EVLA Memo # 54

VLA Site Spectrum Survey: 1-18 GHz Results

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Abstract:

A survey of the 2-18 GHz VLA-local spectrum environment was performed during late 2002 and early 2003. The goals were to 1) determine the instantaneous dynamic range requirements for each of the 8 EVLA receiver bands, 2) document the regions of open spectrum for astronomical observations, and 3) provide a baseline of the current spectrum environment for future detection and mitigation efforts. Presented are 1) daily, calibrated SPFD grayscale plots of each 1 GHz wide band, 2) a spreadsheet log of each day's SPFD data with a list of top emitters, 3) a histogram plot of each day's SPFD data, and 4) a percent occupancy plot of each day's SPFD data.

1 Introduction

A significant factor in the operation of a radio telescope observatory is planning for, and coping with the possible radio frequency interference (RFI) that might interfere with the extremely sensitive observations. Observations are often scheduled around periods of diurnal or spectrally limited interference. In addition, the dynamic range headroom of the various stages of RF signal processing throughout the receiver must be designed to anticipate the power levels that may be encountered during a typical observation. The current VLA receiving system tuning ranges only include a small portion of the 1 to 50 GHz microwave spectrum. At the kick-off meeting for the EVLA engineering project, it was determined that an accurate, spectrum survey of the proposed EVLA microwave bands should be conducted, with the goal of quantitatively determining the absolute power level (in spectral power flux density (SPFD) units) of the top 5 RF emitters in each band. Initial attempts to acquire accurate spectral data were hampered by reliability and calibration problems with the "AilTech" electromagnetic compatibility (EMC) receivers slated for the monitoring task. The acquisition of more reliable Hewlett Packard, HP70000 spectrum analyzers in the summer of 2000 allowed the project to move forward more quickly.

2 Data description

During the fall and winter of 2002/2003, the VLA, radio frequency environmental monitoring system (RF-EMS) was used to log 1 GHz-wide spectral data from 2 GHz through 18 GHz. Additional, detailed 1 to 1.2 GHz and 1 to 2 GHz data monitoring sessions were also run. The data from these peak-hold, spectrum analyzer, display dump files were categorized and briefly described in a spreadsheet. The peak SPFD levels found in each 24-hour plot were included in the spreadsheet. Most of the spectrum analyzer display dump data files were captured in a mode where the 5 minute, peak hold data for a single, 1 GHz frequency band was logged, then the center frequency of the spectrum analyzer was shifted by 1 GHz. The resulting frequency multiplexed monitor data was broken down into the following sub-bands: 2-8 GHz multiplexed plots, 8-12 GHz multiplexed plots, and 12-18 GHz multiplexed plots, as required by the frequency coverage of the receiving antennae. Each day generated 288, 5-minute peak-hold data files. Due to the frequency multiplexing, the data for each sub-band had the following time resolution:

2-8 GHz: 2, 5-minute peak hold data files per hour per 1 GHz sub-band.
8-12 GHz: 3, 5-minute peak hold data files per hour per 1 GHz sub-band.
12-18 GHz: 2, 5-minute peak hold data files per hour per 1 GHz sub-band.

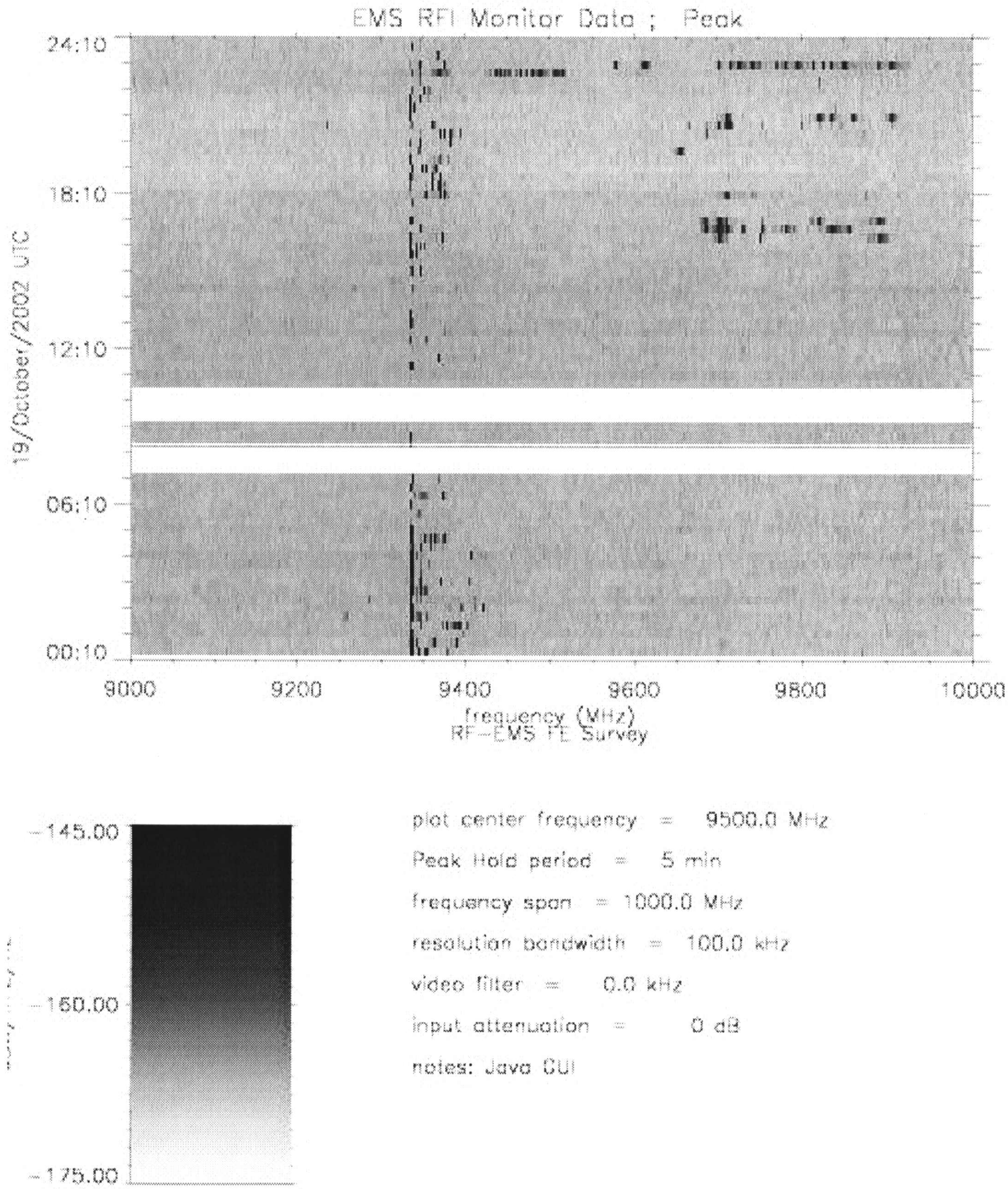
The spectrum analyzer resolution bandwidth (RBW) was fixed at 100 KHz for all plots, as a compromise between scanning speed and frequency resolution. This bandwidth allowed for a sweep speed of 300 mS per 1 GHz span, or 900 sweeps per 5-minute peak hold period. Each 5-minute, peak-hold, spectrum analyzer display dump consisted of 1024 data points, each representing the power detected at that frequency in the 100 KHz RBW around that frequency.

