

RECENT PROGRESS IN ACTIVE ANTENNA DESIGNS FOR THE LONG WAVELENGTH ARRAY (LWA)

K. P. Stewart¹, B. Hicks¹, N. Paravastu¹, R. F. Bradley², C. R. Parashare², W. C. Erickson³, C. Gross¹, E. Polisensky¹, P. C. Crane¹, P. S. Ray¹, N. E. Kassim¹, K. W. Weiler¹

¹*Naval Research Laboratory
4555 Overlook Ave SW
Washington, DC 20375 USA
ken.stewart@nrl.navy.mil*

²*National Radio Astronomy Observatory
Charlottesville, VA, USA*

³*University of Tasmania
Hobart, Australia*

ABSTRACT

We present new designs for active antenna systems optimized for HF/VHF radio astronomy, ionospheric science, space weather, and other radio science applications. Active antenna designs have been developed and tested which satisfy the need for high linearity and stability while achieving Galactic background dominated noise levels. The presence of very strong terrestrial radio-frequency interference (RFI), and world-wide propagation at these frequencies require that the preamplifiers have very high dynamic range. Distortion products must be below the Galactic background level for RFI mitigation techniques to be successful. Individual antennas should have broad response patterns to cover most of the sky without pointing mechanisms, but with decreased sensitivity at low elevations. Ideal designs would also be immune to environmental effects such as temperature variations and precipitation. For projects such as the LWA, where thousands of receptors will be needed, they must also be robust, inexpensive, and easy to manufacture and install. We discuss high-performance designs that are optimized for cost-sensitive applications such as the LWA.

INTRODUCTION

The LWA will be a new multi-element, synthesis-imaging telescope for radio astronomy at dekameter/meter wavelengths. It will provide higher resolution and sensitivity than any existing low-frequency telescope. Digital hardware and software will enable pointing and frequency agility with multi-beaming capability allowing simultaneous, full-sensitivity observations in widely separated directions. The final system will involve thousands of receiving elements with dual-polarized receptors covering the frequency range from 23 to 80 MHz.

The LWA will investigate the high-redshift universe, the epoch of reionization, transient sources, and the interstellar medium. It will be a powerful instrument for solar radio studies as well as ionospheric and space weather research (Kassim [1]).

This paper describes the active antennas that have been designed for the Long Wavelength Demonstration Array (LWDA) currently under construction near the Very Large Array (VLA) in New Mexico, USA. The LWDA station will have 128 antennas in a random pattern within a 50 m radius arranged to minimize the sidelobes of the array response pattern.

ANTENNA DESIGN

Fig. 1 shows a drawing of the LWDA “blade” antenna design. Each dual-polarized antenna consists of two dipoles, positioned orthogonally about a vertical axis. Each dipole arm is an Al plate 105 cm long and 28 cm wide, tapering to a point where it attaches to the mast. The arms are inclined 45° below horizontal to broaden the e-plane response and increase sky coverage. The feedpoint is 1.1 m above the ground. The active balun is designed to fit inside the 10 cm square mast at the feedpoint between the dipole arms.

Research in radio astronomy at the Naval Research Laboratory is supported by funding from the Office of Naval Research.

