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LWDA Site Trip Report

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1. Introduction

We visited the LWDA site from July 19th through July 24th, 2006. Our group included Namir Kassim, Paul Ray, Bill Erickson, Steve Ellingson, and Ylva Pihlström. Greg Taylor stopped by for an afternoon. In this trip report, we describe our activities at the site, the measurements we made, and note some lessons learned. A detailed analysis of the data will be presented elsewhere.

2. Initial Work

The first order of business was to construct the large blade antenna (see Figure 1). This went quite smoothly. We built it next to the shelter, then carried it out to its eventual location about 10 meters from the edge of the LWDA array. The cables from shelter to the blade were protected by 2 inch PVC conduit. Using a compass, and the shadow cast by the Sun at transit, we aligned the dipole with the North-South direction.

Fig. 1.— Constructing the big blade at the site.

We also worked with Tom Baldwin and James Robnett of NRAO to get the fiber internet to the site working. Thanks to good preparation and their expert help, this went very smoothly and a

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100 Mbit/s connection is now available in the hut via a 16-port switch that accepts up to 8 regular twisted pair (10/100Base-T) ethernet plugs and up to 8 SC-connector (100Base-FX) fiber internet connections (see Figure 2). We left two modest length cables in the shelter but a couple of longer ones would be a good addition. Computers connected to the switch that are configured to use DHCP will be assigned NRAO guest IP addresses that work fine for network access. Computers that are going to be resident in the shelter should have their MAC addresses given sent to Paul Ray and `helpdesk@aoc.nrao.edu` so that they can be assigned a static IP address (the range assigned to us is 146.88.201.32 to 146.88.201.39) and given a network name like `<machine>.vla.nrao.edu`. NRAO will then configure the DHCP server to always assign the static IP address to that MAC address, so no configuration changes need to be made on the computer itself. The LWDA site network configuration is documented on the LWA Wiki under the "Technical Discussion Board" (`http://www.phys.unm.edu/~lwa/phpwiki/index.php/Technical%20Discussion%20Board`).

Fig. 2.— The AT-8088/SC network switch in the shelter.

3. Measurements

3.1. Initial Measurements With Handheld SA

We began our measurements of the big blade antenna with Steve Ellingson's handheld spectrum analyzer and laptop with Labwindows/CVI program that he wrote. This program read sweeps from the spectrum analyzer and wrote them to simple (∼2kB) binary files as fast as it could, which turns out to be close to one file per second. The code configures the analyzer to have densely packed spectral channels (i.e. 301 points spaced by RBW, with VBW=RBW) across the observing band. The "sample" detector of the analyzer was used. For our observations we used an RBW of 300 kHz, which resulted in a frequency range of 10–100 MHz.

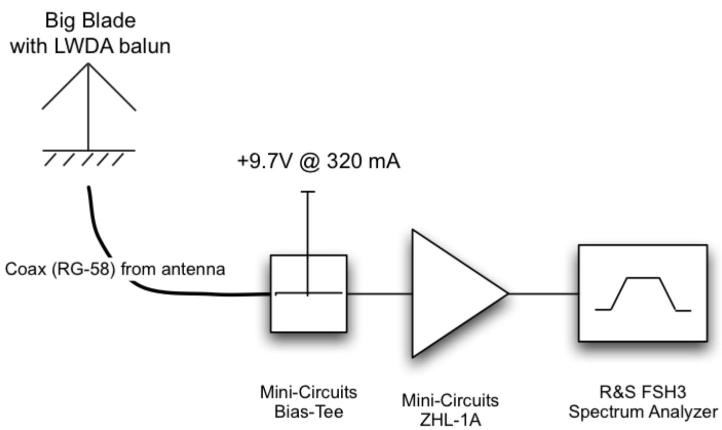

Fig. 3.— Diagram of experimental setup for big blade measurements.

Our experimental setup was as follows (see Figure 3). A big blade antenna was at the LWDA site, set up a few meters from the LWDA dipoles (see Figure 1), using the Hicks/Teletech balun, powered via a Mini-Circuits Bias-Tee with 9.7V at 320 mA. We used 90 feet + 20 feet of RG-58 cable to connect to the spectrum analyzer in the shelter with a MiniCircuits ZHL-1A amplifier. The spectrum analyzer was a handheld Rohde & Schwartz FSH3. The data files are named `xxxxxx_yymmdd.hhmmss.dat`, where `xxxxxx` is a sequence number, and the date/time recorded are EDT (which is local time +2hours, or UTC −4 hours). The data log is shown in Table 1.