The raw, dBm data from the spectrum analyzer was converted to SPFD units using antenna and line characterization data, and using real-time, system noise temperature data. The RF-EMS front end includes a wide-band noise injection system that generates a data vector (1-dimensional matrix) of the system gains and losses verses frequency. The C-based, custom data acquisition program automatically switches-in the noise source, and generates the post-injection, system calibration data vector at the start of each 5 minute peak-hold cycle. It is the SPFD-calibrated data which is used for the plots and analysis of this report.

3 Grayscale plot description

A custom, IDL data analysis and plotting program ("plotgrayscale") was used to generate a 3-dimentional, 24-hour plot of each day's 5-minute peak-hold, SPFD scan files for presentation purposes, 1 plot for each 1 GHz sub-band per day. The horizontal axis of these "grayscale" plots represents the frequency of the data. The vertical axis of the grayscale plots represents the time ordinate. The intensity of the power (calibrated to SPFD units applied to the input of the monitoring antenna) at that frequency and time is represented as a grayscale level, with dark representing a higher power level. The dynamic range of the plots was selected to allow subtle changes in power levels to be discernable, while still covering the widest range of total signal strengths, from the noise level of the receiving system in that band, to the strongest signal expected. The plotting program allowed the data to be represented by a single byte, or 256 levels.

The plotting program that generated the 24-hour, grayscale plots for each 1 GHz sub-band was written to replicate each 5-minute peak-hold data file to fill-in the next 3 or 5, 5 minute time slots while the system was recording data for another sub-band in order to give the illusion of continuity in the grayscale plots. This fact accounts for the graininess of the plots. The following plot from October 19, 2002 shows a typical X-band grayscale plot:



The plots may be viewed on the NRAO web site at:

http://www.aoc.nrao.edu/vla/html/ems_plots.shtml

The SPFD plots for each frequency sub-band are stored in the "PFD" directory named with a frequency range that includes the starting frequency of that sub-band (e.g.: A plot for 9-10 GHz data would be stored in the "X-band" section link labeled: "X-band 8.6-9.6 GHz PFD plots"). Beneath each link is the directory with the individual postscript (.ps) files for each day. The plot filenames are listed according to the following convention: SAHP_gs_yyyymmdd.ps, where "SAHP" indicates that the data was recorded from a Hewlett Packard spectrum analyzer, "gs" indicates that it is a grayscale plot, and "yyyymmdd" encodes the date the plot represents.

4 Spread sheet log description

Each 24-hour, SPFD grayscale plot was manually viewed, and a brief, qualitative description of what was seen was recorded in the EXCEL spreadsheet mentioned above. The "all" sheet of the spreadsheet lists the days for which data had been recorded for each 1 GHz sub-band. If emitters could be seen in the grayscale plot, that date was entered in **BOLD** print. The date format is "yyyymmdd". The separate sub-band sheets include the same date column from the "all" sheet, then list the bearing of the antenna, the maximum SPFD detected, the frequency of the emitter, and a brief description of the signal characteristics. The data for column showing the maximum SPFD detected and its frequency was generated using a custom, data analysis program written in C ("peaksniffer2") which loaded-in the SPFD vs. frequency files for an entire day, and determined the maximum value.

The entire spreadsheet may be found stored on the NRAO server, "filehost" at:

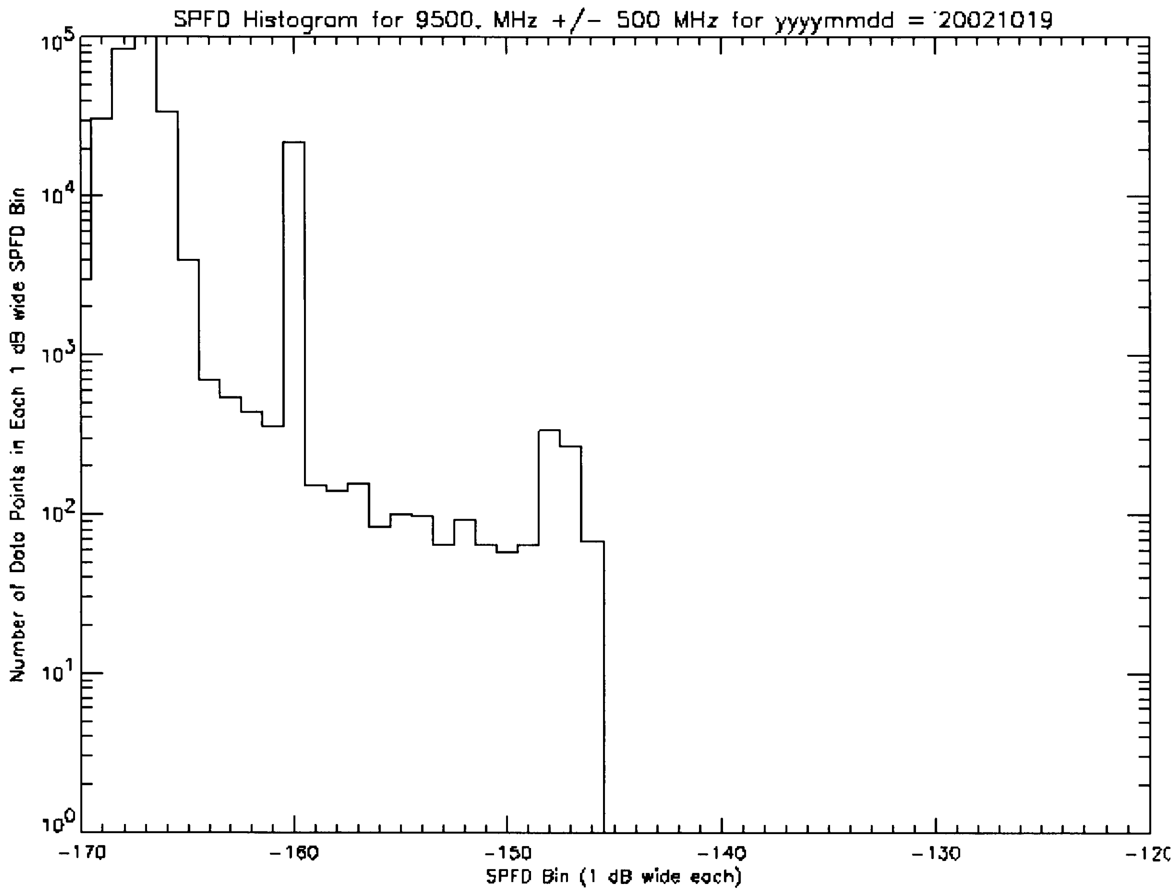
"/home/filehost/evla/techdocs/fe/RFI_survey/ems-survey4.xls".

