LWA Equipment RF Emissions: Spectrum Analyzers and Laptops

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Summary

I report on measurements in the VLA shielded chamber of the radio frequency emission levels of spectrum analyzers and laptops. The aim of the measurements was to determine whether this type of equipment could be used at the LWDA site during standard VLA operations. Two brands of spectrum analyzers and laptop computers were measured, and the emission levels are similar in the different brands. The measured emissions are therefore considered typical of spectrum analyzers and laptops. The results of the measurements suggest that this type of equipment can be operated at the LWDA site during standard VLA observations.

1. Description of Performed Tests

The tests described in detail below are divided into three categories: a) high resolution bandwidth (RBW 100 Hz) emissions tests according to NRAO standards, b) low resolution bandwidth (RBW 10 kHz) emissions tests, and c) emissions tests using the VLA. The devices that were tested included an IBM Thinkpad laptop, a Macintosh Powerbook, a Rohde & Schwarz spectrum analyzer, and an HP 8590L spectrum analyzer. The test data was taken during 7/22/06 and 7/23/06.

1a. NRAO standard emissions test (100 Hz RBW)

The measurements were performed according to NRAO standard procedures for measuring emission levels of devices in the VLA shielded chamber. The details of the NRAO procedures were provided by Dan Mertely (NRAO), and are summarized here together with specific details of our tests.

The NRAO standard tests use two specific setups; one for each of the two frequency ranges 0-1 GHz and 1-20 GHz. 500 and 1900 points were recorded in the 0-1 GHz and 1-20 GHz setup respectively. Both setups used a 100 Hz resolution bandwidth (RBW) and 1 ksec sweep time. The VLA shielded chamber has no mode-stirrer, and instead each measurement was repeated three times with the receiving antenna placed at three different locations on the receiving end of the shielded chamber.

The device under test (DUT) was placed on top of a fiberglass cart, located at least 1 m from the walls of the chamber. The DUT was powered via a power supply located outside the chamber, connected via a bulkhead connection in the wall of the shielded chamber. The spectrum analyzers were fed with an incoming signal from a signal generator located outside the chamber. This signal was set to 2 GHz for the 0-1 GHz scans, and 0.1 GHz for measurements above 1GHz. No applications were running on the laptops during the measurements. However, the laptops were set not to enter a power-saving mode.

The receiving antenna was a broadband disc-cone antenna, which was placed at three different positions on the receiving end of the shielded chamber. The antenna was connected via a bulkhead connection in the wall to a HP 71210C spectrum analyzer, located outside the shielded chamber. Data taken from the spectrum analyzer were stored on a desktop computer. The HP 71210C pre-amplifier was switched off during the 0-1 GHz tests, and switched on during the 1-20 GHz tests. At all times, the peak hold mode was used on the spectrum analyzer.

The data analysis also follows NRAO standard procedures: For each spectral point the peak power of the three measurements is used. This ensures a worst-case scenario for the emission levels. This measured power is corrected for chamber insertion loss, a 300 m space loss to the nearest VLA antenna (CW7) and the shielding provided by the LWDA equipment shelter. The tested equipment will be operated inside this shelter, which provides a minimum of 30 dB shielding (Pihlström, Mertely & Aguilera 2006). The shielded chamber insertion losses have been measured by NRAO and were provided to us by Dan Mertely. After those corrections, we have the estimated resulting power incident at the nearest EVLA antenna. This value is compared to the allowed incident power determined from EVLA detrimental power flux densities (Perley 2002), assuming the RF will enter via a side lobe with 0 dBi gain.

Figure 1-4 show the results from the 0-1 and 1-20 GHz tests for the four devices respectively. With the narrow RBW and relatively few recorded points, the actual frequency coverage is coarse. Under the assumption that RFI is coarsely distributed and narrow banded, these results indicate that the emission levels will fall below the EVLA detrimental levels.

