Radio Frequency Interference Analysis of Spectra from the Big Blade Antenna at the LWDA Site

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Introduction

The LWA analog receiver will be required to amplify and digitize RF signals over the full bandwidth of at least 20–80 MHz. This frequency range is populated with a number of strong sources of radio frequency interference (RFI), including several TV stations, HF broadcast transmissions, ham radio, and is adjacent to the FM band. Although filtering can be used to attenuate signals outside the band, the receiver must be designed with sufficient linearity and dynamic range to observe cosmic sources in the unoccupied regions between the, typically narrowband, RFI signals. A receiver of insufficient linearity will generate inter-modulation products at frequencies in the observing bands that will make it difficult or impossible to accomplish the science objectives. On the other hand, over-designing the receiver is undesirable because any excess cost or power usage will be multiplied by the 26,000 channels in the full design and may make the project unfeasible.

Since the sky background is low level and broadband, the linearity requirements primarily depend on the RFI signals presented to the receiver. Consequently, a detailed study of the RFI environment at candidate LWA sites is essential. Often RFI surveys are done using antennas optimized for RFI detection such as discone antennas. However, such data are of limited usefulness for setting the receiver requirements because what is relevant is what signals are passed to the receiver when it is connected to the actual LWA antenna. Thus, we have chosen to do an RFI survey using the Big Blade antenna that was specified as the strawman LWA antenna design in LWA Memo #35.

We investigated the statistics of the RFI across the spectrum by looking at the minimum, median, and maximum at each frequency over several different time intervals. We also tabulate the maximum power in each of the known TV and FM channels in the band. Finally, we tabulate the frequency and power spectral density (PSD) of all other RFI found in the spectra over several different time intervals.

The measurements presented here were made at the LWDA site about 60 miles west of Socorro, New Mexico near the center of the VLA. Clearly, this data collection and analysis needs to be repeated at many (if not all) candidate LWA station sites.

Data Collection and Analysis

The Specmaster system (see LWA Memo #74) was configured to collect a spectrum from the Big Blade antenna about once per second, with summed data dumped every two sweeps. We set the averaging mode to power averaging (RMS) and the detector type to sample mode. Each measured spectrum covers 2000 frequency bins over the range 13.0 to 115.0 MHz with a

resolution bandwidth (RBW) of 51 kHz per frequency bin. This densely samples the spectrum over the full frequency range, i.e. even a narrowband signal can't hide between two frequency bins, as is possible when the RBW is less than the step between frequency bins. Data have been collected in this basic configuration since October 2006. For the current analysis, we are using the data from the Big Blade dipole oriented North-South. We chose to analyze a set of data from 2006-11-28 17:00 to 2006-11-29 1700 MT due to a lack of obvious solar bursts during that time period.

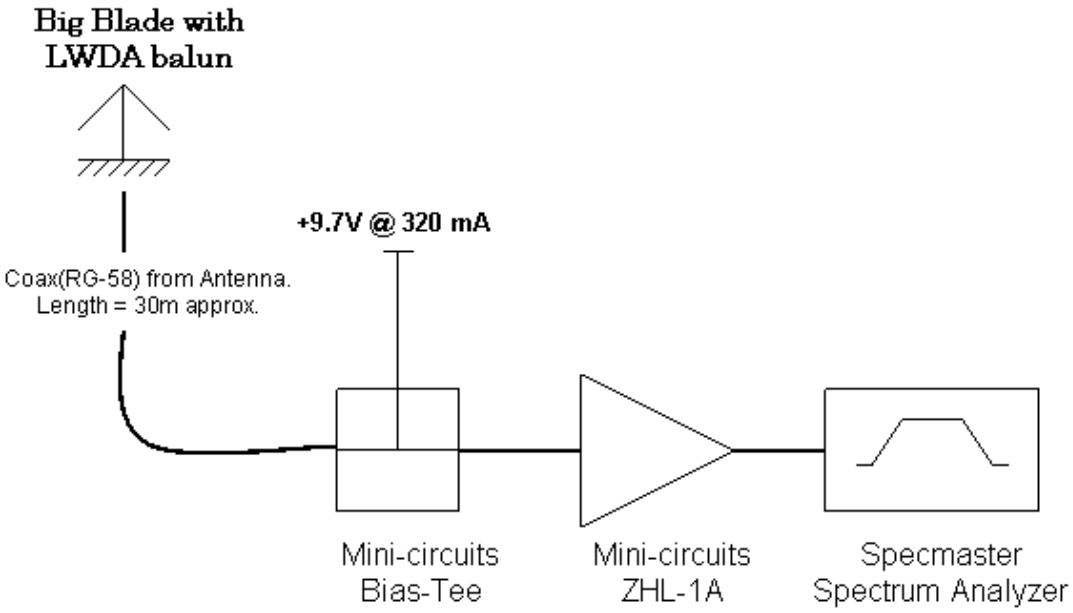

Figure 1. Diagram of experimental set-up for big blade measurements. Balun gain was +24 dB, amplifier gain +17 dB and the cable loss was calculated from site measurements.

Corrections Applied to Data

In all of our analysis, we report power spectral densities, in dB(mW/RBW), converted back to the levels at the balun input. This requires correcting the measured power from the spectrum analyzer to account for the active gain in the system, as well as the loss in the RF transmission cable.

The active gain in the system is $G_{\rm balun}$ = +24 dB from the Hicks/TeleTech balun, and $G_{\rm amp}$ = +17 dB from the Mini-Circuits ZHL-1A amplifier, both assumed to be independent of frequency. The cable loss correction was derived from earlier measurements made by S. Ellingson of the same cables, as documented in LWA Memo #42 (see Figure 7 in that memo). We used a simple linear fit of the data (in dB) vs. frequency as our cable loss model, which is

$$L_{\rm cable}({\rm dB}) = 0.0395 f_{\rm MHz} + 1.6274 \text{, where } f_{\rm MHz} \text{ is the frequency in MHz}$$

Sky Temperature Model

We define an objective criterion that RFI will be included in our lists if it exceeds the power expected from the sky background in a 51 kHz bin by 10 dB. 10 dB was adopted as a fiducial value, as levels below this are unlikely to cause linearity problems. We compute the expected sky noise beginning with the model of Cane (1979, MNRAS, **189**, 465), using for intensity

$$I_\nu = I_g \nu^{-0.52} \frac{1 - e^{-\tau(\nu)}}{\tau(\nu)} + I_{eg} \nu^{-0.80} e^{-\tau(\nu)}$$

with units of W m^{-2} Hz^{-1} sr^{-1}, where $I_g = 2.48 \times 10^{-20}$ (Galaxy contribution), $\tau(\nu) = 5.0\nu^{-2.1}$, $I_{eg} = 1.06 \times 10^{-20}$ (extragalactic noise) and ν (for this situation) is the frequency in MHz. (see Eqn. 18 of LWA Memo #22 by S. Ellingson). The sky temperature model is converted from units of T [K] to units of PSD[dB (mw/RBW), RBW=51 kHz] using

$$P = B\, k_\mathrm{B}\, T$$

where B is the bandwidth, k_B is Boltzmann's constant and T is temperature in Kelvin.

To compute the expected power from the sky, we corrected for the impedance mismatch efficiency (IME) and predicted ground loss, as described in LWA Memo #40, eqns. 1–5. The IME was computed using a NEC-2 model of the big blade, and the ground loss was modeled using the data from Memo #40, Fig 11, which is for a somewhat different antenna, but is close enough for the purposes of this work.

We then added 250K, independent of frequency, to the model to account for the excess noise contributed by the balun. Note that the sky temperature model predicts the *minimum* power from the sky since it is based on the sky spectrum at the galactic pole. The measured sky power can exceed this by a couple of dB at the maximum of the diurnal variation, which will cause a slight change in our RFI detection threshold as a function of local sidereal time.

Analysis

To show the overall character of the RFI, we plot the maximum, minimum and median power spectral density (PSD) [dB (mw/RBW), RBW=51.0 kHz] over four different 5-minute intervals separated by 6 hours (Figures 2–5). In Figure 6, we show the same statistics computed over a 24-hour interval. Looking at the minima (blue line) it is clear that nearly all frequency bins are unoccupied by RFI at least *some* of the time. The clear exception, are the TV stations and FM stations. In addition, the TV and FM transmissions are of known frequency and bandwidth. As a result, we have chosen to separately analyze the TV and FM signals from the rest of the intermittent RFI.

The TV and FM signals are characterized in Tables 2 and 3, where the difference between the tables is simply an integration time of 5 minutes for Table 2 and 24 hours for Table 3. For the NTSC TV stations, we tabulate the maximum power in 306 kHz (6 RBW bins) bandwidth at the audio and video carriers for each channel. We also tabulate the maximum total power in the full

6 MHz (118 RBW bins) ATSC frequency channel. For each of the 100 allocated FM stations, we tabulate the maximum power in a 204 kHz (4 RBW bins) bandwidth over the integration time.

We then excluded the frequencies of the NTSC TV carriers and FM radio bands from the analysis of the sporadic RFI environment. Tables 4–7 display the RFI signals above our threshold over four 5-minute intervals spaced by 6 hours.

New 40 MHz RFI Signal Detected

With different data than used in the above analysis, a 40 MHz signal has been observed with the EW polarization of the Big-Blade-1 antenna over a period of three months (Figure 7). This 40 MHz RFI has a central frequency at ~39.9 MHz, with a ~1.0 MHz bandwidth. This RFI has been observed at varying strengths since as early as October 2006. The strength of this RFI increased greatly after a 6 hour data gap on December 6, 2006. The 40 MHz signal was much lower in strength by January 28th, but has increased in strength up to February 24th, with the strength then being roughly constant up to the present (2007-03-06).