A complete analysis of the data taken will be presented in a follow-up memo, so we just show some quick illustrative results here. Sample spectra from the big blade are shown in Figure 4. These spectra clearly show Galactic background noise dominated performance and a reasonable amount of rather clean spectral bins, despite the large resolution bandwidth of 300 kHz. For the LWA, we expect to use much finer resolution which will only increase the fraction of usable spectrum. Also obvious are RFI from the FM band, three TV channels, and HF transmissions below ~ 20 MHz.

We made some measurements that will allow modestly accurate calibration of the data. First, we took data with the balun inputs terminated with 50Ω loads, which approximate a 300 K effective temperature, shown in Figure 5. The total $T_{\rm sys}$ for the red curve should be ~ 300 K from the load plus ~ 255 K for the balun noise temperature, for a total of ~ 550 K. This indicates that the antenna temperature from the sky seems to stay several dB above the balun noise all the way to the top of the LWA operating band, which is great. For future reference, we note that the command used to make the figure was:

Table 1. FSH3 Data Log

Directory	Configuration
060719a	Short initial test run with antenna connected.
Sky noise measurements with ? dipole	
060719b	Balun inputs each terminated with 50 ohms
060719c	Short run with sky connected to Big Blade “B” (E-W) dipole
060719d	Long run 6:15pm - 11:34pm when program stopped writing files
060720a	Resume long run after 5 hour gap, 4:44am - 9:03am local time
060720b	Same, 9:04am - 9:46am local time
060720c	Balun inputs terminated with 50 ohms
060720d	Big Blade “A” dipole (N-S) on sky
060720e	Back to “B” dipole (E-W) to check RFI
Series of noise source measurements with +31 dB ENR noise source and HP var atten	
060720f	Noise source off
060720g	0 dB atten
060720h	10 dB atten
060720i	20 dB atten
060720h	30 dB atten
060720k	40 dB atten
060720l	50 dB atten
Sky noise measurements with E-W dipole	
060720m	On ”B” (E-W) dipole, 12:40pm - 4:19pm, local
060720n	4:19pm - 6:04pm
060720o	6:17pm - 11:13pm
060720p	11:15pm - 4:01am
060721a	4:02am - 8:32am
060721b	Balun inputs each terminated with 50 ohms
060721c	On ”B” (E-W) dipole 8:47am -
060721d	VLA arc welder experiment (but we didn’t start fast enough)
	10:06 power on, 10:09 arc on 1 min, 10:11 power off
060721e	VLA arc welder experiment second try
	10:24:50 welder on, 10:26:50 arc on, 10:27:50 arc off, 10:28:55 welder off