1b. Low resolution bandwidth measurements

In Sect. 1a, the underlying assumption is that RFI spikes are narrow and isolated across the band. Emissions from equipment such as laptops and spectrum analyzers might deviate from this assumption, additional measurements using 10 kHz RBW were therefore performed. A 10 kHz RBW corresponds better to the spectral resolutions used in the calculations of the EVLA detrimental levels (Perley 2002). Three frequency ranges were scanned, each with 2000 points: 1-3 GHz, 3-5 GHz and 0-1 GHz (sweep times 60, 60 and 120 sec respectively). The remaining test setup and the data analysis were identical to what is described in Sect. 1a.

Figures 5-8 display the results of these tests. An offset in the data can be seen at 1 GHz, which most likely is due to the fact there does not exist complete chamber calibration data (for every antenna at every frequency). Clearly, there is additional emission at frequencies not covered by the high RBW tests described in Sect. 1a. This suggest that the emission spectrum is not dominated by a few, isolated RFI spikes, but rather by a number of more densely packed spikes. The 10 kHz RBW used in this test setup is comparable to the 1 km/s spectral resolution used to calculate the EVLA detrimental levels (Perley 2002). Therefore, additional required shielding levels of the order of 15dB are implied.

1c. VLA observations

During VLA P-band and 4-band observations, NRAO require equipment such as PCs, laptops and spectrum analyzers to be turned off. During the night of 07/24/06, VLA observations was conducted by the PI Aaron Cohen, who is also associated with LWA. With the PI's permission, we used 20 minutes of the VLA P-band observations to see if RFI could be seen when we had our Sigmon RFI monitoring system up and running. The major components of this system are a spectrum analyzer and a laptop running control software. The system was run with the LWDA shelter door closed for 7 minutes, and then with the door open for 7 minutes. Even though the P-band observations do not fully correspond to the detrimental levels estimated for the VLA, it is comforting from Fig. 9 to see that no RFI from our RFI monitoring system could be detected even with the door to the shelter open.

2. Results and Conclusions

By following RFI measurement procedures suggested by NRAO, the data presented here show that laptops and spectrum analyzers do not generate RFI above the EVLA detrimental levels. This assumes operations within the LWDA shelter, and a space loss of 300 m to the nearest VLA antenna.

Additional measurements, performed with setup parameters more directly comparable to the assumptions made for calculating EVLA detrimental levels, indicate that an additional shielding of about 15 dB may be desirable. In this context, it should be pointed out that the 30 dB shielding assumed by the LWDA shelter are lower limit and on average the shelter shields 40 dB. Moreover, most VLA antennas are located on distances larger than 300 m from the LWDA shelter, thus having more shielding due to space loss.

At present NRAO does enforce any rules regarding operating laptops or spectrum analyzers at the VLA site. An exception is the request to switch off such equipment during P-band and 4-band observations. With our measurements we have shown that operating laptops and spectrum analyzers inside the LWDA shelter will, in the worst case, produce a few spikes ~15 dB above the EVLA detrimental levels at the W14 antenna. At most times we expect no harmful effects at all.

Given that this decision is supported by NRAO, these tests suggest that testing can be started at the LWDA site on a daily basis. Exceptions to this will be a) in the case of VLA P- and 4-band observations, and b) if NRAO will enforce general rules of operating laptops and similar equipment on the VLA site. If additional shielding will be requested in order to account for emission peaks that might occur at levels above the detrimental levels (Figs. 5-8), we should consider additional shielding of laptops and spectrum analyzers by placing them in boxes perhaps padded with carbon loaded foam.

