



S-Parameter Measurements of the LWA Antenna and FEE

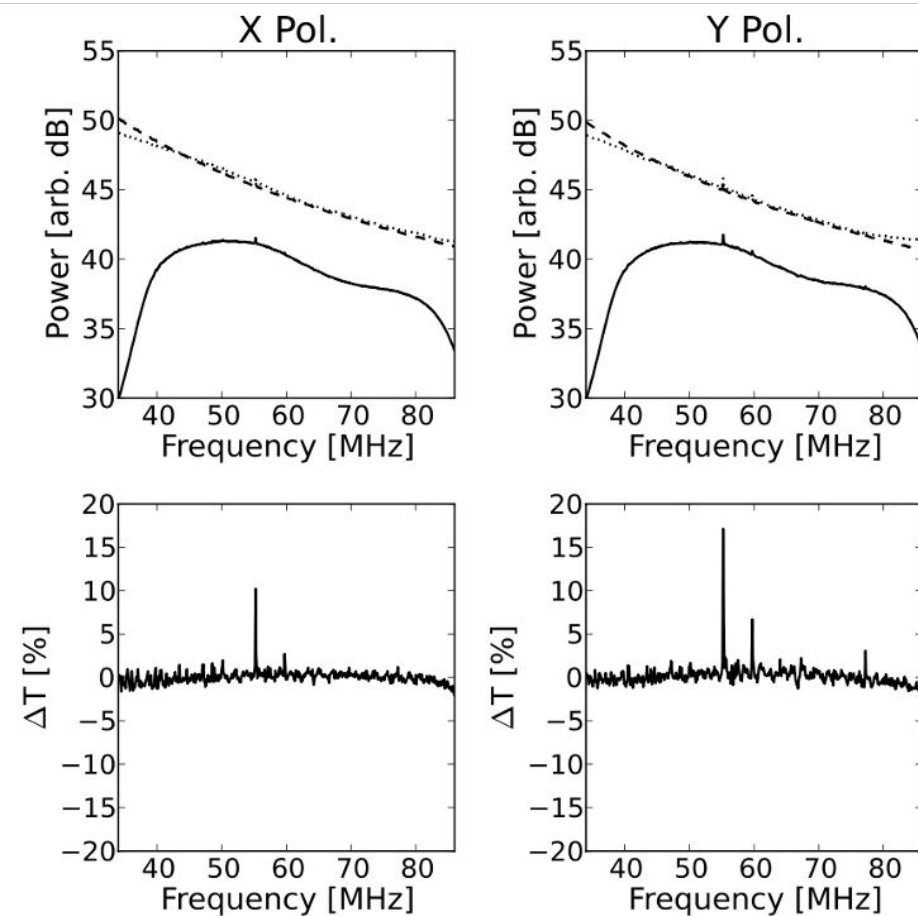
Christopher DiLullo, Whitham Reeve, Brian Hicks, and Jayce Dowell

June 2, 2023



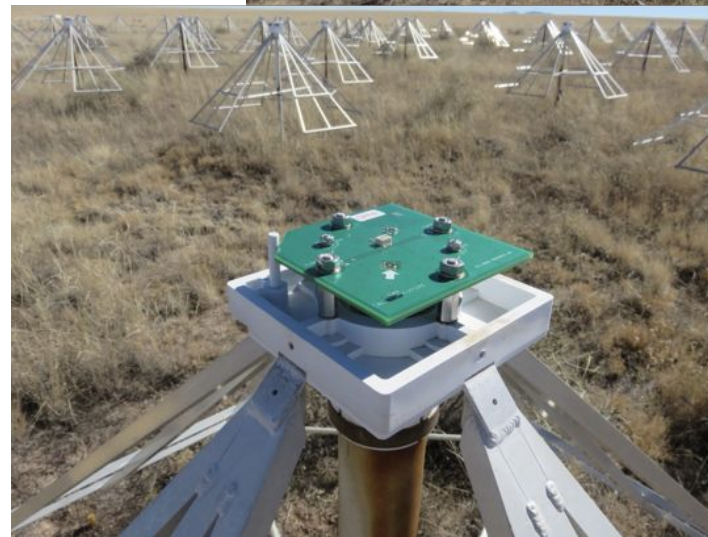
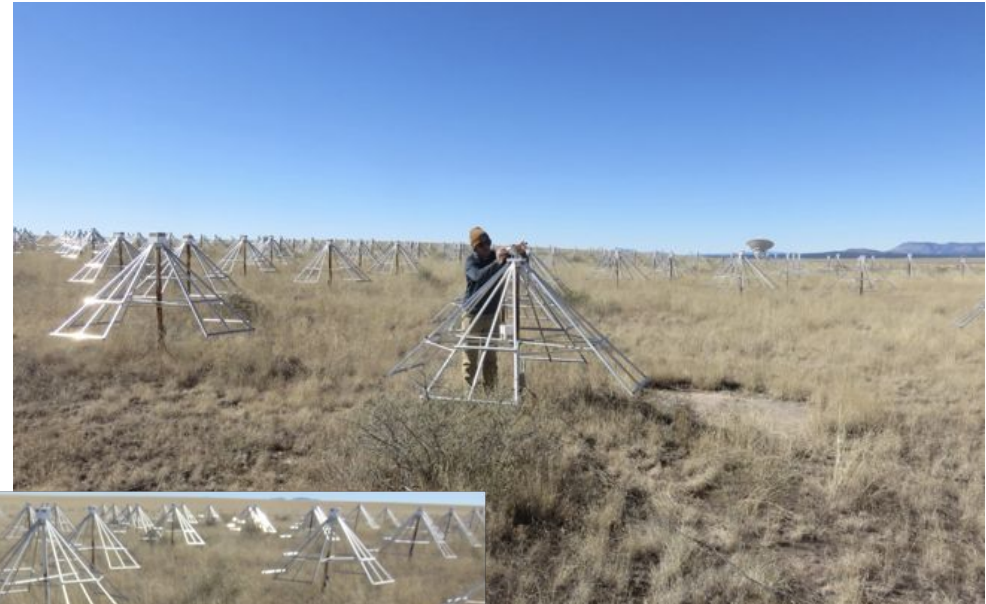
Motivation

- Impedance mismatch (IMM) between antenna and front end electronics (FEEs) will cause reflection of incident power
- Direct measurement of the IMM at the antenna feed points is difficult due to the hybrid coupler on the FEE board
- One of the required corrections for sky survey data
- Important to understand for our ongoing global 21 cm signal experiment