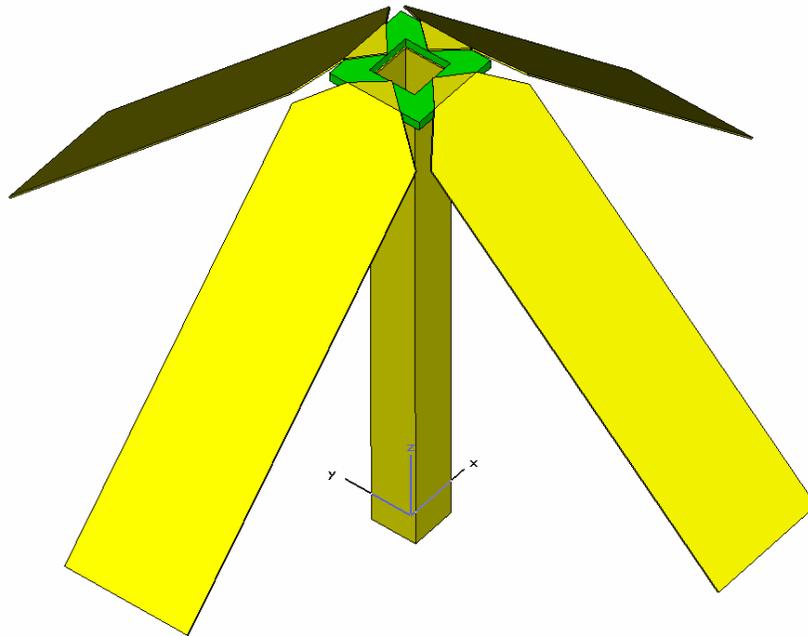


Fig. 1. LWDA blade antenna design. The mast height is 1.1 m. The maximum blade width is 28 cm. The total blade length is 105 cm with a 45° taper at the feed points. The Al mast is 10 cm square.

Two different software packages, CST Microwave Studio and NEC-4, were used to simulate the performance of the antennas. Fig. 2 shows the good agreement between the measured and calculated feedpoint impedance. The measurement was done outdoors over average ground. An infinite, zero-resistance ground plane was assumed for the Microwave Studio numerical results shown in the figure.

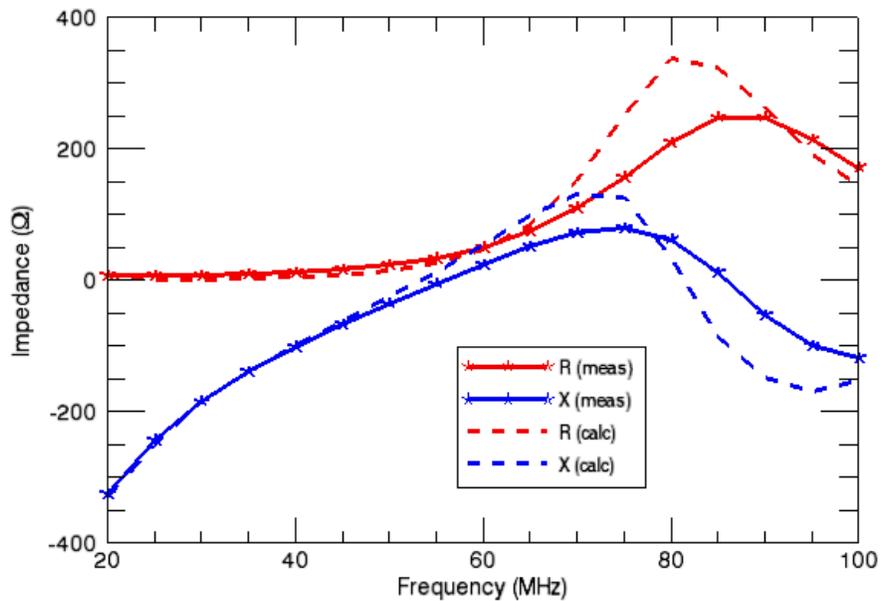


Fig. 2. Measured and calculated impedance of the blade antenna.

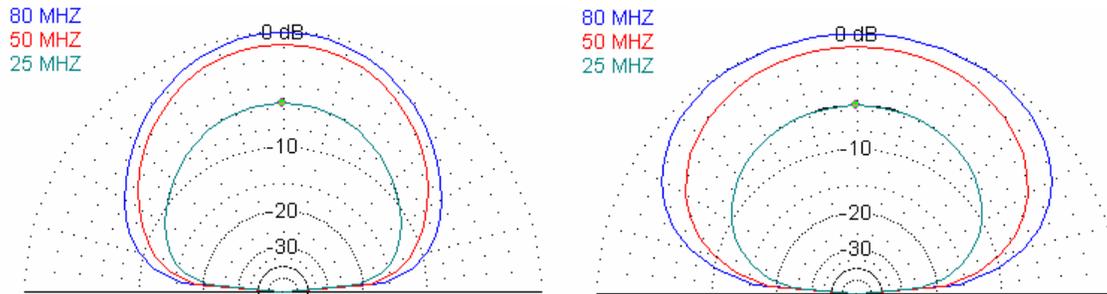


Fig. 3. E-plane (left) and H-plane (right) response of the antennas at 25, 50, and 80 MHz.