Excerpts from that spreadsheet of particular interest are included in the body of this document, and the entire spreadsheet is included in appendix A.

5 Histogram plot description

For each 1 GHz sub-band, the SPFD, peak-hold data for an entire 24-hour period was processed using a custom IDL program ("printgsstats") to generate a histogram plot, showing the distribution of the recorded power levels. These postscript plots may be viewed on the same NRAO web page as the grayscale plots described above.

The horizontal axis of these histogram plots represents the SPFD power level. The vertical axis represents the number of SPFD data points in a 1 dB bin around that power level that occurred during that 24-hour period. Since none of the sub-bands on any day logged had a significant percentage of usage, the peak of each SPFD histogram may be assumed to be the background, or noise level of the receiving system. Power level bins 3 or more dB to the right of the peak (representing higher power levels) were empirically found to represent actual emitters. The broader the high-power side of the curve is, the greater the number of actual emitters in that 1 GHz sub-band in that 24 hour period. The bins furthest to the right represent the highest SPFD levels recorded in that 1 GHz sub-band in that 24-hour period. By reviewing a number of days of these plots, a statistically accurate measure of the instantaneous dynamic range requirements of the EVLA receiving system that includes that 1 GHz sub-band may be calculated. The following plot from October 19, 2002 shows a typical X-band histogram plot:



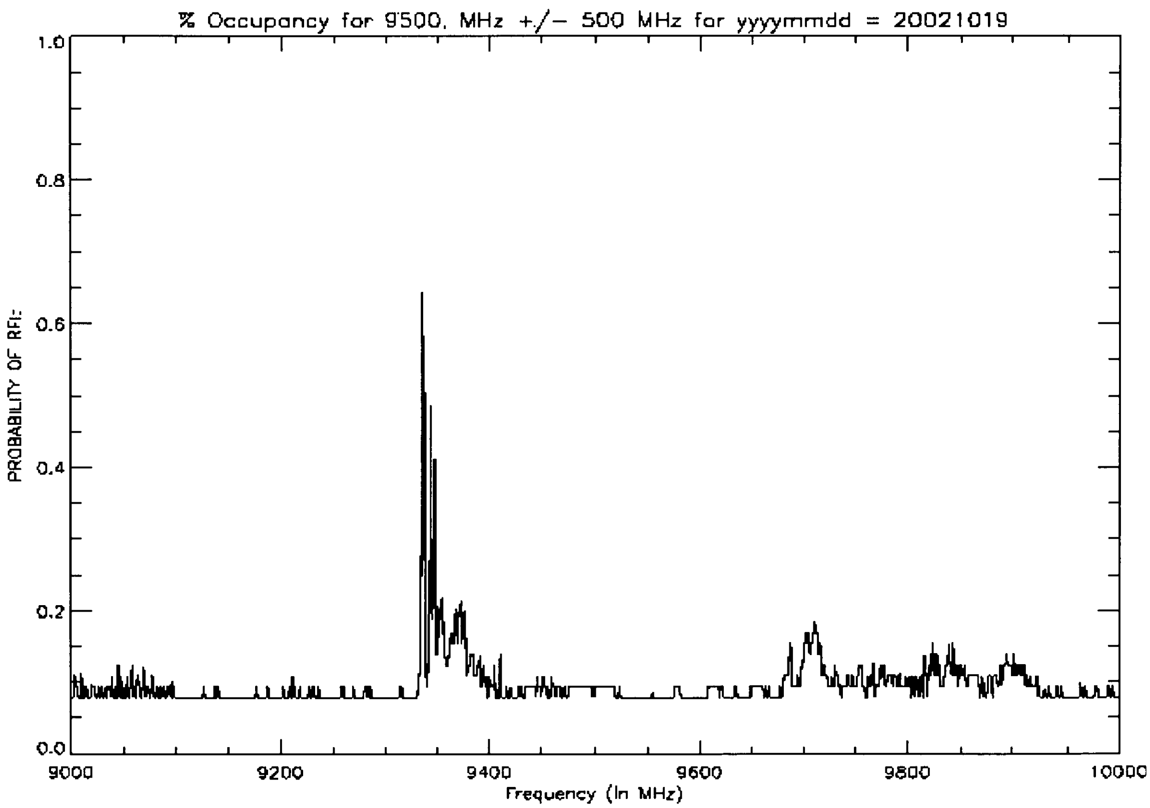
The histogram plot filenames are listed according to the following convention: histo_fffff_yyyymmdd.ps, where "histo" indicates that the plot is a SPFD histogram plot, "fffff" encodes the center frequency of that 1 GHz sub-band, and "yyyymmdd" encodes the date the plot represents.

6 Percent occupancy plot description

For each 1 GHz sub-band, the SPFD, peak-hold data for an entire 24-hour period was processed using a custom IDL program ("plotprob2") to generate a probability plot, showing the percent of the time that that 100 KHz-wide frequency bin was in-use. These postscript plots may be viewed on the same NRAO web page as the grayscale and histogram plots described above.

Because the noise level of the system was not constant across the entire 1 GHz span, the IDL code divided the span into 10 sub-spans, each approximately 100 MHz wide. A histogram was performed on each of these sub-spans in order to determine the local noise level. Thresholding of the SPFD data in each sub-span at a power level 3 dB above the frequency-local noise level allowed the detection of most of the real emitters, while eliminating most of the noise. Summing the number of hits above the threshold, then dividing by the total number of files for that day generated the data for the percent occupancy plots shown.

