







Characterization of the LWA Antenna and Station Beam Pattern

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Outline

- Measuring the LWA Antenna Impedance Mismatch
 - Motivation
 - Current Efforts
 - Results
- Simulating the Sidelobes of the LWA-SV Beam Pattern
 - Motivation and Methodology
 - Preliminary results
- Future Efforts and Summary

Measuring the LWA Antenna Impedance Whitham Reeve (Reeve Engineers), Brian Hicks (NRL), Jayce Dowell (UNM)

- Problems:
 - Impedance mismatch (IMM) between antenna and front end electronics (FEEs) will cause reflection of incident power
 - 2. Direct measurement of the IMM at the antenna feed points is difficult without custom calibration and testing fixtures
- Motivations:
 - 1. Improved absolute calibration of the LWA Low Frequency Sky Survey
 - 2. 21 cm Cosmology experiments using LWA antennas



Making the Measurements

- Equipment:
 - Keysight N9917A Microwave Analyzer in *Network Analyzer* mode
 - 2 Test cables: LMR-240 with N-M and SMA-M, 37 ft (11 m) long
 - 50 Ω termination, N-F
 - Custom Calibration Fixtures (Brian Hicks, NRL)
 - Custom Test Fixtures (Brian Hicks)

Moving the Reference Plane: Custom Fixtures

Calibration Fixtures (pads at feedpoints)



Test Fixtures (direct connection to feedpoints)



Moving the Reference Plane: Custom Fixtures

Calibration Fixtures (pads at feedpoints)

Test Fixtures (direct connection to feedpoints)



Antenna Installation and Measurements





- Measure reflection coefficient, S11
- Frequency | Mag (dB) | Phase (deg)
- Convert to complex impedance

Impedance Results

North-South Dipole





Impedance Matching Efficiency (IME)

- S11 = Γ = A $\cdot e^{i \cdot \phi}$
- $\Gamma = (Z Z_0) / (Z + Z_0)$
- IME = $1 |\Gamma|^2$
- Assumes $Z_0 = 100 + 0i \Omega$
- Model is from Hicks et al. (2012)



Impedance Matching Factor (IMF)

 Try using Impedance Matching Factor, which accounts for the actual impedance of the FEE

$$IMF = \frac{\left(1 - \left|\Gamma_{ANT}\right|^{2}\right)\left(1 - \left|\Gamma_{RX}\right|^{2}\right)}{\left|1 - \Gamma_{ANT}\Gamma_{RX}\right|^{2}}$$

Rudge, A., Milne, K., Olver, A., Knight, P., The Handbook of Antenna Design, Vol. 1 and 2, Peter Peregrinus Ltd, 1986

• This reduces to IME when $\Gamma_{RX} = 0$

FEE Impedance Measurements



FEE Impedance Measurements

DG85AQ Vector Network Analyzer Software



DG8SAQ Vector Network Analyzer Software





V2.0

IME vs IMF



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Correcting Sky Survey Data



IME

Simulating the Sidelobes of the LWA-SV Beam

- Beamformed approach to detecting the global 21 cm signal (DiLullo et al. 2020 & 2021)
- Custom "achromatic" beamforming framework keeps main lobe constant, but sidelobes have lots of structure
- What contribution do the sidelobes have to the measured spectrum/residuals?
- Following methods of Price (2022) (submitted to PASA)



Simulating the Sidelobes of the LWA-SV Beam

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Sidelobe Contributions Simulated Spectra Simulate beam pattern across Full Beam Spectrum 800 Full Beam - Gaussian 2750 Gaussian Mainlobe Spectrum MSF Fit frequency for given pointing and LST 2500 Fit circular Gaussian to the main lobe 700 2250 Multiply each with a sky model to simulate the observed spectrum Temperature [K] 1750 ₆₀₀ Temperature [00 Difference yields sidelobe 1750 contributions 1500 Fit a N=5 MSF to the sidelobe contributions to estimate contribution¹²⁵⁰ 400 to residuals after foreground 1000 subtraction 300 60 65 70 75 80 85 60 65 70 75 80 85 Frequency [MHz] Frequency [MHz] 16

XX Data Overview

Sidelobe Residuals

Sidelobe Residuals



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Current and Future Efforts

Impedance Measurements:

- 1. Planning to make measurements at the New Mexico stations (LWA1, LWA-SV, and LWA-NA) this Fall
- 2. Need more v2.0 FEE boards to test (November-ish)

Sidelobe and Beam Characterization:

- 1. Investigating alternative beamforming frameworks which might lower sidelobe contributions
- 2. Can simulations be used to help model out sidelobe contribution?

Summary

- We have measured the impedance of the LWA antenna and front end electronics to better understand the effects of mismatch. Improved calibration of LWA LFSS data
- Planning to make measurements at the stations in New Mexico and need to evaluate the newest version of the FEE (v2.0)
- Sidelobe contribution to beamformed 21 cm observations can be simulated (to first order) in a simple fashion
- Simulations are consistent with observed residuals
- Alternate beamforming frameworks needed to lower sidelobe amplitudes

Thank You!



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Calibration Fixtures

Short



Calibration Fixtures

Open



Calibration Fixtures



Load