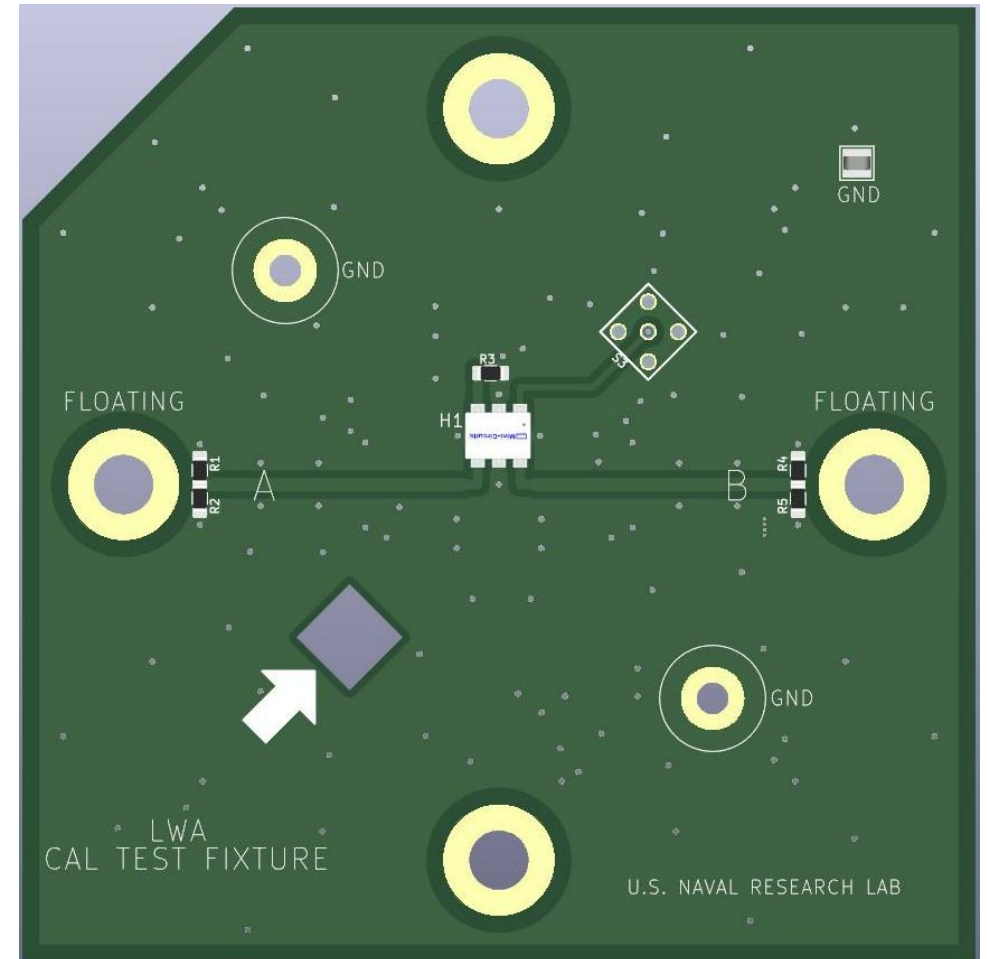
Methodology

- Custom Calibration Fixtures that de-embed the hybrid coupler were fabricated
 - Shifts the VNA reference plane to the antenna feedpoints
- Three sets of S-parameter measurements:
 - Single antenna: Dipole-Dipole
 - Two antenna: Antenna-Antenna
 - FEE
- Measurements taken in New Mexico at all three LWA sites in November 2022 and FEEs in Anchorage in February 2023



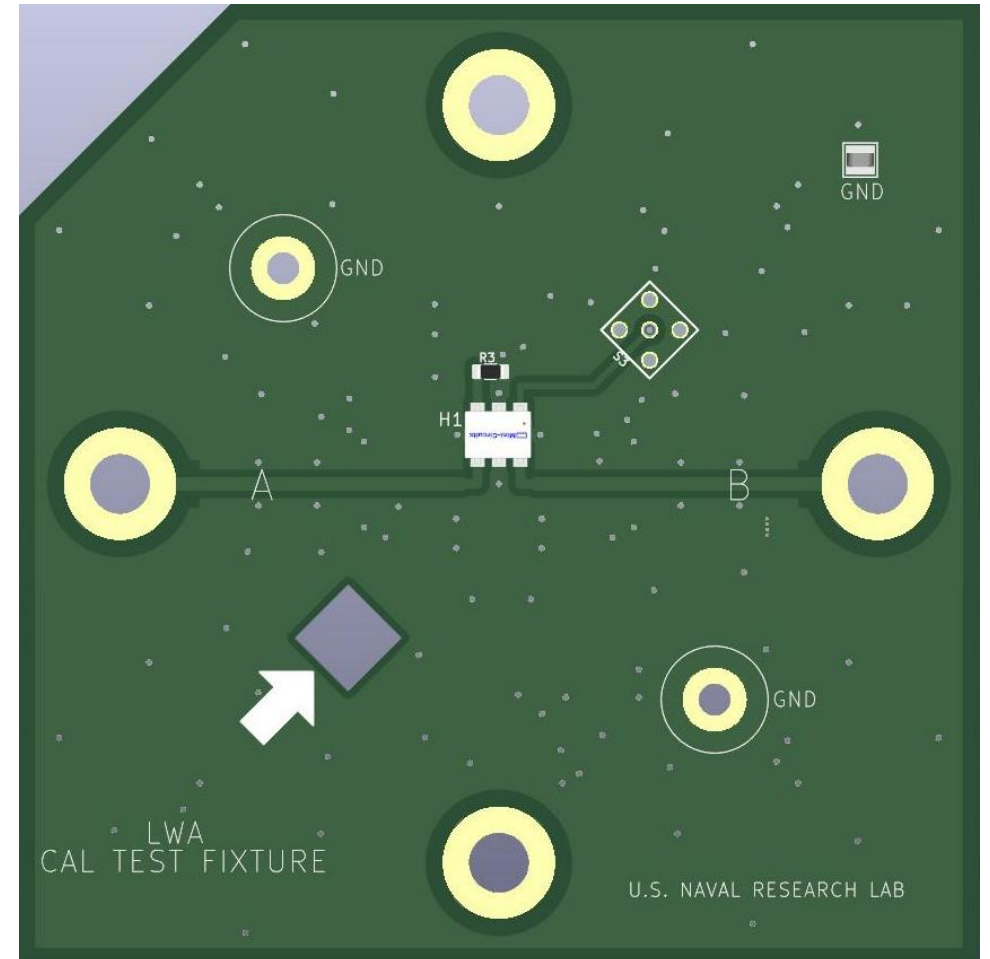
Custom Calibration Fixtures

- Dual assembly calibration PCBs which de-embed the hybrid coupler
- Pads for calibration standards near balanced feedpoints but not connected
- Calibration Standards:
 - Open – Empty pads
 - Short – 0 Ω resistors on pads
 - Load – 50 Ω resistors on pads
 - Thru – Two Test Fixtures connected at feed points