Analysis on the Fork (online 2007-01-17) and the new Big Blade antenna (Big-Blade-2, online 2007-02-16) may help with the determination of the source of the 40 MHz RFI. The 40 MHz signal was not observed with the NS polarization of the Fork or of Big-Blade-1, but is now being observed with the NS polarization of the Big-Blade-2. With the Big-Blade-1 balun apparently turned off during the change-over from Big-Blade-1 to Big-Blade-2 on 2007-02-16, the 40 RFI MHz signal was observed in the data gap (~19:45 to 20:32UT) for Big Blade-1 and the data gap (~20:32 to 20:39UT) of Big-Blade-2, which strongly suggest that the RFI is internally generated.

Occupancy Rate Plots

Looking at occupancy rates for each frequency bin can help identify the more frequent RFI. As an example, we made log plots of occupancy rates over the second week of November 2006 when higher intensity solar bursts were absent. For clarity we divided the 13 to 115 MHz range into three sections 13 to 51 MHz, 49 to 89 MHz (covering all TV station bandwidths) and 87 to 115 MHz (covering all FM station bandwidths). The Figures 8-10 show some rates below 0.1% from roughly 30 to 55 MHz, between the TV station signals and at frequencies above 108.5 MHz (higher than FM station bandwidths).
Over the one week period, TV channel 2 and 5 showed rates of 100% occupancy; TV channel 3 showed rates of 1-10% for Video and Audio signal; TV channel 4 showed 100% for Video and 1-10% for Audio; TV channel 6 showed 1-10% for Video and 100% for the Audio signal.
Most of the FM stations observed, showed 100% occupancy rate with others mostly above 10%.

These observations are some of the reasons why continued RFI monitoring is important to the project. For reference, FCC frequency allocations 12.23 to 117.975 MHz are shown in Figure 11.

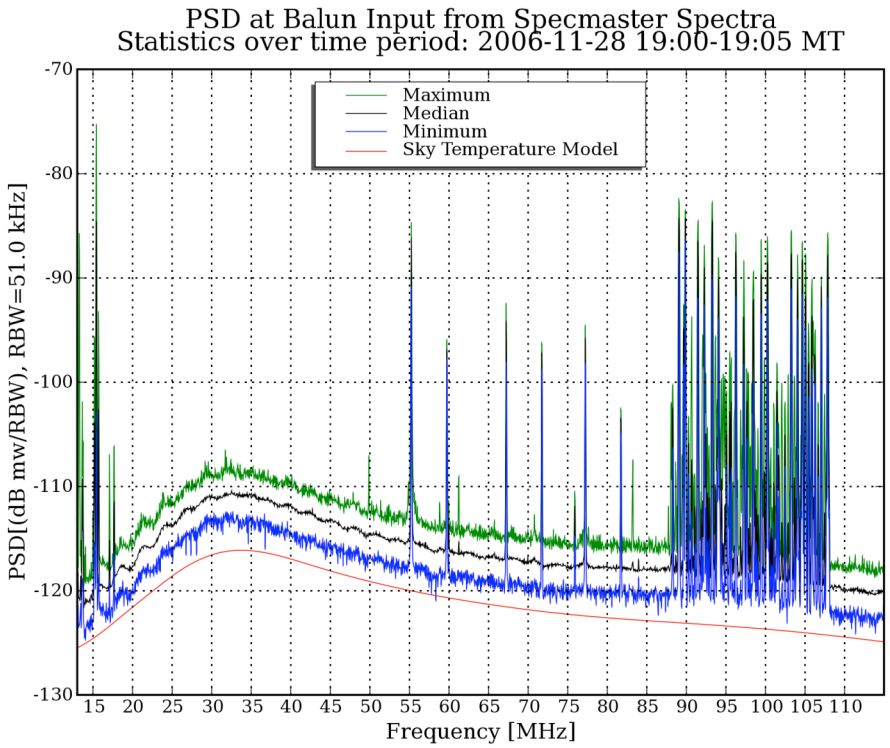

Figure 2. 5-min (period 1) spectra after gain & cable loss corrections.

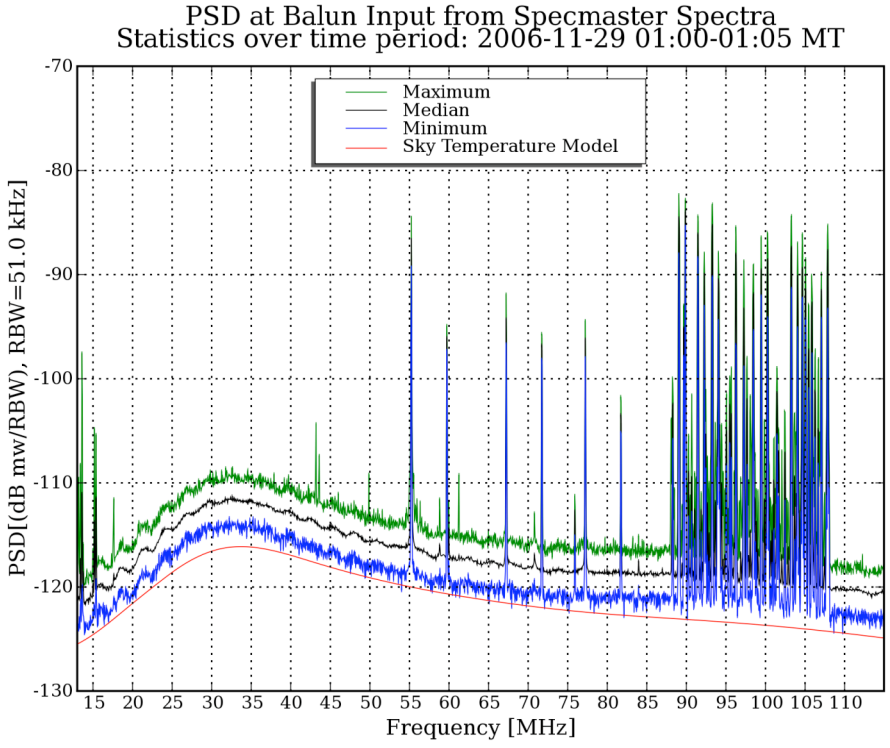

Figure 3. 5-min (period 2) spectra after gain & cable loss corrections.

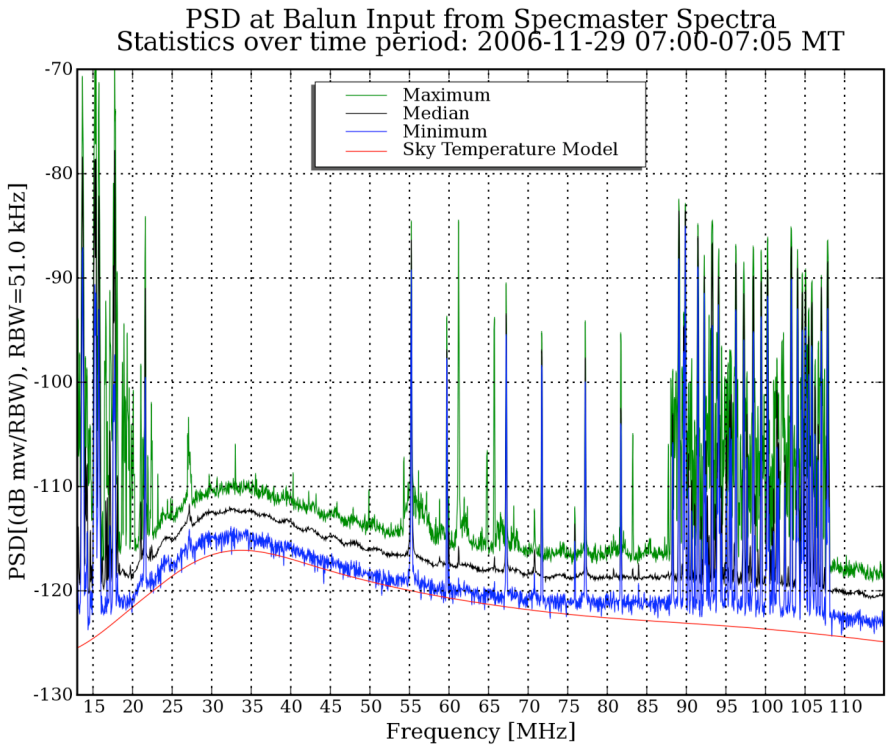

Figure 4. 5-min (period 3) spectra after gain & cable loss corrections.