The horizontal axis of these histogram plots represents the frequency bin, or channel. The vertical axis represents the percent of time that that 100 KHz-wide frequency bin was in-use during that 24-hour period. The following plot from October 19, 2002 shows a typical X-band probability plot:



The percent occupancy plot filenames are listed according to the following convention: prob_fffff_yyyymmdd.ps, where "prob" indicates that the plot is a SPFD probability plot, "fffff" encodes the center frequency of that 1 GHz sub-band, and "yyyymmdd" encodes the date the plot represents.

7 Data Results Summary

7.1 L-band Results

From the 1-2 GHz spreadsheet shown below, and the grayscale, histogram, and probability plots located at
http://www.aoc.nrao.edu/vla/interference/ems_plots/pfd/lband_high/,
we can see that there were interfering signals detected in this band on every day of the survey, with the strongest signals typically in the 1 - 1.2 GHz Distance Measuring Equipment (DME) avionics navigation band. The histogram plots for the 1 – 2 GHz band typically show the strongest emitters in the –140 dBW/m^2/Hz range, which correspond to the results of the peak-search program results entered into the spreadsheet. The probability plots indicate that 100 KHz channel occupancy for these strongest of signals approaches 100% in the DME, Iridium, and United States Forest Service (USFS) microwave links regions of the L-band spectrum.

1-2 GHz	Bearing	Max SPFD	@ MHz	Comments
020807	OMNI	-140.51	1135	"Strong DME stuff 1000-1150, esp. @ 1030 & 1090 MHz. GPS L2 @ 1228, radars 1250-1350, Iridium @ 1621-1627, USFS uWave links > 1690."
020806	OMNI	-140.15	1146	Same as 20020807 + strong 1-2 noise at 1830 UTC--? Due to channelized activity @ 1800-1900 MHz at that time?
020805	OMNI	-137.14	1621	Same as 20020807
020804	OMNI	-140.42	1146	Same as 20020807
020803	OMNI	-140.35	1140	Same as 20020807
020802	OMNI	-140.36	1085	Same as 20020807
020801	OMNI	-140.09	1217	"Same as 20020807 + GPS L2 jamming @ 1800 & 1900 UTC? Note also channelized activity at 2230 & 2300, from 1800-1900 MHz."
020731	OMNI	-139.96	1135	Same as 20020807
020730	OMNI	-140.16	1147	Same as 20020807 + strong broadband noise cent @ 1200 MHz from 1500-1600 UTC.
020729	OMNI	-140.03	1141	Same as 20020807
020728	OMNI	-140.32	1146	Same as 20020807
020727	OMNI	-137.89	1632	Same as 20020807

1-2 GHz Spreadsheet: 2002 – 2003 EVLA RFI Survey

Most of these sources are fairly well known from previous surveys. (See the L-band overlay plot from 1998 at
http://www.aoc.nrao.edu/vla/interference/lband/CurrentOverlay.jpg,
and the L-band section of the "VLA upgrade RFI Survey Update" located at
http://www.aoc.nrao.edu/vla/html/rfi.shtml.)

In addition, the DME region was studied and reported on in detail in the fall 2001 RF-EMS survey—See VLA/VLBA Interference Memoranda #23. The diurnal nature of the aircraft traffic in the central New Mexico area can be clearly seen in the 1 – 1.2 GHz region of the grayscale plots, where the DME transponder traffic becomes very light during the late evening to early morning hours, local time. Although regional USFS microwave link RFI has been studied and reported on frequently in the past at the VLA (see VLA Test Memoranda #162), the current survey includes the lightly studied 1750 – 2000 MHz upper L-band region, which shows even stronger RFI sources than those in the 1710 – 1750 MHz region seen in previous surveys and the daily "W8 monitor" grayscale plots.

7.2 S-band Results

The plots and spreadsheet pages for the 2 – 4 GHz region (ELVA S-band) show a significant reduction in the number of signals, as compared to those seen at L-band. From the spreadsheet excerpt shown below, it can be seen that the regions of worst RFI correspond to the Digital Audio Radio Satellite (DARS) broadcast band of 2320 – 2345 MHz, the local "wireless cable" television and broadband wireless services (MDDS & IFTS) at 2550 – 2600 MHz, and the NEXTRAD and other WSR-88 Doppler radars from Albuquerque, Cannon AFB, and WSMR/Holloman AFB found from 2700 – 2800 MHz.

Peak SPFD values in the –133 dBW/m^2/Hz range were recorded for the strongest of the radar signals at 2710 and 2742 MHz, as well as the occasional broadband noise signals (or stepped CW signals) recorded on January 3rd and 5th. Most histogram plots show peak SPFD values generally in the –135 dBW/m^2/Hz range. An interesting phenomena was recorded on January 6th, when what appears to be a CW signal sweeping through the 60 MHz region from 2710 – 2770 MHz continued for 6 hours from 1600 – 2200 UTC. The source of this swept CW is still to be determined. Similar swept CW signatures were recorded in other bands, especially the 4 – 5 GHz band, which averaged 5 or more "hits" per day, some very strong. However, these swept CW tracks would usually not occur for more than a single 5-minute peak hold file continuously.

2-3 GHz	Bearing	Max SPFD	@ MHz	Comments
030112	OMNI	-135.72	2710	20030109 notes + Moderate to strong stepped CWs as wide as 400 MHz throughout the day from 2350-2900 MHz + V-strong 10 Mhz-wide burst @ 2460 MHz throughout day.
030111	OMNI	-135.29	2709	20030109 notes + Moderate to strong stepped CWs as wide as 400 MHz throughout the day from 2700-2900 MHz + V-strong 10 Mhz-wide burst @ 2460 MHz throughout day.
030110	OMNI	-134.92	2709	20030109 notes + Moderate to strong stepped CWs as wide as 400 MHz throughout the day from 2700-2900 MHz + V-strong 10 Mhz-wide burst @ 2460 MHz @ 1500 UTC.
030109	OMNI	-134.07	2742	DAS moderate and continuous 2320-2345 MHz. Continuous 3 MHz wide strong sig at 2710 MHz. Intermittent strong 1 MHz wide RFI @ 2810 MHz.+ 20030108 notes.
030108	OMNI	-133.72	2742	20030109 notes + Moderate to strong stepped CWs as wide as 400 MHz throughout the day from 2500-3000 MHz
030107	OMNI	-134.99	2709	Same
030106	OMNI	-133.74	2742	Same except stepped CWs only from 2700-2800 MHz almost continuous from 1630-2300 UTC
030105	OMNI	-133.64	2454	"Same as 20020109/20030108 except only 1 150 MHz span of moderate stepped CW at 0800, + v-strong 50 MHz wide cent at 2460 @ 2000."
030104	OMNI	-134.38	2742	"Same as 20020109/20030108 except only 1 150 MHz span of moderate stepped CW at 0800, + v-strong 10 MHz wide cent at 2455 @ 0030."
030103	OMNI	-130.34	2464	Same as 20020109/20030108
				etc