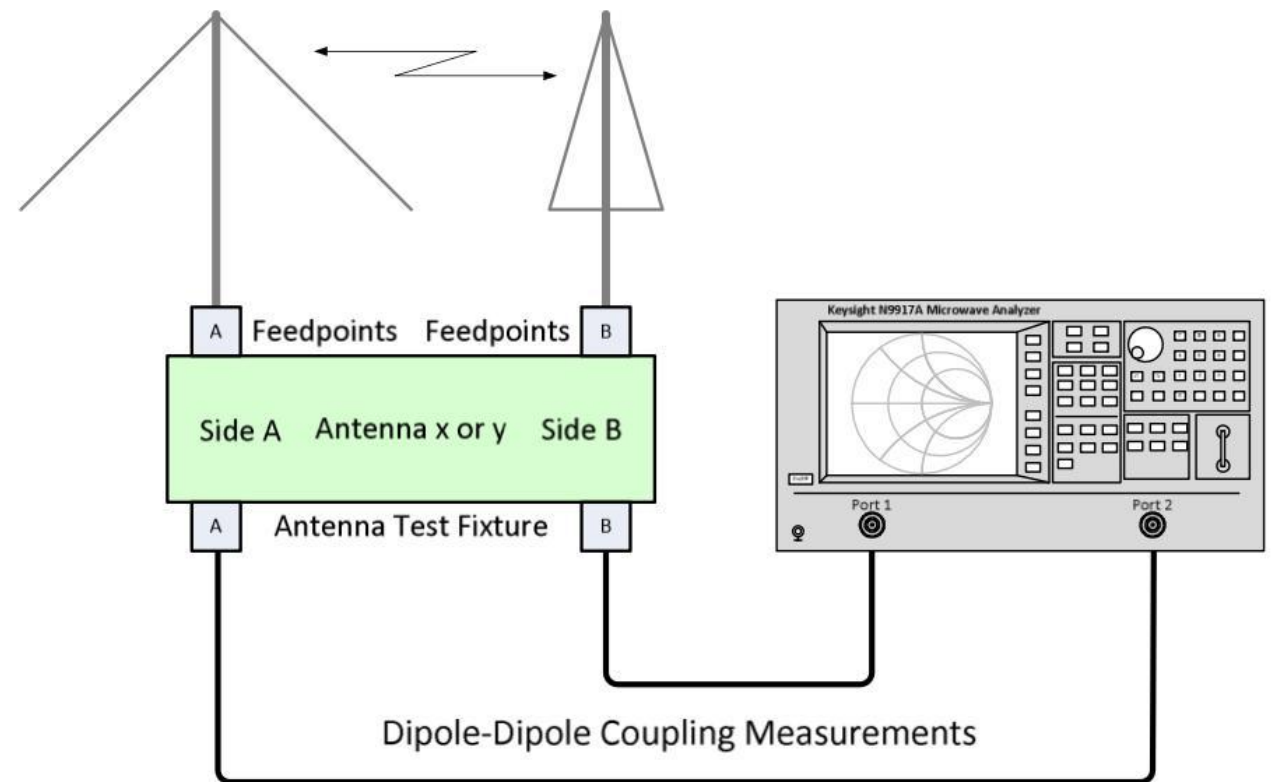
Antenna Test Fixtures

- Enables connection of unbalanced (50 ohm) vector network analyzer to balanced dipole feed points through hybrid coupler
- Identical to Calibration Fixtures except
 - Traces from hybrid coupler connect to the dipole feedpoints
 - No components on traces
- Dual assemblies like FEE: 2 PCBs

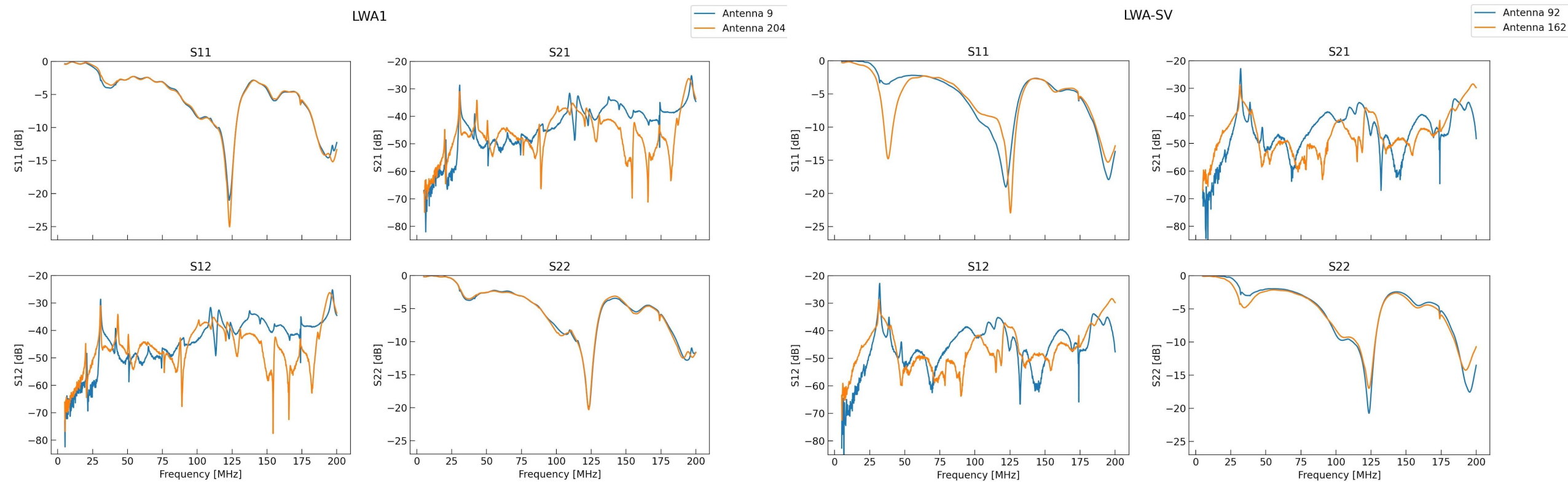


Single Antenna (Cross-Dipole) Measurements

- Two port calibration of VNA
 - Two ports calibrated separately
- Measurements at different antenna locations within the arrays
- S_{11} and S_{22} measure the reflection coefficient (impedance matching) of each of two dipoles
- S_{12} and S_{21} measure the cross-dipole coupling strength