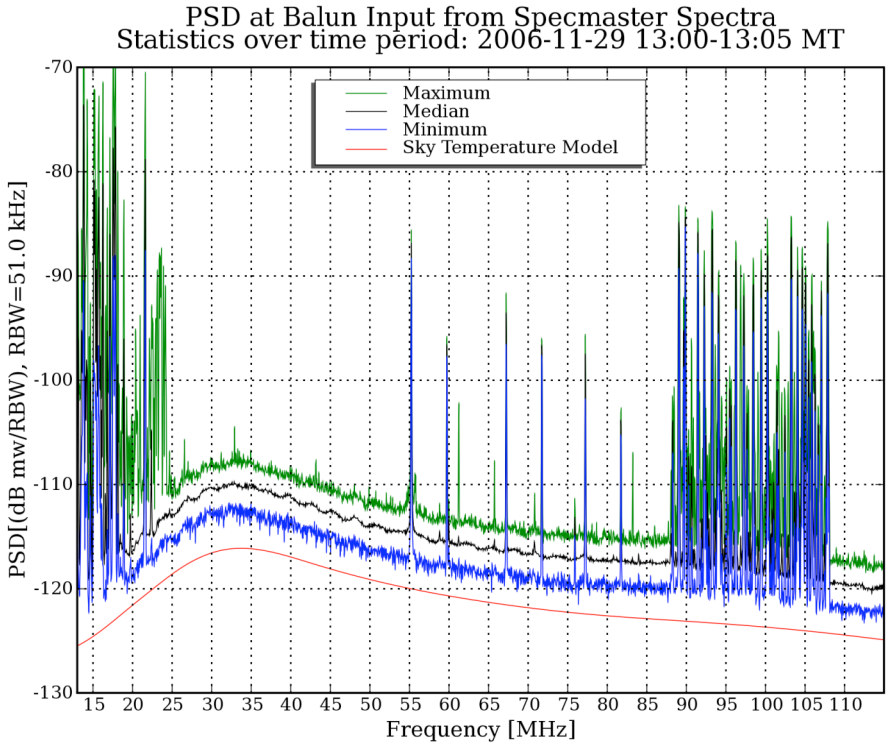

Figure 5. 5-min (period 4) spectra after gain & cable loss corrections.

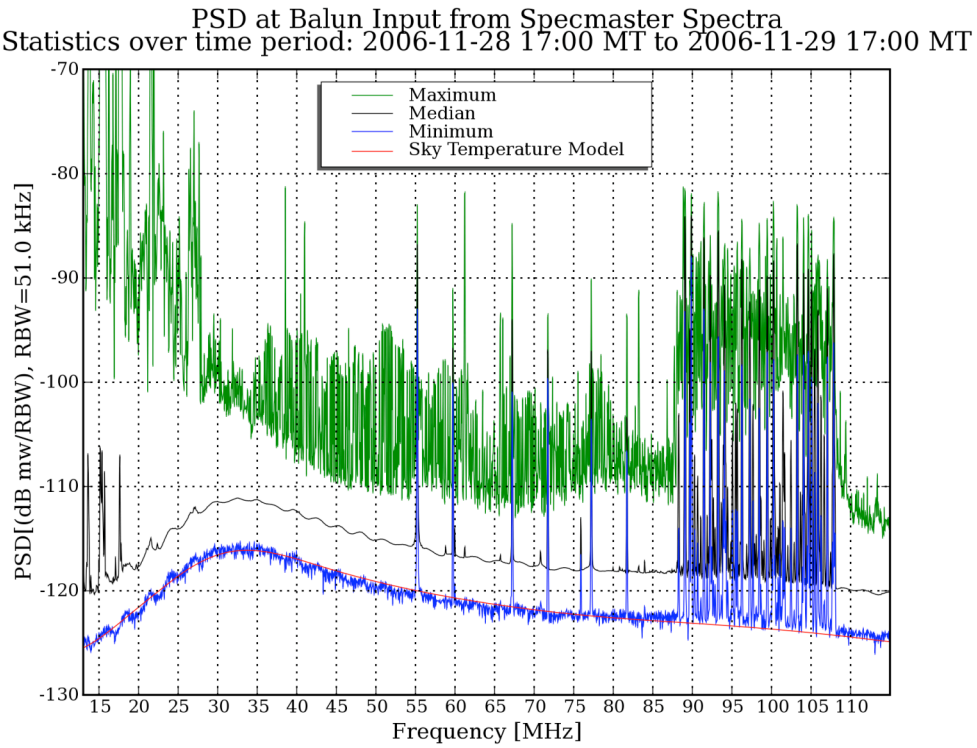

Figure 6. 24-hours of Spectra after gain and cable loss corrections.

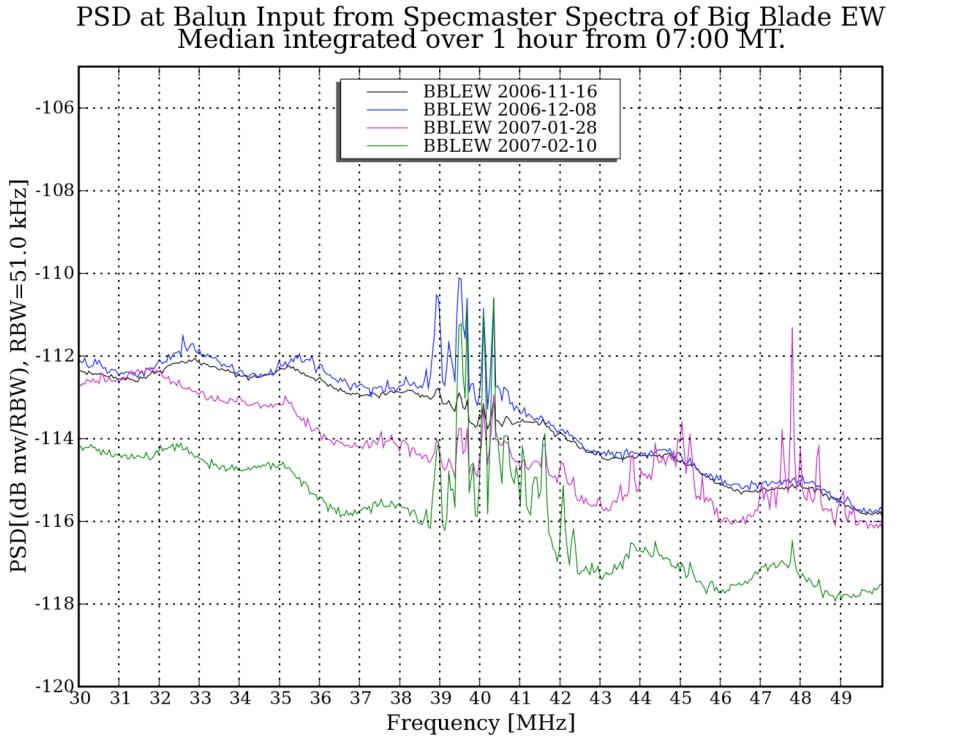

Figure 7. One-hour spectra over 3 months showing 40 MHz RFI strength.

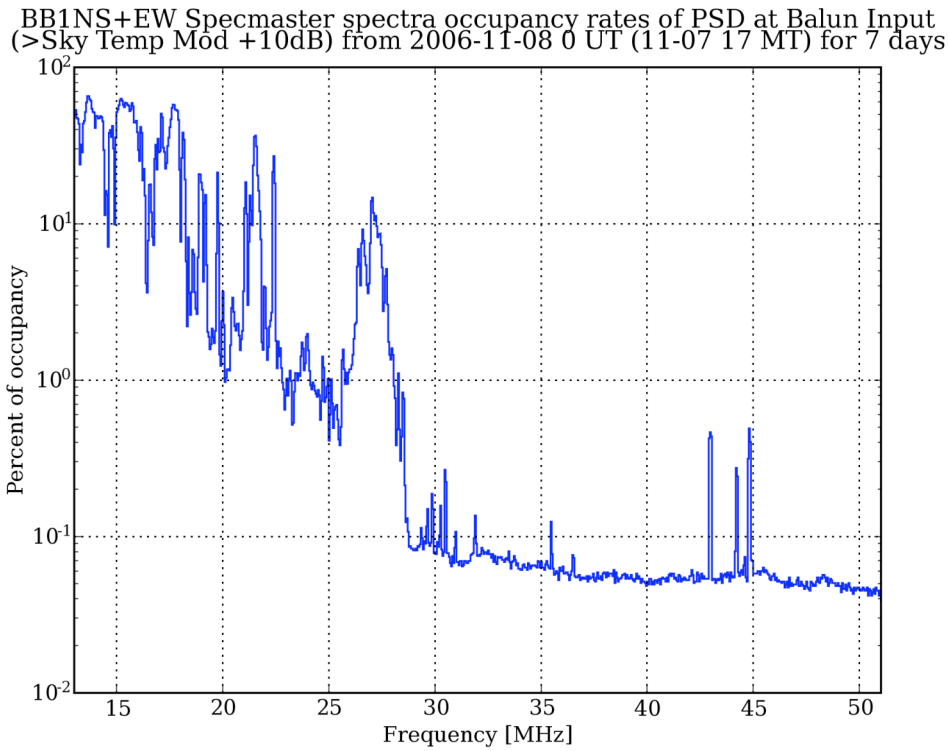

Figure 8. Occupancy plot (13-51 Mhz) showing percent of time PSD> Sky Temp Model+10 dB.