NEC-4 was used to calculate the response patterns of the antennas over average soil with a dielectric constant of 13 and a conductivity of 5 mS/m. Fig. 3 shows the predicted 3 dB beam widths of approximately 80° (E-plane) and 110° (H-plane), between 25 and 80 MHz.

DUAL-POLARIZATION BALUN DESIGN

The most recent balun developed for LWDA prototyping (Fig. 4) is a high-linearity, low-noise device based on inexpensive MMIC amplifiers, since cost and physical space constraints are major considerations in this effort. The primary components in this design are Minicircuits Gali-74 amplifiers and a Tele-Tech HX68A Magic-T Hybrid. The balun is configured with feedpoints capacitively coupled to the amplifiers with the outputs connected to the hybrid in a push-pull arrangement to increase the IP2. Care was taken to avoid asymmetries in the layout and to arrange bias networks orthogonally. Feedpoint connections to the dipole arms are made at the top of the unit, with output and power connections exiting from the bottom of the unit inside the mast. To facilitate efficient manufacture, a novel layout scheme was developed that allows two identical single-sided boards to be populated independently. The circuit boards are then assembled with their ground planes facing each other and rotated 90°. Power is passed through isolated pads in the ground plane which align when the boards are assembled. To maintain 50 ohm stripline connections throughout the circuit that match component widths, 39 mil circuit board stock was used.

Table 1. Fundamental Characteristics of MMIC based Dual Polarization Balun

Nominal Gain	24.5 dB
Average Noise Temperature	250 K from 10 to 90 MHz
Input 1 dB Compression Point	-5 dBm
Input 2 nd Order Intercept (IP2)	+19 dBm
Input 3 rd Order Intercept (IP3)	+7.5 dBm

Bradley and Parashare [2] extensively characterized the performance of this unit (Table 1). The gain of the unit is flat to within approximately 1 dB over the 10 to 90 MHz range with the phase balanced to within 3° (Fig. 5). The system noise temperature is 250 ± 10 K from 20 MHz to greater than 160 MHz (Fig. 6).

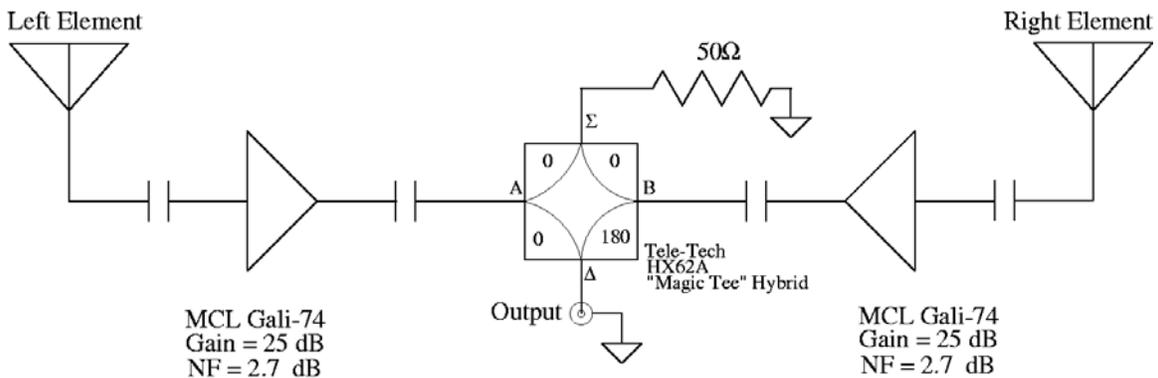


Fig. 4. Block diagram of the LWDA active balun.