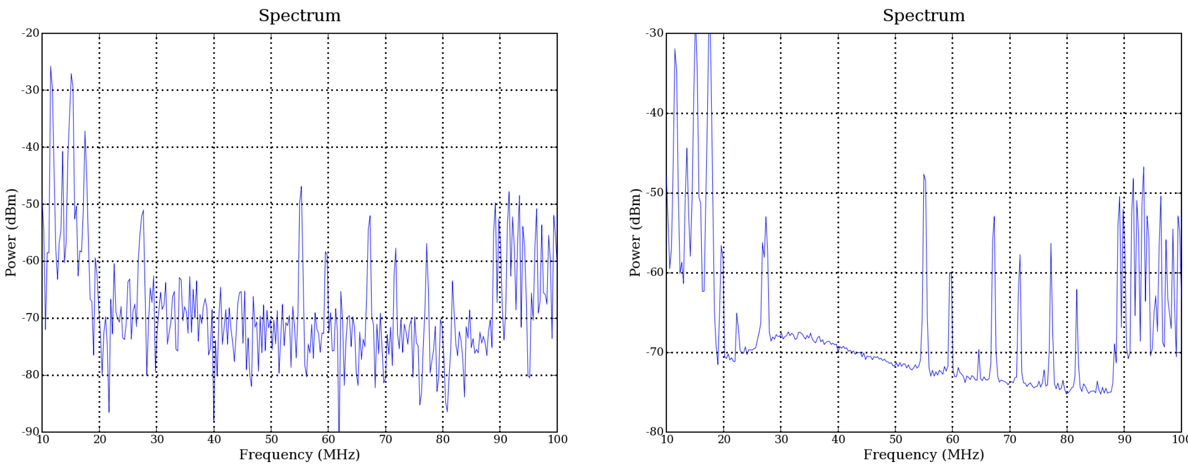

Fig. 4.— *Left*: A typical single sweep spectrum from the FSH3 spectrum analyzer. *Right*: The average of all 236 spectra taken in directory 060719c

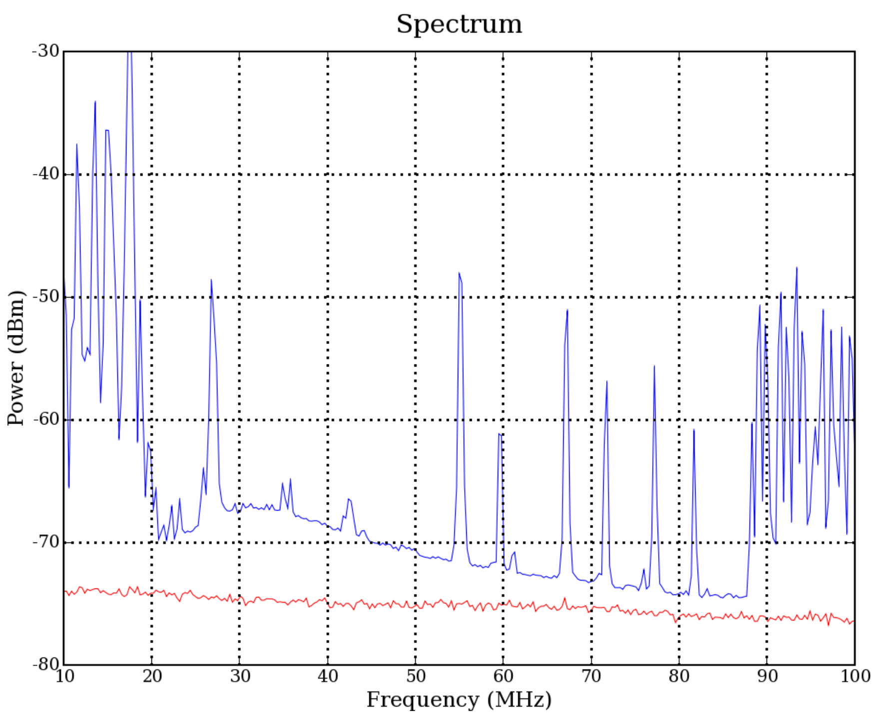

Fig. 5.— An average spectrum of the big blade (E-W dipole; directory 060720b) in blue, and the spectrum resulting from terminating the inputs of the balun with 50Ω loads in red.