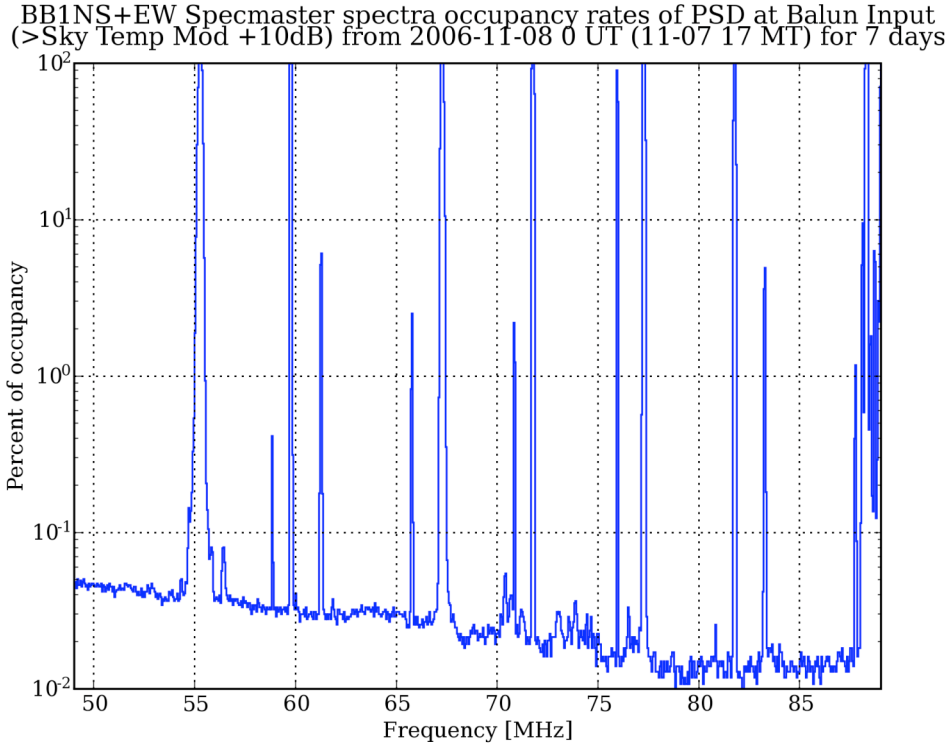

Figure 9. Occupancy plot (49-89 Mhz) showing percent of time PSD> Sky Temp Model+10 dB.

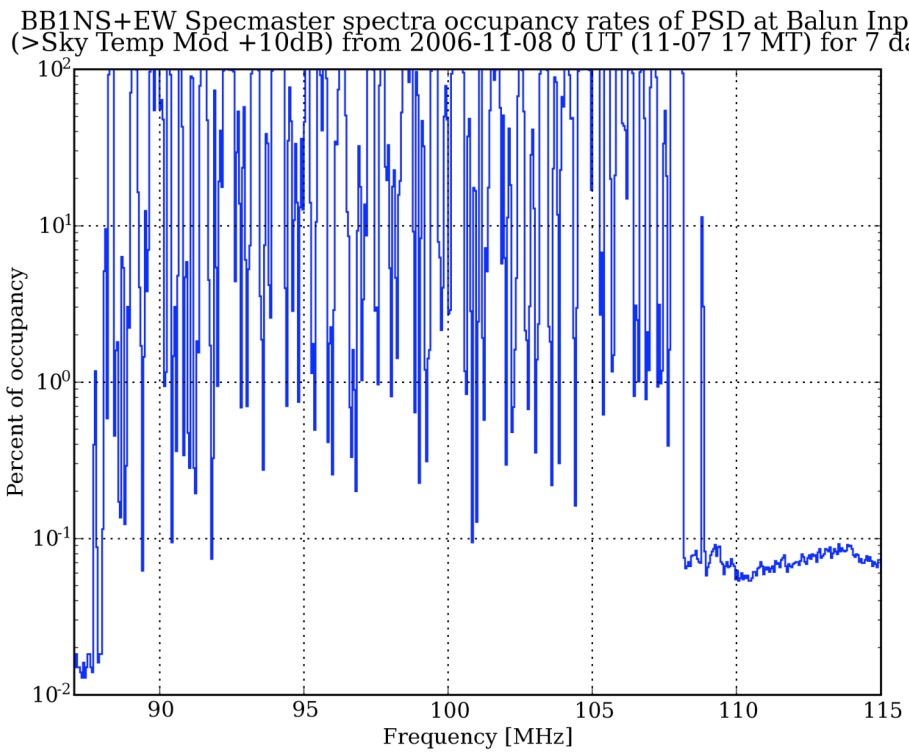

Figure 10. Occupancy plot (87-115 Mhz) showing percent of time PSD> Sky Temp Model+10 dB.

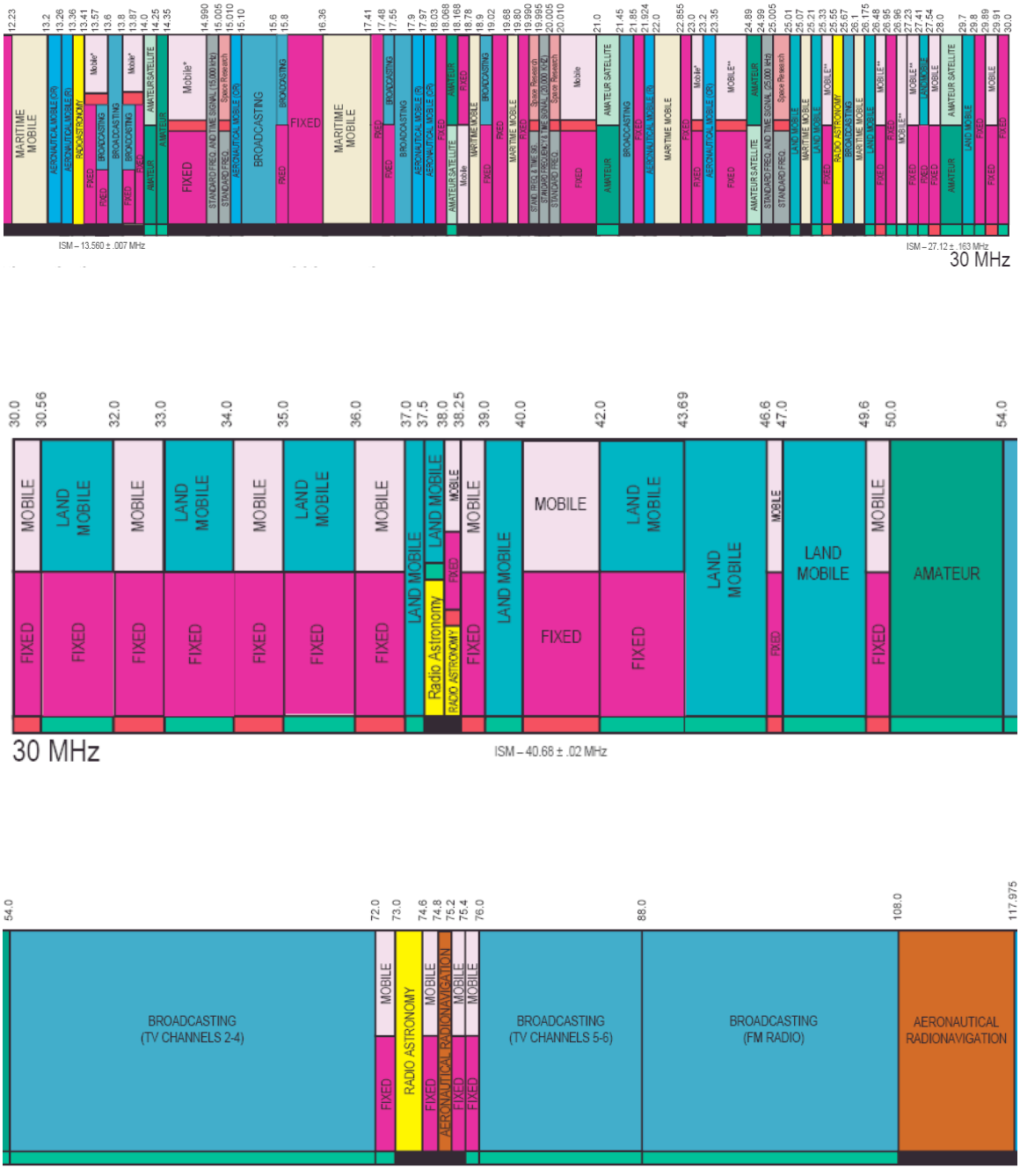

Figure 11. Frequency allocations from 12.23 to 117.975 MHz
(http://www.ntia.doc.gov/osmhome/allochrt.pdf)

Table 2. TV/FM ref. for instantaneous PSD[dB mw/RBW] at Balun Input
of Specmaster spectra. Max of sweeps: 2006-11-29 07:00-07:05 MT.

