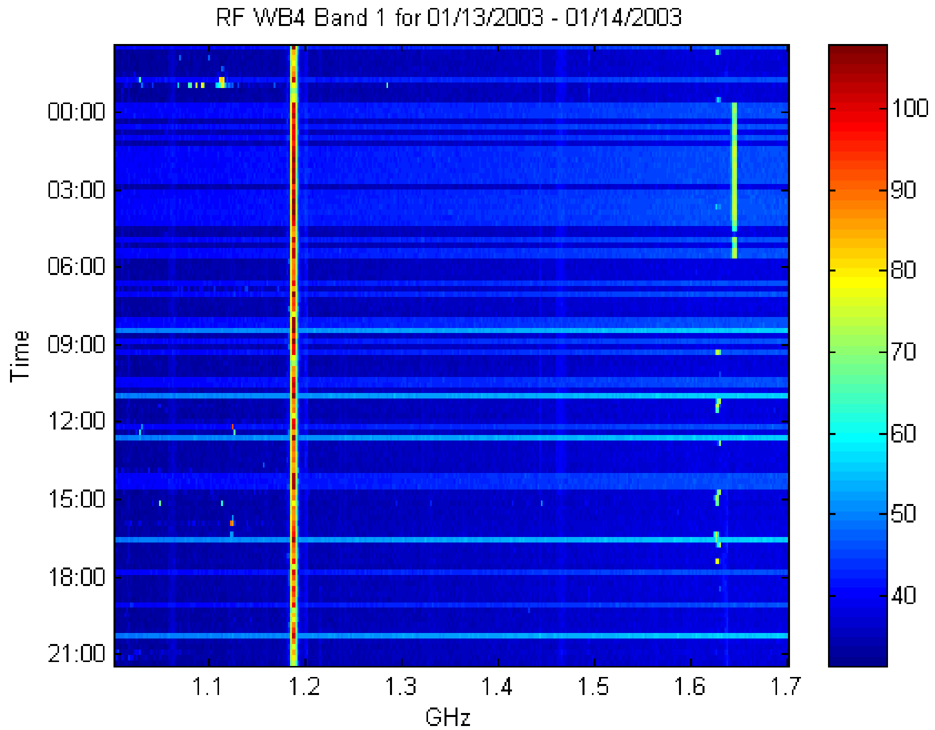

Figure 4-9 RF WB4 Band 1 (dBuV/m)

4.7 MAPO Building Data

4.7.1 Wide band sweep data over a 24-hour period were recorded at the MAPO building. All of the data have been converted to dBuV/m and plotted as spectrograms. The spectrograms containing signals have been included in Appendix E. The spectrograms in the appendix contain many interesting unidentified signals. A few examples of the MAPO data are included below.

4.7.2 The radio environment at MAPO was generally much less noisy than at the RF building, as illustrated by Figure 4-10 for the frequency range from 10 kHz to 100 kHz. In this figure, some low frequency signals, possibly VLF stations, can be seen. However, the Stanford transmitter (section 8.1) at 19.3 kHz was not on during the time the data were recorded.

4.7.3 Figure 4-11 shows that the wide band noise seen at the RF building was also observed at MAPO, but not nearly so strong. This figure also shows that there were some low frequency harmonics in the spectrum at MAPO.

4.7.4 There are some interesting signals that appear in several of the bands in WB2. One of these is illustrated in Figure 4-12, which shows a low level, very wide band signal around 70 MHz that is drifting in frequency.

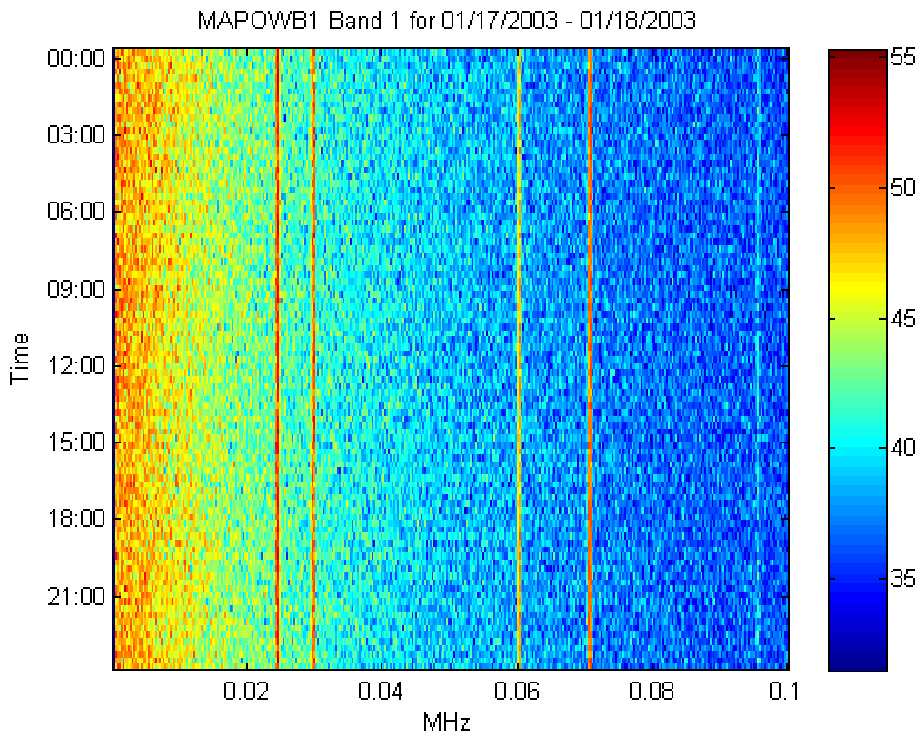

Figure 4-10 MAPO WB1 Band 1 (dBuV/m)

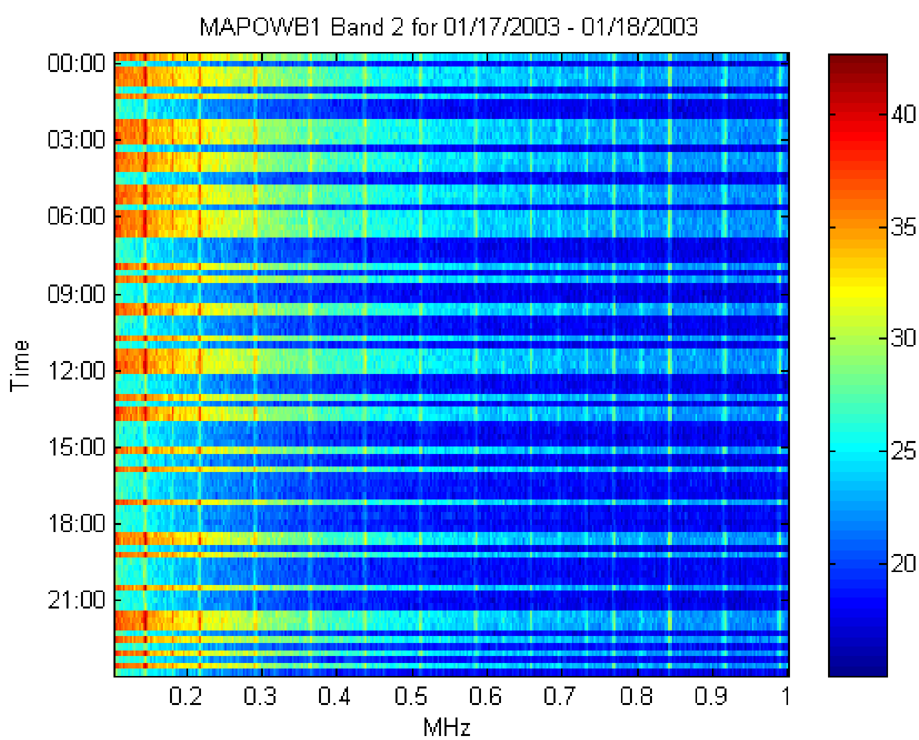

Figure 4-11 MAPO WB1 Band 2 (dBuV/m)

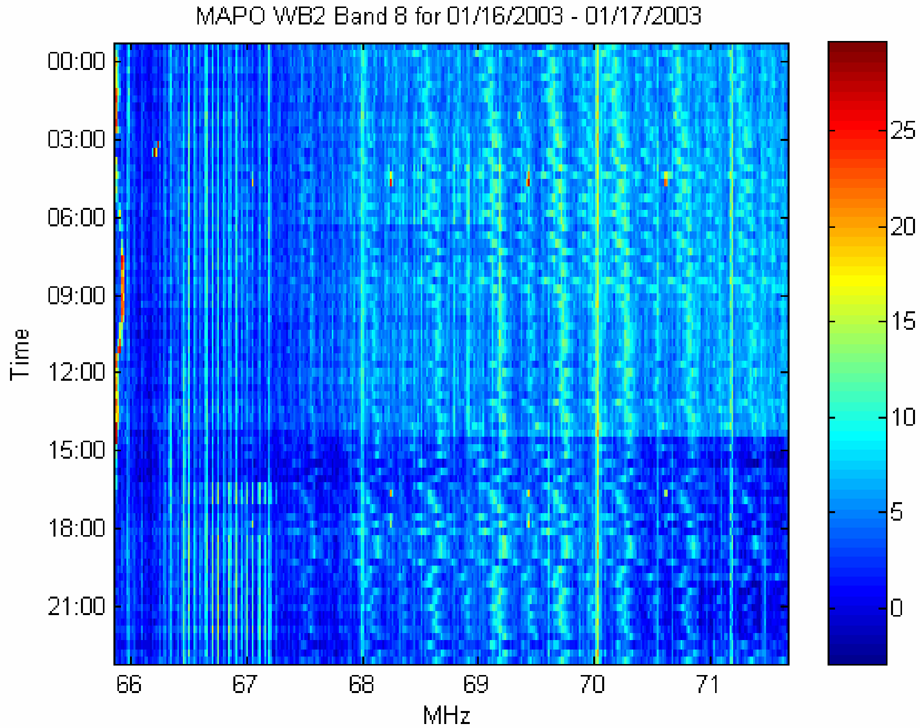

Figure 4-12 MAPO WB2 Band 8 (dBuV/m)

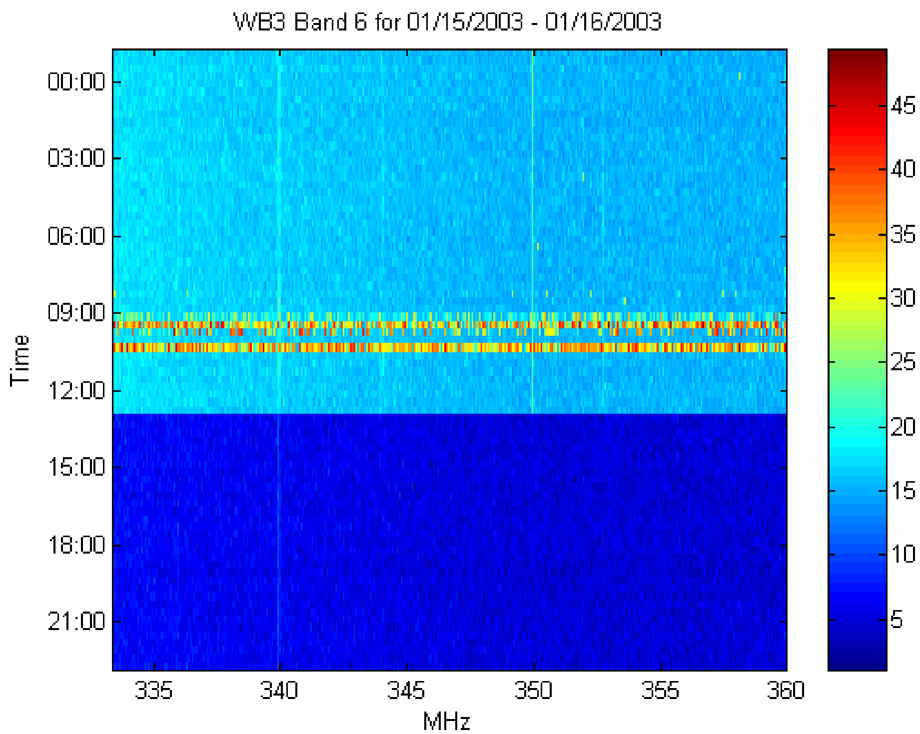

Figure 4-13 MAPO WB3 Band 6 (dBuV/m)

4.7.5 While making the WB3 recordings at MAPO, it was discovered that the shuttle van generated very strong wide band impulsive noise. This dominated the data recorded during the period when it occurred, if the spectrum analyzer was in maximum hold mode. In order to eliminate this effect we switched the spectrum analyzer was switched to average mode during the time WB3 was being recorded. An example of the effect is illustrated in Figure 4-13, which shows that the change in mode occurred at about 15:00 on the second day of recording. Note the strong impulsive noise events that occurred before that time. There are several other spectrograms in WB3 illustrating the same effect.

4.7.6 The spectrogram for the band between 1 and 1.7 GHz is shown in Figure 4-14. The TACAN signal at 1187 MHz can be seen, as well as some intermittent signals around 1.5 and 1.6 GHz. There are also some signals just above 1 GHz.

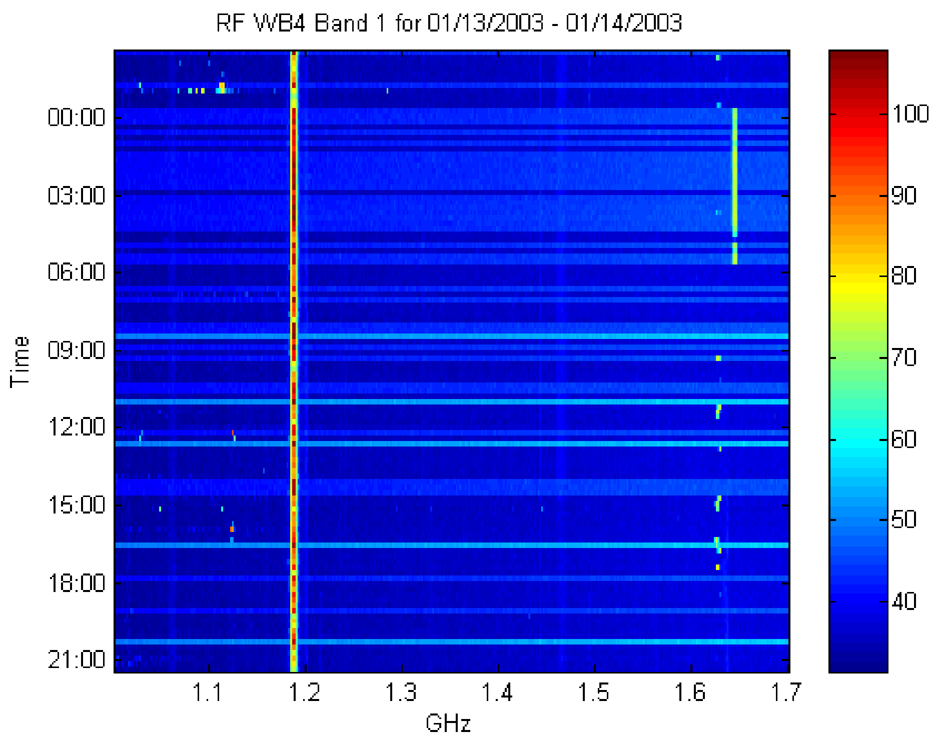

Figure 4-14 RF WB4 Band 1 (dBuV/m)

5 Low Frequency Measurements

5.1 Introduction

5.1.1 The original SOW requested measurements of ELF out-of-band emissions at the South Pole as well as baseline emitted radiation reference levels at selected locations in the Dark Sector, the Quiet Sector, and at SPRESO (Task number 3, 4, and 6 of the original SOW reference 1.2.1). Further communications (reference 1.2.3 and 1.2.4) in an attempt to clarify this gave the indication that measurements over a wider frequency range than just ELF were desired. In order to accomplish this task, SPAWARSYSCEN San Diego constructed a special 4-coil magnetometer that was calibrated to make magnetic field measurements over the range of 1 Hz to 4 kHz. dBµV/m

5.1.2 The final details of the low frequency measurements at the South Pole were worked out based on discussions with on-site personnel and Professor Umran Inan of Stanford University. The measurements were to be taken over a frequency range of 1 Hz to 850 Hz in order to complement measurements that had been taken by Stanford earlier in the season.

5.1.3 During the process of making these measurements, it was discovered that both the shield on the cable at the exit point of the magnetometer and the cable connector had been damaged. The magnetometer was sealed, but the cable shield and connector were repaired and the magnetometer appeared to be working. Unfortunately, upon return to the states, the magnetometer calibration was tested and it was found to be not working. The repairs made to the cable shield at the South Pole were still good, but the center conductor of the cable was broken where it exits the magnetometer.

5.1.4 Since it is not known when this center conductor was broken, some of the data may be good. The data have been processed and are included in Appendix F.

5.1.5 In an attempt to determine the validity of this data, measurements of the noise level for the damaged magnetometer were taken at SPAWARSYSCEN San Diego and Charleston. The results of these measurements indicate that the data may be good. As a further check, the data were compared to the Stanford University measurements in the frequency range where they overlapped. Again the indications were that the data may be good, but neither of these tests is conclusive. This is further discussed in Appendix F.

5.2 Conclusions

5.2.1 Even though the tests indicate that the data may be good, they are nevertheless of limited use because of the uncertainty in their validity and because the inverter used to power the instrumentation at the remote sites resulted in strong interfering spectral lines. To be sure this data is accurate, the measurements must be repeated.

6 University of Colorado VHF Radar

6.1 Background

The University of Colorado operates a VHF meteor radar at the South Pole. This radar has been operational since January 2002 and is used to measure the spatial structure and temporal evolution of the horizontal wind field at elevations of 80-105 km over the South Pole. The transmit array consists of 4 multi-element Yagi antennas pointing at the grid cardinal directions. The receive antenna is an array of 5 pairs of horizontal crossed dipoles. The transmitter has a peak power rating of about 10 kW. The center frequency is 46.28 MHz and the waveform envelope consists of 30 μs Gaussian pulses with a pulse repetition rate of 305 Hz.

6.2 Objective

.

The objective of this task was to measure the out of band and spurious radiation from this radar.

6.3 Measurement configuration:

6.3.1 The radar is located in the vicinity of the RF building. Figure 6-1 is a picture showing the RF building and the Marisat/Goes terminal dish. The University of Colorado RADAR installation can be seen in the foreground of the picture. The Radar shelter is the wooden building in the foreground and it is located approximately 150 yards from the RF building. The RADAR antenna array elements can be seen surrounding the shelter.

6.3.2 The spectrum measurements were made at the RF building. The receiving antennas for the measurement were placed on top of the RF building with the HP 8563A Spectrum Analyzer located inside.

6.3.3 The spectrum around the fundamental frequency (46.28 MHz) was recorded using the Biconical antenna (20 - 330 MHz). The antenna was connected directly to the Spectrum Analyzer by 50 feet of RG-58 coaxial cable. The amplifier was not used to avoid saturation by the strong signal at the fundamental frequency.

6.3.4 The harmonics were measured using a different instrumentation configuration. In this case a 76 MHz high-pass filter was connected just after the antenna. This was followed by the HP 8447D instrumentation amplifier having 26dB ± 2 dB gain from 100 kHz to 1.3 GHz. The high-pass filter was used to keep the amplifier from saturating due to the strong signal at the fundamental frequency. The amplifier was located on the roof close to the filter and the output was fed to the Spectrum Analyzer using the same 50 feet piece of RG-58 coax.

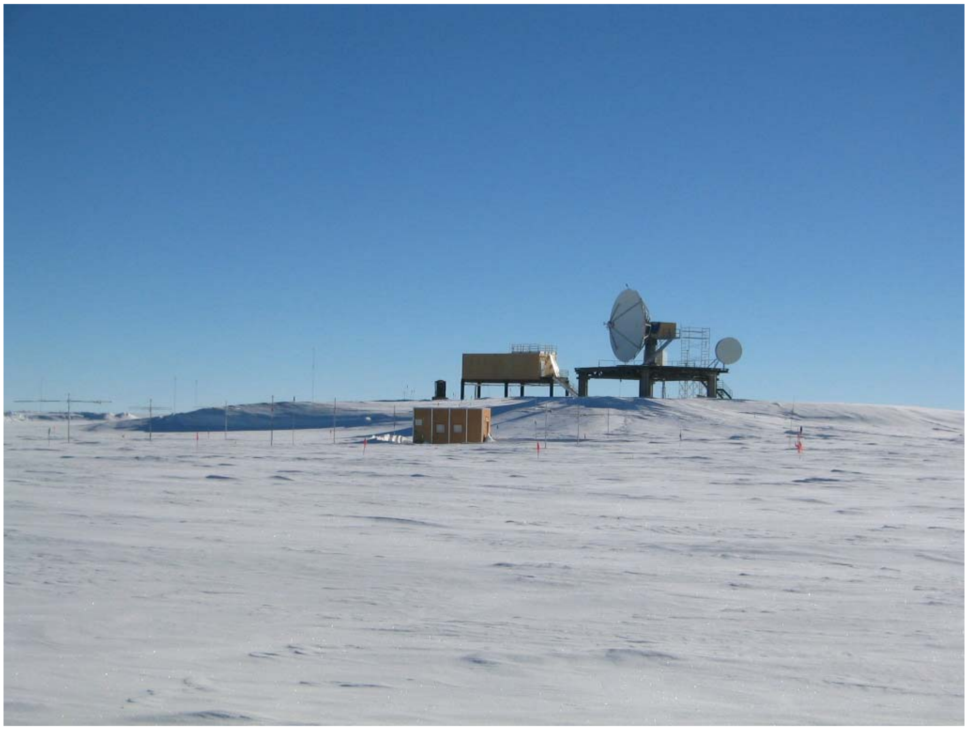

Figure 6-1 South Pole RF building (on stilts) with Marisat/Goes Dish and University of Colorado VHF radar (foreground).

6.3.5 The Biconical antenna (20 – 330 MHz) was used to measure the lower order harmonics, while the higher order harmonics were measured using the Log Periodic antenna (300 MHz – 1.8 GHz). The 7^{th} harmonic (324 MHz) was measured using both antennas independently as a check.

6.3.6 The signal for vertical polarization exceeded the signal for horizontal polarization and vertical polarization was used for all the measurements recorded.

6.4 Measurements

6.4.1 Fundamental

6.4.1.1 The spectrum of the fundamental is shown in Figure 6-2. Note that there are occasional noise impulses that occurred during the time this spectrum was recorded.

6.4.1.2 Figure 6-2 shows that the center frequency is 46.28 MHz. The observed 3 dB bandwidth is 100 kHz. The bandwidth between the first two nulls of the spectrum is 1.35 MHz. The first spectral peak on either side of the fundamental is about 55 dB below the fundamental. All other spectral peaks are 60 dB or more below the fundamental.

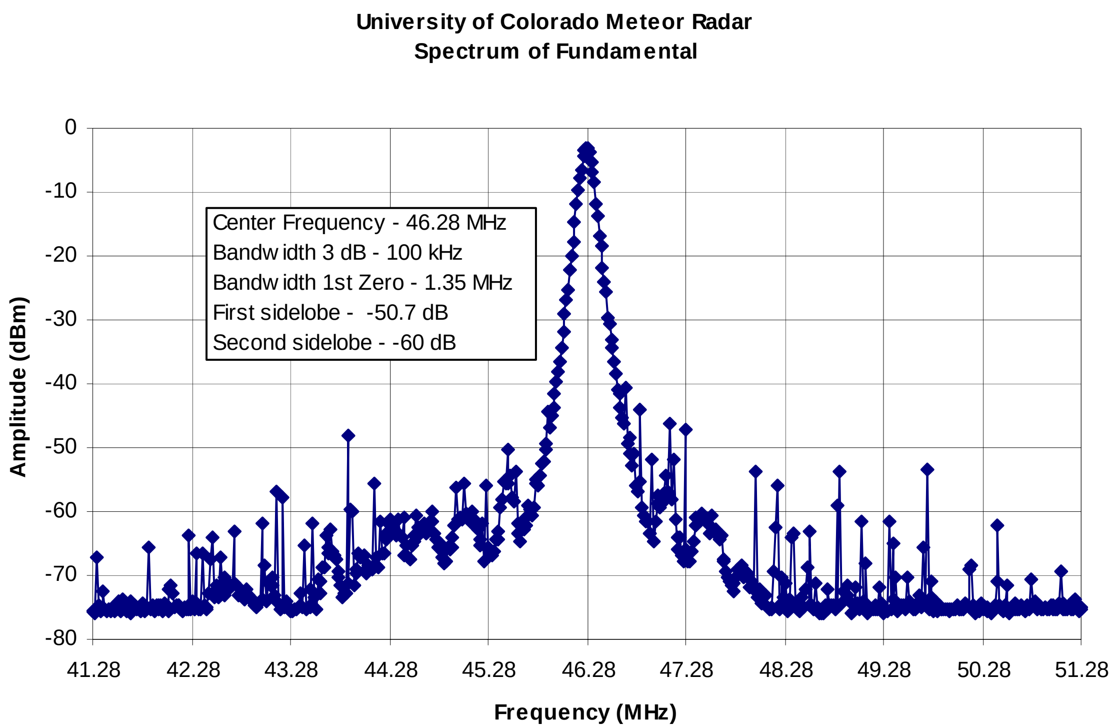

Figure 6-2 University of Colorado Meteor Radar Fundamental Spectrum.

6.4.1.3 The measurements of the fundamental and harmonics were converted into absolute field strength given in Table 6-1 below. The method for conversion and the calibration data used are given in the first part of Appendix E.

6.4.1.4 Note that the field strength of the fundamental is +116 dBuV/m.

6.4.2 Harmonics

6.4.2.1 The field strength of all harmonics observed is given in the table. Note that the absolute field strength level for the 7th harmonic measured with the Biconical antenna and the Log Periodic antenna are essentially the same, giving credibility to the antenna factors and calibration values used to calculate the absolute signal strength.

6.4.2.2 The last column of Table 6-1 gives the ratio of the observed harmonic level to the level of the fundamental. Note that the second harmonic is 53 dB below the fundamental. The largest harmonic is the 6th at 46.5 dB below the fundamental. The other harmonics are lower and generally fall off with increasing order. The highest order harmonic observed was the 23rd at 84 dB below the fundamental. The frequency of this harmonic is above 1 GHz, and it seems unusual that the radar should be radiating frequencies this high.

Table 6-1 University of Colorado VHF RADAR Fundamental and Harmonics at RF Building				
	Freq		Vert E	Rato to Fundamental
Harmonic	MHz	Antenna	dBuV/m	dB
=====	=====	=====	=====	=====
1	46.29	Bicone	116.39	0
2	92.58	Bicone	62.97	-53.42
3	138.87	Bicone	57.47	-58.92
4	185.16	Bicone	61.15	-55.24
5	231.45	Bicone	58.40	-57.99
6	277.74	Bicone	66.46	-49.92
7	324.03	Bicone	47.19	-69.20
7	324.03	LP	47.39	-69.00
8	370.32	LP	52.87	-63.51
9	416.61	LP	50.46	-65.93
10	462.9	LP	58.38	-58.01
11	509.19	LP	39.58	-76.81
12	555.48	LP	58.22	-58.17
13	601.77	LP	40.81	-75.57
14	648.06	LP	49.18	-67.20
15	694.35	LP	44.11	-72.28
16	740.64	LP	38.94	-77.44
17	786.93	LP	37.57	-78.82
18	833.22	LP	36.77	-79.62
19	879.51	LP	40.44	-75.94
20	925.8	LP	36.70	-79.69
21	972.09	LP	31.87	-84.52
22	1018.38	LP	36.77	-79.61
23	1064.67	LP	32.72	-83.67

6.4.2.3 Figure 6-3 shows a plot of the magnitude of the harmonics relative to the fundamental versus frequency. The harmonic order is delimited by the label next to the data point. The figure shows that the 6^{th}, 10^{th} and 12^{th} harmonics are the strongest. The fact that the even order harmonics are stronger indicates the waveform is distorted more on one polarity than the other (e.g. saturating on the positive half cycle but not the negative half cycle).

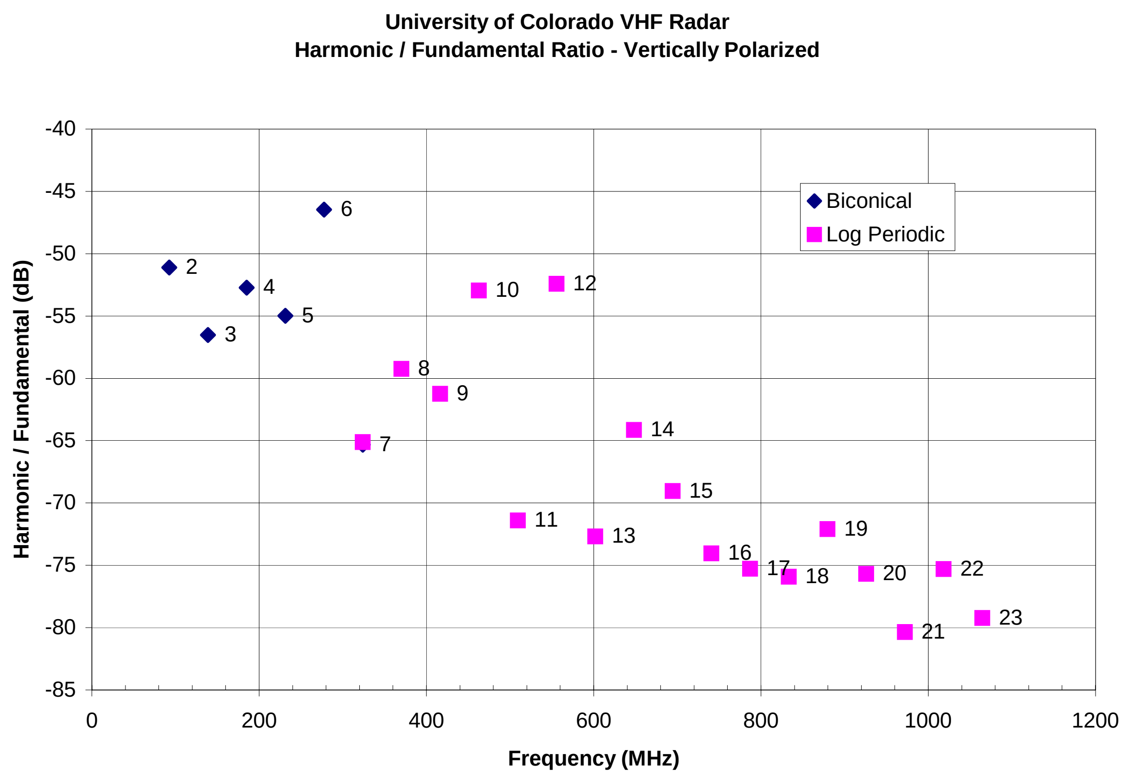

Figure 6-3 University of Colorado VHF RADAR Harmonic/Fundamental ratio versus frequency.

7 RADHAZ Zones for the TCI Antenna near Summer Camp.

7.1 Background

7.1.1 The last item in the SOW was to chart RADHAZ zones for the TCI-550 antenna at its proposed location near Summer Camp that might be used for backup voice communications. The maximum radiated energy from the transmitter is 1000 watts PEP.

7.1.2 This antenna is already installed and in use as a receiving antenna. It is an HF Conical Monopole located near the edge of Summer Camp (Figure 7-1). This antenna is marked “Receive Only, Do Not Transmit” on the patch panel connection in the Communications Center. However, the RADHAZ study was requested because this antenna is the tertiary backup for transmitting in case of an emergency. Since it is located close to a Summer Camp Jamesway residence, the operators (and residents) wanted to be sure there was no RADHAZ danger to personnel in the Jamesway in the event this antenna was used for transmitting.

7.1.3 This antenna is listed as Tower 9 on the drawings, but the antenna model is not identified. The feed of the antenna was covered in snow, and it was not possible to obtain identifying information from the antenna itself. The tower was estimated to be approximately 40 feet tall (Figure 7-2).

7.1.4 The distance from the center tower of this antenna to the closest point of residential Jamesway (J4) in Summer Camp is 90 feet. There is a diesel heater and diesel fuel tank located next to the Jamesway on the side closest to the antenna. The heater is in the plywood structure next to the Jamesway seen in Figure 7-2. The diesel fuel tank, partly covered by snow, can be seen on the right of the plywood structure in the picture. The distance from the center tower of the antenna to the edge of the fuel tank is also 90 feet.

7.1.5 Discussions with the communications operators indicated that three main HF frequencies are used for transmitting, 4,077 kHz, 8,088 kHz, and 11,553 kHz. They also indicated that the highest frequency used would be less than 16,000 kHz.

7.2 Measurements

7.2.1 NARDA model 8718B Radiation Hazard field strength meters were a part of the equipment taken to the South Pole. These meters use a thermocouple to obtain accurate signal strength readings, and the thermocouple would not stabilize in the -20°F outdoor temperatures. Instead, a plan was developed to use the wideband monopole without its amplifier. The monopole was to be calibrated at a point relatively distant from the antenna by measuring with and without the amplifier. This required transmitting CW with the transmitter. Unfortunately, the transmitters would not operate in that mode, and the measurements had to be scrubbed. The alternative approach is to perform a predictive analysis.

7.3 Radiation Hazard Limits

7.3.1 The radiation hazard standard used is US IEEE C95.1 1999 (reference 1.2.9). This standard gives Maximum Permissible Exposure (MPE) limits for Electromagnetic (EM) fields in the frequency range 3 kHz to 300 GHz. There are two types of areas identified for application of these standards, controlled areas and uncontrolled areas. The MPE limits for uncontrolled areas, where personnel are not aware of their exposure, are lower (more restrictive) than for controlled areas. The residential area of the Jamesways fits the category of an uncontrolled area.

7.3.2 The MPE is given in terms of the maximum electric field (E field) and the maximum magnetic field (H field) to which personnel can be exposed. A limit on induced and contact body current is given as well. In the HF frequency range the MPEs are frequency dependent. The E and H field MPE limits are given in Table 7-1 and plotted versus frequency in Figure 7-3. At South Pole Station, the body current limit has been ignored because there is no conducting ground to provide a current path.

Figure 7-1 Tower T9 Conical Monopole near Summer Camp

Figure 7-2 Base of T9 near Summer Camp

Table 7-1 Maximum Permissible Exposure Limits (IEEE C95.1 1999)		
Frequency	Electric Field (V/m rms)	Magnetic Field (A/m rms)
3 – 30 MHz	823.8/f MHz	16.3/f MHz
	Current (mA rms)	
	Through both feet	Through each foot
.1 – 100 MHz	90	45

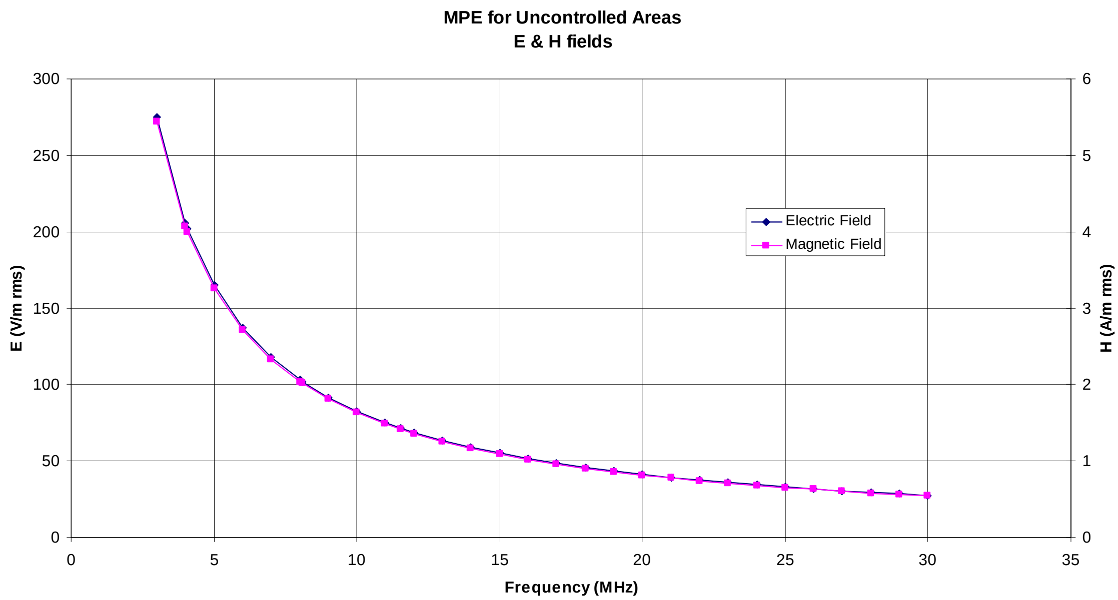

Figure 7-3 Maximum Permissible Limits for EM field exposure, uncontrolled areas

7.3.3 Note that the exposure limits for E and H fields fall off as frequency increases. In general higher frequencies require more separation from the transmitting antenna to remain below the RADHAZ limits. From the chart above the limits at 16 MHz are $E \leq 50$ V/m and $H \leq 1$ A/m.

7.4 Calculation

7.4.1 A simple calculation was done using MININEC (Paragraph 1.2.12) for a one-quarter-wave monopole above a perfectly conducting ground plane at two frequencies, 4.77 MHz and 16.0 MHz. The Electric and Magnetic fields were calculated as a function of distance and normalized by the MPE as given in Table 7-1 and Figure 7-3. The results of the calculations are given in Figure 7-4. From this figure, it is seen that for a given frequency, the electric field is the determining factor requiring greater distances from the antenna to keep the field below the MPE limit. Also, the figure illustrates the fact that the limiting distance increases with frequency.

7.4.2 For the two cases shown, the 16 MHz electric field limit is controlling, meaning it requires the greatest distance from the antenna to ensure that the fields are below the MPE. For a quarter wave monopole at 16 MHz, the figure shows that distance is only 4 feet. The actual antenna (conical monopole) is not resonant and will have reactive fields that tend to increase this distance. The fact that the antenna is not on perfectly conducting ground but snow, a lossy dielectric, will tend to decrease this distance. Also, the fact the feed point is covered with snow will reduce the efficiency of the antenna, which also tends to reduce the fields and hence this distance.

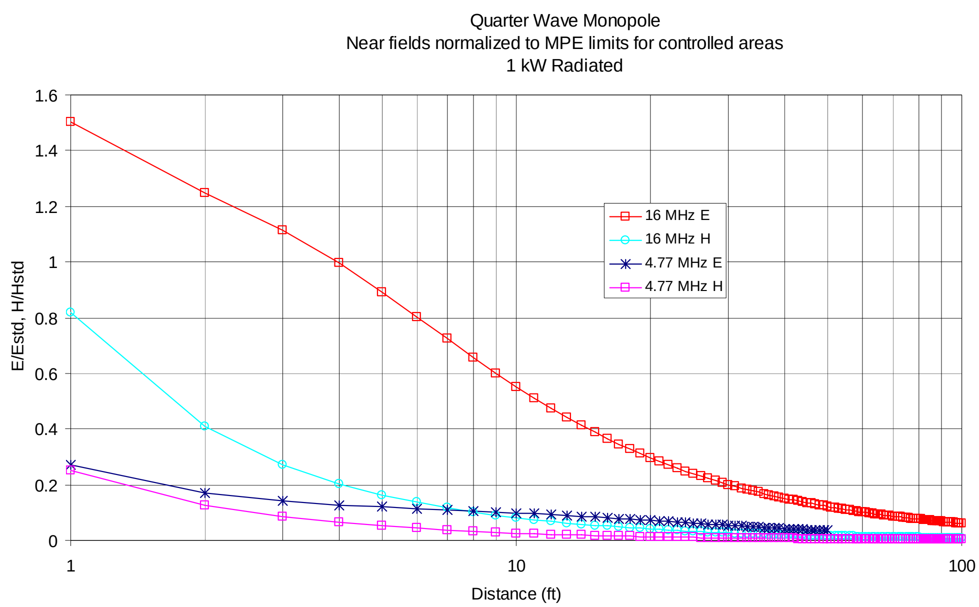

Figure 7-4 Quarter wave monopole near fields normalized to MPE, uncontrolled areas

7.5 Manufacturers Data

7.5.1 The manufacturer of the HF conical monopole is TCI in Fremont, CA. The manufacturer was contacted to identify the antenna model. The antenna was identified as a TCI mode 506-7N based on the pictures (Figure 7-1 and Figure 7-2) and the estimated height. This was consistent with information obtained from the South Pole inventory by communications personnel. The frequency range for this antenna is 4 – 24 MHz with a specified SWR of 2.5:1 or less. The tower height is 42 feet, and the width between guy anchors is 80 feet. It has a ground screen that is completely buried in the snow but no information is available about the ground screen.

7.5.2 Regarding potential radiation hazard, the manufacturer supplied an e-mail statement as follows (reference 1.2.13): “At an input power level of 1 kW or less, no fields will exceed ANSI standards for uncontrolled MPE at any frequency up to 16 MHz at any point more than 20 feet from the mast. This would be the case assuming 100% efficiency, a perfect reflecting plane and no burial in snow; in fact, the actual conditions will act to reduce the fields and give you some extra margin." The manufacturer's value of 20 feet is consistent with but greater than that indicated by the calculations of the previous section. The e-mail is included in Appendix B.

7.6 Hazard of Electromagnetic Radiation to Fuels (HERF)

7.6.1 NAVSEA/NAVAIR/SPAWAR OP3565 (reference 1.2.10) contains the criteria used to evaluate HERF. This document addresses the possibility of accidentally igniting fuel vapors by RF induced arcs during fuel-handling operations in proximity to high power transmitting antennas. The standard indicates that the flammability of fuels is dependent upon their volatility as well as the temperature and vapor pressure.

7.6.2 Diesel fuels, JP-5, JP-8 and kerosene are considered to be non-volatile fuels under normal temperatures. There are normally no HERF issues associated with these fuels since their vapor pressures are low enough that, under ordinary temperatures, there is virtually no chance of fire from RF-induced arc. Diesel fuel would not be flammable below 120 degrees Fahrenheit. Although there are usually no HERF issues associated with non-volatile fuels, a 50 feet minimum safe separation distance is recommended between the transmit antenna and fueling/fuel-handling operations.

7.6.3 The Jamesway heaters use diesel fuel (JP-8). The HERF standard indicates there is no HERF issue for diesel fuel because it is not volatile, especially at low temperature. The Jamesway heater and fuel container are more than 50 feet from the conical monopole antenna, and there are no HERF issues involved with transmitting from this antenna.

7.7 Conclusion

The residential Jamesway is located well beyond the distance within which RADHAZ would exist when transmitting from the conical monopole denoted Tower 9 at the South Pole Station. It is also beyond the recommended distance for the HERF criteria. The conclusion is that there are no RADHAZ or HERF issues for personnel occupying the Jamesway should this antenna be used for transmitting. The conclusion for RADHAZ is based on IEEE standard C95.1 1999 (1.2.9) and a transmitter power of up to 1 kW at any frequency up to 16 MHz. Under the same criteria, even when transmitting, personnel could approach the antenna to within 20 feet of the central tower without concern for RADHAZ.

8 Other EMC/EMI Issues

8.1 VLF Transmitter

8.1.1 Stanford University was in the process of activating a VLF transmitter beacon during the South Pole Station survey. The antenna is a 7 km long resonant dipole elevated approximately 10 feet above the surface of the fern. It is located in the dark sector approximately parallel to the skiway with the feed point about 2 km away from the MAPO building. The transmitter consists of an 8 kW solid state amplifier, but the signal has a low duty cycle transmitting an unmodulated CW signal on 19.3 kHz for 1 minute out of every 15 minutes. The VLF transmitter signal was examined using the spectrum analyzer and a loop antenna at the site in the MAPO area. However, the transmitter was not fully operational, and no measurements of the signal with the transmitter at full power were made. At low power, the fundamental was observed, but no harmonics were evident.

8.1.2 There was an interference problem reported involving the VLF signal and the Antarctic Muon and Neutrino Detector Array (AMANDA). The SPAWAR team was not involved in this problem except by discussion. The following is a description of the problem based on those discussions.

8.1.3 The original neutrino detectors are photo-multipliers buried in the ice and connected back to the signal processing - data recording system via unshielded twisted pair transmission lines. The VLF transmission results in an interference signal that appears on the photo-multiplier lines. Some of the newer photo multipliers are fed back to the instrumentation via fiber optic lines. These do not have any interference from the VLF signal.

8.1.4 The interfering VLF signal arises due to induction of a common mode voltage signal on both lines of the twisted pair. The twisted pair is input into a balanced instrumentation amplifier that would normally eliminate the common mode interference. However, one side of the twisted pair carries 1 kV DC which supplies the power to the photo-multipliers. A blocking capacitor is used at the input to the instrumentation amplifier to keep this voltage out of the amplifier input. This configuration unbalances the amplifier input impedance deteriorating the common mode rejection. This interference can be reduced by balancing the amplifier input through the use of symmetrical blocking capacitors or the addition of a transformer.

8.2 Wideband HF Noise

8.2.1 The survey team was were made aware of a wideband HF noise issue at the South Pole following their return by an e-mail dated March 12, 2003 (reference 1.2.14). This noise was observed in the HF band during the summer of 2001-02. A spectrum plot that was included in the reference is given below as Figure 8-1. The figure shows that the noise is fairly broadband below 4 MHz. It is periodic having peaks about every 50 kHz. The duty cycle is approximately every 10 minutes and they did some rough direction finding indicated the source was somewhere near Summer Camp. The interference disappeared during times when the rod well was turned off, which indicates it is probably due to the rod well pump.

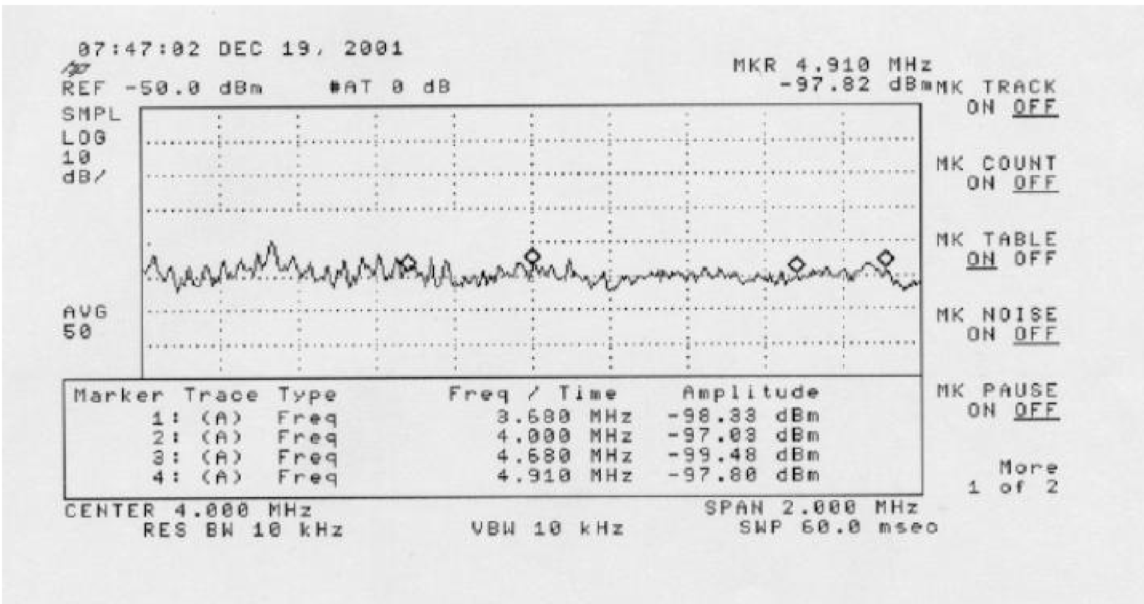

Figure 8-1 Spectrum of HF noise observed during summer 2001-02.

8.2.2 As discussed in section 4, the 24 Hour wide band spectrum recordings were taken at the RF building. These have been plotted as spectrograms, which are given in Appendix E. Four of these spectrograms have been repeated below as Figure 8-2 RF WB1 Band 3 (dBuV/m) through Figure 8-5. These are the spectrograms for sweep WB1, bands 3 - 6, which cover the frequency range from 1 to 5 MHz.

8.2.3 Examination of these figures reveals wide band noise that occurs intermittently during the 24-hour period monitored. This noise appears as horizontal lines of increased level in each of the bands shown. There are some 18 occurrences of these noise bands at various times during the 24-hour period. Some appear to have longer duration than others, although this could be deceiving, since the dwell time for the recording was only ½ minute out of 12 minutes. Note that this noise occurs less frequently at night.

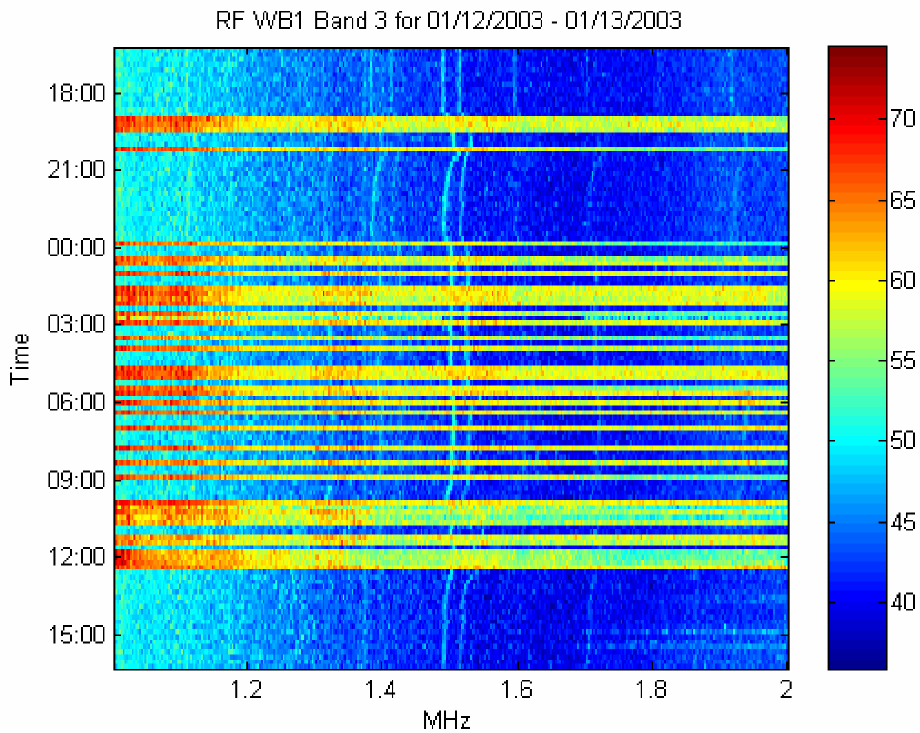

Figure 8-2 RF WB1 Band 3 (dBuV/m)

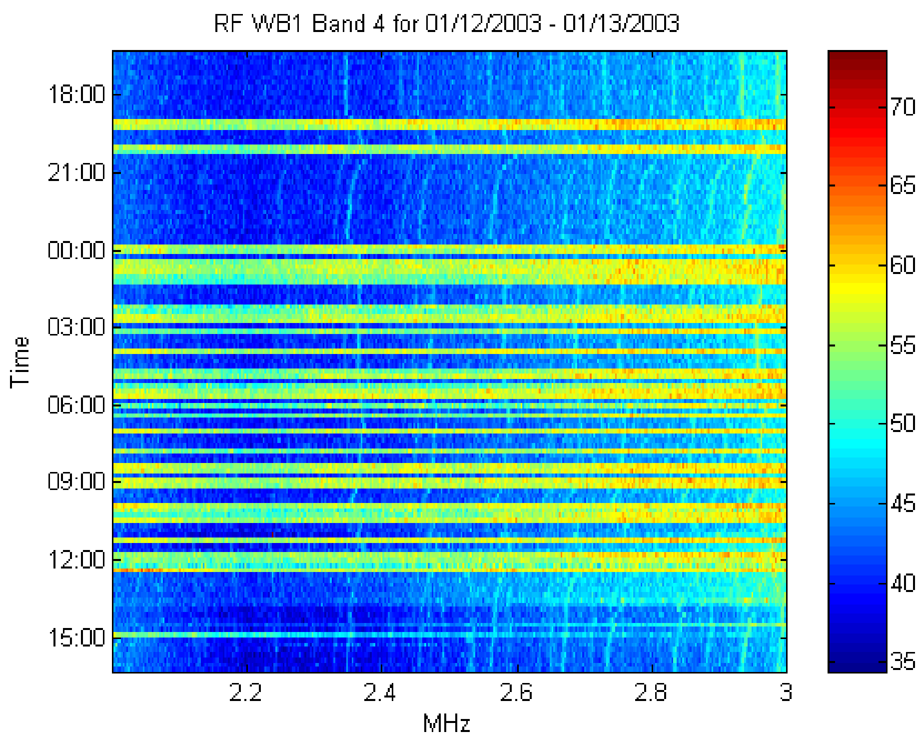

Figure 8-3 RF WB1 Band 4 (dBuV/m)

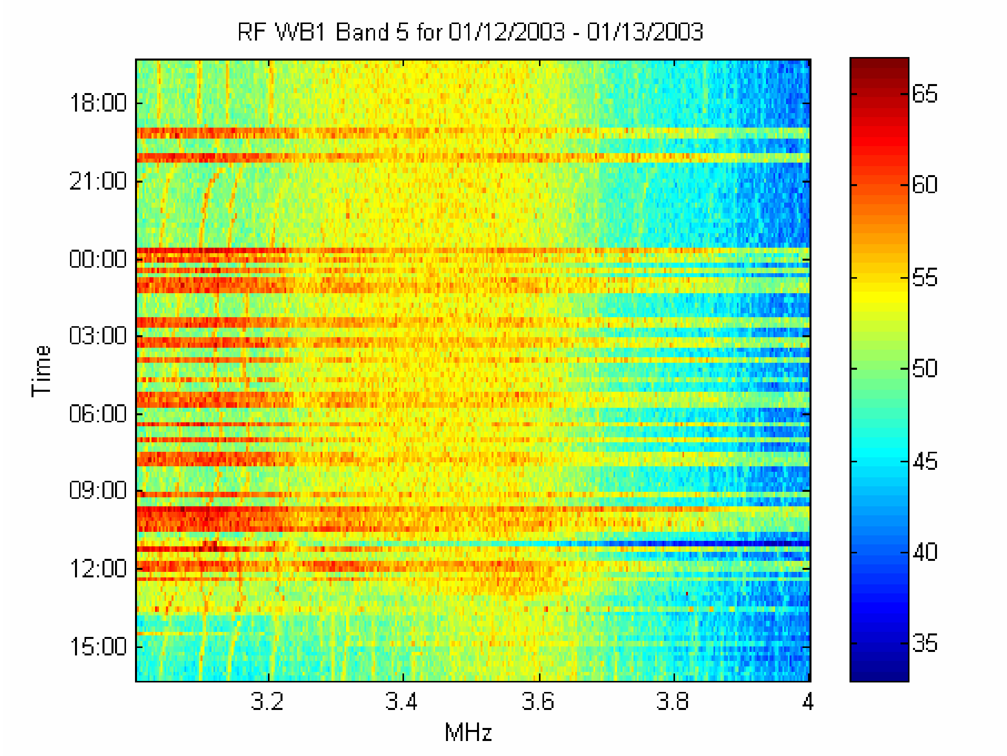

Figure 8-4 RF WB1 Band 5 (dBuV/m)

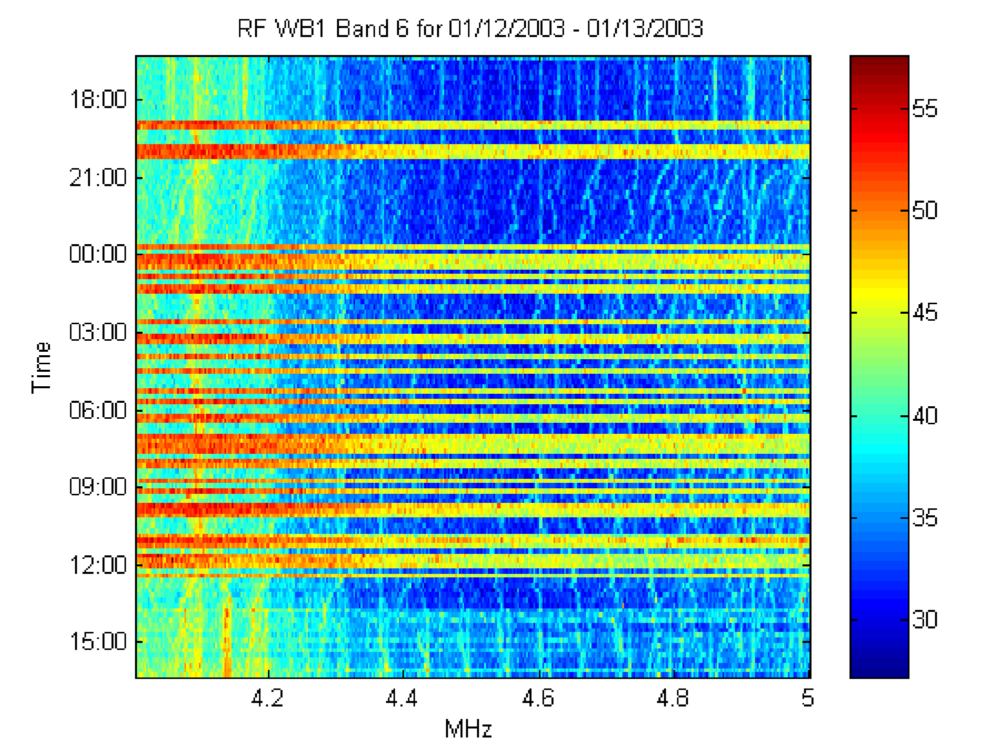

Figure 8-5 RF WB1 Band 6 (dBuV/m)

8.2.4 The figures show that this wideband noise has spectral peaks at about 1 MHz, 3.1 MHz, and 4.1 MHz. This noise can be seen as high as 12 MHz (RF WB1, Band 13, Appendix E). It is also evident down to 50 kHz (RF WB1, Band 2, Appendix E). Also, note in Figure 8-4 there is another wide band noise source, present all the time. Most of its power lies between 3.2 MHz and 3.6 MHz, and it is not as strong as the intermittent source.

8.2.5 The intermittent wideband noise in the spectrograms shown has characteristics similar to that discussed in reference 1.2.14 and is probably due to the same source. The time sequence of the interference may help identify the source.

9 Summary and Conclusions

This document reports the South Pole portion of the Antarctic EMI/EMC survey performed during January/February 2003. This task involved monitoring the effects of electromagnetic radiation on selected electronic equipment and systems under the cognizance of the National Science Foundation at both McMurdo Station and Amundsen-Scott South Pole Station. SPAWARSYSCEN Charleston tasked SPAWARSYSCEN San Diego to participate in the South Pole Station portion of this effort. Only the South Pole efforts are reported here.

9.1 South Pole Marisatt/Goes Terminal Interference

9.1.1 The objective of this task was to determine the source of the interference to the SPM/GT terminal downlinks.

9.1.2 The interference had not been observed in at least a year. Nevertheless, these downlink frequencies were monitored for a 24-hour period at the RF building. Statistical analysis of this data revealed one possible low level interfering signal that was present at least 80% of the time in the Goes band at 1687.5 MHz.

9.2 Satellite Uplink Signal Strength at MAPO

9.2.1 The objective of this task was to measure the absolute level of the signal strength from the SPM/GT terminal uplink transmitters in the vicinity of the MAPO building.

9.2.2 The magnitude of the Marisat, Goes, and TDRS satellite uplink signals was measured at the MAPO building. The signal strengths varying as the dish moved to track the satellite. The Marisat signal was the strongest, with a maximum observed level equal to +80 dBuV/m, in close agreement with the level predicted.

9.2.3 Other signals were examined within the 1-2.5 GHz band at MAPO. In this frequency range, TACAN on 1.19 GHz was the strongest signal at +85 dBuV/m. The second harmonic of TACAN was also observed. Intermittent low level signals were observed in the range just above 1 GHz and in the ISM band between 2.4 and 2.5 GHz.

9.2.4 The shuttle van generated strong impulsive ignition noise when it was nearby. Snowmobiles and possibly LC-135s were also observed to generate impulsive noise to a lesser extent. Noise suppression ignition systems should be installed on the shuttle van, snowmobile and other gasoline combustion engines operated at South Pole Station.

9.3 Wide Band RF Spectrum Record

9.3.1 The objective of this task was to provide a record of the RF spectrum for use as comparison following the communications system upgrade.

9.3.2 The spectrum from 10 kHz to 22 GHz was recorded over a 24 hour period at both the RF building and the MAPO building. The results were processed to display spectrograms showing the signals present during that period. A brief snapshot of this same spectrum was taken at SPRESO site, and spectrum plots are given showing signals observed. There are many unidentified signals shown in the spectrums and spectrograms given in Appendix E.

9.4 Low Frequency Measurements

9.4.1 The objective of this task was to record the spectrum from 1 Hz up to 10 kHz.

9.4.2 Stanford University had already made records of the spectrum starting at 500 Hz. To complement these measurements, the spectrum was recorded from 1 Hz to 850 Hz at several locations, including 7 sites where Stanford made their measurements.

9.4.3 Unfortunately the magnetometer cable was discovered to be broken upon return to the states. Comparison with the Stanford data and other tests to determine the validity of the data were not conclusive, but indicated the data may be okay. They are included in Appendix F.

9.5 University of Colorado VHF RADAR

9.5.1 The objective of this task was to measure the out of band emissions from the University of Colorado VHF Meteor Radar.

9.5.2 The measurements were taken at the RF building, close by the radar site. A large number of harmonics were observed up to the 23rd, corresponding to 1.018 GHz. Many of the even harmonics were stronger than the odd harmonics.

9.6 RADHAZ Zones for the TCI Antenna Near Summer Camp

9.6.1 The objective of this task was to measure the RADHAZ zones around the TCI conical monopole located near the summer camp housing area.

9.6.2 Measurements were not taken due to equipment difficulties on site. Upon return, the manufacturer identified the antenna from pictures as a TCI-566-7N. The manufacturer provided a written email indicating that, based on IEEE C95.1-1999, RADHAZ does not exist for distances greater than 20 feet from the tower with 1 kW input power for frequencies below 16 MHz. The nearest summer camp building is well beyond that. Also, there are no HERF issues when using this antenna for transmitting.

9.6.3 This antenna can be safely used for transmitting without concern for RADHAZ to the occupants of the nearby Jamesway or HERF involving the diesel fuel container just outside the Jamesway.

9.7 Other EMC/EMI Issues

9.7.1 Two additional items not in the SOW were examined briefly. The first issue involved interference to the AMANDA neutrino detector array by the new Stanford University VLF transmitter. The SPAWAR team was not involved with this problem except by discussion. These discussions indicated that there is a VLF signal induced on the unshielded twisted pair cables used to connect to the buried neutrino detectors to the instrumentation. The interference is exacerbated by the fact that the input to the recording instrumentation amplifiers is unbalanced. Some methods to balance the input and reduce this interference are discussed in the report.

9.7.2 The second issue involved broadband HF noise that had been observed near Summer Camp during the summer season of 2001-02. That report indicated that the noise occurs coincidental with operation of the rod well pump, indicating the pump motor as the probable cause.

9.7.3 The 24-hour spectral records taken at MAPO, RF Building and SPRESO were examined for evidence of this broadband interference. The RF building is the closest site to Summer Camp. The spectral record there contains strong broadband interference that occurred intermittently. This noise appeared less frequently during a few hour time period after midnight local time. This noise has three spectral peaks occurring at about 1 MHz, 3.1 MHz, and 4.1 MHz. This noise was much weaker in the MAPO data and no evidence of this noise was seen in the SPRESO data.

9.7.4 The intermittent wideband noise in the spectrograms for the data taken at the RF Building has characteristics similar to that discussed in reference 1.2.14 and is probably due to the same source. The time sequence of the interference may help identify the source.

Appendix A Original SOW

Statement of Work
Code 323 EMI/EMC Technical Events
Antarctica FY03
(Final 7-17-02)
(Prioritized, with comments, South Pole Only)

This Statement of Work (SOW) defines the requirements for monitoring the effects of electromagnetic radiation of selected electronic equipment and systems under the cognizance of the National Science Foundation. This effort will involve travel to Antarctica, including McMurdo Station and Amundsen-Scott South Pole Station during the 2002/2003 Austral Summer Operating Season, between 01/05/03 – 02/05/03. The work effort will involve the evaluation of equipment installations and on site analysis of EMI and EMC.

As the technical event will be constrained by schedule and/or budget, the task lists below are organized in priority order per site. The technical event will have two distinct schedules, one for South Pole Station and the other for the McMurdo region. Actual on-site dates at South Pole depend on the availability of housing and transportation. As a result the McMurdo schedule may be split into two phases in order to accommodate variances in the Pole schedule.

**Code 323 questions and requested information denoted in red

**Information known about tasks denoted in blue

Amundsen-Scott South Pole Station:

1. Find the source of L-Band interference in the SPM/GT (South Pole Marasitt/Goes Terminal) downlink passband (South Pole). What are the characteristics of the EMI? Is it intermittent or regular? Is it mild, medium, or severe? How is it manifested?

2. Measure and provide baseline emitted radiation reference levels for the SPTR (South Pole Tedris Relay) and SPM/GT earth stations at the MAPO building in the Dark Sector.
    a. This is a spectrum occupancy survey What frequency bands need to be monitored?

3. Measure and provide baseline emitted radiation reference levels HF background at five selected locations, including 3 Dark Sector sites, at South Pole Station in the USAP frequency bands.
    a. This is a spectrum occupancy survey What frequencies need to be monitored, or do they want from 2 - 32 MHz?

4. Measure and identify ELF out-of-band emissions at South Pole.
    a. What are the ELF operating frequency bands? What ELF frequency bands need to be monitored? What are the suspected sources of the ELF emissions. Why are they interested in this data?

5. Measure and identify VHF/UHF out of band emissions of the U. Colorado meteor radar located at the RF Building.
    a. What are the VHF/UHF operating frequency bands?

6. Measure and provide baseline emitted radiation reference levels for at least five locations in the Quiet Sector, including the South Pole Remote Earth Observatory (SPRESO) site. SPRESO is a seismic monitoring station located about 7km distant from the station.
    a. This is a spectrum occupancy survey What frequency bands need to be monitored? What other locations?

7. Chart RADHAZ zones for TCI-550 antenna in its proposed location near Summer Camp to be used for backup voice communications. Maximum radiated energy from transmitter will be 1000 Watts PEP.
    a. This system is presently installed. It has not been operated because the people at Summer Camp was concerned about it being located so close to Summer Camp.
    b. Requests that we perform a HERP survey to determine if the system will be a problem at Summer Camp.
    c. Please submit the parametric data for the TCI-550 antenna and transmitter.

Note:

A. Please submit the parametric data for all transmitters and receives operating at McMurdo and the South Pole sites. This will allow us to perform EMC/EMI analysis.

B. Need a designated vehicle at both sites and a POC to coordinate tasks at the sites

C. Code 323 requests that the diesel power supplies be made available at McMurdo and South Pole sites

Appendix B Reference Emails

From: Powell, Nick (South Pole) [mailto:Nick.Powell@spole.gov]
Sent: Wednesday, November 20, 2002 10:24 PM
To: 'Peebles, Mike'; 'chamcj@pacbell.net'
Cc: McAfee, Bill (South Pole); Mendoza, Felix (Denver); Wisch, Michael (Denver); Sullivan, Paul (South Pole); 'Rushing, Matthew E'; SMITH, PATRICK; Brooks, Daniel (Denver); Grant, BK (South Pole); Delore, Richard J (McMurdo); Dunbar, Stephen (Denver)
Subject: RE: South Pole EMI Visit

Mike & Craig,
Here is our response to the questions.

1. Who will be the POC at South Pole?
Bill McAfee - Primary
Nick Powell - Secondary
Tel: (303) 790-8606 ext 62803 (VOIP phone when the satellite is up)
(808) 659-2608 (Iridium - available 24 hours a day)
ext 240 & 351 on station

2. Requested items - We will make every effort to accommodate EMI study personnel needs - thanks for the heads-up. Approximately how much weight and cube will the equipment have? We want to make sure we have adequate space and the right vehicle available.

3. Exactly where is SPTR located?
SPTR is located in the Elevated Dormitory, approximately 500 feet from the main station.

4. Do you have specific locations in mind for this task?
In addition to the comments below I would recommend the following locations:

a. Dark Sector Locations: 1. Near the AST/RO facility, 2. Beyond the Dark Sector Lab towards the VLF transmitter site, 3. Grid south of the SPASE 2 facility towards the end of the Skiway
b. Main Station Locations: 1. In the vicinity of the RF Bldg, 2. In the vicinity of ARO/Clean Air Building
c. If possible, it would be worth taking measurements at SPRESO (8 km from main station) and at a location half way between SPRESO and the main station. These are in the Quiet Sector.

See also Frequencies to be Monitored section below.

5. "Measure and identify VHF/UHF out of band emissions of the U. Colorado meteor radar located at the RF Building."

We concur with the recommendation to look at In-band emissions (~46 MHz). However, some initial looks when the experiment was first installed indicated their transmitter was very clean with no noticeable out of band emissions. This is probably a low priority task.

6. "Measure and provide baseline emitted radiation reference levels for at least five locations in the Quiet Sector, including the South Pole Remote Earth Observatory (SPRESO) site. SPRESO is a seismic monitoring station located about 7km distant from the station."

We believe 5 locations in the quiet sector might be excessive. Measurements taken at SPRESO, a midpoint between the main station and SPRESO, and ARO would suffice. Also this could be performed in conjunction with #4. See the frequency discussion below also.

7. Can the MacKay HF transceivers transmit CW?
We will have to do some checking on how to implement this, but there is a provision for CW transmission on the equipment front panel. What power level, and for how long is this mode desired?

8. For the ELF task, where are the experiments mentioned by Dr. Weatherwax being conducted?
We can not answer this question since we do not have the task descriptions. Could a copy of the taskings be forwarded to Bill and I at South Pole?

9. What is the location of the TDRSS transmitter?
The TDRSS transmitter is part of SPTR and located in the Elevated Dormitory

Comments on Frequencies to be monitored.
To get an effective baseline of the station's RF emission signature, if possible we would like to see 2 classes of measurements made at all measurement locations:

a. A sweep across the RF spectrum from 10 kHz to 22 GHz, perhaps broken up into reasonably sized bands. This should provide a baseline snapshot of the RF environment at the station for future comparisons when new transmitter sources are installed.

b. Detailed examination of bands surrounding authorized frequencies in VLF, HF, VHF, UHF, L-Band, S-Band, and Ku-band. Particular interest surrounds the 2.4 GHz ISM band. Dave Kroth should have a listing of authorized frequencies for the station.

Please contact us if you have any questions or need additional information.