2-3 GHz Spreadsheet: 2002 – 2003 EVLA RFI Survey

The typical probability plot shows greater than 50% occupancy of any 100 KHz spectrum analyzer RBW channel only for those 3 or 4, strongest emitters mentioned earlier. Other than the DARS, MMDS, and NEXTRAD signals, the 2 – 3 GHz band averages less than 10% occupancy.

The 3 – 4 GHz region of S-band was even quieter most of the time, with many days completely clear, down to the noise level of the RF-EMS receiving system (around –164 dBW/m^/Hz, judging from the peak of the histogram plots). However, a number of days did have multiple RFI hits of a very strong (-118 dBW/m^2/Hz) CW sweeping over 5 to 15 MHz of the band in the 3200 – 3400 MHz region. The spreadsheet excerpt below shows a few such hits on January 3rd and 9th. The hits were sporadic in time, but generally occurring during from noon to mid-afternoon local time. The grayscale plot for the 6th of January shows another interesting case of a CW signal sweeping over 100 MHz of the band for a period of 6.5 hours, centered at 3650 MHz. This may be a case of an L6 1st LO module in one of the nearby antennas losing lock, and "jittering" around a central lock frequency for sometime before the next set-up moved it to another lock frequency.

3-4 GHz	Bearing	Max SPFD	@ MHz	Comments
030112	OMNI	-159.28	3335	
030111	OMNI	-159.46	3309	
030110	OMNI	-159.14	3439	
030109	OMNI	-119.95	3349	Weak swept CW from 3000-3350 MHz at 1600. Very strong 10 - 50 MHz wide multiple RFI hits centered at 3350 throughout the local afternoon.
030108	OMNI	-138.08	3381	1 Strong 10 MHz wide hit at 3380 MHz at 0115 UTC.
030107	OMNI	-118.89	3221	"Multiple strong to very strong 10-20 MHz RFI hits at 3225 MHz, late morning through afternoon local time."
030106	OMNI	-118.68	3351	"2 strong to very strong 10-20 Mhz wide RFI hits at 3225 MHz, late morning through afternoon local time. Swept CW 100 MHz wide cent at 3650 all afternoon."
030105	OMNI			
030104	OMNI	-118.47	3251	Strong Broadband RFI from 3200 to 3300 at 1920 UTC
030103	OMNI	-117.95	3380	"Strong to very strong swept CW RFI, 10-20 MHz wide in 3200-3400 MHz region from 1600-2100 UTC."
				Etc...

3-4 GHz Spreadsheet: 2002 – 2003 EVLA RFI Survey

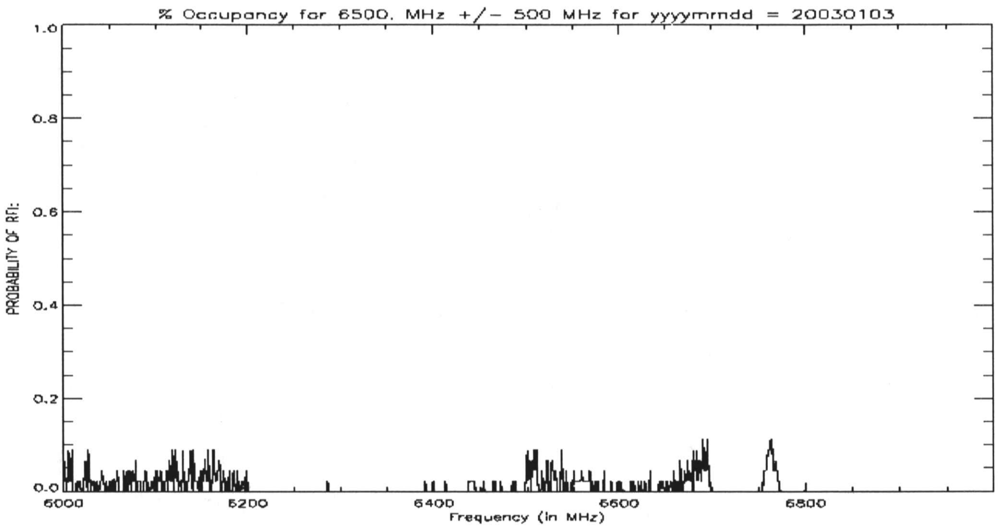
7.3 C-band Results

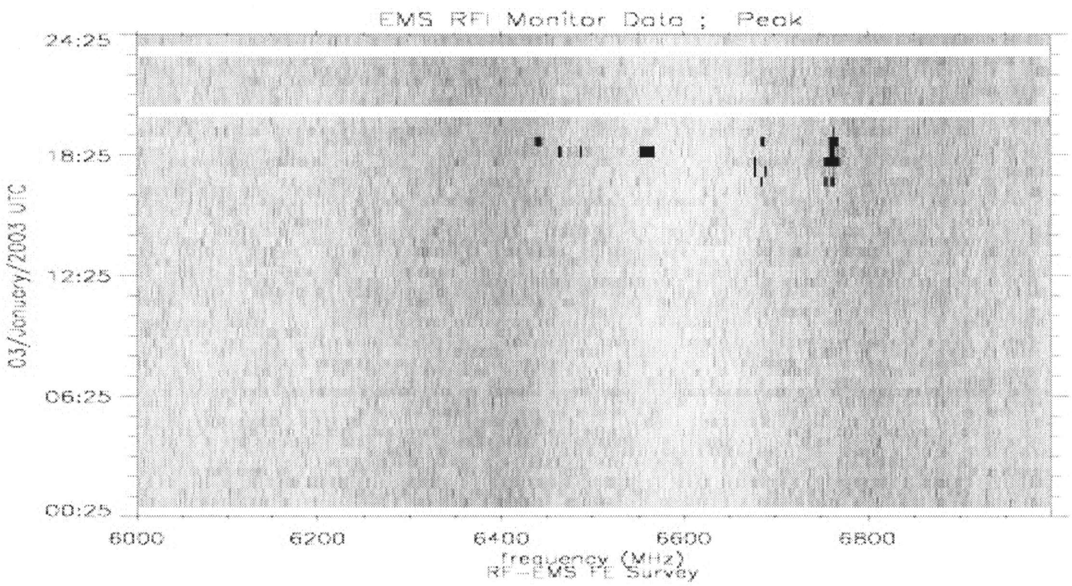
The most interesting phenomena seen in the EVLA 4 – 8 GHz band was the frequent (as often as 14 times per day) swept CW signal referenced in the S-band chapter of this report. The RFI was seen most every day of the survey, with the exception of December 30th, which only recorded a few, weak hits. It was thought to be another case of VLA antenna, LO set-up and lock problems, however, the grayscale plot for January 1st shows a significant number of such hits, even though the array was shut-down for New year's day. The spreadsheet excerpt shown below, as well as a number of histogram plots indicate peak SPFD levels in the –145 dBW/m^2/Hz range, with the strongest signal recorded on January 11th.