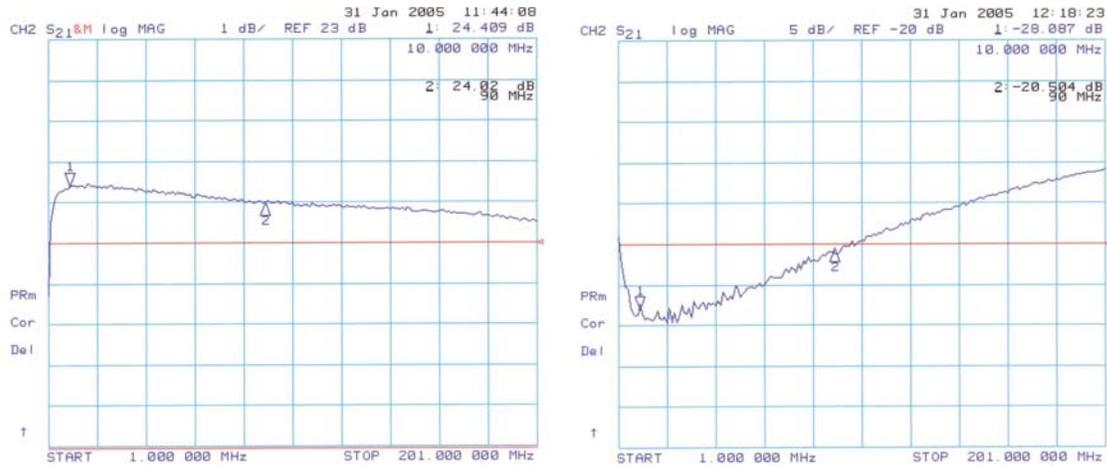


Fig. 5. Gain (left) and phase shift (right) as a function of frequency from 1 to 201 MHz.

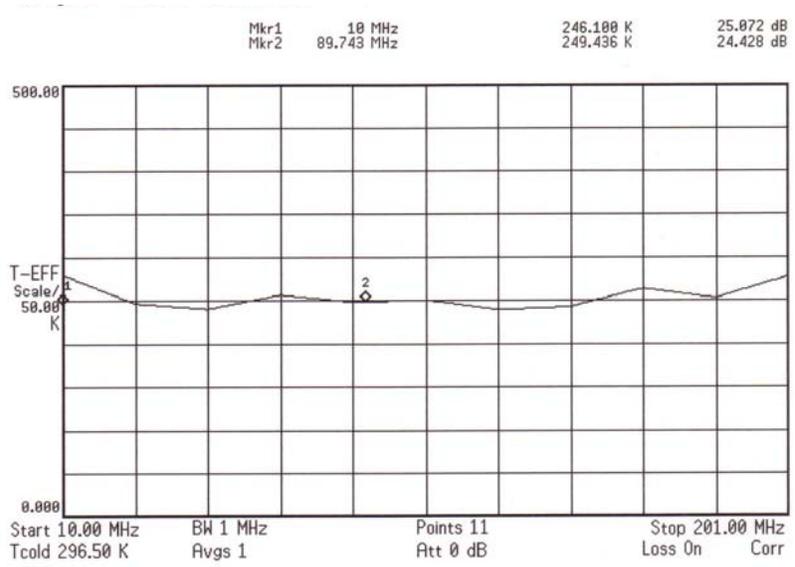


Fig. 6. Measured noise temperature of the active balun.

CONCLUSION

We have designed an active dipole antenna system that can be used in radio science applications that have stringent system noise and linearity requirements. The immediate planned application is the Long Wavelength Demonstration Array, which is currently being designed and built on the VLA site near Socorro, NM. Prototypes have been constructed and field tests are underway to explore the electromagnetic properties of this active antenna system and provide crucial insight into the expected behavior of the LWDA.

REFERENCES

- [1] N. E. Kassim, *et al.*, "The low-frequency array (LOFAR): opening a new window on the universe," *Planetary and Space Science*, vol. **52**, pp.1343–1349, 2004.
- [2] R.F. Bradley and C.R. Parashare, "Evaluation of the NRL LWA Active Balun Prototype", NRAO NTC-DSL Laboratory Report 01, Rev. A, February 2005.