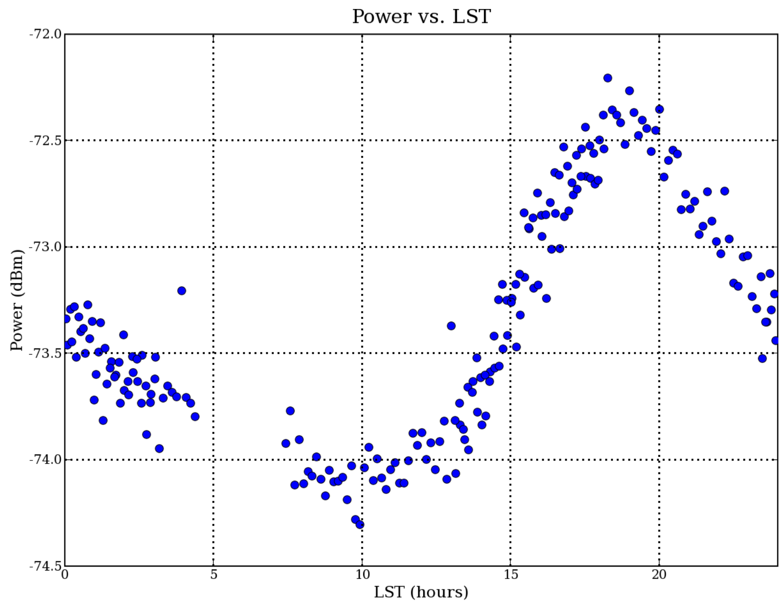

Fig. 6.— A plot of the power in the 74 MHz band as a function of local sidereal time. The observed [min,max] values at LST [11,18] hrs, respectively, are consistent with the projected motion of the Galactic plane on the sky as seen from the VLA site (e.g. Galactic center near 18h RA).

```
py se_plotavg.py -n 3600 -f list20b.txt -c calfiles19b20c.txt
```

In addition, we measured the round trip cable loss vs. frequency using the R&S tracking generator, as shown in in Figure 7. This information will be used in subsequent analysis to get absolute power levels of RFI at the balun inputs, for example.

Finally, we are able to make some nice dynamic spectra that show some good information about the time/frequency dependence of the RFI environment at the site, as seen by a big blade. An example is shown in Figure 8.

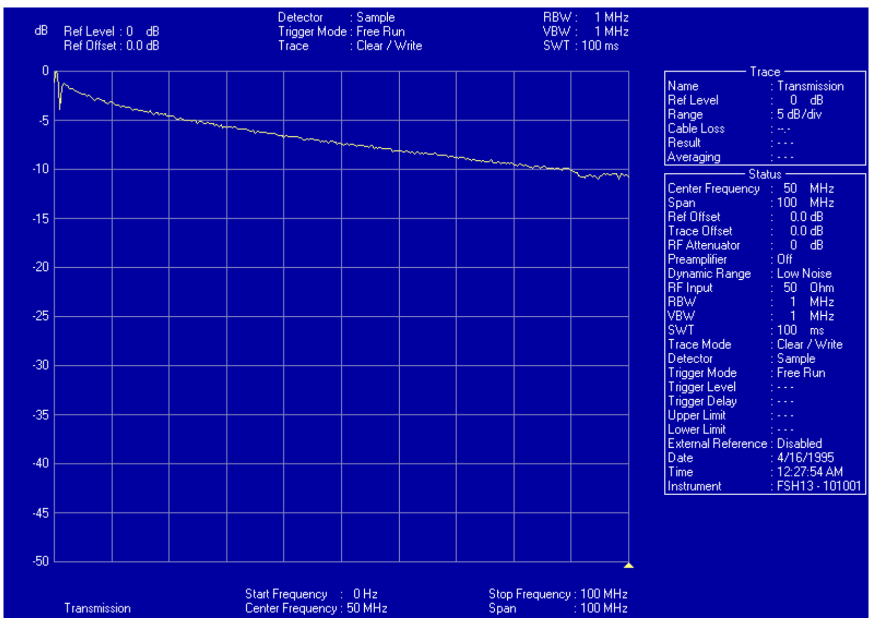

Fig. 7.— Cable loss measurement using the FSH3 and tracking generator. NOTE that this is the round trip cable loss, so that it is TWICE the loss that is experienced by signals from the sky!