TV/FM CHNL	REF_FREQ	SIGNAL_TYPE	PSD_SUM	PSD_UNITS_in_[RBW]
TV KASA CH 2	55.26 MHz	NTSC Video,	-83.50	dB(mw/RBW) in 306 kHz
TV KASA CH 2	59.76 MHz	NTSC Audio,	-92.56	dB(mw/RBW) in 306 kHz
TV KASA CH 2	57.01 MHz	ATSC,	-82.66	dB(mw/RBW) in 6.018 MHz
TV KENW CH 3	61.26 MHz	NTSC Video,	-81.46	dB(mw/RBW) in 306 kHz
TV KENW CH 3	65.76 MHz	NTSC Audio,	-91.22	dB(mw/RBW) in 306 kHz
TV KENW CH 3	63.01 MHz	ATSC,	-80.87	dB(mw/RBW) in 6.018 MHz
TV KOB CH 4	67.26 MHz	NTSC Video,	-89.14	dB(mw/RBW) in 306 kHz
TV KOB CH 4	71.76 MHz	NTSC Audio,	-92.75	dB(mw/RBW) in 306 kHz
TV KOB CH 4	69.01 MHz	ATSC,	-87.47	dB(mw/RBW) in 6.018 MHz
TV KNME CH 5	77.26 MHz	NTSC Video,	-92.68	dB(mw/RBW) in 306 kHz
TV KNME CH 5	81.76 MHz	NTSC Audio,	-92.92	dB(mw/RBW) in 306 kHz
TV KNME CH 5	79.01 MHz	ATSC,	-89.38	dB(mw/RBW) in 6.018 MHz
TV KOCT CH 6	83.24 MHz	NTSC Video,	-102.66	dB(mw/RBW) in 306 kHz
TV KOCT CH 6	87.74 MHz	NTSC Audio,	-103.98	dB(mw/RBW) in 306 kHz
TV KOCT CH 6	84.99 MHz	ATSC,	-96.72	dB(mw/RBW) in 6.018 MHz
FM KNMA	88.1 MHz		-96.81	dB(mw/RBW) in 204 kHz
FM KLYT	88.3 MHz		-96.61	dB(mw/RBW) in 204 kHz
FM KPKJ	88.5 MHz		-99.12	dB(mw/RBW) in 204 kHz
FM 990428MC	88.7 MHz		-95.57	dB(mw/RBW) in 204 kHz
FM KNMI	88.9 MHz		-95.82	dB(mw/RBW) in 204 kHz
FM KANW/KQAI	89.1 MHz		-80.36	dB(mw/RBW) in 204 kHz
FM KELP	89.3 MHz		-102.91	dB(mw/RBW) in 204 kHz
FM KVLK	89.5 MHz		-96.04	dB(mw/RBW) in 204 kHz
FM KTDB	89.7 MHz		-91.68	dB(mw/RBW) in 204 kHz
FM KUNM	89.9 MHz		-81.61	dB(mw/RBW) in 204 kHz
FM KRDR/KRLU	90.1 MHz		-103.32	dB(mw/RBW) in 204 kHz
FM 12	90.3 MHz		-98.17	dB(mw/RBW) in 204 kHz
FM 13	90.5 MHz		-98.18	dB(mw/RBW) in 204 kHz
FM 14	90.7 MHz		-95.63	dB(mw/RBW) in 204 kHz
FM 15	90.9 MHz		-103.87	dB(mw/RBW) in 204 kHz
FM 16	91.1 MHz		-101.96	dB(mw/RBW) in 204 kHz
FM 17	91.3 MHz		-100.92	dB(mw/RBW) in 204 kHz
FM 18	91.5 MHz		-82.89	dB(mw/RBW) in 204 kHz
FM 19	91.7 MHz		-103.49	dB(mw/RBW) in 204 kHz
FM 20	91.9 MHz		-104.36	dB(mw/RBW) in 204 kHz
FM 21	92.1 MHz		-103.85	dB(mw/RBW) in 204 kHz
FM 22	92.3 MHz		-86.35	dB(mw/RBW) in 204 kHz
FM 23	92.5 MHz		-98.10	dB(mw/RBW) in 204 kHz
FM 24	92.7 MHz		-100.47	dB(mw/RBW) in 204 kHz
FM 25	92.9 MHz		-92.23	dB(mw/RBW) in 204 kHz
FM 26	93.1 MHz		-93.25	dB(mw/RBW) in 204 kHz
FM 27	93.3 MHz		-81.61	dB(mw/RBW) in 204 kHz
FM 28	93.5 MHz		-105.10	dB(mw/RBW) in 204 kHz
FM 29	93.7 MHz		-100.06	dB(mw/RBW) in 204 kHz
FM 30	93.9 MHz		-93.92	dB(mw/RBW) in 204 kHz
FM KZRR	94.1 MHz		-85.15	dB(mw/RBW) in 204 kHz
FM 32	94.3 MHz		-101.35	dB(mw/RBW) in 204 kHz
FM 33	94.5 MHz		-95.47	dB(mw/RBW) in 204 kHz

Table 2 continued...

TV/FM CHNL	REF_FREQ	SIGNAL_TYPE	PSD_SUM	PSD_UNITS_in_[RBW]
FM 34	94.7 MHz		-103.31	dB(mw/RBW) in 204 kHz
FM 35	94.9 MHz		-98.07	dB(mw/RBW) in 204 kHz
FM 36	95.1 MHz		-97.43	dB(mw/RBW) in 204 kHz
FM 37	95.3 MHz		-95.45	dB(mw/RBW) in 204 kHz
FM 38	95.5 MHz		-94.76	dB(mw/RBW) in 204 kHz
FM 39	95.7 MHz		-94.15	dB(mw/RBW) in 204 kHz
FM Magdelena	95.9 MHz		-99.82	dB(mw/RBW) in 204 kHz
FM 41	96.1 MHz		-96.05	dB(mw/RBW) in 204 kHz
FM 42	96.3 MHz		-84.75	dB(mw/RBW) in 204 kHz
FM 43	96.5 MHz		-97.48	dB(mw/RBW) in 204 kHz
FM 44	96.7 MHz		-108.01	dB(mw/RBW) in 204 kHz
FM 45	96.9 MHz		-103.30	dB(mw/RBW) in 204 kHz
FM 46	97.1 MHz		-95.57	dB(mw/RBW) in 204 kHz
FM 47	97.3 MHz		-86.61	dB(mw/RBW) in 204 kHz
FM 48	97.5 MHz		-98.10	dB(mw/RBW) in 204 kHz
FM 49	97.7 MHz		-97.24	dB(mw/RBW) in 204 kHz
FM 50	97.9 MHz		-103.46	dB(mw/RBW) in 204 kHz
FM 51	98.1 MHz		-103.51	dB(mw/RBW) in 204 kHz
FM 52	98.3 MHz		-100.49	dB(mw/RBW) in 204 kHz
FM 53	98.5 MHz		-84.27	dB(mw/RBW) in 204 kHz
FM 54	98.7 MHz		-98.14	dB(mw/RBW) in 204 kHz
FM 55	98.9 MHz		-103.75	dB(mw/RBW) in 204 kHz
FM 56	99.1 MHz		-100.51	dB(mw/RBW) in 204 kHz
FM 57	99.3 MHz		-102.49	dB(mw/RBW) in 204 kHz
FM 58	99.5 MHz		-86.54	dB(mw/RBW) in 204 kHz
FM 59	99.7 MHz		-102.23	dB(mw/RBW) in 204 kHz
FM 60	99.9 MHz		-100.37	dB(mw/RBW) in 204 kHz
FM 61	100.1 MHz		-104.93	dB(mw/RBW) in 204 kHz
FM 62	100.3 MHz		-84.78	dB(mw/RBW) in 204 kHz
FM 63	100.5 MHz		-101.44	dB(mw/RBW) in 204 kHz
FM 64	100.7 MHz		-105.34	dB(mw/RBW) in 204 kHz
FM 65	100.9 MHz		-103.97	dB(mw/RBW) in 204 kHz
FM 66	101.1 MHz		-98.27	dB(mw/RBW) in 204 kHz
FM 67	101.3 MHz		-96.96	dB(mw/RBW) in 204 kHz
FM 68	101.5 MHz		-95.71	dB(mw/RBW) in 204 kHz
FM 69	101.7 MHz		-99.69	dB(mw/RBW) in 204 kHz
FM 70	101.9 MHz		-104.56	dB(mw/RBW) in 204 kHz
FM 71	102.1 MHz		-92.77	dB(mw/RBW) in 204 kHz
FM 72	102.3 MHz		-93.79	dB(mw/RBW) in 204 kHz
FM 73	102.5 MHz		-101.30	dB(mw/RBW) in 204 kHz
FM 74	102.7 MHz		-104.02	dB(mw/RBW) in 204 kHz
FM 75	102.9 MHz		-99.04	dB(mw/RBW) in 204 kHz
FM 76	103.1 MHz		-100.23	dB(mw/RBW) in 204 kHz
FM 77	103.3 MHz		-82.51	dB(mw/RBW) in 204 kHz
FM 78	103.5 MHz		-106.67	dB(mw/RBW) in 204 kHz
FM 79	103.7 MHz		-101.25	dB(mw/RBW) in 204 kHz
FM 80	103.9 MHz		-103.18	dB(mw/RBW) in 204 kHz
FM 81	104.1 MHz		-85.62	dB(mw/RBW) in 204 kHz
FM 82	104.3 MHz		-104.48	dB(mw/RBW) in 204 kHz

Table 2 continued...