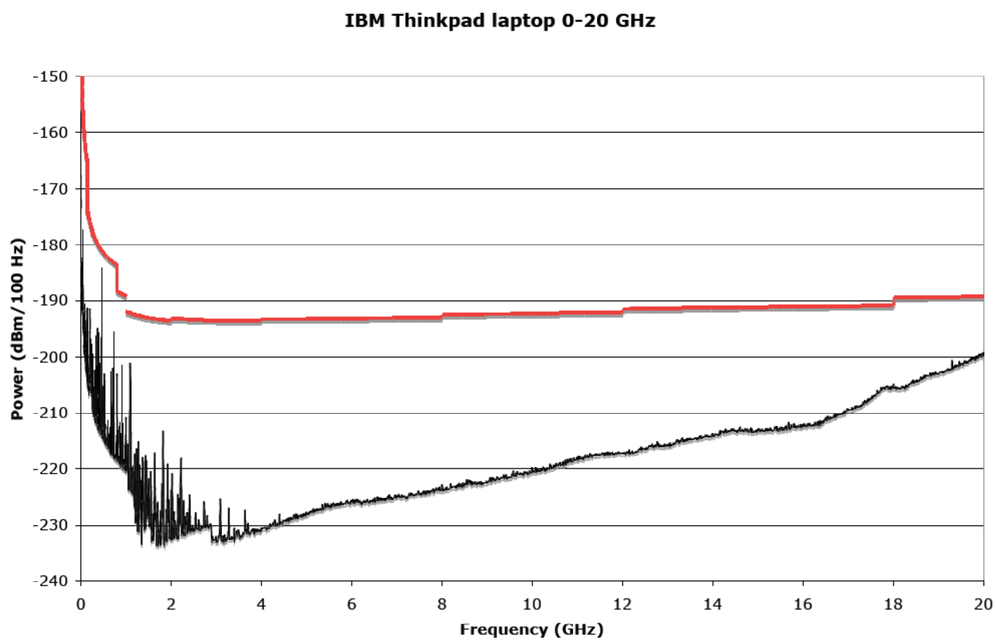

Figure 1: Emission levels of the IBM Thinkpad laptop in the 0-20 GHz range (100 Hz RBW). The solid, red line shows the EVLA detrimental levels.

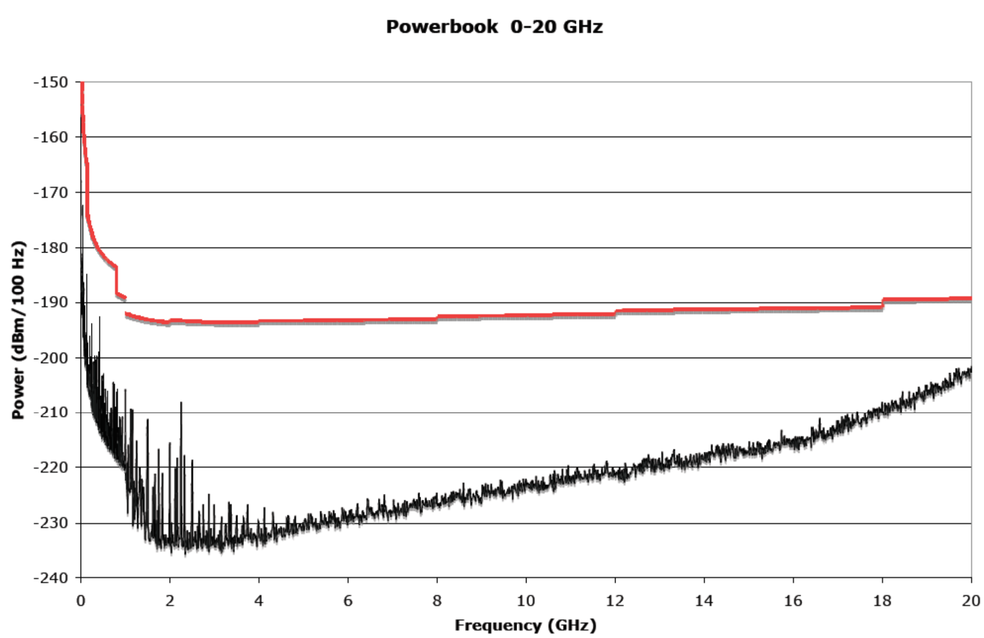

Figure 2: Emission levels of the Macintosh Powerbook in the 0-20 GHz range (100 Hz RBW). The solid, red line shows the EVLA detrimental levels.