Nick Powell
Bill McAfee

Hope this is of interest

-----Original Message-----
From: Powell, Nick (South Pole) [mailto:Nick.Powell@spole.gov]
Sent: Wednesday, November 20, 2002 10:24 PM
To: 'Peebles, Mike'; 'chamcj@pacbell.net'
Cc: McAfee, Bill (South Pole); Mendoza, Felix (Denver); Wisch, Michael (Denver); Sullivan, Paul (South Pole); 'Rushing, Matthew E'; SMITH,

PATRICK; Brooks, Daniel (Denver); Grant, BK (South Pole); Delore, Richard J (McMurdo); Dunbar, Stephen (Denver)
Subject: RE: South Pole EMI Visit

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b. Detailed examination of bands surrounding authorized frequencies in VLF, HF, VHF, UHF, L-Band, S-Band, and Ku-band. Particular interest surrounds the 2.4 GHz ISM band. Dave Kroth should have a listing of authorized frequencies for the station.

Please contact us if you have any questions or need additional information.

Nick Powell
Bill McAfee

Hope this is of interest

Subject: RE: Antarctic EMI

Date: Wed, 13 Nov 2002 11:15:09 -0500
X-MS-Has-Attach:
X-MS-TNEF-Correlator:
Thread-Topic: Antarctic EMI
Thread-Index: AcKBDyPRMSPNiORiTuiRD0ssvZqimwKICgVA
From: "Weatherwax, Allan" <aweatherwax@siena.edu>
To: "Peder Hansen" <peder@spawar.navy.mil>
X-OriginalArrivalTime: 13 Nov 2002 16:15:08.0967 (UTC)
FILETIME=[D5FD5B70:01C28B2F]
X-MailScanner: Found to be clean

Hello Peder,

Please do not hesitate to contact me if further information is required. Please note my new address and phone numbers below.

Best regards,
-Al Weatherwax

Prof. Allan T. Weatherwax
Siena College - Dept. of Physics
Loudonville, NY 12211-1462
Phone: 518.786.5089
Fax: 518.783.2986

DC (mHz range) - 1 Hz
Bell Laboratories - Lucent Technologies operate fluxgate magnetometers monitoring fluctuation in the Earth's magnetic field between DC (mHz range) and 1 Hz.

0.001 Hz - 20 Hz
Search coil magnetometers operated at South Pole Station provide information on wave activity in the 0.001 Hz - 20 Hz frequency range.

30 Hz - 30 kHz
Stanford University operates an ELF/VLF system at South Pole Station where continuous and synoptic and wide-band ELF/VLF measurements provide key information on the diverse range of wave activity in the Earth's ionosphere and magnetosphere.

10 kHz - 5000 kHz (5 MHz)
Dartmouth College operates passive LF/MF/HF radio receivers at South Pole Station monitoring auroral radio emissions.

20.5 MHz - 51.4 MHz
At South Pole Station, the University of Maryland operates broadbeam riometers at 20.5, 30, 38.2, and 51.4 MHz.

From: "Khalil, Kathy" <khalilk@spawar.navy.mil>
To: "Duffy, Frederick B." <duffyf@spawar.navy.mil>,
"Hansen, Dr. Peder M."
<peder@spawar.navy.mil>,
"Sandusky, Don" <sanduskd@spawar.navy.mil>
Subject: FW: South Pole EMI Visit
Date: Mon, 25 Nov 2002 10:58:55 -0500
X-Mailer: Internet Mail Service (5.5.2655.55)
X-MailScanner: Found to be clean

> ----------
> From: Weatherwax, Allan
> Sent: Thursday, November 21, 2002 5:06 PM
> To: Craig Chambers
> Cc: khalilk@spawar.navy.mil; pdsmith@mcmurdo.gov
> Subject: RE: South Pole EMI Visit
>
>
> Hello Craig:
>
> Perhaps it is best to provide you with a map of the various instruments.
> Below are links to maps of our Pole antennas, and more general
> information on our passive receivers etc.
>
> http://www.polar.umd.edu/UAPscience.html
>
> http://www.polar.umd.edu/spa_uap_instruments.jpg1
>
>
> * Measurements out near the VLF antenna would be useful. This antenna is
> located approximately 1-km from the dome, in the opposite direction of the
> dark sector. As you will see, several of the antenna arrays are located in
> this vicinity (the large imaging riometer array is buried). It would be
> interesting to see if noise levels fall off in this direction. It might
> also help characterize any EMI from the dark-sector instruments/station.
> We have been placing antennas further away from the dome to get out of the
> near field. It has helped, especially for the LF/MH/HF receiver.
>
> * The ELF-HF bands are the most important to our studies, as outlined in
> my last email.
>
> * A passive LF/MF/HF antenna will probably be placed out in the SPRESO
> building next year; the actual antenna will be another 1-2 km away from
> this remote station. Prof. Jim LaBelle will be at Pole in early December
> (he is the PI on this project).
>
> * I think the only instruments that might overlap in frequency with the
> meteor radar would be the riometers, which are at discrete frequencies

> between 20-50 MHz.
>
> Best regards,
> -AL

Date: Fri, 22 Nov 2002 13:05:03 -0800
To: Peder Hansen <peder@spawar.navy.mil>
From: Umran Inan <inan@nova.stanford.edu>
Subject: Re: South Pole ELF Survey
Cc: berto@nova.stanford.edu, Jeff Chang <jccchang@stanford.edu>,
Evans Paschal <epaschal@worldnet.att.net>
X-MailScanner: Found to be clean

Peder --- Yes, you can assume that we will do the ELF/VLF noise survey at Pole. On the other hand, since part of the motivation for the survey may be the fact that other experimenters are worried about interference from the Beacon Transmitter, it might be useful for you to do one too. In fact, we will not cover the ELF range that you cover (certainly not below 100 Hz), so it might be best if you could at least do a limited survey.
Thanks.
--Umran

Hi Umran,

Based on the info you sent me (below) your PhD student is going to do the South Pole ELF survey this season. Therefore, I would like to take it off my list, which already more than fills the time allotted. Is that OK with you?

Peder

At 08:00 AM 11/18/2002 -0800, you wrote:
Peder --- Yes, this is a survey that I initiated and intended to do at Pole last year, but could not get to it, since my stay there was cut short due to weather delays. I had carried down our "Hum Sniffer", with its 56-cm square loop (air-core) antenna, which can measure down to 1 microvolts/m in the 100 Hz to 20 kHz range, but could not get to it. I then left the equipment with the Science Tech there, and left a plan of measurement points (see attached), and she actually went out and did measurements. However, I believe something went wrong and the data is not any good. I think it was because she did not hit the "record" button twice on our rather strange TASCAM portable DAT recorder.

My PhD student Robert Moore is going down to Pole on Dec 16th (CHC-MCM) and he will carry the Hum Sniffer back in and will do this test. I am sure you will be able to talk to him about this there. He also knows a lot about VLF transmitters and has written our codes for demodulating their MSK etc., so I think you will enjoy talking to him.

I will arrive in early January and actually may get there before you so you and I and Robb can meet together. He probably will do the survey before the end of December, since our operation gets a lot busier in January. Thanks and best regards.

--Umran

Hi Umran, I'm working on info about the German station.

On another topic, one of the requirements for the EMI/EMC survey I'm leading at the South Pole is an ELF "out-of-band survey". Your name is mentioned as one of the principles. Do you know anything about this requirement?

At the moment our intent is to attempt to record spectrum in the ELF band (i.e. 30-300 Hz). I imagine your magnetometers are much more sensitive than our loops so it may be a waste of time. I'm trying to borrow a magnetometer from Jack Dea which may be better, at least at the low end. Anyway, if this requirement came from you let me know what you desire. we aim to please and will try to gather the data you want. Peder

Richard.Greene@Dielectric.spx.com	
Date	Thursday, March 6, 2003 9:33 am
To	peder@spawar.navy.mil
Subject	RAD HAZ ZONE: 20 feet

Dear Mr Hansen:

Thank you for the jpegs of the Model 506 antenna at the South Pole. Following is our statement about the radiation hazard zone surrounding this antenna:

At an input power level of 1 kW or less, no fields will exceed ANSI standards for uncontrolled MPE at any frequency up to 16 MHz at any point more than 20 feet from the mast.

This would be the case assuming 100% efficiency, a perfect reflecting plane and no burial in snow; in fact, the actual conditions will act to reduce the fields and give you some extra margin.

Hope this helps. We wish you all the best in your project "down there."

RR Greene
Director, Applications Engineering
Broadcast and Communications Division
TCI, a Dielectric Company
ph: 510 687 6218
fx: 510 687 6101
email: richard.greene@dielectric.spx.com

"Peder M. Hansen" <peder@spawar.navy.mil>

03/04/2003 01:41 PM

To: richard.greene@spx.com
cc:
Subject: Information Request

Hi Richard,

It was enjoyable to talk with you today. I have been working at SPAWAR Systems Center San Diego (and it's predecessors) for the past 32 years. The early part of that work involved HF and the latter part involved VLF work. I did some measurements on Dr. Tanner's Pan Polar antenna in Greece back in the early 80's before it was torn down. As a part of that we visited TCI and met with Dr. Tanner.

As per our conversation today, I recently returned from the South Pole where we did an EMC/EMI/RADHAZ survey. The RADHAZ survey involved what I believe to be a TCI model 506-7-N HF antenna (picture attached). The antenna is situated relatively close to a group of Jamesway tents used to house personnel during the summer known as "Summer Camp". Unfortunately we could not make the RADHAZ measurements while there partly because our equipment would not work in the cold and partly because they could not get the transmitter to operate in CW mode.

In order to complete this task it would be extremely helpful if TCI could provide us with the distance from the center tower such that the fields beyond that distance are always below the Permissible Exposure Limit (PEL) with 1 kW into the antenna at the 4 frequencies given in the table below. Note the PELs at each frequency for both E and H field have been determined from IEEE C95.1 1999 and are given in the table.

Frequency MHz	E field limit V/m	H field limit A/m
4.0	206	4.08
8.0	103	2.04
12.0	68.7	1.41
16.0	51.5	1.02

Your consideration in this matter will be most appreciated!!

Very Respectfully, Peder

-----Original Message-----
From: Rushing, Matthew E [mailto:rushingm@spawar.navy.mil]
Sent: Wednesday, March 12, 2003 1:27 PM
To: Duffy, Frederic Spawar
Subject: FW: South Pole EMI/EMC Issue with Science Community

Duffy,

Below is some email FYI about some stuff identified at South Pole

MATT RUSHING

SPAWARSYSCEN Charleston
ATS Systems Engineering
Code 362MR
Tel: (843) 218-5225
Mobile: (843) 452-2312
Fax: (843) 554-6511
DSN: 588-5225
rushingm@spawar.navy.mil

-----Original Message-----
From: Powell, Nick [mailto:Nick.Powell@usap.gov]
Sent: Wednesday, March 12, 2003 1:03 PM
To: SMITH, PATRICK; Leger, Dave
Cc: Mendoza, Felix; McAfee, Bill; Brooks, Daniel; Bacon, James; Ravenscroft, Don; Rushing, Matt; Peebles, Mike; Kroth, Dave; Roy, Andre; Wisch, Michael
Subject: RE: South Pole EMI/EMC Issue with Science Community

Pat and Dave,
During the 2001-02 summer we saw a noise source when doing some HF radio frequency spectrum monitoring. I've attached a spectrum analyzer plot which shows the noise. Note the sawtooth pattern in the lower half of the plot. This is the noise. It was a periodic, fairly broadband noise below 4MHz that had amplitude peaks about every 50 kHz. The duty cycle was on the order of ten minutes I believe. We did some rough DFing and idications pointed to something near Summer Camp but didn't follow-up on it then. I wanted to look at it this year but did not have the time. Hopefully this year's EMI study captured it. I'm curious, did Dartmouth give any indication of frequency or characterization of the interference?
Questions? Please get in touch.
Cheers
Nick

-----Original Message-----
From: Smith, Patrick D.
To: 'Leger, Dave'
Cc: Smith, Patrick D.; 'Nick.Powell@usap.gov'
Sent: 3/12/2003 7:05 AM
Subject: RE: South Pole EMI/EMC Issue with Science Community

Hi Dave:
The issue will most likely be arcing noise generated by pump motors or electrical contactors. This will generate a fairly intense broadband noise across the spectrum, with the greater noise occurring at the lower frequencies, which is where Dartmouth is operating.
I forgot to copy Nick Powell on this message, so I'm adding him to my reply to you so Nick can see the traffic.
Rgds,
Pat

-----Original Message-----
From: Leger, Dave [mailto:Dave.Leger@usap.gov]
Sent: Wednesday, March 12, 2003 8:42 AM
To: SMITH, PATRICK
Subject: RE: South Pole EMI/EMC Issue with Science Community

Thanks Pat - interesting. It would never have occurred to me to
associated
RF with the rodwell.

Dave
-----Original Message-----
From: Smith, Patrick D. [mailto:pdsmith@nsf.gov]
Sent: Wednesday, March 12, 2003 6:40 AM
To: 'bill.mcafee@usap.gov'; 'dave.leger@usap.gov'
Cc: 'don.ravenscroft@usap.gov'; 'andre.roy@usap.gov'; 'rushingm@spawar.navy.mil'; 'peeblesm@spawar.navy.mil'; 'kculin@ljt.com'; Smith, Patrick D.; Brier, Frank W.; Marty, Jerry; 'Daniel.Brooks@usap.gov'; 'David.Kroth@navy.mil'; 'michael.wisch@usap.gov'
Subject: South Pole EMI/EMC Issue with Science Community

Bill, Dave:
Here is a clip from the science section of the latest South Pole SITREP:
"AO-128-O Dartmouth: Noise that is constantly on the lower band of the Dartmouth instrument went away a number of times a few weeks ago. The times and durations of this improvement in data have are exactly coincident to turning off the Rodwell. An inspection of the Rodwell with RF noise interference in mind may produce a less noisy system."
Earlier in the report the SITREP says that the new Elevated Station sewer outfall was activated due to problems with the old Rodwell outfall. A clear assessment from the station as to what specific equipment/systems are suspected of causing the problem will be useful. Is this something that the winter-over comm techs can coordinate with the science techs and station operations? Once we find a cause-effect relationship it will be good to document the findings and the resolution and put on file. I would like for Dave Kroth at SPAWAR to get a copy for the USAP rf spectrum management files.
This is something that we should be mindfull of for both SPSM and routine South Pole operations.
Thanks,
Pat

Patrick D. Smith
Manager, Technology Development, Polar Research Support

National Science Foundation
Office of Polar Programs
4201 Wilson Blvd, Room 755
Arlington, VA 22230
Office Tel. (703) 292-7455   Fax (703) 292-9080
Email: pdsmith@nsf.gov
WWW: http://www.nsf.gov/od/opp/start.htm
http://www.polar.org
Information Technology on the Final Frontier
Wiring the Seventh Continent for Science

<<Low HF Noise Spec An.jpg>>

[] Low HF Noise Spec An1.jpg

Appendix C South Pole Frequency Assignments

Table C-1 South Pole Frequency Assignments

USAP Band Plan
South Pole Station

Freq KHz	Description	Max Power	Country	Location	Antenna Location
19.3	VLF Experimental			South Pole	
4719.5	US-5 Long Range Air/Gnd	k1	ANTR	South Pole	HF Ant Field
4771.5	US-17 Antartic Common	w500	ANTR	South Pole	HF Ant Field
5727.5	US-5 Long Range Air/Gnd	k1	ANTR	South Pole	HF Ant Field
6709.5	US-5 Long Range Air/Gnd	k1	ANTR	South Pole	HF Ant Field
7340	US-16 Antarctic RATT	k1	ANTR	South Pole	HF Ant Field
8999.5	US-5 Long Range Air/Gnd	k1	ANTR	South Pole	HF Ant Field
9007.5	US-17 Antarctic common	k1	ANTR	South Pole	HF Ant Field
9032	US-5 Long Range Air/Gnd	k1	ANTR	South Pole	HF Ant Field
9073	US-16 Antarctic RATT	k1	ANTR	South Pole	HF Ant Field
11156	US-16 Antarctic RATT	k1	ANTR	South Pole	HF Ant Field
11256.5	US-5 Long Range Air/Gnd	k1	ANTR	South Pole	HF Ant Field
1154.5	US-17 Antarctic common	w500	ANTR	South Pole	HF Ant Field
12098.5	US-16 Antarctic RATT	k1	ANTR	South Pole	HF Ant Field
13551.5	US-16 Antarctic RATT	k1	ANTR	South Pole	HF Ant Field
14761.5	Mars	k1	ANTR	South Pole	HF Ant Field
14805	US-16 Antarctic RATT	k1	ANTR	South Pole	HF Ant Field
Freq MHz					
46.1	U of CO Vert Radar	k10		South Pole	RF Building
126.2	US-7 Local Air/Gnd	W500	ANTR	South Pole	Dome
143	USB-1 Industrial/Disaster Cont	w50	ANTR	South Pole	Dome
148.56	GOES-3 Uplink		SPCE	ANTR	
401-405	Radiosonde Ground Station	w25	ANTR	South Pole	Balloon Inflation Facility
996	Radio Nav Land Station	k5	ANTR	South Pole	
1187	USA-1 Radio Nav TACAN	k1.5	ANTR	South Pole	Taxiway Loop
1537.0-1541.5	MARISAT downlink				
1636.5-1645	INMARSAT Uplink	w57.5	ANTR	ANTR	Elevated Dorm
1680	USA-5 Metrological Radio	w 0.3	ANTR	South Pole	
1682.1-1694.2	GOES-3 Downlink		ANTR	South Pole	
2039.6459	TDRSS Uplink	w10	ANTR	South Pole	Elevated Dorm
2071.1	GOES-3 Uplink		ANTR	South Pole	Elevated Dorm
2215	TDRSS Uplink	w10	ANTR	ANTR	Elevated Dorm
7195	Experimental	w12.5	ANTR	South Pole	
9080	Surveillance Radar	k150	ANTR	South Pole	

Appendix D South Pole Equipment List

Table D-1 Equipment List

Manufacturer	Model #	Item	SN
HP	8563A	ANALYZER,SPECTRUM	3110A00588
HP	35665A	ANALYZER, DYNAMIC SIGNAL	3124A00640
HP	8563A OPTION 026	SPECTRUM ANALYZER	3305A02393
NARDA	8718B	SURVEY METER	1590
NARDA	8718B	METER	1586
NARDA	8723	PROBE	11051
NARDA	8733	PROBE	7023
NARDA	8762	PROBE	7014
NARDA	8754	PROBE,ISOTROPIC	4024
AH SYSTEMS	AK-18G	ANTENNA KIT	NONE
ANTENNA RESEARCH	LPD-2010/RA	ANTENNA	127
HP	85901A	SOURCE,AC POWER	3052K02582
JCA TECHNOLOGY	JCA12-1110LN	LOW NOISE AMPLIFIER	1100
JCA TECHNOLOGY	JCA23-3052	LOW NOISE AMPLIFIER	102
HP	8447D	AMPLIFIER, DUAL 0.1-1300MHZ	1937A02572
HP	8350B	SWEEP GENERATOR	2933A13051
ETS-LINDGREN	HI-3702	CLAMP-ON METER	61542
ETS-LINDGREN	HI-4416	DIGITAL READOUT	107935
HP	8449B	PREAMPLIFIER	3008A00810
STODDART	92341-1	ANTENNA, HORN BASE	24
STODDART	91889-1	ANTENNA, HORN	27
HP	8562A	SPECTRUM ANALYZER	2741A01270
HP	8565E	SPECTRUM ANALYZER	3724A00715
AH SYSTEMS	AK-18G	ANTENNA KIT	NONE
MINI-CIRCUITS	ZHL-0812MNL-SMA	AMPLIFIER	D042402-11
ANTENNA RESEARCH	CPRA-118/B	ANTENNA,PARABOLIC	102
HP	8447A	AMPLIFIER	2123A05683
MICROPHASE	HT-70	HIGH PASS FILTER	503
HP	8447D	AMPLIFIER, DUAL 0.1-1300MHZ	1937A02572
HP	8449B	PREAMPLIFIER	3008A00810

Appendix E Wide Band Spectrum Record Data

E Wide Band Spectrum Record Data

E.1 CALIBRATION AND CONVERSION

E.1.1 The spectrum analyzer data were recorded as dBm versus frequency. The data were converted to incident electromagnetic field strength in dBuV/m using the following formula.

$$E \text{ dBuV/m} = V \text{ dBm} + 107 + AF + L1 - GA + L2 \qquad \text{Eq. E1}$$

Where E is the rms electric field strength in dBuV/m,
V is the spectrum analyzer reading in dBm,
AF is the antenna factor in dB 1/m,
L1 is the loss of the coax from the antenna to the amplifier,
GA is the amplifier gain and
L2 is the loss of the coax from the amplifier to the spectrum analyzer.

E.1.2 The term 107 arises from the combination of the conversion from dBm to dBV, which is -13 dB, along with the conversion from dBV to dBuV, which is +120 dB.

E.1.3 Antenna Factor

E.1.3.1 The antenna factor converts the antenna output voltage to electric field strength. The antenna factor units are 1/m. This factor is supplied by the manufacturer of the antennas in terms of dB per meter. Five different antennas were used for various portions of the wide band sweep measurements. They are listed in Table E-1 below. Note two different antennas were used for WB2. The ETS 3119B biconical antenna was borrowed from the station and only used for WB2 at SPRESO.

Table E-1 South Pole Antennas used for Wide Band Sweeps

Wide Band Sweep	Frequency Range	Antenna
=====	=====	=====
WB1	10 kHz - 25 MHz	SAS-200/550-1 active monopole
WB2	25 MHz - 300 MHz	SAS-200/542 biconical
WB3	25 MHz – 300 MHz	ETS 3110B biconical
WB3	300 MHz - 1 GHz	SAS-200/ 510 larger LP
WB4	1 GHz - 22 GHz	SAS-200/ 518 small LP

E.1.3.2 The antenna factor data as given by the manufacturer are shown in Figures E-1 to E- 3. The antenna factor for the active monopole is a constant (-4 dB 1/m) over the band from 10 kHz to 100 MHz. Interpolation tables were developed for these antenna factors to calculate the antenna factor at any frequency within its band. The antenna factor for the small Log Periodic (LP) is quite smooth and for that a simple formula was developed.

E.1.3.3 The interpolation tables and formula were used in a Matlab program to convert the data to dBuV/m and plot it versus frequency. The manufacturer's data points, which were also used for he interpolation tables, are shown in the figures. The curve labeled "calculated" in Figure E-3 is a plot of the formula fitted to the data for the small LP. Note that in this figure the data points above 18 GHZ were extrapolated and the curve fit to those points.

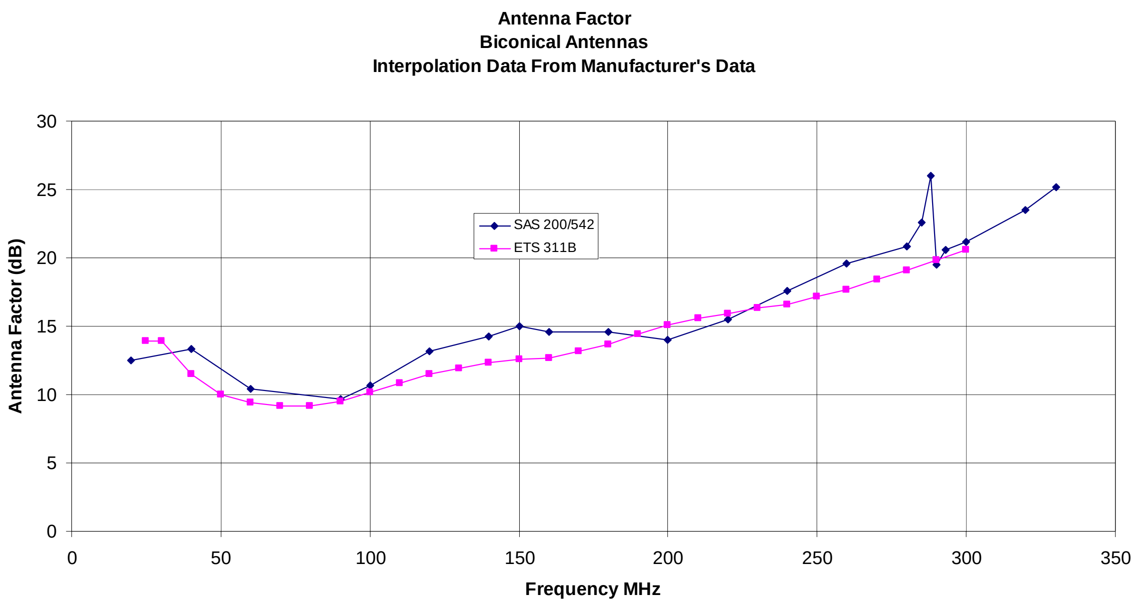

Figure E-1 Biconical Antenna Factors

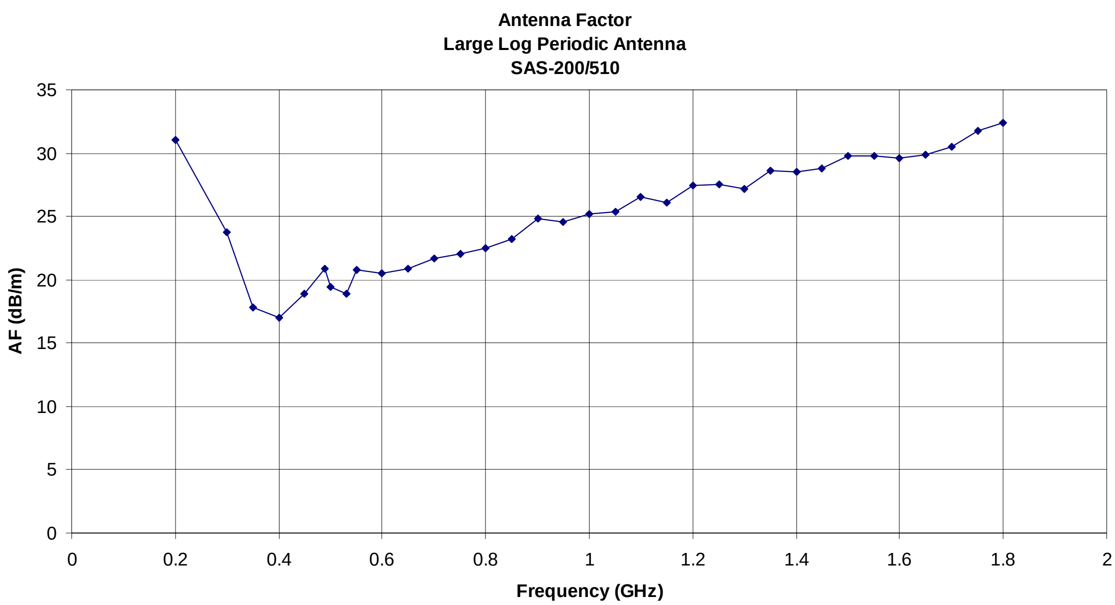

Figure E-2 Large Log Periodic Antenna Factor

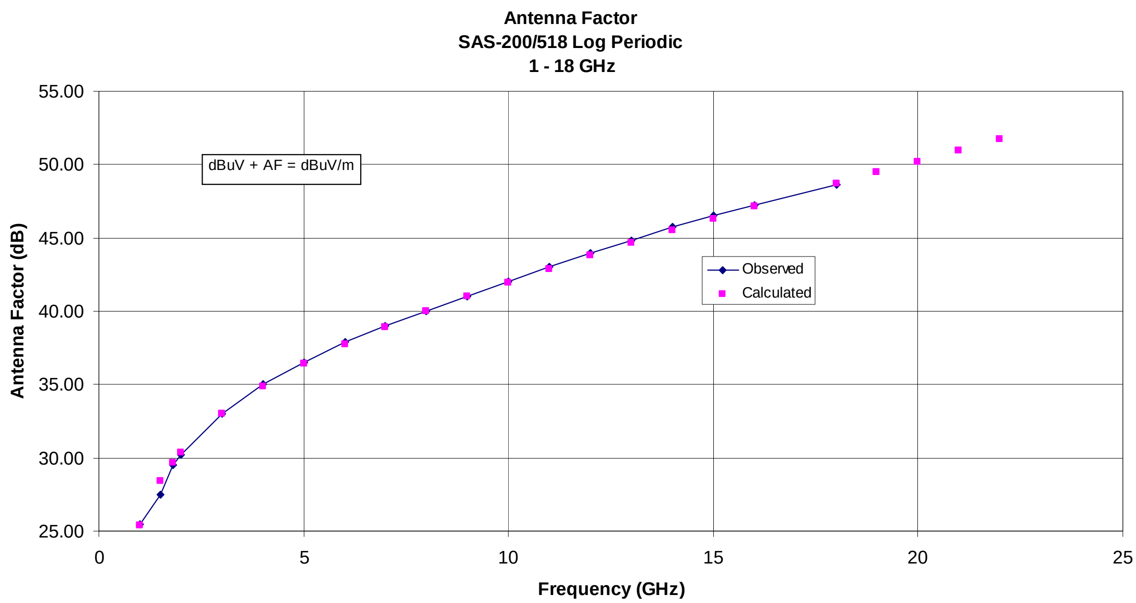

Figure E-3 Small Log Periodic Antenna Factor

E.1.4 Cable Attenuation

E.1.4.1 There were several pieces of coaxial cable used to connect the antenna, amplifier and spectrum analyzer. The loss in these cables as a function of frequency was measured, and simple formulas developed to calculate this loss were used in the Matlab program to convert and plot the data. Table E-2 below lists the coaxial cables used at the South Pole. The cable losses correspond to L1 and L2 in Equation E1.

Table E-2 Cables & Filters

A2	High Pass Filter
A4	Short Green Cable 3’ LL-142
A6	Silver Cable 17’ RG-55
A9	Long Black Cable 30’ RG-58
A11	Long Green Cable 50’ LL-142
SB22	Short Black Cable 7’ RG-58

E.1.4.2 The measured calibration data and the corresponding formulas developed for the conversion process are shown in the Figures below. Note that the high pass filter and the short green cable calibration data are included. They were not used for the wide band sweeps, but they were used for the University of Colorado radar spectrum measurements and the satellite ground station signal strength measurements at the MAPO building.

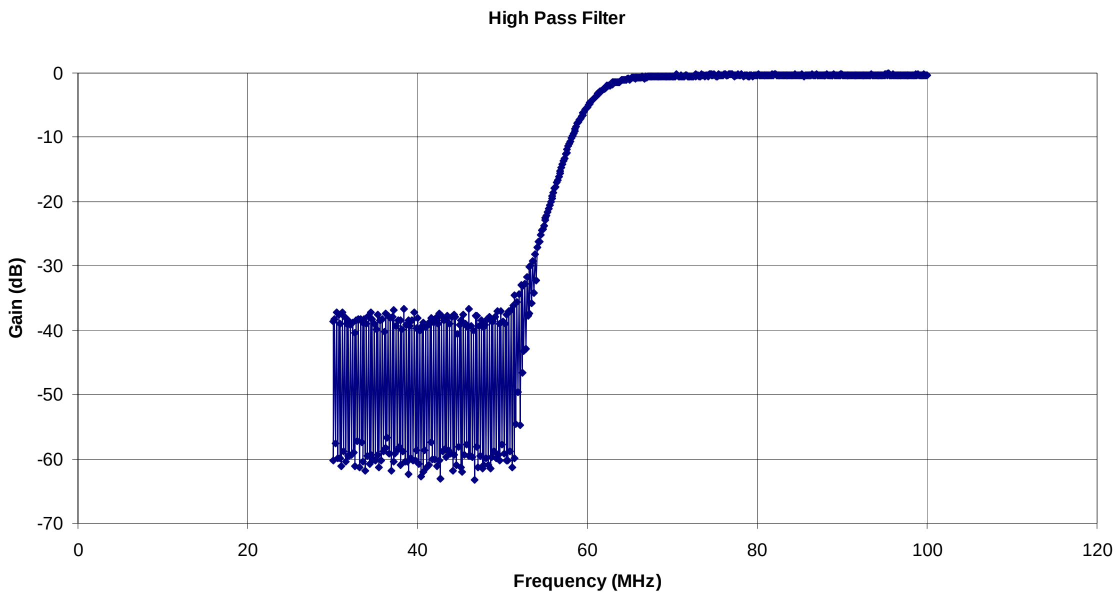

Figure E-4 High Pass Filter (A2) Gain versus Frequency

E.1.4.3 The high pass filter has more than 40 dB attenuation at the fundamental frequency (46.28 MHz) of the University of Colorado radar and an insertion loss of approximately 0.1 dB at all the harmonics.

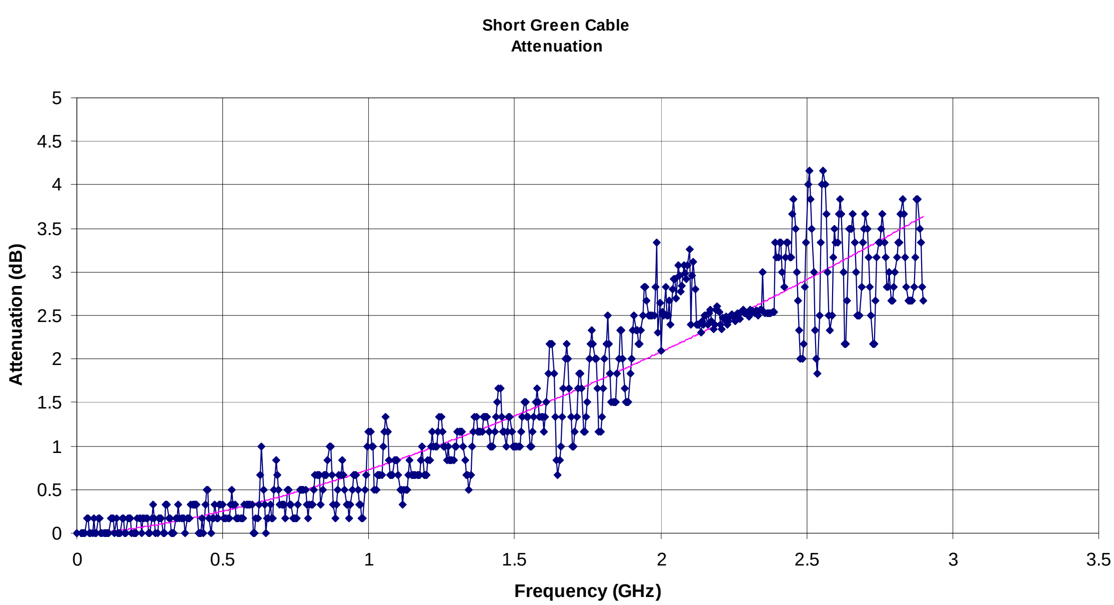

Figure E-5 Cable A4 Attenuation versus Frequency

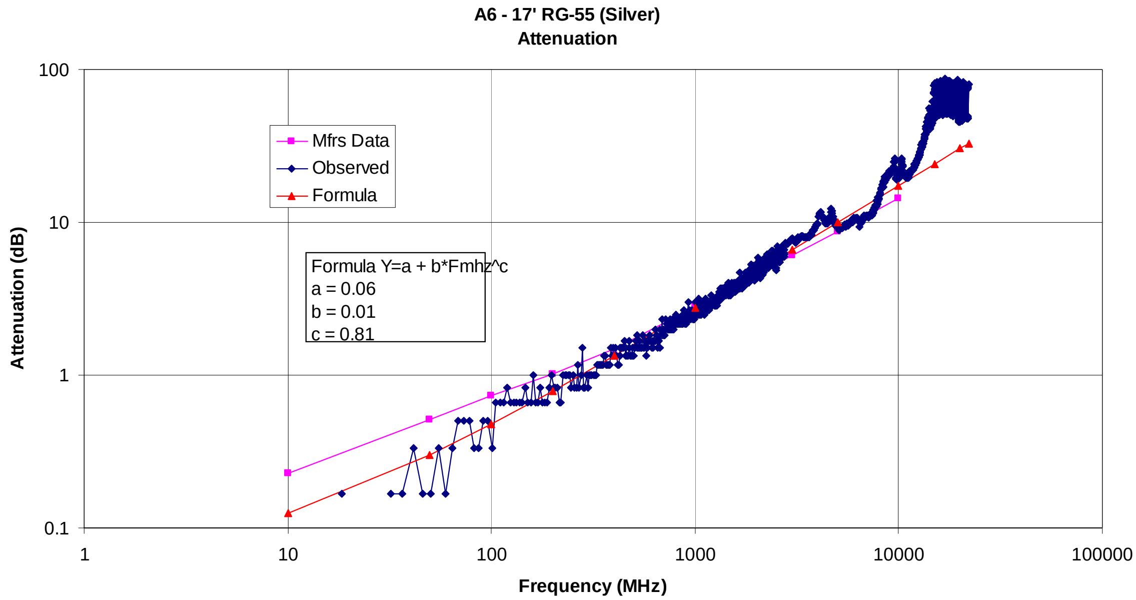

Figure E-6 Cable A6 Attenuation

E.1.4.4 The cable A6 was used in the WB4 sweeps, which went up to 22 GHz. However, the cable loss increases rapidly with frequency above 10 GHz, and it is unlikely that any signals above 10 GHz would be detected.

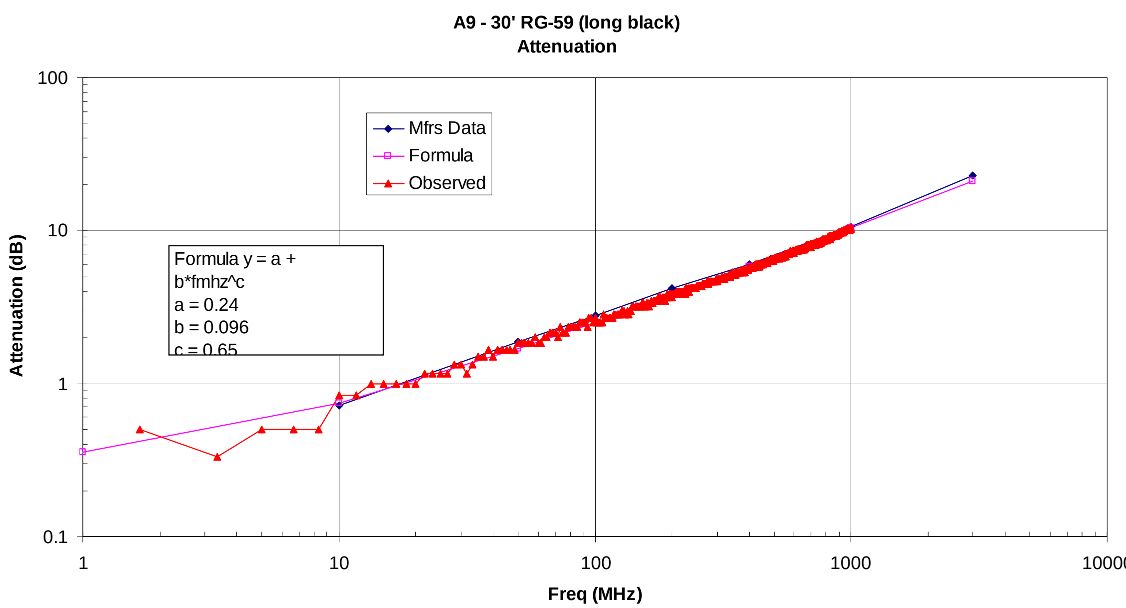

Figure E-7 Cable A9 Attenuation

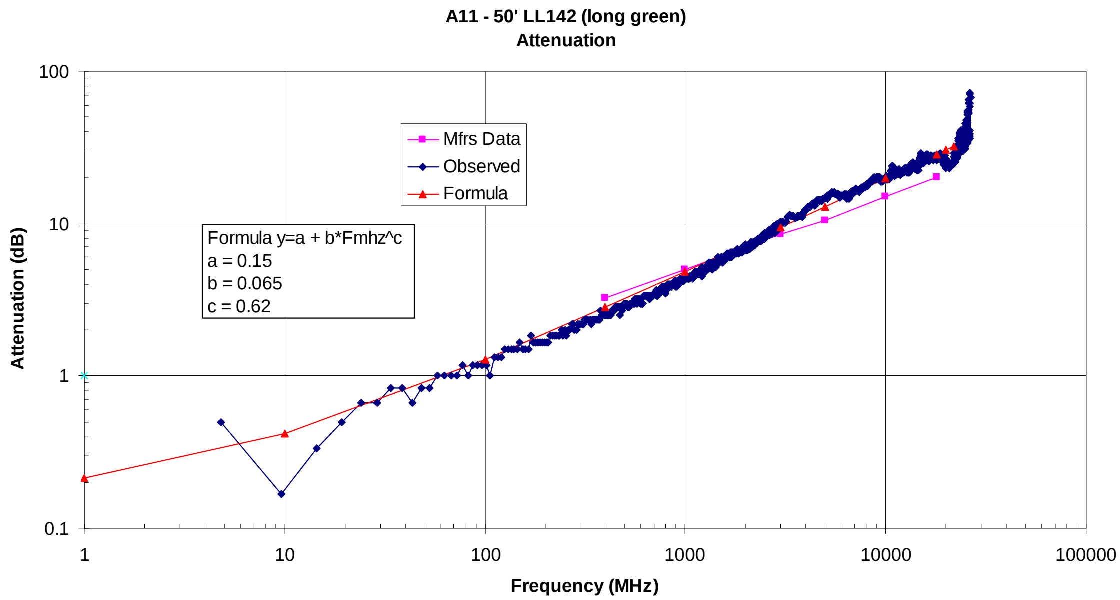

Figure E-8 Cable A11 Attenuation

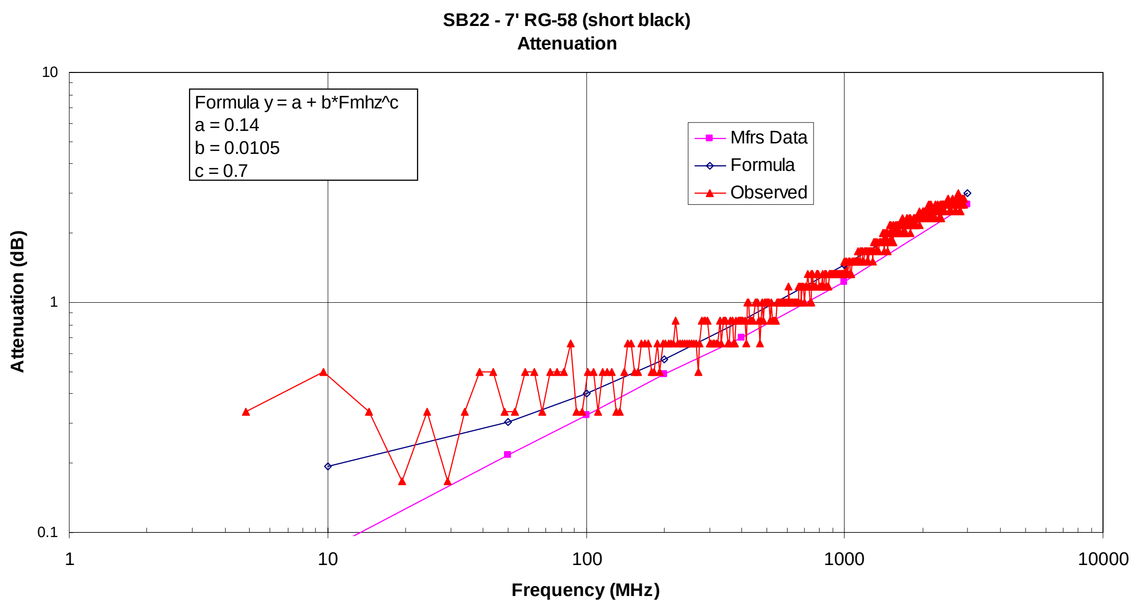

Figure E-9 Cable SB22 Attenuation

E.1.5 Amplifier Gain

E.1.5.1 Three amplifiers were used in taking the South Pole Measurements. These were the HP8447D, the HP8449B, and the JCA 12-1110LN low noise amplifier used for the Marisat/Goes interference measurements. The gain and curve fit formulas for the two HP amplifiers are given in Figures E-8 and E-9 below.

E.1.5.2 The HP8447D was used for sweeps WB2 and WB3 that go from 25 MHz to 1 GHZ. Over this frequency range a good approximation to the amplifier gain is a constant value of +27 dB.

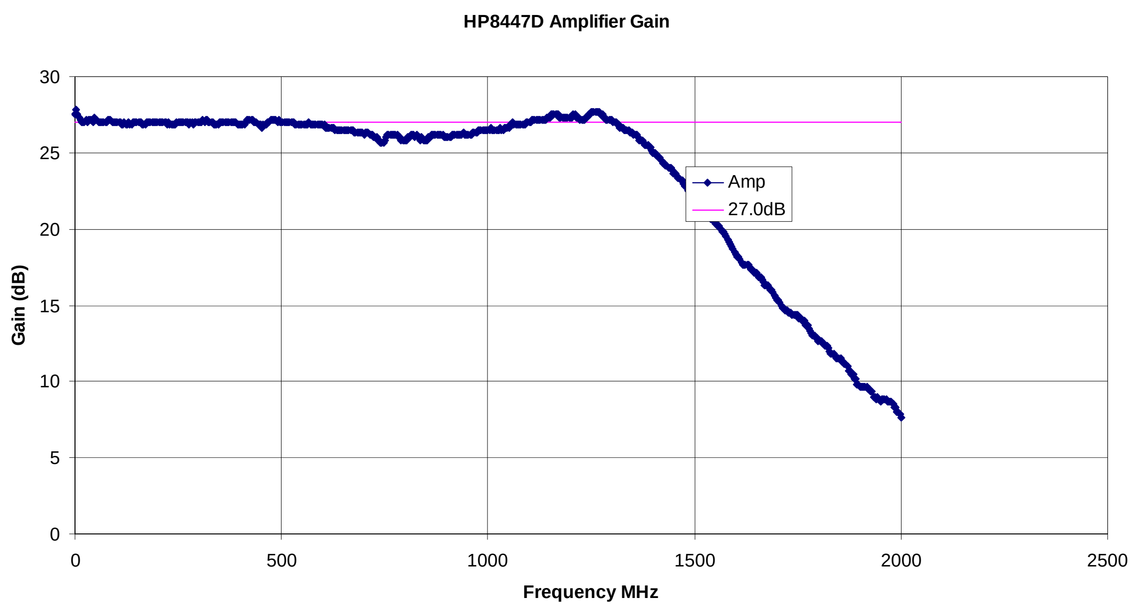

Figure E-10 HP8447D Amplifier Gain

E.1.5.3 The HP8449B was used for the WB4 sweep from 1 to 22 GHz. The gain of this amplifier is shown in Figure E-9 along with the curve fit used in the Matlab program. A ninth order polynomial was used to fit the data.

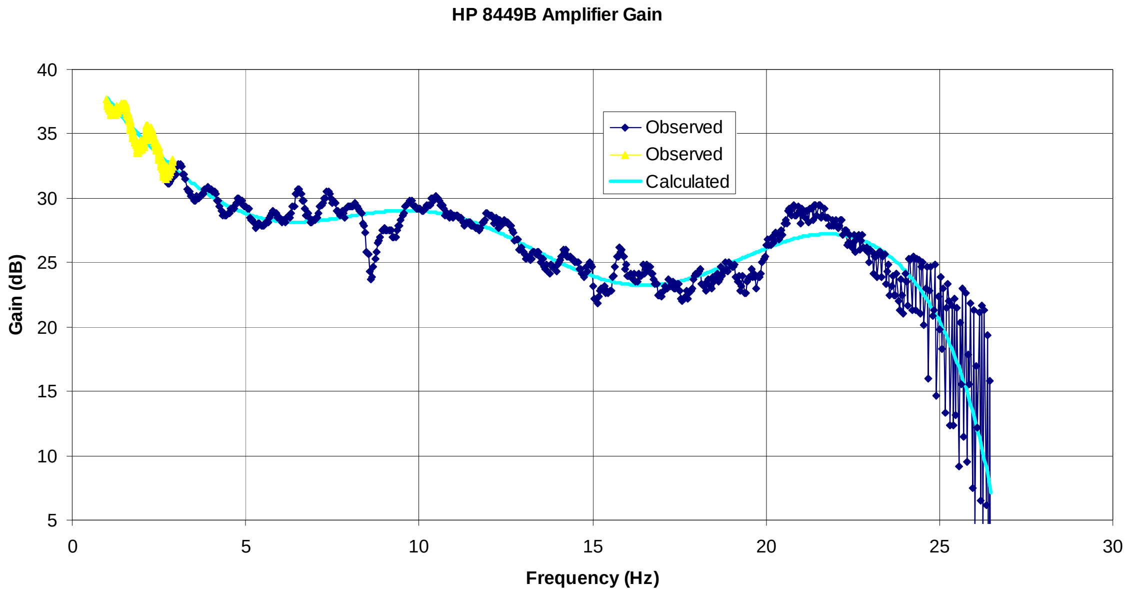

Figure E-11 HP8449B Amplifier Gain versus Frequency.

E.2 Data Plots

E.2.1 The plots of the data are included in three sections below. All of the plots were converted to field strength using the method described in E.1.

E.2.2 The first section E.3 is the SPRESO data. Due to the limited time available at SPRESO, this data consists of single spectrum records for each band in the wide band sweeps. See section 4 of the report for a description of the wide band sweeps and bands. All of the data taken at SPRESO were examined using the Matlab viewing program. Only plots for bands that had signals present are included in the data below.

E.2.3 At SPRESO, the HP8447D amplifier used for the two middle bands (WB2 and WB3) was not available because it was still in service at the MAPO building. Consequently the sensitivity was reduced significantly for the bands in these two sweeps. These bands comprise the frequency range from 25 MHz to 1 GHz.

E.2.4 The last two sections contain spectrograms of the 24 hour data taken at the RF building and the MAPO building. The coaxial cables used for these measurements significantly reduce the system sensitivity for frequencies above 10 GHz.

E.2.5 Some data from each site is presented and discussed in section 4 of the main body of the report.

E.3 SPRESO Wide Band Sweep Data

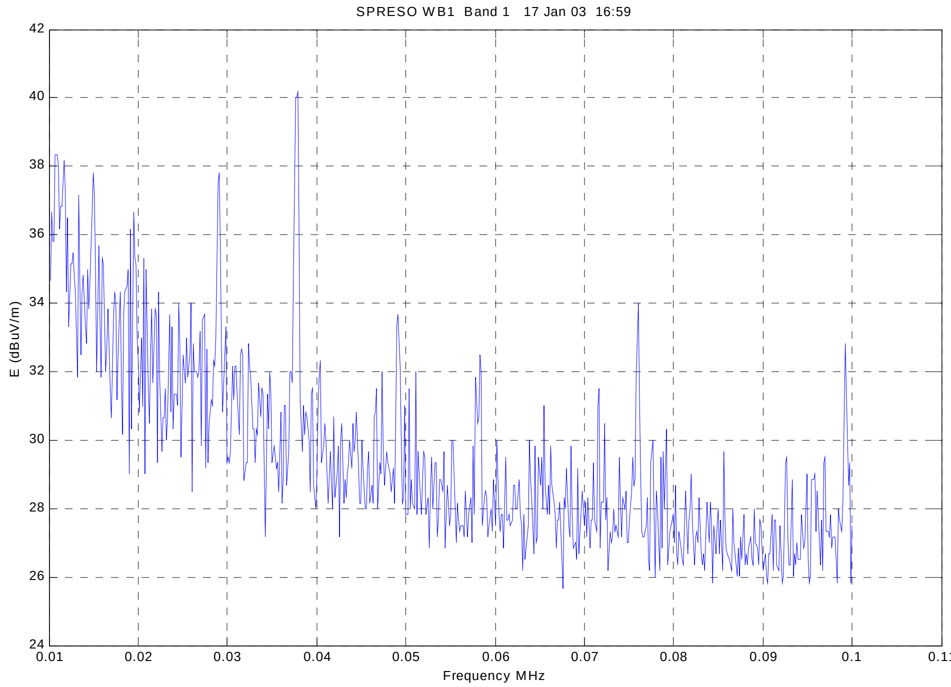

Figure E-12 SPRESO WB1 BAND 1.

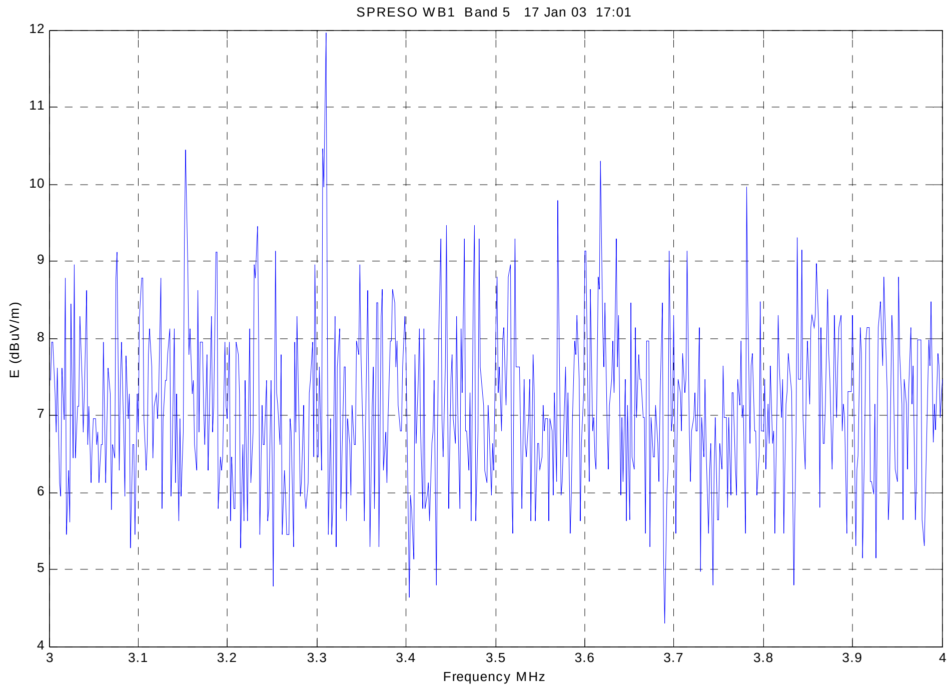

Figure E-13 SPRESO WB1 BAND 5.