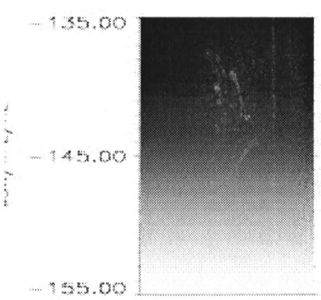
4-5 GHz	Bearing	Max SPFD	@ MHz	Comments
030111	OMNI	-140.65	4325	Weak to Moderate Broadband RFI from 4250 to 4350 throughout the day. Sharp fq edges: appears to be swept CW.
030110	OMNI	-153.67	4326	Weak to Moderate Broadband RFI from 4250 to 4350 throughout the day. Sharp fq edges: appears to be swept CW.
030109	OMNI	-152.72	4315	Weak to Moderate Broadband RFI from 4250 to 4350 throughout the day. Sharp fq edges: appears to be swept CW.
030108	OMNI	-148.30	4358	Moderate to Strong Broadband RFI from 4250 to 4400 MHz throughout the day--Esp strong @ 0515
030107	OMNI	-152.80	4321	Weak to Moderate Broadband RFI from 4250 to 4350 throughout the day.
030106	OMNI	-144.92	4900	Mod to strong Broadband RFI from 4250 to 4400 MHz throughout the day-- Esp strong @ 0545. Much broadband RFI 4500-4650 from 1600 - 2200 UTC.
030105	OMNI	-151.11	4325	Moderate to strong Broadband RFI from 4250 to 4350 throughout the day.
030104	OMNI	-147.09	4317	Moderate to strong Broadband RFI from 4250 to 4350 throughout the day.
030103	OMNI	-148.86	4278	Weak to strong Broadband RFI from 4250 to 4350 throughout the day.
030102	OMNI	-152.33	4341	Weak to strong Broadband RFI from 4250 to 4350 throughout the day.
030101	OMNI	-145.48	4324	Weak to strong Broadband RFI from 4250 to 4350 throughout the day.
021231	OMNI	-147.41	4000	Strong to very strong Broadband RFI from as low as 4000 to as high as 4350MHz at different times all day long
021230	OMNI	-154.46	4200	Weak to Moderate Broadband RFI from 4200 to 4350 from 0130 to 0600 UTC
				Etc...

4-5 GHz Spreadsheet: 2002 – 2003 EVLA RFI Survey

The 5-8 GHz region of the EVLA C-band appeared nearly devoid of any RFI, with only the occasional "walk-through" of a swept CW signal visible in the 6 – 7 GHz region of the grayscale plots. The results of the "peak search" program entered into the spreadsheet show that some of these hits were quite strong, however, with a peak SPFD level as high as –103 dBW/m^2Hz recorded on January 3rd. The signals were extremely transitory, however, and would not pose a significant obstacle to EVLA observing. Notice in the probability plot for that day shown below, how low the percent occupancy was. Even in those 100 KHz frequency bins that included the swept CW (as can be identified in the grayscale plot for the same day) the probability plot shows the channels occupied only around 10% of the time.







plot center frequency = 6500.0 MHz
Peak Hold period = 5 min
frequency span = 1000.0 MHz
resolution bandwidth = 100.0 kHz
video filter = 0.0 kHz
input attenuation = 0 dB
notes: Java GUI