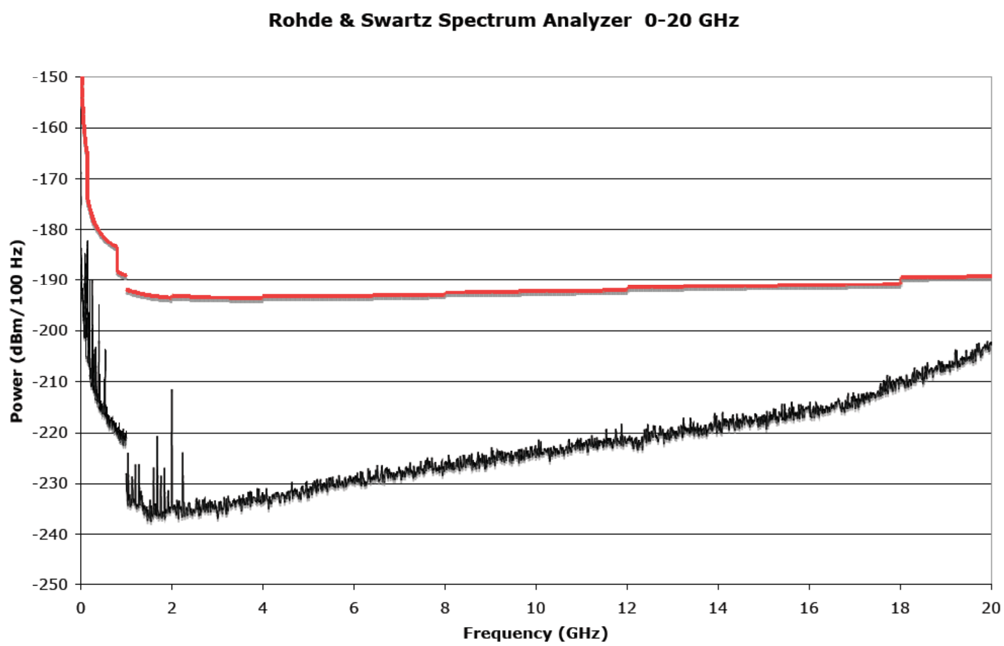

Figure 3: Emission levels of the Rohde & Schwarz spectrum analyzer in the 0-20 GHz range (100 Hz RBW). The solid, red line shows the EVLA detrimental levels.

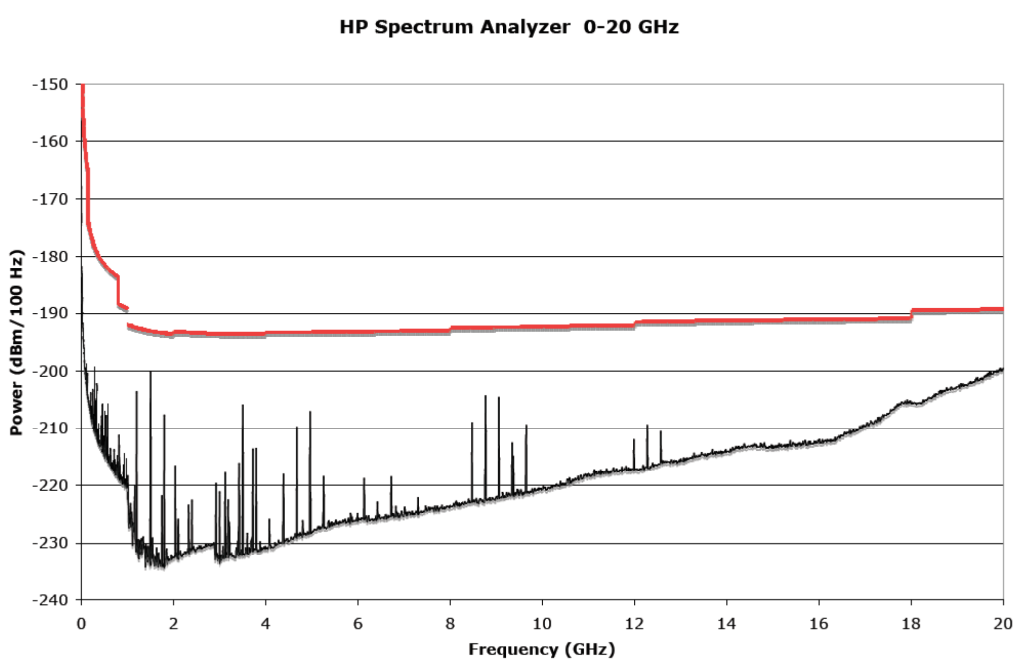

Figure 4: Emission levels of the HP spectrum analyzer in the 0-20 GHz range (100 Hz RBW). The solid, red line shows the EVLA detrimental levels.