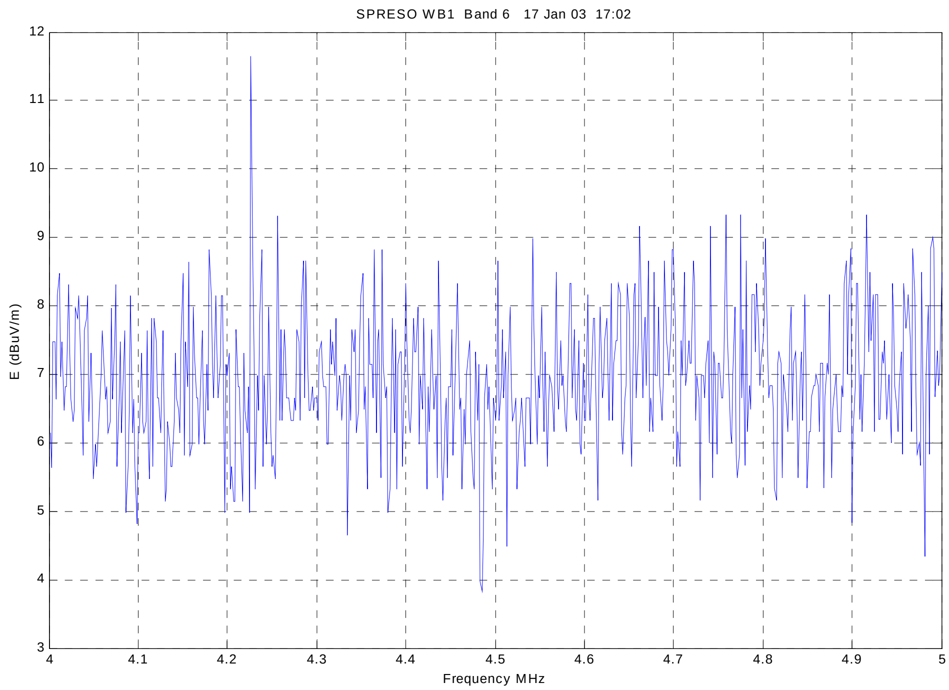

Figure E-14 SPRESO WB1 BAND 6

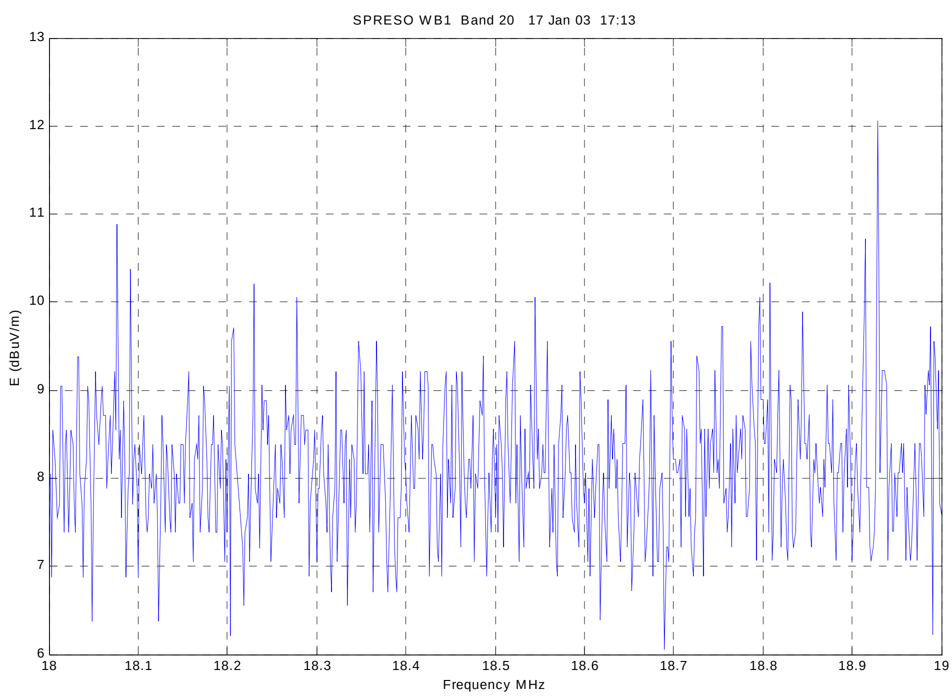

Figure E-15 SPRESO WB1 BAND 20

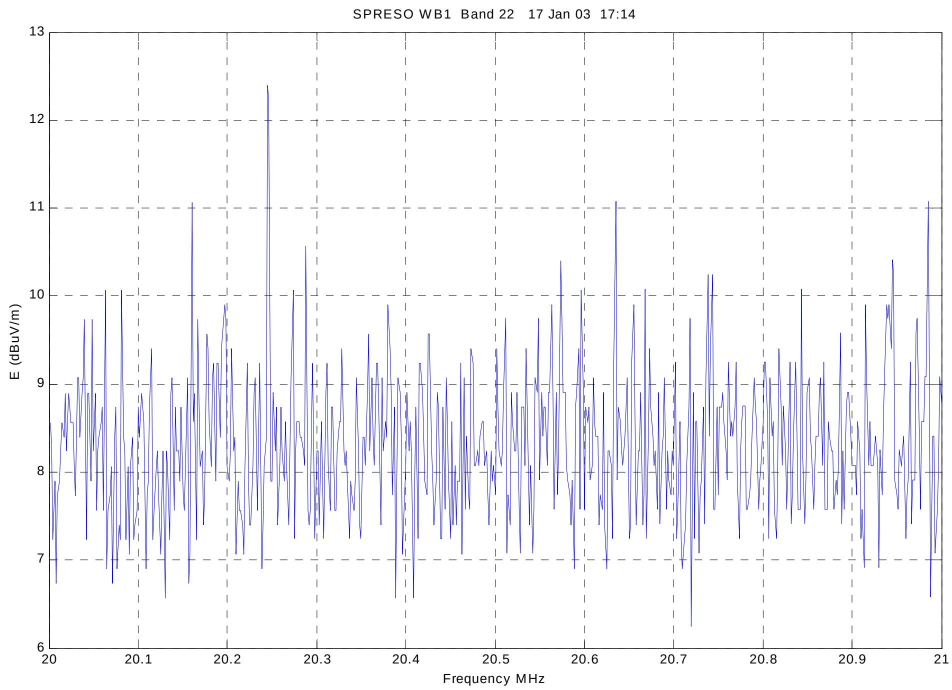

Figure E-16 SPRESO WB1 BAND 22

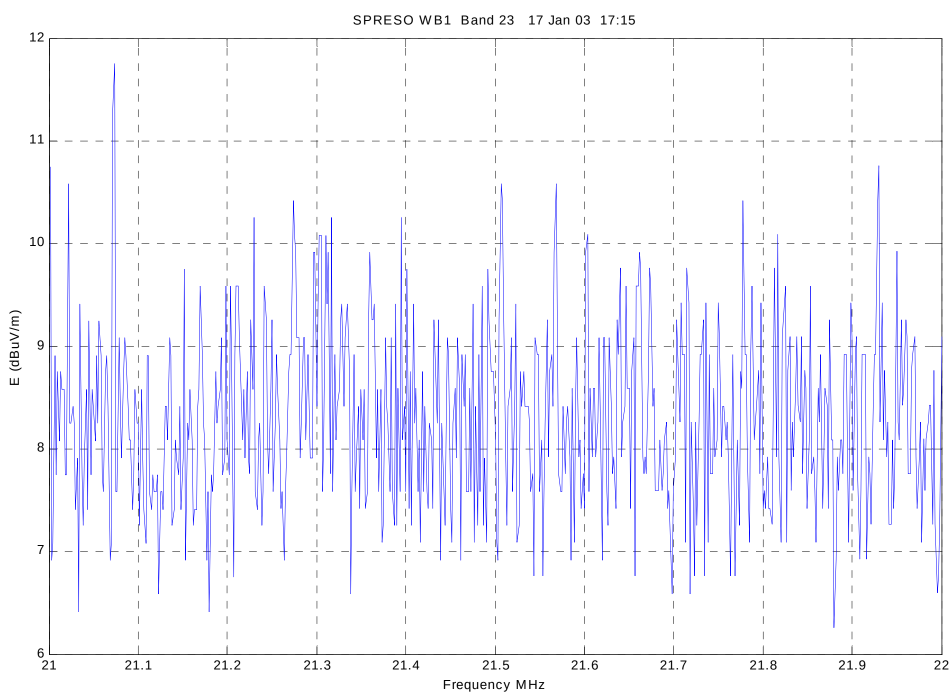

Figure E-17 SPRESO WB1 BAND 23

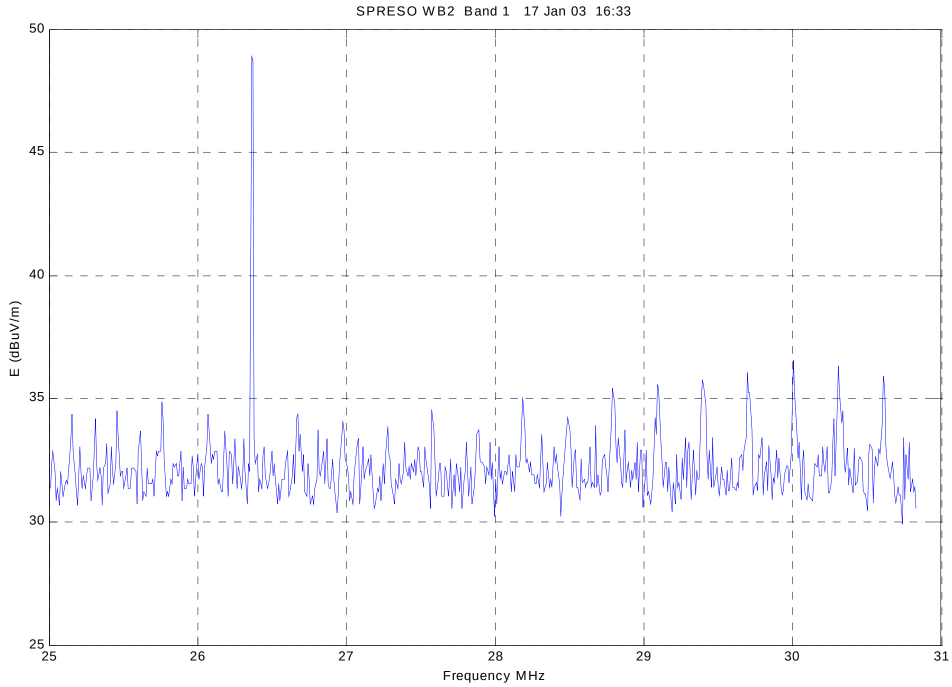

Figure E-18 SPRESO WB2 BAND 1

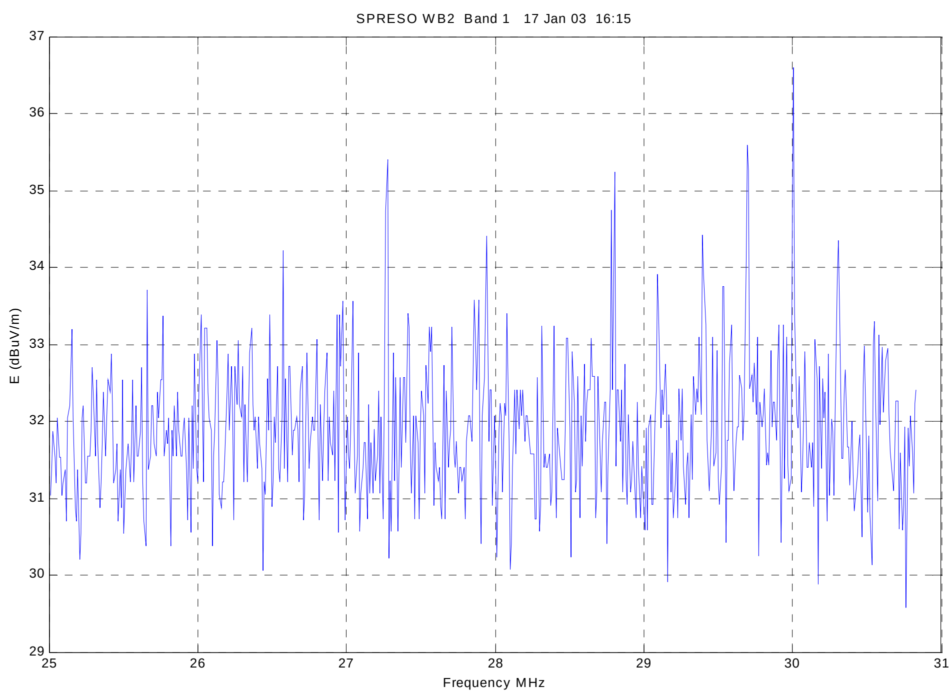

Figure E-19 SPRESO WB2 BAND 1

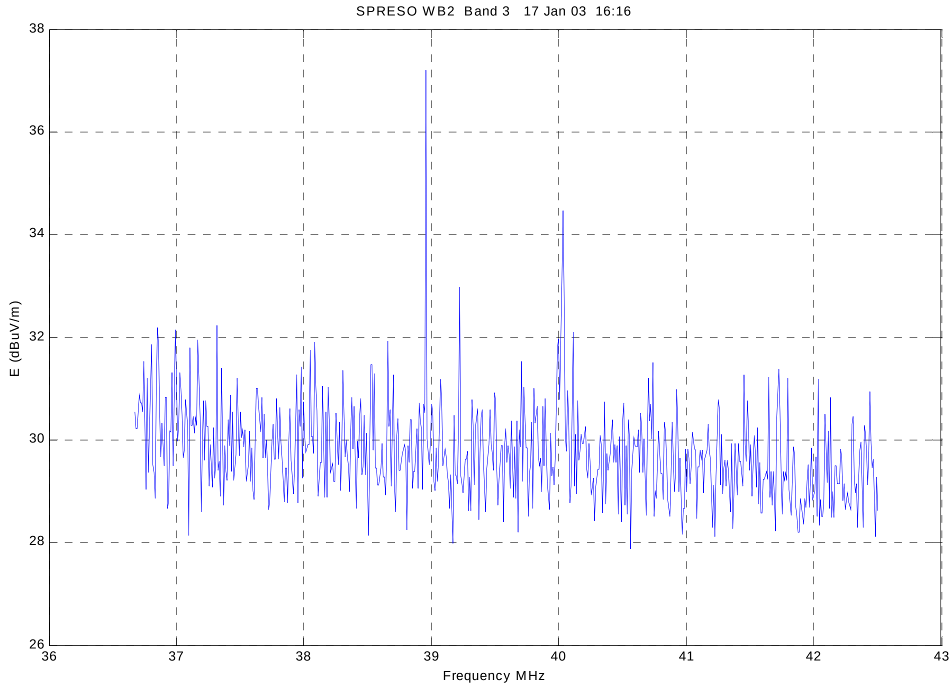

Figure E-20 SPRESO WB2 BAND 3

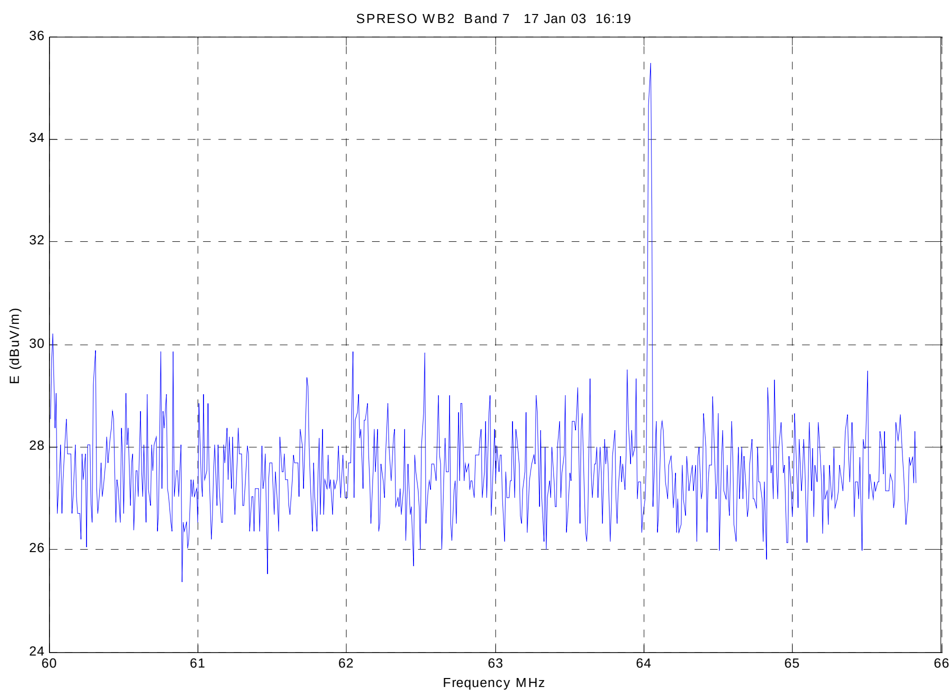

Figure E-21 SPRESO WB2 BAND 7

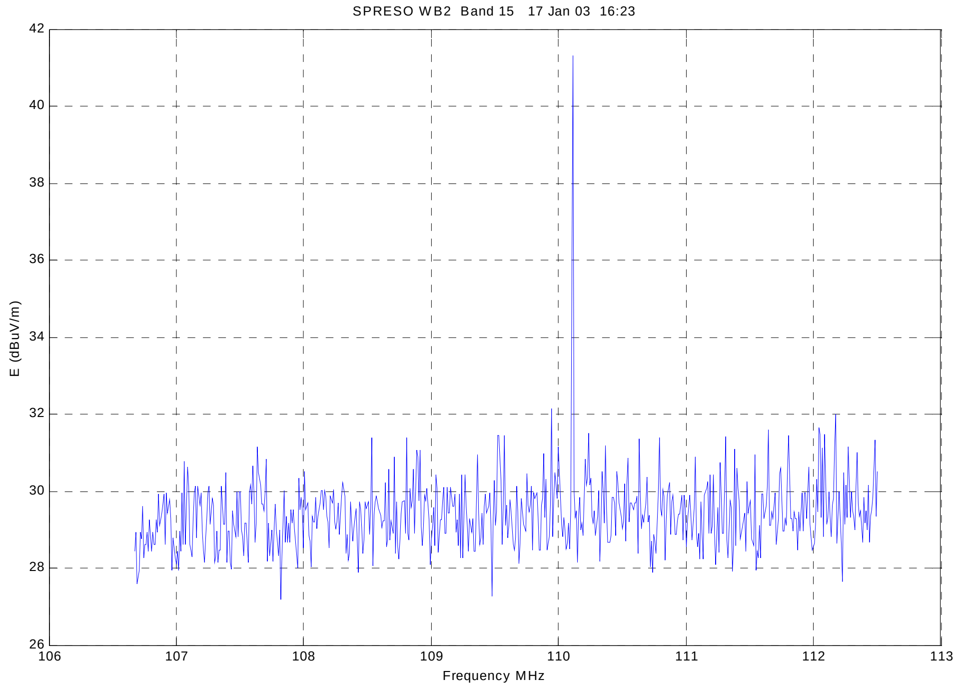

Figure E-22 SPRESO WB2 BAND 15

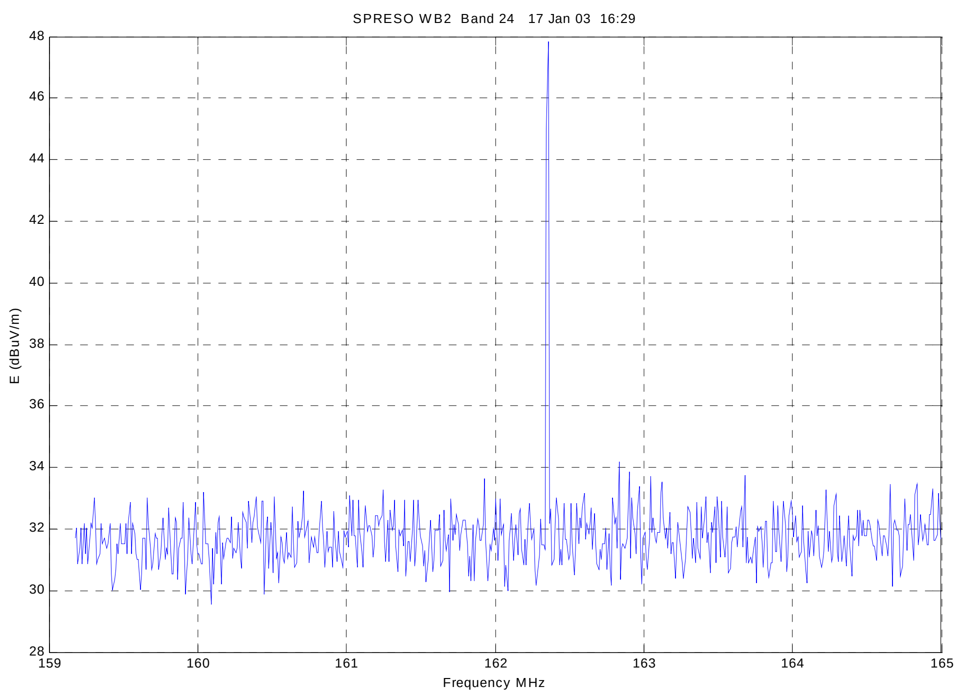

Figure E-23 SPRESO WB2 BAND 24

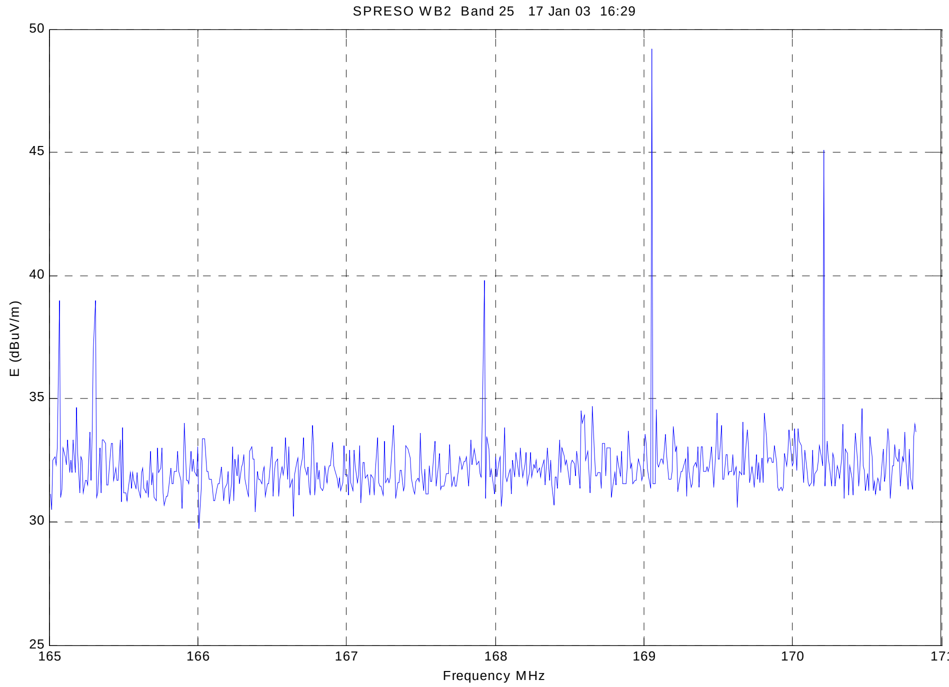

Figure E-24 SPRESO WB2 BAND 25

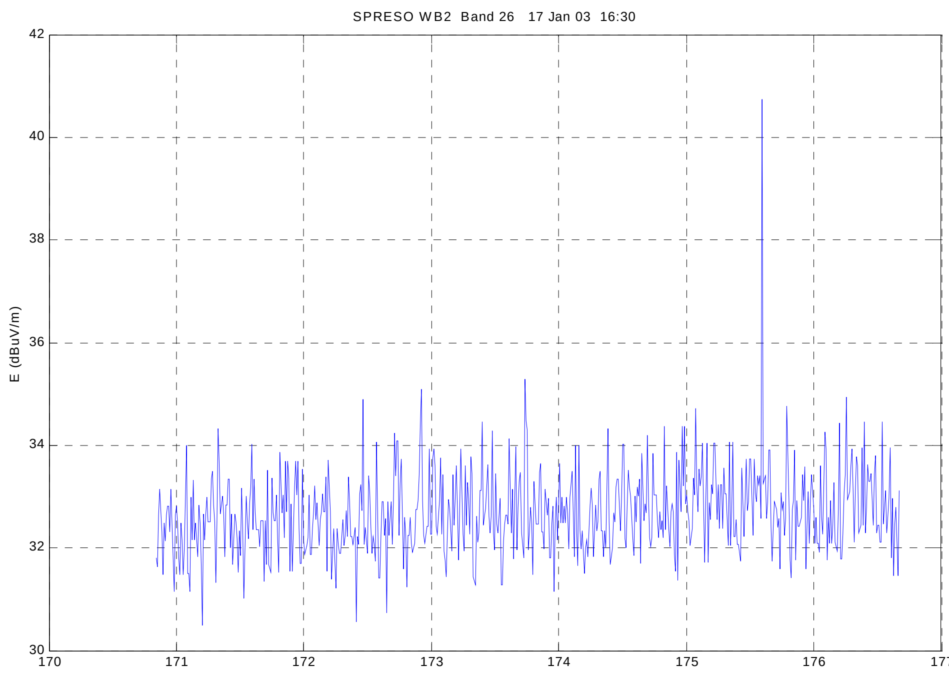

Figure E-25 SPRESO WB2 BAND 26

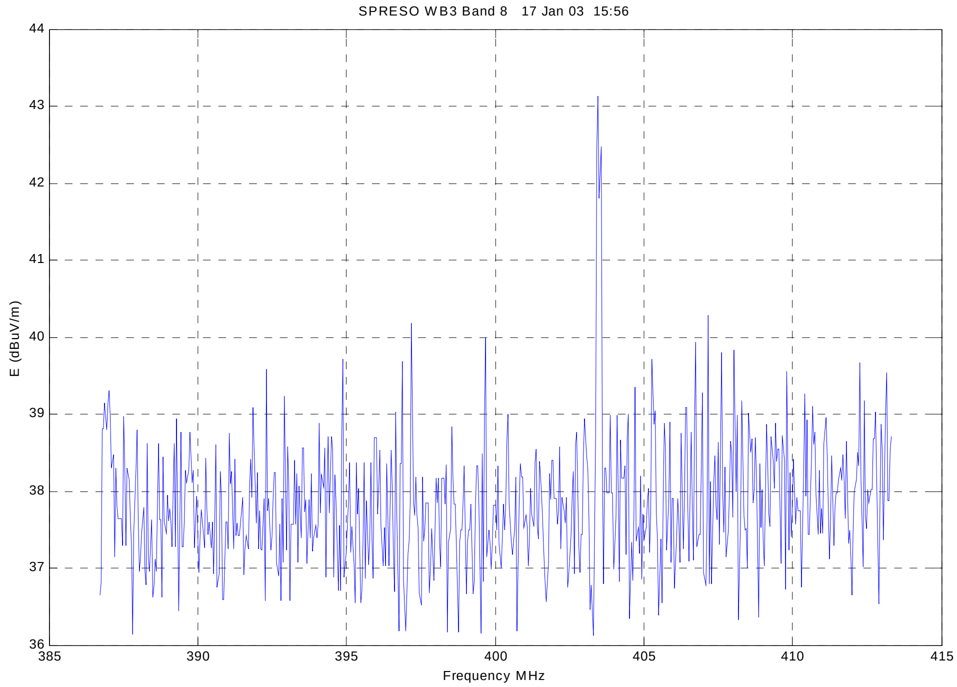

Figure E-26 SPRESO WB3 BAND 8

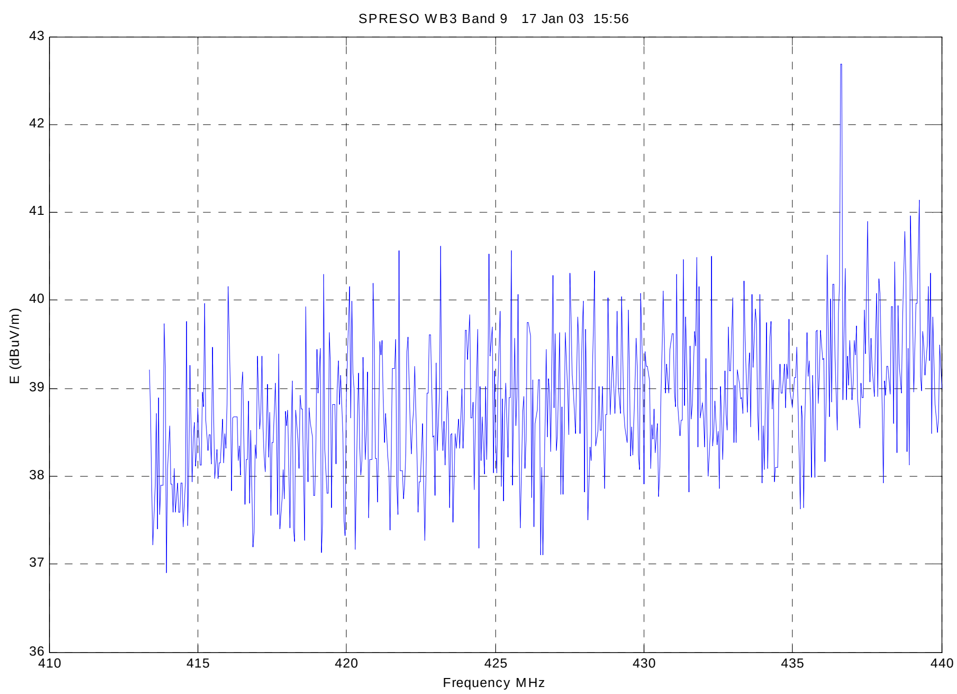

Figure E-27 SPRESO WB3 BAND 9

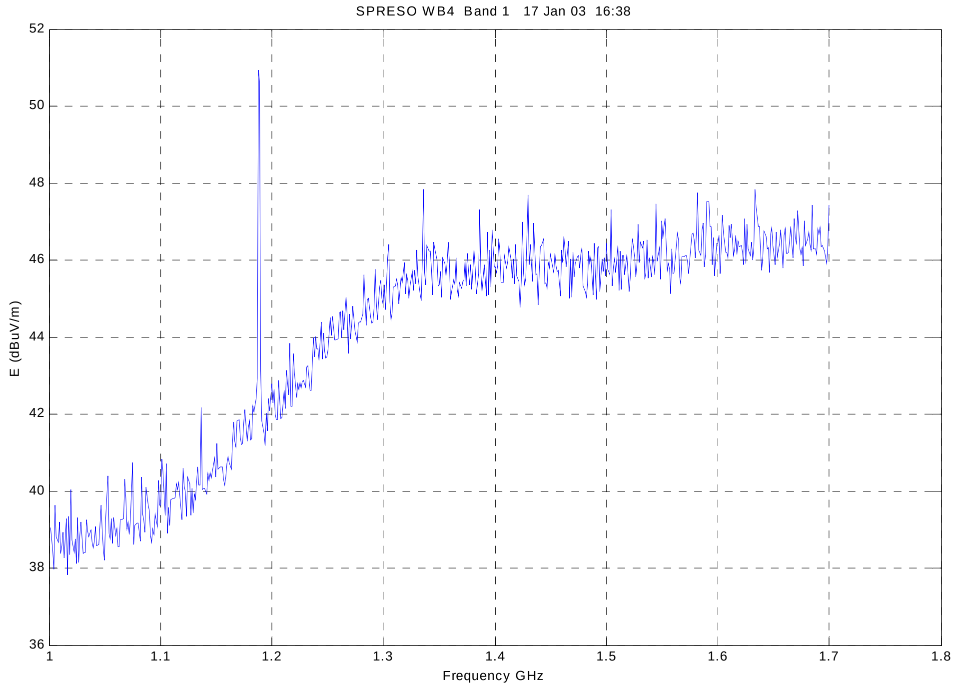

Figure E-28 SPRESO WB4 BAND 1

E.4 RF BUILDING Wide Band Sweep Data

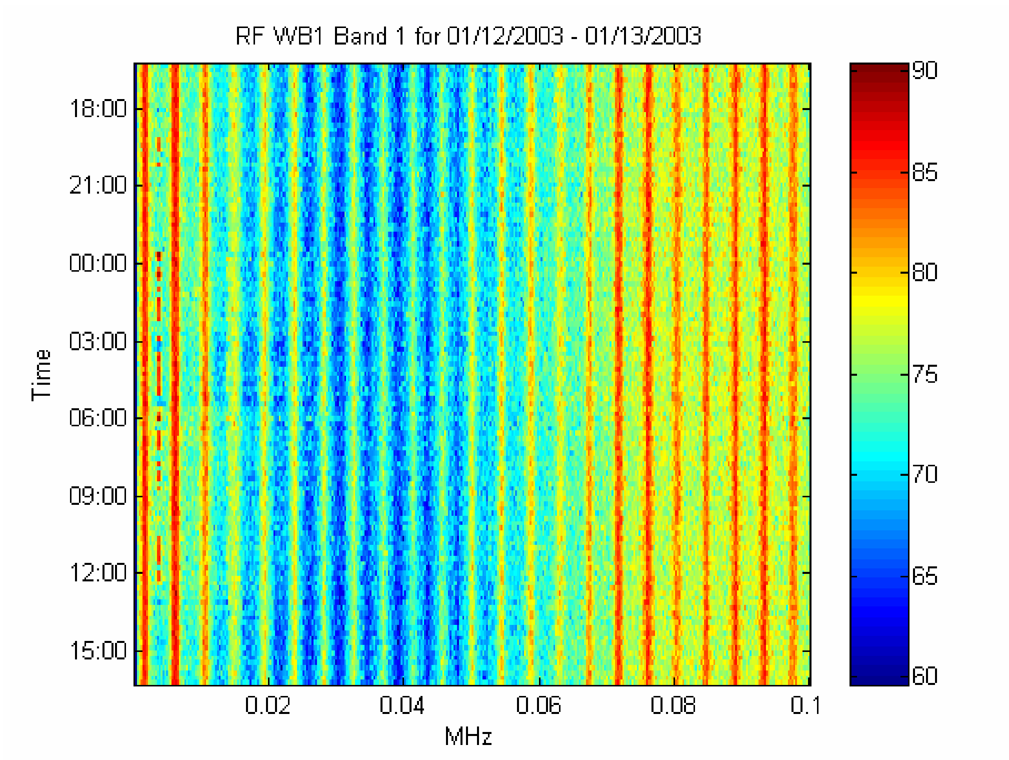

Figure E-29 RF BLDG WB1 BAND 1 (dBuV/m)

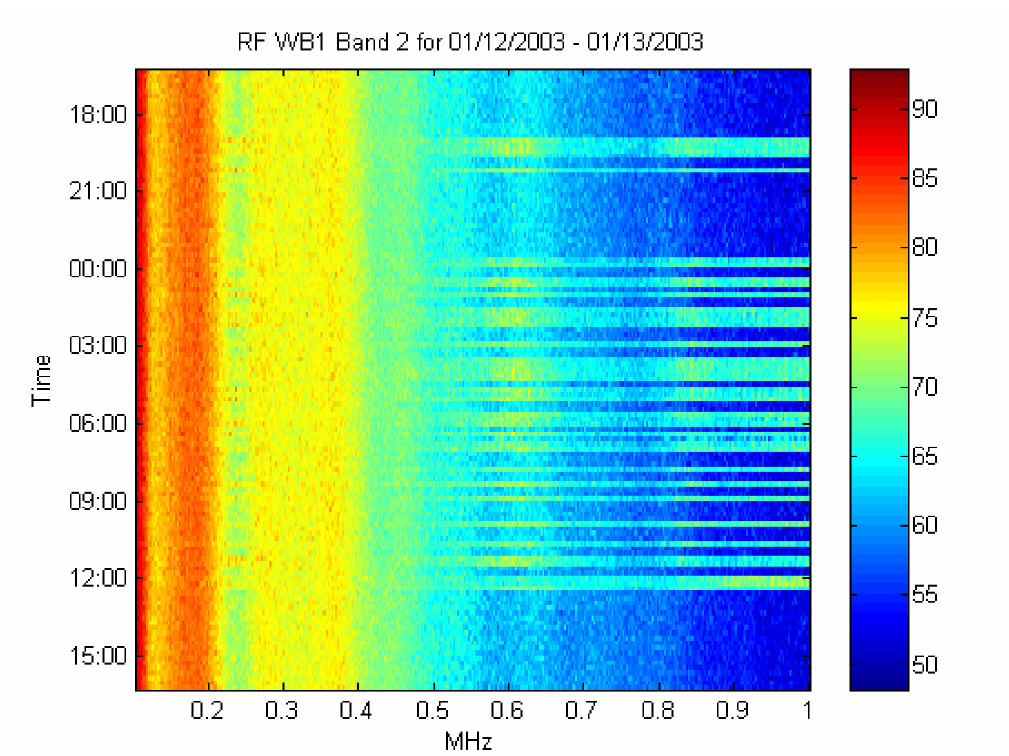

Figure E-30 RF BLDG WB1 BAND 2 (dBuV/m)

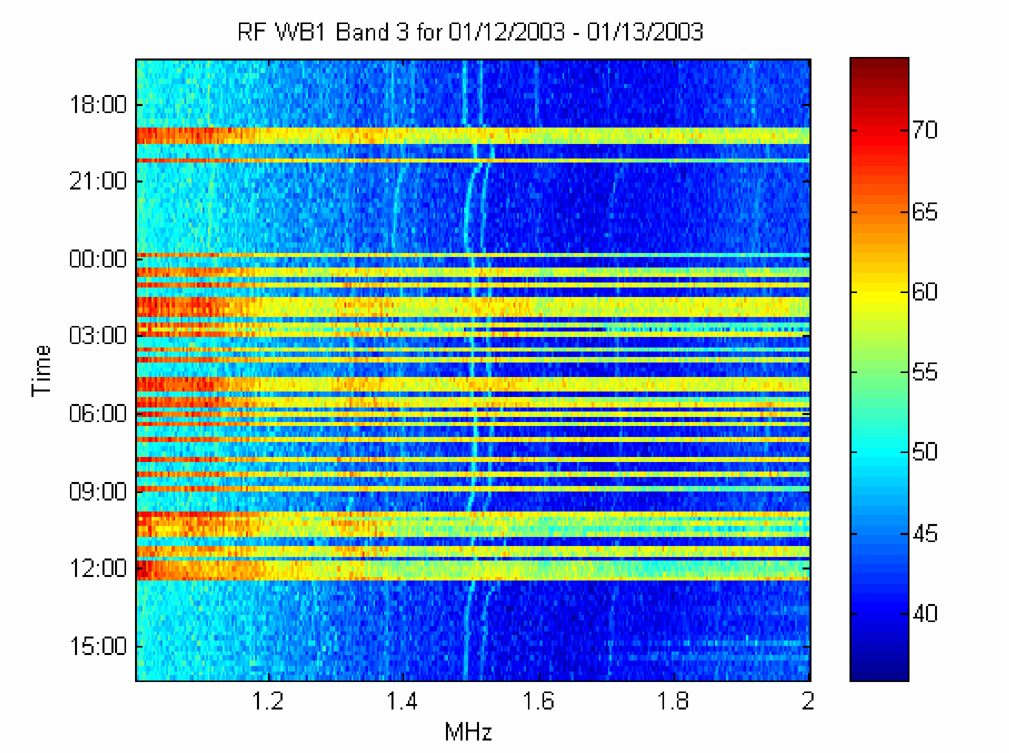

Figure E-31 RF BLDG WB1 BAND 3 (dBuV/m)

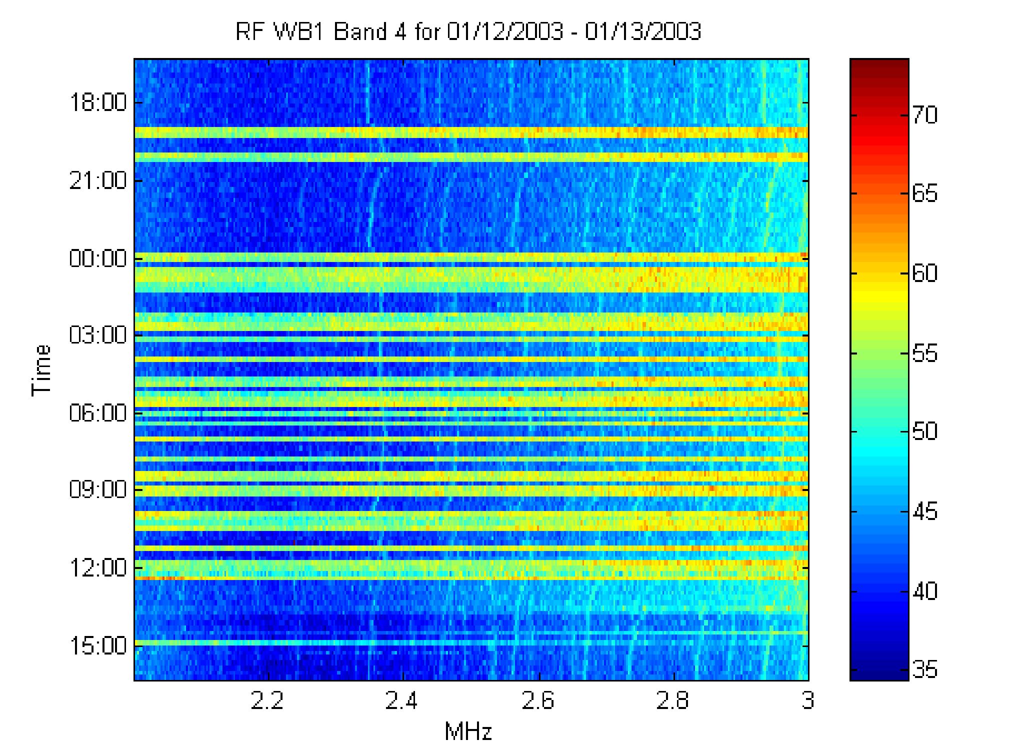

Figure E-32 RF BLDG WB1 BAND 4 (dBuV/m)

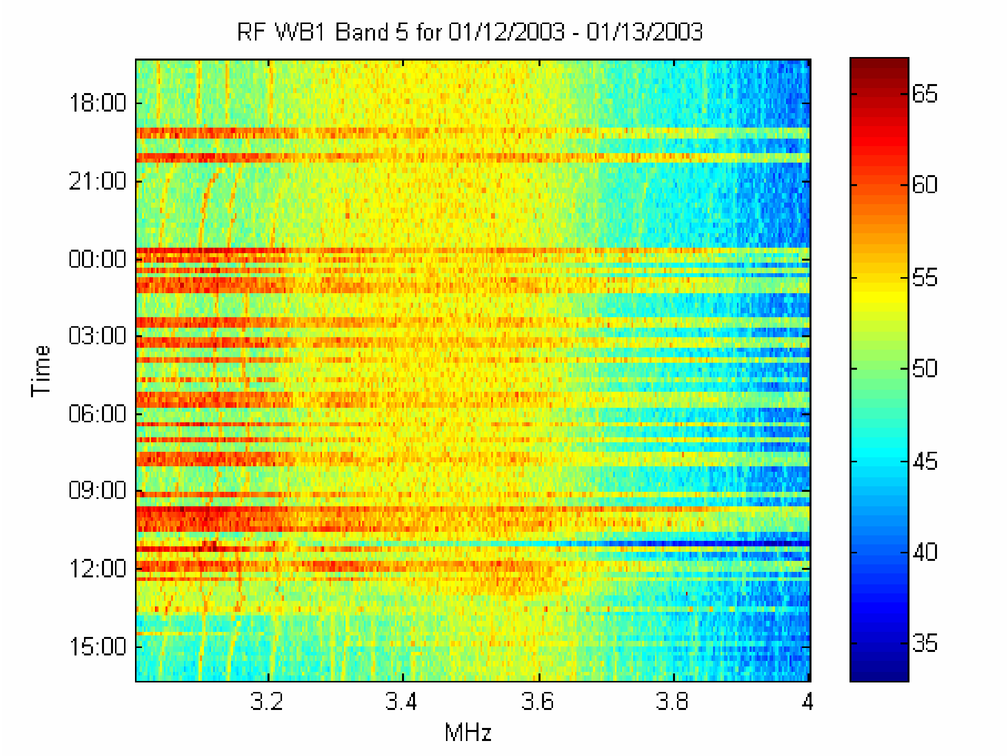

Figure E-33 RF BLDG WB1 BAND 5 (dBuV/m)

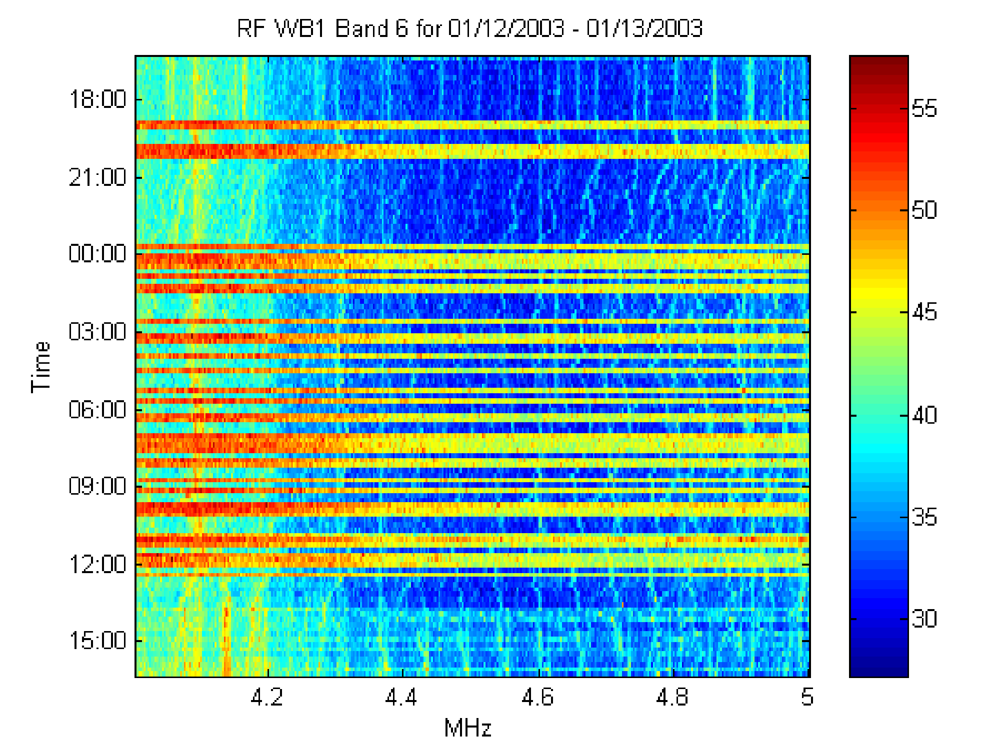

Figure E-34 RF BLDG WB1 BAND 6 (dBuV/m)

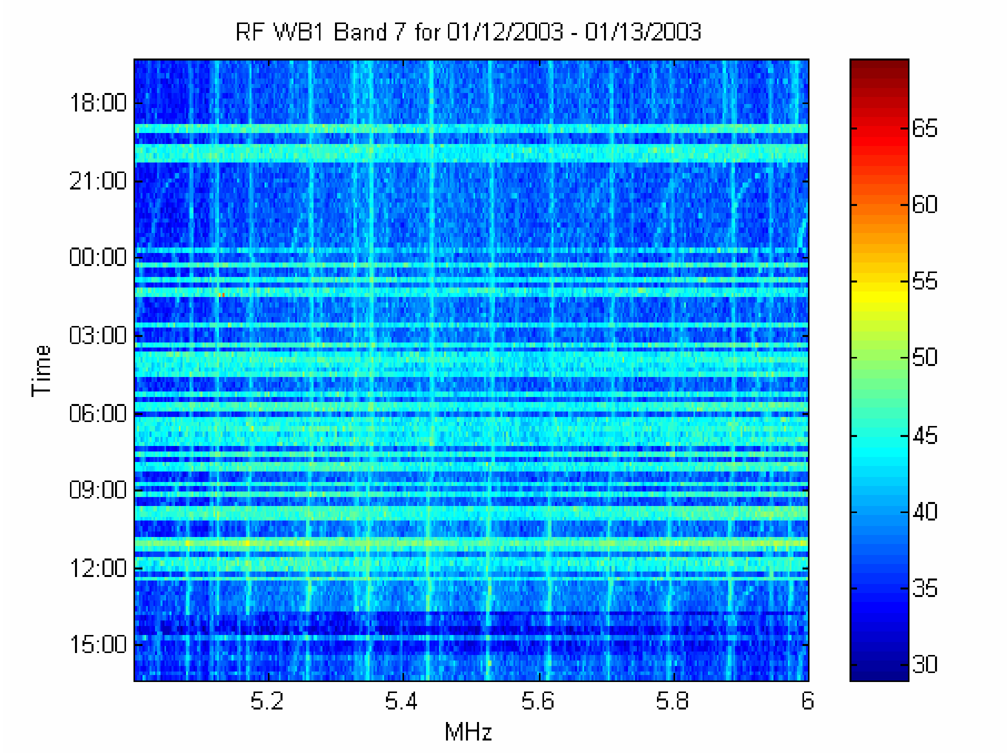

Figure E-35 RF BLDG WB1 BAND 7 (dBuV/m)

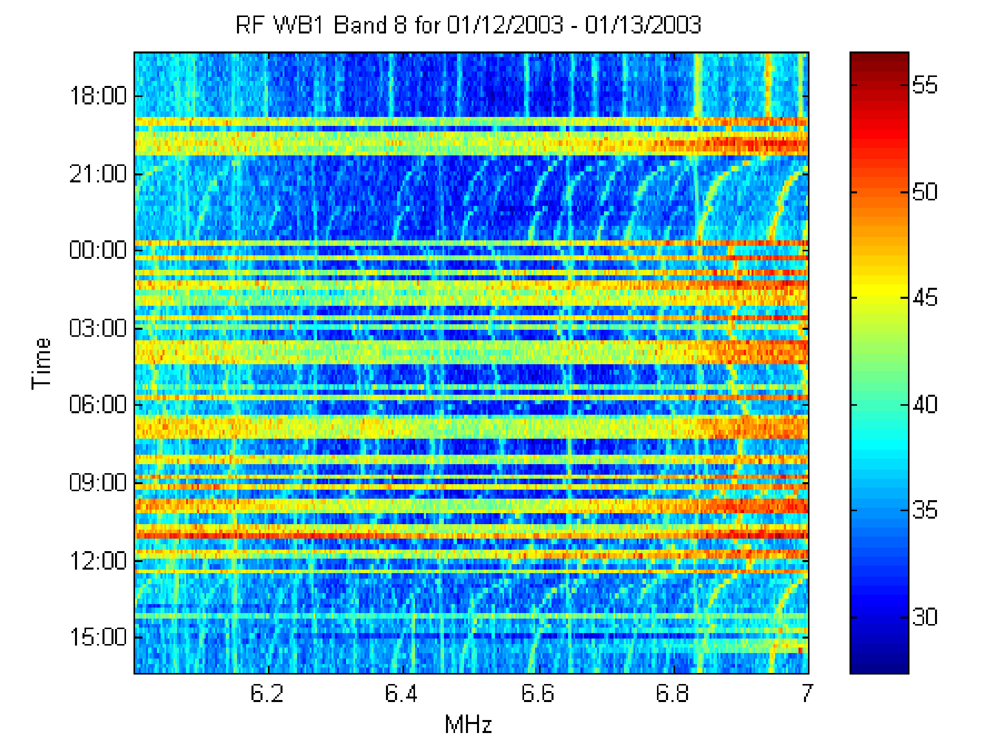

Figure E-36 RF BLDG WB1 BAND 8 (dBuV/m)

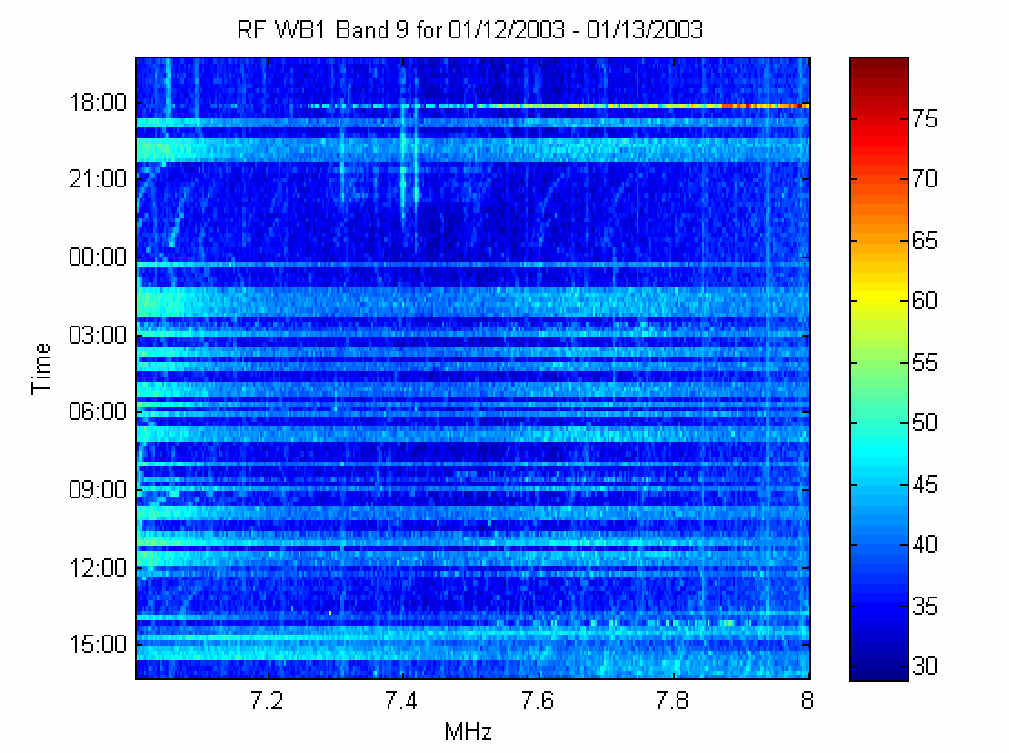

Figure E-37 RF BLDG WB1 BAND 9 (dBuV/m)

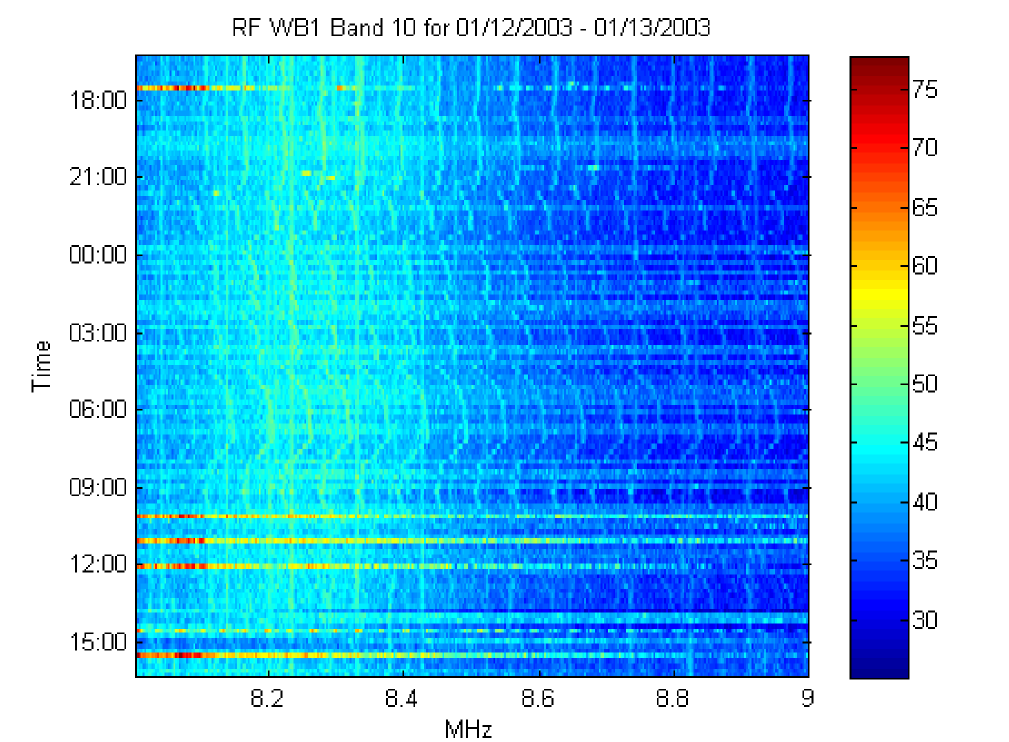

Figure E-38 RF BLDG WB1 BAND 10 (dBuV/m)

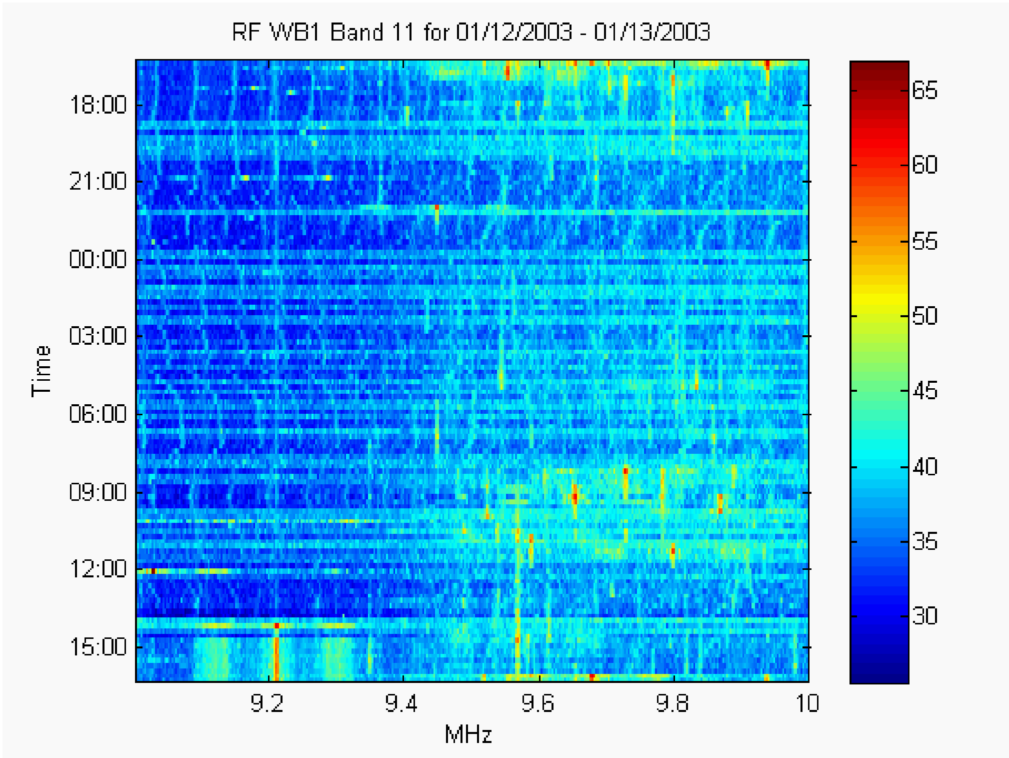

Figure E-39 RF BLDG WB1 BAND 11 (dBuV/m)

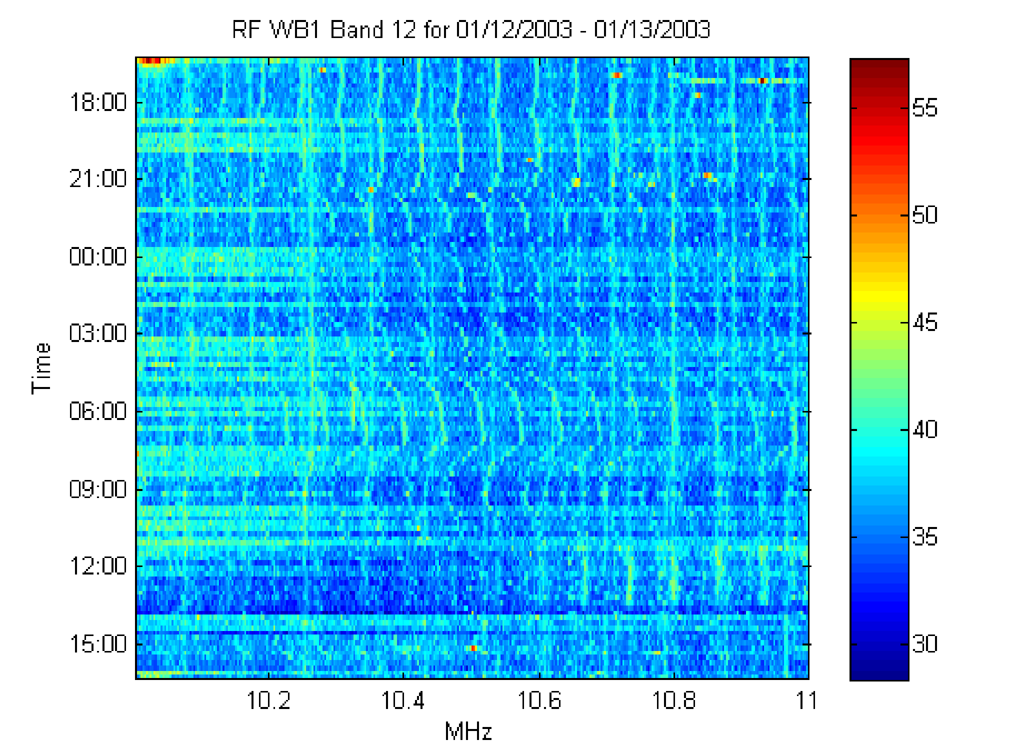

Figure E-40 RF BLDG WB1 BAND 12 (dBuV/m)

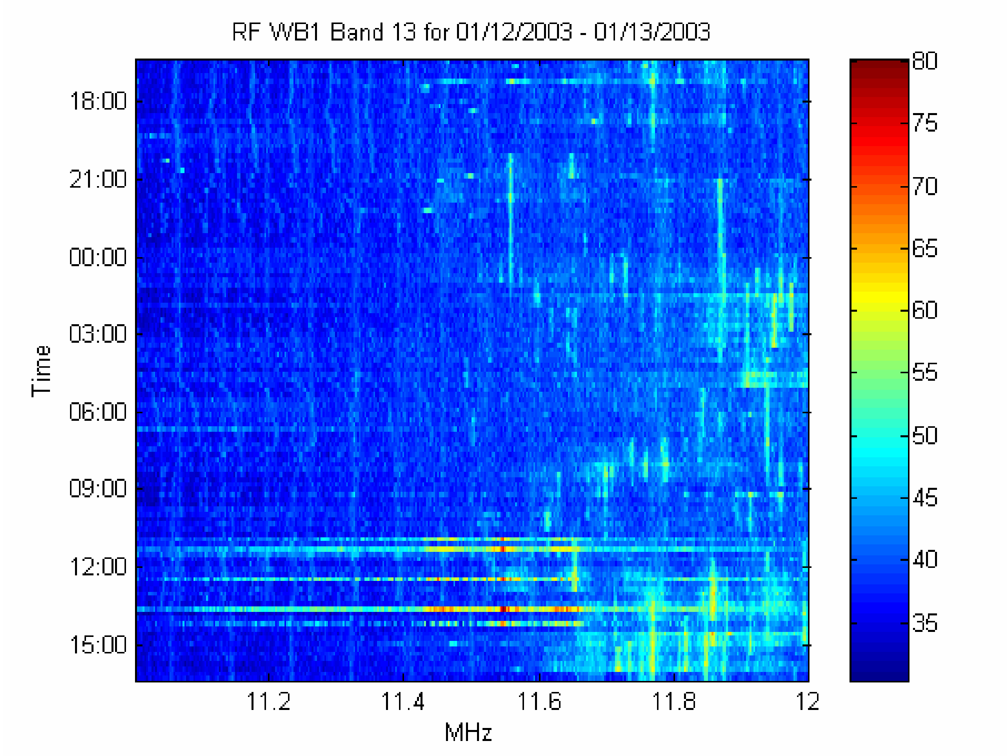

Figure E-41 RF BLDG WB1 BAND 13 (dBuV/m)

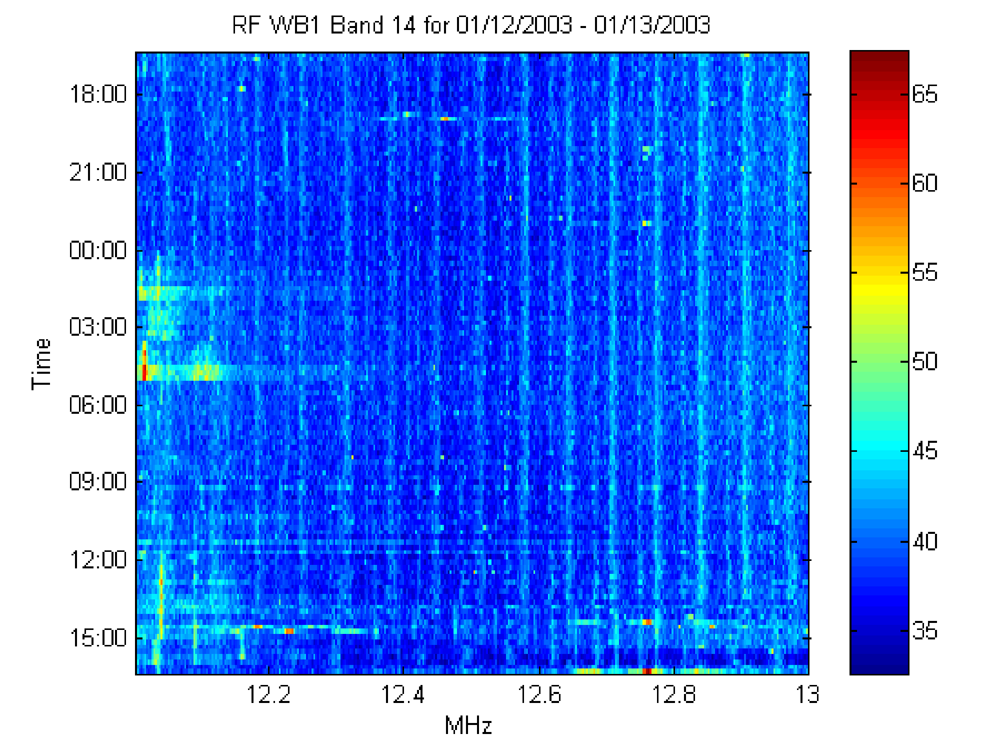

Figure E-42 RF BLDG WB1 BAND 14 (dBuV/m)

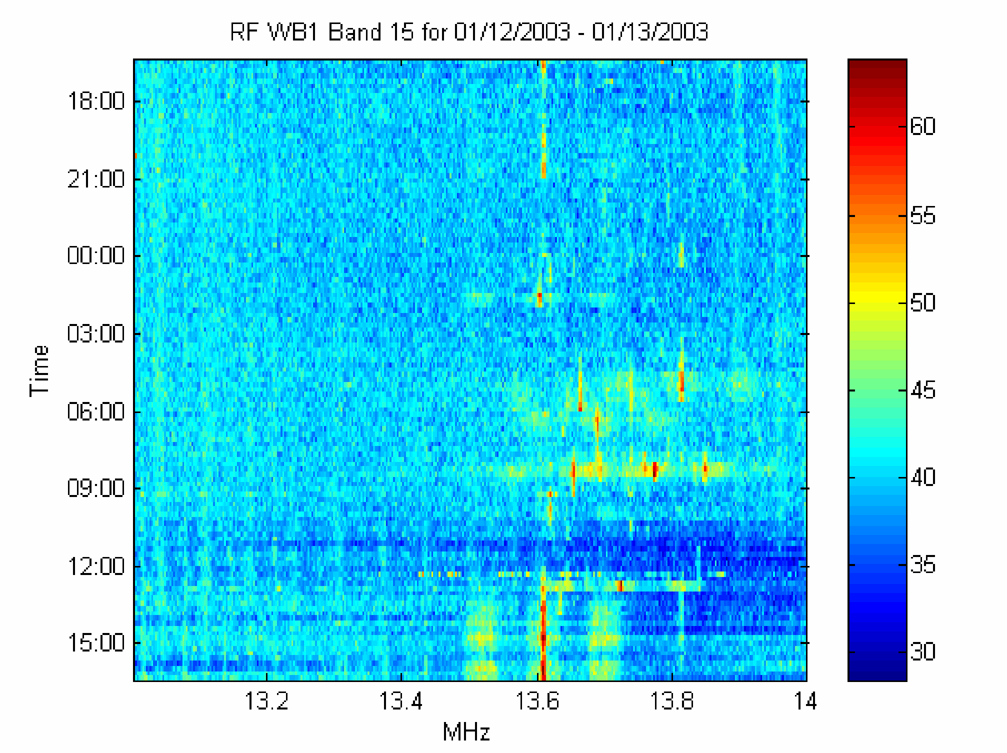

Figure E-43 RF BLDG WB1 BAND 15 (dBuV/m)

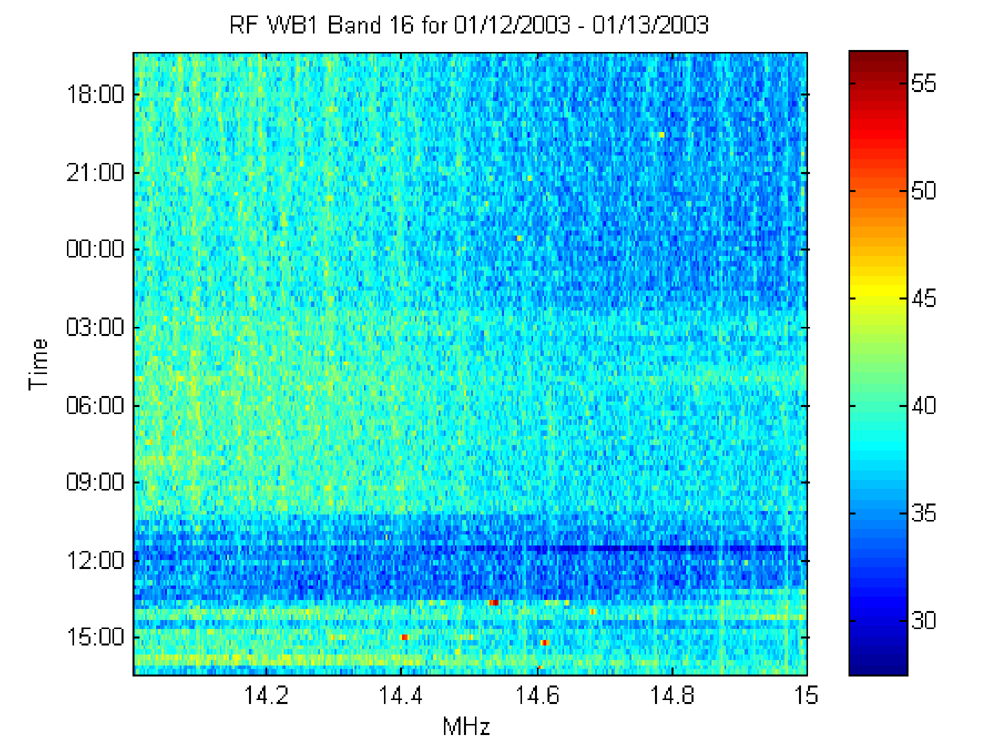

Figure E-44 RF BLDG WB1 BAND 16 (dBuV/m)

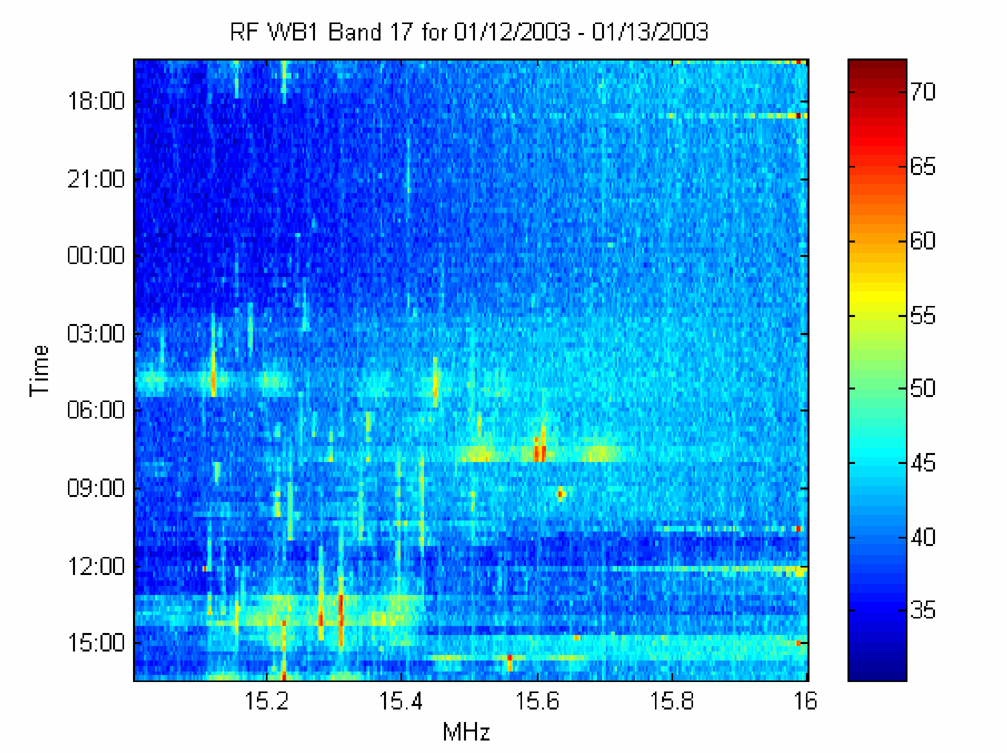

Figure E-45 RF BLDG WB1 BAND 17 (dBuV/m)

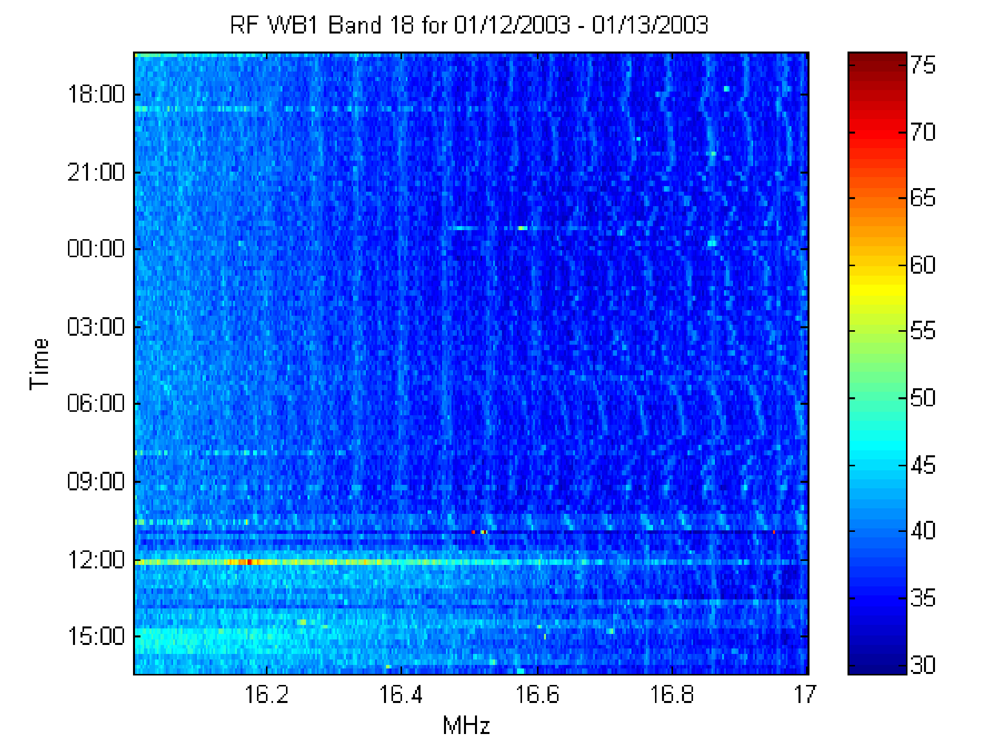

Figure E-46 RF BLDG WB1 BAND 18 (dBuV/m)

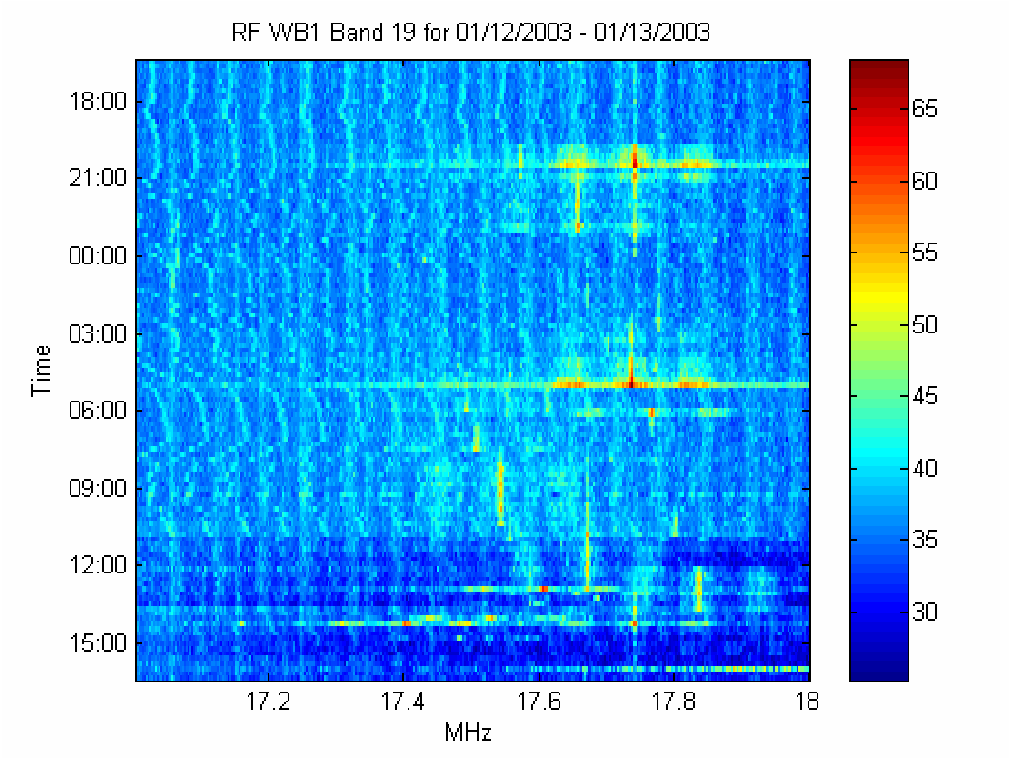

Figure E-47 RF BLDG WB1 BAND 19 (dBuV/m)

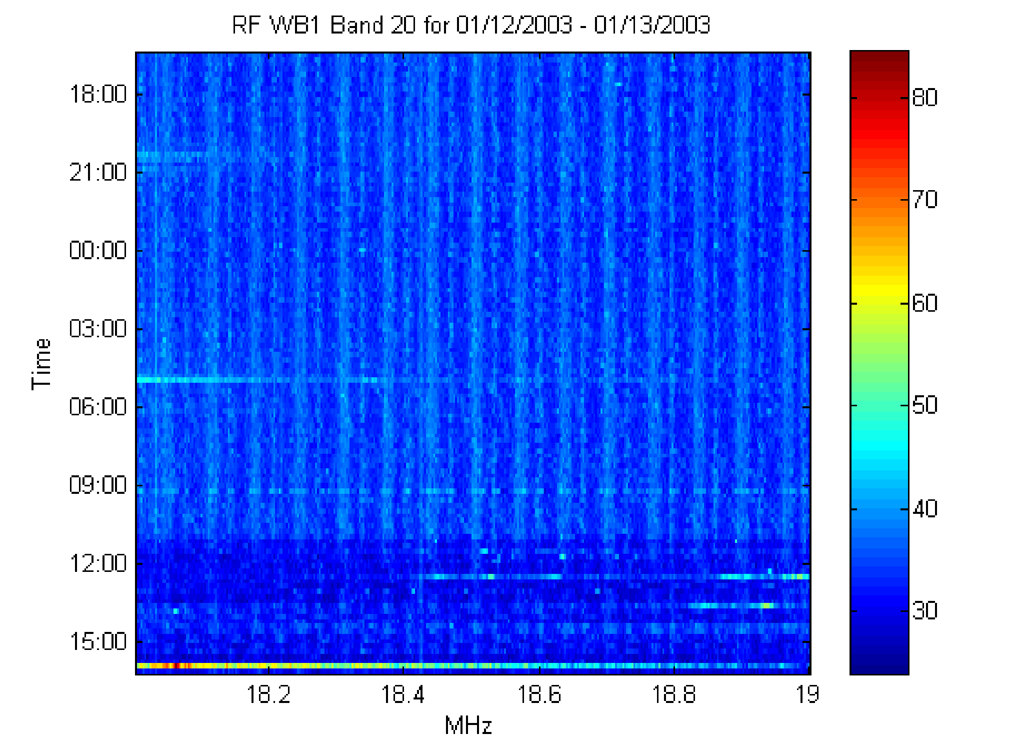

Figure E-48 RF BLDG WB1 BAND 20 (dBuV/m)

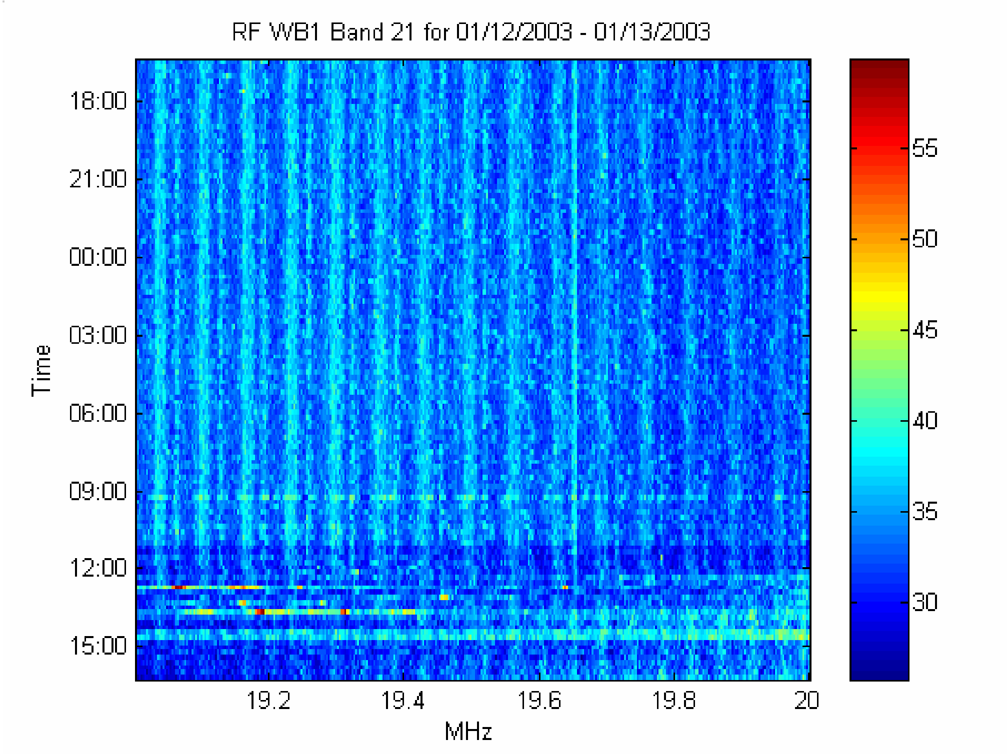

Figure E-49 RF BLDG WB1 BAND 21 (dBuV/m)

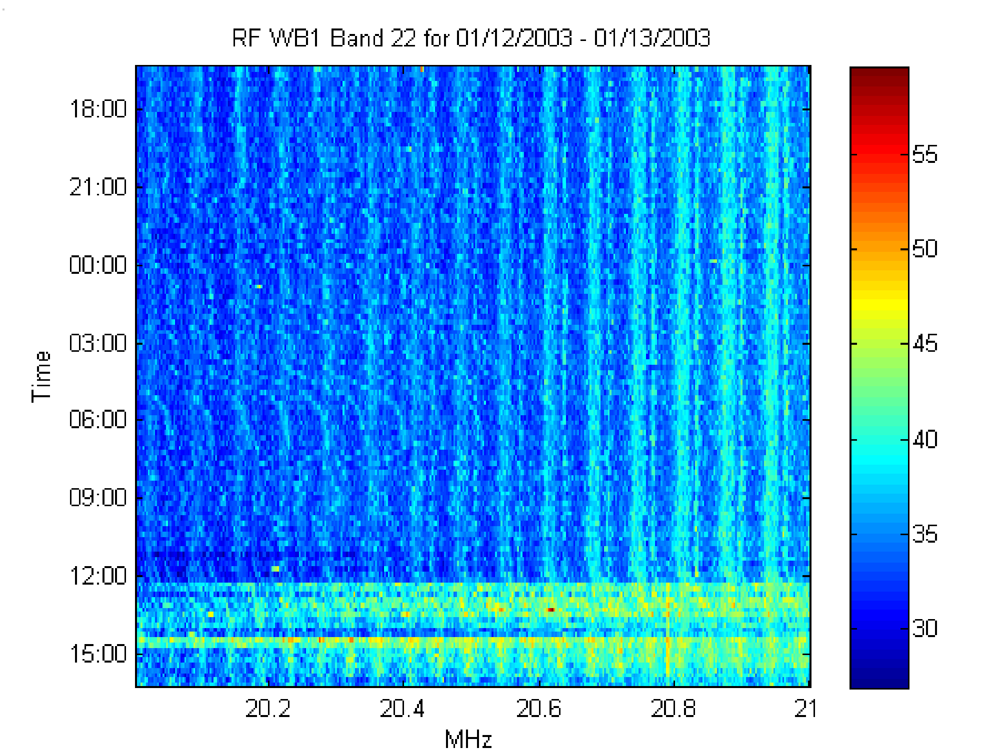

Figure E-50 RF BLDG WB1 BAND 22 (dBuV/m)

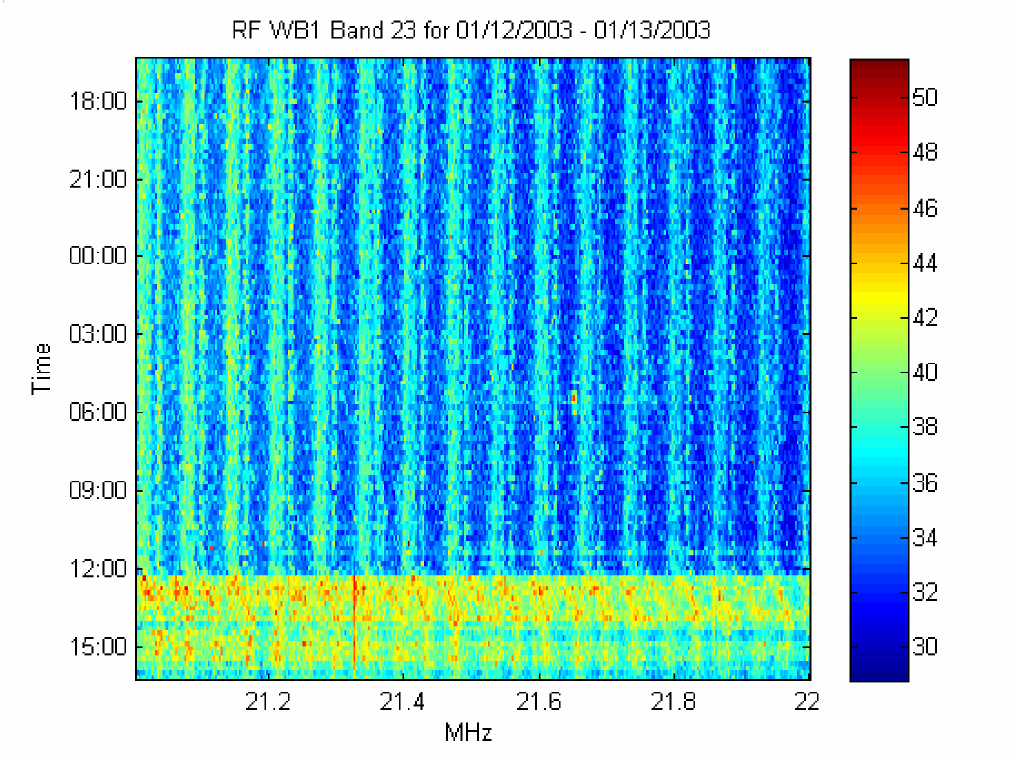

Figure E-51 RF BLDG WB1 BAND 23 (dBuV/m)