TV/FM CHNL	REF_FREQ	SIGNAL_TYPE	PSD_SUM	PSD_UNITS_in_[RBW]
FM 83	104.5 MHz		-95.95	dB(mw/RBW) in 204 kHz
FM 84	104.7 MHz		-87.53	dB(mw/RBW) in 204 kHz
FM 85	104.9 MHz		-101.62	dB(mw/RBW) in 204 kHz
FM 86	105.1 MHz		-86.55	dB(mw/RBW) in 204 kHz
FM 87	105.3 MHz		-94.20	dB(mw/RBW) in 204 kHz
FM 88	105.5 MHz		-90.55	dB(mw/RBW) in 204 kHz
FM 89	105.7 MHz		-102.80	dB(mw/RBW) in 204 kHz
FM 90	105.9 MHz		-87.82	dB(mw/RBW) in 204 kHz
FM 91	106.1 MHz		-105.99	dB(mw/RBW) in 204 kHz
FM 92	106.3 MHz		-95.82	dB(mw/RBW) in 204 kHz
FM 93	106.5 MHz		-104.92	dB(mw/RBW) in 204 kHz
FM 94	106.7 MHz		-93.28	dB(mw/RBW) in 204 kHz
FM 95	106.9 MHz		-96.87	dB(mw/RBW) in 204 kHz
FM 96	107.1 MHz		-88.32	dB(mw/RBW) in 204 kHz
FM 97	107.3 MHz		-99.03	dB(mw/RBW) in 204 kHz
FM 98	107.5 MHz		-97.27	dB(mw/RBW) in 204 kHz
FM 99	107.7 MHz		-102.32	dB(mw/RBW) in 204 kHz
FM 100	107.9 MHz		-83.70	dB(mw/RBW) in 204 kHz

Table 3. TV/FM ref. for instantaneous PSD[dB mw/RBW] at Balun Input of Specmaster spectra. Max of sweeps: 2006-11-28 17:00 MT to 2006-11-29 17:00 MT

TV/FM CHNL	REF_FREQ	SIGNAL_TYPE	PSD_SUM PSD_UNITS_in_[RBW]
TV KASA CH 2	55.26 MHz	NTSC Video,	-81.84 dB(mw/RBW) in 306 kHz
TV KASA CH 2	59.76 MHz	NTSC Audio,	-89.27 dB(mw/RBW) in 306 kHz
TV KASA CH 2	57.01 MHz	ATSC,	-81.16 dB(mw/RBW) in 6.018 MHz
TV KENW CH 3	61.26 MHz	NTSC Video,	-78.81 dB(mw/RBW) in 306 kHz
TV KENW CH 3	65.76 MHz	NTSC Audio,	-91.22 dB(mw/RBW) in 306 kHz
TV KENW CH 3	63.01 MHz	ATSC,	-78.51 dB(mw/RBW) in 6.018 MHz
TV KOB CH 4	67.26 MHz	NTSC Video,	-83.42 dB(mw/RBW) in 306 kHz
TV KOB CH 4	71.76 MHz	NTSC Audio,	-90.57 dB(mw/RBW) in 306 kHz
TV KOB CH 4	69.01 MHz	ATSC,	-82.48 dB(mw/RBW) in 6.018 MHz
TV KNME CH 5	77.26 MHz	NTSC Video,	-88.98 dB(mw/RBW) in 306 kHz
TV KNME CH 5	81.76 MHz	NTSC Audio,	-90.63 dB(mw/RBW) in 306 kHz
TV KNME CH 5	79.01 MHz	ATSC,	-87.01 dB(mw/RBW) in 6.018 MHz
TV KOCT CH 6	83.24 MHz	NTSC Video,	-89.51 dB(mw/RBW) in 306 kHz
TV KOCT CH 6	87.74 MHz	NTSC Audio,	-94.58 dB(mw/RBW) in 306 kHz
TV KOCT CH 6	84.99 MHz	ATSC,	-87.94 dB(mw/RBW) in 6.018 MHz
FM KNMA	88.1 MHz		-89.39 dB(mw/RBW) in 204 kHz
FM KLYT	88.3 MHz		-93.36 dB(mw/RBW) in 204 kHz
FM KPKJ	88.5 MHz		-88.91 dB(mw/RBW) in 204 kHz
FM 990428MC	88.7 MHz		-89.63 dB(mw/RBW) in 204 kHz
FM KNMI	88.9 MHz		-79.65 dB(mw/RBW) in 204 kHz
FM KANW/KQAI	89.1 MHz		-78.97 dB(mw/RBW) in 204 kHz
FM KELP	89.3 MHz		-91.06 dB(mw/RBW) in 204 kHz
FM KVLK	89.5 MHz		-91.14 dB(mw/RBW) in 204 kHz
FM KTDB	89.7 MHz		-87.61 dB(mw/RBW) in 204 kHz
FM KUNM	89.9 MHz		-80.57 dB(mw/RBW) in 204 kHz
FM KRDR/KRLU	90.1 MHz		-85.75 dB(mw/RBW) in 204 kHz
FM 12	90.3 MHz		-91.18 dB(mw/RBW) in 204 kHz
FM 13	90.5 MHz		-85.59 dB(mw/RBW) in 204 kHz
FM 14	90.7 MHz		-86.38 dB(mw/RBW) in 204 kHz
FM 15	90.9 MHz		-85.33 dB(mw/RBW) in 204 kHz
FM 16	91.1 MHz		-84.00 dB(mw/RBW) in 204 kHz
FM 17	91.3 MHz		-93.26 dB(mw/RBW) in 204 kHz
FM 18	91.5 MHz		-80.45 dB(mw/RBW) in 204 kHz
FM 19	91.7 MHz		-89.46 dB(mw/RBW) in 204 kHz
FM 20	91.9 MHz		-94.57 dB(mw/RBW) in 204 kHz
FM 21	92.1 MHz		-86.23 dB(mw/RBW) in 204 kHz
FM 22	92.3 MHz		-84.01 dB(mw/RBW) in 204 kHz
FM 23	92.5 MHz		-88.42 dB(mw/RBW) in 204 kHz
FM 24	92.7 MHz		-90.52 dB(mw/RBW) in 204 kHz
FM 25	92.9 MHz		-91.22 dB(mw/RBW) in 204 kHz
FM 26	93.1 MHz		-89.33 dB(mw/RBW) in 204 kHz
FM 27	93.3 MHz		-79.34 dB(mw/RBW) in 204 kHz
FM 28	93.5 MHz		-96.91 dB(mw/RBW) in 204 kHz
FM 29	93.7 MHz		-88.90 dB(mw/RBW) in 204 kHz
FM 30	93.9 MHz		-86.37 dB(mw/RBW) in 204 kHz
FM KZRR	94.1 MHz		-84.28 dB(mw/RBW) in 204 kHz
FM 32	94.3 MHz		-92.71 dB(mw/RBW) in 204 kHz

Table 3 continued...

TV/FM CHNL	REF_FREQ	SIGNAL_TYPE	PSD_SUM PSD_UNITS_in_[RBW]
FM 33	94.5 MHz		-85.27 dB(mw/RBW) in 204 kHz
FM 34	94.7 MHz		-89.36 dB(mw/RBW) in 204 kHz
FM 35	94.9 MHz		-88.32 dB(mw/RBW) in 204 kHz
FM 36	95.1 MHz		-90.19 dB(mw/RBW) in 204 kHz
FM 37	95.3 MHz		-86.84 dB(mw/RBW) in 204 kHz
FM 38	95.5 MHz		-87.81 dB(mw/RBW) in 204 kHz
FM 39	95.7 MHz		-83.46 dB(mw/RBW) in 204 kHz
FM Magdelena	95.9 MHz		-95.78 dB(mw/RBW) in 204 kHz
FM 41	96.1 MHz		-86.52 dB(mw/RBW) in 204 kHz
FM 42	96.3 MHz		-81.91 dB(mw/RBW) in 204 kHz
FM 43	96.5 MHz		-87.28 dB(mw/RBW) in 204 kHz
FM 44	96.7 MHz		-93.18 dB(mw/RBW) in 204 kHz
FM 45	96.9 MHz		-87.72 dB(mw/RBW) in 204 kHz
FM 46	97.1 MHz		-90.71 dB(mw/RBW) in 204 kHz
FM 47	97.3 MHz		-84.80 dB(mw/RBW) in 204 kHz
FM 48	97.5 MHz		-89.28 dB(mw/RBW) in 204 kHz
FM 49	97.7 MHz		-88.98 dB(mw/RBW) in 204 kHz
FM 50	97.9 MHz		-89.67 dB(mw/RBW) in 204 kHz
FM 51	98.1 MHz		-89.25 dB(mw/RBW) in 204 kHz
FM 52	98.3 MHz		-87.23 dB(mw/RBW) in 204 kHz
FM 53	98.5 MHz		-83.00 dB(mw/RBW) in 204 kHz
FM 54	98.7 MHz		-90.93 dB(mw/RBW) in 204 kHz
FM 55	98.9 MHz		-90.07 dB(mw/RBW) in 204 kHz
FM 56	99.1 MHz		-89.78 dB(mw/RBW) in 204 kHz
FM 57	99.3 MHz		-87.13 dB(mw/RBW) in 204 kHz
FM 58	99.5 MHz		-83.26 dB(mw/RBW) in 204 kHz
FM 59	99.7 MHz		-91.79 dB(mw/RBW) in 204 kHz
FM 60	99.9 MHz		-87.45 dB(mw/RBW) in 204 kHz
FM 61	100.1 MHz		-92.81 dB(mw/RBW) in 204 kHz
FM 62	100.3 MHz		-80.82 dB(mw/RBW) in 204 kHz
FM 63	100.5 MHz		-91.36 dB(mw/RBW) in 204 kHz
FM 64	100.7 MHz		-84.15 dB(mw/RBW) in 204 kHz
FM 65	100.9 MHz		-99.12 dB(mw/RBW) in 204 kHz
FM 66	101.1 MHz		-89.40 dB(mw/RBW) in 204 kHz
FM 67	101.3 MHz		-92.42 dB(mw/RBW) in 204 kHz
FM 68	101.5 MHz		-82.95 dB(mw/RBW) in 204 kHz
FM 69	101.7 MHz		-92.43 dB(mw/RBW) in 204 kHz
FM 70	101.9 MHz		-90.62 dB(mw/RBW) in 204 kHz
FM 71	102.1 MHz		-89.64 dB(mw/RBW) in 204 kHz
FM 72	102.3 MHz		-91.92 dB(mw/RBW) in 204 kHz
FM 73	102.5 MHz		-93.35 dB(mw/RBW) in 204 kHz
FM 74	102.7 MHz		-92.43 dB(mw/RBW) in 204 kHz
FM 75	102.9 MHz		-89.05 dB(mw/RBW) in 204 kHz
FM 76	103.1 MHz		-91.71 dB(mw/RBW) in 204 kHz
FM 77	103.3 MHz		-80.27 dB(mw/RBW) in 204 kHz
FM 78	103.5 MHz		-91.64 dB(mw/RBW) in 204 kHz
FM 79	103.7 MHz		-92.90 dB(mw/RBW) in 204 kHz
FM 80	103.9 MHz		-91.74 dB(mw/RBW) in 204 kHz
FM 81	104.1 MHz		-82.68 dB(mw/RBW) in 204 kHz
FM 82	104.3 MHz		-95.26 dB(mw/RBW) in 204 kHz
FM 83	104.5 MHz		-92.52 dB(mw/RBW) in 204 kHz

Table 3 continued...