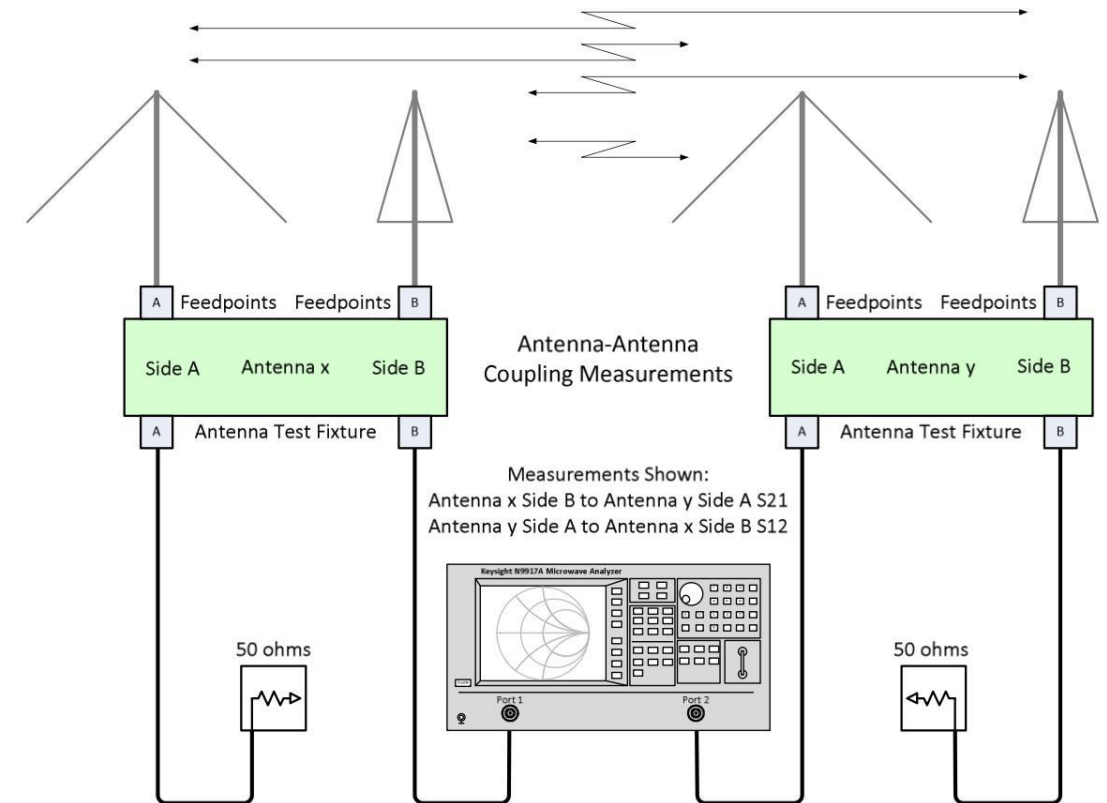


Single Antenna Cross-Coupling Results

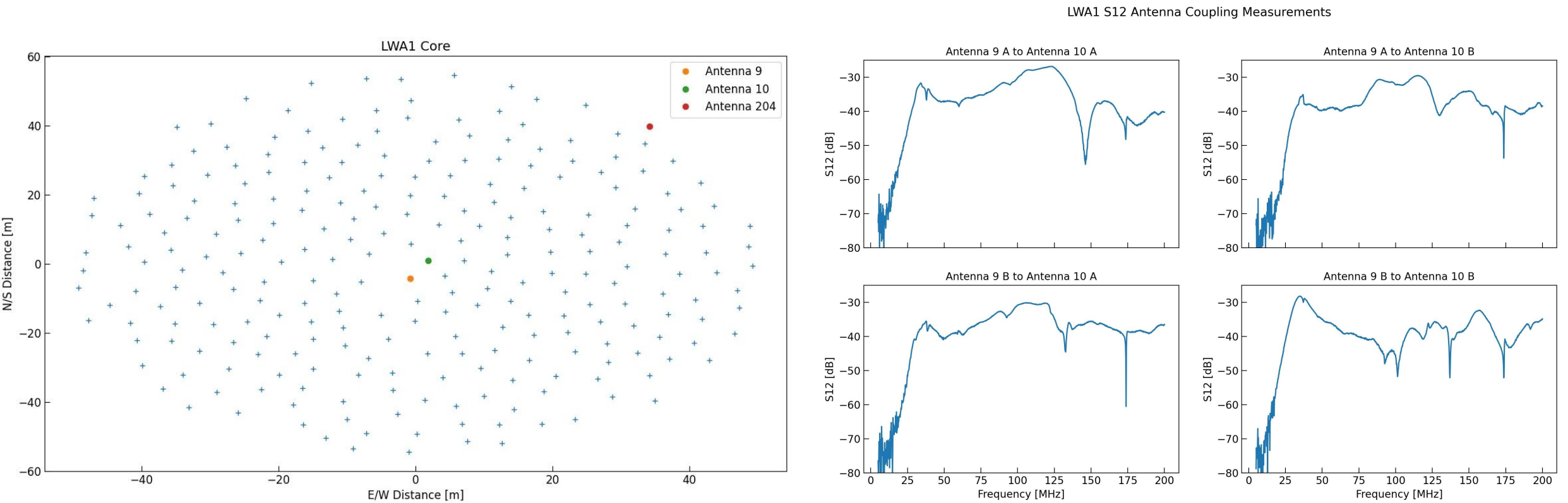


Cross-Antenna Coupling Measurements

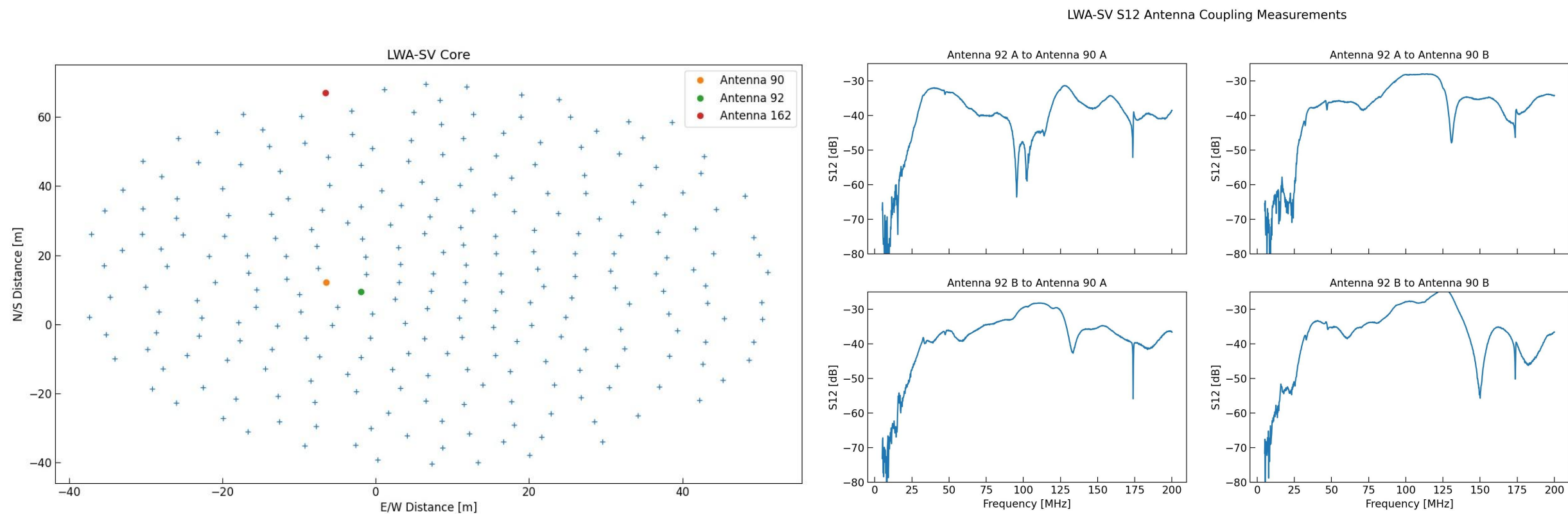
- VNA connected to two nearby antennas, X and Y
- VNA Port 1 is connected to Antenna X Polarization A/B and Port 2 is connected to Antenna Y Polarization A/B
- Reciprocal measurements
- S_{11} and S_{22} measure the reflection coefficient of each dipole
- S_{12} and S_{21} measure the coupling strength between the two dipoles