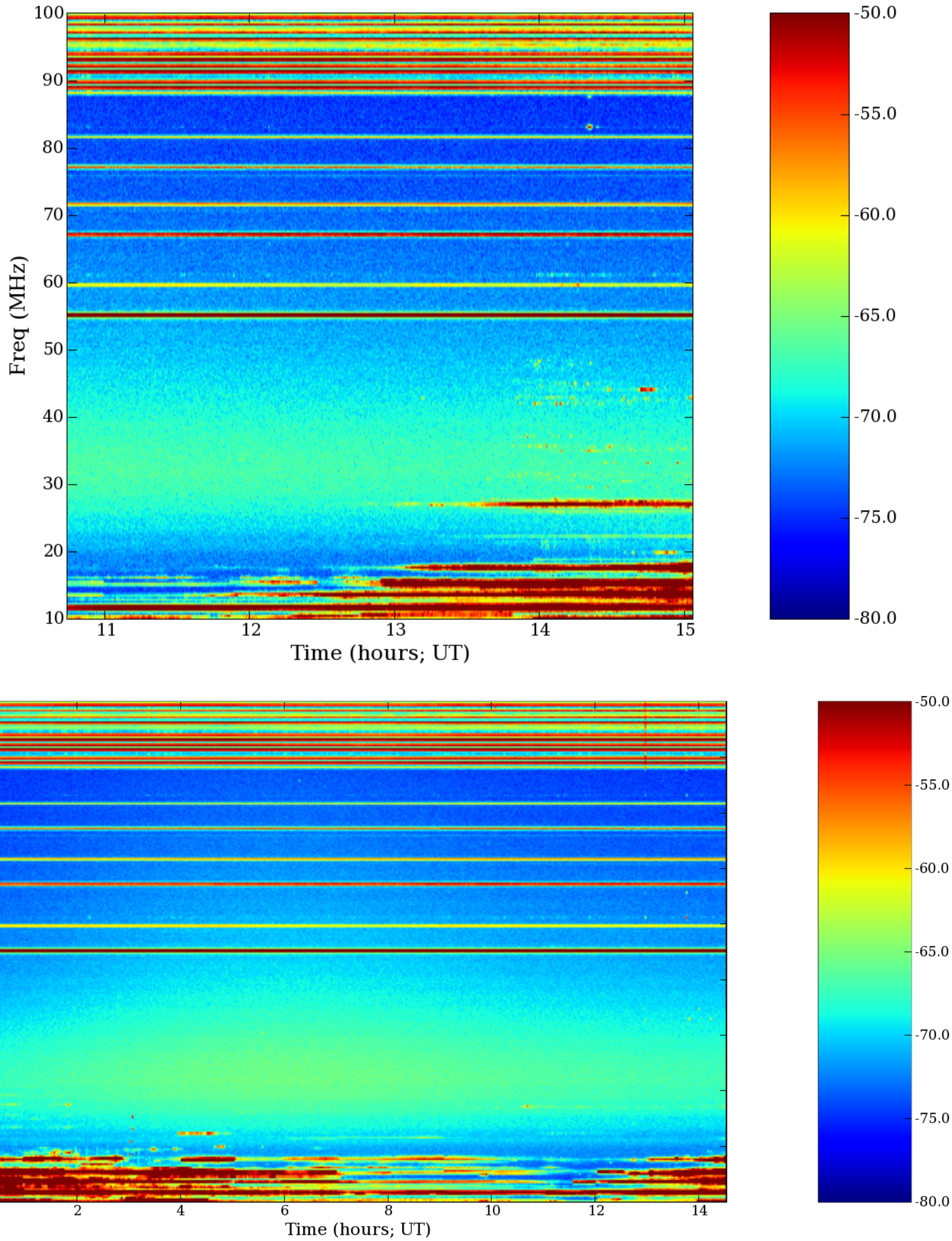

Fig. 8.— Dynamic spectra obtained with the big blade antenna showing the time dependence of the RFI and the diurnal variation in the Galactic noise level.

4. Set Up Long Term Measurements With Specmaster System

Our next task was to set up for longer term measurements with the SpecMaster system. The SpecMaster system will be fully documented in a separate Memo, so we just describe it briefly here. It consists of an Agilent E4440A Spectrum Analyzer controlled by a laptop PC running Windows and a custom LabWindows/CVI application written by Brian Hicks, which was based on a similar program written by Steve Ellingson. The laptop also controls a 4-port switch by means of a Measurement Computing USB digital I/O board. Thus, the system can make spectral measurements of up to 4 inputs and record the data, all under computer control. We can access the system remotely using Microsoft Remote Desktop.

We set up the SpecMaster to take data on two polarizations of an LWDA "small blade" (LWDA Antenna #3) as well as two polarizations of the big blade that we installed. The big blade used the same Mini-Circuits bias-Tee and preamplifiers (ZHL-1A) as the previous setup. The small blade used a custom bias-Tee built by Brian Hicks to power the balun, and the Mini-Circuits amplifiers supplied by ARL:UT for use in the LWDA analog chain to provide +22 dB of gain to bring the sky noise well above the noise floor of the spectrum analyzer.