TV/FM CHNL	REF_FREQ	SIGNAL_TYPE	PSD_SUM PSD_UNITS_in_[RBW]
FM 84	104.7 MHz		-82.30 dB(mw/RBW) in 204 kHz
FM 85	104.9 MHz		-96.12 dB(mw/RBW) in 204 kHz
FM 86	105.1 MHz		-83.58 dB(mw/RBW) in 204 kHz
FM 87	105.3 MHz		-89.00 dB(mw/RBW) in 204 kHz
FM 88	105.5 MHz		-88.06 dB(mw/RBW) in 204 kHz
FM 89	105.7 MHz		-85.86 dB(mw/RBW) in 204 kHz
FM 90	105.9 MHz		-85.08 dB(mw/RBW) in 204 kHz
FM 91	106.1 MHz		-85.35 dB(mw/RBW) in 204 kHz
FM 92	106.3 MHz		-88.18 dB(mw/RBW) in 204 kHz
FM 93	106.5 MHz		-93.60 dB(mw/RBW) in 204 kHz
FM 94	106.7 MHz		-93.28 dB(mw/RBW) in 204 kHz
FM 95	106.9 MHz		-91.84 dB(mw/RBW) in 204 kHz
FM 96	107.1 MHz		-87.11 dB(mw/RBW) in 204 kHz
FM 97	107.3 MHz		-89.48 dB(mw/RBW) in 204 kHz
FM 98	107.5 MHz		-93.15 dB(mw/RBW) in 204 kHz
FM 99	107.7 MHz		-90.14 dB(mw/RBW) in 204 kHz
FM 100	107.9 MHz		-81.41 dB(mw/RBW) in 204 kHz

Table 4. Unknown RFI of Specmaster spectra (2006-11-28 19:00-19:05 MT) > (SkyTMod+10), PSD[dB mw/RBW] at Bal Input (max per frequency channel).

SM MAX FREQ[MHz]	SM PEAK[PSD]	SkyTmod+10[PSD]
13.05	-115.00	-115.49
13.10	-111.56	-115.47
13.20	-100.08	-115.43
13.26	-85.89	-115.41
13.31	-88.53	-115.39
13.36	-109.78	-115.37
13.46	-115.32	-115.33
13.61	-107.54	-115.26
13.66	-102.01	-115.24
13.71	-108.92	-115.22
13.77	-105.80	-115.19
14.99	-112.72	-114.61
15.14	-104.36	-114.53
15.19	-95.80	-114.50
15.25	-99.38	-114.47
15.30	-111.80	-114.45
15.35	-100.84	-114.42
15.40	-78.60	-114.39
15.45	-75.42	-114.36
15.50	-88.70	-114.34
15.65	-105.12	-114.25
15.70	-93.37	-114.22
15.76	-98.26	-114.20
17.08	-107.09	-113.42
17.13	-111.51	-113.39
17.64	-106.30	-113.08
17.69	-106.18	-113.05
49.89	-107.17	-109.11
75.91	-110.60	-112.34
75.97	-111.44	-112.34
108.01	-95.83	-114.29
108.06	-106.03	-114.29
108.11	-110.12	-114.30

Table 5. Unknown RFI of Specmaster spectra (2006-11-29 01:00-01:05 MT) > (SkyTMod+10), PSD[dB mw/RBW] at Bal Input (max per frequency channel).

SM MAX FREQ[MHz]	SM PEAK[PSD]	SkyTmod+10[PSD]
13.15	-113.36	-115.45
13.20	-109.61	-115.43
13.36	-115.14	-115.37
13.41	-108.28	-115.35
13.46	-113.08	-115.33
13.56	-109.66	-115.28
13.61	-97.57	-115.26
13.66	-101.95	-115.24
15.14	-109.74	-114.53
15.19	-104.84	-114.50
15.35	-110.91	-114.42
15.40	-105.40	-114.39
15.45	-113.27	-114.36
17.64	-111.58	-113.08
43.21	-104.38	-107.71
43.62	-107.42	-107.81
75.91	-111.25	-112.34
75.97	-112.29	-112.34
108.01	-97.64	-114.29
108.06	-105.65	-114.29
108.11	-109.41	-114.30

Table 6. Unknown RFI of Specmaster spectra (2006-11-29 07:00-07:05 MT) > (SkyTMod+10), PSD[dB mw/RBW] at Bal Input (max per frequency channel).

SM MAX FREQ[MHz]	SM PEAK[PSD]	SkyTmod+10[PSD]
13.00	-102.74	-115.51
13.05	-102.66	-115.49
13.10	-94.04	-115.47
13.15	-100.29	-115.45
13.20	-106.98	-115.43
13.26	-106.29	-115.41
13.31	-97.35	-115.39
13.36	-103.30	-115.37
13.41	-109.96	-115.35
13.46	-107.83	-115.33
13.51	-95.71	-115.30
13.56	-85.97	-115.28
13.61	-80.35	-115.26
13.66	-70.82	-115.24
13.71	-74.62	-115.22
13.77	-77.57	-115.19
13.82	-84.42	-115.17
13.87	-93.51	-115.15
13.92	-110.45	-115.12
13.97	-107.53	-115.10
14.02	-104.03	-115.08
14.07	-97.70	-115.05
14.12	-106.16	-115.03
14.17	-100.65	-115.01
14.22	-98.78	-114.98
14.28	-99.50	-114.96
14.33	-105.80	-114.94
14.38	-107.56	-114.91
14.43	-109.81	-114.89
14.48	-104.61	-114.86
14.53	-109.56	-114.84
14.58	-105.25	-114.81
14.63	-104.22	-114.79
14.68	-104.42	-114.76
14.73	-109.26	-114.74
14.79	-109.69	-114.71
14.84	-113.15	-114.69
14.89	-112.18	-114.66
14.94	-111.59	-114.63
14.99	-109.37	-114.61
15.04	-100.88	-114.58
15.09	-80.13	-114.55
15.14	-78.02	-114.53
15.19	-74.60	-114.50
15.25	-70.27	-114.47
15.30	-77.04	-114.45
15.35	-63.37	-114.42
15.40	-66.22	-114.39
15.45	-88.03	-114.36
15.50	-104.53	-114.34

Table 6 continued...

SM MAX FREQ[MHz]	SM PEAK[PSD]	SkyTmod+10[PSD]
15.55	-95.75	-114.31
15.60	-99.11	-114.28
15.65	-91.48	-114.25
15.70	-74.14	-114.22
15.76	-71.42	-114.20
15.81	-80.21	-114.17
15.86	-84.70	-114.14
15.91	-94.93	-114.11
15.96	-101.14	-114.08
16.01	-113.55	-114.05
16.16	-113.23	-113.97
16.21	-112.55	-113.94
16.42	-111.71	-113.82
16.47	-98.13	-113.79
16.52	-100.12	-113.76
16.57	-98.97	-113.73
16.62	-92.37	-113.70
16.67	-94.79	-113.67
16.72	-110.03	-113.64
16.78	-105.41	-113.61
16.83	-103.93	-113.58
16.88	-110.08	-113.54
16.93	-110.66	-113.51
16.98	-109.10	-113.48
17.08	-101.96	-113.42
17.13	-91.36	-113.39
17.18	-96.13	-113.36
17.24	-96.61	-113.33
17.29	-98.33	-113.30
17.34	-103.69	-113.27
17.39	-105.52	-113.23
17.44	-104.45	-113.20
17.49	-102.11	-113.17
17.54	-88.25	-113.14
17.59	-81.08	-113.11
17.64	-89.31	-113.08
17.69	-80.46	-113.05
17.75	-69.50	-113.01
17.80	-74.79	-112.98
17.85	-74.00	-112.95
17.90	-83.23	-112.92
17.95	-109.65	-112.89
18.00	-102.12	-112.86
18.05	-89.55	-112.82
18.10	-93.32	-112.79
18.15	-104.69	-112.76
18.20	-110.92	-112.73
18.66	-105.06	-112.44
18.71	-98.24	-112.41
18.77	-105.95	-112.38

Table 6 continued...

