ACTIVE BALUN/DIPOLE DEVELOPMENT FOR THE LOW FREQUENCY ARRAY*

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ABSTRACT

We are developing and testing active baluns and electrically short dipoles for possible use as the primary wideband receiving elements in the Low Frequency Array (LOFAR) for long wavelength radio astronomy. Two dipoles, with dimensions scaled approximately by a factor of three, have been built and tested. Their useful range occurs when the dipole arms are approximately 1/8 to 1/2 wavelength long. The antenna temperatures vary from about 25 % to 100 % of the average brightness temperature of the Galactic background. With these parameters it is easy to make the amplifier noise levels low enough that final system temperature is dominated by the Galactic background.

INTRODUCTION

LOFAR will be a new multi-element, interferometric, imaging telescope for radio astronomy at decameter/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 different receptors covering different portions of the LOFAR frequency range, currently planned to be 10 to 240 MHz. The receptor must therefore be inexpensive, simple, robust, and easy to manufacture and install.

RESULTS

Figure 1 is a drawing of the dipole antennas, with the dimensions for each one shown in Table 1. Each dipole arm is hexagonal with one dimension of the hexagon stretched to approximately three times its other two dimensions, forming a “fat” dipole. The smaller dipole has arms of dimensions 1.20 m × 0.30 m while the larger one has arms 3.24 m × 1.00 m. The arms of each dipole are inclined 45° below horizontal in order to increase the E-plane response at low elevations. The feed point of the smaller dipole is 1.32 m above a ground plane and the larger one is at 3.48 m. In order to minimize losses caused by a poor ground at low frequencies where the coupling between the dipole and its image is very strong, a 5 m × 10 m ground screen was placed beneath the dipoles. It consists of 4.25 mm diameter steel wires welded together in a 200 mm square grid.

The dipoles were tested with an active balun (Figure 2), i.e. a balun in which amplifiers are connected directly to the dipole arms in order to buffer the dipole impedance variations with frequency. The balun contains separate amplifiers on each arm of the dipole followed by a wide-band balanced-to-unbalanced transformer. The use of separate amplifiers greatly reduces common mode shield currents that could flow if the dipole were connected directly to the transformer. The Motorola CA2832C wideband linear amplifier was chosen because of its low noise figure (5 dB), high dynamic range (ITO = 47 dBm), and low distortion. However, its high cost and high power consumption make it unsuitable for use in LOFAR, where thousands of units will be needed. An inductive shunt is also placed across the dipole terminals; its value is such that it approximately resonates with the dipole capacitance at the frequency where the dipole arms are 1/8 wavelength long.

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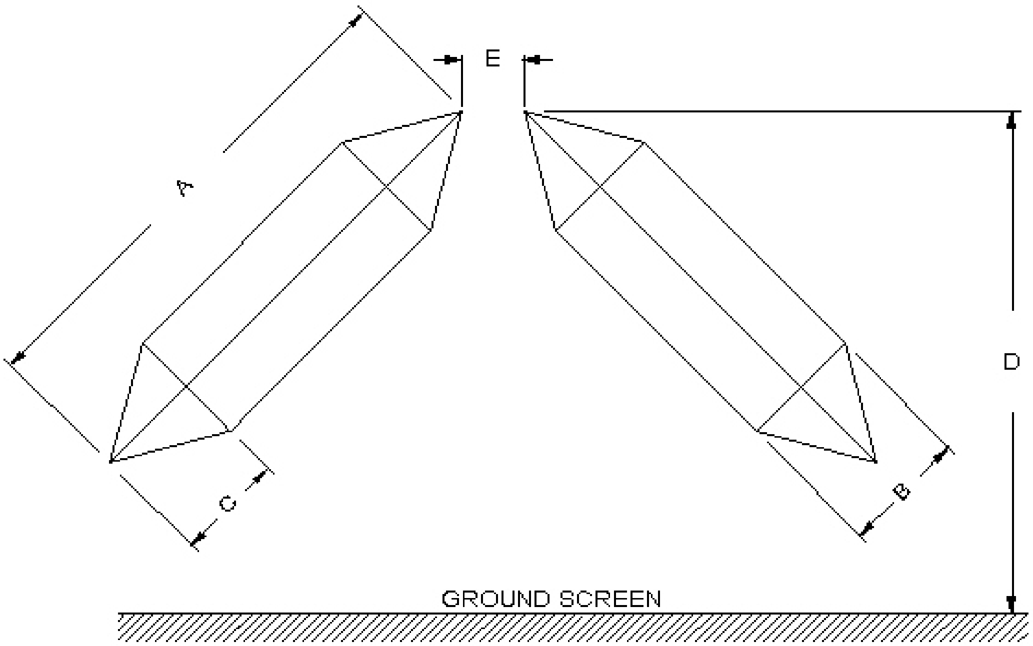