LWA1 Cross-Antenna Coupling Results



LWA-SV Cross-Antenna Coupling Results

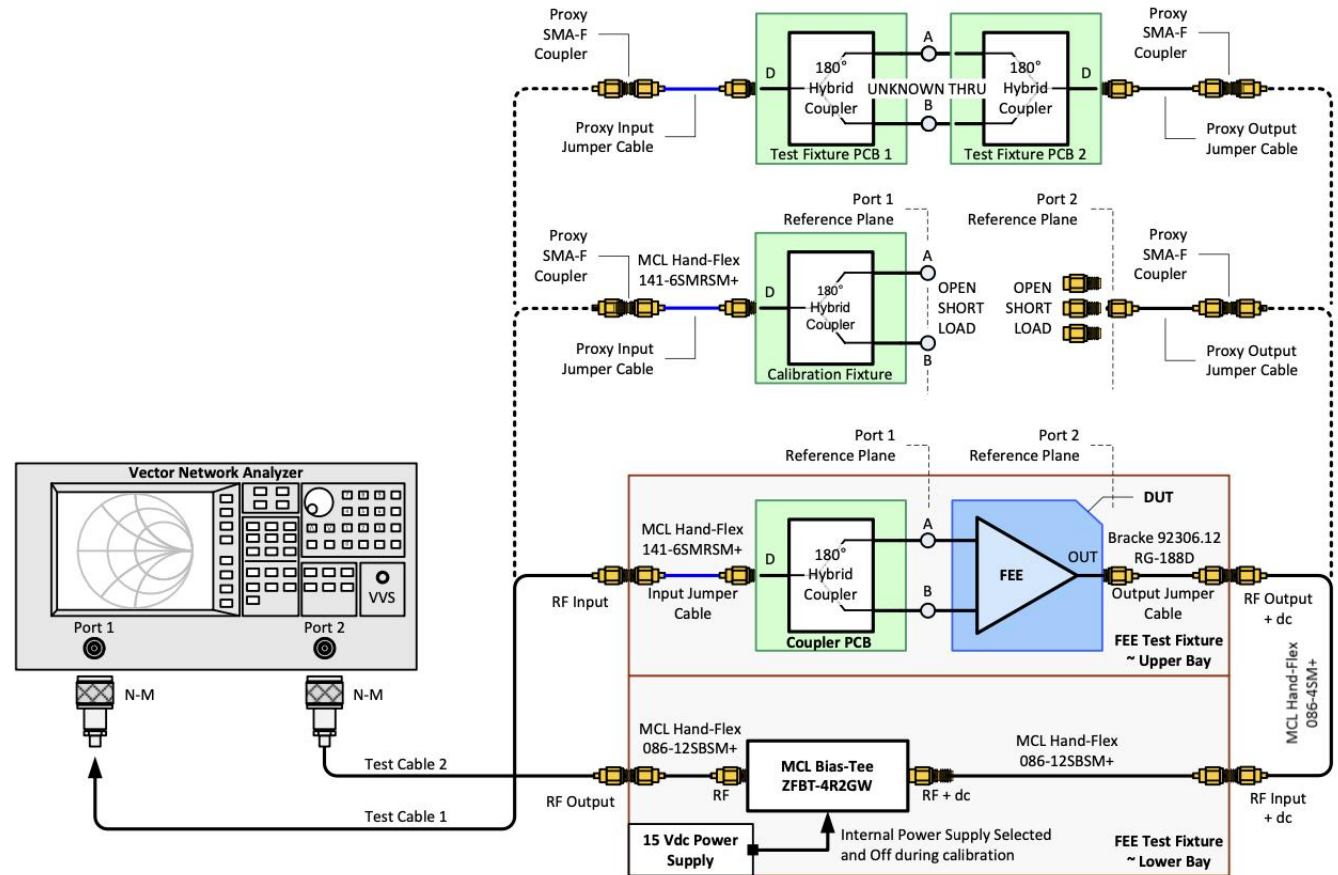


FEE Impedance Corrections

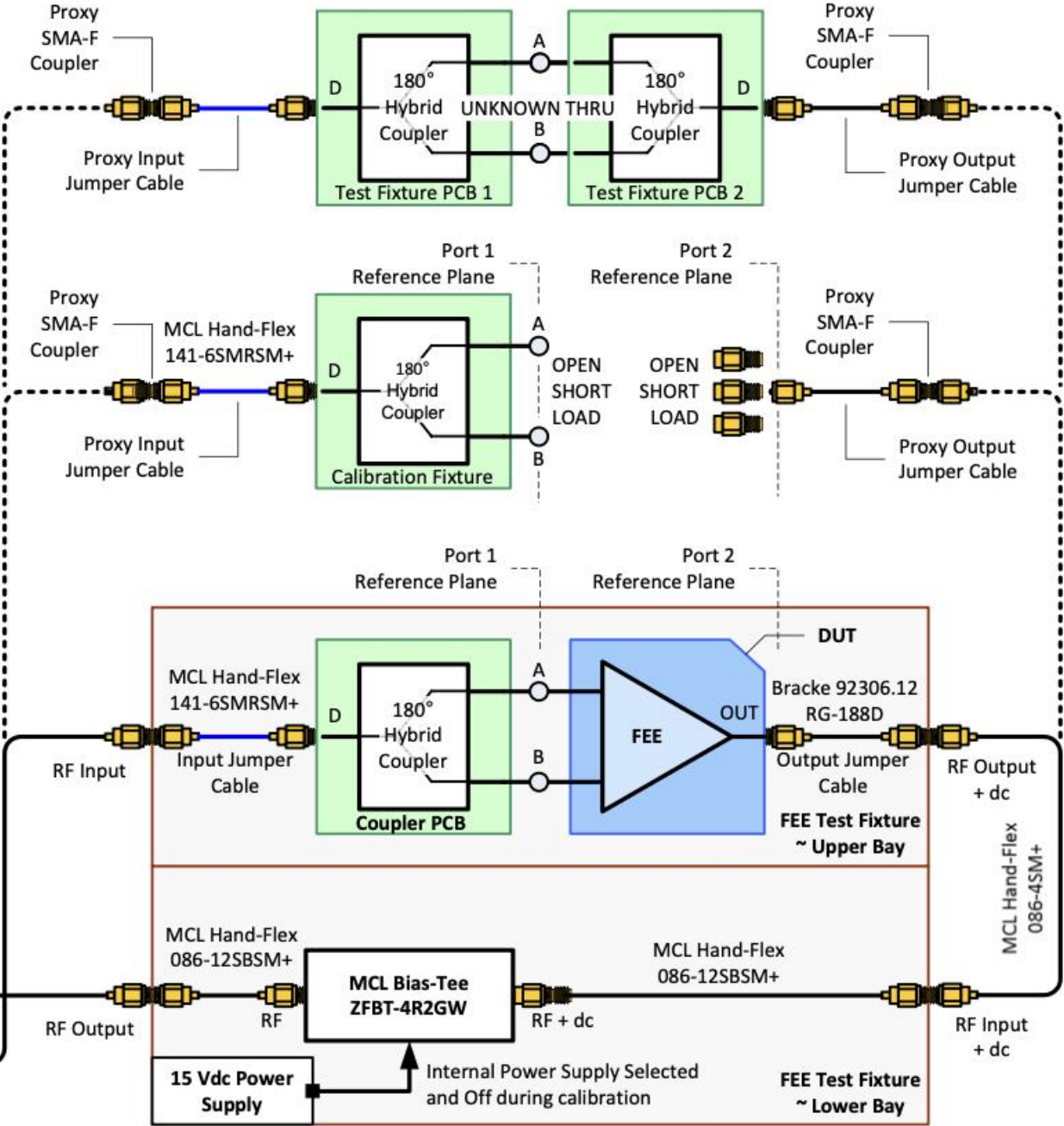
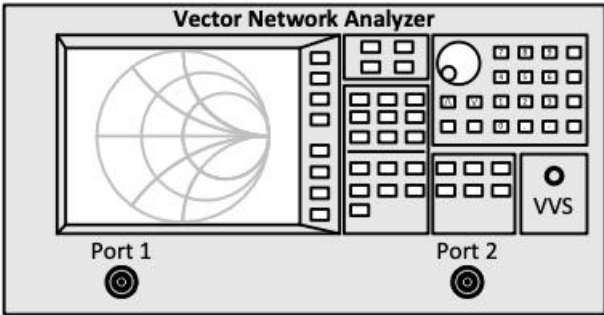
- Impedance Mismatch Efficiency (IME): $IME = 1 - |\Gamma_{ant}|^2$;
 - Assumes FEE balanced $Z_0 = 100 + 0j \Omega$
 - Probably unrealistic
- Impedance Matching Factor (IMF): $IMF = \frac{(1 - |\Gamma_{ant}|^2)(1 - |\Gamma_{RX}|^2)}{|1 - \Gamma_{ant}\Gamma_{RX}|^2}$
 - Accounts for the true, complex impedance of the FEE
 - Need to measure FEE reflection coefficient Γ_{RX}
 - Reduces to IME when FEE is perfectly matched: $\Gamma_{RX} = 0$