SM MAX FREQ[MHz]	SM PEAK[PSD]	SkyTmod+10[PSD]
18.87	-103.63	-112.31
18.92	-94.55	-112.28
18.97	-100.90	-112.25
19.02	-107.60	-112.22
19.07	-101.53	-112.18
19.12	-101.96	-112.15
19.28	-101.59	-112.06
19.33	-95.44	-112.02
19.38	-102.58	-111.99
19.43	-103.19	-111.96
19.48	-103.85	-111.93
19.53	-108.34	-111.90
19.58	-100.68	-111.86
19.63	-107.03	-111.83
19.74	-110.31	-111.77
19.84	-104.23	-111.71
19.89	-106.65	-111.67
19.94	-108.73	-111.64
19.99	-111.09	-111.61
20.04	-104.64	-111.58
20.09	-100.92	-111.55
20.14	-108.81	-111.52
20.19	-108.94	-111.48
20.25	-108.89	-111.45
21.01	-106.04	-110.98
21.06	-98.42	-110.95
21.11	-106.15	-110.92
21.32	-105.46	-110.80
21.37	-109.85	-110.77
21.47	-105.46	-110.70
21.52	-104.20	-110.67
21.57	-88.47	-110.64
21.62	-84.27	-110.61
21.67	-94.44	-110.58
21.93	-107.19	-110.43
21.98	-108.60	-110.40
22.34	-108.11	-110.18
22.39	-102.09	-110.15
22.44	-107.31	-110.12
22.49	-105.77	-110.09
23.21	-108.96	-109.66
26.98	-105.09	-107.63
27.08	-103.51	-107.59
27.13	-106.94	-107.57
27.19	-106.84	-107.54
27.29	-106.86	-107.50
33.00	-106.09	-106.16
75.91	-112.10	-112.34
108.01	-96.07	-114.29
108.06	-105.15	-114.29
108.11	-110.64	-114.30

Table 7. Unknown RFI of Specmaster spectra (2006-11-29 13:00-13:05 MT) > (SkyTMod+10), PSD[dB mw/RBW] at Bal Input (max per frequency channel)

SM MAX FREQ[MHz]	SM PEAK[PSD]	SkyTmod+10[PSD]
13.00	-84.87	-115.51
13.05	-77.01	-115.49
13.10	-85.41	-115.47
13.15	-86.81	-115.45
13.20	-94.44	-115.43
13.26	-101.19	-115.41
13.31	-100.50	-115.39
13.36	-101.86	-115.37
13.41	-101.72	-115.35
13.46	-101.18	-115.33
13.51	-94.40	-115.30
13.56	-85.59	-115.28
13.61	-92.64	-115.26
13.66	-93.37	-115.24
13.71	-89.13	-115.22
13.77	-75.33	-115.19
13.82	-58.96	-115.17
13.87	-59.90	-115.15
13.92	-79.35	-115.12
13.97	-100.06	-115.10
14.02	-90.90	-115.08
14.07	-89.22	-115.05
14.12	-87.45	-115.03
14.17	-85.91	-115.01
14.22	-83.63	-114.98
14.28	-73.21	-114.96
14.33	-78.34	-114.94
14.38	-103.63	-114.91
14.43	-113.23	-114.89
14.48	-100.69	-114.86
14.53	-95.98	-114.84
14.58	-106.87	-114.81
14.63	-94.33	-114.79
14.68	-92.72	-114.76
14.73	-106.84	-114.74
14.79	-103.13	-114.71
14.84	-110.09	-114.69
14.89	-113.06	-114.66
14.94	-108.98	-114.63
14.99	-99.96	-114.61
15.04	-93.81	-114.58
15.09	-74.14	-114.55
15.14	-72.25	-114.53
15.19	-79.63	-114.50
15.25	-72.31	-114.47
15.30	-81.11	-114.45
15.35	-92.67	-114.42
15.40	-84.86	-114.39
15.45	-81.88	-114.36

Table 7 continued...

SM MAX FREQ[MHz]	SM PEAK[PSD]	SkyTmod+10[PSD]
15.50	-90.56	-114.34
15.55	-94.67	-114.31
15.60	-88.00	-114.28
15.65	-78.44	-114.25
15.70	-75.42	-114.22
15.76	-72.89	-114.20
15.81	-86.17	-114.17
15.86	-92.21	-114.14
15.91	-93.00	-114.11
15.96	-88.83	-114.08
16.01	-99.19	-114.05
16.06	-101.62	-114.02
16.11	-94.05	-113.99
16.16	-101.34	-113.97
16.21	-77.10	-113.94
16.27	-71.54	-113.91
16.32	-82.07	-113.88
16.37	-112.27	-113.85
16.42	-107.39	-113.82
16.47	-108.21	-113.79
16.52	-103.24	-113.76
16.57	-94.04	-113.73
16.62	-92.99	-113.70
16.67	-106.06	-113.67
16.72	-107.87	-113.64
16.78	-86.33	-113.61
16.83	-83.63	-113.58
16.88	-97.53	-113.54
16.93	-101.05	-113.51
16.98	-101.18	-113.48
17.03	-98.82	-113.45
17.08	-87.97	-113.42
17.13	-76.90	-113.39
17.18	-82.49	-113.36
17.24	-90.69	-113.33
17.29	-94.66	-113.30
17.34	-97.92	-113.27
17.39	-103.12	-113.23
17.44	-98.44	-113.20
17.49	-75.22	-113.17
17.54	-69.16	-113.14
17.59	-66.75	-113.11
17.64	-77.23	-113.08
17.69	-82.96	-113.05
17.75	-73.55	-113.01
17.80	-71.82	-112.98
17.85	-67.54	-112.95
17.90	-76.73	-112.92
17.95	-102.75	-112.89
18.00	-110.64	-112.86

Table 7 continued...

SM MAX FREQ[MHz]	SM PEAK[PSD]	SkyTmod+10[PSD]
18.05	-104.17	-112.82
18.10	-85.41	-112.79
18.15	-80.09	-112.76
18.20	-90.39	-112.73
18.26	-105.82	-112.70
18.31	-100.50	-112.66
18.36	-106.52	-112.63
18.41	-110.02	-112.60
18.46	-109.02	-112.57
18.51	-105.01	-112.54
18.56	-105.05	-112.50
18.61	-112.02	-112.47
18.66	-103.26	-112.44
18.71	-100.90	-112.41
18.77	-104.99	-112.38
18.82	-100.71	-112.34
18.87	-85.93	-112.31
18.92	-82.87	-112.28
18.97	-96.11	-112.25
19.02	-111.04	-112.22
19.07	-110.98	-112.18
19.12	-111.30	-112.15
19.17	-108.08	-112.12
19.23	-108.08	-112.09
19.28	-101.74	-112.06
19.33	-105.45	-112.02
19.43	-106.38	-111.96
19.48	-105.49	-111.93
19.53	-106.46	-111.90
19.63	-106.05	-111.83
19.68	-105.46	-111.80
19.74	-105.41	-111.77
19.79	-110.85	-111.74
19.84	-104.77	-111.71
19.89	-103.47	-111.67
19.99	-110.94	-111.61
20.04	-104.07	-111.58
20.09	-108.98	-111.55
20.19	-108.84	-111.48
20.25	-104.05	-111.45
20.30	-107.76	-111.42
20.35	-106.21	-111.39
20.40	-95.24	-111.36
20.45	-99.42	-111.33
20.50	-105.05	-111.30
20.55	-104.55	-111.26
20.60	-103.04	-111.23
20.65	-104.04	-111.20
20.81	-108.65	-111.11
20.86	-109.72	-111.08

Table 7 continued...

SM MAX FREQ[MHz]	SM PEAK[PSD]	SkyTmod+10[PSD]
20.91	-101.43	-111.05
20.96	-93.92	-111.01
21.01	-101.98	-110.98
21.06	-110.15	-110.95
21.22	-110.10	-110.86
21.27	-109.72	-110.83
21.32	-110.52	-110.80
21.37	-109.28	-110.77
21.42	-108.31	-110.73
21.47	-89.02	-110.70
21.52	-82.24	-110.67
21.57	-75.03	-110.64
21.62	-70.62	-110.61
21.67	-82.17	-110.58
21.78	-108.16	-110.52
21.88	-104.70	-110.46
21.93	-109.16	-110.43
21.98	-107.74	-110.40
22.08	-103.72	-110.33
22.13	-96.13	-110.30
22.18	-99.08	-110.27
22.24	-104.33	-110.24
22.29	-106.54	-110.21
22.34	-99.61	-110.18
22.39	-95.52	-110.15
22.44	-92.93	-110.12
22.49	-96.86	-110.09
22.54	-94.20	-110.06
22.59	-94.60	-110.03
22.64	-109.86	-110.00
22.69	-109.38	-109.97
22.75	-101.86	-109.94
22.85	-99.66	-109.87
22.90	-95.85	-109.84
22.95	-94.23	-109.81
23.00	-107.14	-109.78
23.05	-94.88	-109.75
23.10	-90.80	-109.72
23.15	-89.57	-109.69
23.21	-98.67	-109.66
23.26	-108.52	-109.63
23.31	-105.83	-109.60
23.36	-88.51	-109.57
23.41	-87.93	-109.54
23.46	-93.96	-109.51
23.51	-88.19	-109.48
23.56	-91.93	-109.45
23.61	-90.87	-109.42
23.66	-87.48	-109.39
23.72	-100.16	-109.36

Table 7 continued...

SM MAX FREQ[MHz]	SM PEAK[PSD]	SkyTmod+10[PSD]
23.82	-108.36	-109.30
23.87	-100.52	-109.27
23.92	-89.20	-109.24
23.97	-94.35	-109.21
24.02	-107.20	-109.18
24.07	-99.33	-109.15
24.12	-94.23	-109.12
24.17	-91.08	-109.09
24.23	-97.67	-109.06
24.28	-102.02	-109.03
24.68	-106.92	-108.80
26.57	-105.82	-107.82
32.90	-104.59	-106.16
75.91	-111.47	-112.34
108.01	-94.78	-114.29
108.06	-104.43	-114.29
108.11	-109.88	-114.30