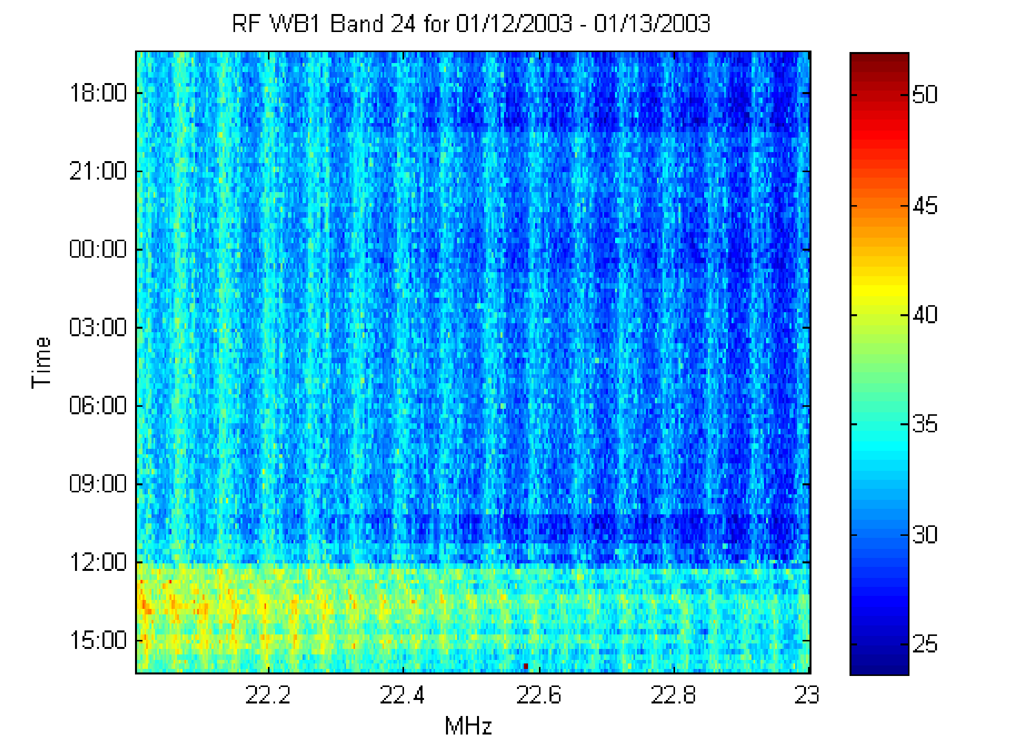

Figure E-52 RF BLDG WB1 BAND 24 (dBuV/m)

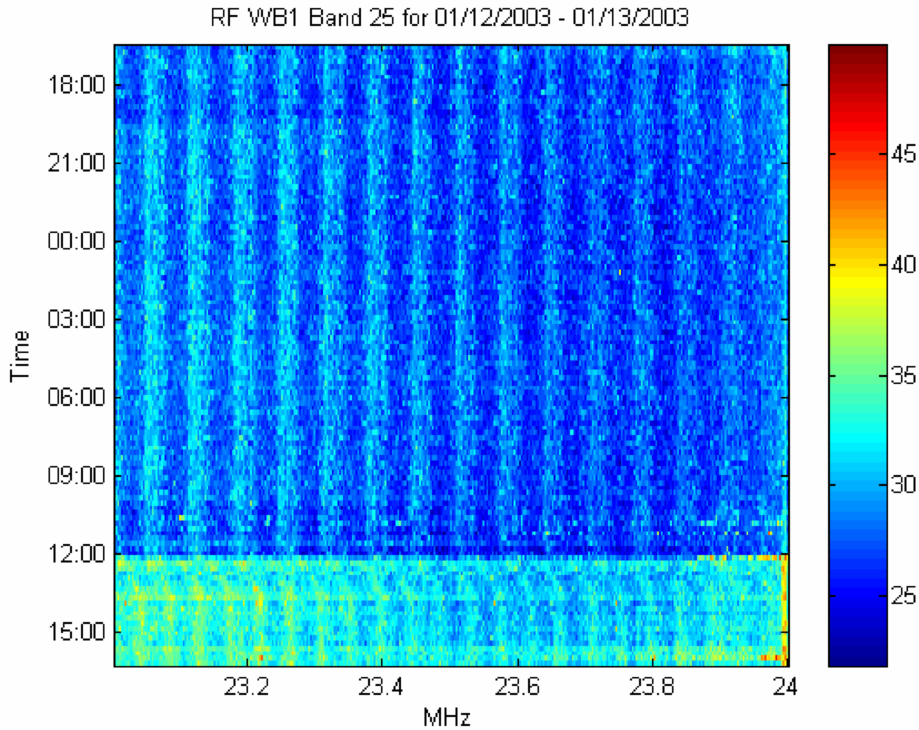

Figure E-53 RF BLDG WB1 BAND 25 (dBuV/m)

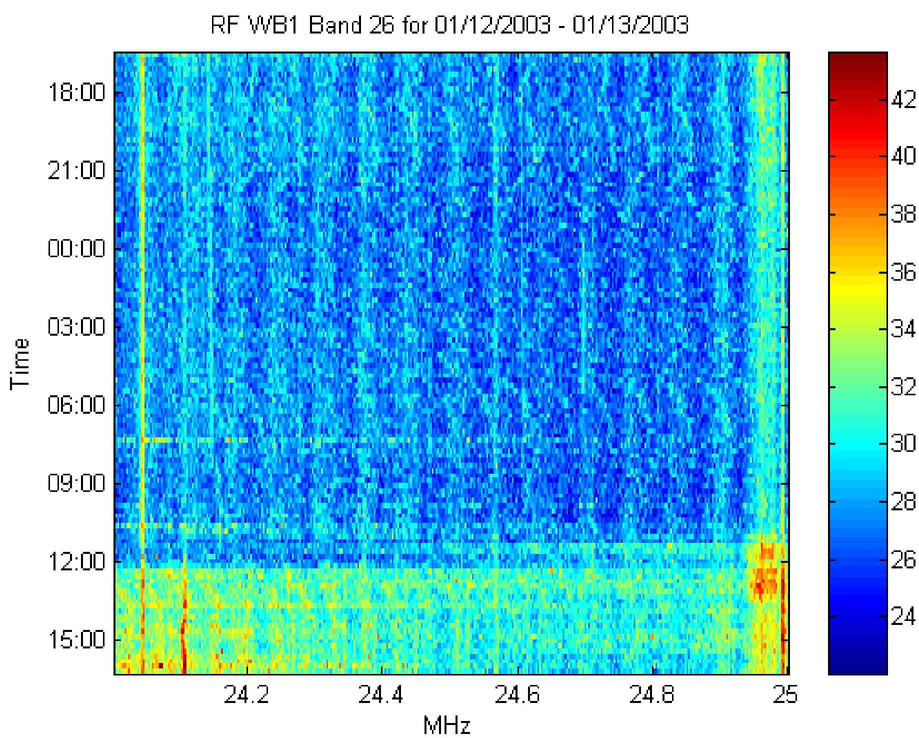

Figure E-54 RF BLDG WB1 BAND 26 (dBuV/m)

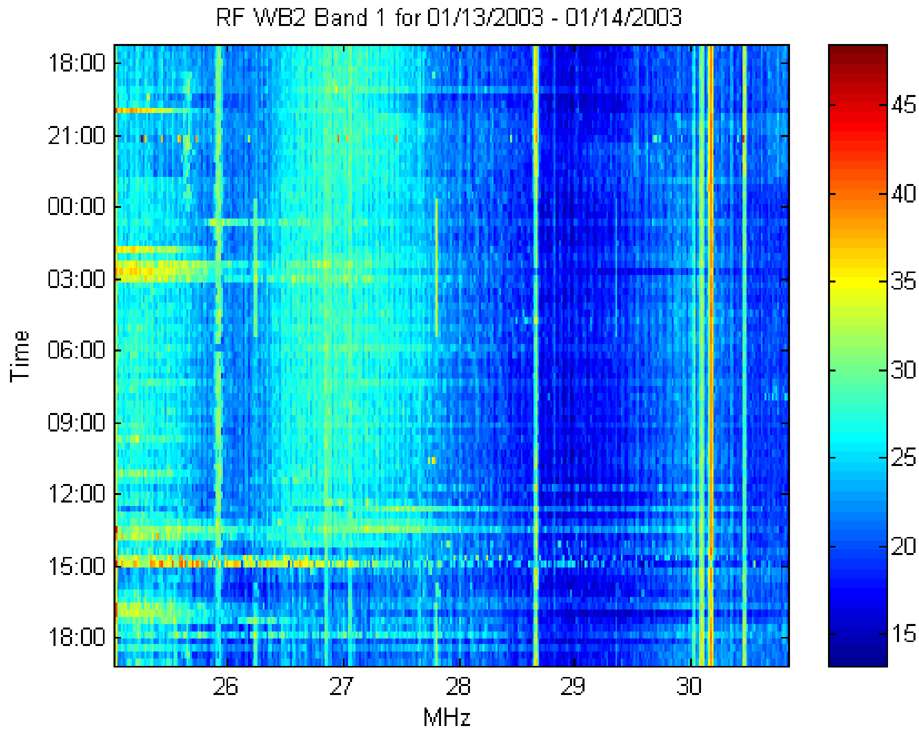

Figure E-55 RF BLDG WB2 BAND 1 (dBuV/m)

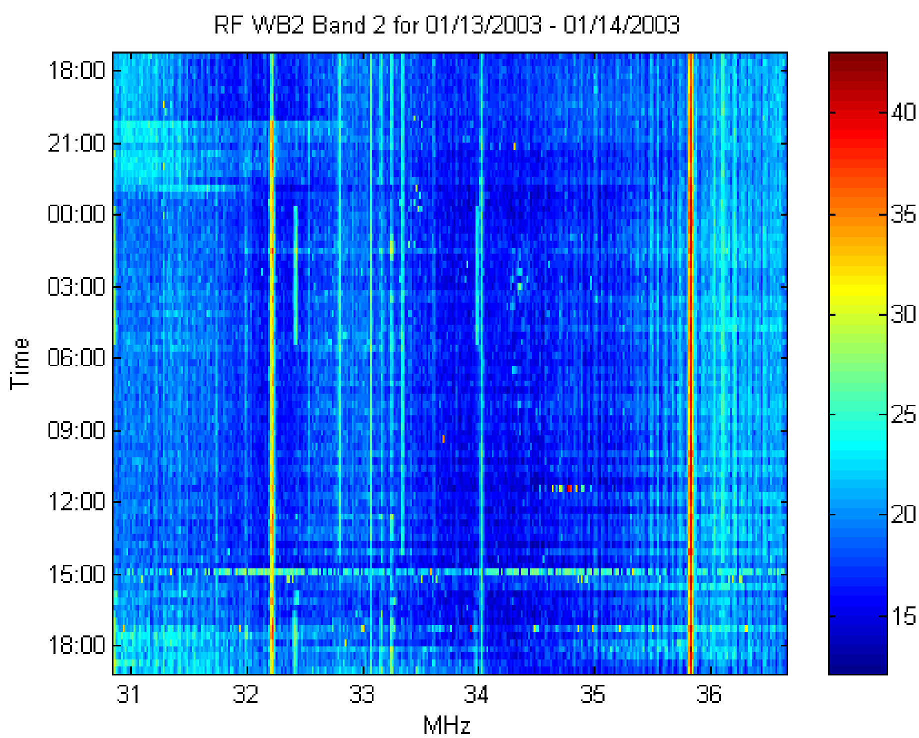

Figure E-56 RF BLDG WB2 BAND 2 (dBuV/m)

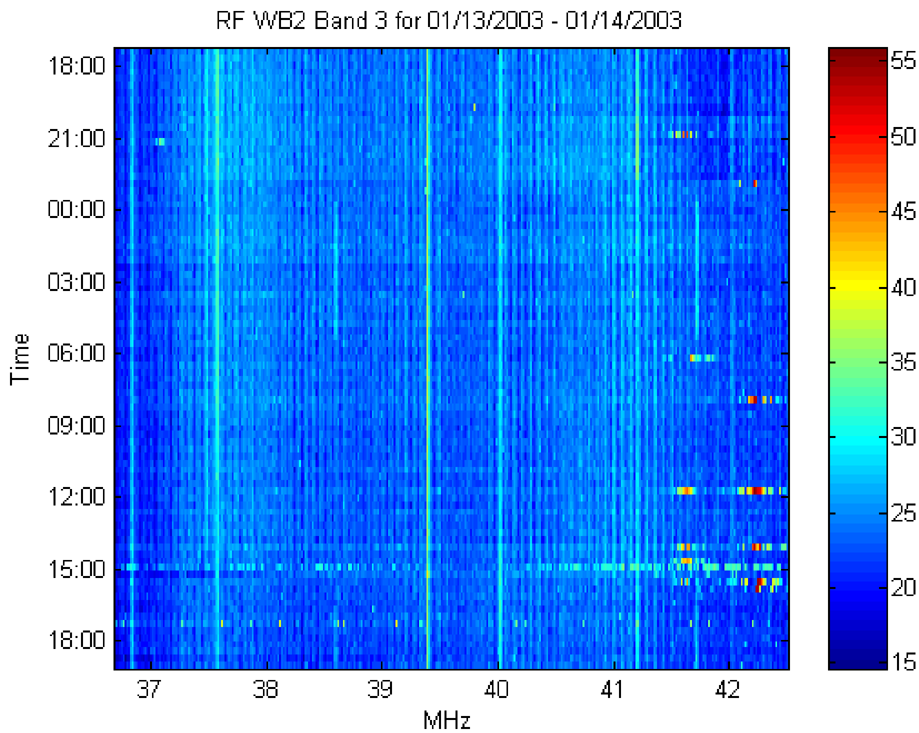

Figure E-57 RF BLDG WB2 BAND 3 (dBuV/m)

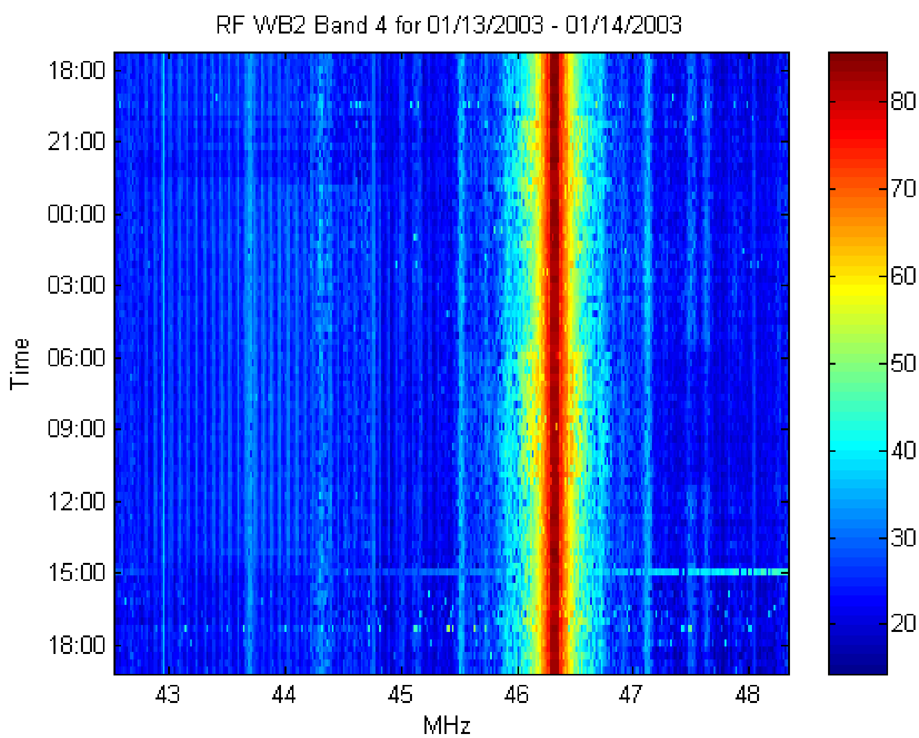

Figure E-58 RF BLDG WB2 BAND 4 (dBuV/m)

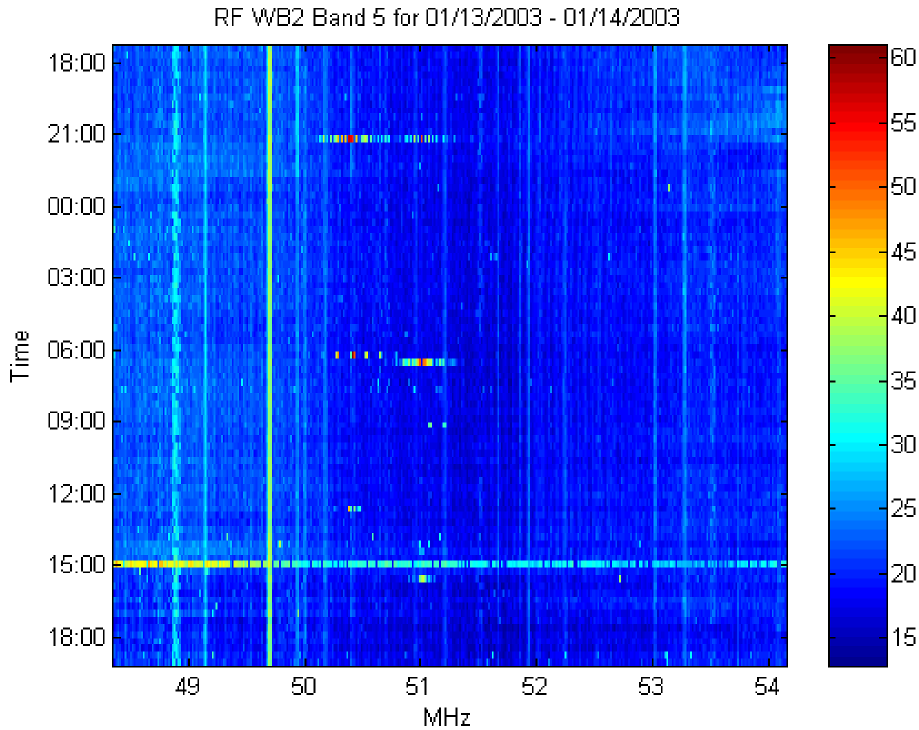

Figure E-59 RF BLDG WB2 BAND 5 (dBuV/m)

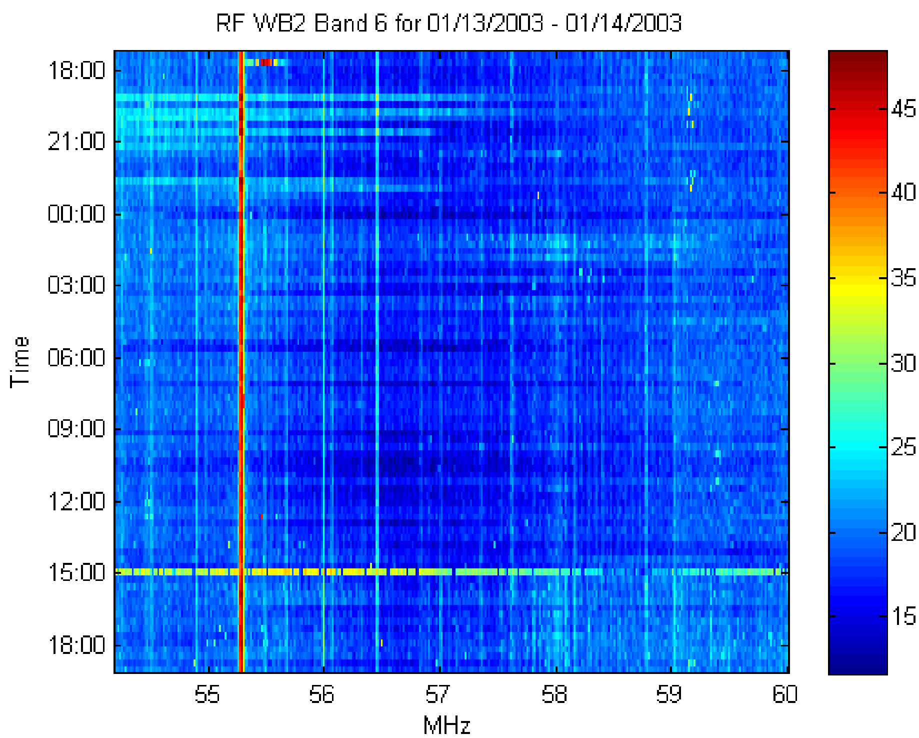

Figure E-60 RF BLDG WB2 BAND 6 (dBuV/m)

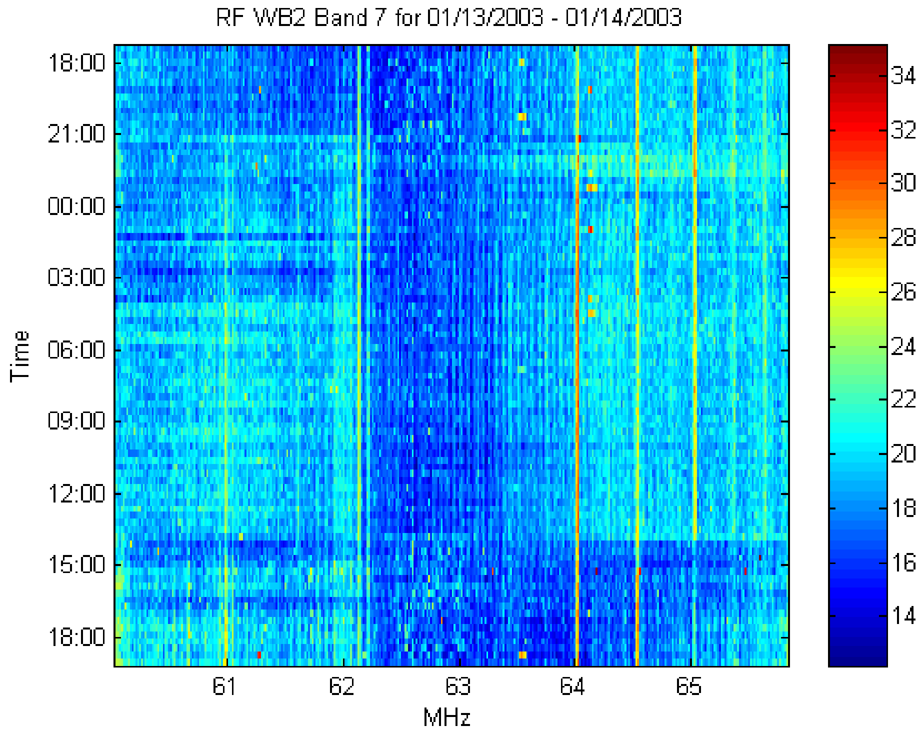

Figure E-61 RF BLDG WB2 BAND7 (dBuV/m)

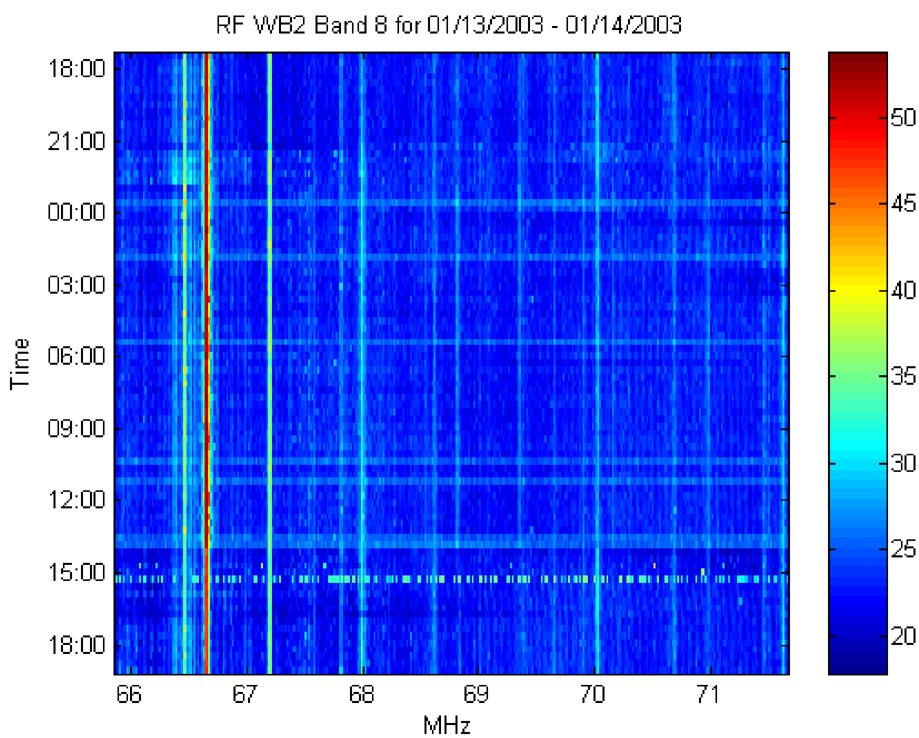

Figure E-62 RF BLDG WB2 BAND 8 (dBuV/m)

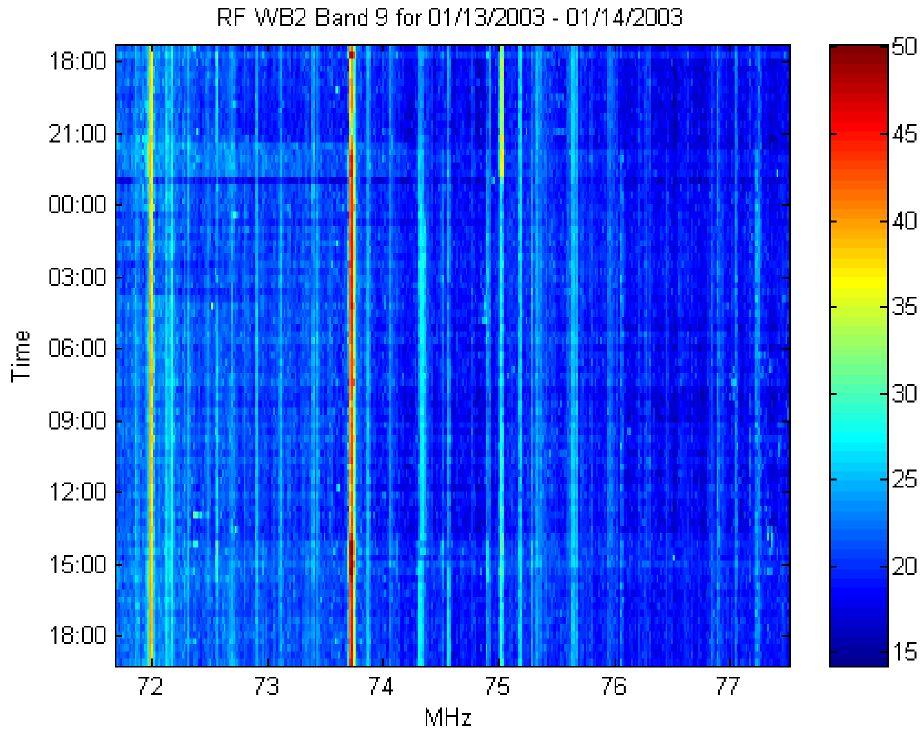

Figure E-63 RF BLDG WB2 BAND 9 (dBuV/m)

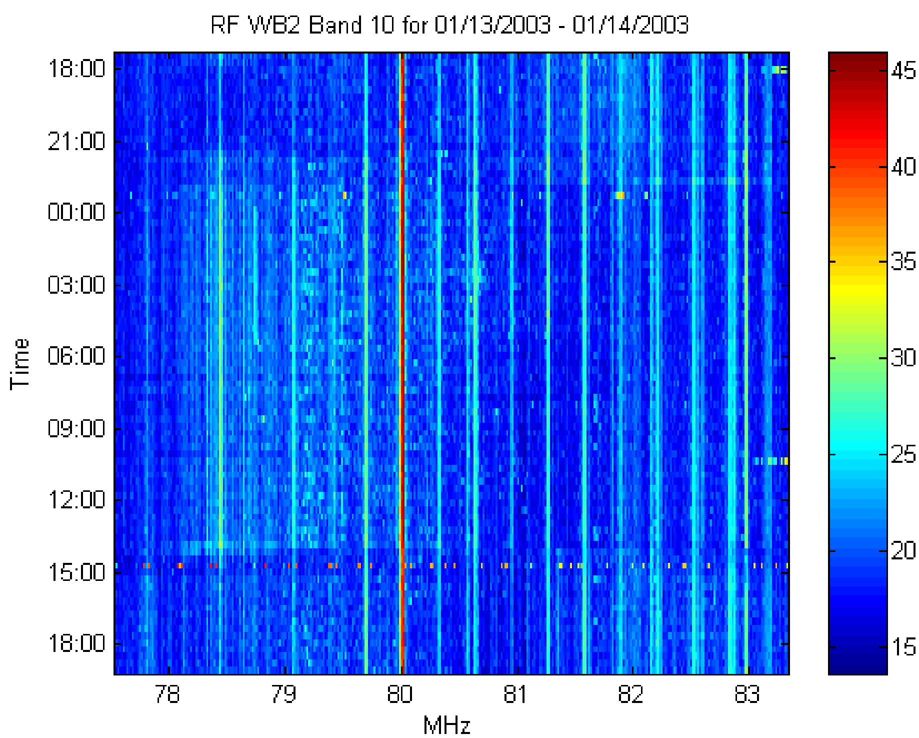

Figure E-64 RF BLDG WB2 BAND 10 (dBuV/m)

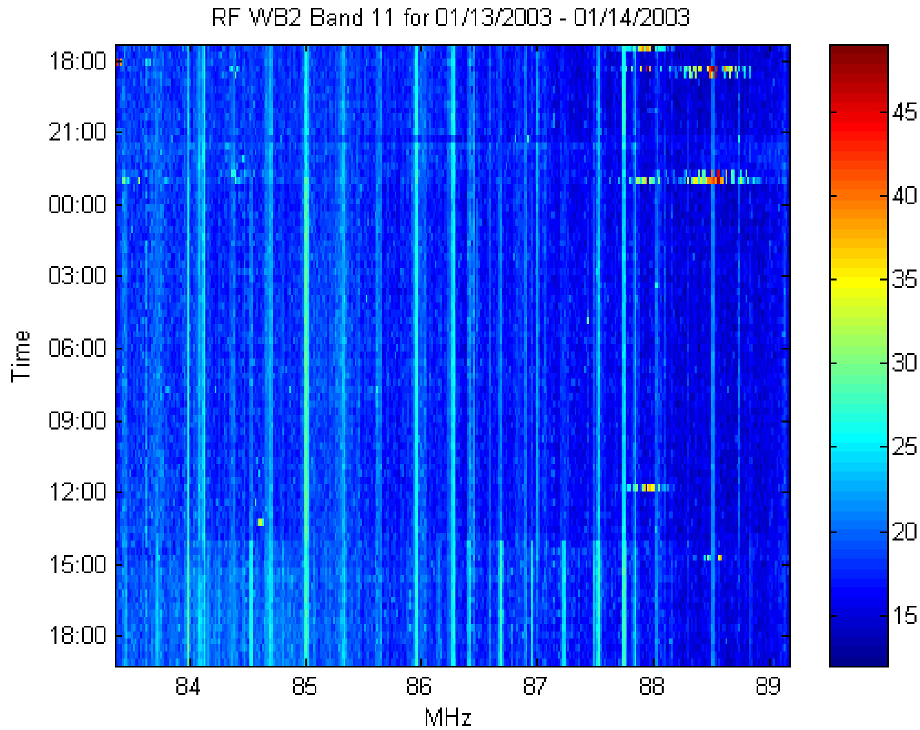

Figure E-65 RF BLDG WB2 BAND 11 (dBuV/m)

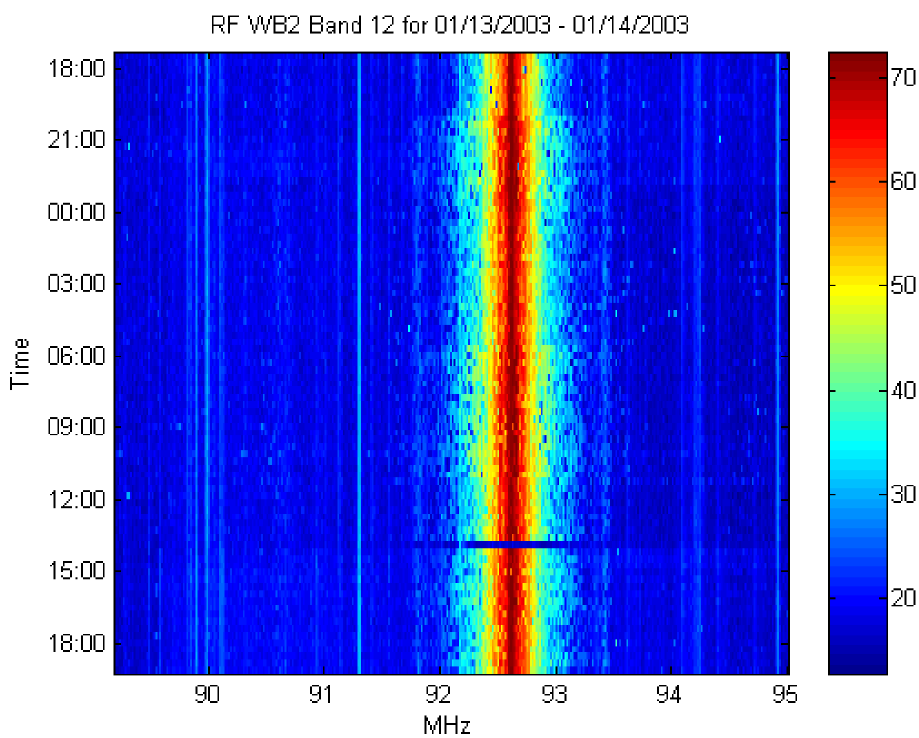

Figure E-66 RF BLDG WB2 BAND 12 (dBuV/m)

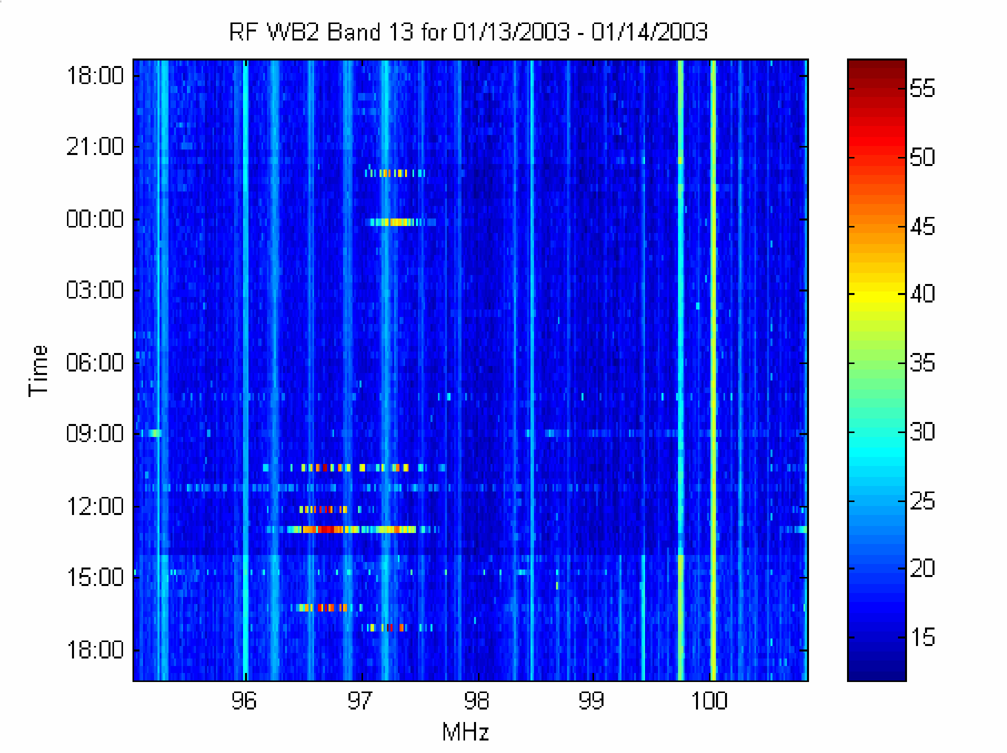

Figure E-67 RF BLDG WB2 BAND 13 (dBuV/m)

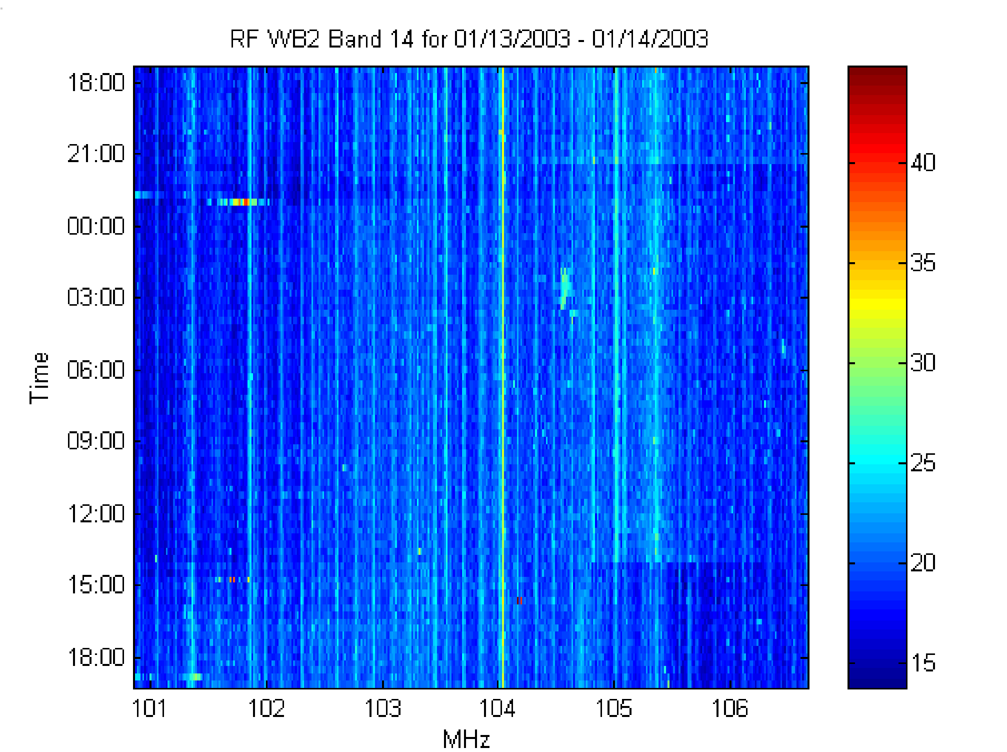

Figure E-68 RF BLDG WB2 BAND 14 (dBuV/m)

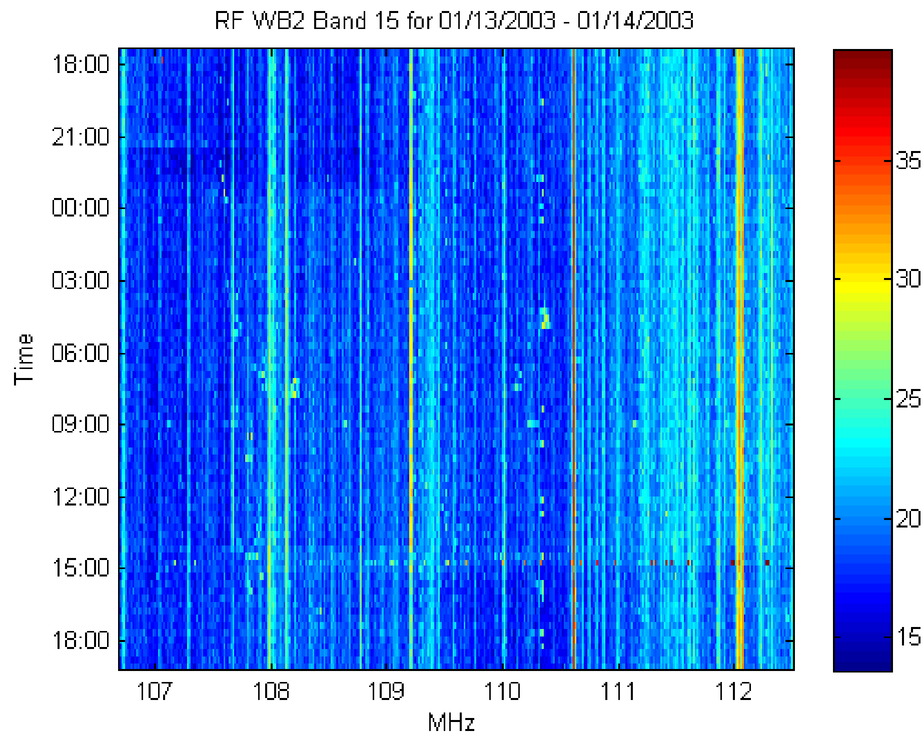

Figure E-69 RF BLDG WB2 BAND 15 (dBuV/m)

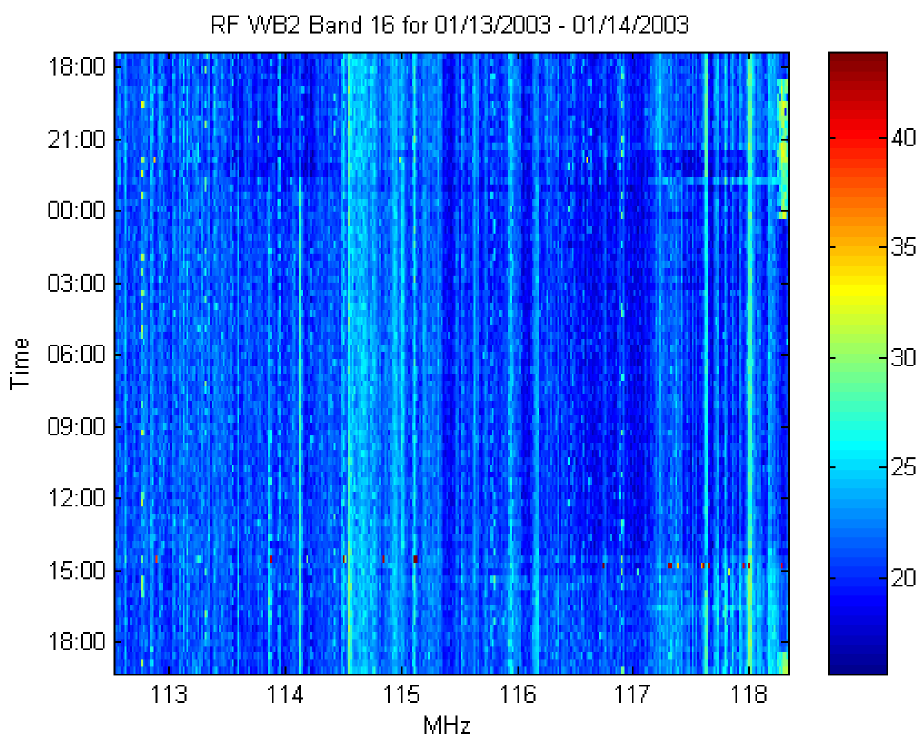

Figure E-70 RF BLDG WB2 BAND 16 (dBuV/m)

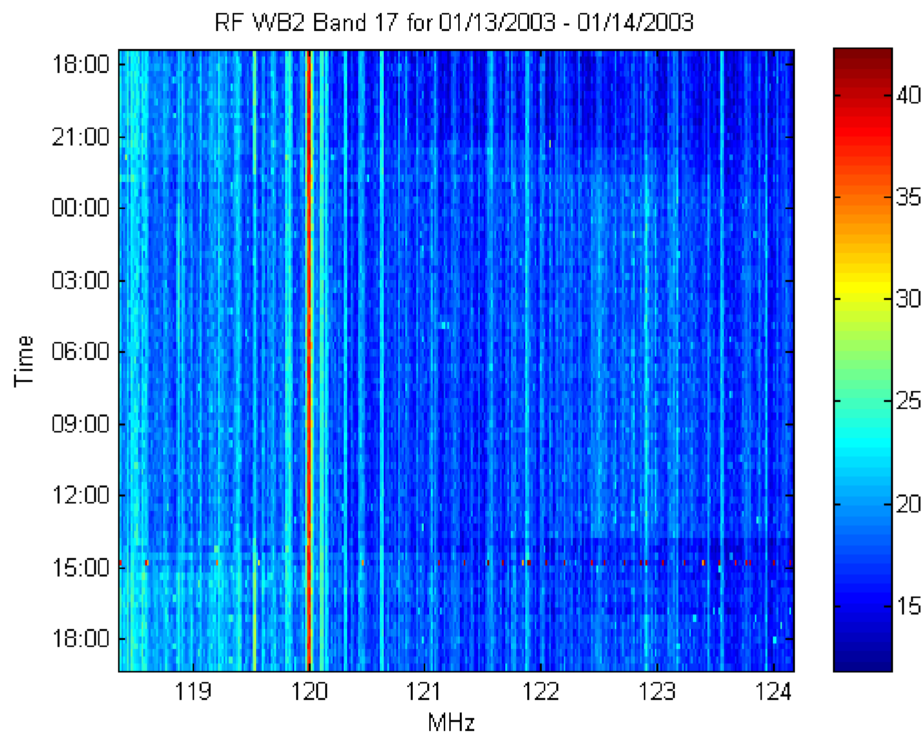

Figure E-71 RF BLDG WB2 BAND 17 (dBuV/m)

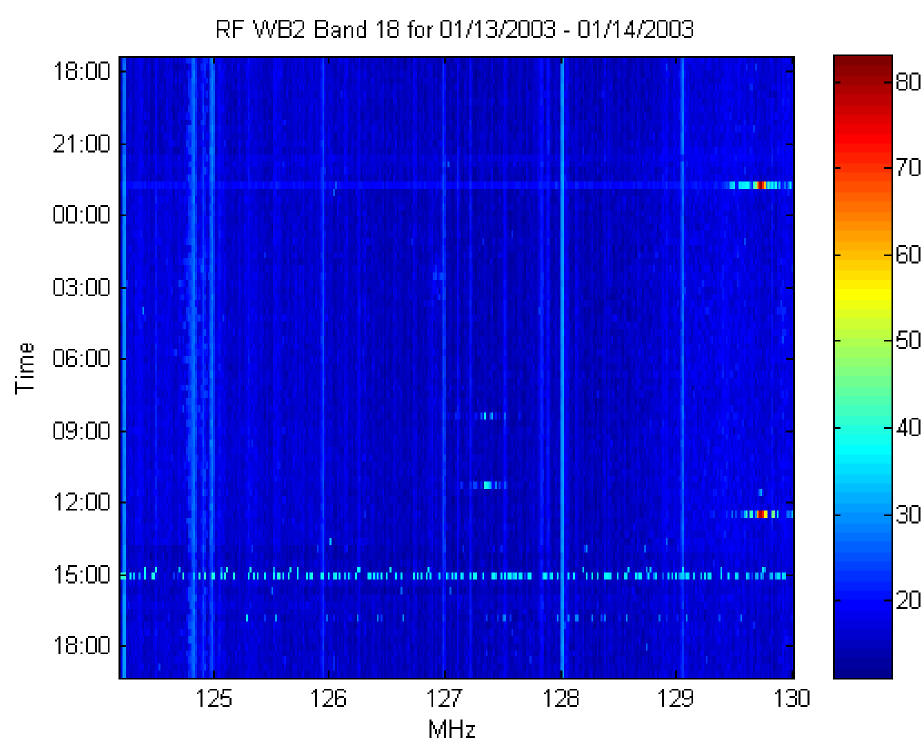

Figure E-72 RF BLDG WB2 BAND 18 (dBuV/m)

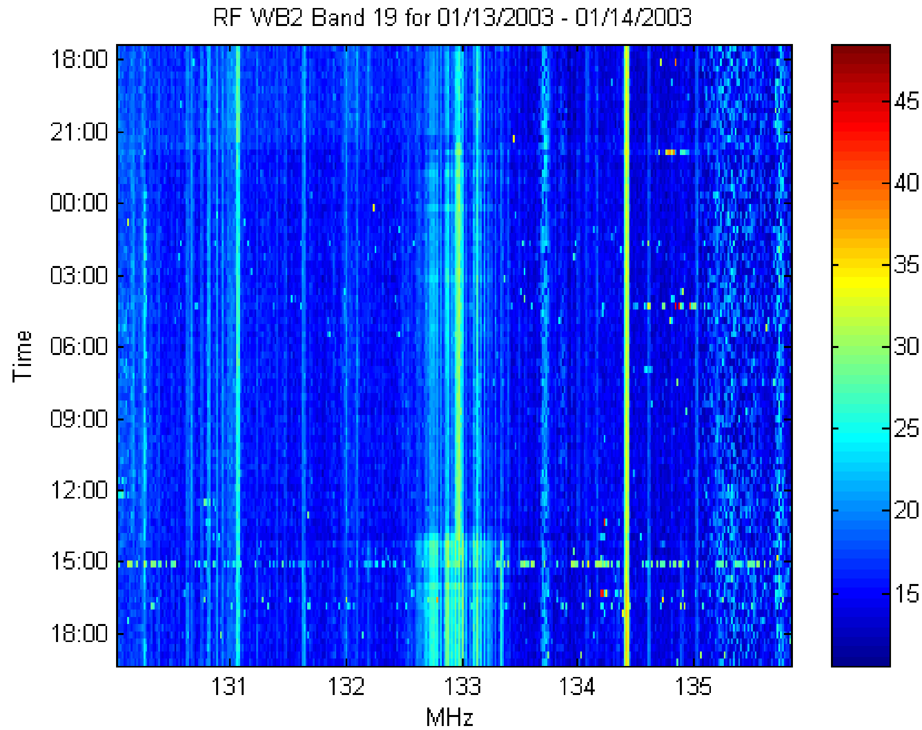

Figure E-73 RF BLDG WB2 BAND 19 (dBuV/m)

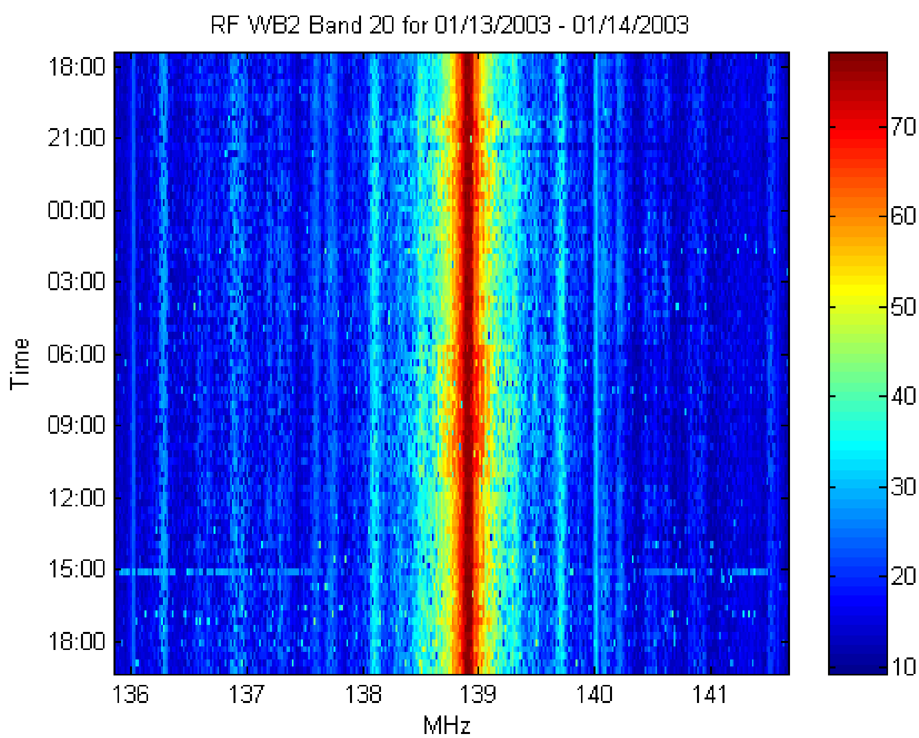

Figure E-74 RF BLDG WB2 BAND 20 (dBuV/m)

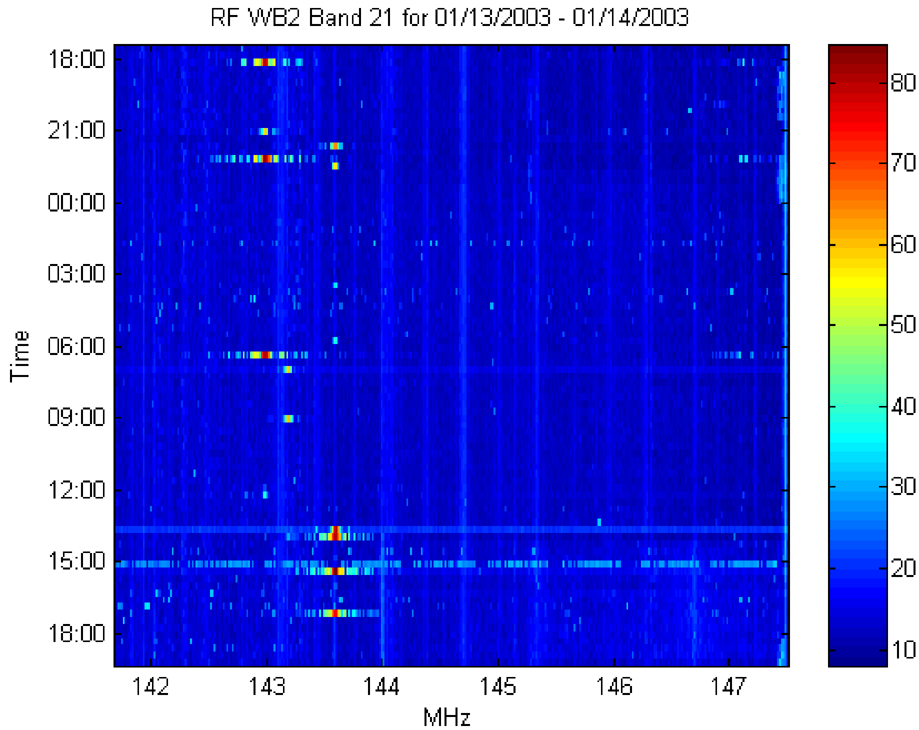

Figure E-75 RF BLDG WB2 BAND 21 (dBuV/m)

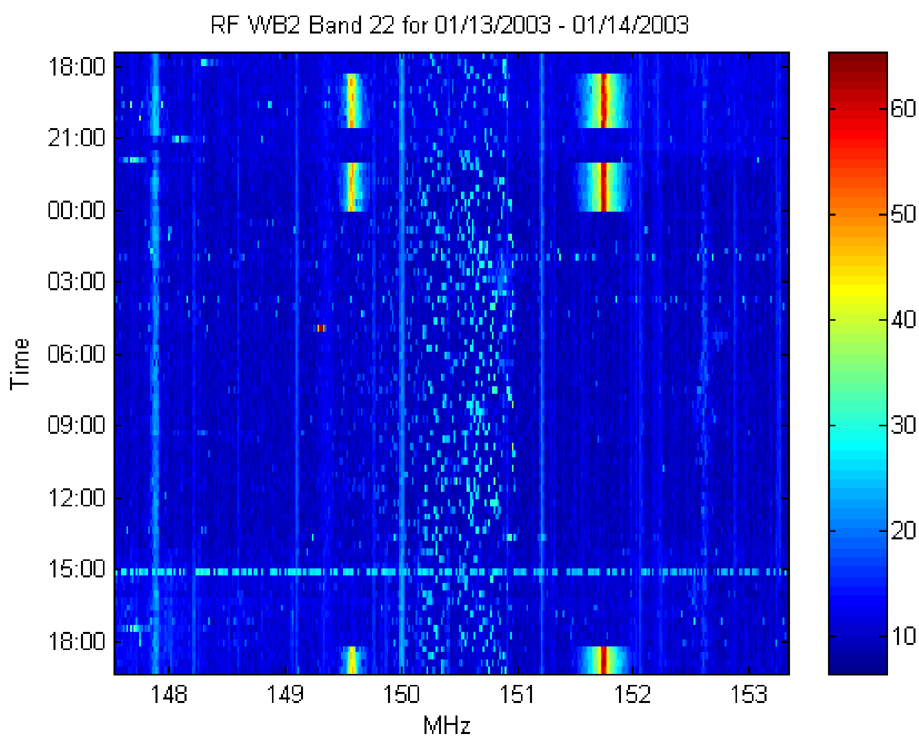

Figure E-76 RF BLDG WB2 BAND 22 (dBuV/m)

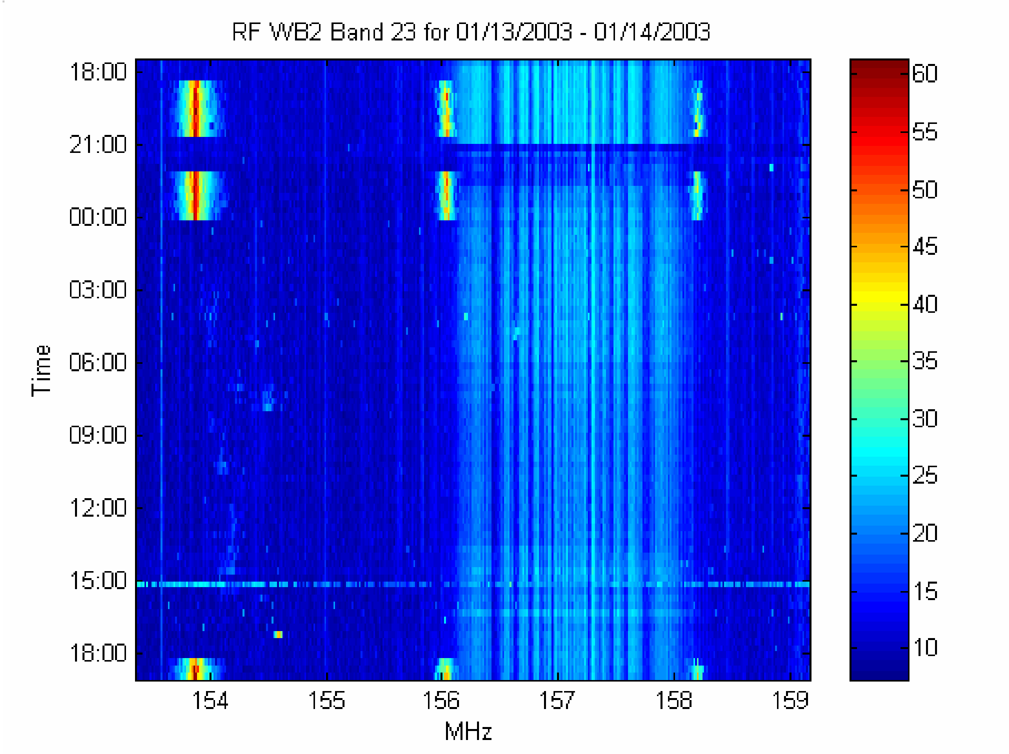

Figure E-77 RF BLDG WB2 BAND 23 (dBuV/m)

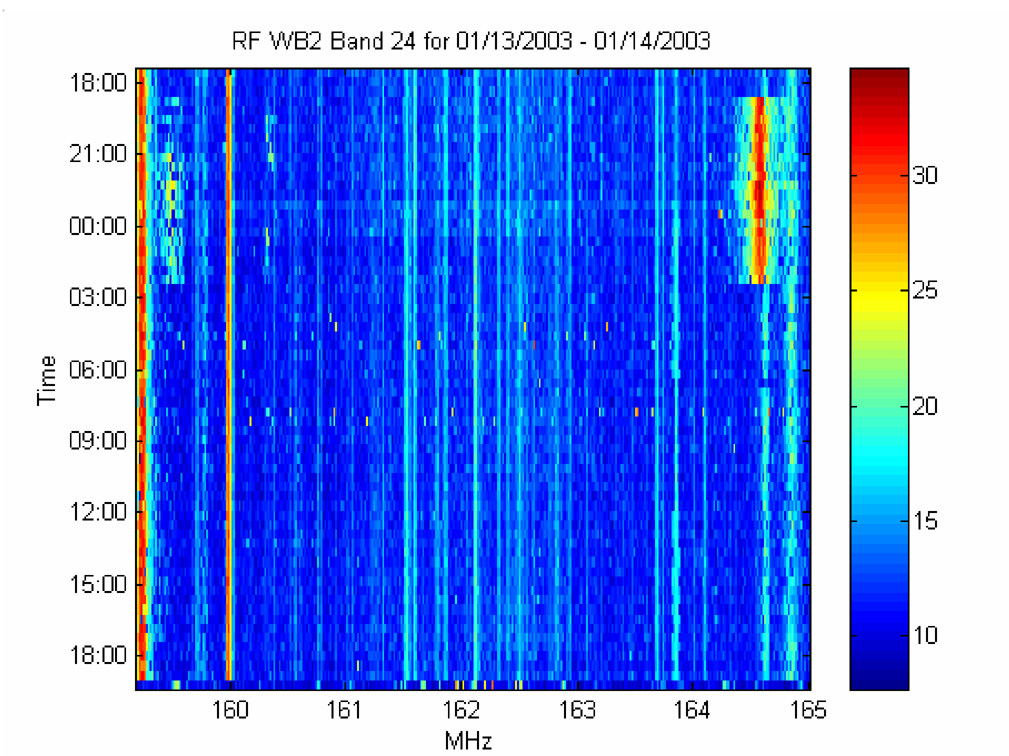

Figure E-78 RF BLDG WB2 BAND 24 (dBuV/m)

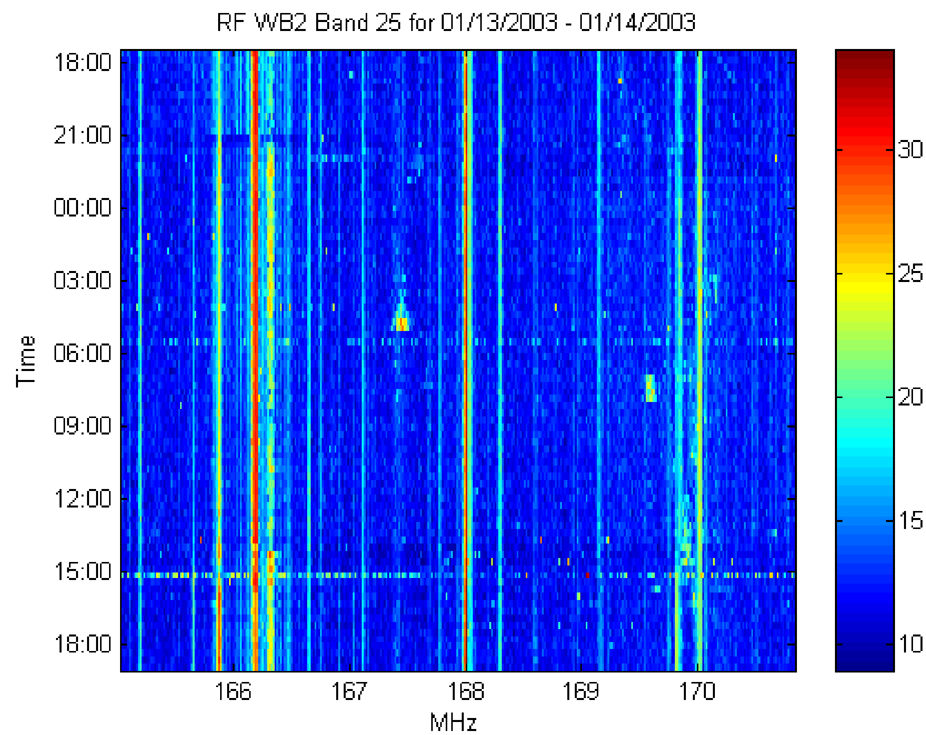

Figure E-79 RF BLDG WB2 BAND 25 (dBuV/m)

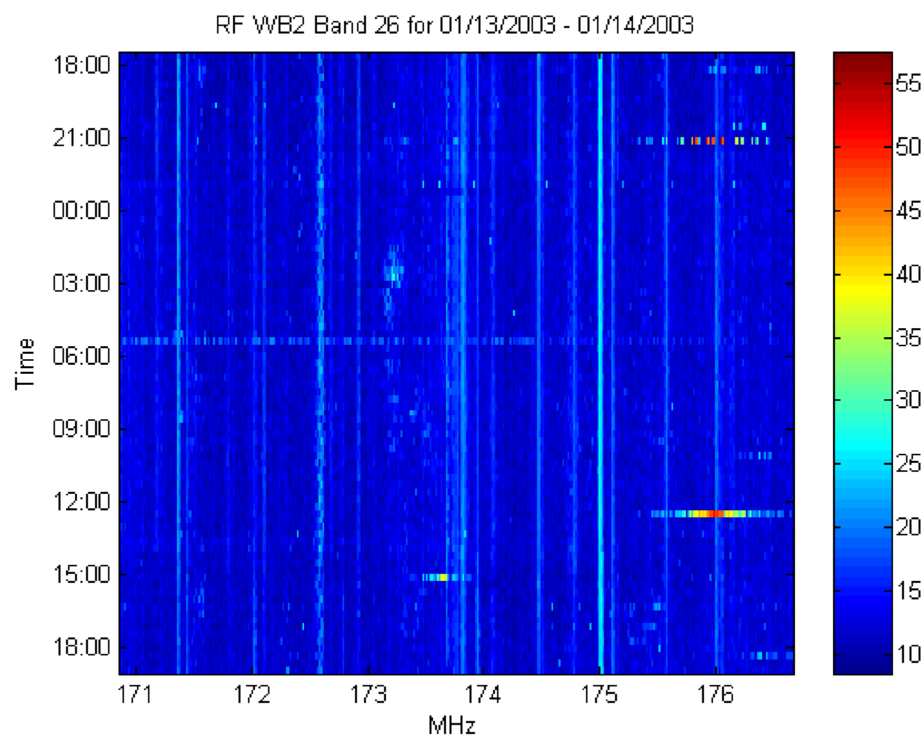

Figure E-80 RF BLDG WB2 BAND 26 (dBuV/m)

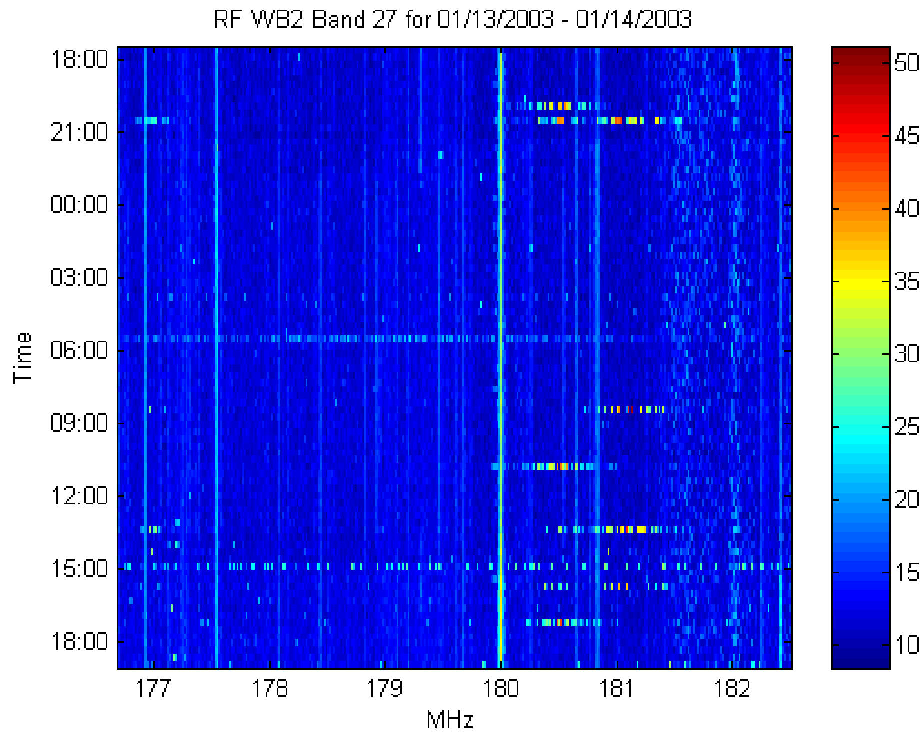

Figure E-81 RF BLDG WB2 BAND 27 (dBuV/m)

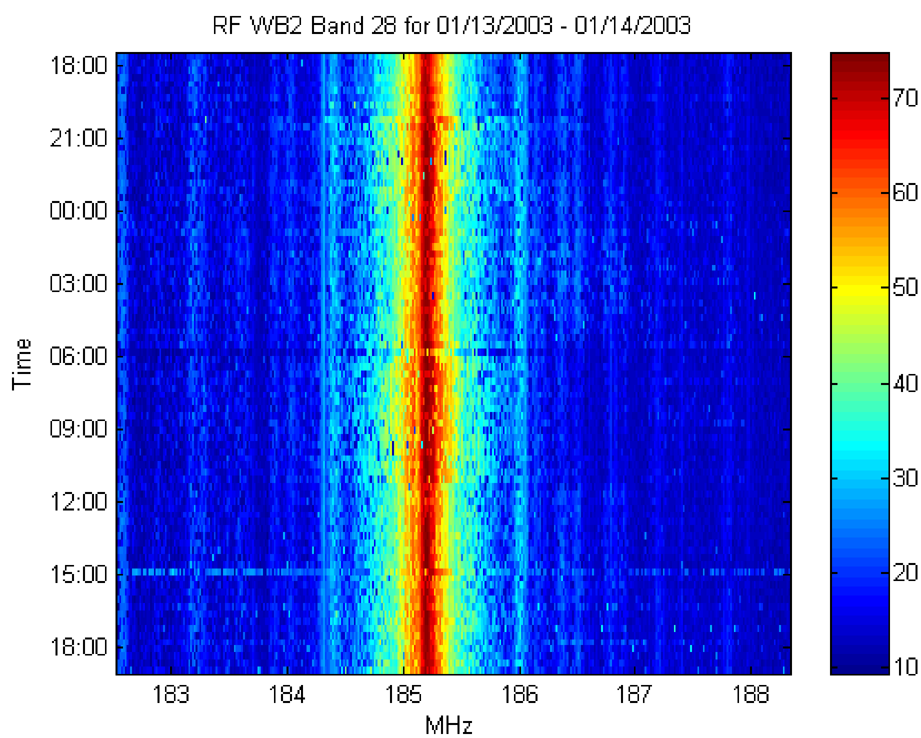

Figure E-82 RF BLDG WB2 BAND 28 (dBuV/m)