FEE S-Parameter Measurements

- Custom testing box
- Hybrid coupler run in reverse to convert the unbalanced VNA signal to a balanced signal at FEE
- Hybrid coupler de-embedded by using the same calibration fixtures as antenna measurements
- Measured 10 v1.8 FEE boards to get (sparse) statistics



DiLullo et al 2023, PASP, 135, 044501



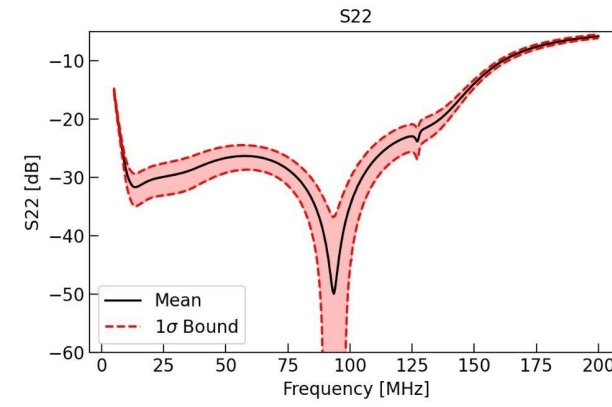
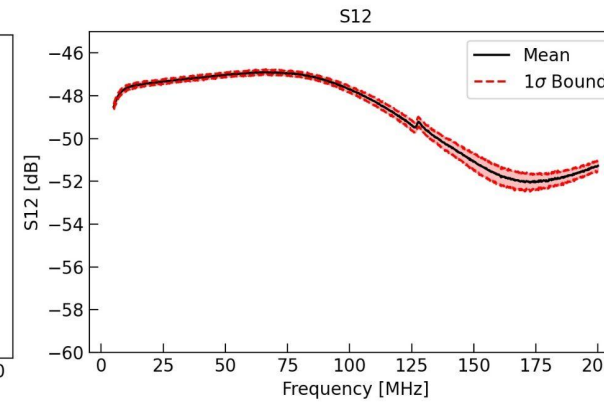
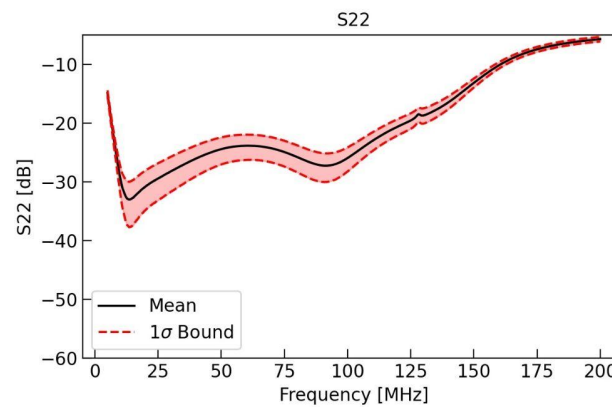
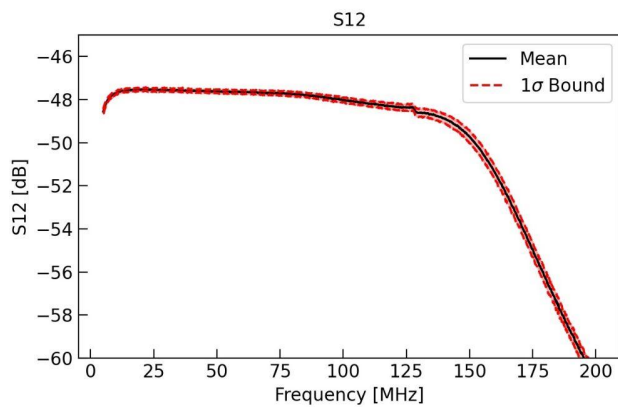
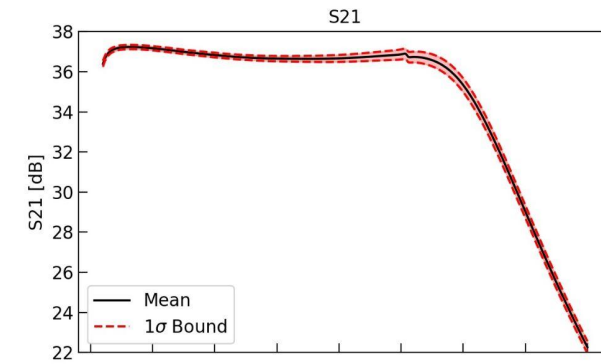
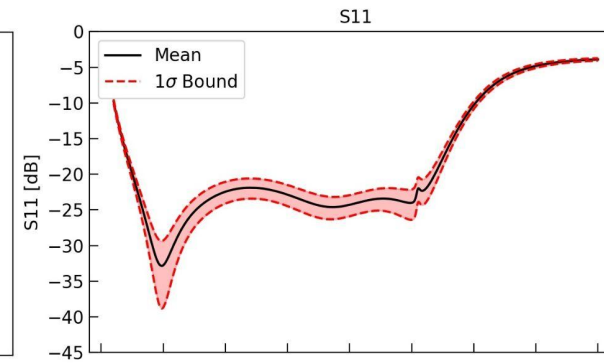
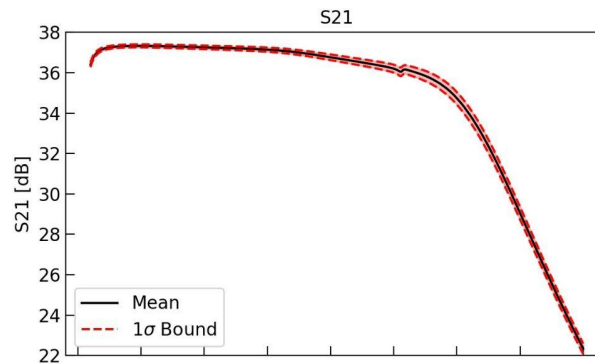
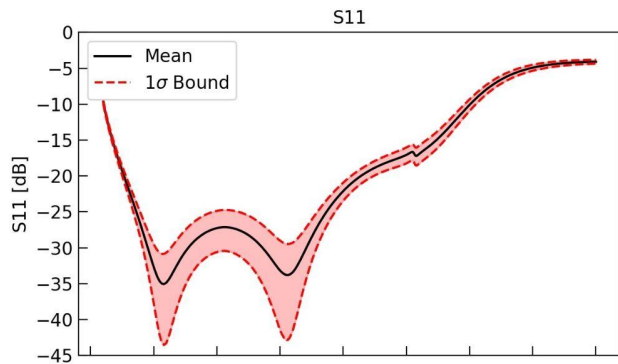
FEE S-Parameter Results