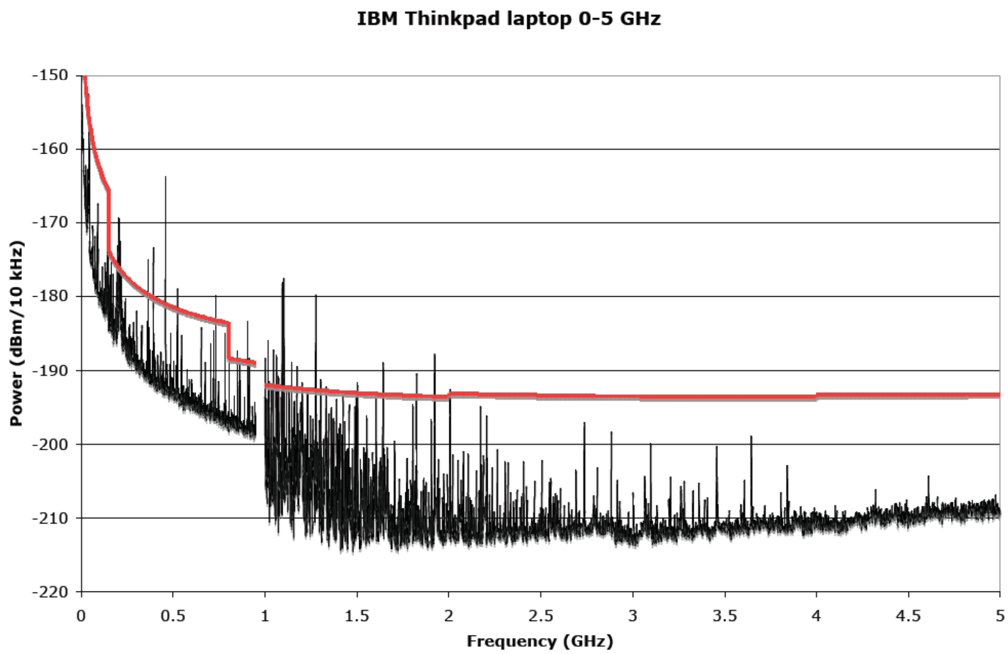

Figure 5: Emission levels of the IBM Thinkpad laptop in the 0-5 GHz range (10 kHz RBW). The solid, red line shows the EVLA detrimental levels.