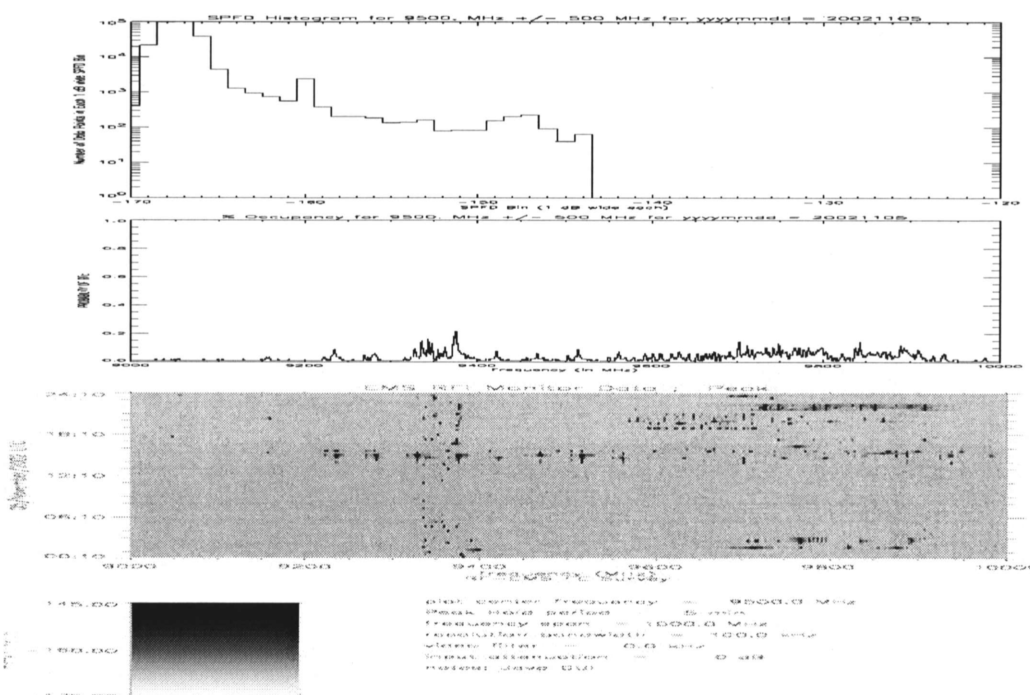
6-7 GHz plots for Jan 3, 2003

7.4 X-band Results

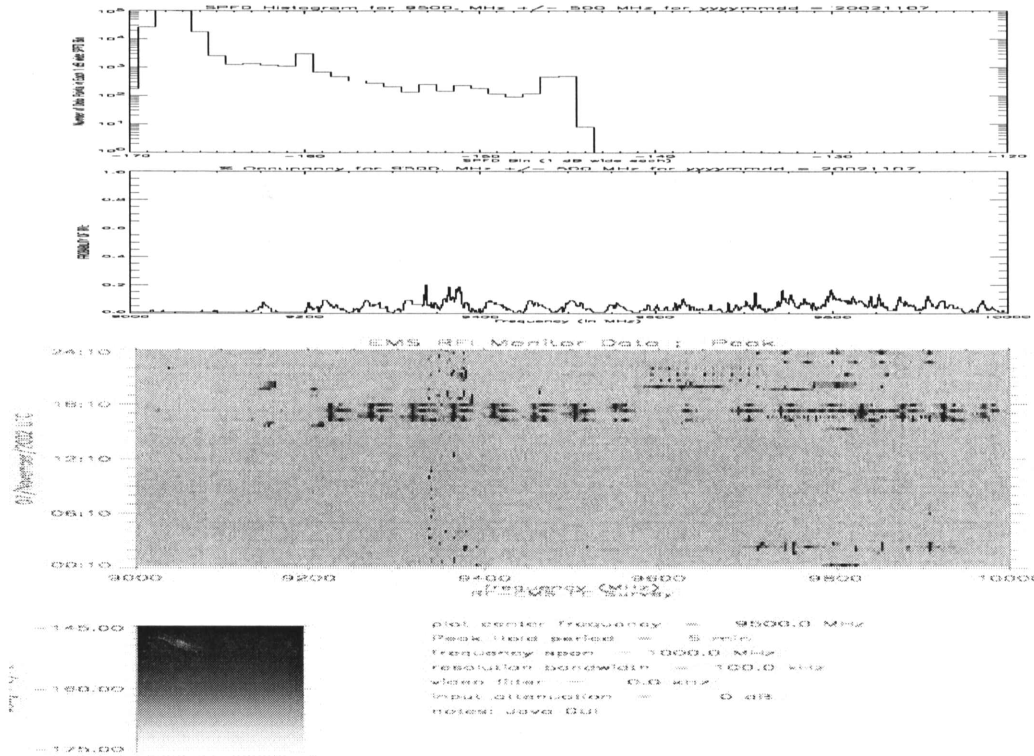
In this band, as with Ku-band, the RF-EMS system antenna was a standard gain horn, which was rotated by the 20 - 40 degree, 3 dB beamwidth every few days. The spreadsheet shows the approximate bearing of the antenna for each day. The gain of the antenna horn varies from 13 dBi at 8 GHz, to 17 dBi at 12 GHz. The correction factors used to compute the SPFD values reported from the recorded dBm power values assume that all signals were in the primary beam (maximum gain) of the antenna. Since the direction to the source of any particular emitter is unknown, actual SPFD values could vary from the calculated (reported) value to as much as 17 dB stronger, assuming a signal actually came-in a 0 dBi sidelobe.

The EVLA X-band (8 – 12 GHz) region of spectrum was also quiet compared to L or S band, with the exception of the 1 GHz segment from 9 – 10 GHz. In that upper section of X-band, commercial and military radars show the same diurnal pattern seen in the DME section of L-band, with activity heaviest during the mid-day and early evening hours. SPFD values for this 1 GHz segment of the band peak around –145 dBW/m^2/Hz for the calibrated data from October 09 – November 12. (Prior plots using the Omni antenna are uncalibrated in this frequency range, and should not be used quantitatively.)

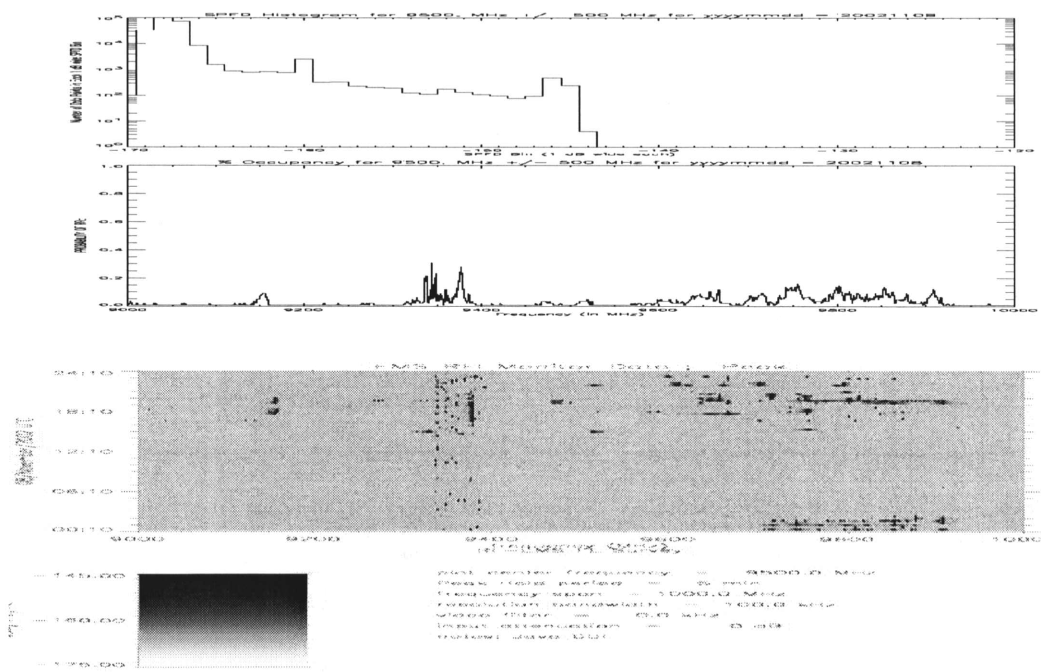
The following histogram plots for a number of representative days show occupancy rates in the under 20% range for the bins of heaviest usage near 9375 MHz.