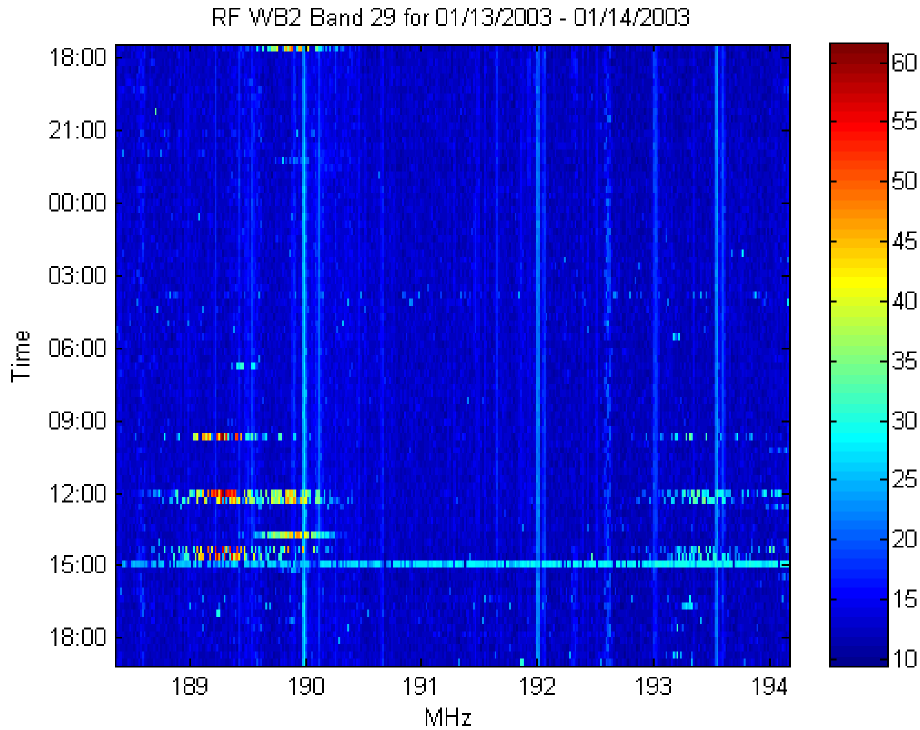

Figure E-83 RF BLDG WB2 BAND 29 (dBuV/m)

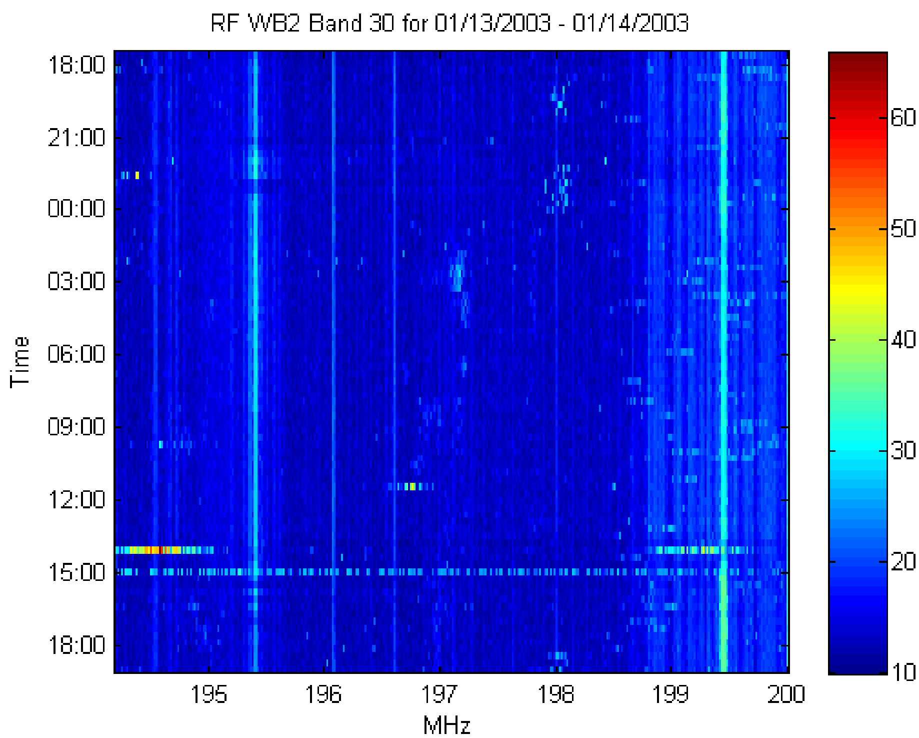

Figure E-84 RF BLDG WB2 BAND 30 (dBuV/m)

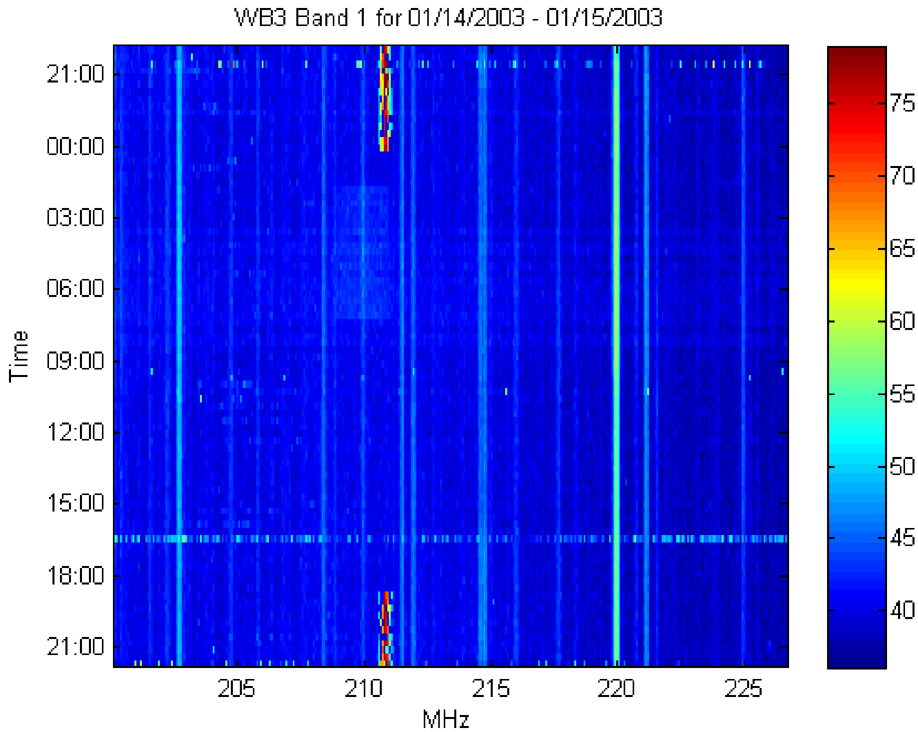

Figure E-85 RF BLDG WB3 BAND 1 (dBuV/m)

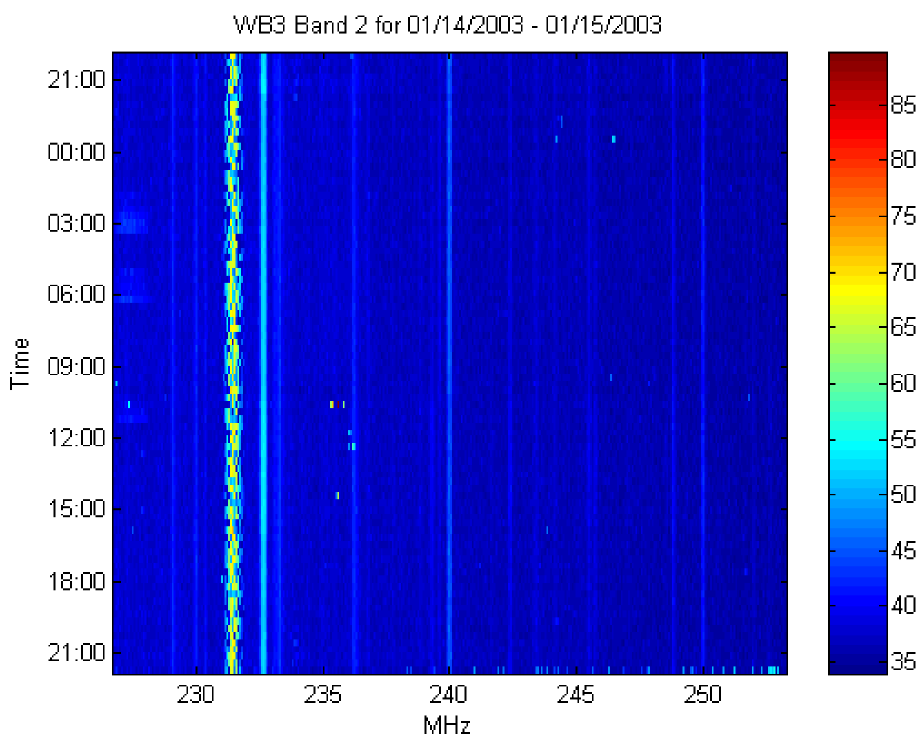

Figure E-86 RF BLDG WB3 BAND 2 (dBuV/m)

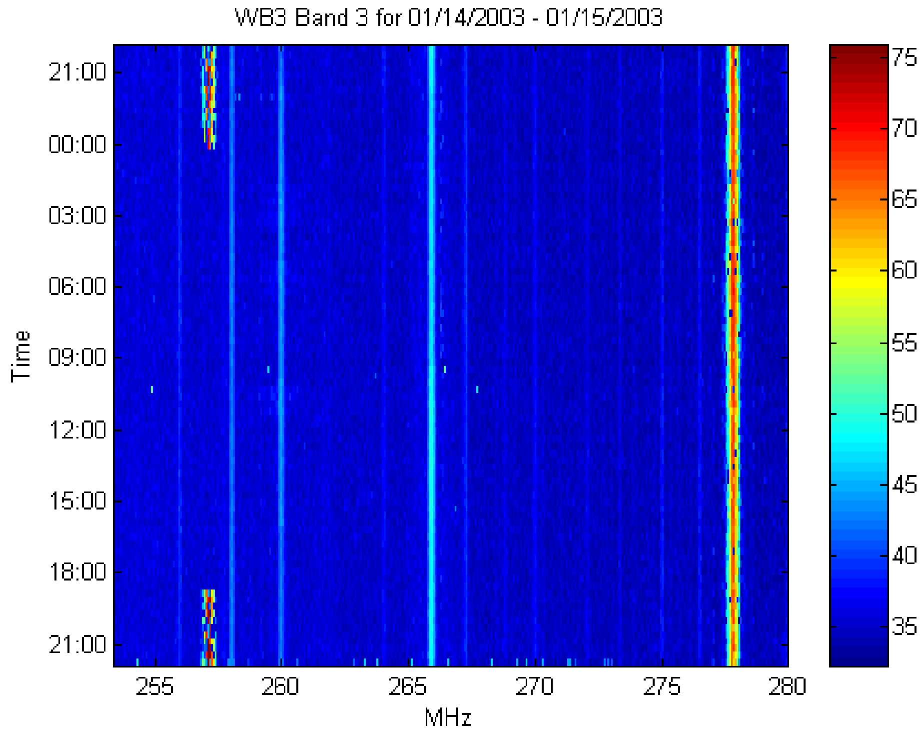

Figure E-87 RF BLDG WB3 BAND 3 (dBuV/m)

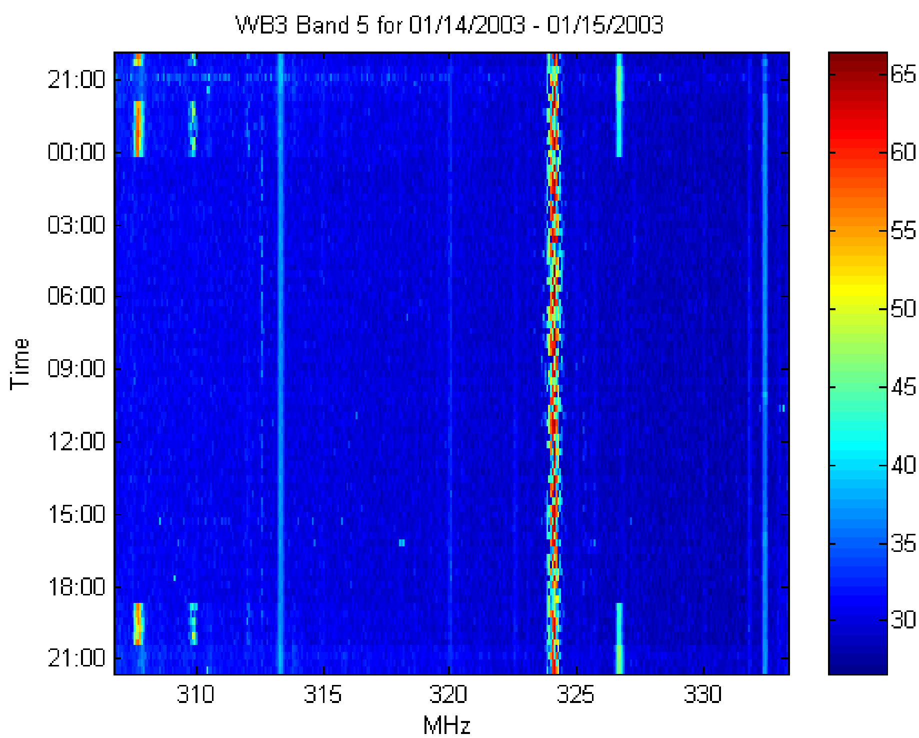

Figure E-88 RF BLDG WB3 BAND 5 (dBuV/m)

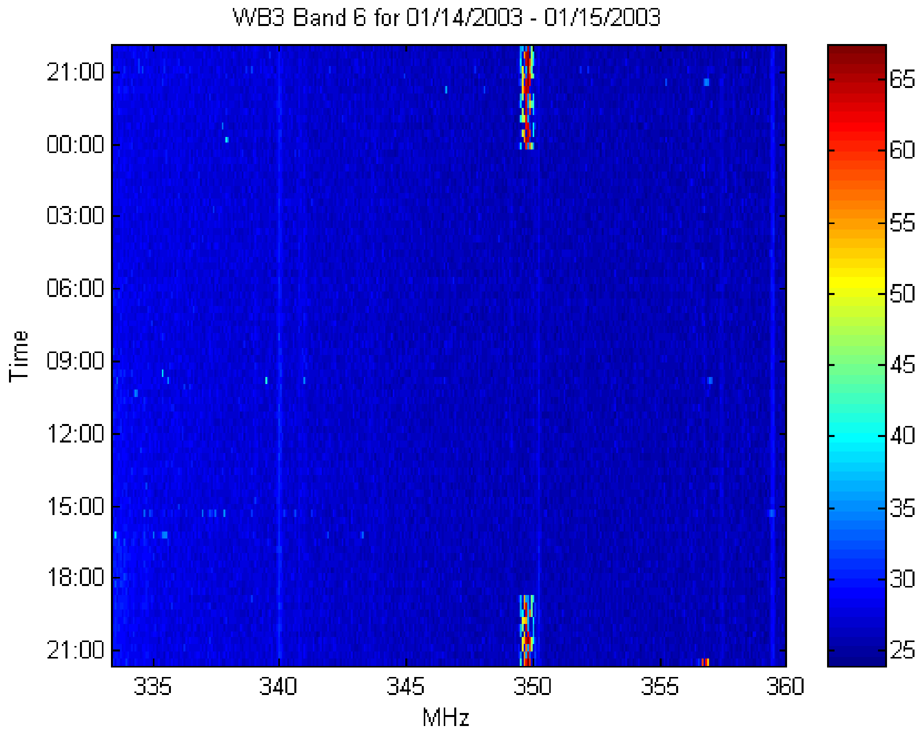

Figure E-89 RF BLDG WB3 BAND 6 (dBuV/m)

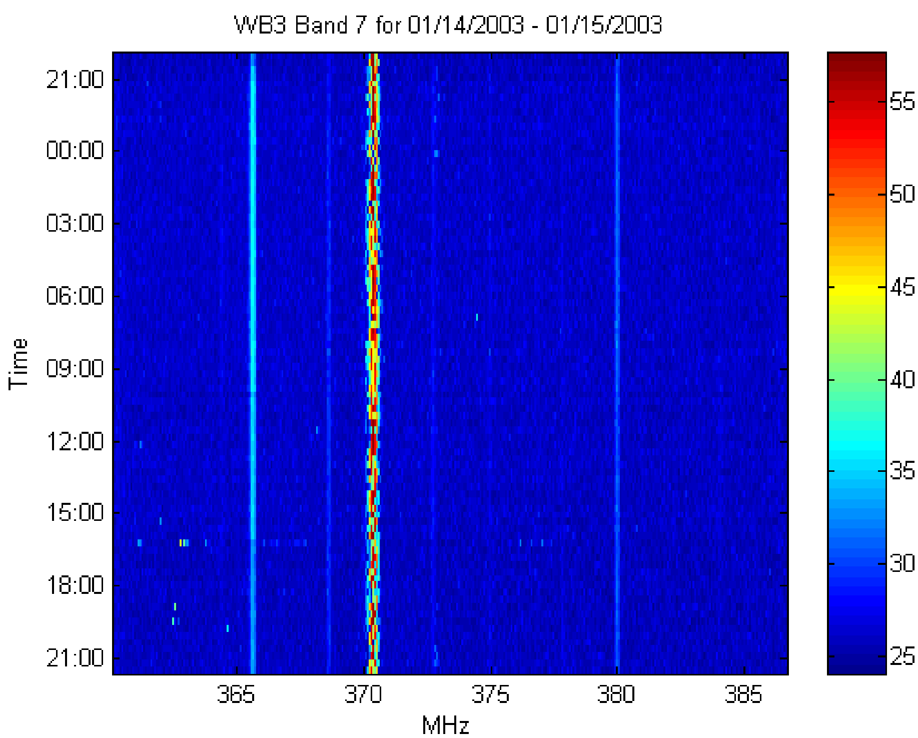

Figure E-90 RF BLDG WB3 BAND 7 (dBuV/m)

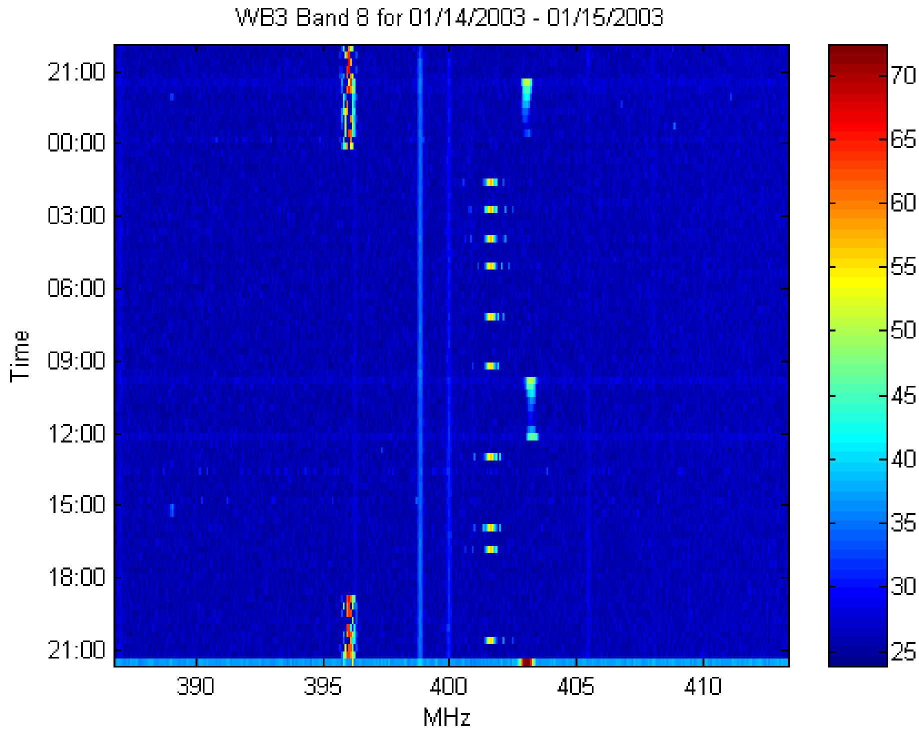

Figure E-91 RF BLDG WB3 BAND 8 (dBuV/m)

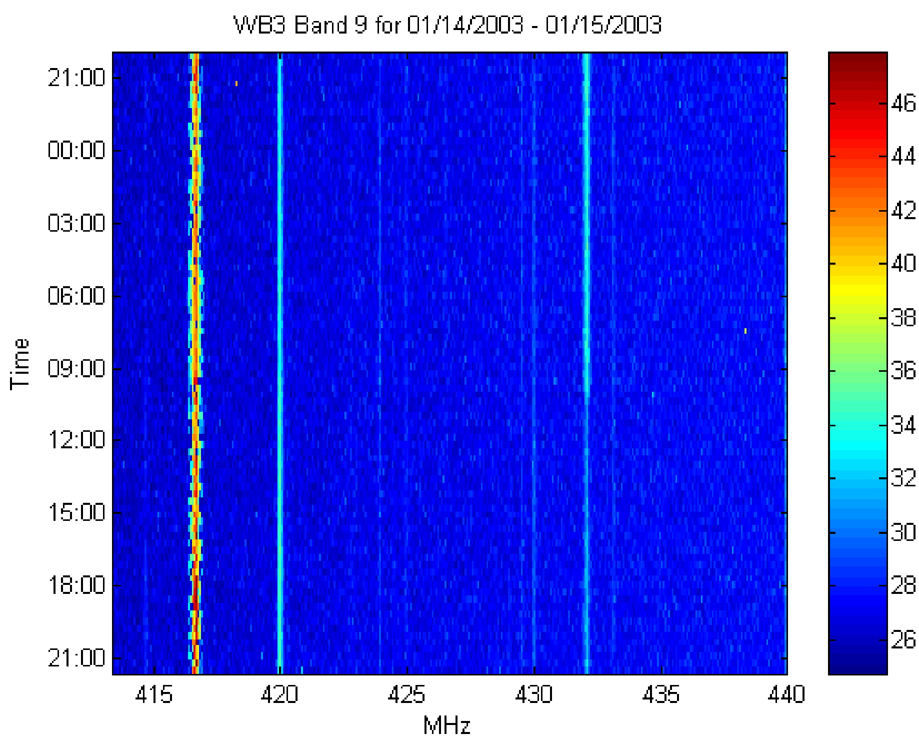

Figure E-92 RF BLDG WB3 BAND 9 (dBuV/m)

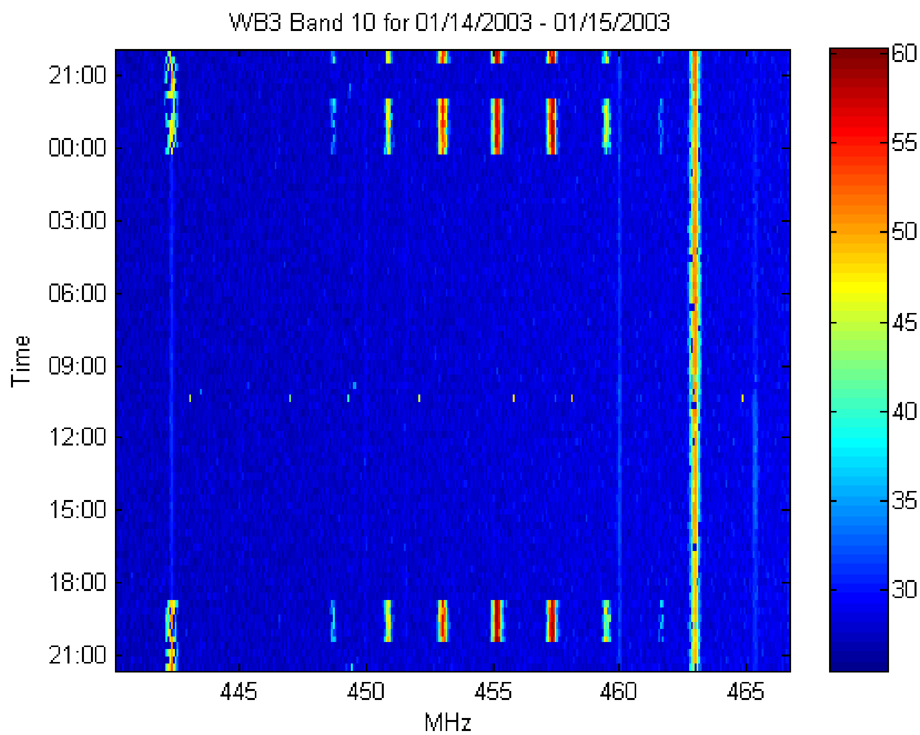

Figure E-93 RF BLDG WB3 BAND 10 (dBuV/m)

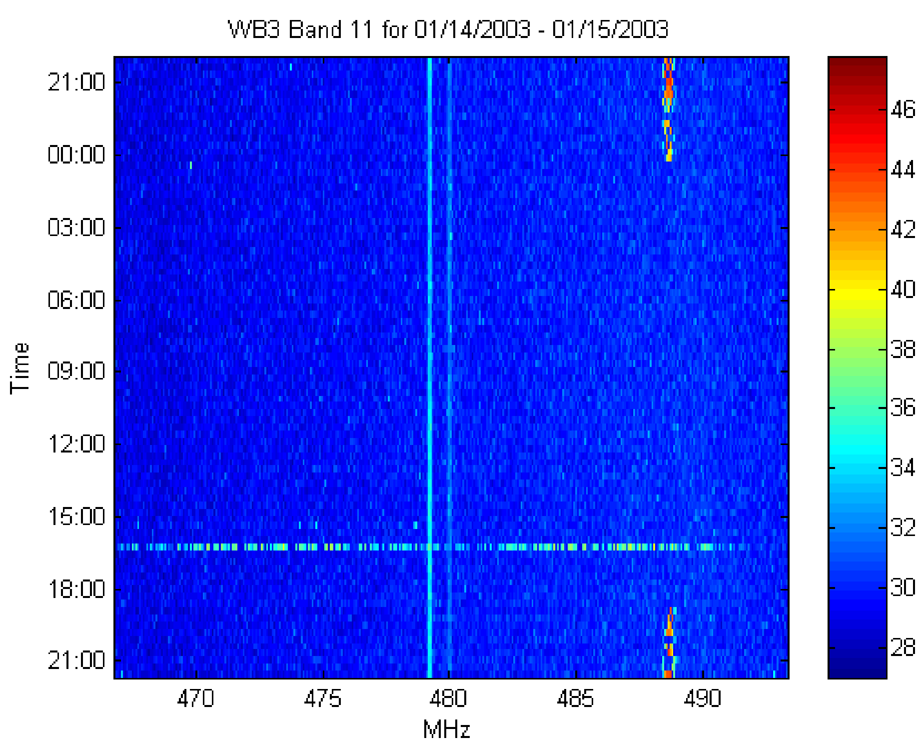

Figure E-94 RF BLDG WB3 BAND 11 (dBuV/m)

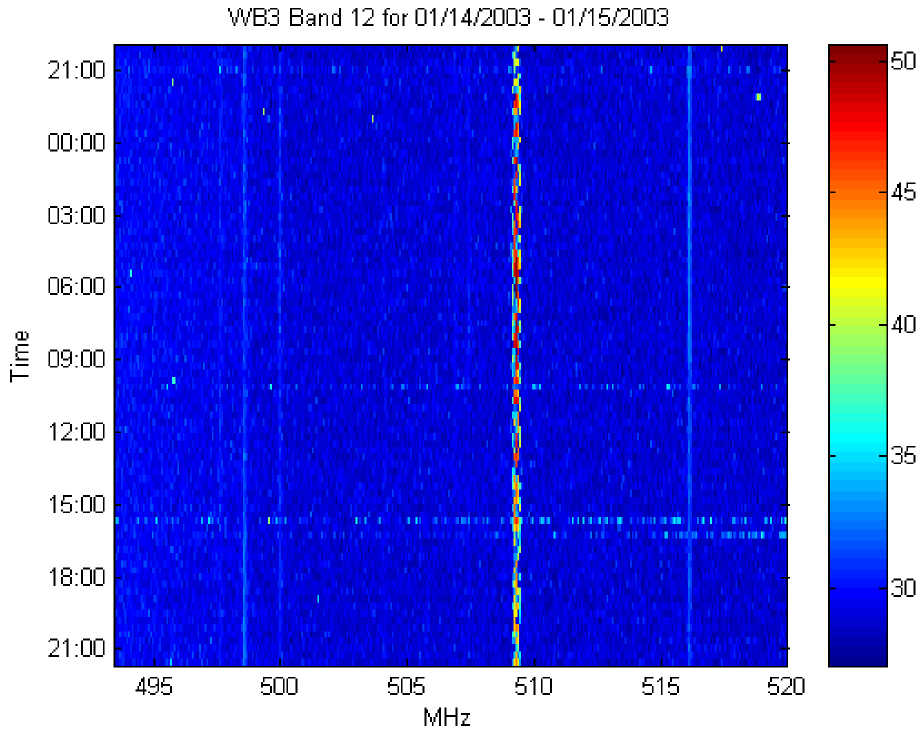

Figure E-95 RF BLDG WB3 BAND 12 (dBuV/m)

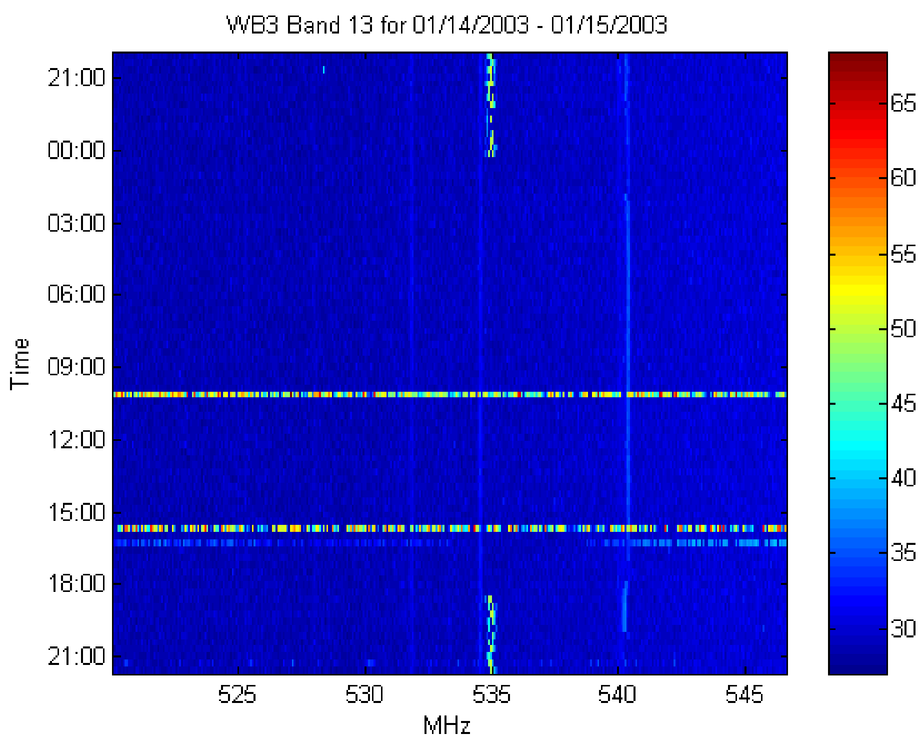

Figure E-96 RF BLDG WB3 BAND 13 (dBuV/m)

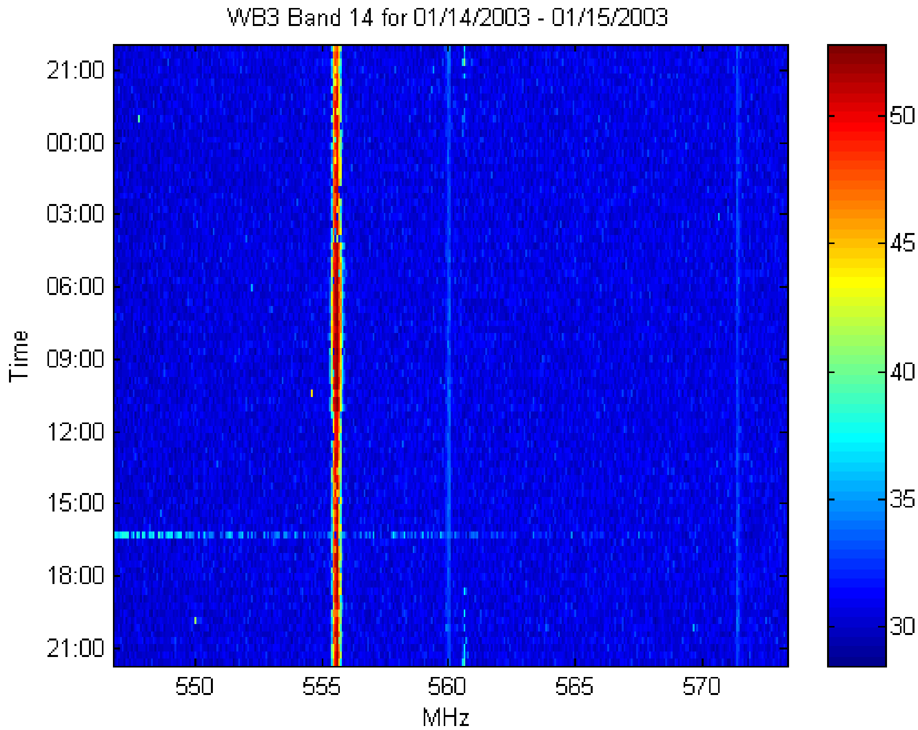

Figure E-97 RF BLDG WB3 BAND 14 (dBuV/m)

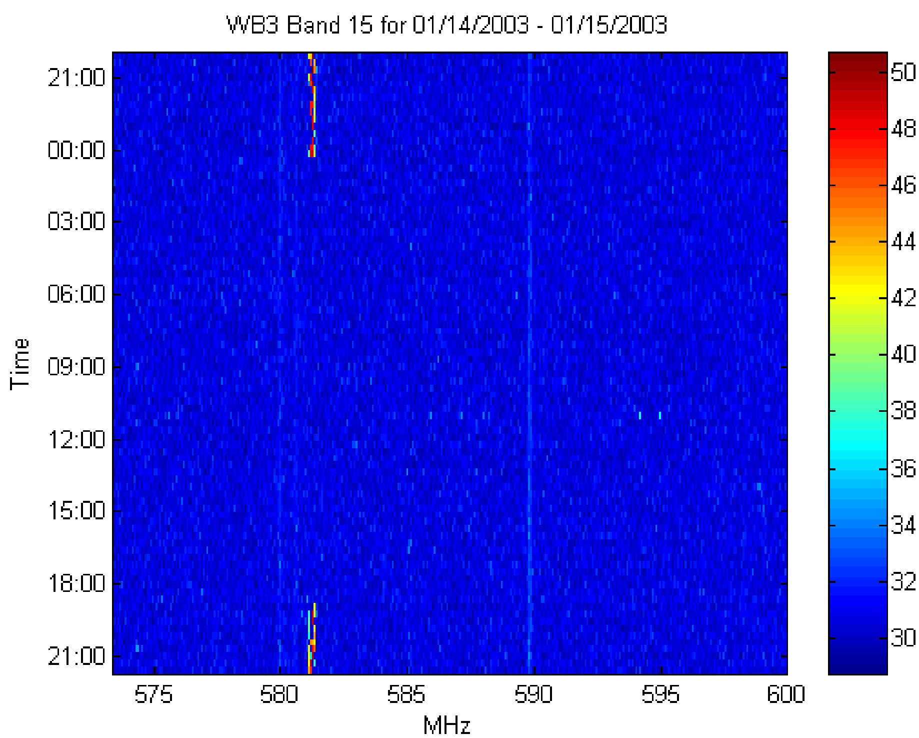

Figure E-98 RF BLDG WB3 BAND 15 (dBuV/m)

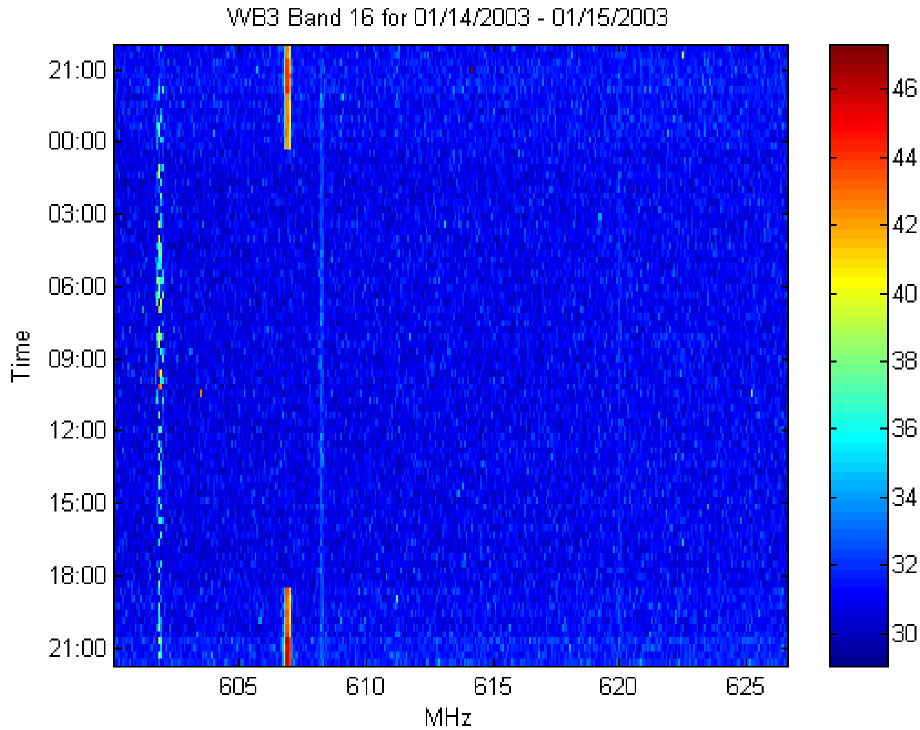

Figure E-99 RF BLDG WB3 BAND 16 (dBuV/m)

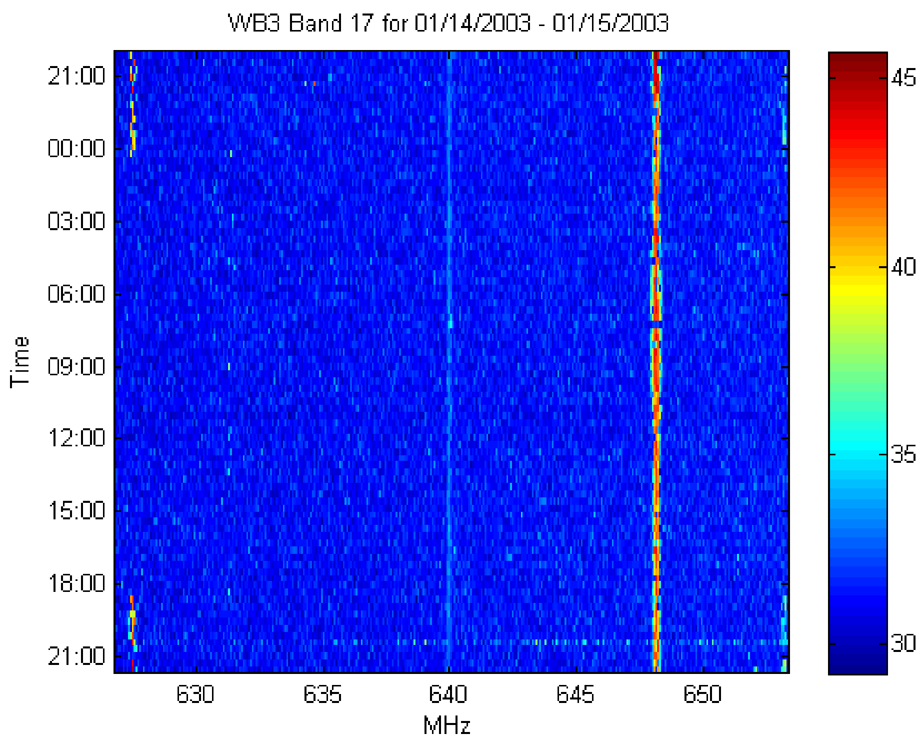

Figure E-100 RF BLDG WB3 BAND 17 (dBuV/m)

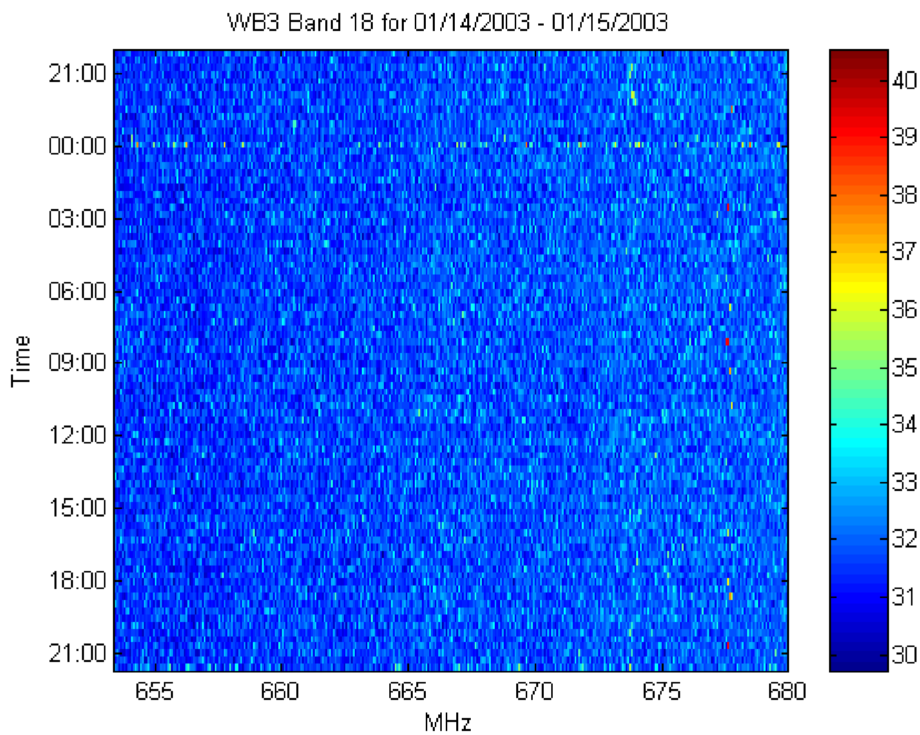

Figure E-101 RF BLDG WB3 BAND 18 (dBuV/m)

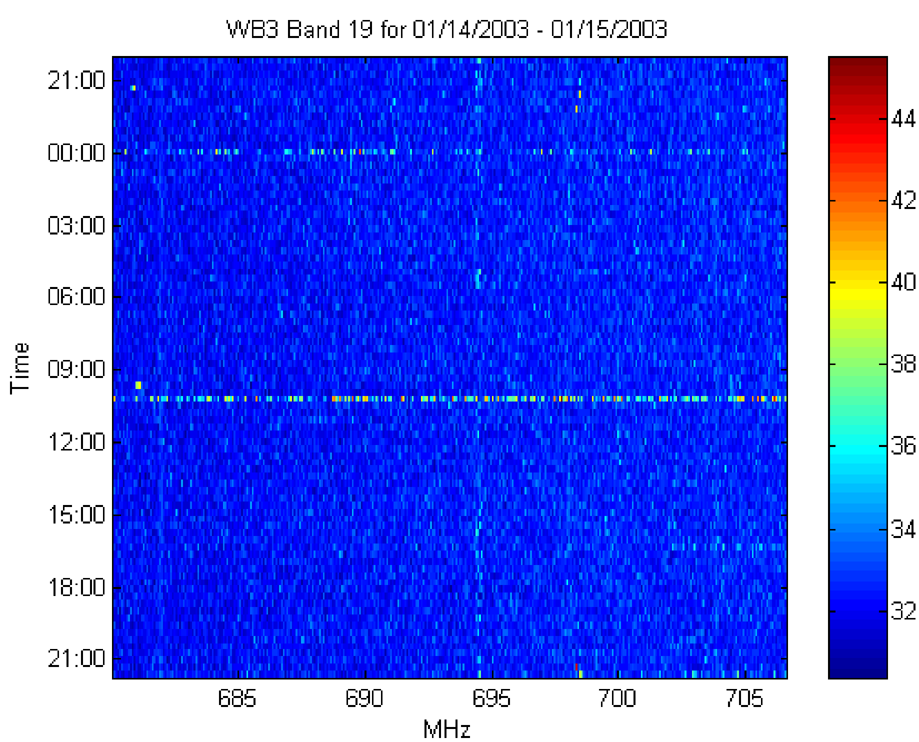

Figure E-102 RF BLDG WB3 BAND 19 (dBuV/m)

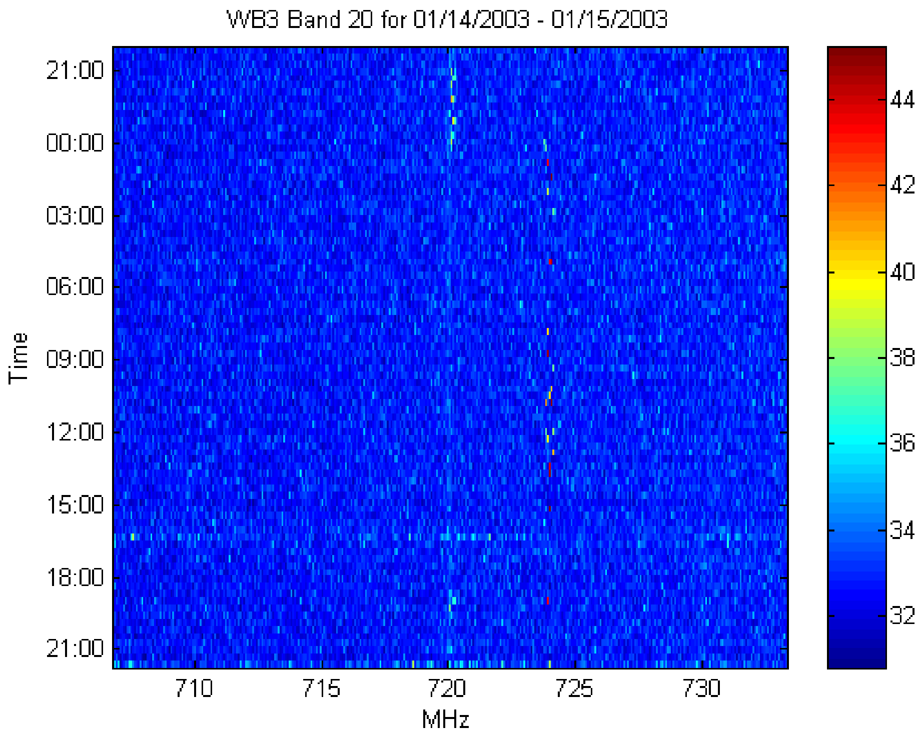

Figure E-103 RF BLDG WB3 BAND 20 (dBuV/m)

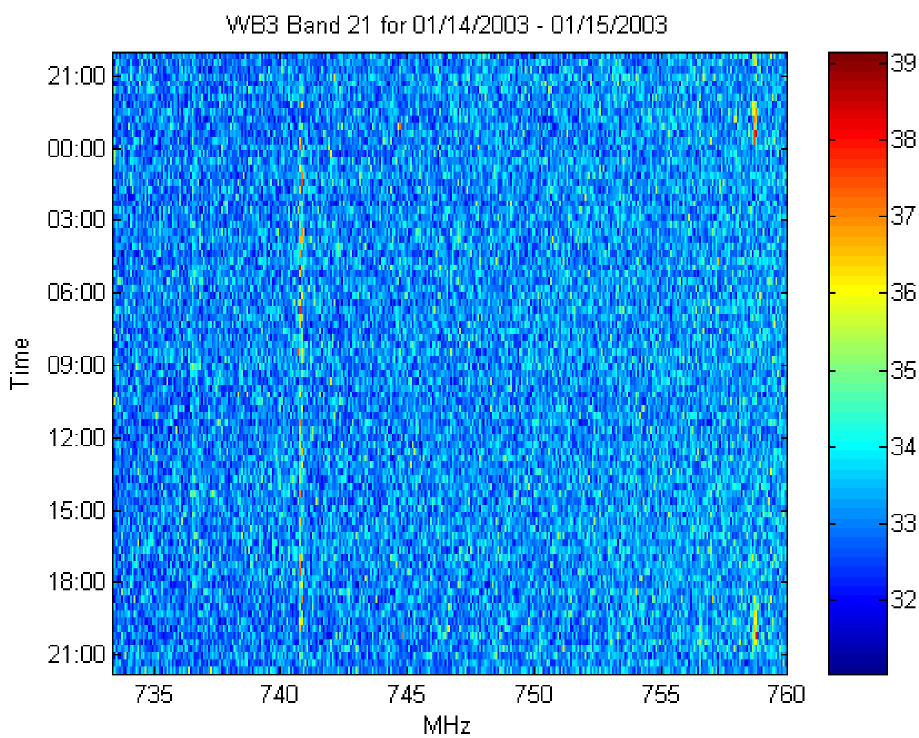

Figure E-104 RF BLDG WB3 BAND 21 (dBuV/m)

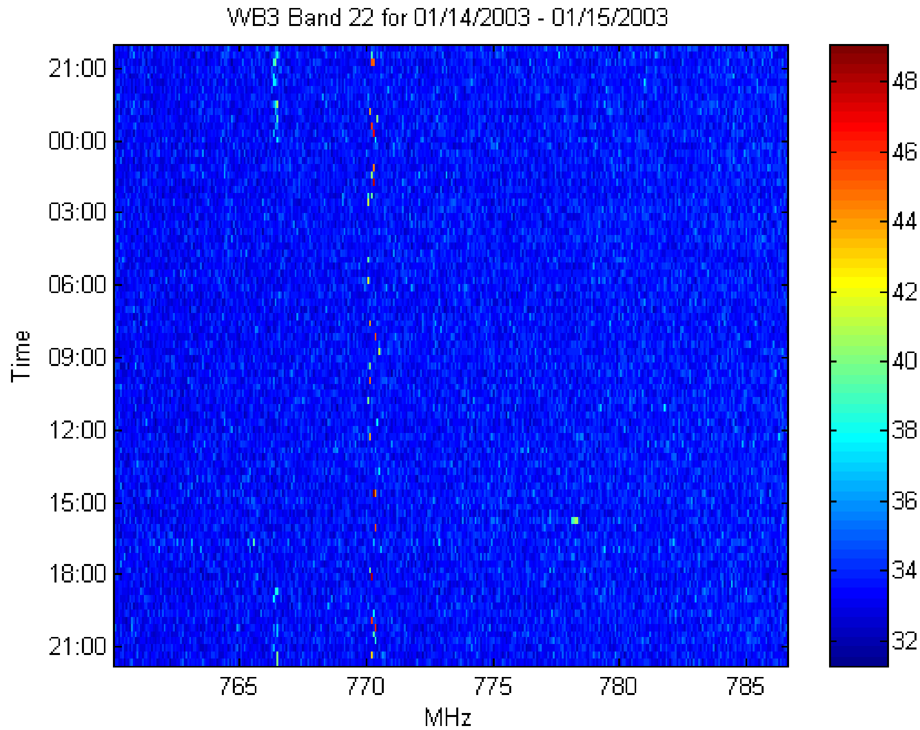

Figure E-105 RF BLDG WB3 BAND 22 (dBuV/m)

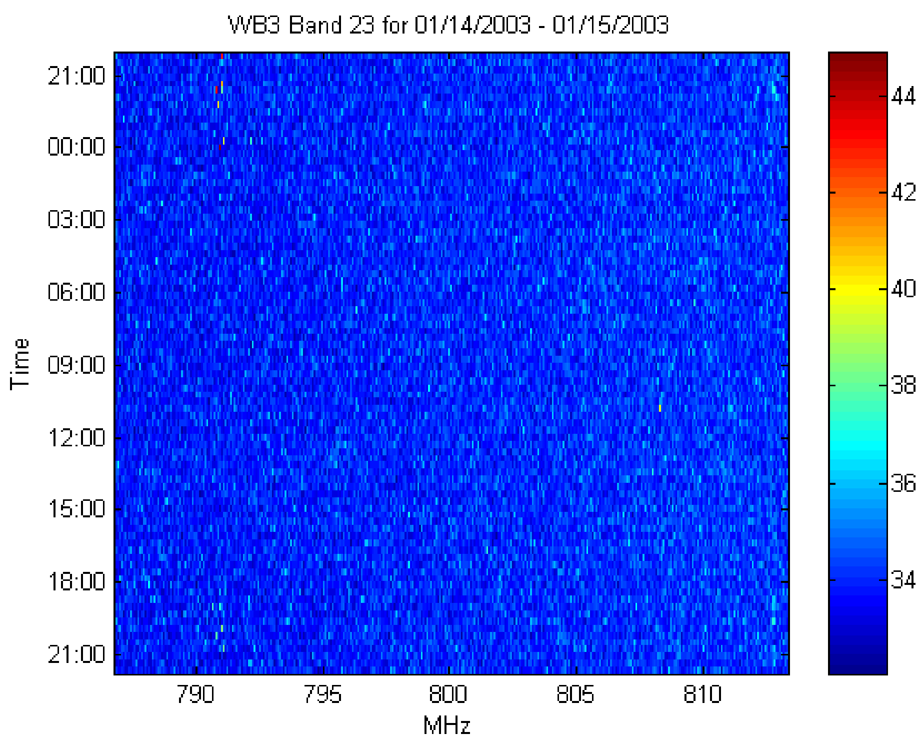

Figure E-106 RF BLDG WB3 BAND 23 (dBuV/m)

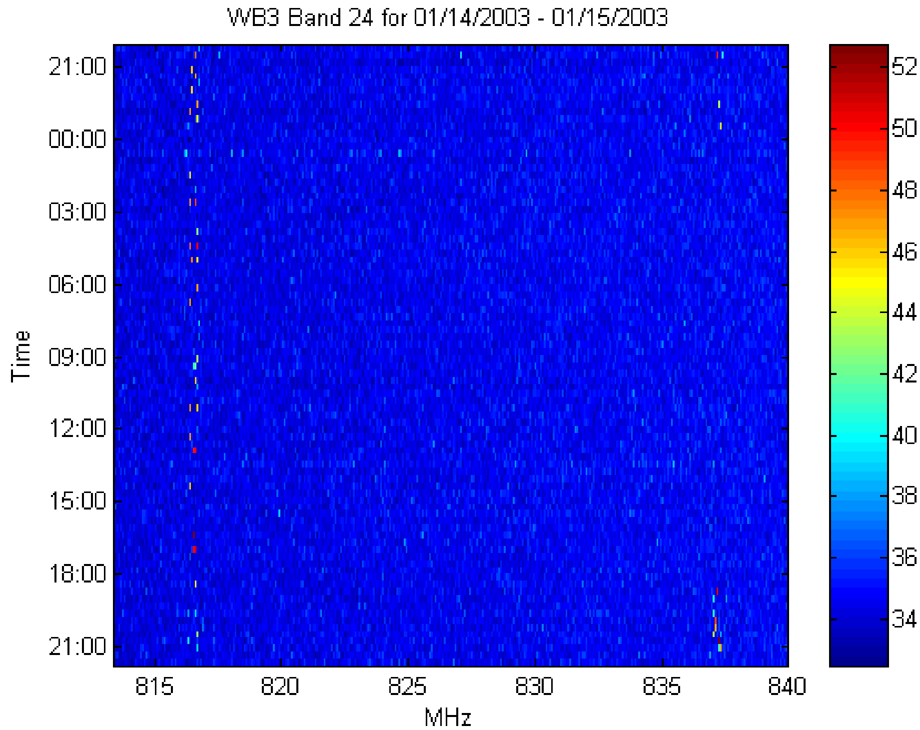

Figure E-107 RF BLDG WB3 BAND 24 (dBuV/m)

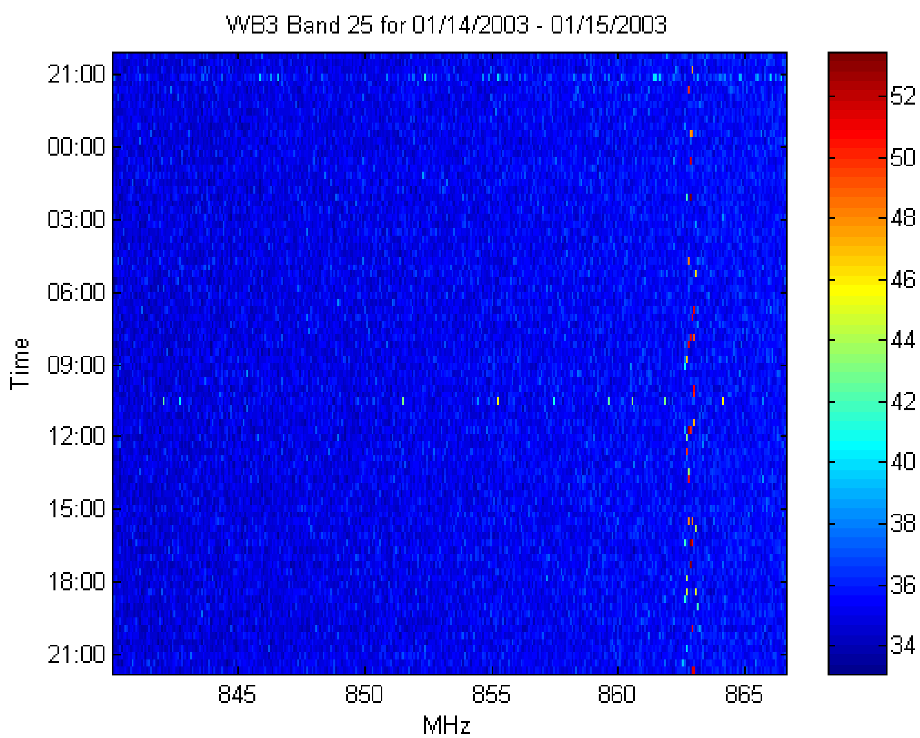

Figure E-108 RF BLDG WB3 BAND 25 (dBuV/m)

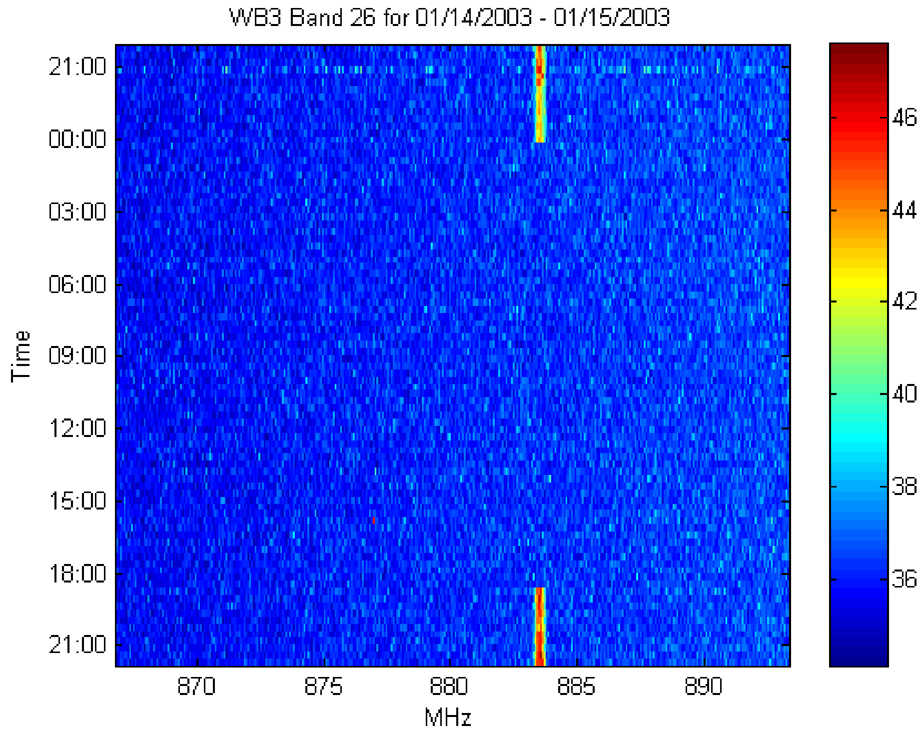

Figure E-109 RF BLDG WB3 BAND 26 (dBuV/m)

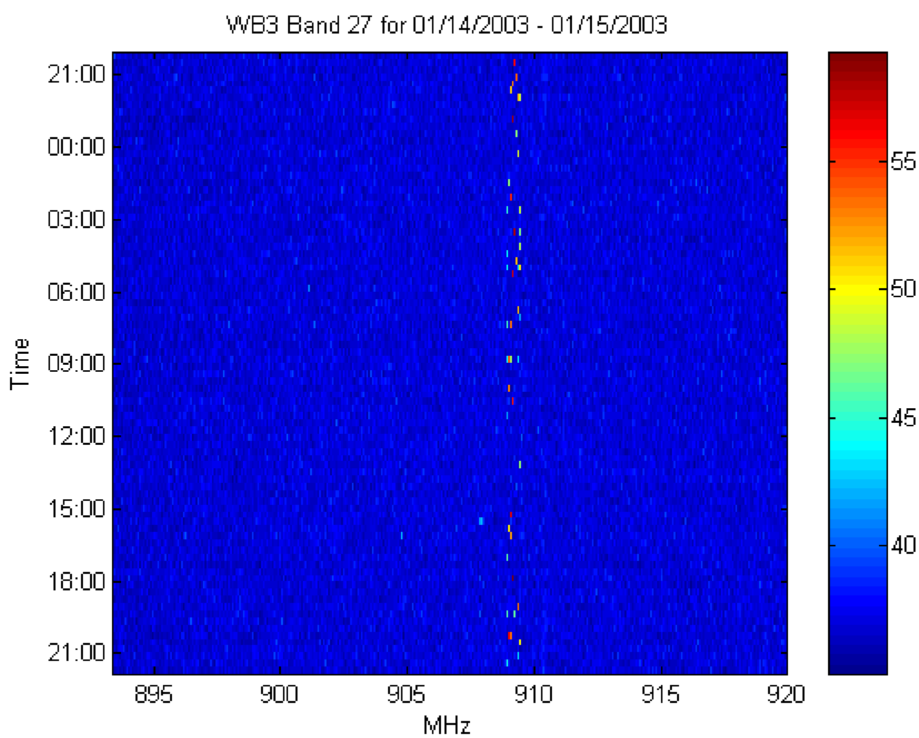

Figure E-110 RF BLDG WB3 BAND 27 (dBuV/m)

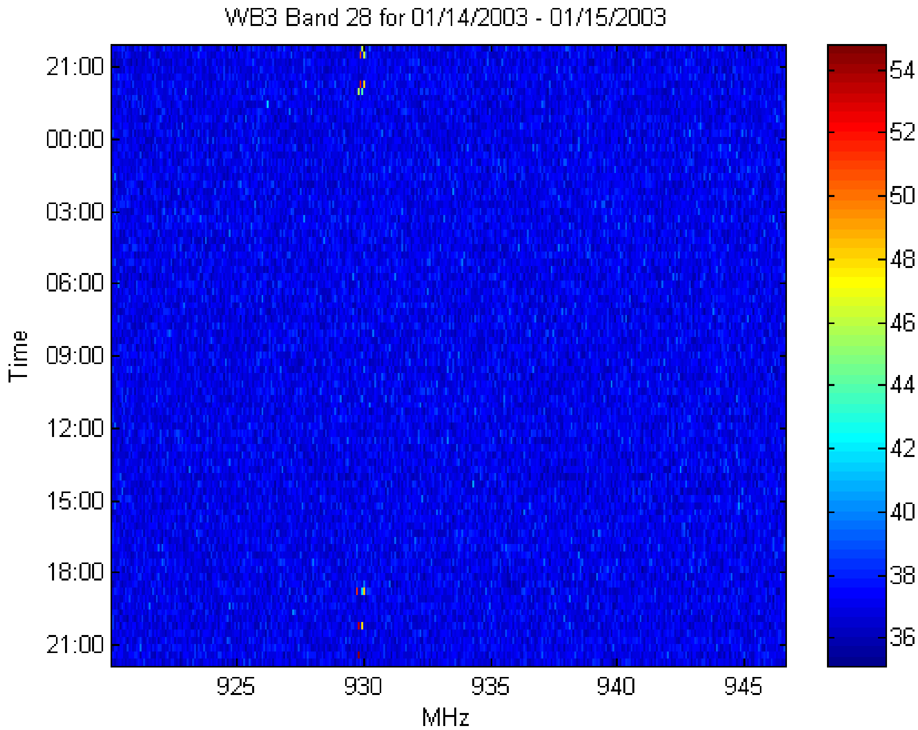

Figure E-111 RF BLDG WB3 BAND 28 (dBuV/m)

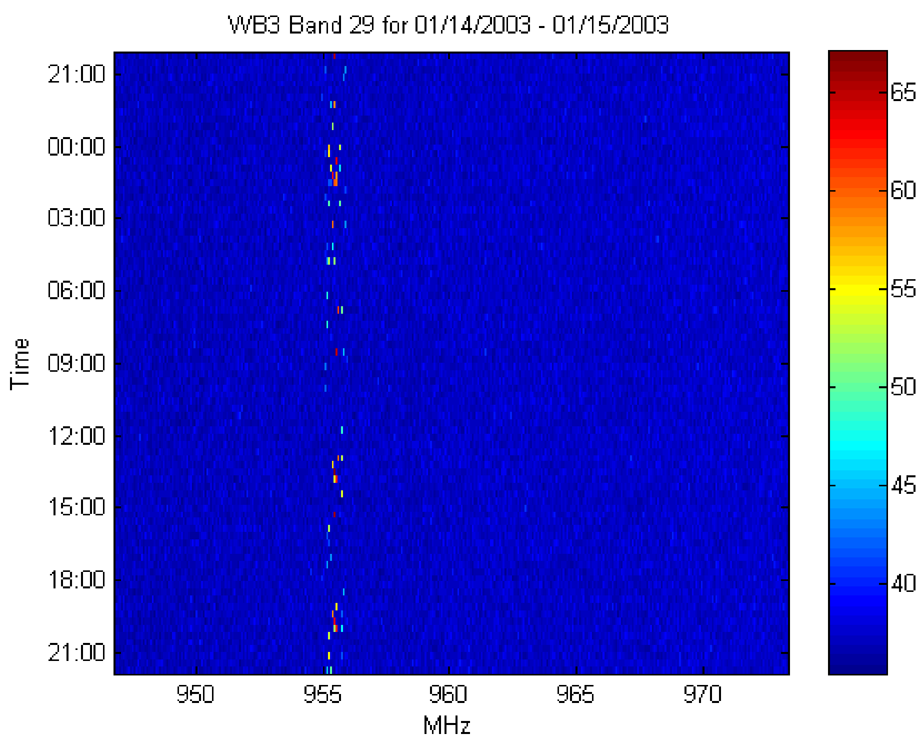

Figure E-112 RF BLDG WB3 BAND 29 (dBuV/m)

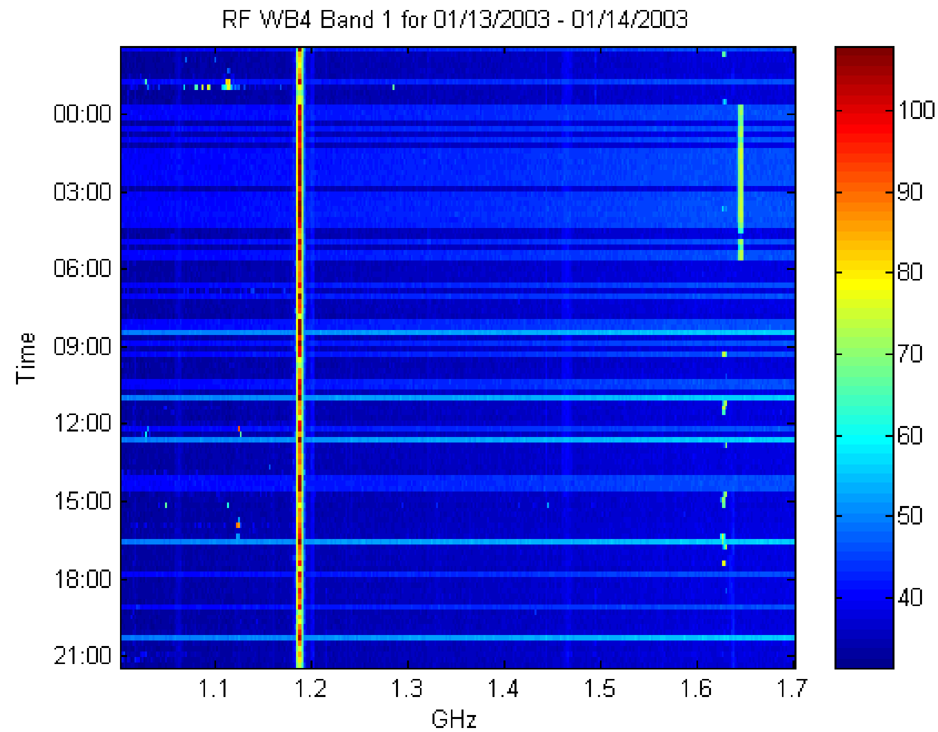

Figure E-113 RF BLDG WB4 BAND 1 (dBuV/m)

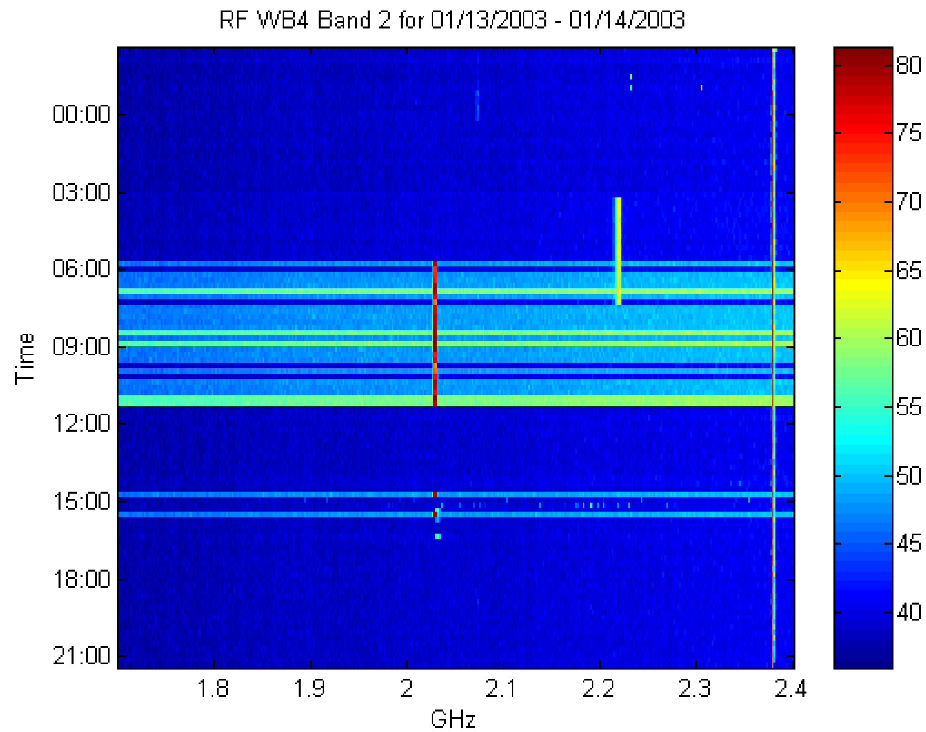

Figure E-114 RF BLDG WB4 BAND 2 (dBuV/m)

