Sky Noise Measurements with the LWDA Small Blade Antenna at the LWDA Site

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I. INTRODUCTION

This report summarizes the activities of our trip to the LWDA site in New Mexico in March, 2006. The purposes of this trip were to aid in the assembly of LWDA antennas, take sky noise measurements using one of the LWDA antennas, and participate in the visit of the International SKA Steering Committee (ISSC) to the LWDA site.

II. LWDA SMALL BLADE ANTENNA ASSEMBLY

Prior to the ISSC visit, we participated in the assembly and installation of eight of the LWDA small blade antennas. This work was done in collaboration with students and faculty from the University of New Mexico and was valuable in acquainting us with the final LWDA antenna design. Figure 1 shows a photograph of some of the assembled small blade antennas at the LWDA site. Hicks baluns assembled and packaged by *Tele-Tech* were mounted inside the antenna masts as shown in Figure 2.

Based on our experience with the assembly of the LWDA antennas, we have included a list of observations and suggested modifications to be integrated into the antenna and balun design as the development of the LWA active antenna progresses.

- An improved feed point connection scheme needs to be developed for the balun inputs. The "pigtails" – short sections of unshielded wire with SMA connectors on one end and eyelets on the other – presently used were cumbersome and delicate to handle during our testing. We will develop a more direct feed point connection scheme for future balun revisions and will also investigate the use of metal strips to connect between the balun and radiating elements.
- We anticipate that the next balun design will incorporate type 'F' connectors for both output connections. This will facilitate the use of the inexpensive 75Ω dual-coax cable that has been characterized by Richard Bradley's team at NRAO-Charlottesville. The new output connection scheme will not incorporate a bias tee network, but will instead utilize the solid ground conductor included with the dual-coax cable to provide power to the balun. Output connections will be conspicuously marked to avoid accidental reversal of polarization outputs during installation.
- The mast structure for the small blade antenna proved to be very solid. Care was taken in the mast design to minimize the number of hand tools required for assembly, but we found that the sheer number of parts made assembly difficult. It is hoped that future designs will be more straightforward to deploy while maintaining the durable characteristics of the present mast.

III. SKY NOISE MEASUREMENTS AT THE LWDA SITE

A portion of our time at the LWDA site was dedicated to obtaining sky noise measurements using the small blade antenna and the Hicks balun. A diagram of our measurement system is shown in Figure 3. A *Tele-Tech* packaged Hicks balun was used for these measurements. This balun featured a bias tee integrated into one of the balun output ports, which allowed us to provide DC power to the balun and extract the RF signal detected by the antenna using a single coaxial line. The second balun output port was terminated with a 50Ω load. The RF signals detected by the antenna were transmitted over 200 ft. of RG-213 coaxial cable to a Rohde & Schwarz spectrum analyzer. A bias tee from *Mini-Circuits* was

Fig. 1. A photograph of the small blade antennas at the LWDA site. There are currently a total of 16 of these antennas at the site.

Fig. 2. A closeup of the Hicks balun mounted inside the mast of one of the blade antennas. The baluns are held in place with a metal bracket. Connections between the balun and the blades are established via "pigtails" – short sections of unshielded wire with SMA connectors on one end and eyelets on the other. The masts are then covered with a molded plastic cap (shown in Figure 1) to protect the balun from the weather.

used to separate the DC power from the RF signals being sent into the spectrum analyzer. A *Miteq* 30 dB amplifier was used to bring signal power levels above the noise floor of the spectrum analyzer. Finally, a laptop computer was connected to the spectrum analyzer to record data.

A sample spectrum from our measurements is shown in Figure 4. Prominent features of the spectrum are labelled in the Figure. Audio and video carriers for television channels 2, 4, and 6 are clearly visible in the spectrum along with international communication signals below 20 MHz. The FM radio band can also be seen above 88 MHz.