North-South

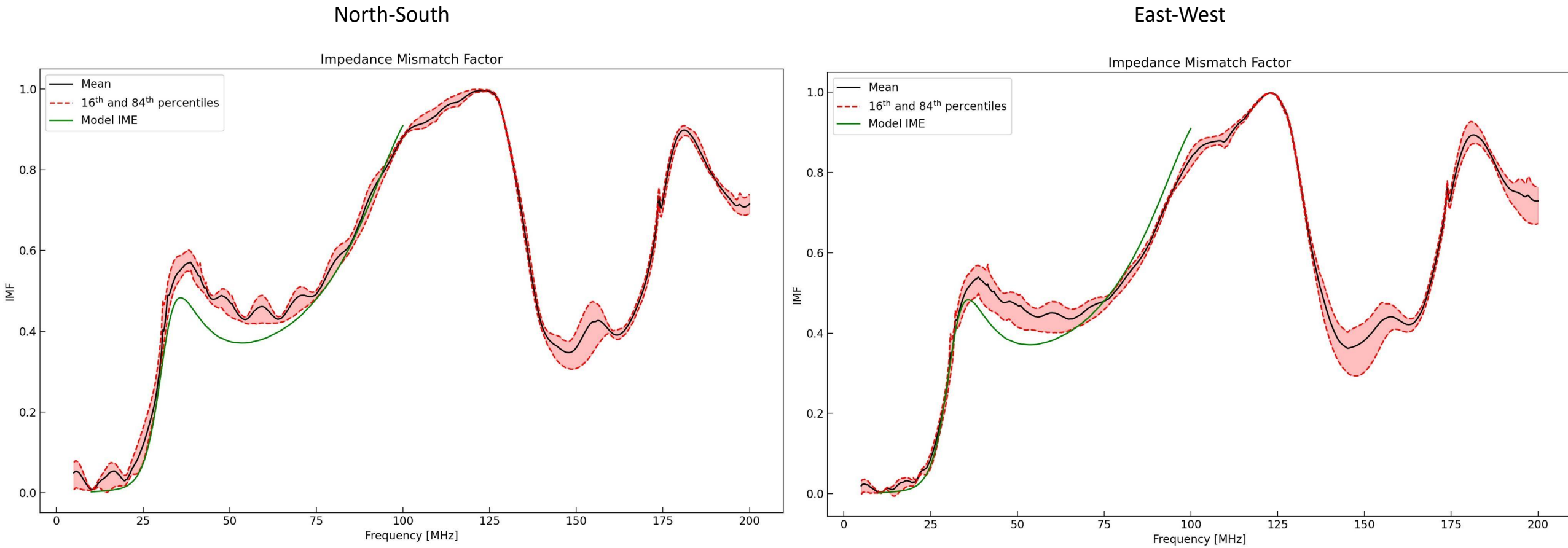
LWA FEE S-Parameters (N=10)

East-West

LWA FEE S-Parameters (N=10)