9-10 GHz plots for Nov 5, 2002

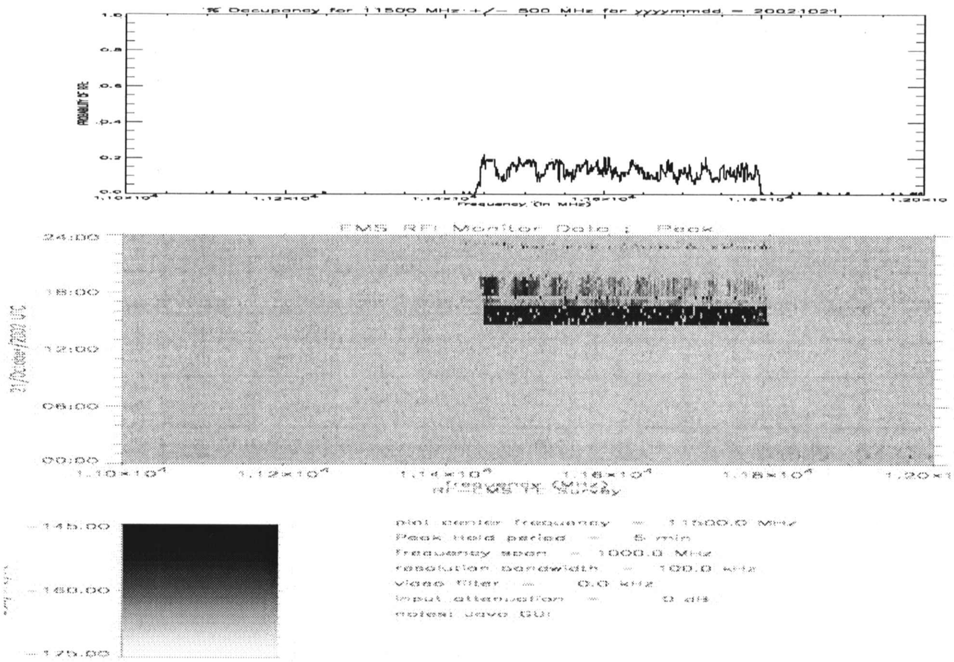


9-10 GHz plots for Nov 7, 2002

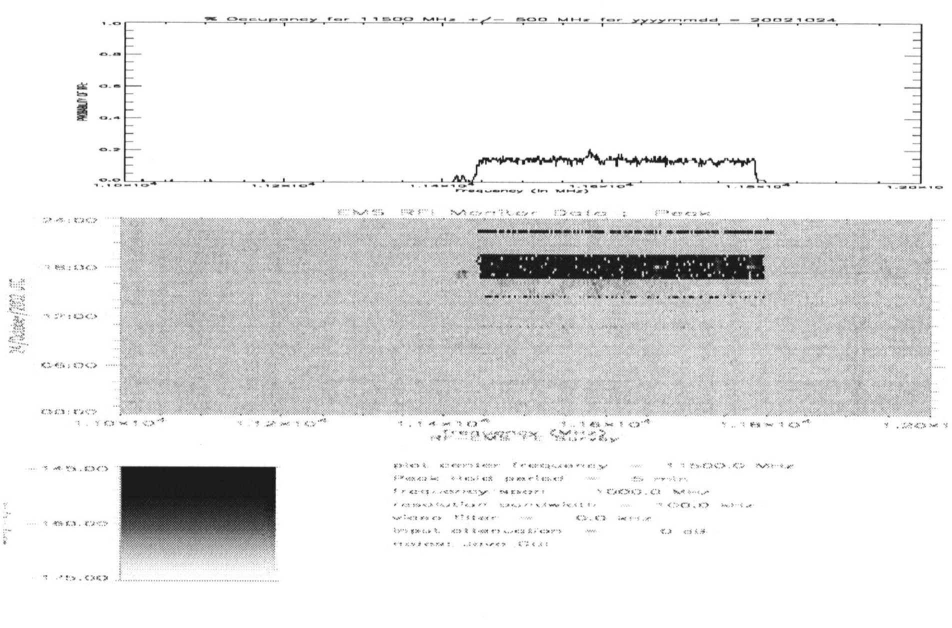


9-10 GHz plots for Nov 8, 2002

The grayscale plots for October 21st and 24th reproduced below show a very interesting case of a strong CW signal sweeping over a 400 MHz-wide region throughout most of the local mid-day hours. Although this same effect is seen on a number of different day: in October and November, the RFI was usually of much shorter duration, generally occupying only a single time bin (5 minutes).



11-12 GHz plots for Oct 21, 2002



11-12 GHz plots for Oct 24, 2002

7.5 Ku-band Results

In this band, as with X-band, the RF-EMS system antenna was a standard gain horn, which was rotated by the 20 - 30 degree, 3 dB beamwidth every few days. The spreadsheet shows the approximate bearing of the antenna for each day. The gain of the antenna horn varies from almost +15 dBi at 12 GHz, to just over 18 dBi at 18 GHz. The correction factors used to compute the SPFD values reported from the recorded dBm power values assume that all signals were in the primary beam (maximum gain) of the antenna. Since the direction to the source of any particular emitter is unknown, actual SPFD values could vary from the calculated (reported) value to as much as 18 dB stronger, assuming a signal actually came-in a 0 dBi sidelobe.

As the spreadsheet shows (Appendix A), very few signals in the 12 – 18 Ghz EVLA Ku band region fell within the sensitivity range of the RF-EMS system. In the over month and a half of observing in this band, signals were detected only a few of the days, as the following table shows:

FREQ	# DAYS OBSERVED	# DAYS WITH SIGNALS	MAX SPFD
12 – 13	44	4	-178
13 – 14	44	6	-176
14 – 15	44	9	-174
15 – 16	44	1	-175
16 – 17	44	17	-167
17 – 18	44	6	-172

RF-EMS Signal detections for EVLA Ku Band November/December, 2002

Percent occupancy figures for those days with detections remains below 2% in most instances, with typically only a single peak-hold detection of a swept CW signal. November 22, 2002 was the rare exception in both the 14 – 15 GHz and 15 – 16 GHz bands, however, with detections of a swept CW signal lasting for over an hour late in the afternoon local time. The 1.5-hour detection in the 14 – 15 GHz band caused the % occupancy for that one day to push above the 5% level over the 400 MHz of the sweep. As can be seen in the above summary chart, the maximum SPFD values over the whole of Ku band were all weaker than –167 dBW/m^2.Hz, with most signals in the –170 dBW/m^2.Hz range.