The spectrum analyzer was set up to take 2000 points with a resolution bandwidth of 43 kHz, which densely samples the spectrum from 10 to 96 MHz. The analyzer internally averages 30 traces, using RMS power averaging and the "Sample" detector.

We started the long run on small and big blades on July 23rd around 12:30pm. To provide some initial calibration, we took short segments of data with each of the balun inputs terminated with a 50 Ω load. Specifically, the small Blade N-S was loaded between 12:33-12:38; the Big Blade N-S was loaded between 12:38-12:44; the small blade E-W was loaded from 12:45-12:48; and the big blade E-W, was loaded from 12:49-12:55. All antennas on sky and taking data starting at 12:59. The system was left in this configuration to run and take data until the next P-band VLA observation when we were required to shut down for RFI reasons. Sample spectra showing the difference between the big and small blades are shown in Figure 9.

4.1. LWDA Notes

We did not do any kind of exhaustive testing of the LWDA small blade antennas, baluns, and cables that are part of the LWDA system, but we did use a couple of them for our measurements. Here we simply note a few things we found in the course of our work:

- Antenna 5 has no balun. It is back at ARL:UT being repaired.
- One of the cables to antenna 1 seems to be bad. We troubleshot it for a while, and finally ended up terminating the cables with 50 ohms. The second (non-powered) cable showed an open circuit, while the other one looked fine.

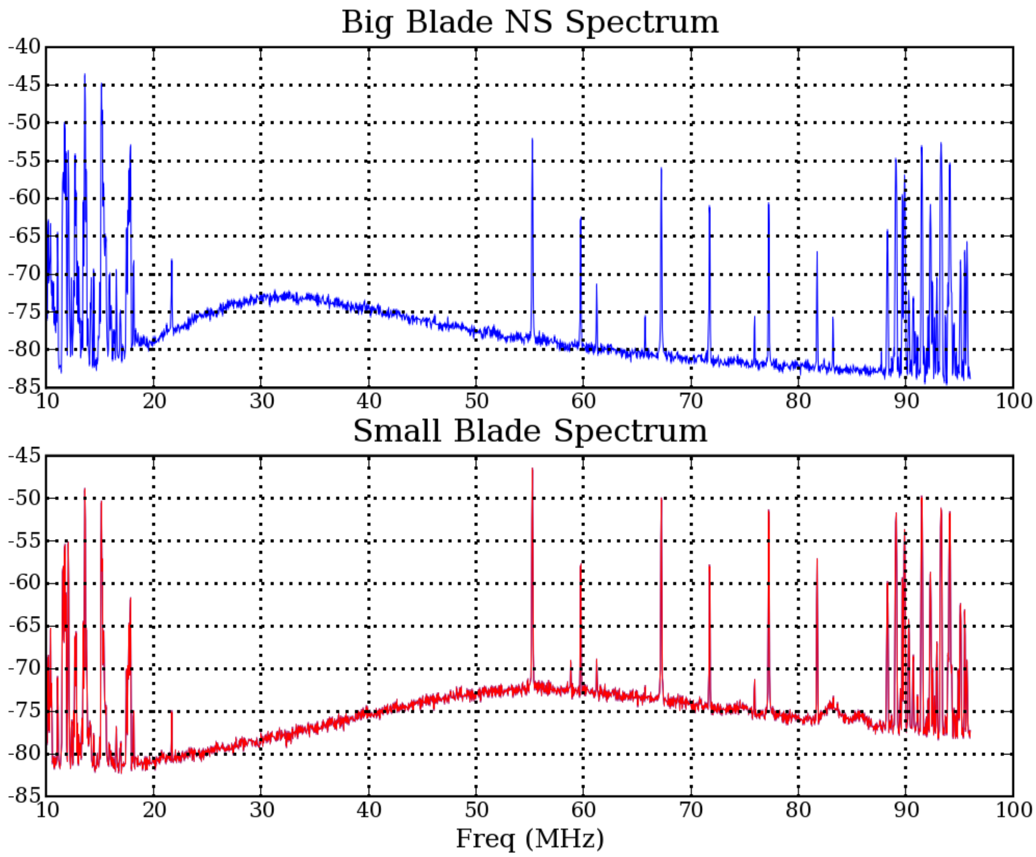

Fig. 9.— Example spectra, as recorded by the SpecMaster system of the N-S polarizations of the big and small blades. Note that the absolute levels are not directly comparable because of different amplifiers and cable lengths. The small blade has about 7 dB additional gain relative to the big blade.