Table I details the gain budget of the measurement system. Subtracting the gain of the measurement system from the power levels in Figure 4 yields the power levels of the signals detected directly at the antenna feedpoint, as shown in Figure 5. This Figure also includes simulated predictions based on

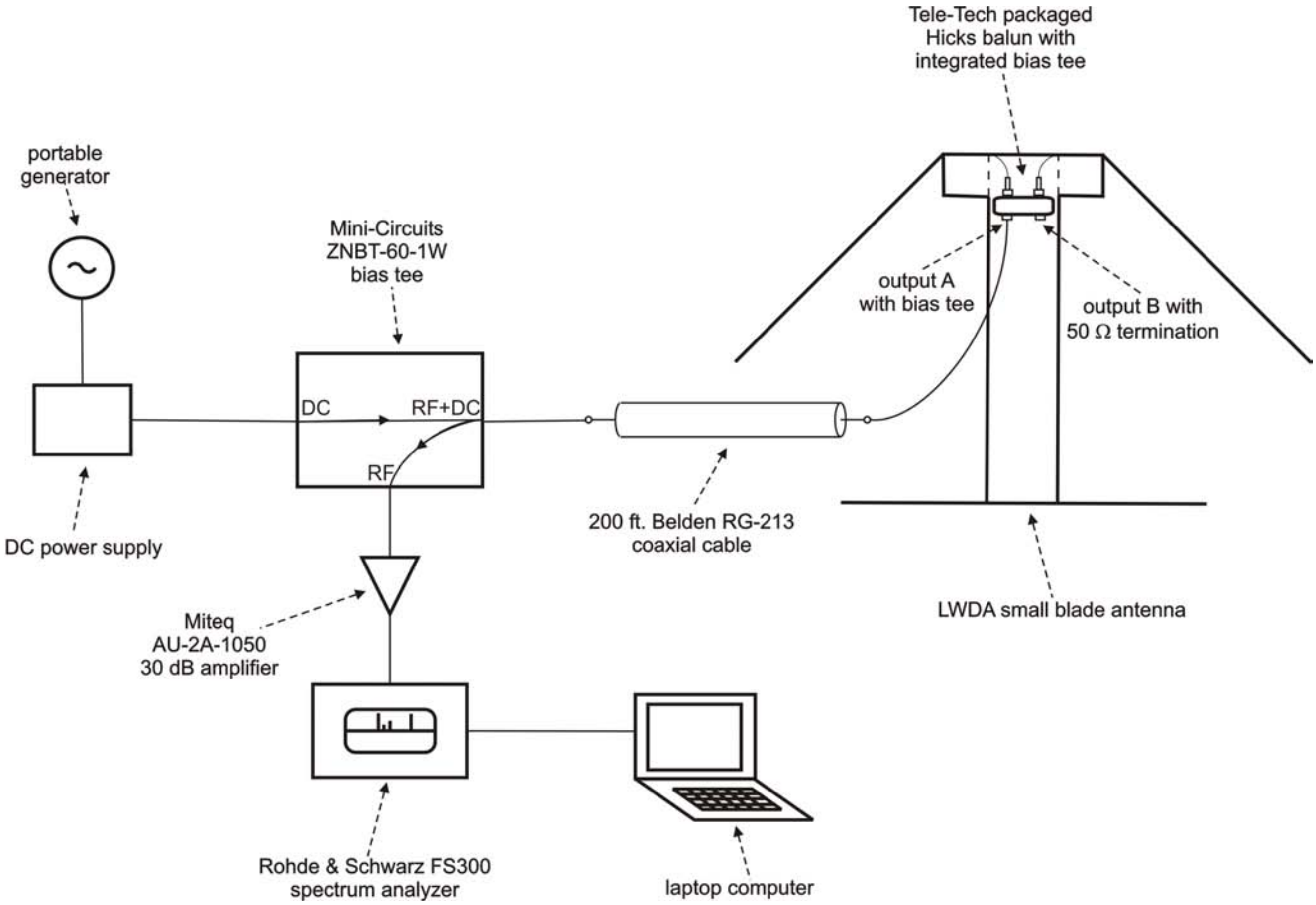

Fig. 3. This measurement system was used to perform sky noise measurements at using the LWDA antenna and the Hicks balun at the LWDA site.