Figure 1. Drawing of the inverted-V dipole antennas. The angle of the arms is 45° below horizontal.

Table 1. Dimensions of the dipoles shown in Figure 1.

Dimensions (m)	*A*	*B*	*C*	*D*	*E*
Small dipole	1.20	0.30	0.26	1.32	0.06
Large dipole	3.24	1.00	0.87	3.48	0.06

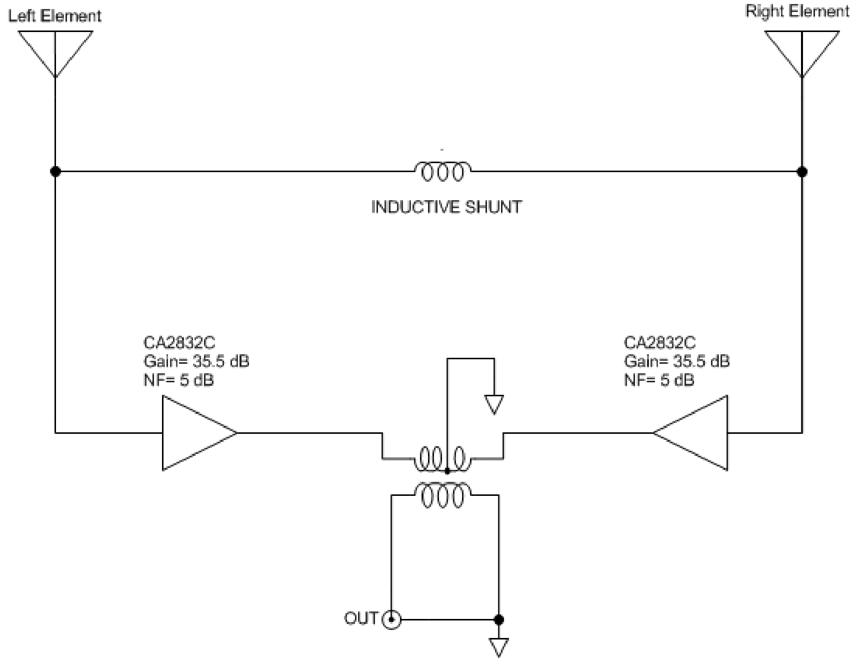

Figure 2. Schematic diagram of the active balun. The transformer gives an impedance step-down of 4:1.

Figure 3 and Figure 4 show Galactic background spectra obtained with the small and the large dipoles, respectively. In both figures, the lowest trace is the system noise with the active balun switched off. The middle trace was made with a 50 Ω load substituted for the dipole. This spectrum shows the thermal noise of the load (290 K) plus the excess noise generated by the preamp (450 K). The top trace shows the spectrum with the dipole connected and observing the sky (both Galactic and terrestrial noise). The large dipole is more sensitive to the increasing Galactic brightness at low frequencies.