- We found an impedance mismatch problem that was causing spectral ripples with period 2 MHz at the low frequency end of the spectrum in the channel with the bias-T. We fixed this by replacing the bias-Tee, so we suspect that the Aeroflex bias-T has poor performance down below 20 MHz. For future LWA work we recommend cheaper, custom bias-Tees that work down to low frequencies.

5. Lessons Learned and Future Work

The Specmaster system, remotely accessible via the internet, represents the first real continuous measurement capability we have at the LWDA site. This will be quickly followed up by the installation of the LWDA receivers. Our group was unanimous in strongly recommending that the LWA project work hard to maintain a continuous "on the air" status from this point forward, as we go from the Specmaster to the LWDA, to the LWA-1 and beyond. This will give our group a strong political presence, critical RFI monitoring, invaluable experience with remote operations, useful experience with environmental effects and equipment failure modes, and interesting science opportunities.

It is unfortunate that the LWDA Teletech baluns ended up being made without a voltage regulator, since this makes them difficult to power in parallel with different lengths of cable, and therefore different losses, to each one.

It is easy to get equipment confused in the shelter. We need to institute careful labeling of stuff at the site. The LWA project should order a bunch of different sized stickers for marking project-owned equipment. NRL has such stickers available and will use them on future trips. We put a couple of Sharpies in the shelter that we used for labeling various items.

Since the shelter lacks a standard telephone connection we found Skype to be an invaluable voice communication tool with the outside world. We established a Skype account for the laptop attached to the Specmaster (Skype-name "lwasite") and suggest this capability be maintained by any future laptops permanently located at the shelter. (Note the timely nature of an ongoing Skype promotion allowing free calls from computers to all US landlines.)

We adhered to an agreed RFI protocol with respect to possible harmful LWDA RF emissions, e.g. shutting down the Specmaster during 74 and 330 MHz VLA observations, keeping the shelter door closed as much as possible. During our visit we had an opportunity to run the system (with shelter door both open and closed) during a 330 MHz VLA observing run, with permission of the PI (Aaron Cohen). No harmful signs of RFI were detected in the VLA data stream, with special attention paid to antenna pairs close to the LWDA site. We also arranged (thanks to Dan Mertley of NRAO) to measure possible RFI from an active "HF" arc-welder at the VLA site complex (see Table 1), and were not able to see it with our Specmaster system, at least in an initial look at the data. In addition to these preliminary RFI measurements, a more rigourous series of tests are currently underway to characterize RF emissions at the LWDA site (led by Ylva Pihlström). Dan

Mertley is the NRAO contact for LWDA RFI issues and he visited us on several occasions during our tests - he was extremely helpful and we look forward to future continued close coordination with him on RFI issues.

Note, a digital TV channel appeared between before 1pm until about 2pm local time on July 22, 2006 (about 67-72 MHz). It seems likely that they were testing their digital TV transmitter in preparation for a switch to full time broadcasting. This is an important reason to have good, ongoing, RFI monitoring.

Here are some suggestions for equipment that would be very useful at the shelter for future work:

- A new laptop for the Specmaster. It should have USB2, microphone, speakers, PCMCIA port, optical drive, and must work without a battery.
- A couple of sheds, one for a workshop and another for storage
- Fly strips and a fly swatter
- More sturdy steps leading up to shelter entry.
- Battery powered drill
- Small UPS for test equipment
- Labels for equipment
- Longer ethernet cables
- 2 folding chairs (small)
- Banana plug to clip leads for power supply connections.
- Good 4-output lab power supply
- Small clamp that attaches to desk with a ball joint holder for soldering
- Broom
- Flashlight, perhaps one magnetic and attached to the outside of the shelter for night time shelter entry
- A remote-accessible power switch for turning off or power-cycling equipment when needed.
- Remote environmental and power monitoring, and a webcam pointing at the antennas.