TABLE I

GAIN BUDGET OF SKY NOISE MEASUREMENT SYSTEM

Component	Gain
Hicks balun	24 dB
Miteq AU-2A-0150 2^{nd} stage amplifier	30 dB
Belden RG-213 coaxial cable (200 ft.) (specified at 50 MHz)	-2.6 dB
Mini-Circuits ZNBT-60-1W bias tee	-0.2 dB
Total system gain	51.2 dB

models of the small blade antenna on earth ground from *EZ NEC* and Cane's model of the galactic noise temperature [1], [2]. Details on the calculations are given in the Appendix.

Discrepancies between simulation and measurement can be explained by a few factors. First, the noise Figure of the Hicks balun (given in Table II in the Appendix) is specified for a 50Ω load and is assumed not to be a function of frequency. Since the antenna impedance is not 50Ω, the balun noise will be higher than the value used in the calculations. Second, the galactic noise temperature model based on Cane's model represents the minimum noise temperature, not its variation as the galactic center rises and sets. Third, the cable attenuation was assumed to be constant over the 10 MHz – 100 MHz band when in reality, it varies by about 1 dB. Finally, the spectrum analyzer has a specified uncertainly of 1.5 dB.

IV. THE ISSC VISIT TO THE LWDA SITE

On March 15, 2006, the International SKA Steering Committee toured the LWDA site. This was the first major showing of the LWDA site to scientists who are not participants in the LWA project. We