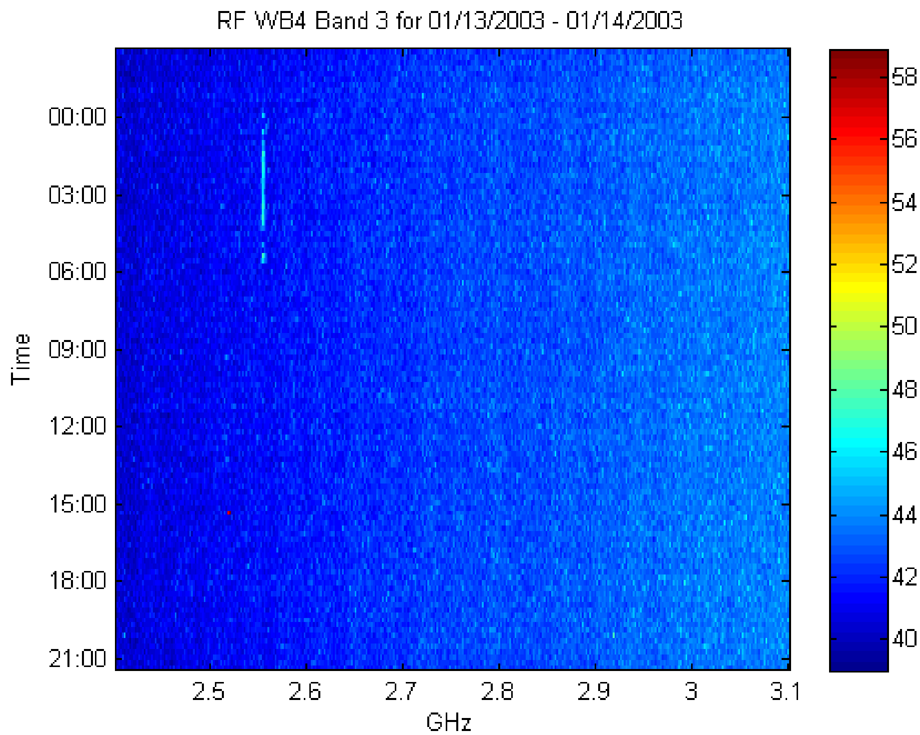

Figure E-115 RF BLDG WB4 BAND 3 (dBuV/m)

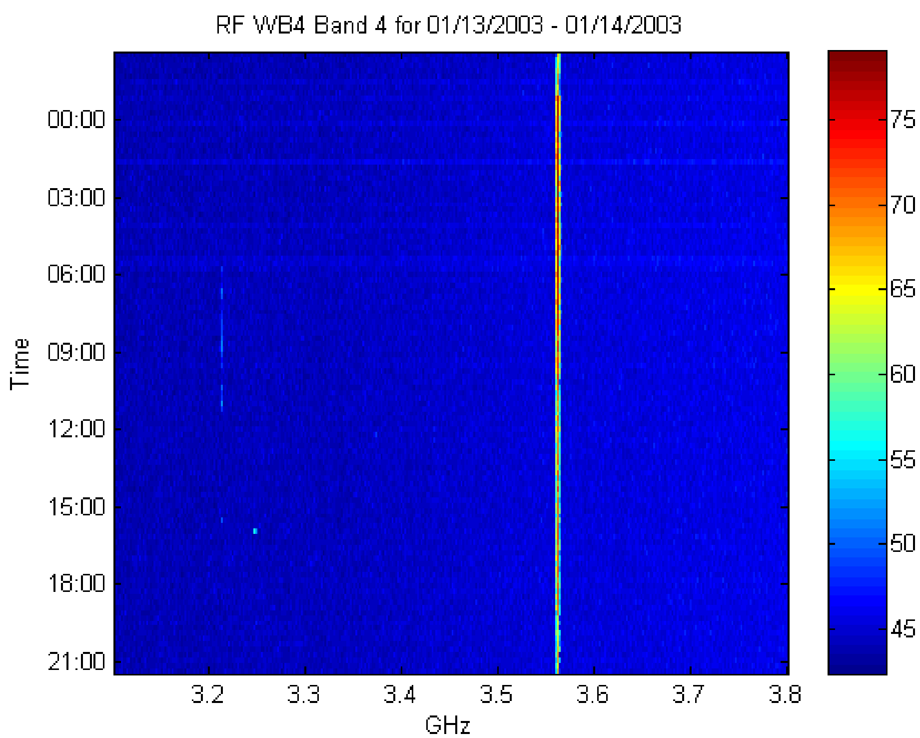

Figure E-116 RF BLDG WB4 BAND 4 (dBuV/m)

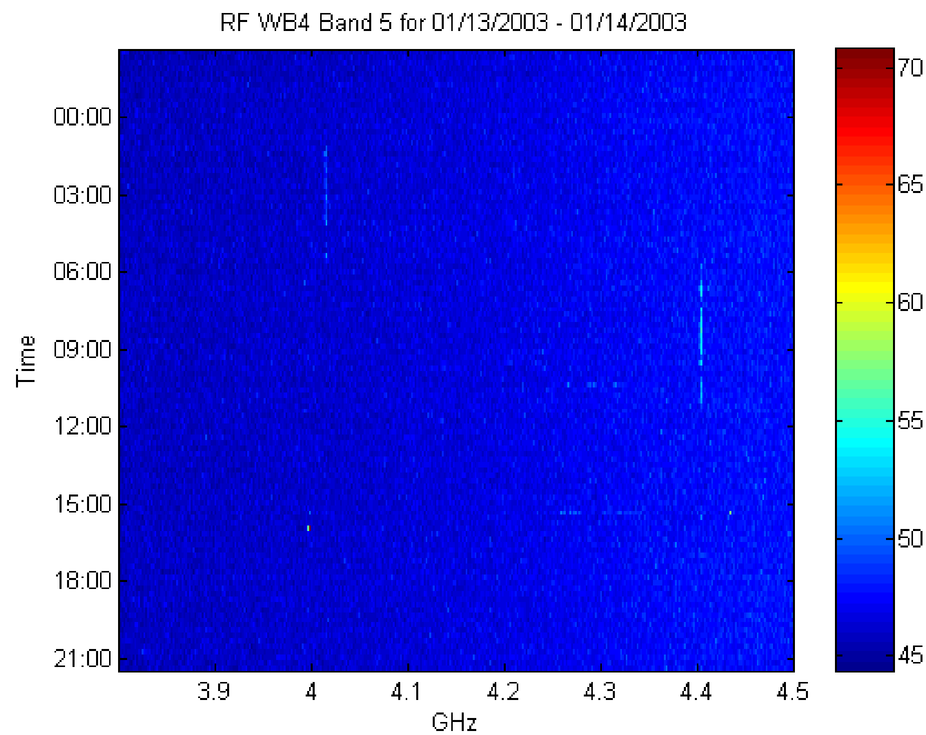

Figure E-117 RF BLDG WB4 BAND 5 (dBuV/m)

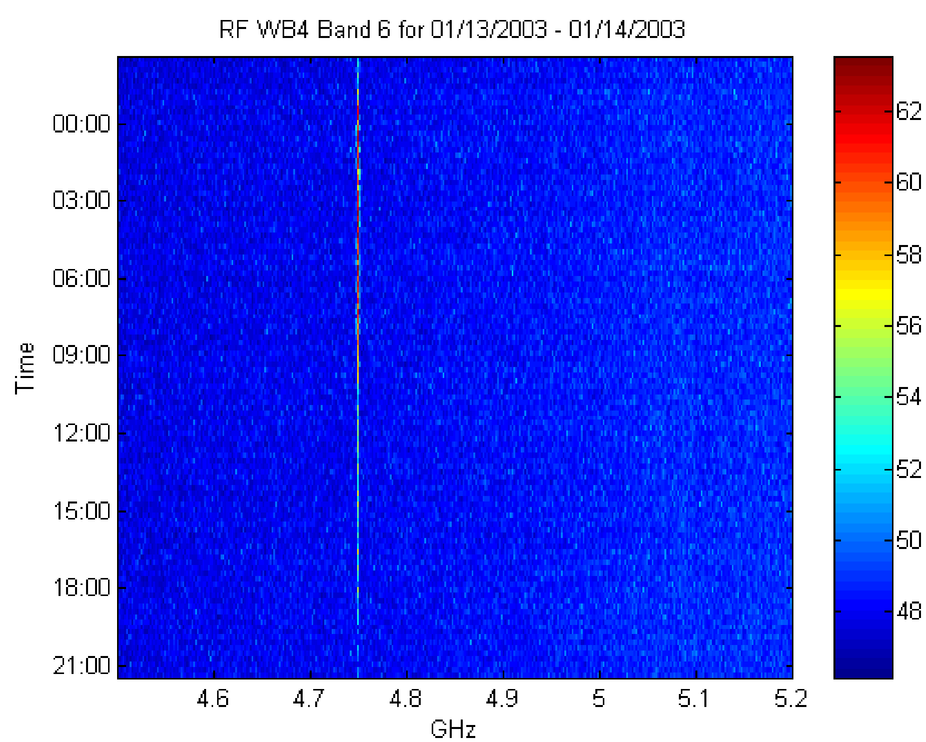

Figure E-118 RF BLDG WB4 BAND 6 (dBuV/m)

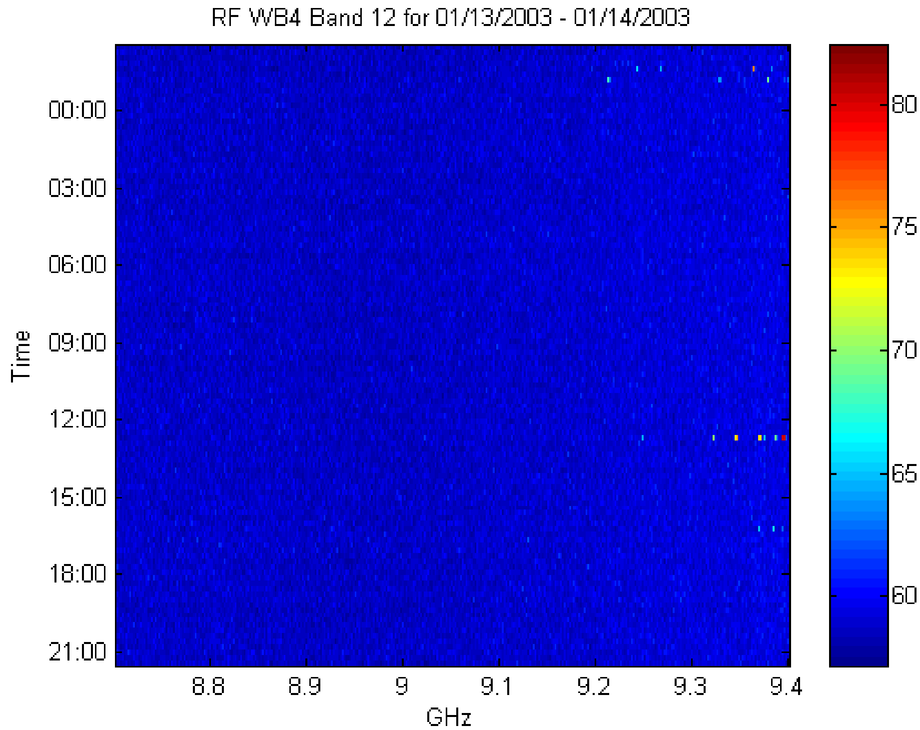

Figure E-119 RF BLDG WB4 BAND 12 (dBuV/m)

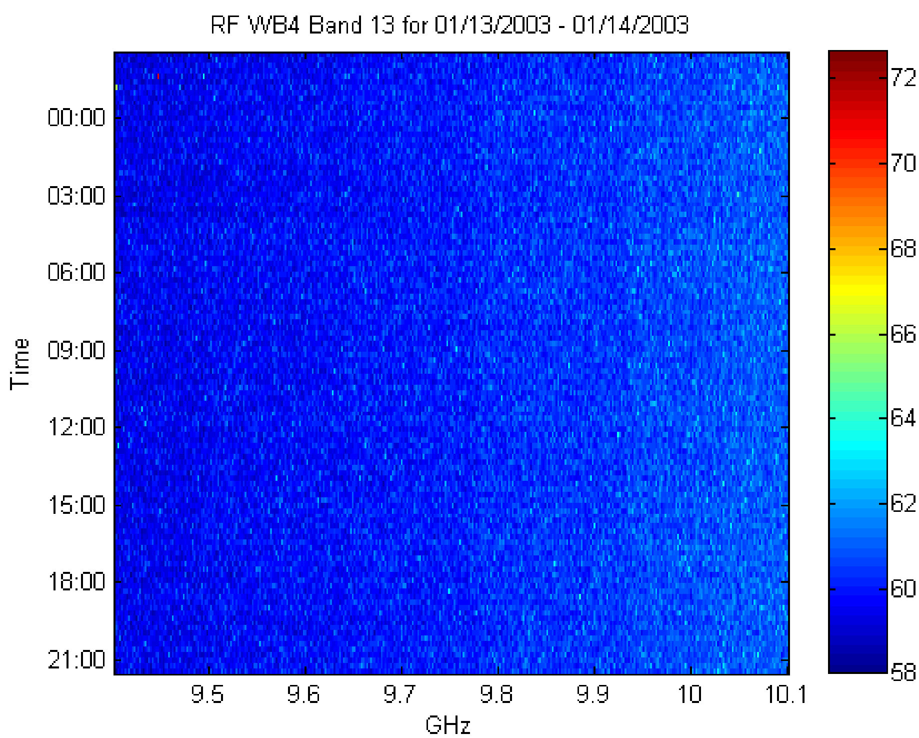

Figure E-120 RF BLDG WB4 BAND 13 (dBuV/m)

E.5 MAPO Building Wide Band Sweep Data

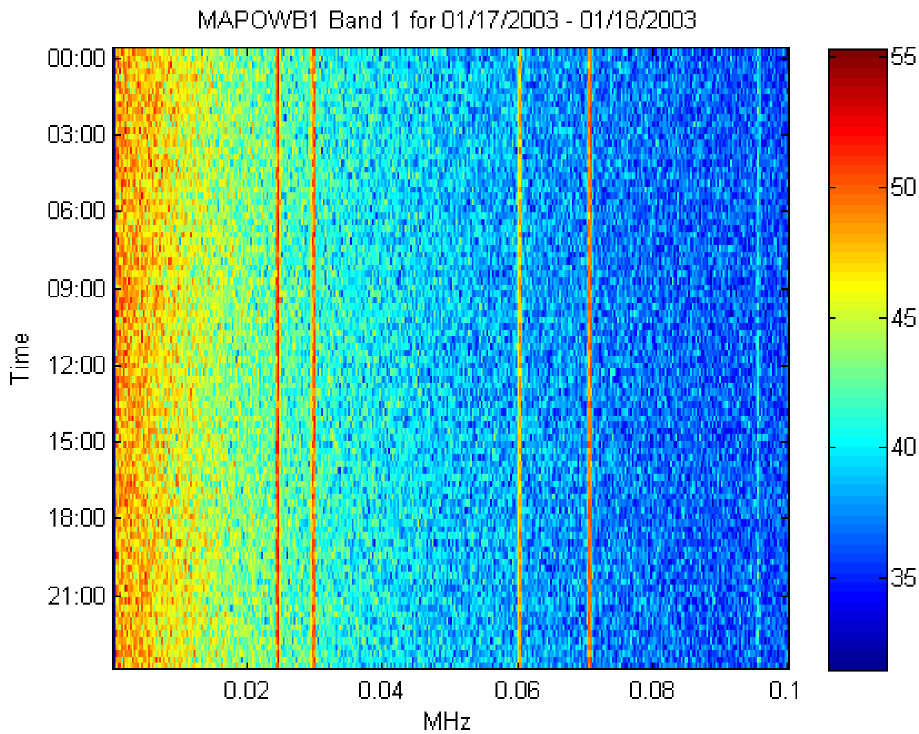

Figure E-121 MAPO WB1 Band 1 (dBuV/m)

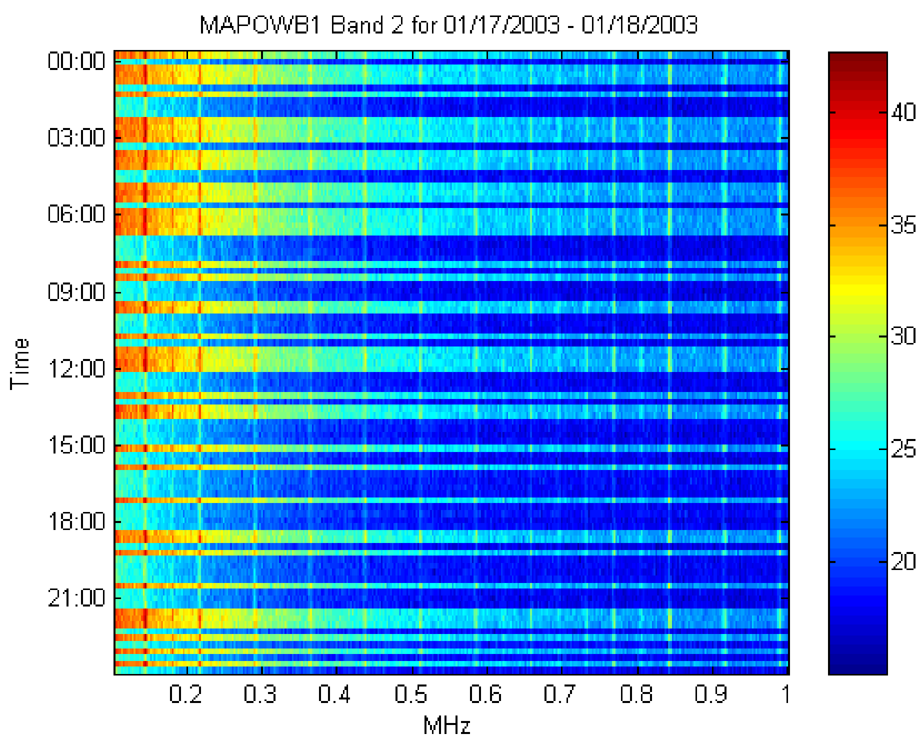

Figure E-122 MAPO WB1 Band 2 (dBuV/m)

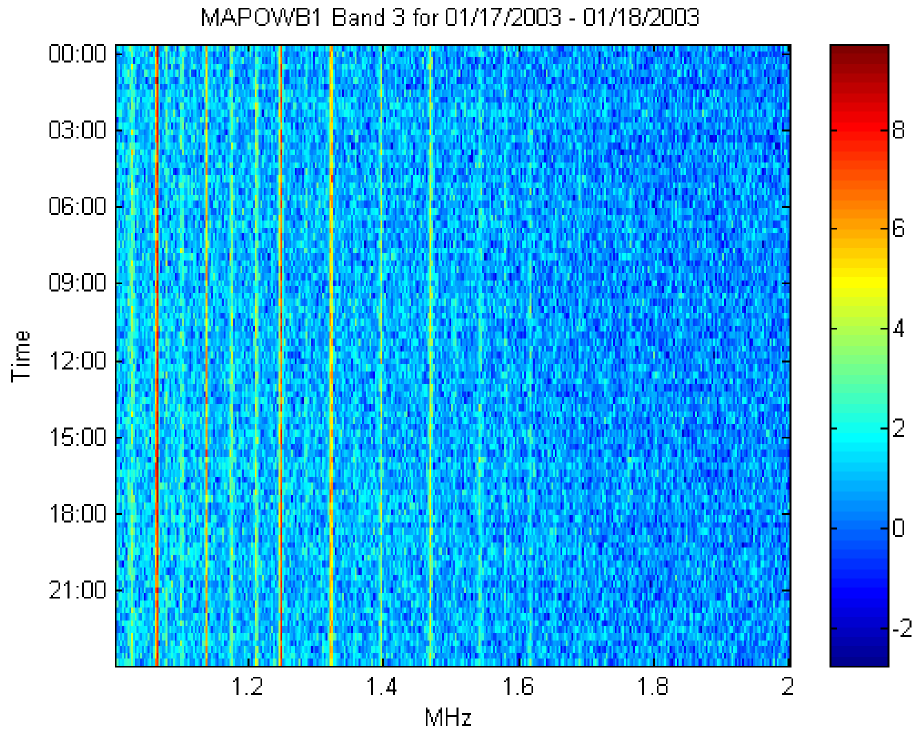

Figure E-123   MAPO WB1 Band 3 (dBuV/m)

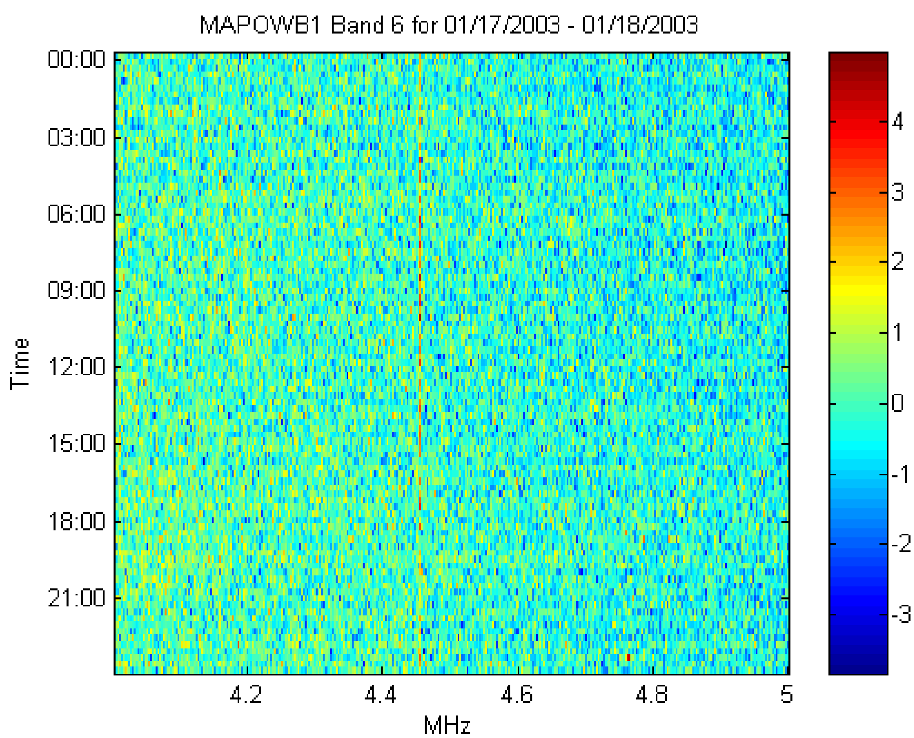

Figure E-124 MAPO WB1 BAND 6 (dBuV/m)

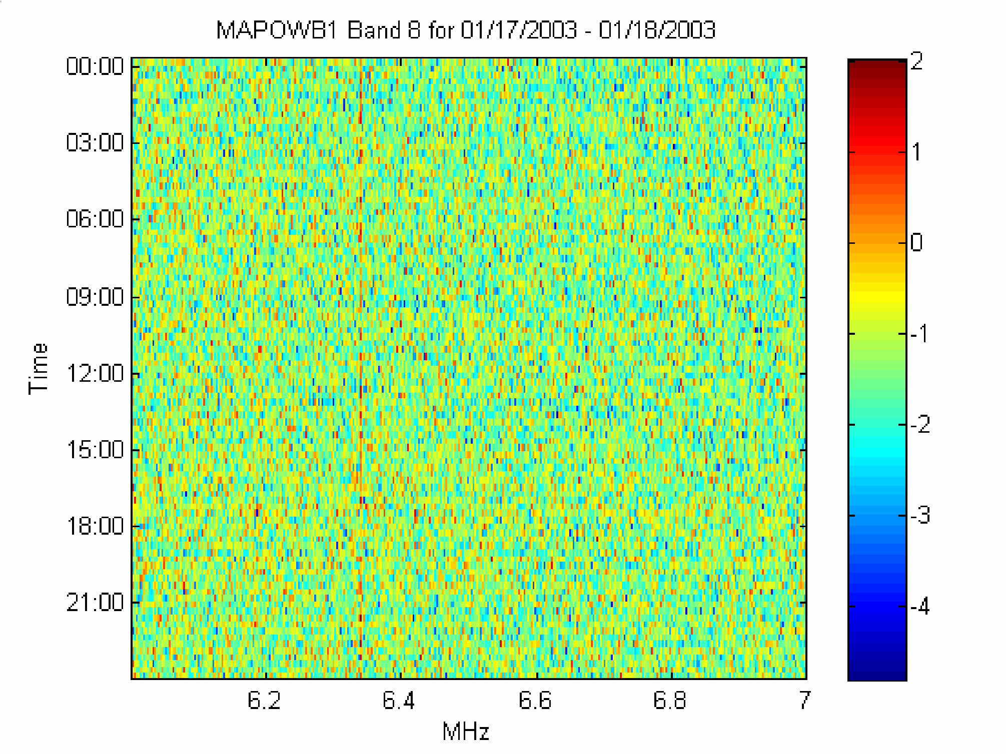

Figure E-125 MAPO WB1 BAND 8 (dBuV/m)

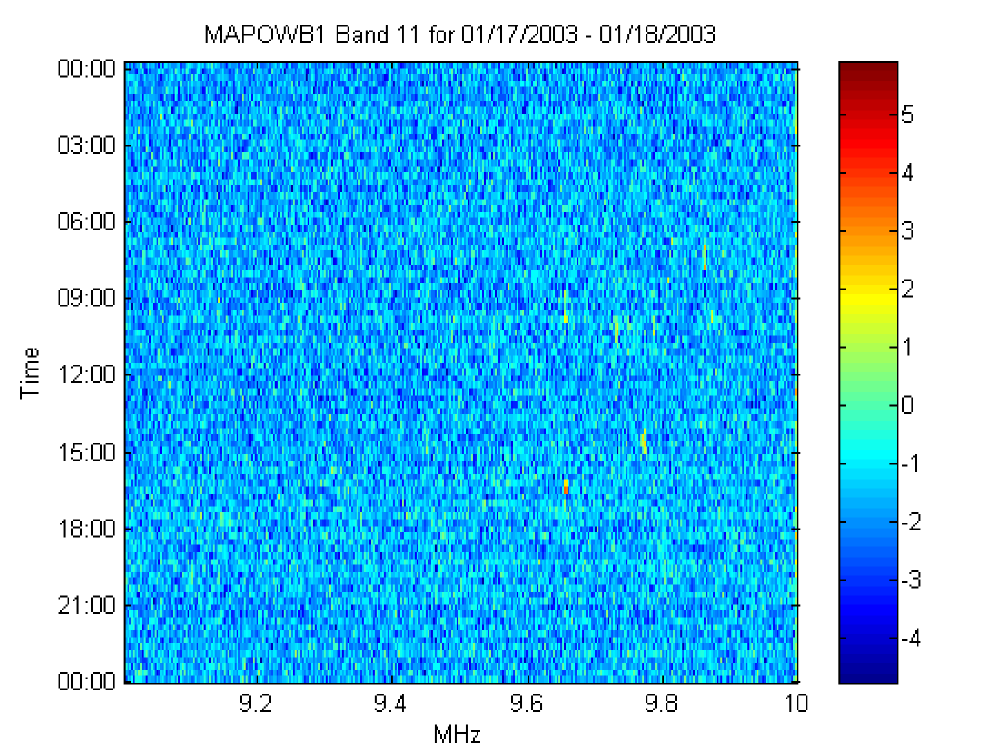

Figure E-126 MAPO WB1 BAND 11 (dBuV/m)

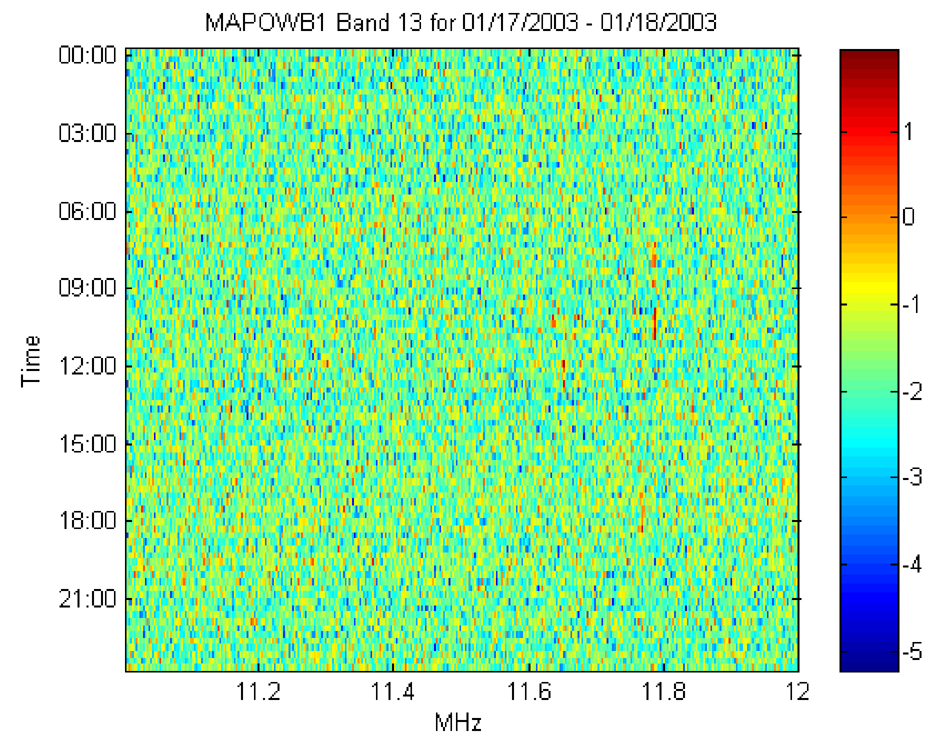

Figure E-127 MAPO WB1 BAND 13 (dBuV/m)

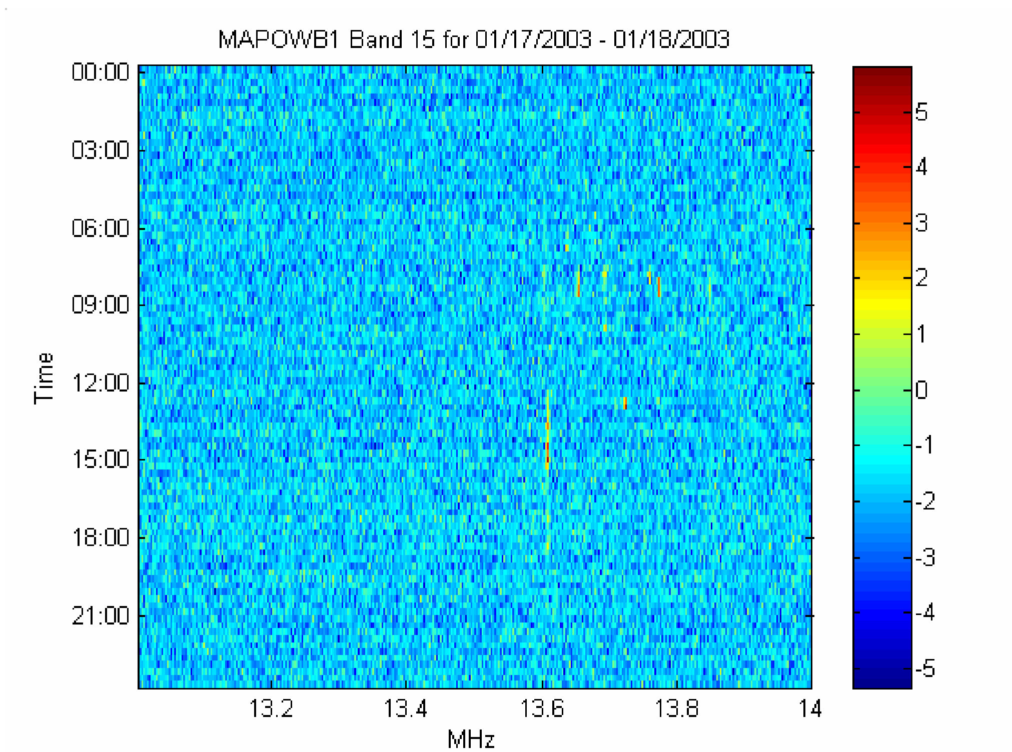

Figure E-128 MAPO WB1 BAND 15 (dBuV/m)

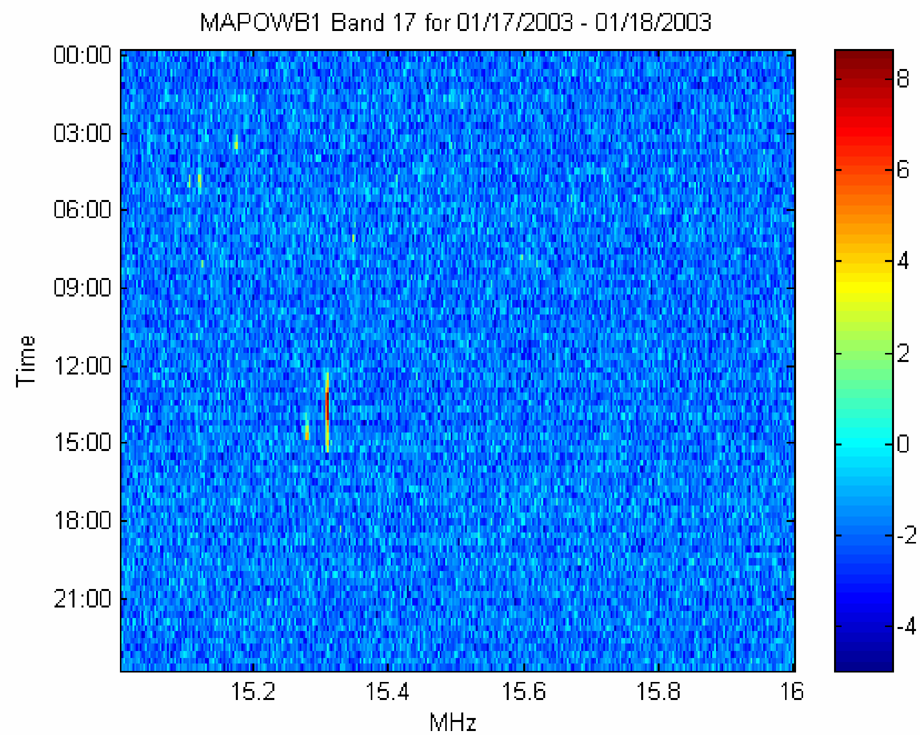

Figure E-129 MAPO WB1 BAND 17 (dBuV/m)

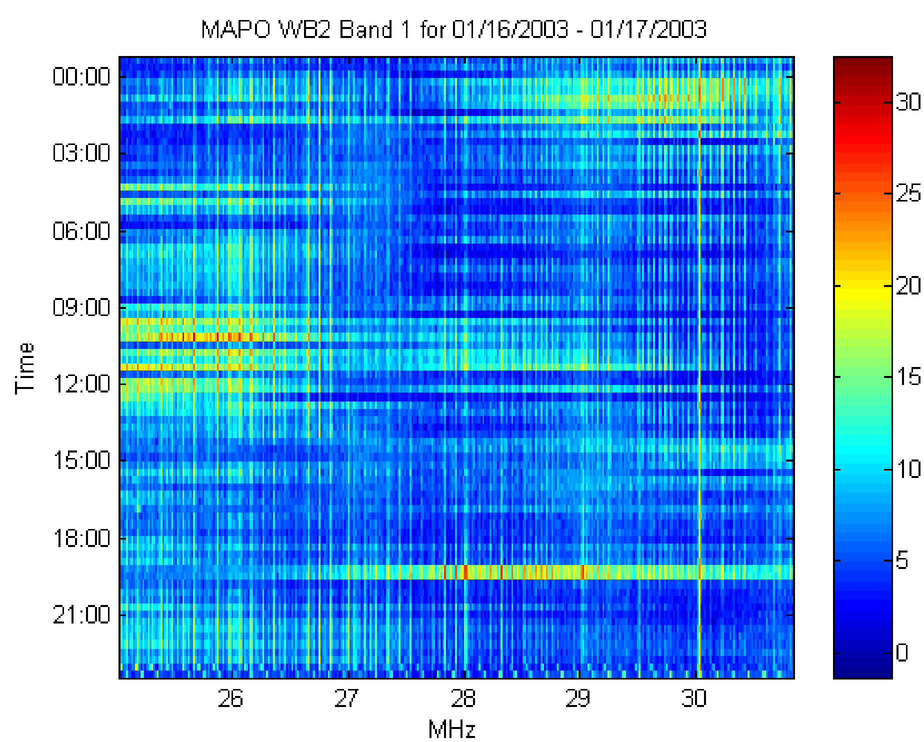

Figure E-130 MAPO WB2 BAND 1 (dBuV/m)

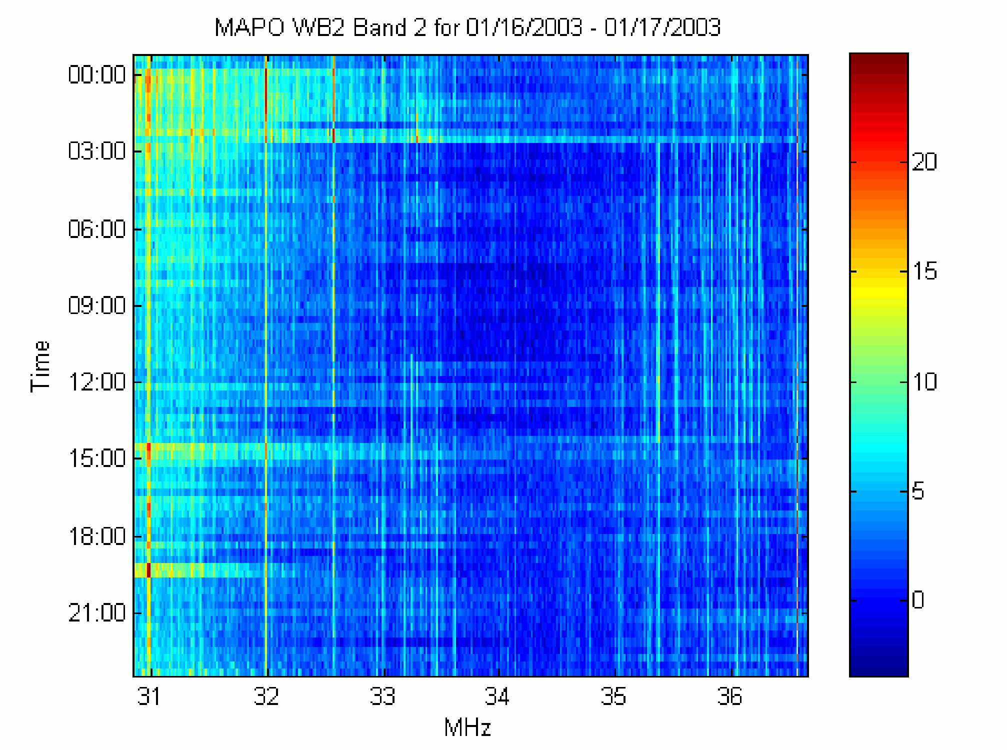

Figure E-131 MAPO WB2 BAND 2 (dBuV/m)

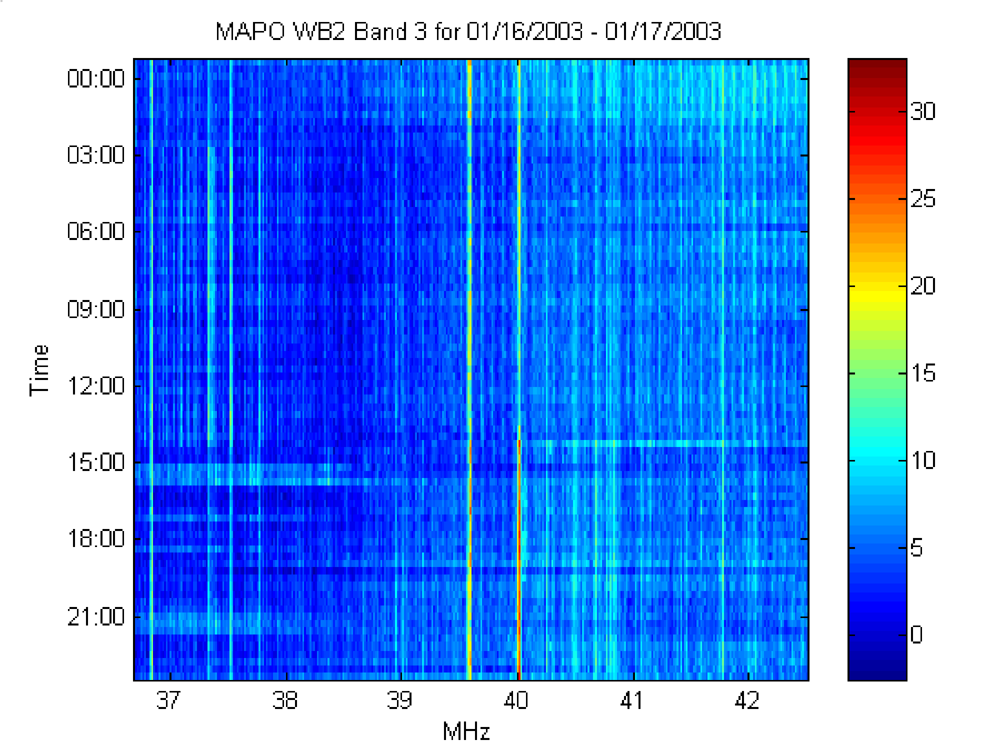

Figure E-132 MAPO WB2 BAND 3 (dBuV/m)

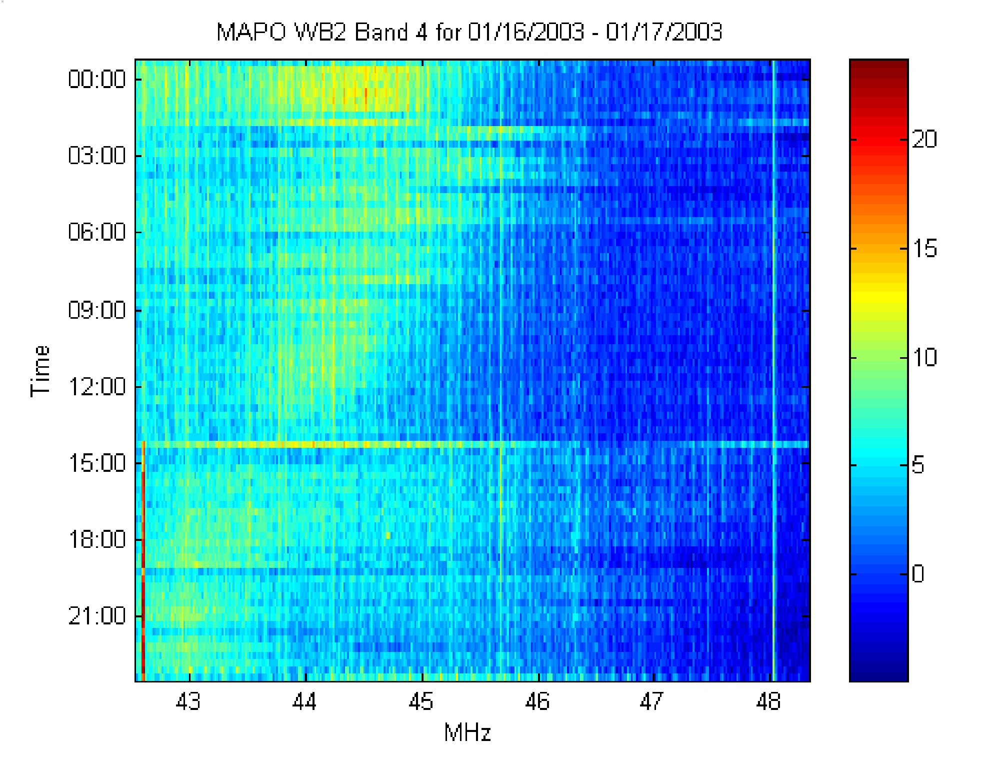

Figure E-133 MAPO WB2 BAND 4 (dBuV/m)

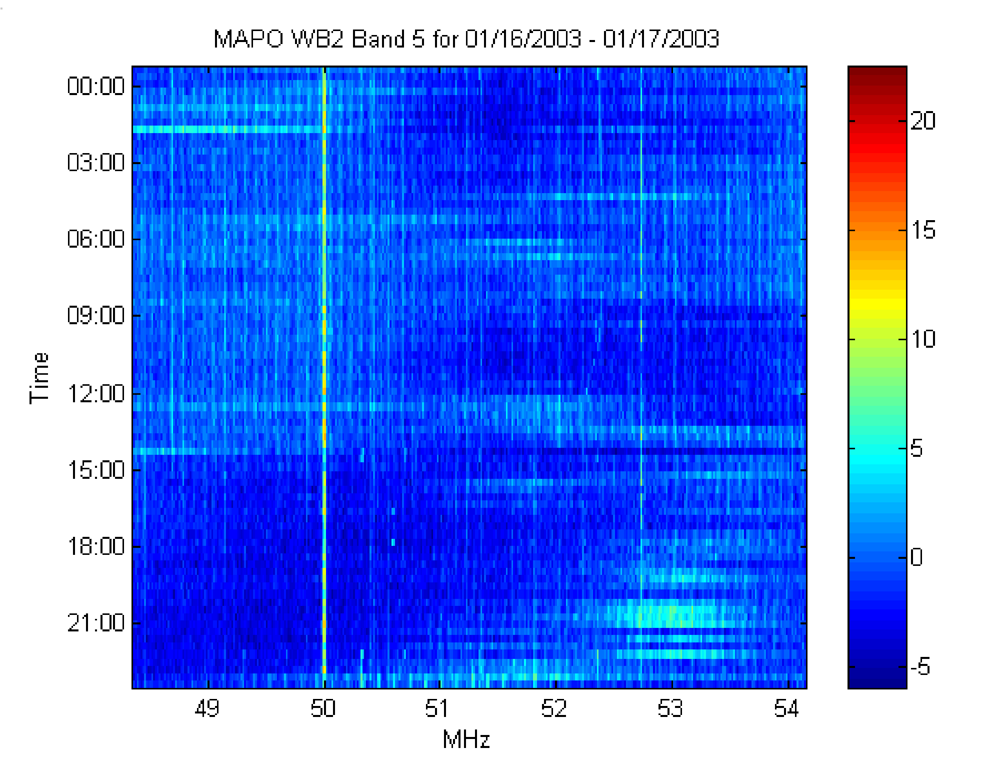

Figure E-134 MAPO WB2 BAND 5 (dBuV/m)

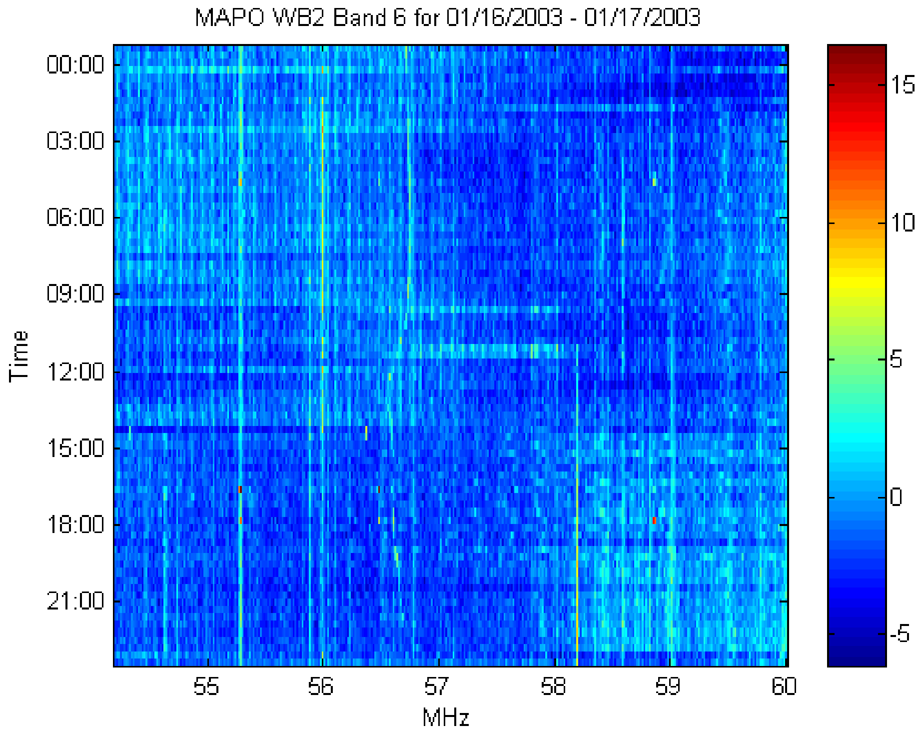

Figure E-135 MAPO WB2 BAND 6 (dBuV/m)

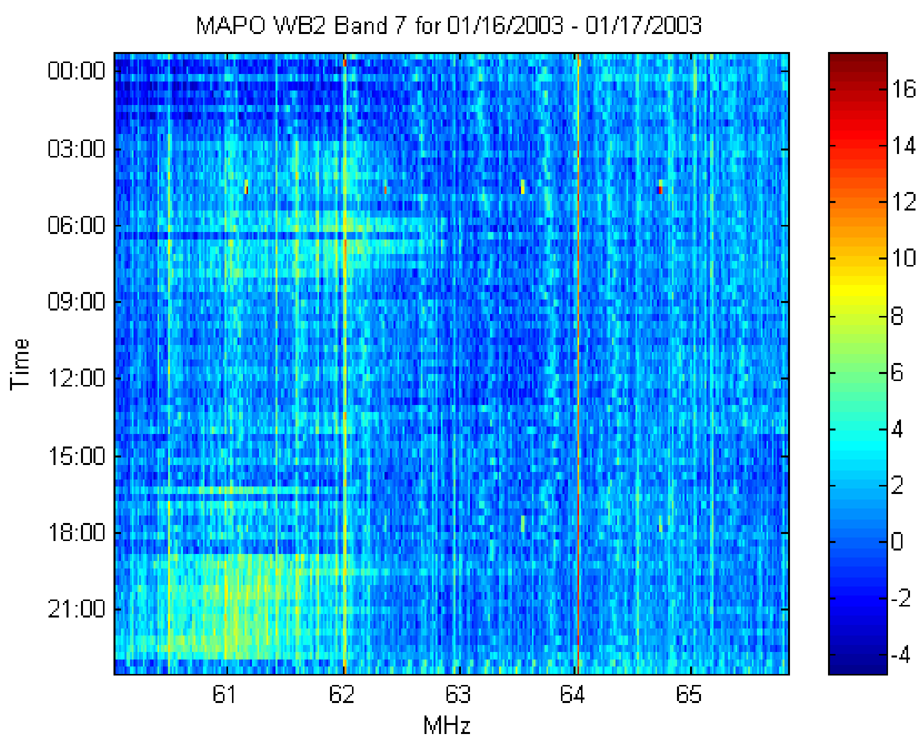

Figure E-136 MAPO WB2 BAND 7 (dBuV/m)

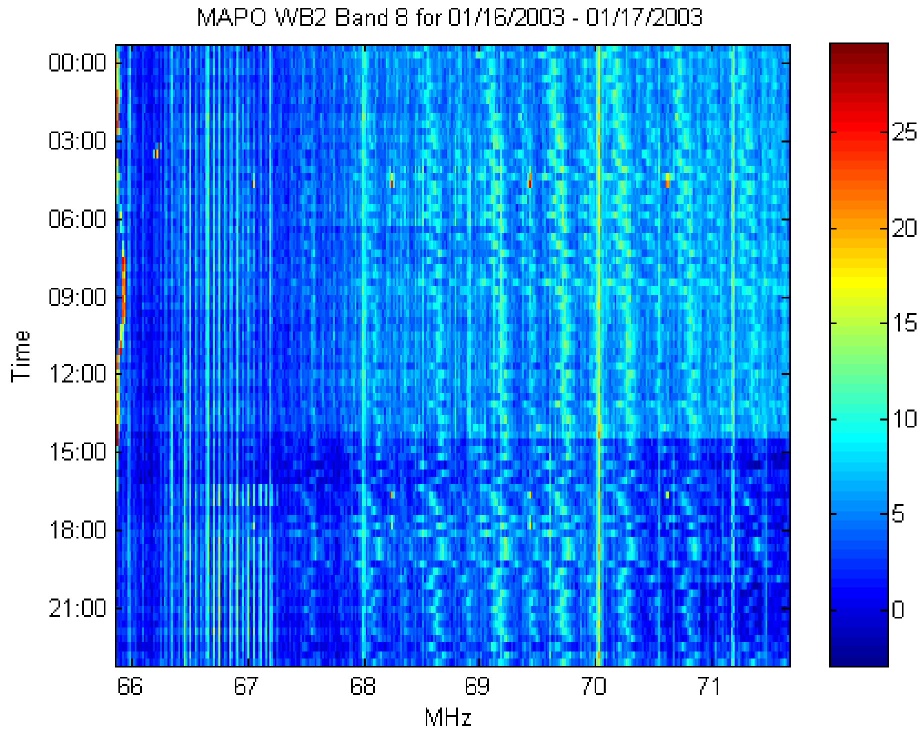

Figure E-137 MAPO WB2 BAND 8 (dBuV/m)

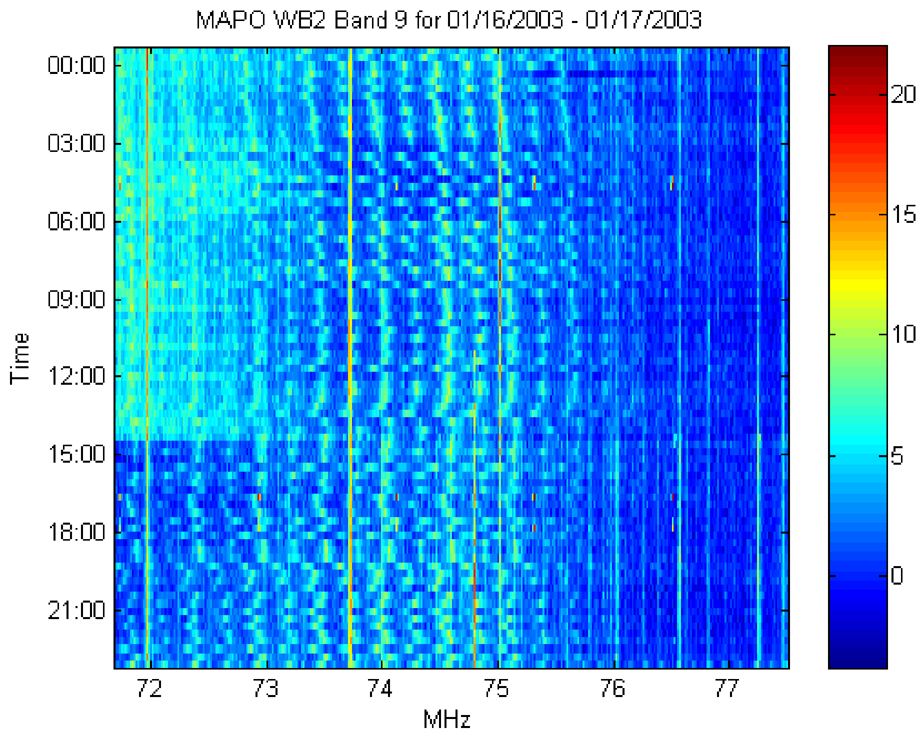

Figure E-138 MAPO WB2 BAND 9 (dBuV/m)

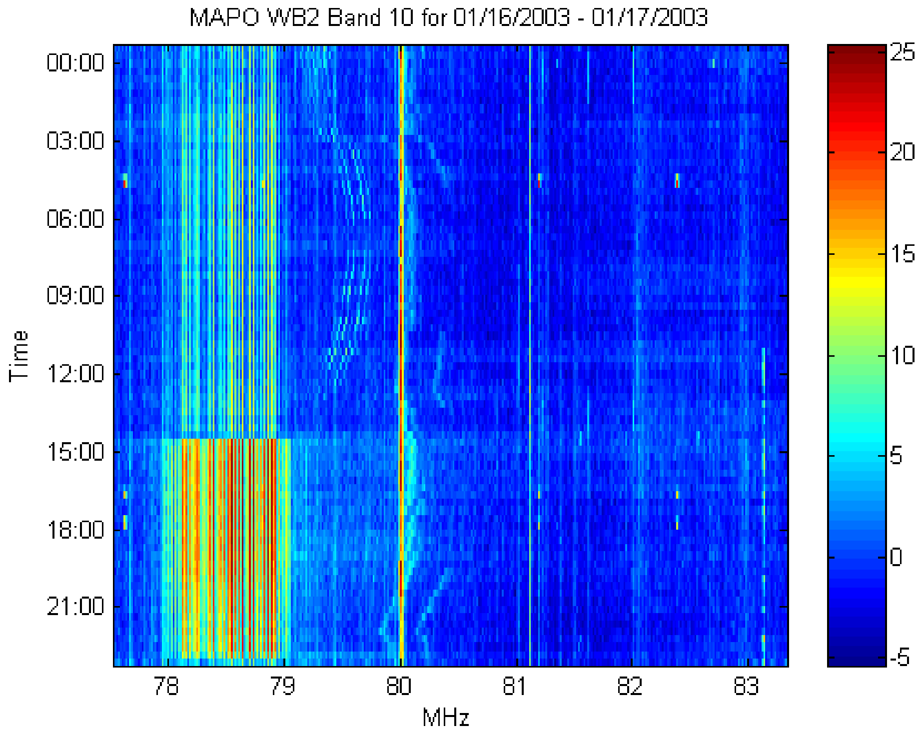

Figure E-139 MAPO WB2 BAND 10 (dBuV/m)

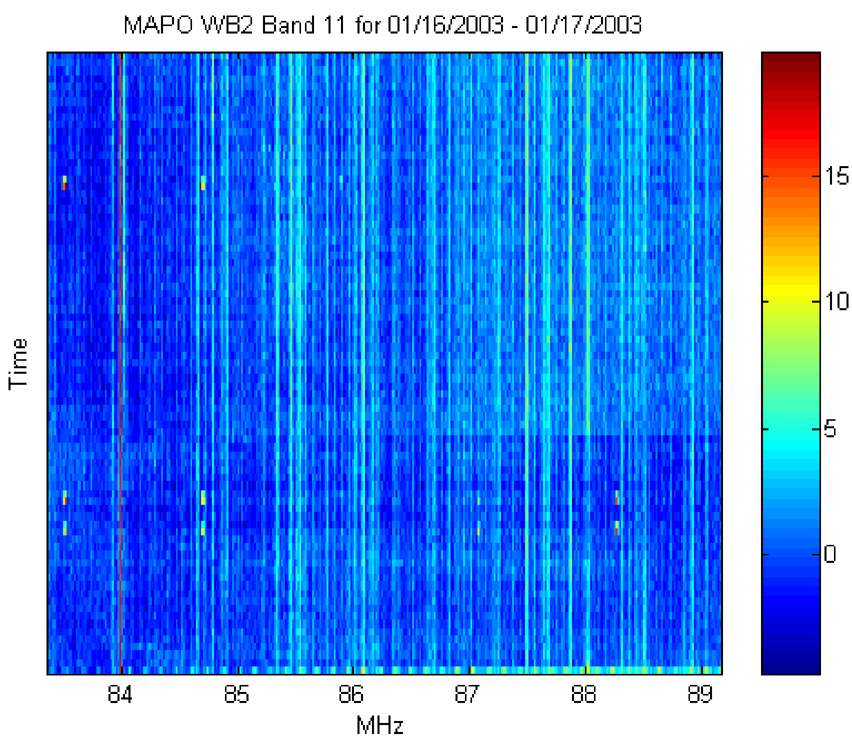

Figure E-140 MAPO WB2 BAND 11 (dBuV/m)

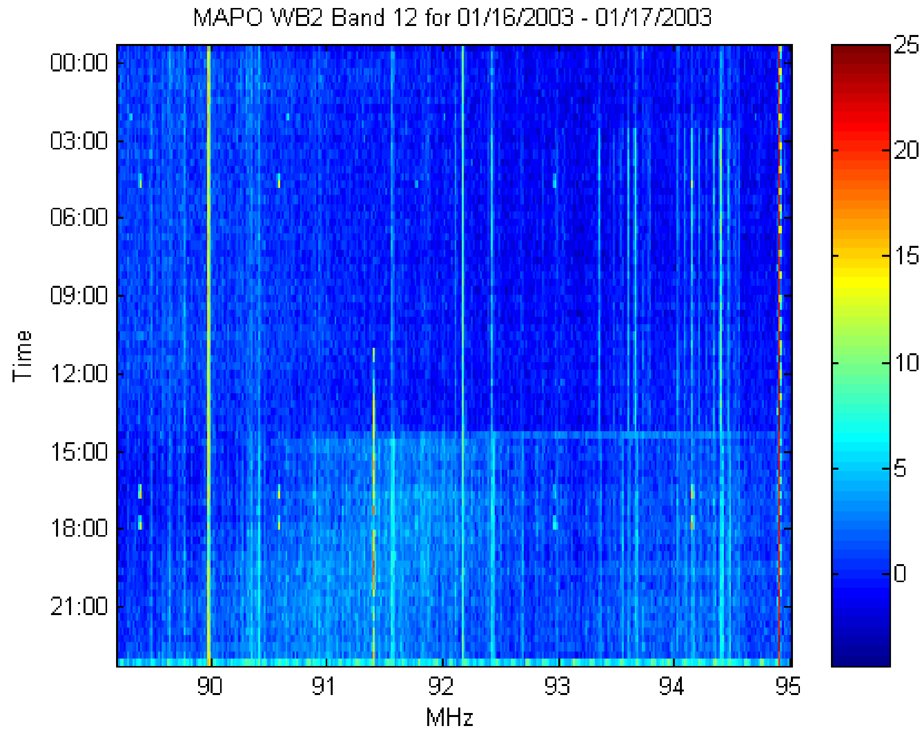

Figure E-141 MAPO WB2 BAND 12 (dBuV/m)

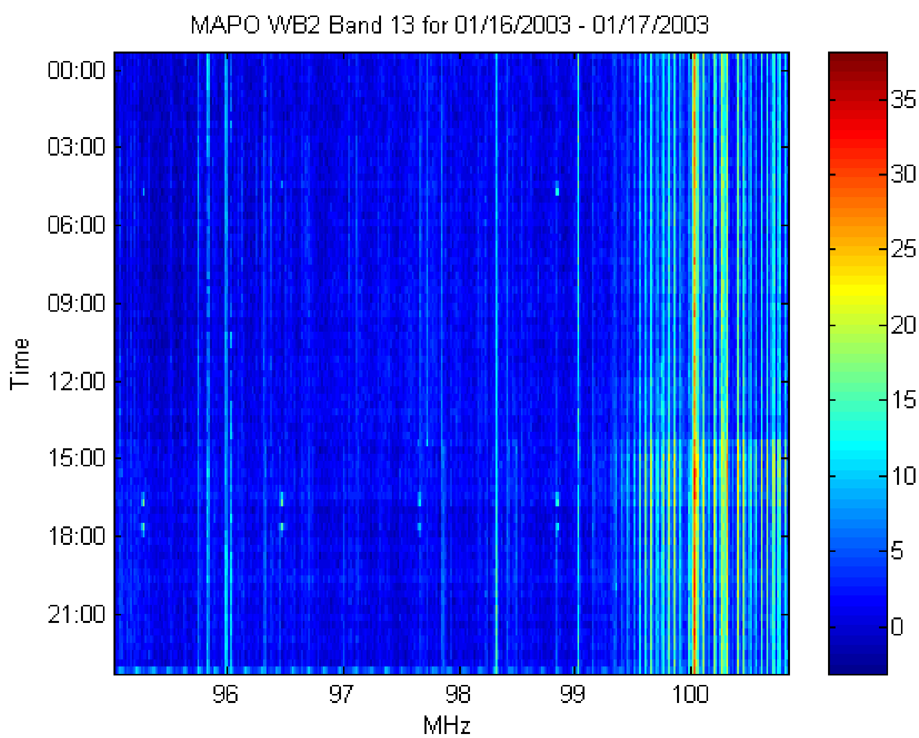

Figure E-142 MAPO WB2 BAND 13 (dBuV/m)

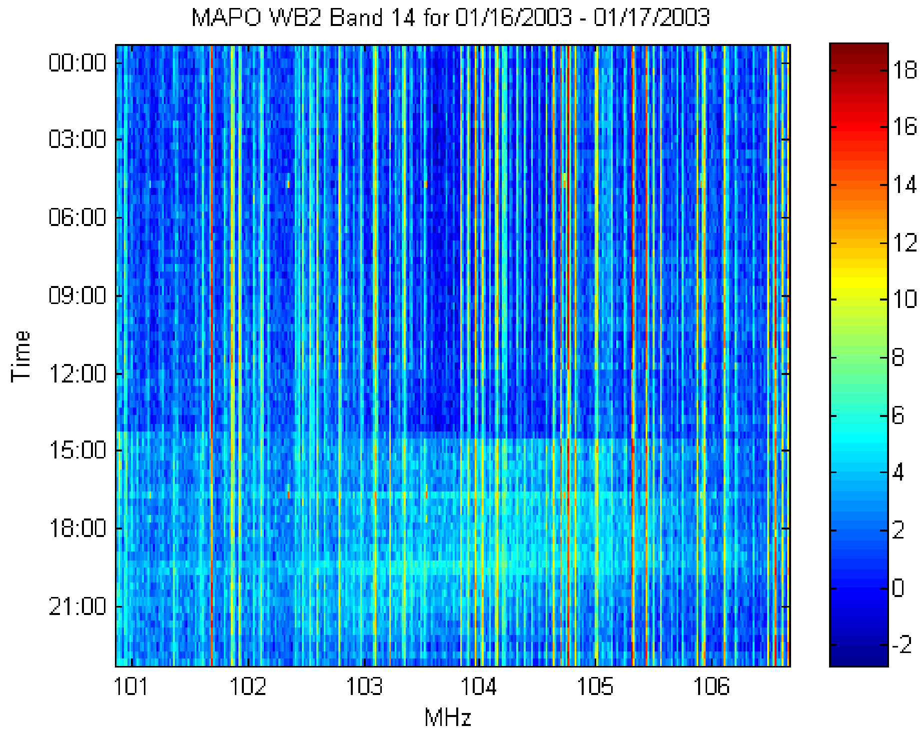

Figure E-143 MAPO WB2 BAND 14 (dBuV/m)

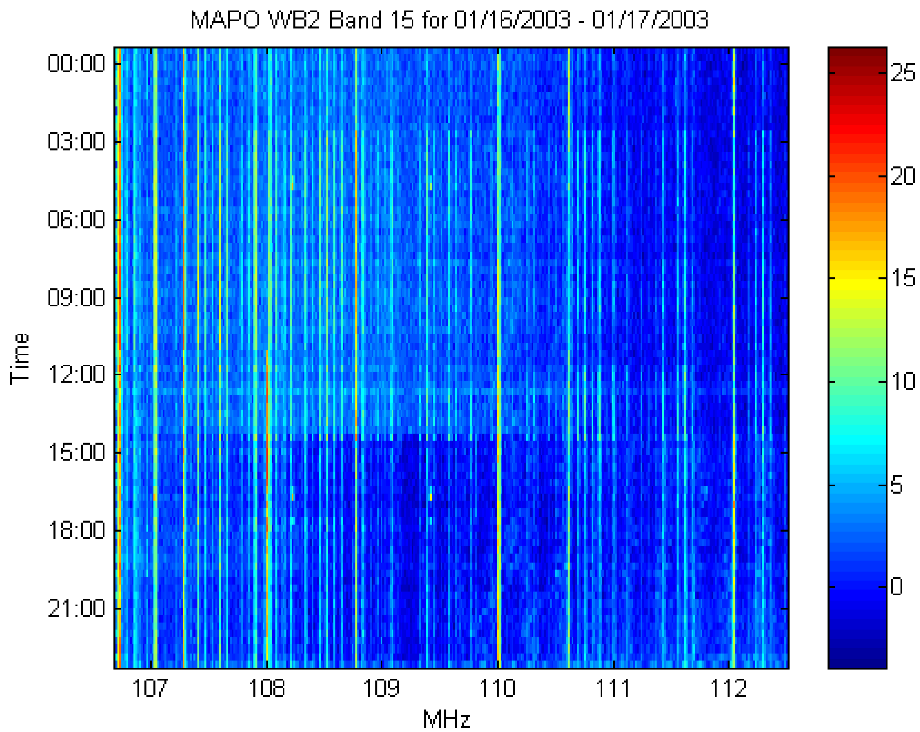

Figure E-144 MAPO WB2 BAND 15 (dBuV/m)

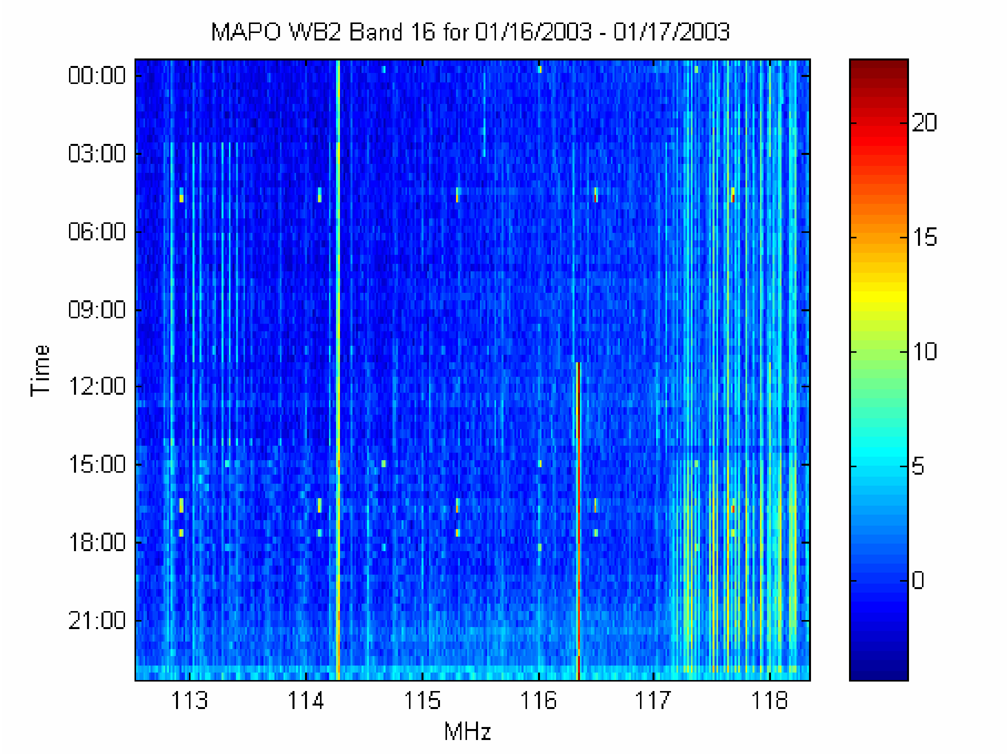

Figure E-145 MAPO WB2 BAND 16 (dBuV/m)