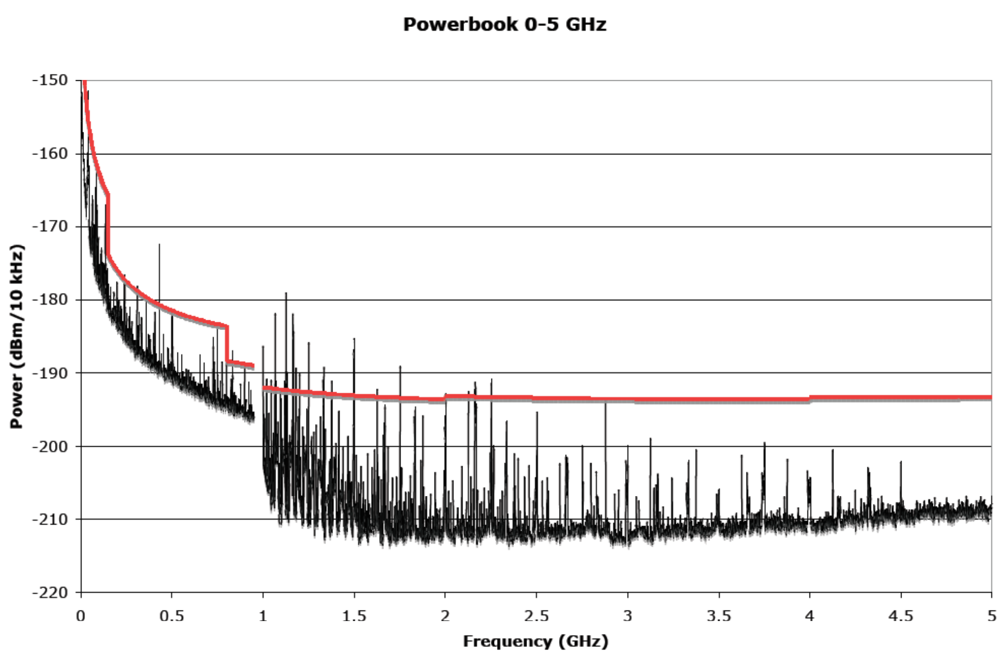

Figure 6: Emission levels of the Macintosh Powerbook in the 0-5 GHz range (10 kHz RBW). The solid, red line shows the EVLA detrimental levels.

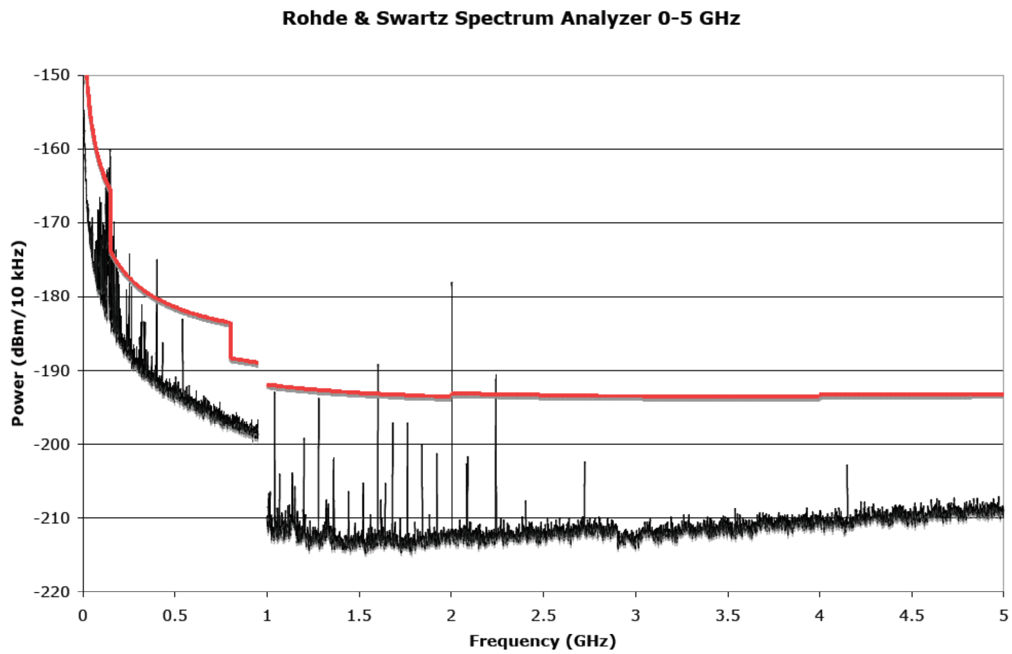

Figure 7: Emission levels of the Rohde & Schwarz spectrum analyzer in the 0-5 GHz range (10 kHz RBW). The solid, red line shows the EVLA detrimental levels.