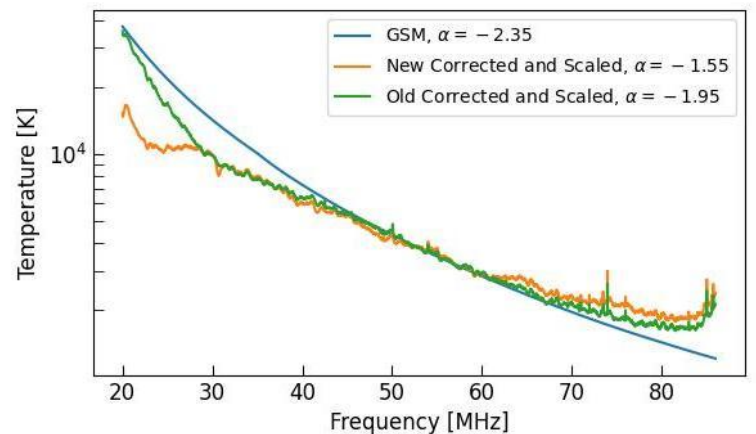
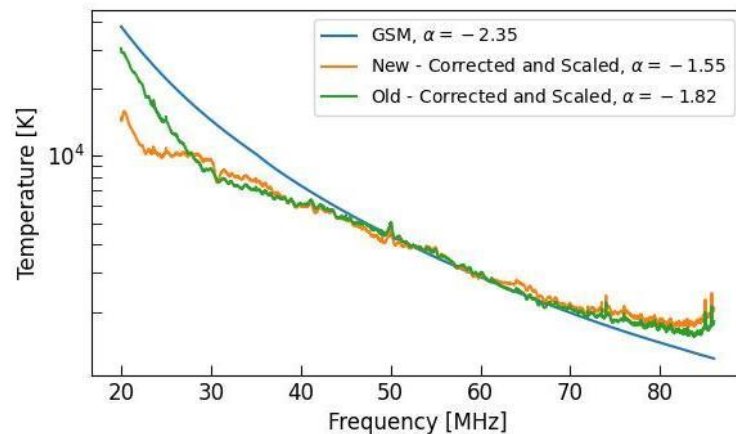
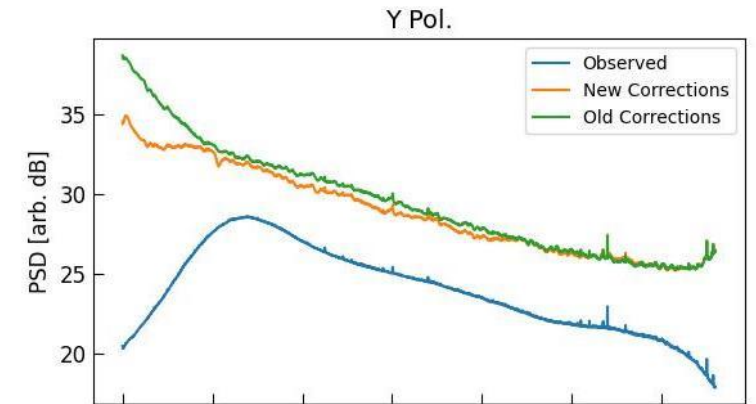
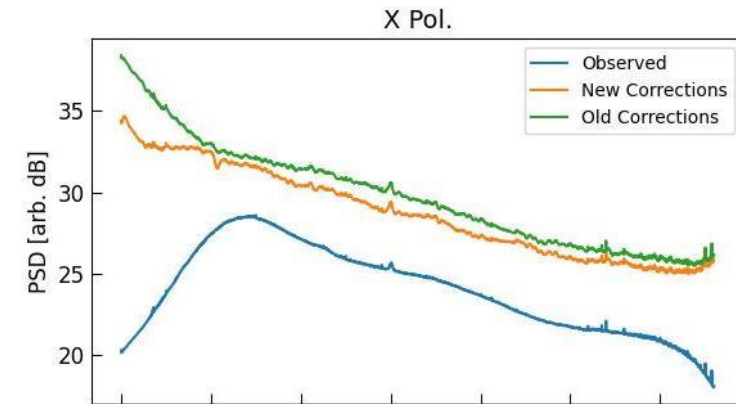


IMF Results



LWA1 Low Frequency Sky Survey Corrections

- New IMF used to correct LFSS data taken in 2019
- Raw data shown in top panels
- Scaled data shown in bottom panels
- New corrections remove “hockey stick” feature, which is nonphysical



Summary

- 2-port S-parameter measurements were carried out for the FEE antenna and Front End Electronics (FEEs)
- Custom Calibration and Test Fixtures were fabricated that de-embed the effects of the hybrid coupler on the FEE
- New Impedance Matching Factor (IMF) corrections were derived for sky survey calibration
- The new corrections show improvement over previous ones as they result in a more physical looking spectrum.

Scattering Parameter Measurements of the Long Wavelength Array Antenna and Front End Electronics

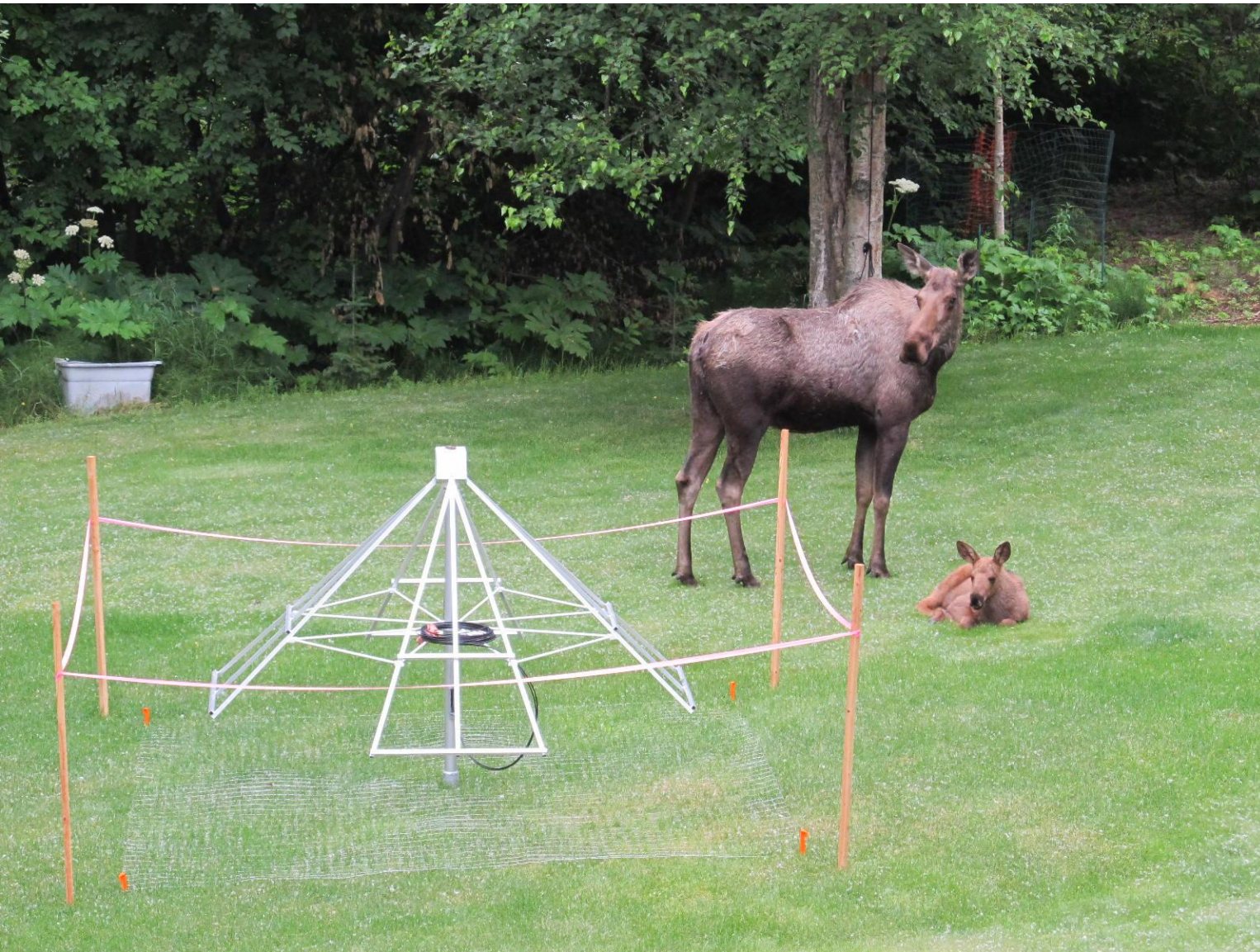
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Special thanks to
our collaborators!

During preliminary
antenna measurements
in Anchorage