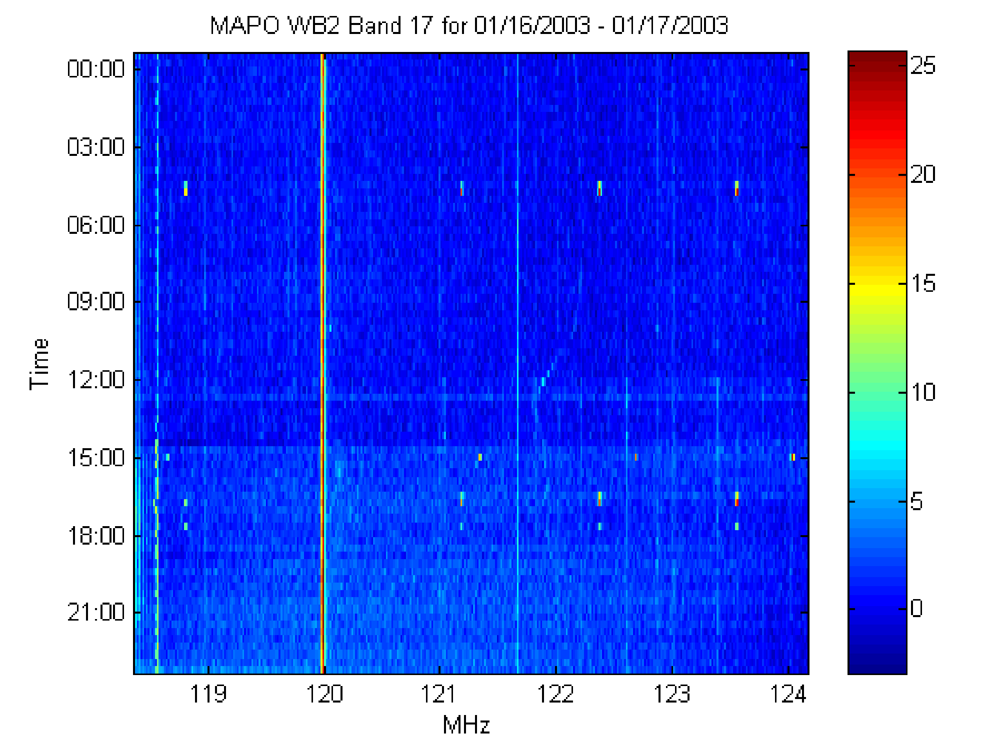

Figure E-146 MAPO WB2 BAND 17 (dBuV/m)

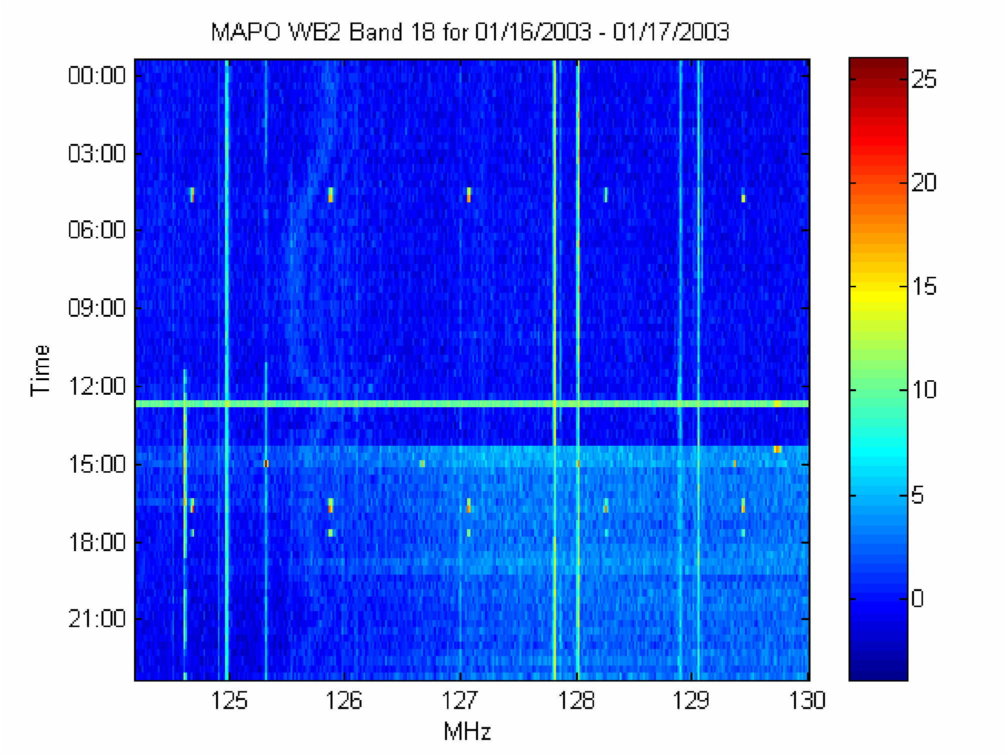

Figure E-147 MAPO WB2 BAND 18 (dBuV/m)

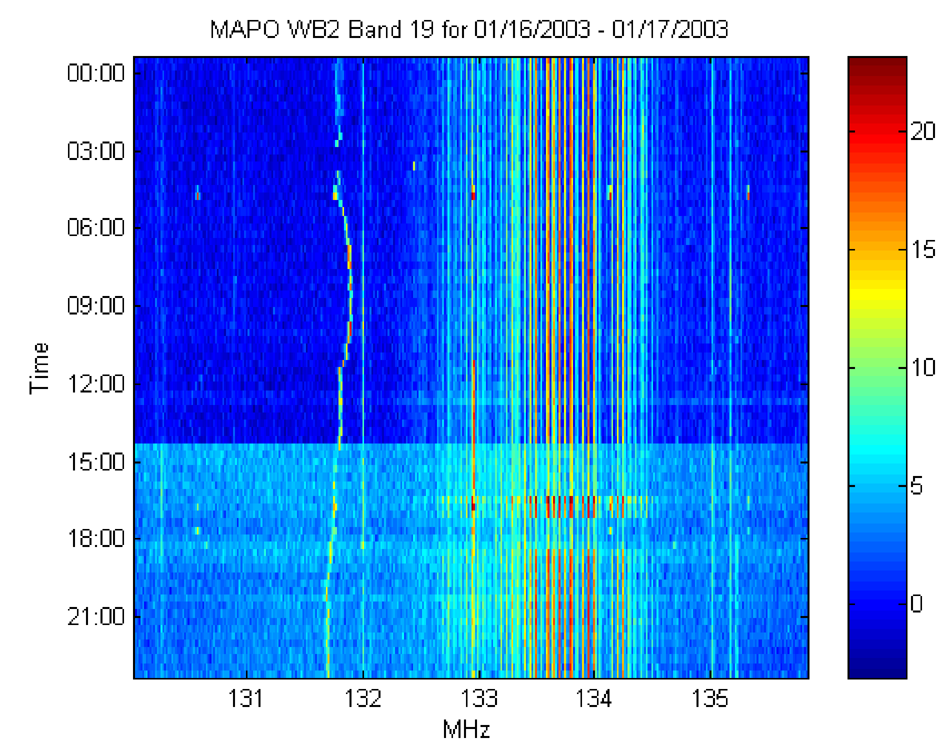

Figure E-148 MAPO WB2 BAND 19 (dBuV/m)

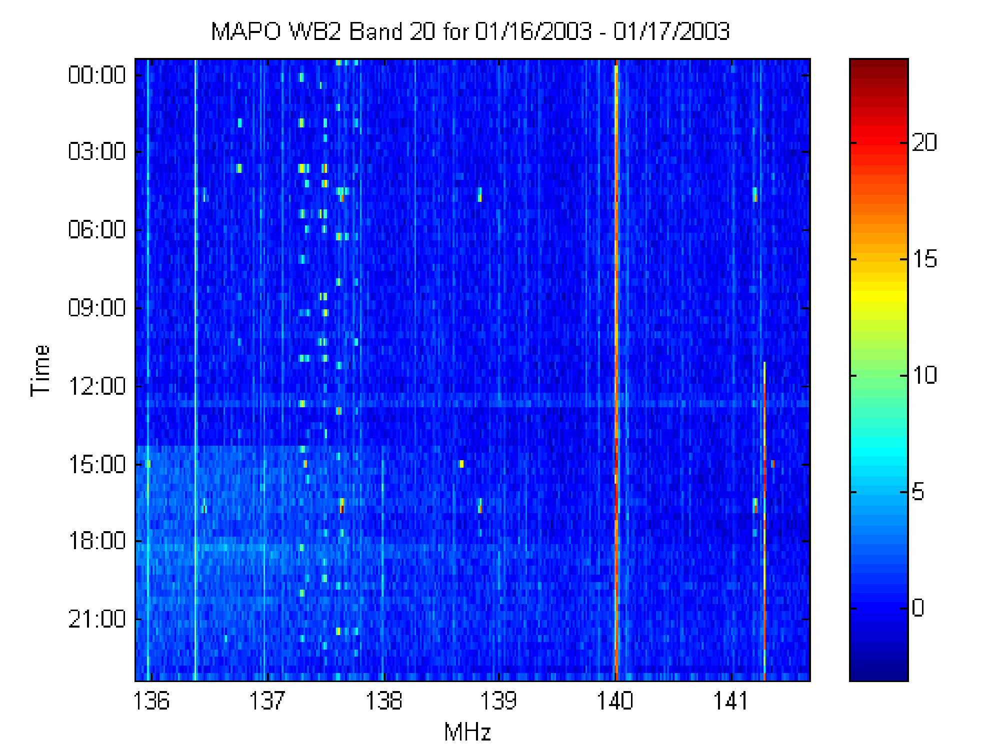

Figure E-149 MAPO WB2 BAND 20 (dBuV/m)

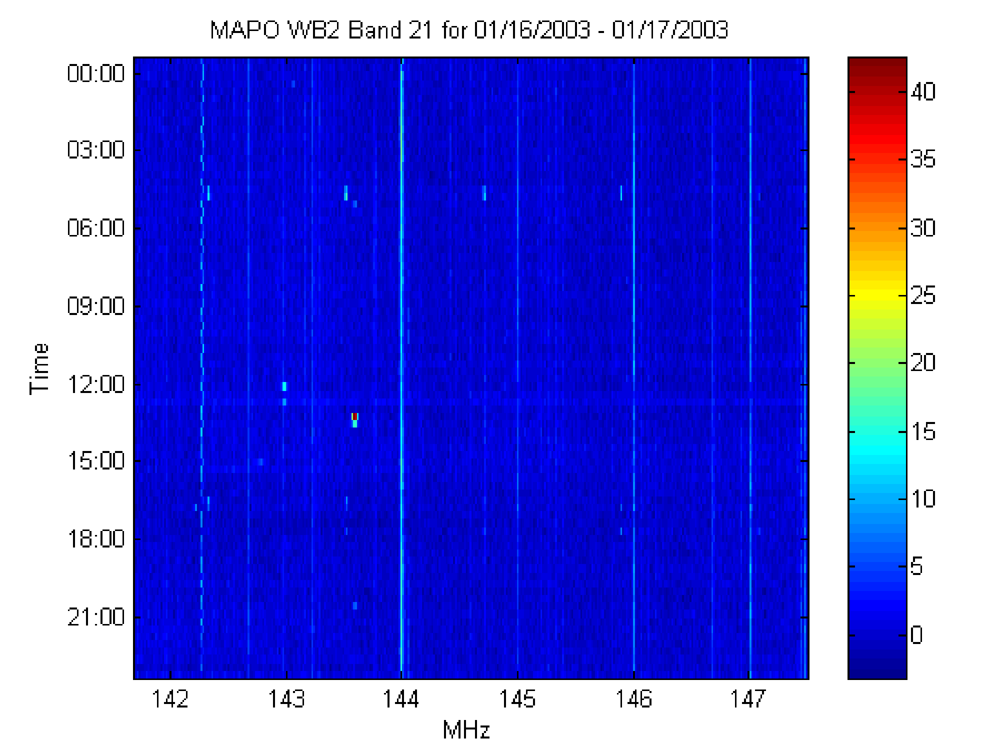

Figure E-150 MAPO WB2 BAND 21 (dBuV/m)

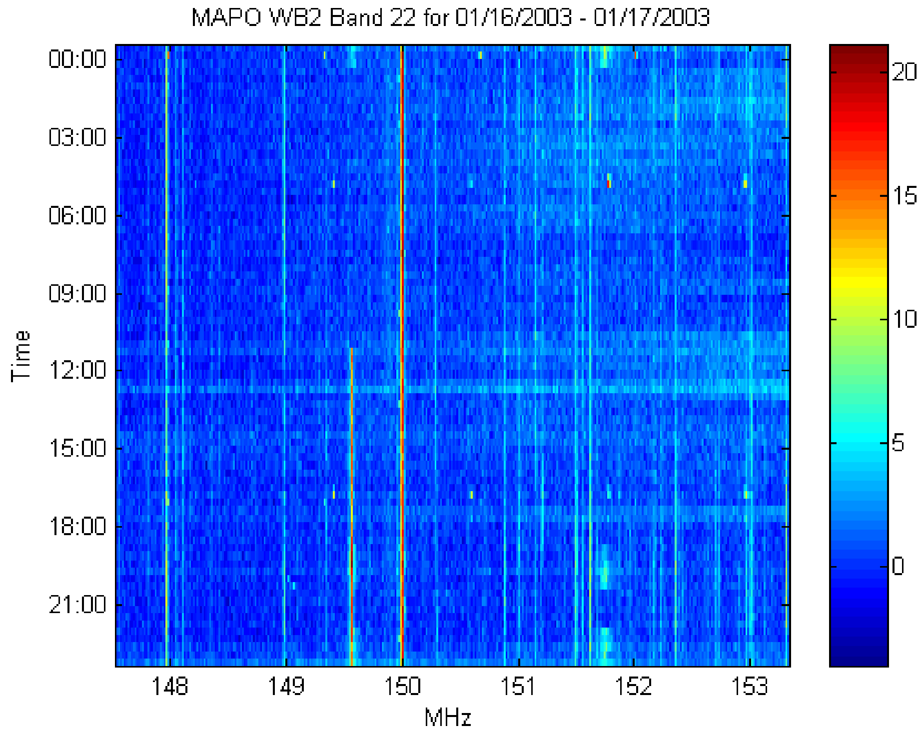

Figure E-151 MAPO WB2 BAND 22 (dBuV/m)

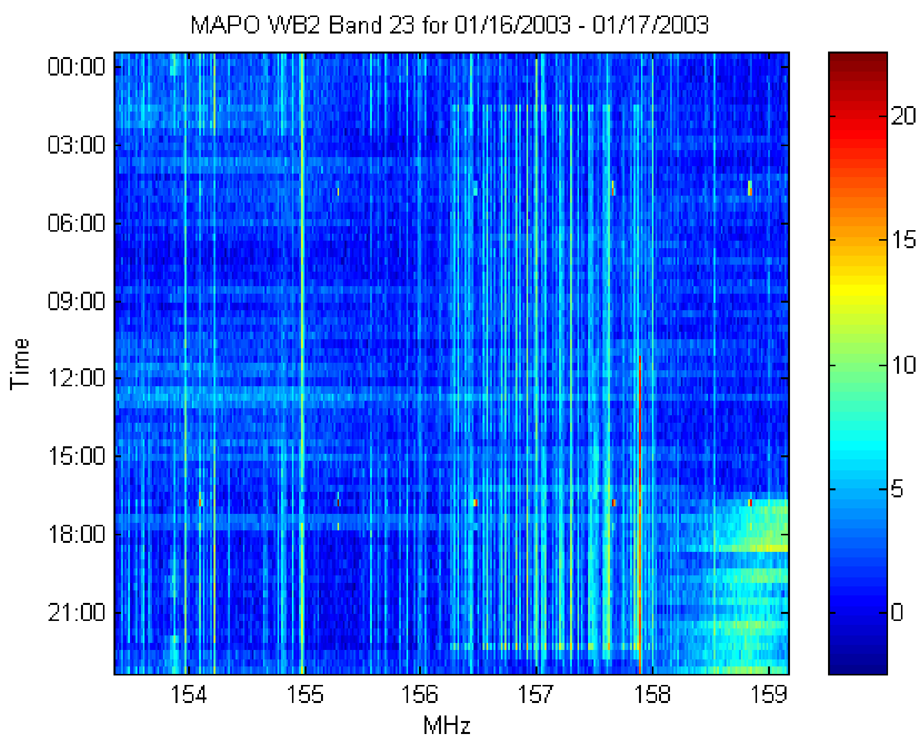

Figure E-152 MAPO WB2 BAND 23 (dBuV/m)

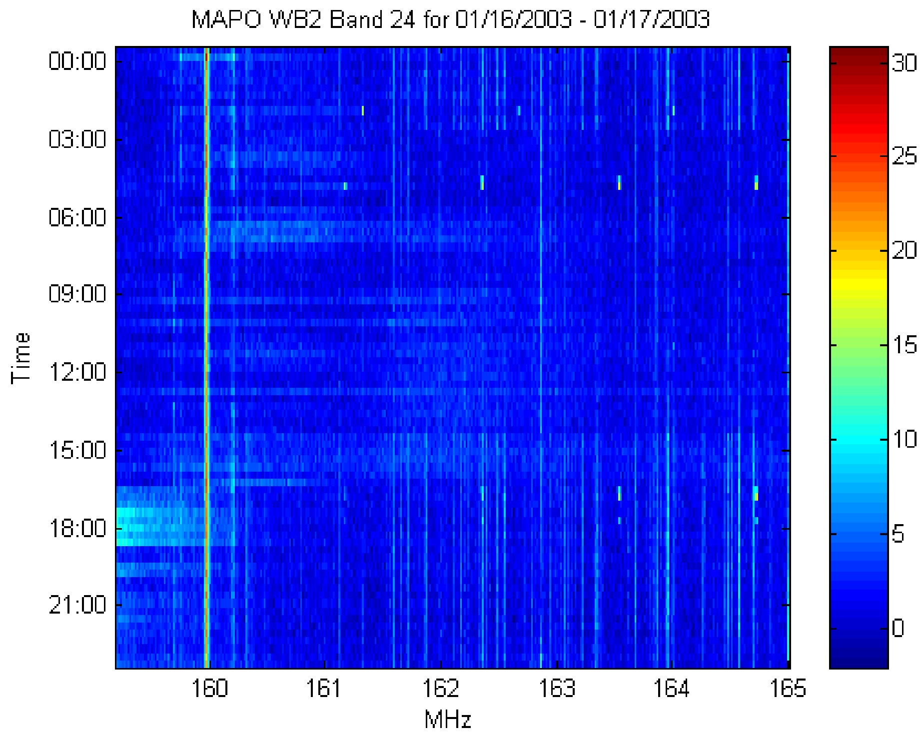

Figure E-153 MAPO WB2 BAND 24 (dBuV/m)

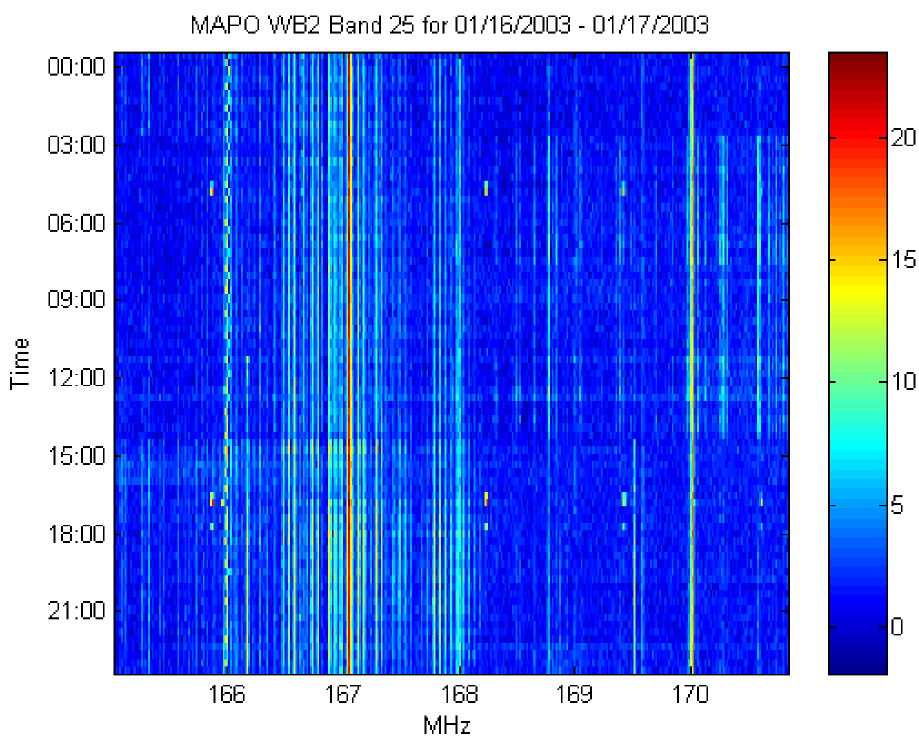

Figure E-154 MAPO WB2 BAND 25 (dBuV/m)

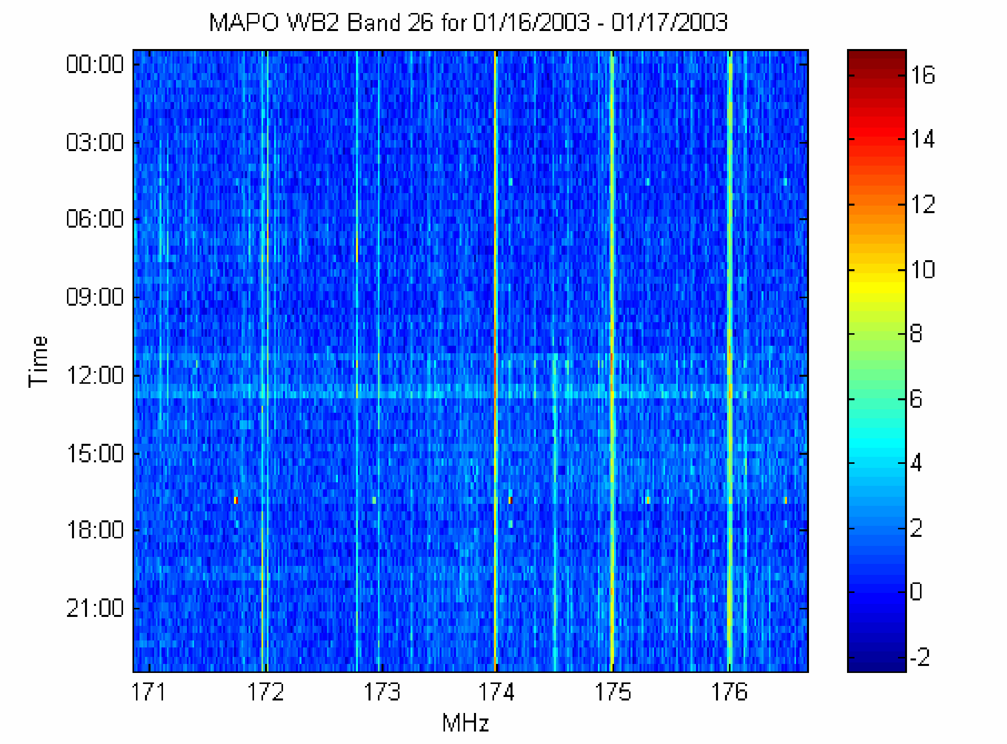

Figure E-155 MAPO WB2 BAND 26 (dBuV/m)

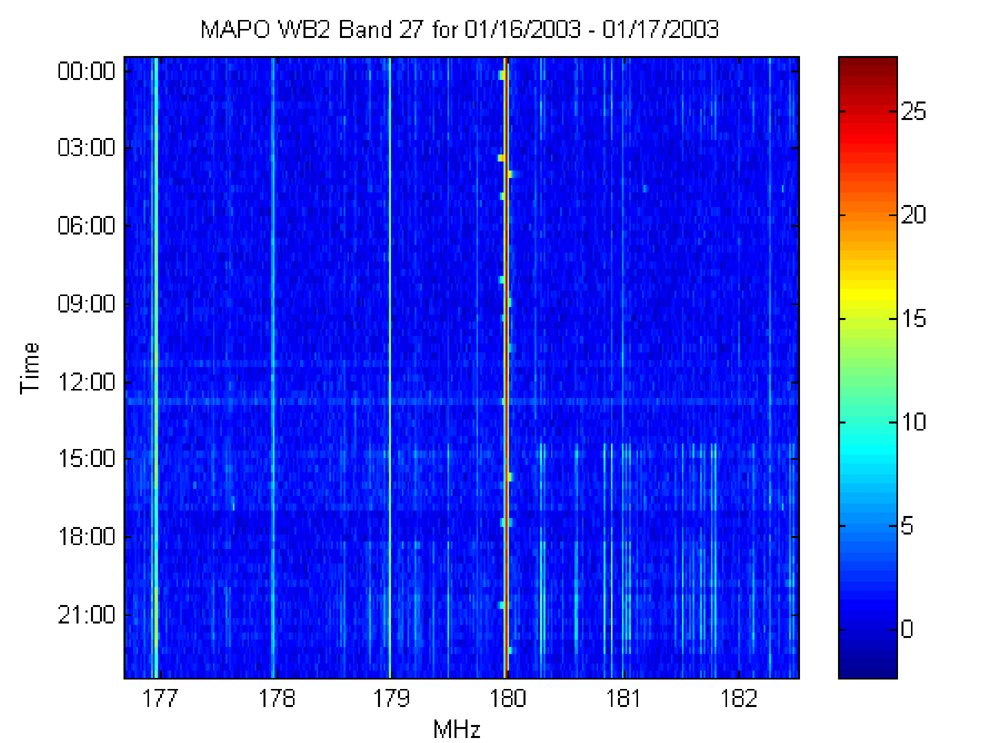

Figure E-156 MAPO WB2 BAND 27 (dBuV/m)

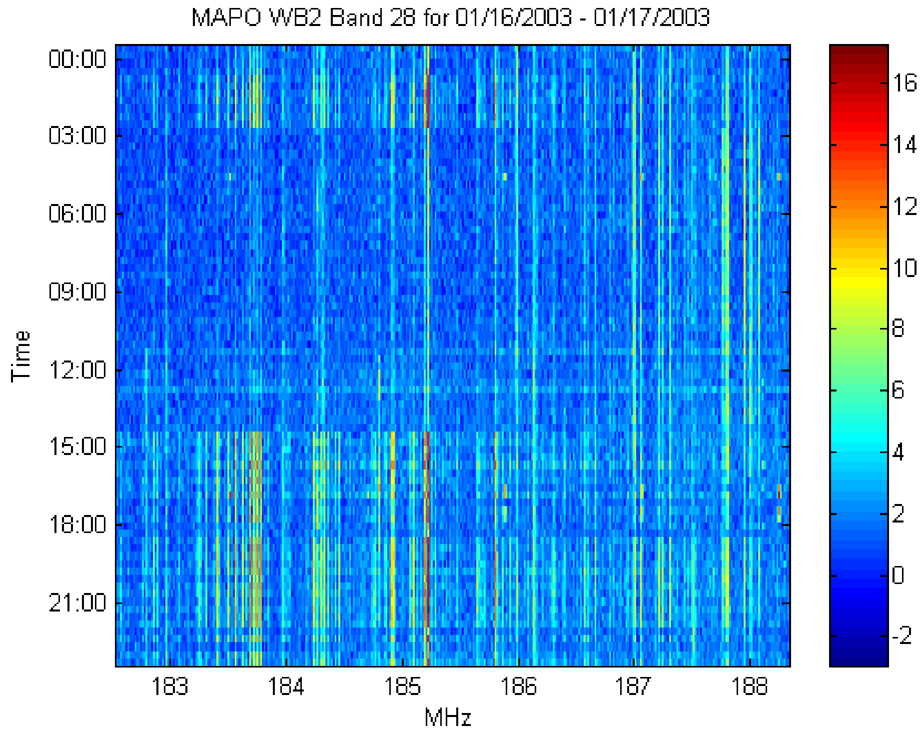

Figure E-157 MAPO WB2 BAND 28 (dBuV/m)

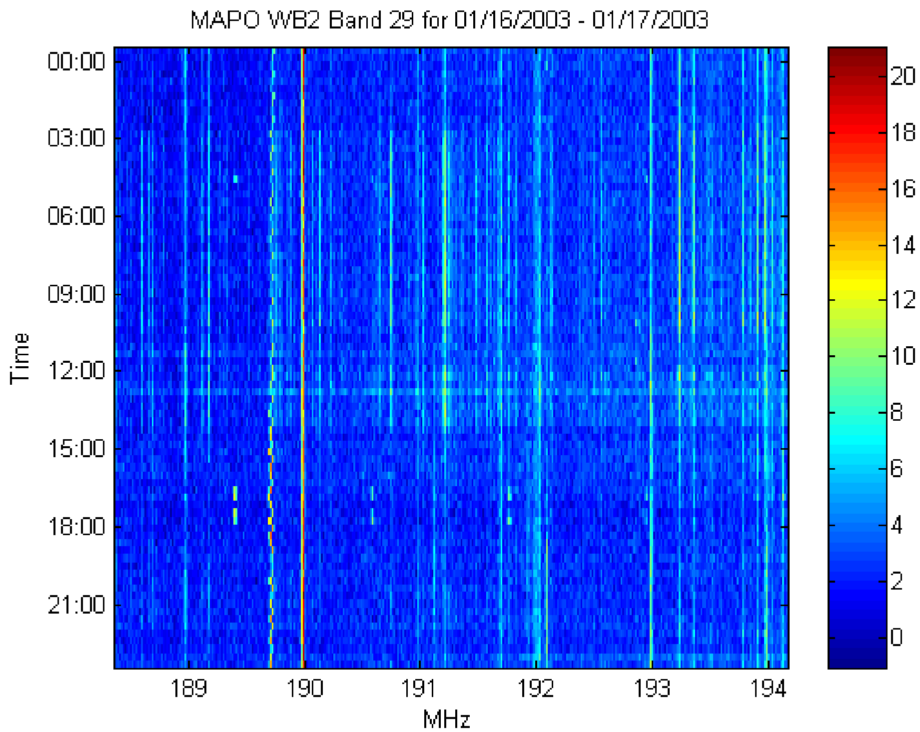

Figure E-158 MAPO WB2 BAND 29 (dBuV/m)

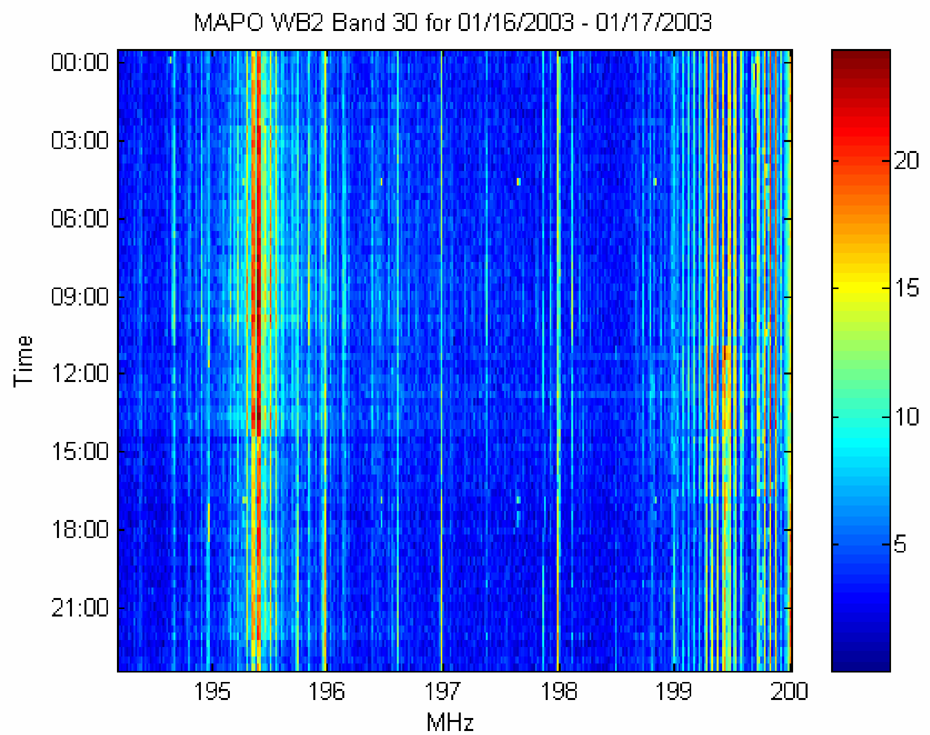

Figure E-159 MAPO WB2 BAND 30 (dBuV/m)

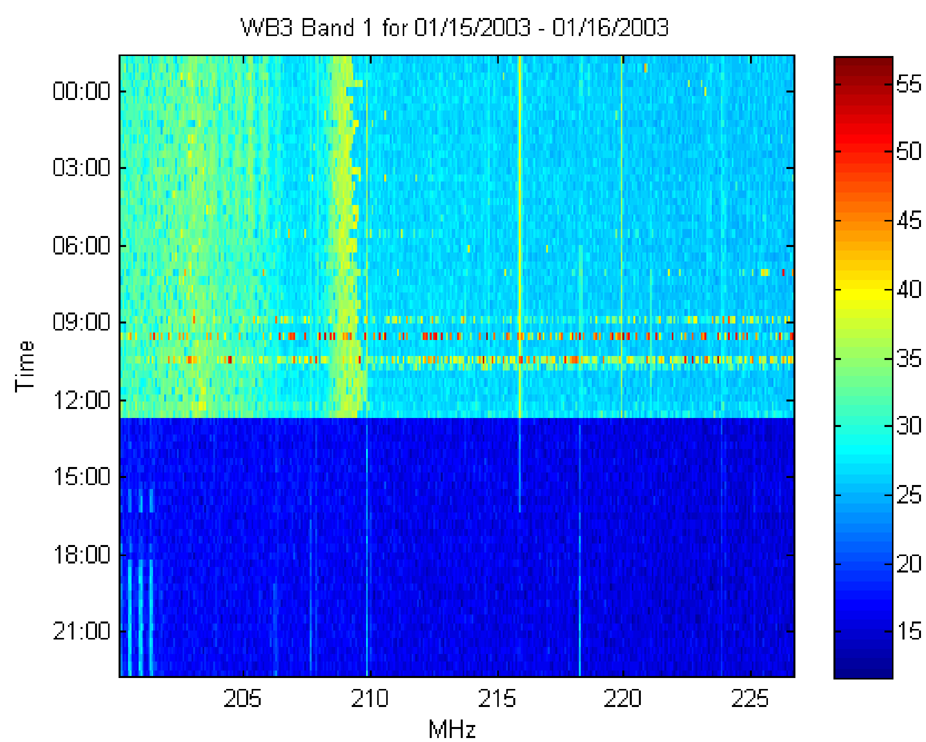

Figure E-160 MAPO WB3 BAND 1 (dBuV/m)

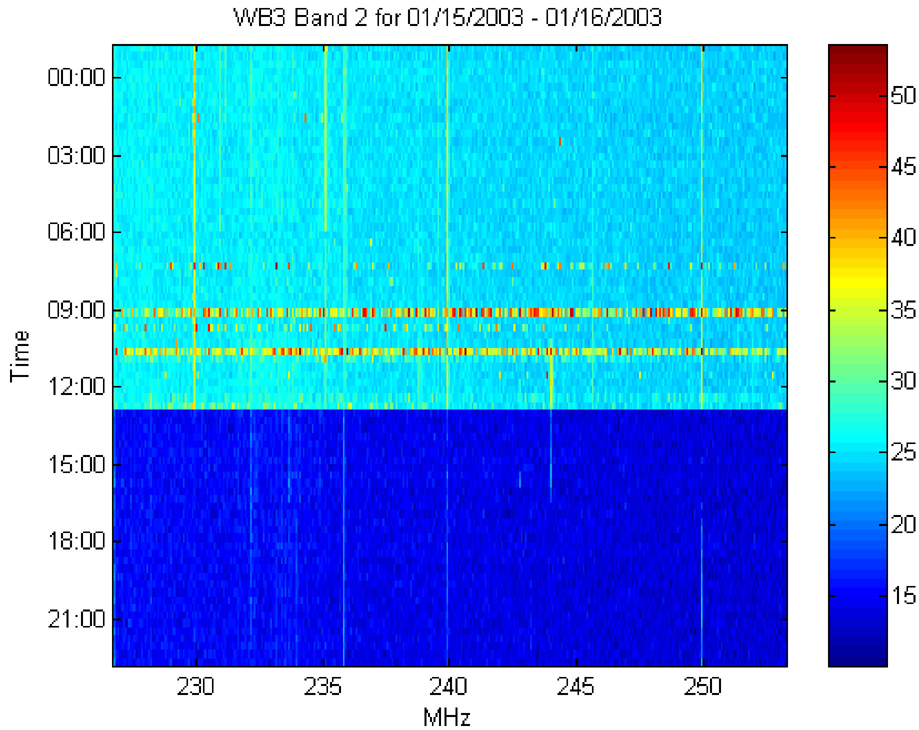

Figure E-161 MAPO WB3 BAND 2 (dBuV/m)

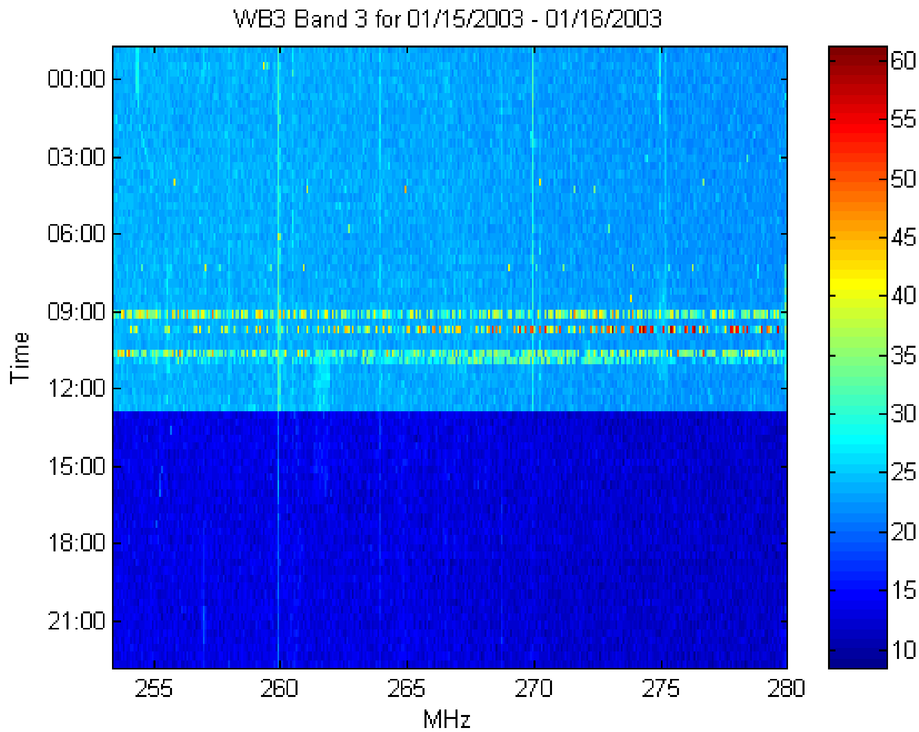

Figure E-162 MAPO WB3 BAND 3 (dBuV/m)

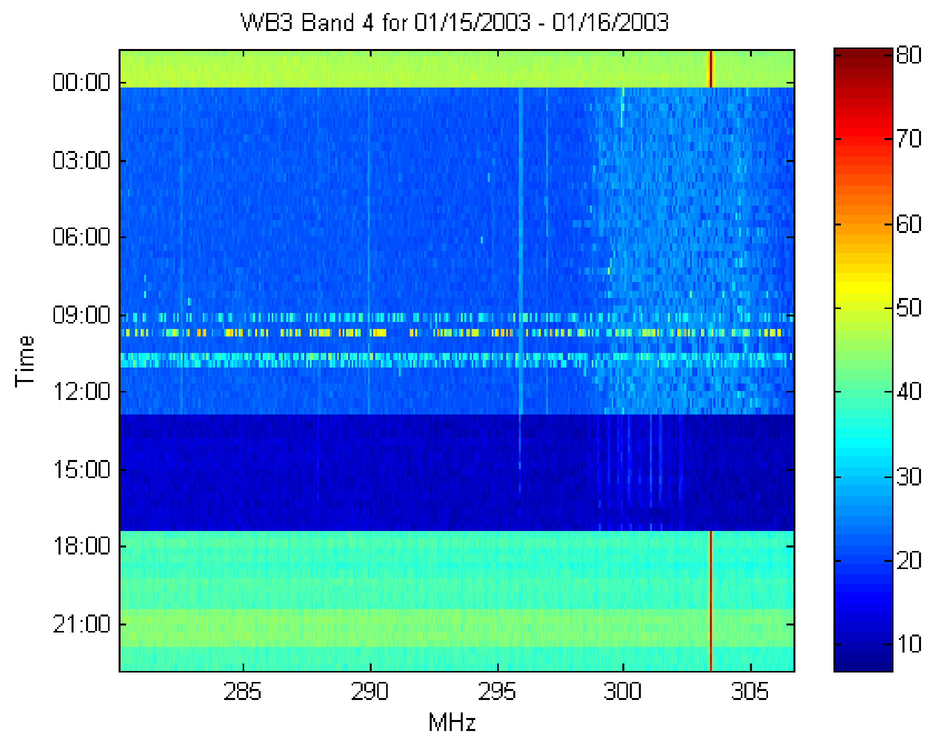

Figure E-163 MAPO WB3 BAND 4 (dBuV/m)

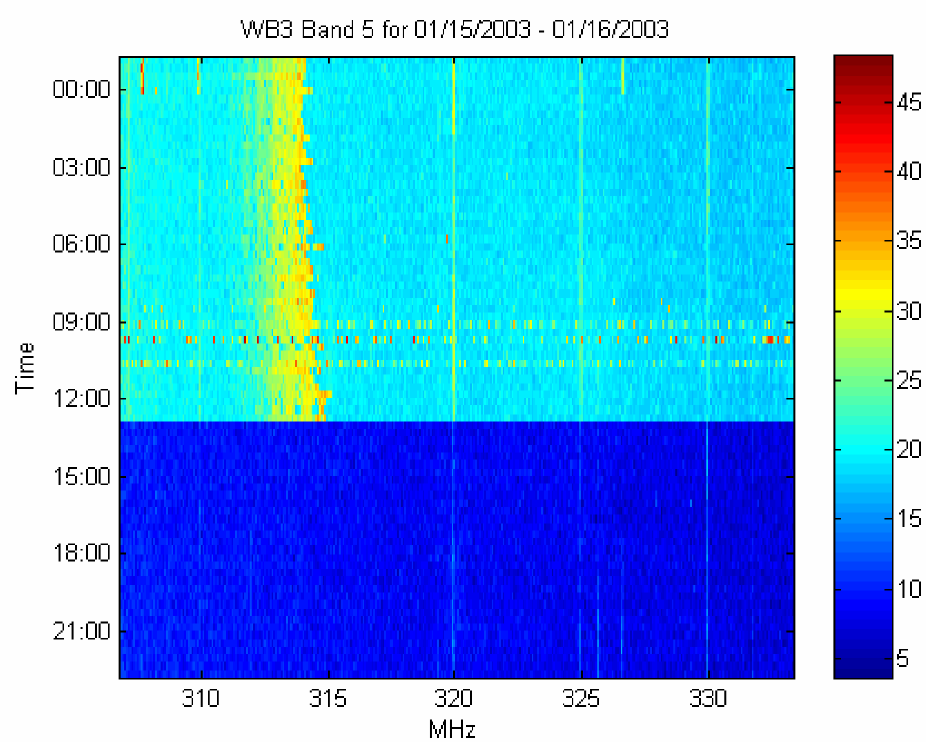

Figure E-164 MAPO WB3 BAND 5 (dBuV/m)

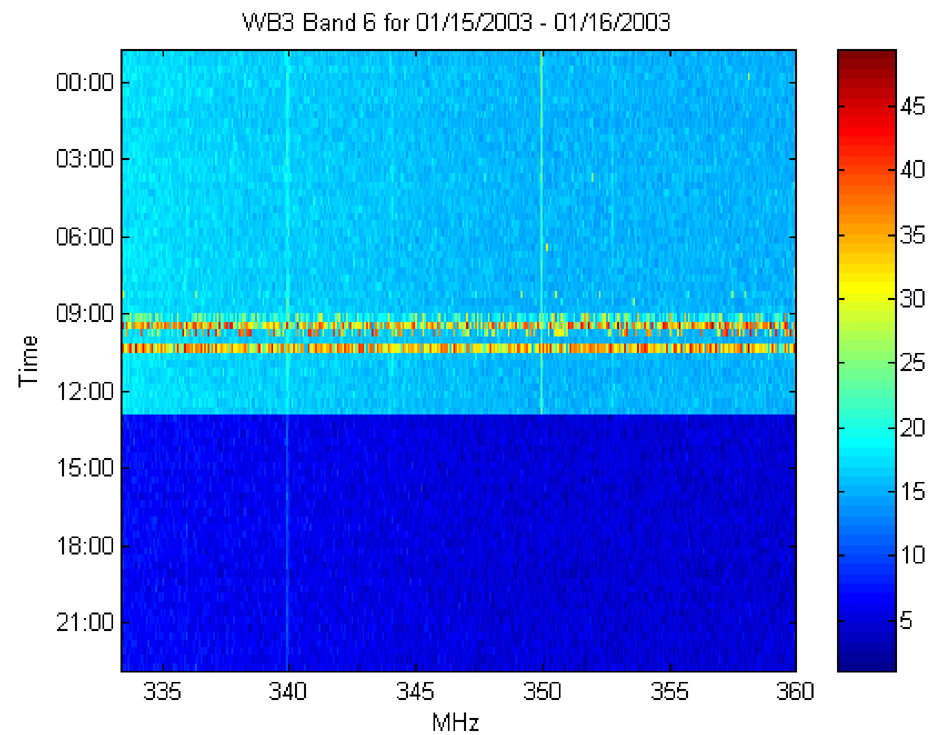

Figure E-165 MAPO WB3 BAND 6 (dBuV/m)

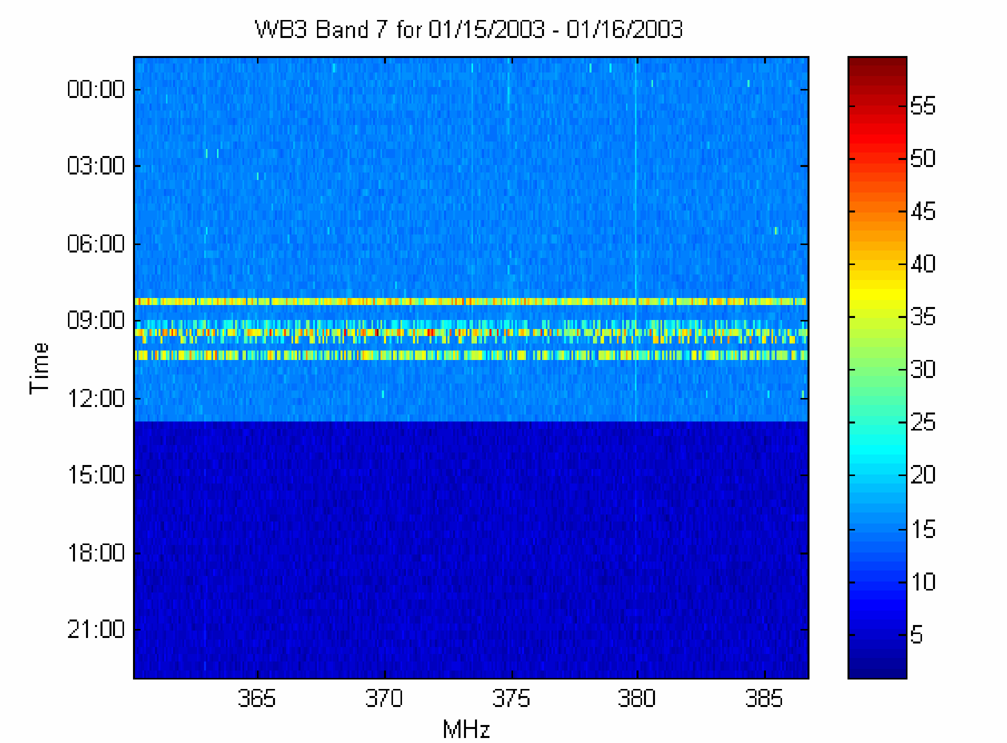

Figure E-166 MAPO WB3 BAND 7 (dBuV/m)

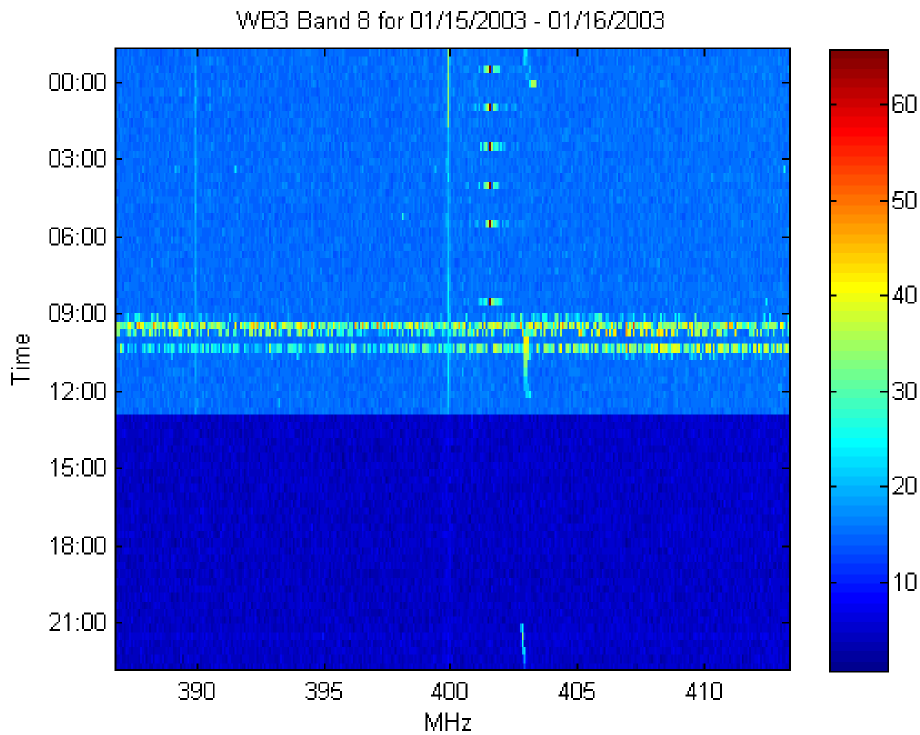

Figure E-167 MAPO WB3 BAND 8 (dBuV/m)

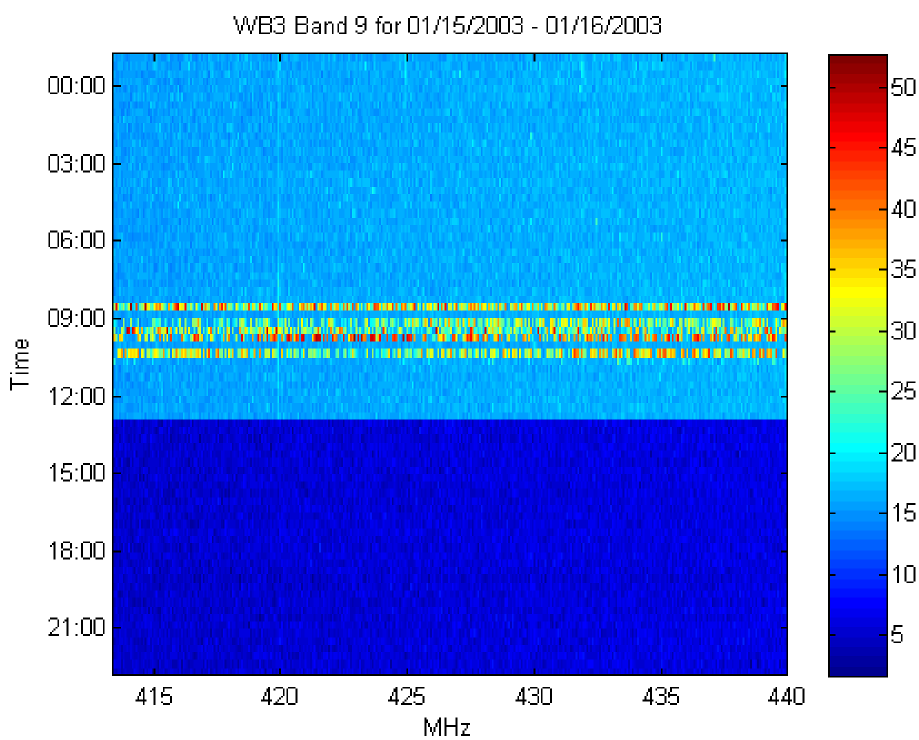

Figure E-168 MAPO WB3 BAND 9 (dBuV/m)

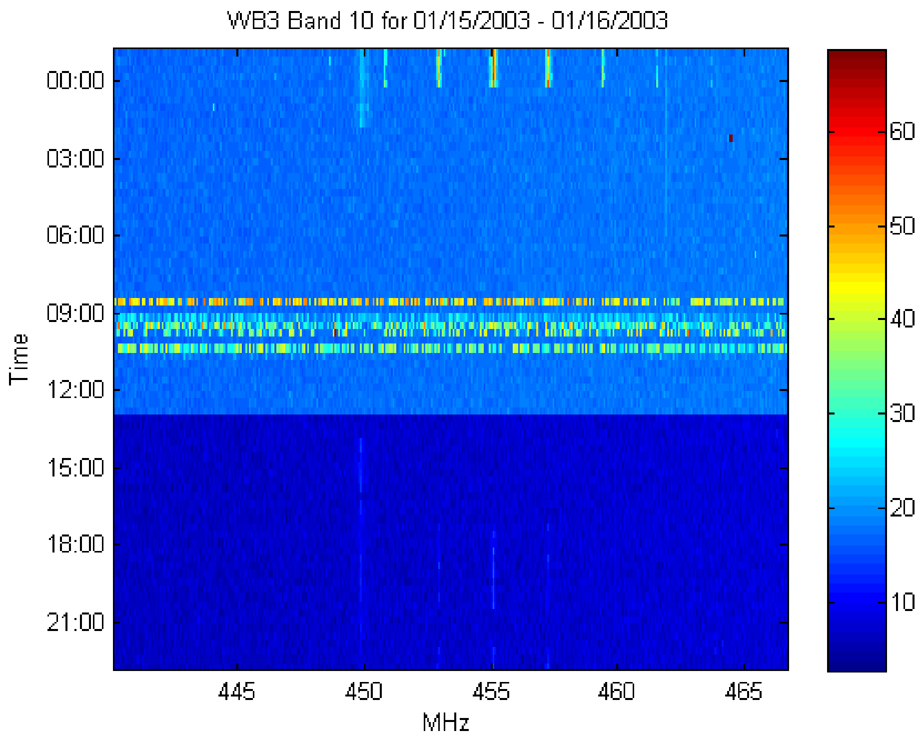

Figure E-169 MAPO WB3 BAND 10 (dBuV/m)

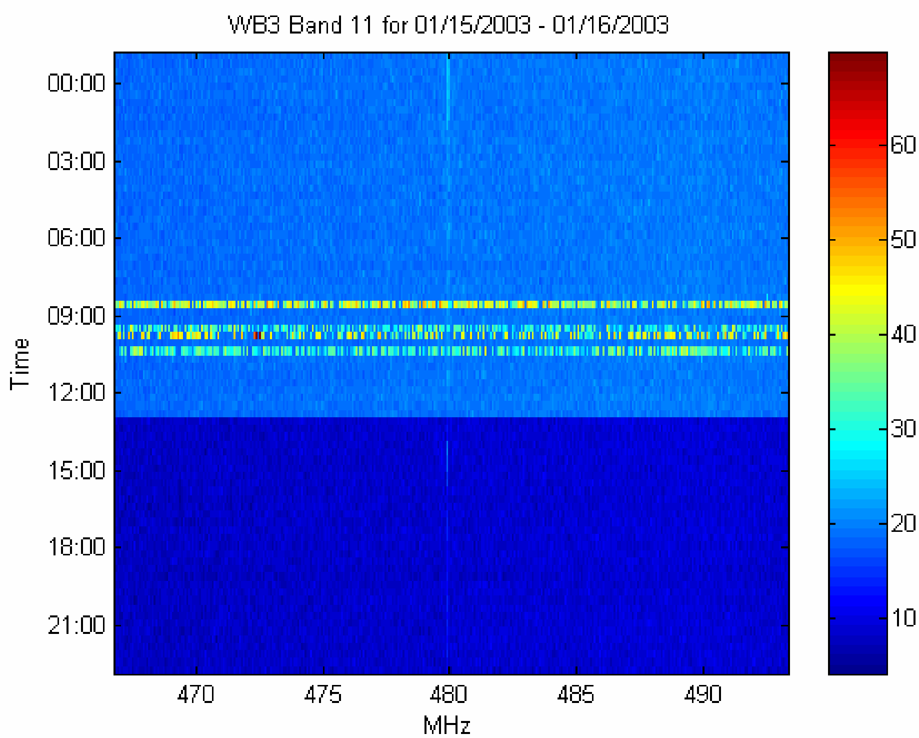

Figure E-170 MAPO WB3 BAND 11 (dBuV/m)

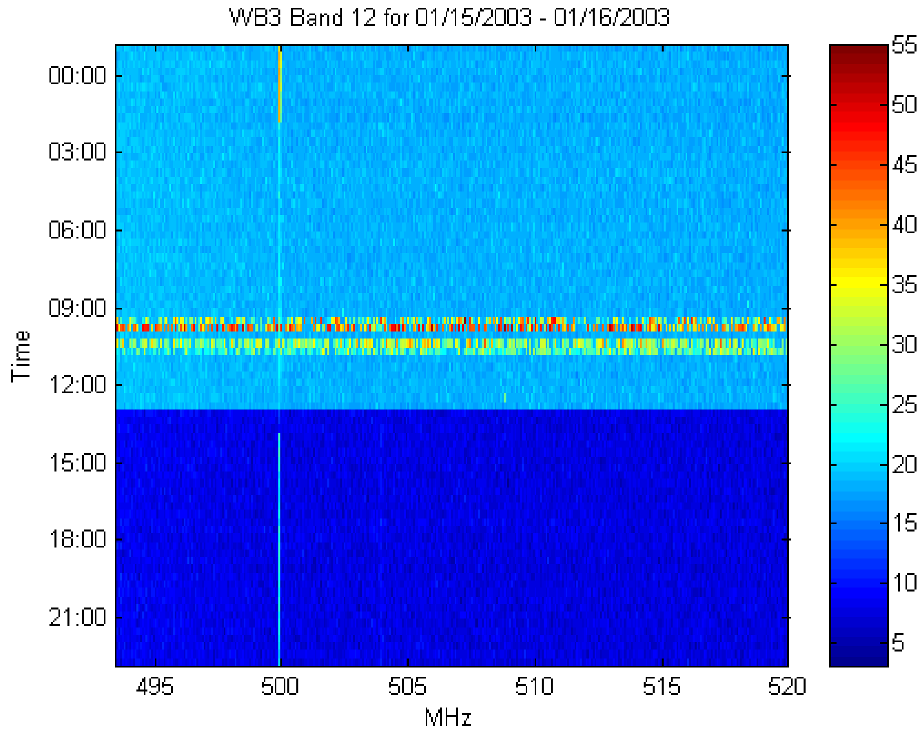

Figure E-171 MAPO WB3 BAND 12 (dBuV/m)

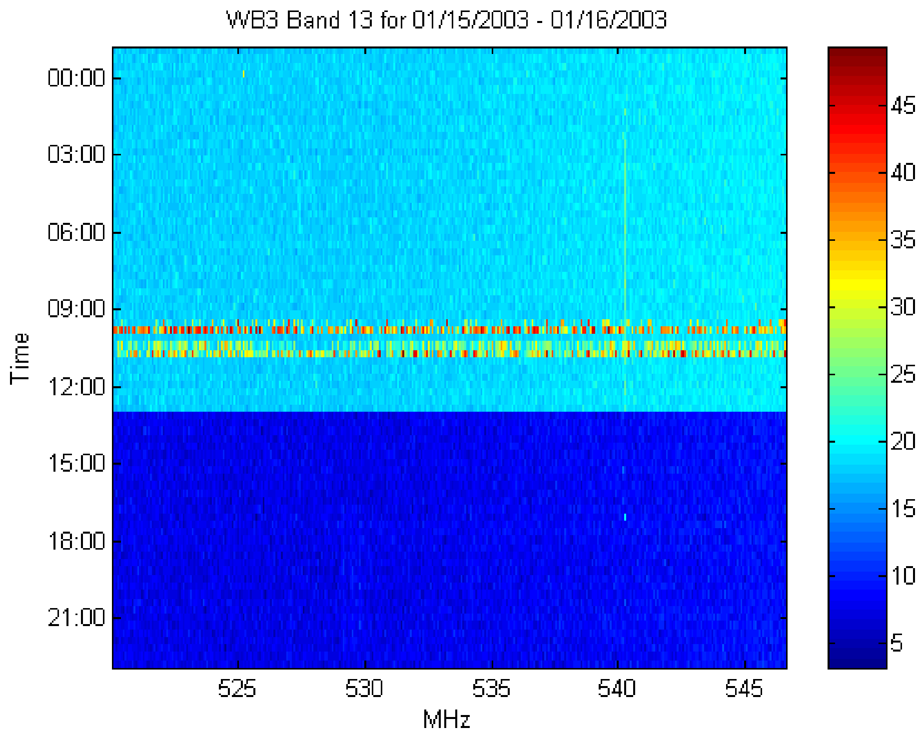

Figure E-172 MAPO WB3 BAND 13 (dBuV/m)

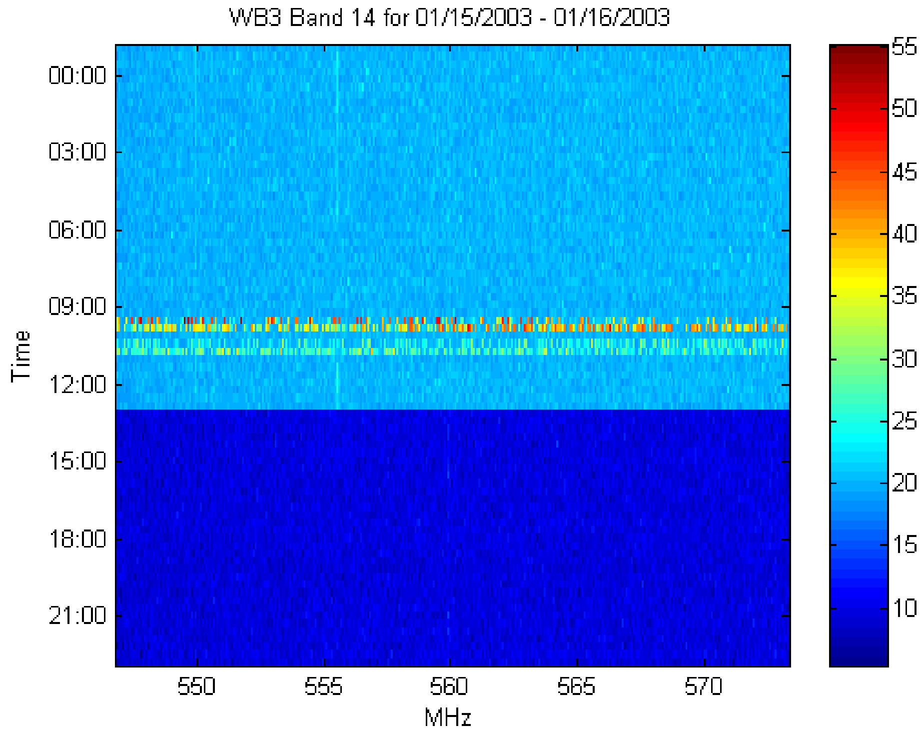

Figure E-173 MAPO WB3 BAND 14 (dBuV/m)

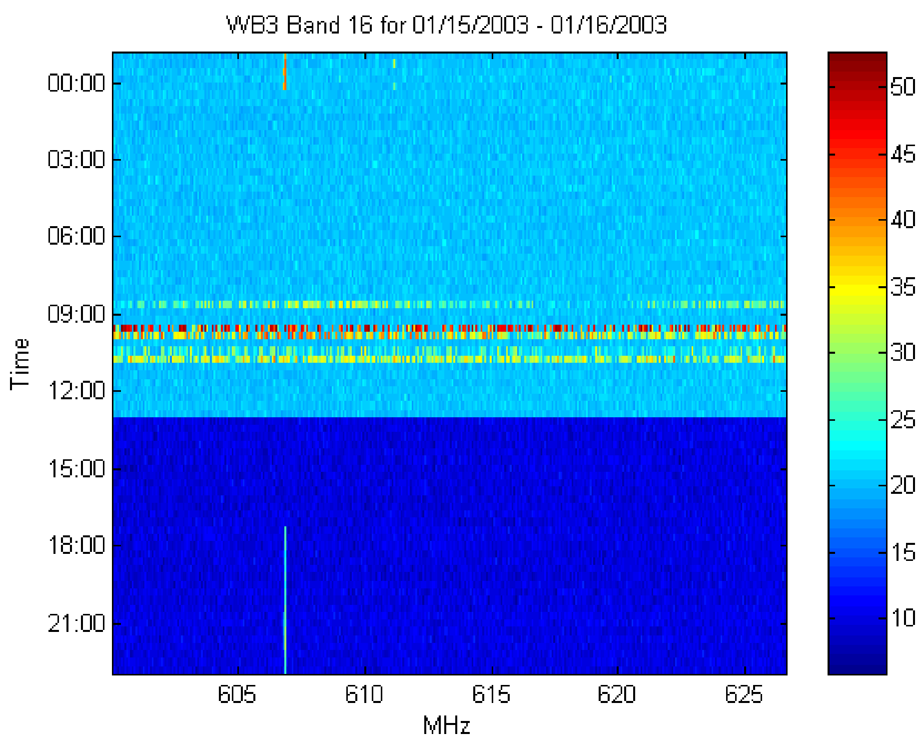

Figure E-174 MAPO WB3 BAND 16 (dBuV/m)

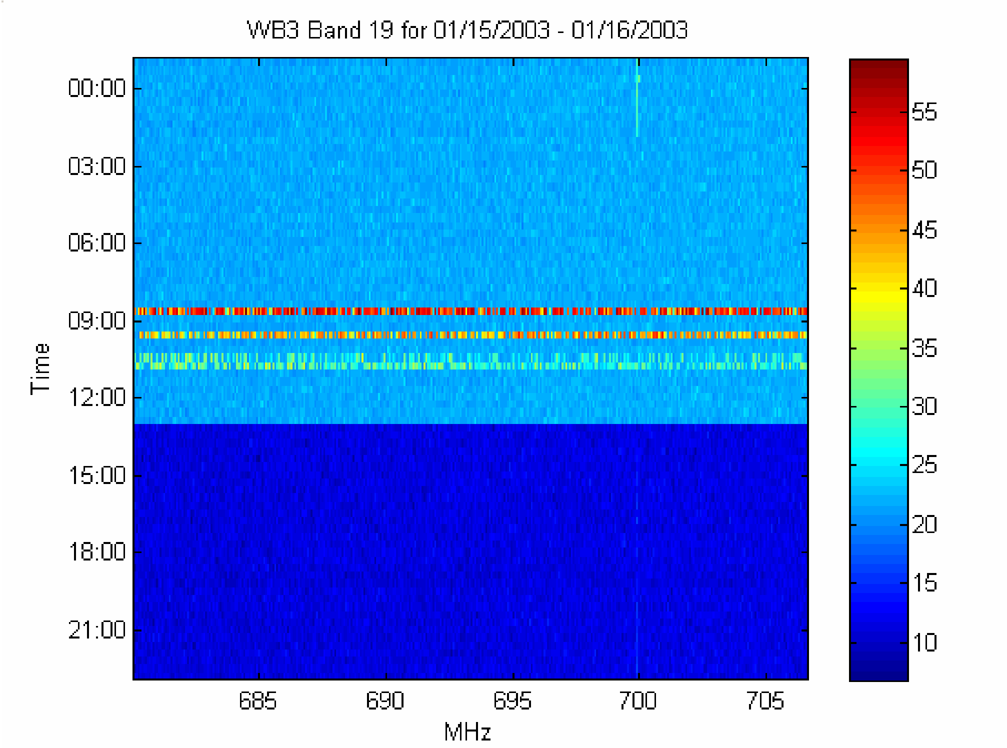

Figure E-175 MAPO WB3 BAND 19 (dBuV/m)

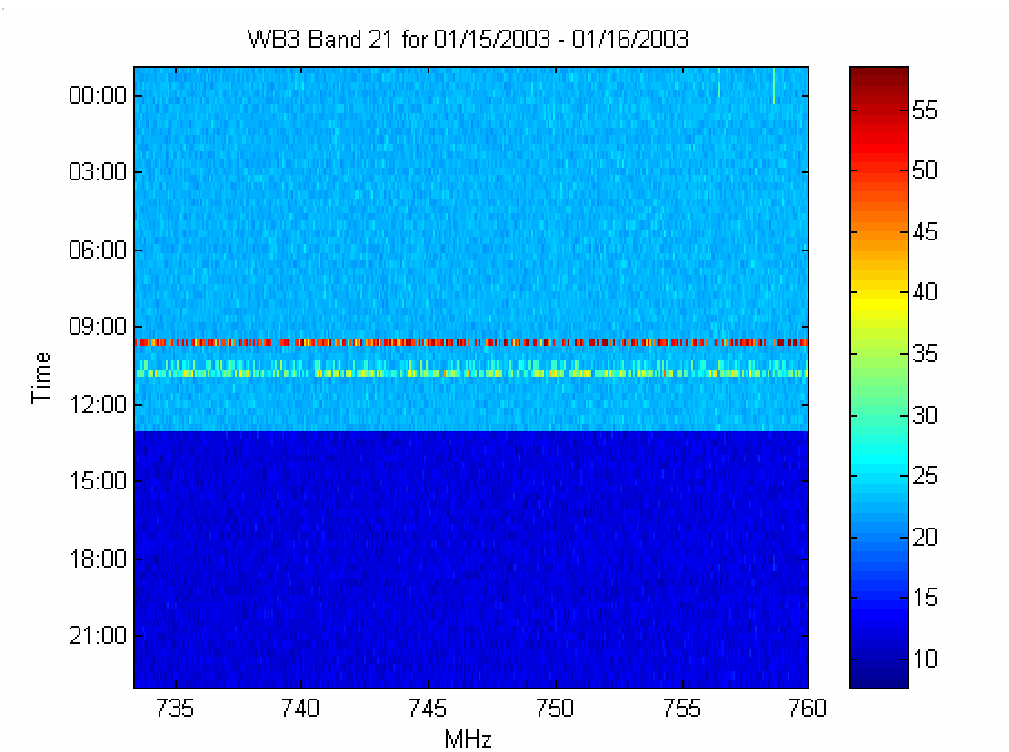

Figure E-176 MAPO WB3 BAND 21 (dBuV/m)