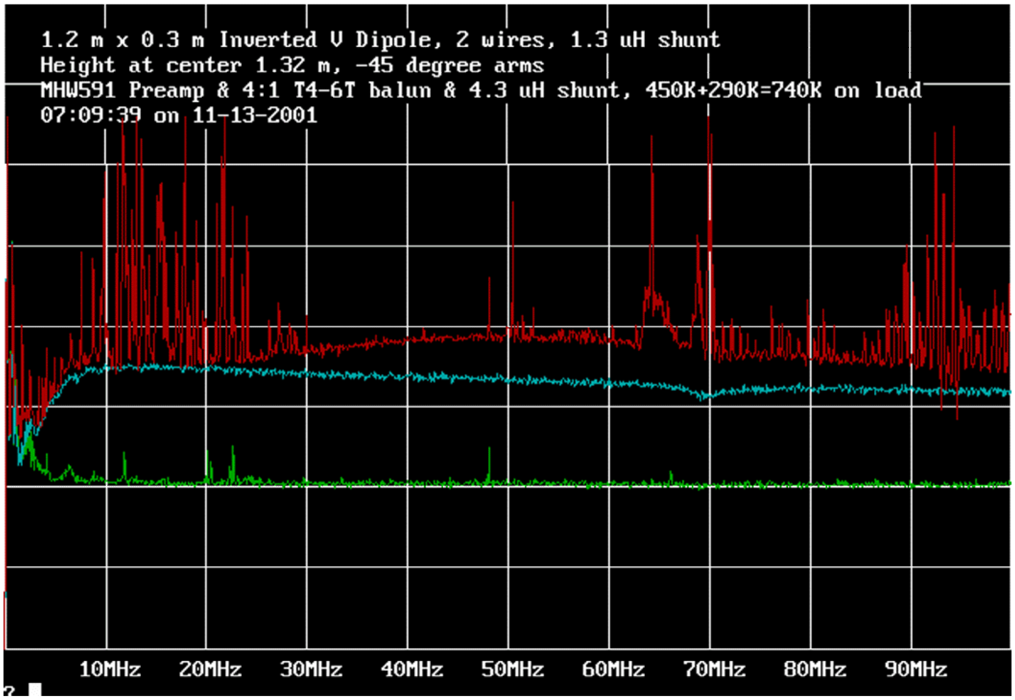

Figure 3. Small dipole spectrum. The curves are, from bottom to top, system noise, dummy load, and sky observations. The vertical axis is the signal strength; each division equals 10 dB.

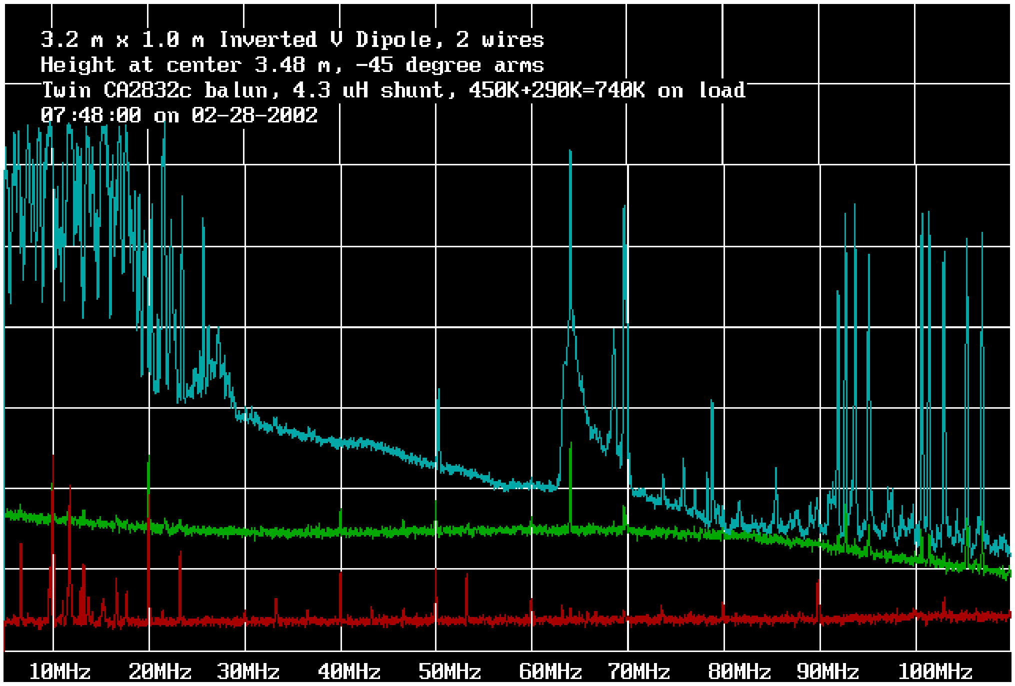

Figure 4. Large dipole spectrum. The three traces correspond to those in Figure 3.