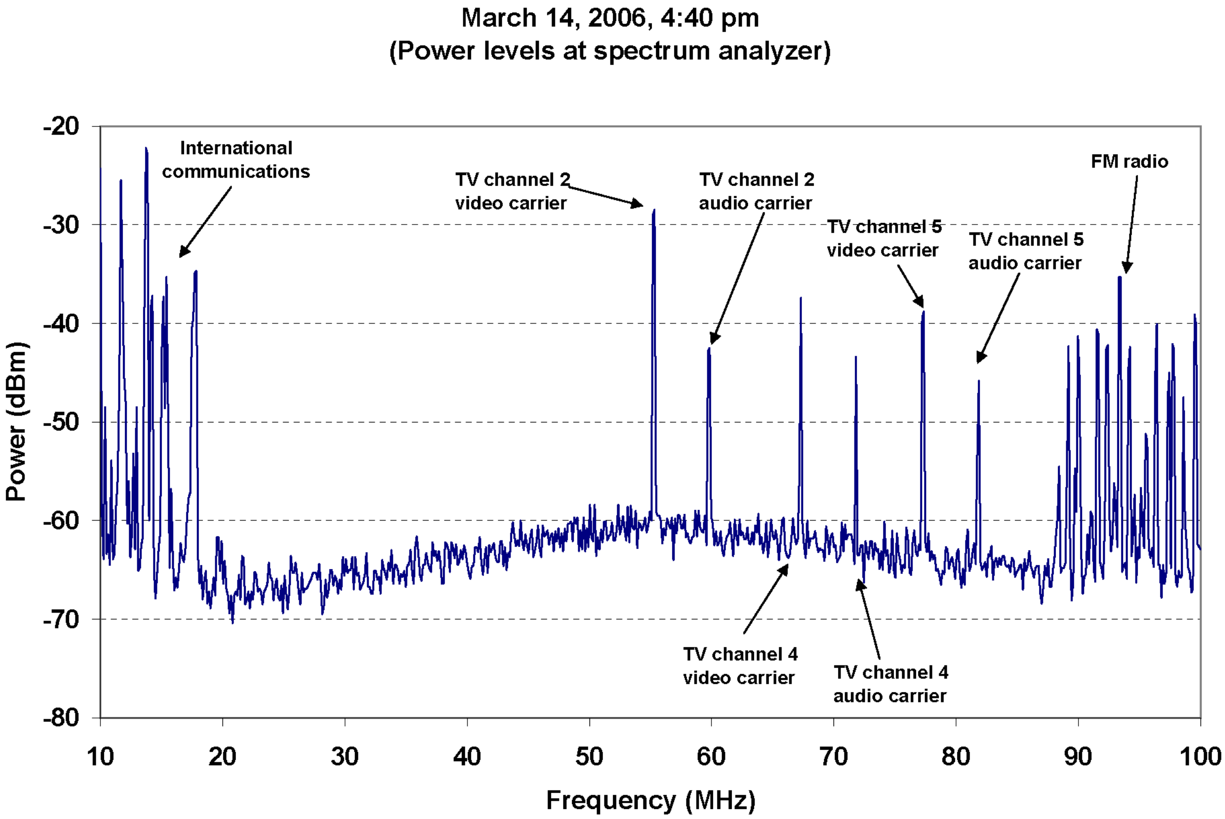

Fig. 4. A sample spectrum taken at the LWDA site with the small LWDA antenna and the Hicks balun. These power levels correspond to the spectrum analyzer input, and take into account the gain of the measurement system (shown in Table I).

felt that the overall interest in the LWA was quite positive. We look forward to further interactions with members of the low frequency radio astronomy community as the LWA project moves forward.