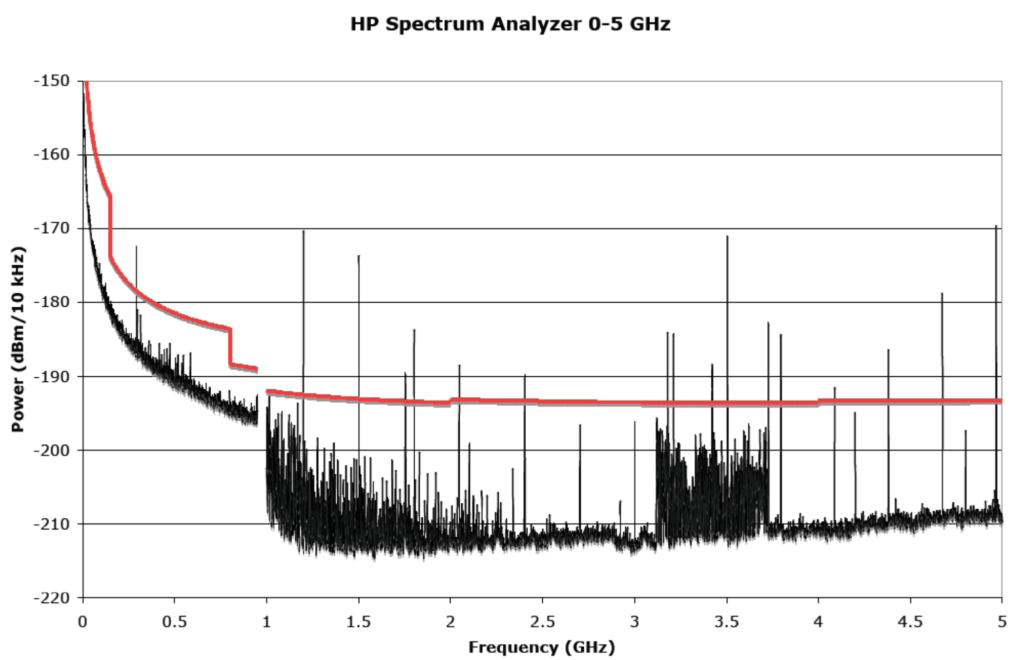

Figure 8: Emission levels of the HP spectrum analyzer in the 0-5 GHz range (10 kHz RBW). The solid, red line shows the EVLA detrimental levels.

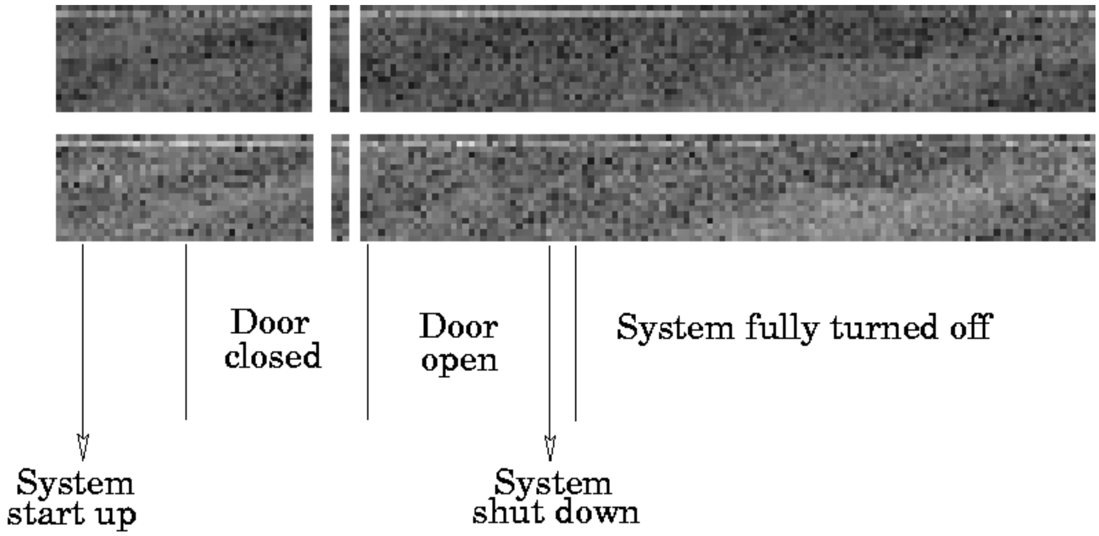

Figure 9: P-band spectrum plot (AIPS task SPFLG) of the raw amplitudes on the baseline closest to the LWDA shelter (right and left hand polarizations plotted individually). No difference can be seen when the Sigmon monitoring system is on or off, indicating little disturbance during typical P-band observations. X-axis is frequency, and time goes from 12:02AM to 12:42AM from left to right.

References:

Pihlström, Mertely & Aguilera, 2006, LWA Memo #51
Perley 2002, EVLA memo #46