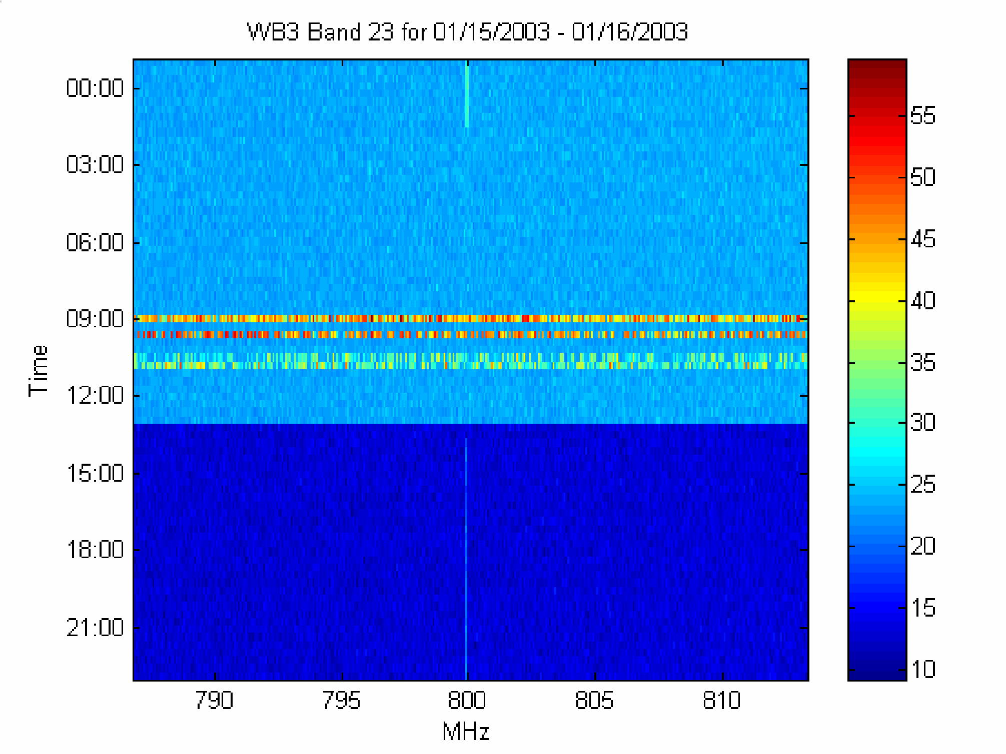

Figure E-177 MAPO WB3 BAND 23 (dBuV/m)

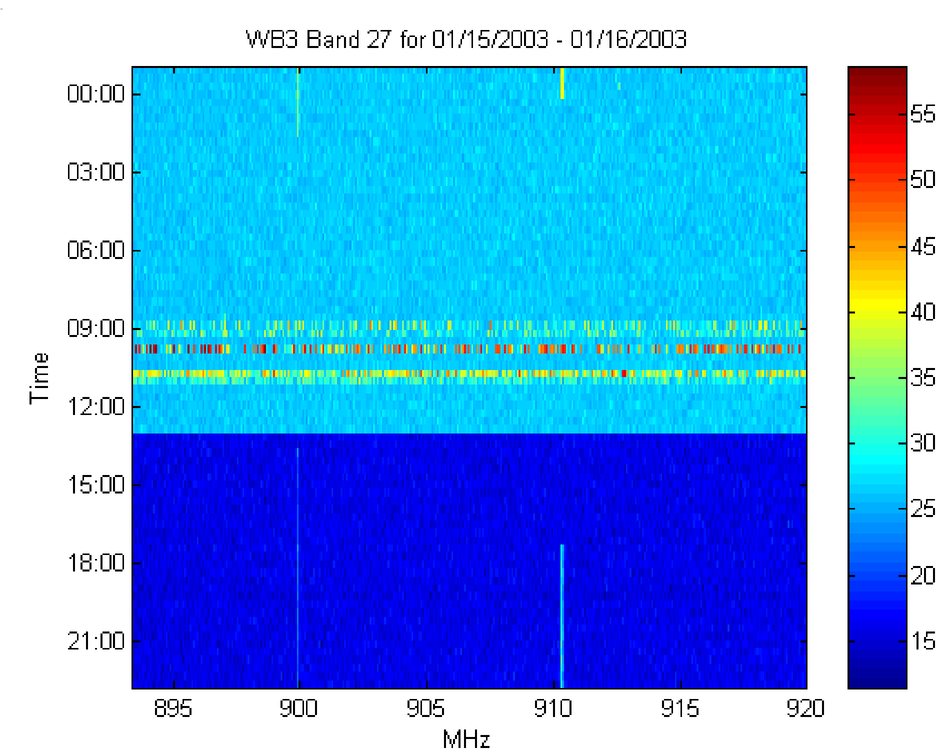

Figure E-178 MAPO WB3 BAND 27 (dBuV/m)

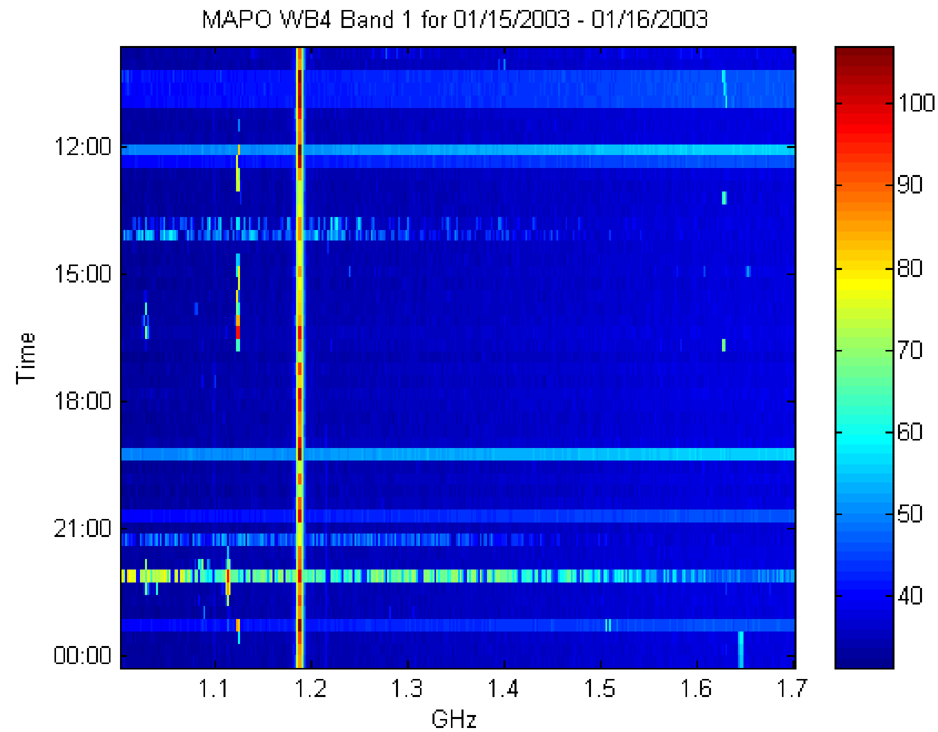

Figure E-179 MAPO WB4 BAND 1 (dBuV/m)

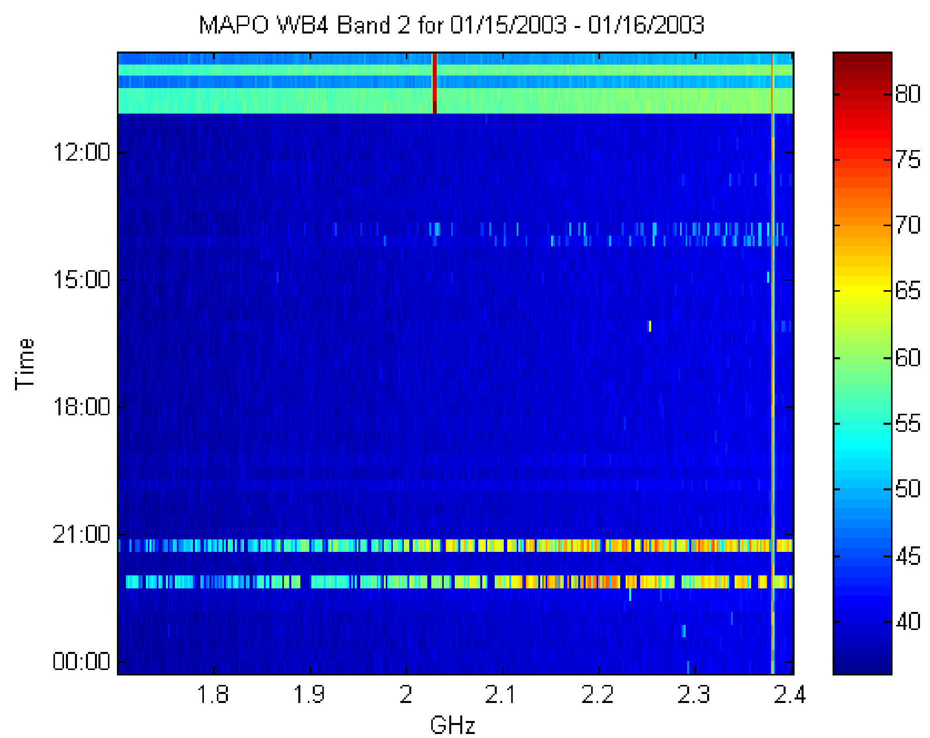

Figure E-180 MAPO WB4 BAND 2 (dBuV/m)

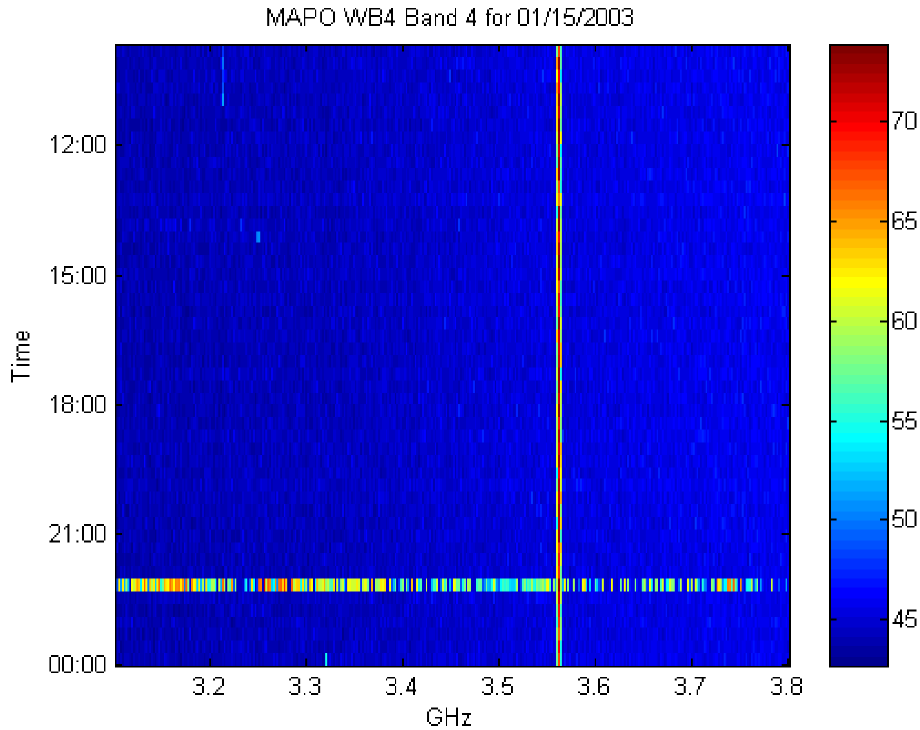

Figure E-181 MAPO WB4 BAND 4 (dBuV/m)

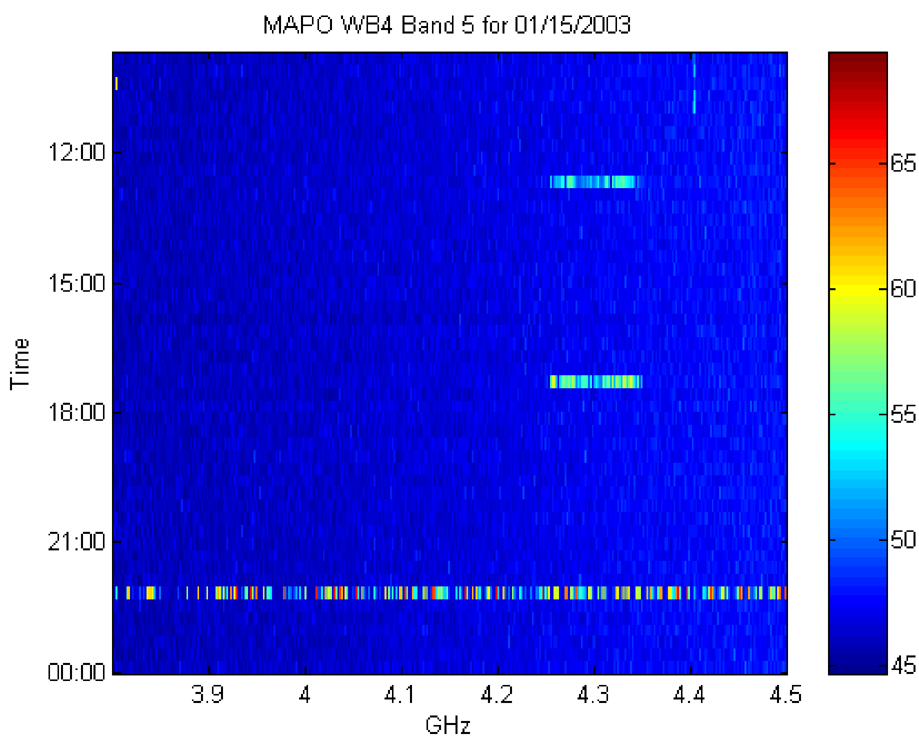

Figure E-182 MAPO WB4 BAND 5 (dBuV/m)

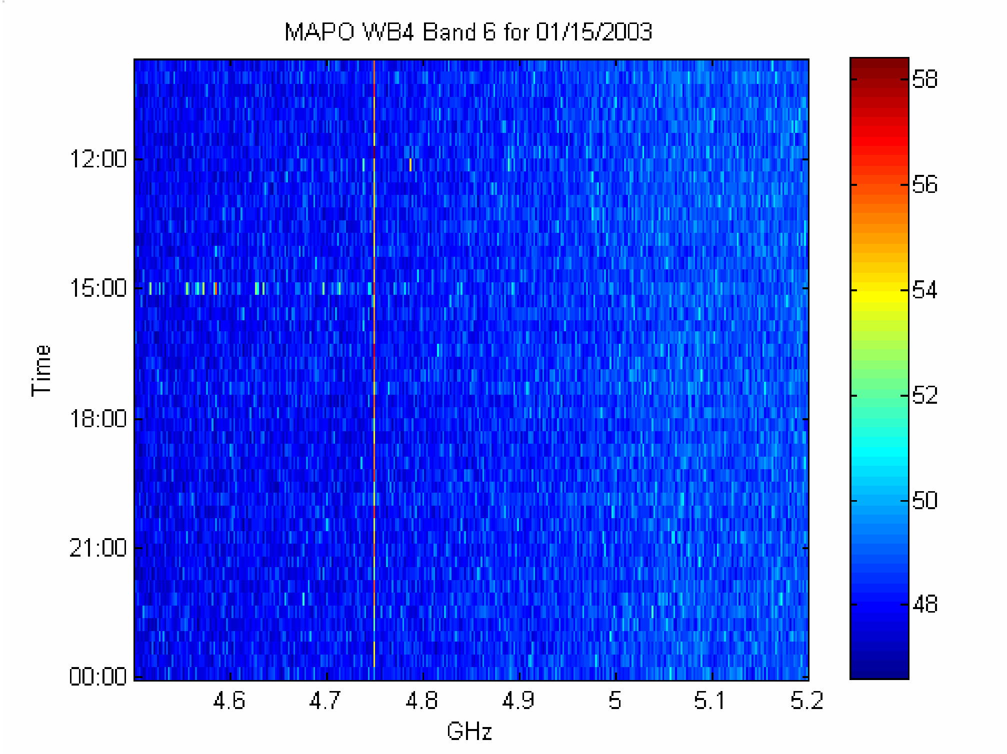

Figure E-183 MAPO WB4 BAND 6 (dBuV/m)

Appendix F Low Frequency Data

F Low Frequency Measurements

F.1 Background

F.1.1 There are several radio experiments that operate at the South Pole station in the ULF to HF bands. These instruments are all passive monitors that focus on specific frequency ranges from approximately DC (1 mHz) to 50 MHz. DC (mHz range) - 1 Hz. In the ULF range Bell Laboratories - Lucent Technologies operate fluxgate magnetometers monitoring fluctuation in the Earth's magnetic field between DC (mHz range) and 1 Hz. Also, Search coil magnetometers operated at South Pole Station provide information on wave activity in the 0.001 Hz - 20 Hz frequency range. Stanford University operates an ELF/VLF system at South Pole Station where continuous and synoptic and wide-band ELF/VLF measurements provide key information on the diverse range of wave activity in the Earth's ionosphere and magnetosphere.

F.1.2 Any ULF/ELF/AF out-of-band emissions could have adverse effects on the sensitivity and quality of these measurements/data. SPAWARSYSCEN Charleston was tasked to make measurements in this frequency range. The resulting information is intended to aid in the design of future instruments and help mitigate potential EMI problems.

F.1.3 Just prior to the survey at South Pole Station, Stanford University did a survey of the AF/LF/VLF bands starting at about 500 Hz. As a result of discussions with the Stanford University personnel on site, including Professor Umran Inan, it was agreed that the best approach would be for SPAWARSYSCEN Charleston to supplement their measurements at frequencies below 500 Hz at as many of the same remote locations as possible. By measuring up to 850 Hz, there is some overlap in the measurements so that the relative calibration of the two systems can be compared.

F.2 Objective

F.2.1 The measurement plan consisted of using the SPAWARSYSCEN San Diego magnetometer to make similar measurements to those of Stanford at as many of the same locations as possible. In addition measurements at the MAPO building in the quite sector, were also made. The measurements were done for three directions of the magnetometer corresponding to those used by Stanford. These consisted of the two horizontal directions; magnetometer axis directed towards the dome, and perpendicular to the direction of the dome. The third direction was with the magnetometer axis vertical.

F.2.2 Two frequency bands were recorded corresponding to 0-50 Hz with 1/8 Hz frequency resolution and 50 – 850 with 2 Hz frequency resolution. The Dynamic Signal Analyzer was set to average 10 sweeps for each of these frequency ranges. At each site the magnetic field was recorded in each of 3 directions corresponding to the magnetometer axis directed towards the dome, perpendicular to the direction to the dome and vertical, the same as had been done in the Stanford University survey.

F.3 Magnetometer

F.3.1 For these measurements, Dr. Jack Dea of SPAWARSYSCEN San Diego, Code 2716 manufactured a custom-made heavily shielded 4-coil magnetometer wound on a special high permeability iron core. The magnetometer was calibrated in a special solenoidal test coil. The calibration curve is given as Figure F-1. Note that the response is relatively flat from 10 Hz to 800 Hz. The sensitivity was measured in a special mu-metal container and over that frequency range the noise level with no signal corresponds to 0.6 pT / √Hz.

F.3.2 The coils and core of the magnetometer are placed in a ½-inch diameter copper water pipe shield. The connection is made by a 50-foot length of RG – 174 coaxial cable that exits through a hole in the copper shield.

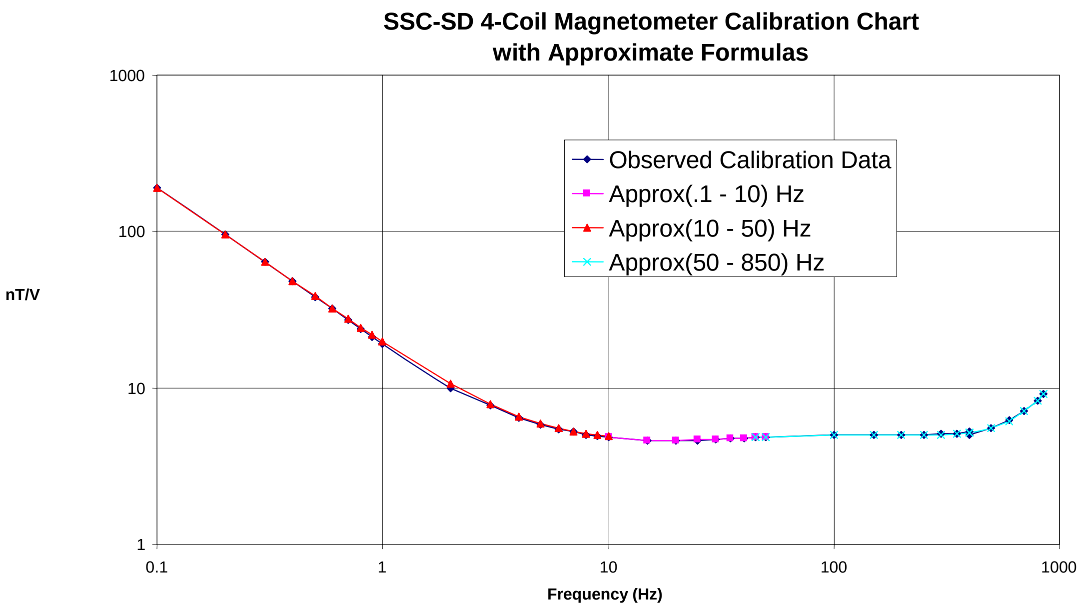

Figure F-1 SSC-SD 4-Coil Magnetometer Calibration Curve

F.4 Measurement Configuration

F.4.1 For the South Pole measurements, the magnetometer cable was extended using a 100-foot piece of special Teflon cable (RG – 58) for use at low temperatures. This allowed the magnetometer to be placed at a distance of 150 feet away from the instrumentation. A special battery powered low noise amplifier was used to amplify the magnetometer signal. This amplifier was located inside where it was warm, just in front of the HP35665A Dynamic Signal Analyzer that was connected to the notebook computer used to record the data. Note that the Signal Analyzer was set to take the average of 10 sweeps. The amplifier has a voltage gain of 1740.

F.4.2 For measurements at remote locations the equipment was placed in a Pisten Bully (tracked vehicle, Figure F-2 and F3). An HP85901A inverter that is especially quiet for EMI/EMC measurements powered the equipment. The magnetometer was placed outside in the snow approximately 150 feet from the Pisten Bully in a direction perpendicular to the direction to the dome (Figure F-2). For the measurements at MAPO in the dark sector, the equipment was located inside a Jamesway tent, and station power was used for the electronic equipment.

F-2 Low frequency measurement configuration

F.5 Measurement Locations

F.5.1 The Stanford University survey locations consisted of 9 remote locations approximately on radials away from the South Pole in the direction of the quiet sector. There are three sites each at distances of 4000', 5000', and 6000' from the Pole on each of three radials. The GPS coordinates for the Stanford measurement locations are given in Table F-1 below.

Table F-1
GPSS Coordinates of Stanford University Low Frequency Survey Sites

Site	Distance from Pole (feet)	Latitude	Longitude
L1	3419	89° 59.437' S	97° 46.308' E
L2	4991	89° 59.178' S	101° 04.705' E
L3	6005	89° 59.011' S	102° 40.466' E
L4	3989	89° 59.343' S	134° 59.577' E
L5	4979	89° 59.180' S	134° 59.386' E
L6	5993	89° 59.013' S	135° 00.812' E
L7	3995	89° 59.342' S	179° 58.395' E
L8	4967	89° 59.182' S	179° 59.722' E

L9	5993	89° 59.013' S	179° 59.491' E

Note that sites L1, L2, and L3 are along the boundary of the Clean Air Sector.

F.5.2 Magnetometer data was recorded at 8 sites. Six of these sites were at or near to the locations used in the Stanford survey. The other two sites were at MAPO in the dark sector and a site in the quiet sector about 1 km away from SPRESO called Beyond SPRESO. The GPS coordinates for these sites are listed in Table 6.2 below.

Table F-2
GPSS Coordinates of SPAWAR Low Frequency Survey Sites

Date	Time	Site	Distance from Pole (feet)	Latitude	Longitude
15 Jan	08:00	MAPO	2653	89° 59.563' S	47° 23.747' W
15 Jan	15:15	L1	3467	89° 59.429' S	101° 01.171' E
16 Jan	14:00	L3	Discovered bad cable connector and broken shield. Measurements resumed following repair.		
16 Jan	16:22	L7	5981	89° 59.015' S	179° 58.395' E
16 Jan	16:52	L9	5969	89° 59.017' S	177° 16.289' E
16 Jan	17:30	L6	6017	89° 59.009' S	136° 25.123' E
16 Jan	18:10	L2	4979	89° 59.180' S	103° 42.908' E
16 Jan	19:45	L3	5951	89° 59.020' S	104° 08.418' E
17 Jan	17:30	Beyond SPRESO	27,222	89° 55.463' S	156° 38.227' E
		SPRESO	26,148	89° 55.720' S	144° 25.562' E

F.6 Measurements

F.6.1 The sites given in Table 6.2 are arranged to correspond to the sequence of the measurements. Note that data were recorded at MAPO and L1 on 15 January. The following day, the connector on the magnetometer cable pulled off while setting up at the first site (L3). The measurements were abandoned and the magnetometer taken to the RF building to attempt repairs. While repairing the connector, a break in the shield was discovered at the point where the cable exited the magnetometer. This break was also repaired. Following these repairs, the magnetometer appeared to be working as, the 60 Hz line and harmonics appeared when it was connected to the Dynamic Signal Analyzer. The measurements above were then completed

F.6.2 Unfortunately, when the calibration of the Magnetometer was checked following completion of the survey, it was not working. Both repairs that had been made at the South Pole were okay but the center conductor of the cable had broken at the exit point from the magnetometer. It is not known when the break occurred, and therefore all the data is suspect.

F.6.3 As part of the effort to determine the validity of the data, it was processed to convert the measurements into dB nT / √Hz using the calibration chart in Figure F-1 and adjusting the level for the bandwidth. The bandwidth adjustments are +9 dB for the 0 – 50 Hz measurements which have 1/8 Hz bandwidth and -3 dB for the 50 - 850 Hz measurements which have 2 Hz bandwidth. These data are given in Figures F-3 to F-18 below. A further discussion of the data validity is included in the last section of this appendix.

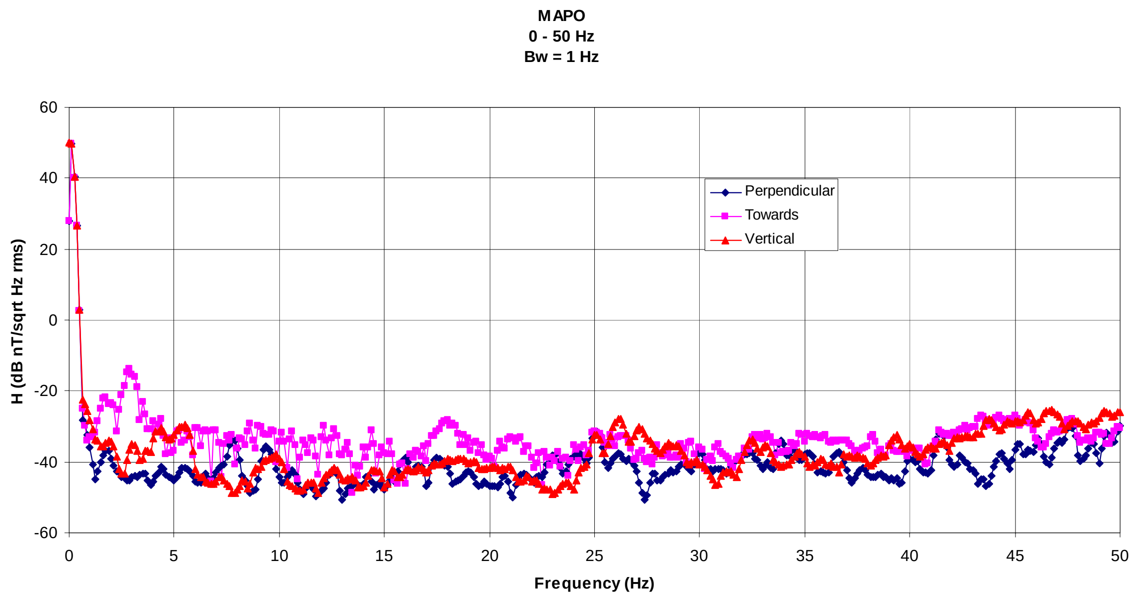

Figure F-3 Three axis data 0 – 50 Hz at MAPO

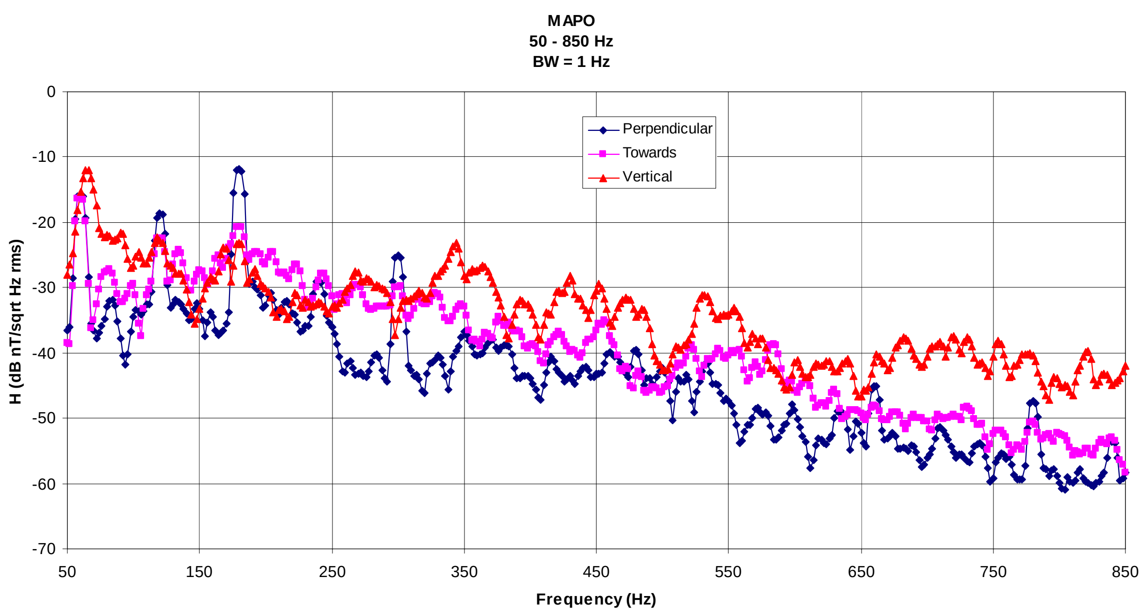

Figure F-4 Three axis data 50 – 850 Hz at MAPO

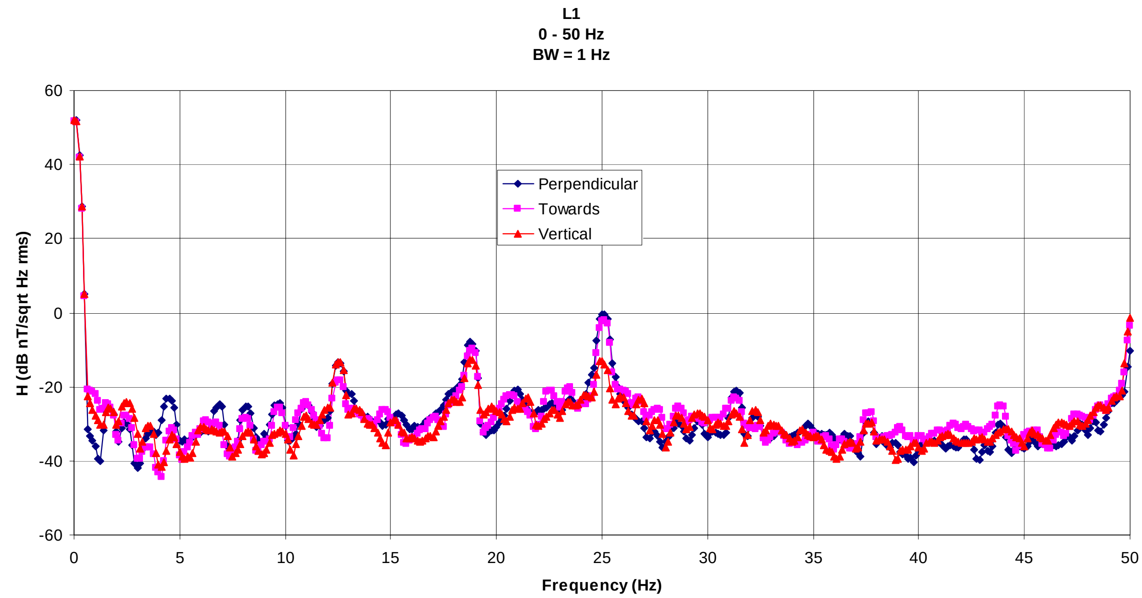

Figure F-5 Three axis data 0 – 50 Hz at L1

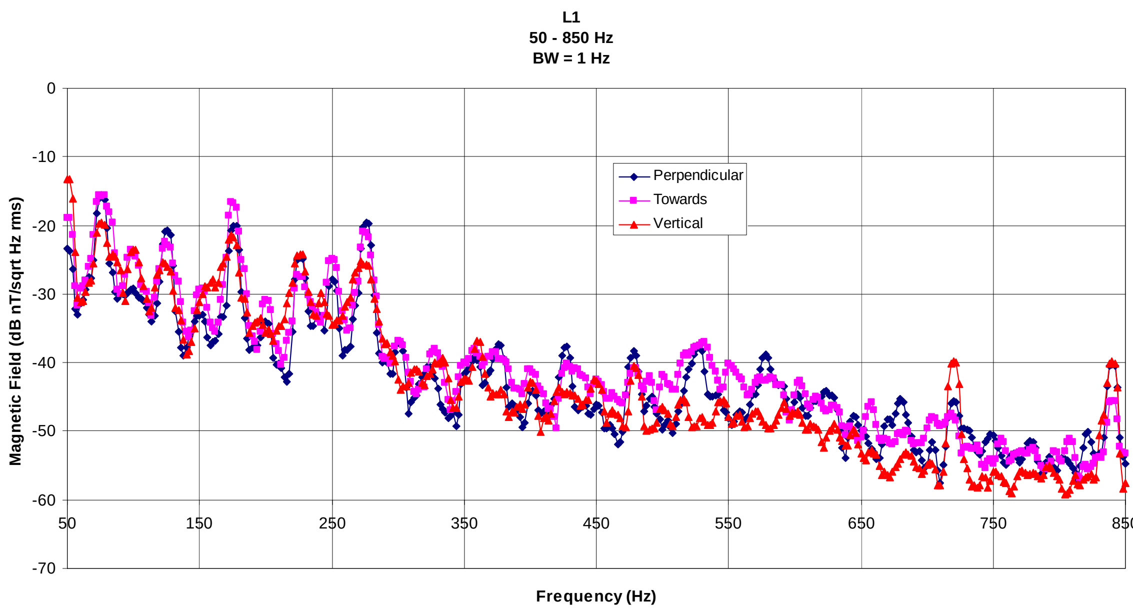

Figure F-6 Three axis data 50 – 850 Hz at L1

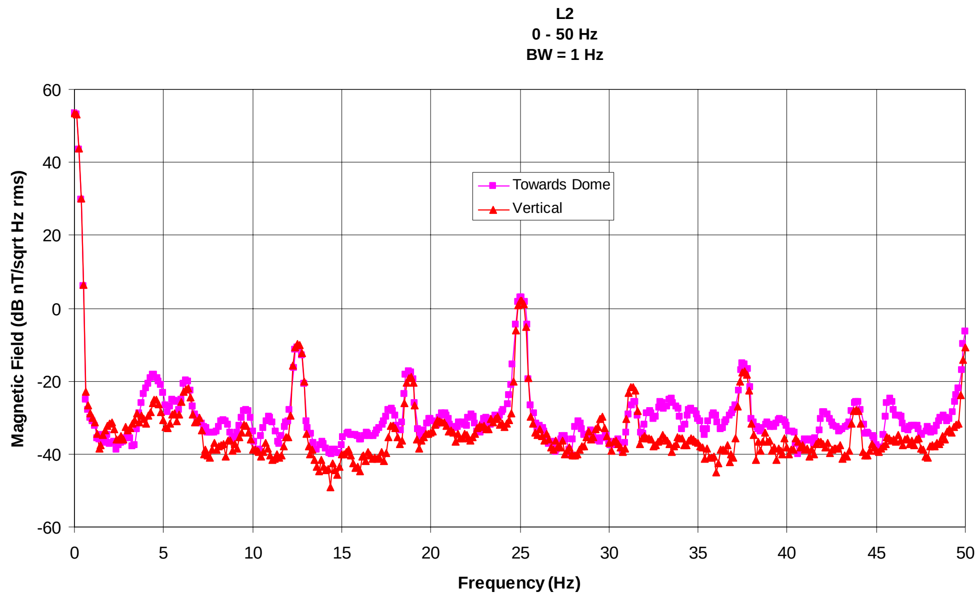

Figure F-7 Two axis data 0 – 50 Hz at L2

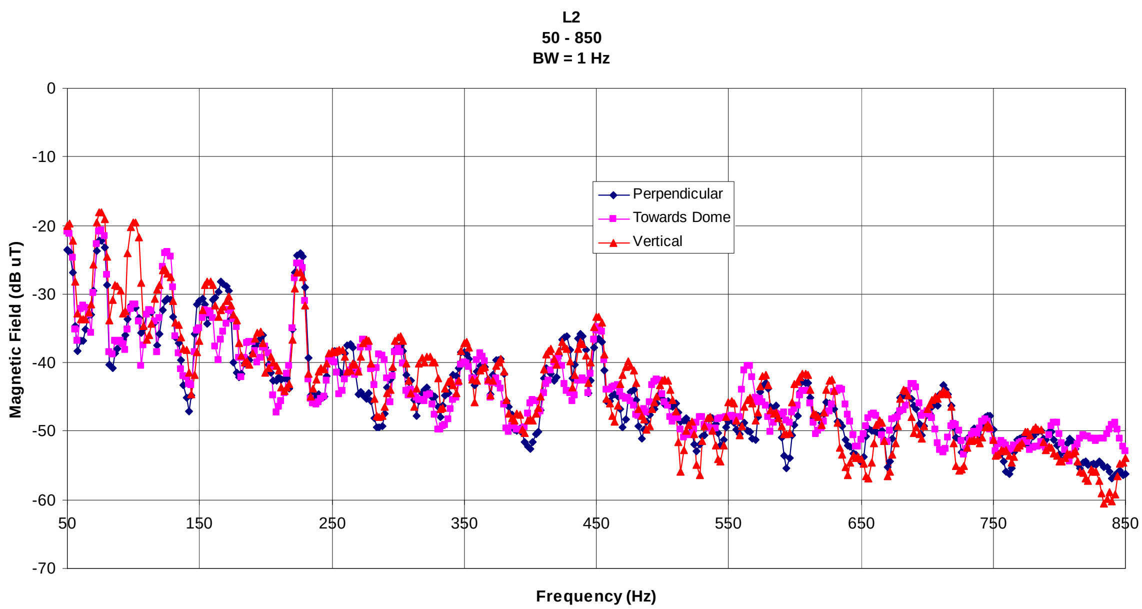

Figure F-8 Three axis data 50 – 850 Hz at L2

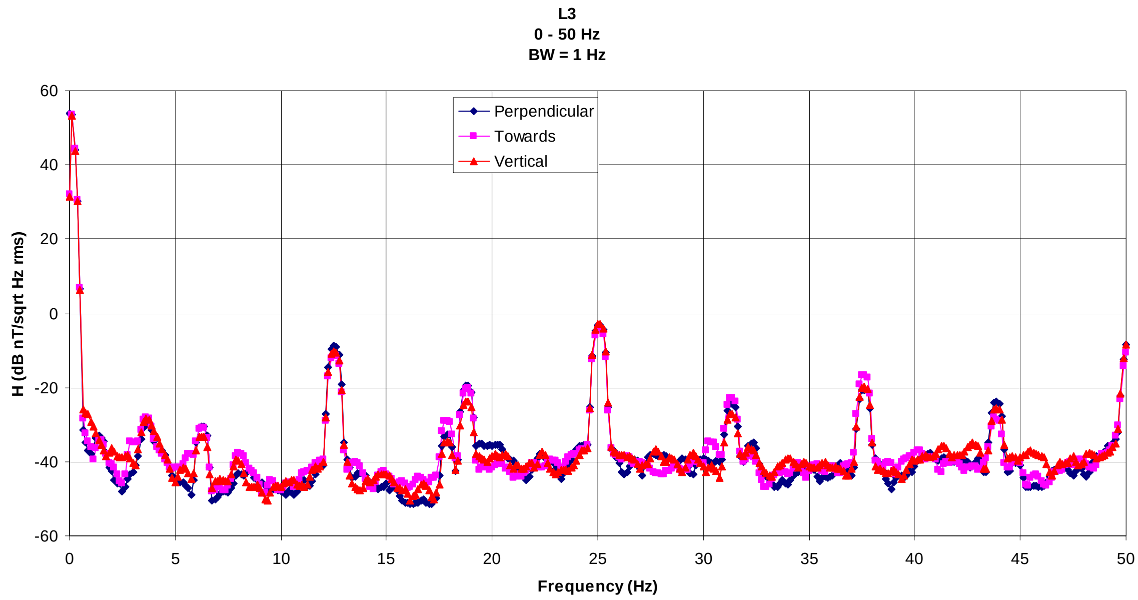

Figure F-9 Three axis data 0 – 50 Hz at L3

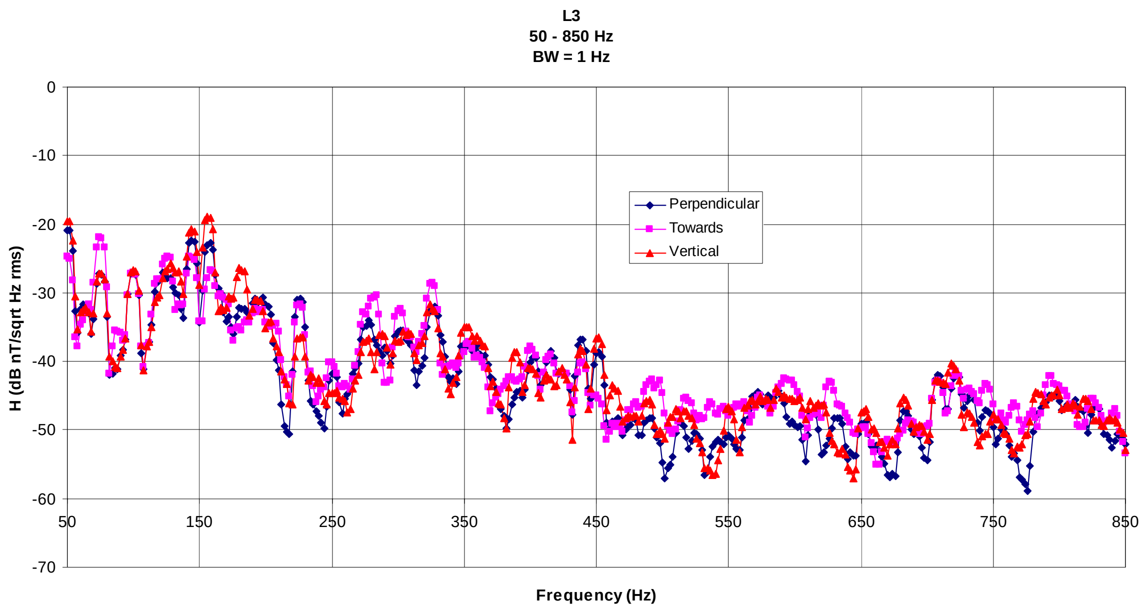

Figure F-10 Three axis data 50 – 850 Hz at L3

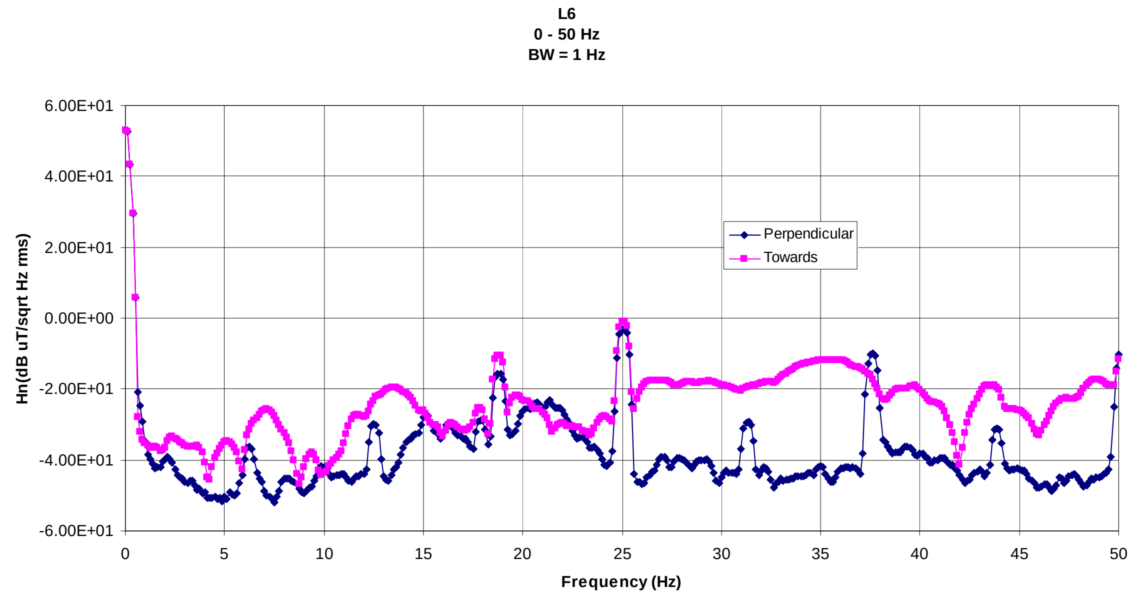

Figure F-11 Two axis data 0 – 50 Hz at L6

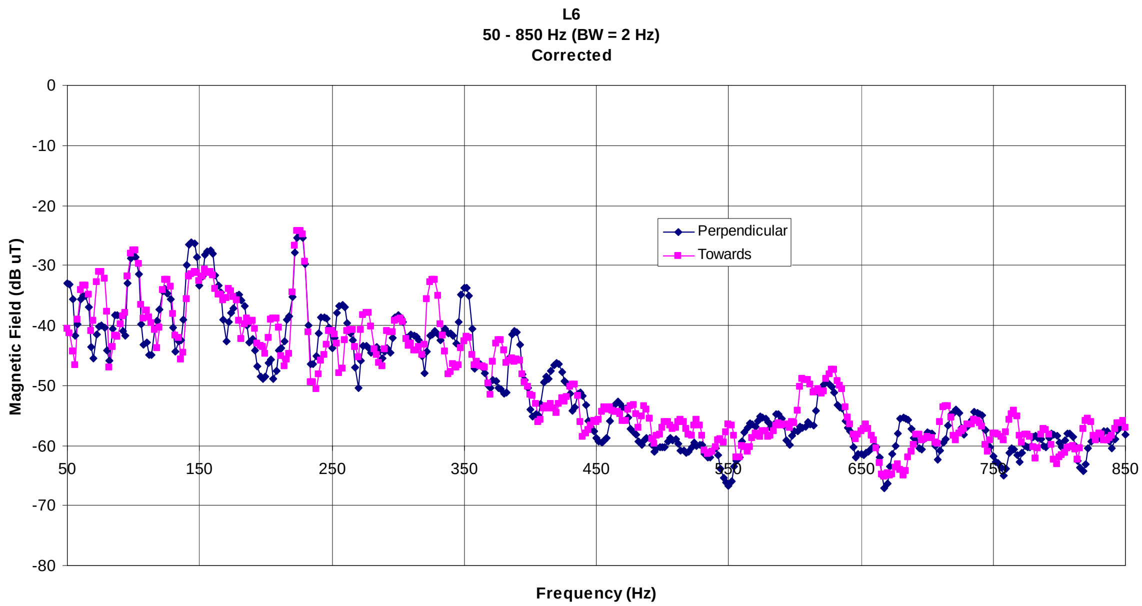

Figure F-12 Two axis data 50 – 850 Hz at L6

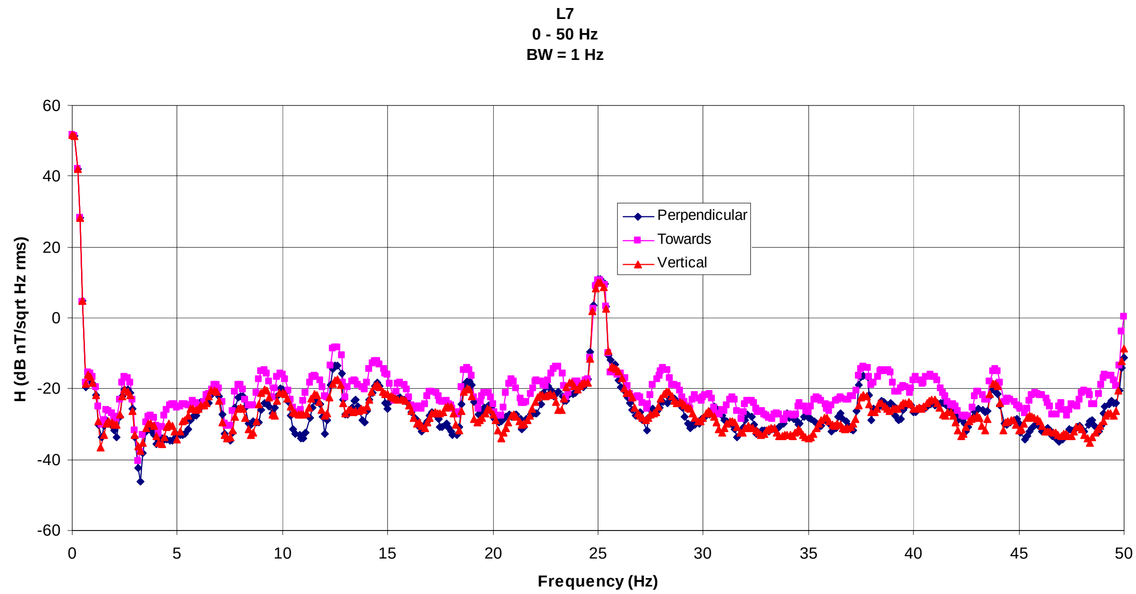

Figure F-13 Three axis data 0 – 50 Hz at L7

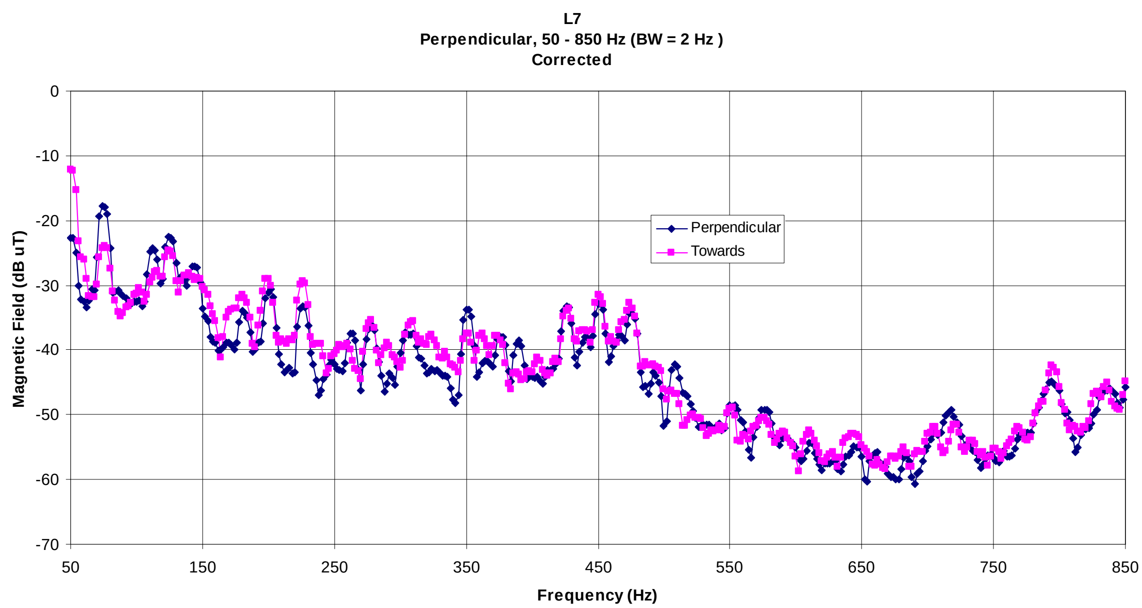

Figure F-14. Two axis data 50 – 850 Hz at L7

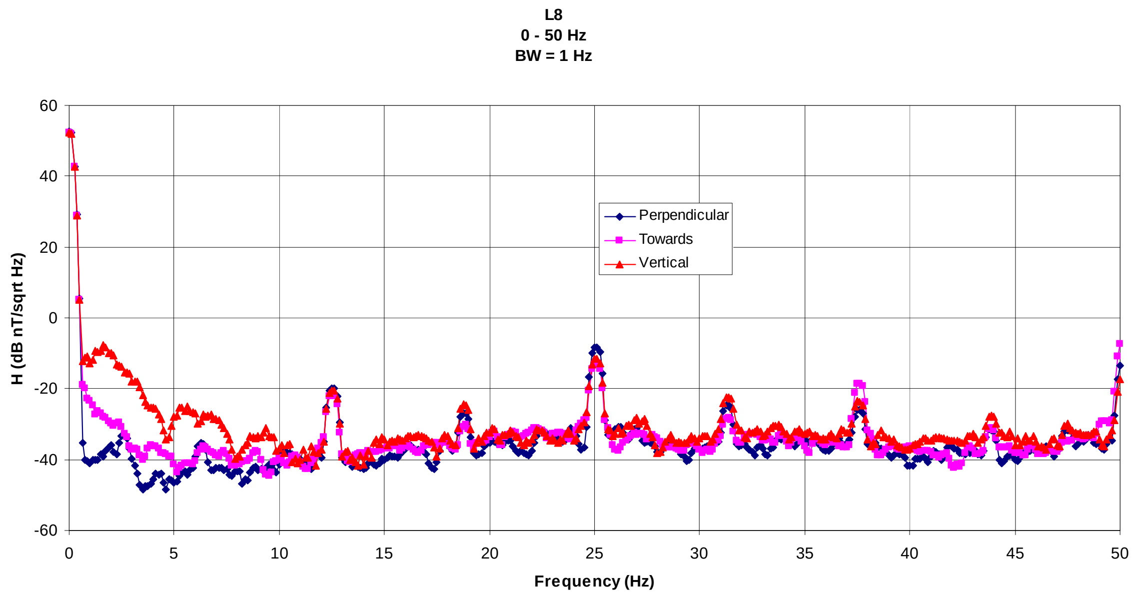

Figure F-15 Three axis data 0 – 50 Hz at L8

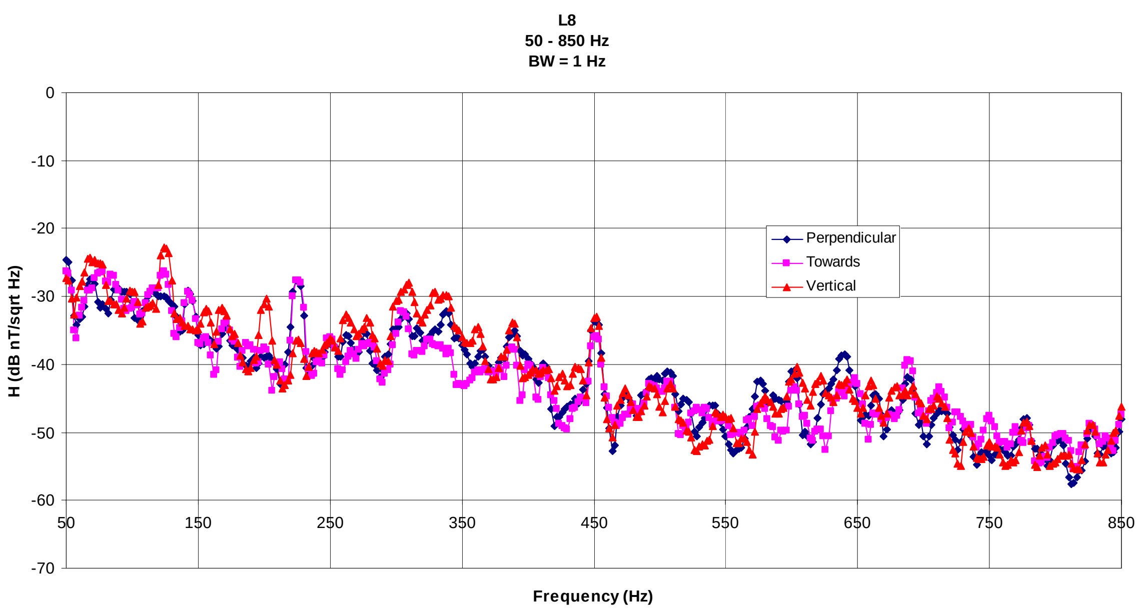

Figure F-16 Three axis data 50 – 850 Hz at L8

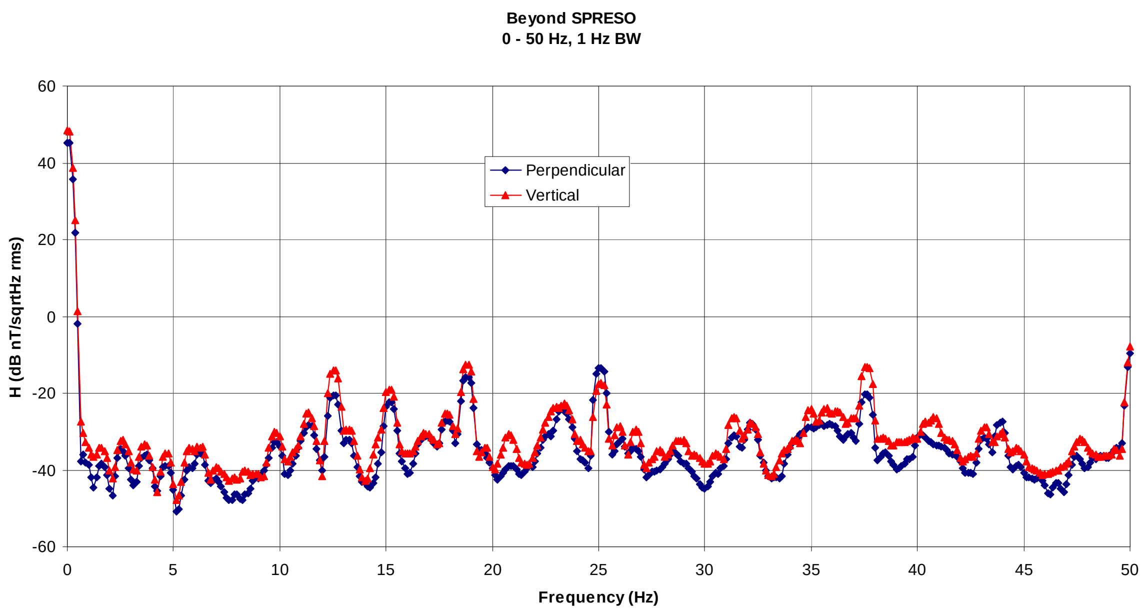

Figure F-17 Two axis data 0 – 50 Hz at Beyond SPRESO

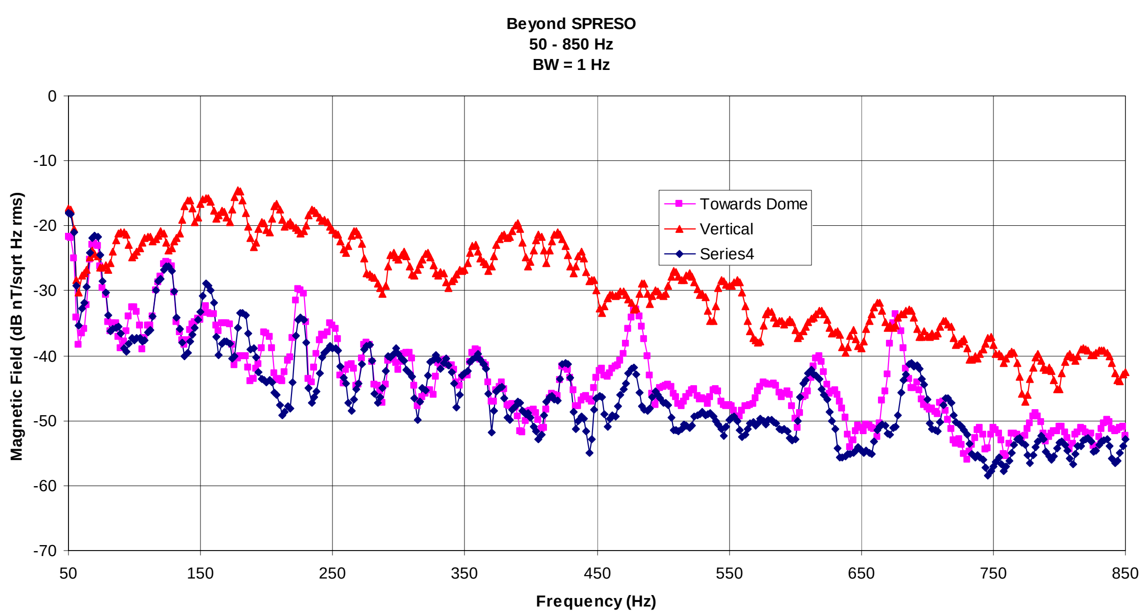

Figure F-18 Three axis data 50 – 850 Hz at Beyond SPRESO

F.7 Discussion

F.7.1 0 – 50 Hz Data

F.7.1.1 The inverter was not used for the data taken at MAPO. The 0 – 50 Hz data in Figure F-3 show little in the way of features. The data for all three axes are similar, and the noise floor falls between the levels of -30 to -45 dB nT/√Hz .

F.7.1.2 The 0 – 50 Hz data at all sites other than MAPO contain many spectral lines. The most notable of these lines are at 12.5, 18.9, 25.1, 31.5, 37.6, 44, and 50 Hz. They are approximately the same strength in all of the plots. The strongest of these is at 25 Hz and 50 Hz. The source of these lines could be either the inverter or the Pisten Bully, which was running at a distance of 150' away from the magnetometer. The Pisten Bully was running at MAPO, but the inverter was not used, therefore the lines are attributed to the inverter.

F.7.1.3 The background noise level (noise floor) varies at the various sites. For example, at L1, the noise floor varies between -25 and -35 dB nT/√Hz. While at L8 the noise floor is lower, being nearly constant at between -40 to -50 dB nT/√Hz. The noise floor at Beyond SPRESO, the site farthest from the main station, was lower at -40 to -50 dB nT/√Hz. The noise floor in this frequency range tends to be lower at greater distances from the station, consistent with expectations.

F.7.1.4 There are some other interesting features in the 0 – 50 Hz data. For example, at L8, there was considerable energy at 0 – 7 Hz that could correspond to magnetospheric disturbances. Also, note that the noise floor in the perpendicular data taken at L6 is much higher and covers up many of the lines.

F.7.2 50 – 850 Hz Data

F.7.2.1 The 50 – 850 Hz data taken at MAPO are shown in Figure F-4. These data show characteristics that would be expected for good magnetometer data. First, the 60 Hz line and harmonics is evident in both horizontal data sets, but is stronger in the "Perpendicular" set, which corresponds to the direction of maximum response towards the main station and power plant. Note that the level of the vertical data is generally greater than that for the two horizontal data sets and does not contain the 60 Hz and harmonics lines. The noise floor is around -30 dB nT/√Hz at 50 Hz and falls off to about -55 to -60 dB nT/√Hz at 850 Hz.

F.7.2.2 At L1, the 50 - 850 Hz data (Figure F-6) exhibit the 50 Hz and a few harmonics which are attributed to the inverter. The 60 Hz line and a few harmonics are present as would be expected, but they are weak. In addition, there are stronger lines of 76 Hz and harmonics out to the 11th. These could also be due to the inverter, since they were not present in the MAPO data. The noise floor falls off similarly to the MAPO data.

F.7.2.3 The other 50 – 850 Hz data sets taken with the inverter are similar to L1, although in most of them, the 50 and 76 Hz signals and the harmonics obscure the 60 Hz signals. The strong inverter signal seems inconsistent with the magnetometer pickup being 150 feet away from the inverter and may be an indication of electric field pickup on the cable. The noise floor at the lower end of the frequency range tends to be lower with greater distance from the station, consistent with expectations. However, the noise floor at the upper end of the band is nearly constant at about -55 dB nT/√Hz. The vertical signal at Beyond

SPRESO was considerably higher than the other signals, and the noise obscures all of the spectral lines.

F.8 Attempts to Determine Data Validity

F.8.1 Broken Cable Measurements

F.8.1.1 Upon return to San Diego, the magnetometer was connected to a different spectrum analyzer and the noise floor data recorded. These measurements were taken for the configuration with the magnetometer + broken cable + extension cable (paragraph F.4.1) + amplifier, as well as with the amplifier with no cable and with the input both open circuited and terminated in 50 Ohms. These data are shown in Figure F-19. The noise floor with the amplifier input terminated was flat at -100 dBV/√Hz and is off scale.

F.8.1.2 This data has been compared to the MAPO raw data in Figure F-20. Note the MAPO data was the first set taken at the South Pole, and the inverter was not used there. The comparison in Figure F-20 has conflicting results, some indicating the probability of good data and some indicating probability of bad data. First, the levels in the 0 – 50 Hz band at MAPO are well below those measured with the broken cable at SPAWARSYSCEN San Diego. This is an indication of good data, although there could be local noise being picked up on the outside of the cable at SPAWARSYSCEN San Diego that would make this level higher. Secondly the 60 Hz lines show up in the MAPO data and they do not show up in the San Diego Data. This is an indication of good data, although again there is the possibility that the 60 Hz line at MAPO was picked up on the outside of the cable and that strong local noise at SSC-SD obscures this form of pickup. The fact that the noise floor falls off at approximately the same rate and nearly the same level for both data sets is an indication that the data may not be good, although this could be coincidence. The comparison to the other South Pole Data sets is similar.

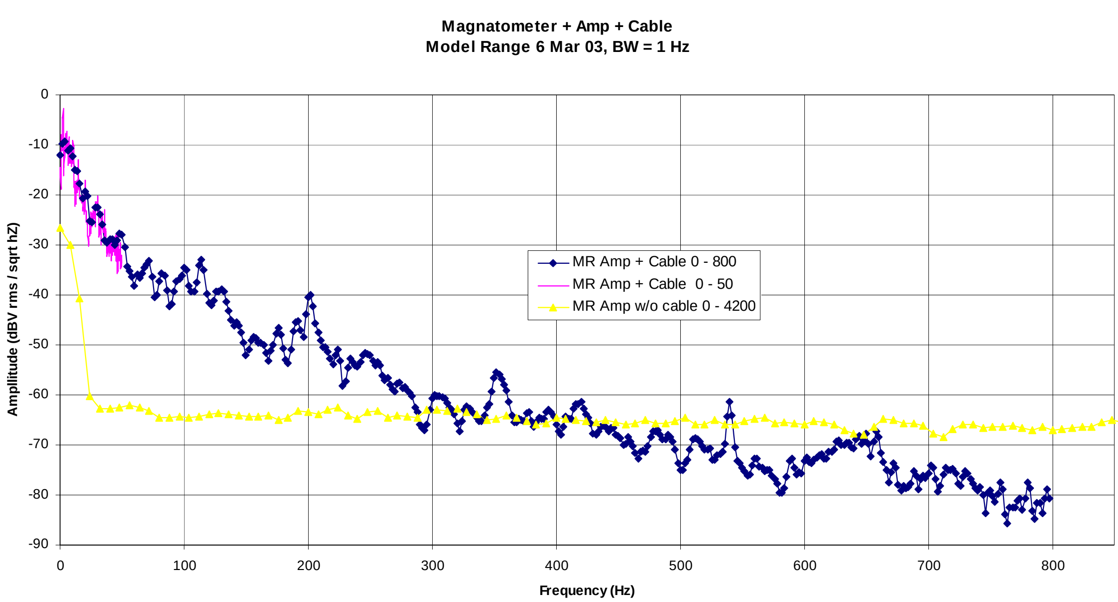

Figure F-19 Measured data with broken magnetometer cable

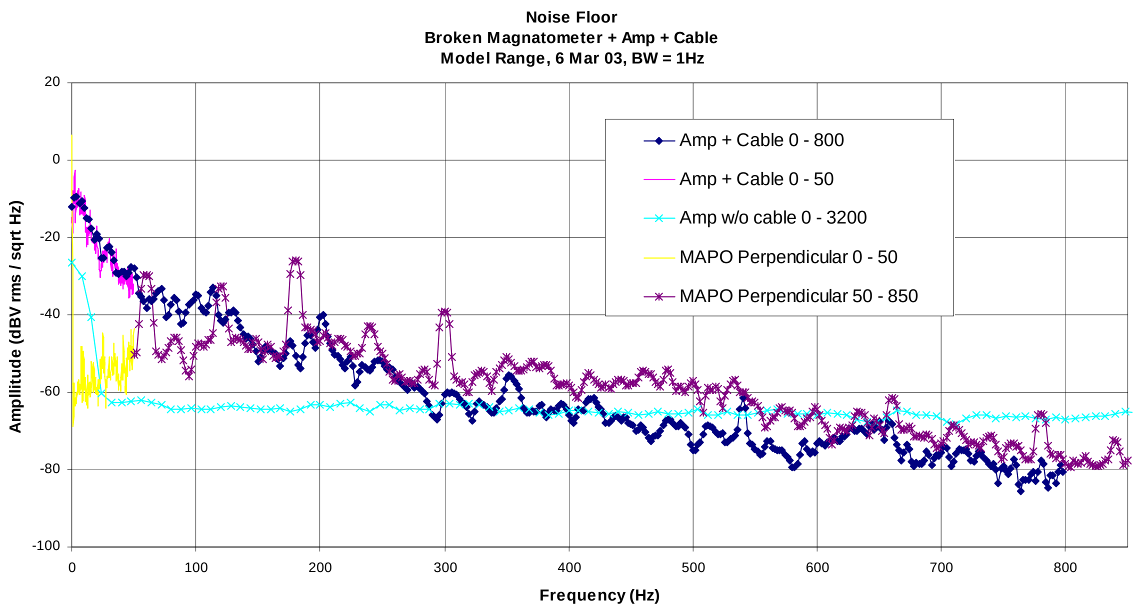

Figure F-20 Comparison of MAPO data to SSC-SD broken cable data.

F.8.2 Comparison to Stanford Data

F.8.2.1 The data measured by Stanford indicate very similar levels to those we measured at frequencies above 500 Hz. This is an indication that the data may be good but it is not conclusive.

F.8.3 Conclusion

F.8.3.1 This data cannot be validated with certainty, and therefore, it must be treated with suspicion. Even if the data is good, the presence of the 50 and 76 Hz lines, and their harmonics, which are attributed to the inverter, make the data above 50 Hz of limited utility.