Figure 5 is a dynamic spectrum of two solar bursts obtained with the large dipole. It shows that the system has sensitivity from <12 MHz to >110 MHz. The cutoff at 12 MHz is due to the ionosphere; we believe that the dipole actually works down to at least 5 MHz. Although the dipole has sensitivity up to >110 MHz, its usefulness for astronomical observations above 50 MHz declines because the antenna response decreases at the zenith and develops strong side lobes near the horizon.

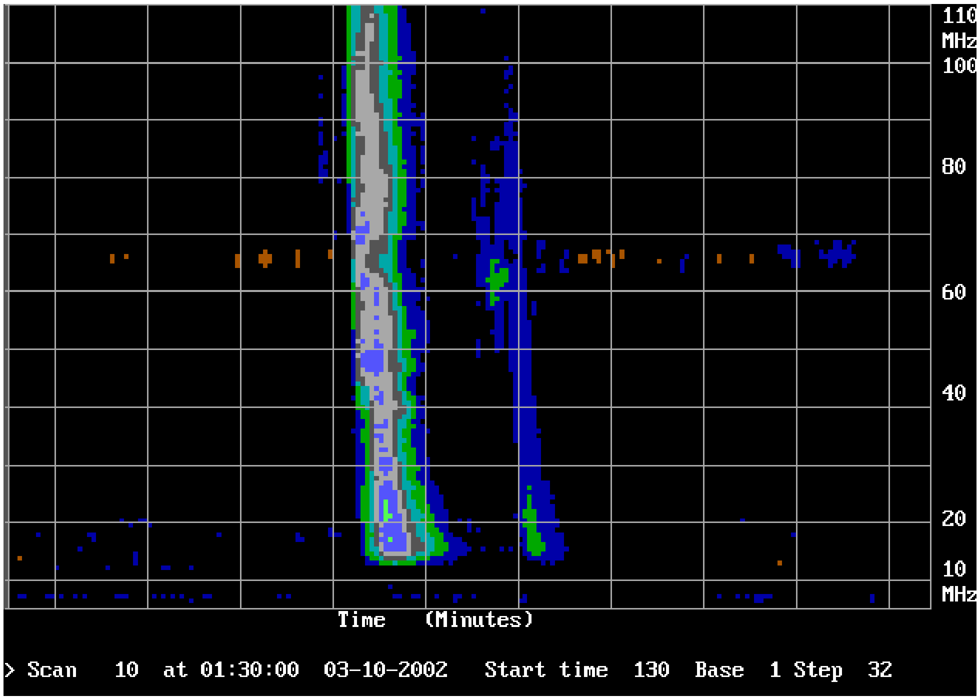

Figure 5. A spectrum of two solar bursts observed with the large dipole.

CONCLUSIONS

Two different sized "fat" inverted-V dipoles with active baluns were tested by observing the Galactic background and the Sun. We found that they work with reasonable efficiency over the frequency range in which the dipole arms vary from about 1/8 wavelength to 1/2 wavelength, i.e. from 30 to 110 MHz for the smaller dipole and from 10 to 50 MHz for the larger one. The low frequency limits appear to be set by resistive losses and low efficiencies caused by the strong coupling between the dipole and its image. The high frequency limits occur where the dipole is too high above the ground screen (~ $\lambda/2$) and its response pattern begins to develop a null at the zenith making it inappropriate for radio astronomical observations. Systems designed along these lines appear to be possible receptors for LOFAR in the 10 to 110 MHz range.