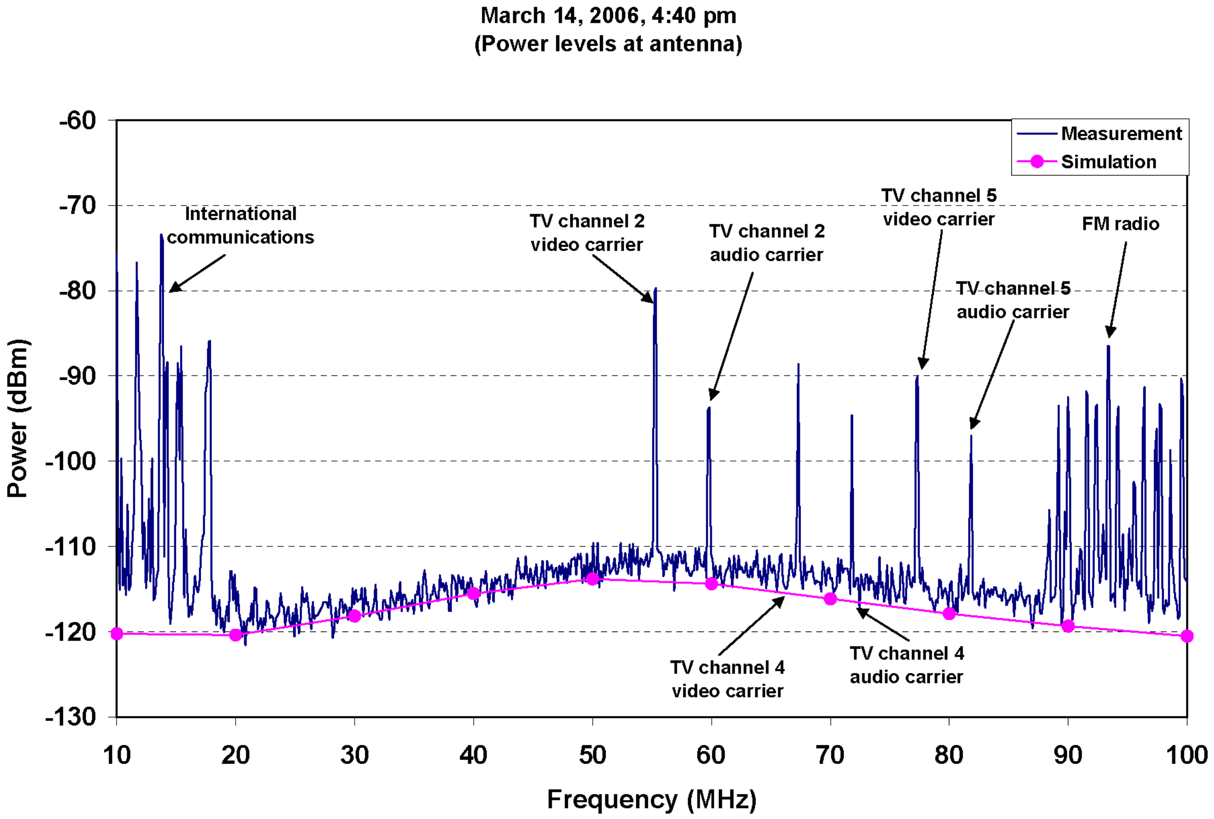

Fig. 5. A sample spectrum taken at the LWDA site with the small LWDA antenna and the Hicks balun. These are the power levels directly detected at the antenna feedpoint, before amplification by the Hicks balun and *Miteq* amplifier. Simulations based on *EZ NEC* models of the small blade are also shown. Details on the calculation of the simulated curve are given the Appendix

TABLE II

NOISE FIGURES, NOISE TEMPERATURES AND GAINS OF SKY NOISE MEASUREMENT SYSTEM

Component	Noise Temperature	Noise Figure	Gain
Hicks balun	250 K	2.4 dB	24 dB
Miteq AU-2A-0150 2^{nd} stage amplifier	110 K	1.4 dB	30 dB

APPENDIX

Calculating the Detected Power at the Antenna Based on Cane's Galactic Noise Model, Antenna Simulations and System Noise Analysis

In order to generate the theoretical curve in Figure 5, it was necessary to account for the galactic noise temperature at the antenna input as well as the noise in the measurement system [3].

Power due to galactic noise is given by equation 1

$$P_{galaxy} = k * T_{galaxy}(1 - \Gamma^2_{antenna}) * B \tag{1}$$

where k is Boltzmann's constant, B is the resolution bandwidth of our measurement (30kHz), $\Gamma_{antenna}$ is the antenna reflection coefficient based on *EZ NEC* simulations of the LWDA antenna on Earth ground ($\sigma = 0.005$ S/m, $\epsilon_r = 13$), and T_{galaxy} is the galactic noise temperature obtained from Cane's model [1].

Taking only the active components of the measurement system (the Hicks balun and the *Miteq* amplifier) into account, the system noise temperature is given by equation 2

$$T_{sys} = T_{balun} + \frac{T_{Miteqamp}}{G_{balun}} \tag{2}$$

where T_{balun} and $T_{Miteqamp}$ are the noise temperatures of the Hicks balun and *Miteq* amplifier respectively, and G_{balun} is the gain of the Hicks balun. All of these values are given in Table II.

The total system noise temperature, including the contribution of the lossy passive components (the RG-213 coaxial cable and the *Mini-Circuits* bias tee) is given by equation 3

$$T_{systotal} = (L - 1)T_{phys} + LT_{sys} \tag{3}$$

where L is the total cable and bias tee attenuation given in Table I and is equal to 1.9 (or 2.8 dB), T_{phys} is the physical temperature of the cable and bias tee (290 K), and T_{sys} is given in equation 2. For the measurement system shown in Figure 3, $T_{systotal} = 740$ K.

The corresponding noise temperature (in dB) is given by equation 4.

$$NF_{systotal} = 10 * log\left[\frac{T_{systotal}}{290K} + 1\right] \tag{4}$$

For the measurement system shown in Figure 3, $NF_{systotal} = 5.5$ dB. Converting P_{galaxy} in equation 1 to units of dBm and adding $NF_{systotal}$ yields the simulated curve in Figure 5.

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