

EDGES



SARAS



Ground-based Global 21-cm Experiments: Preparing for the Moon

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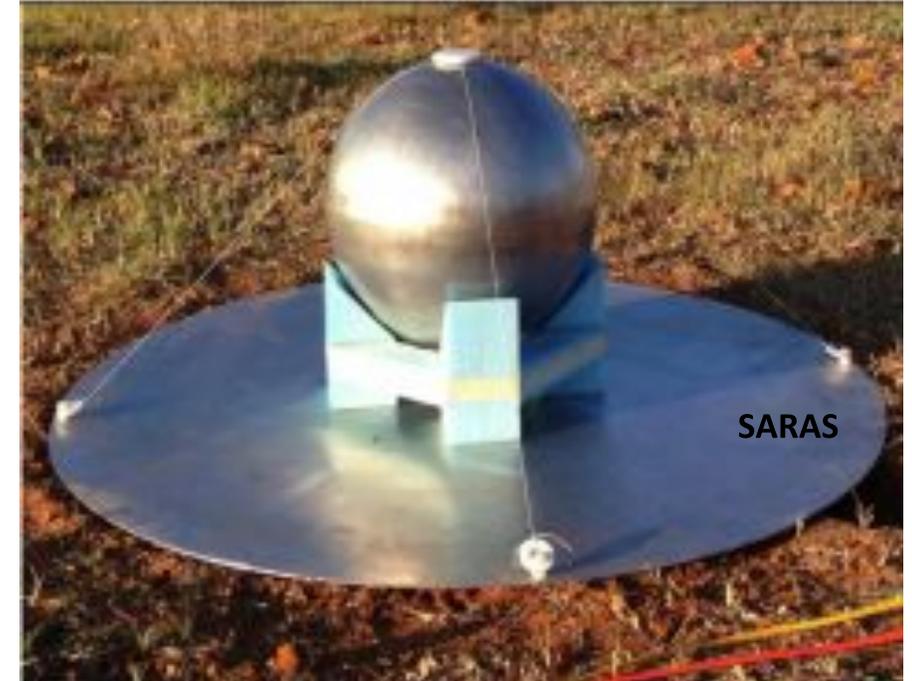
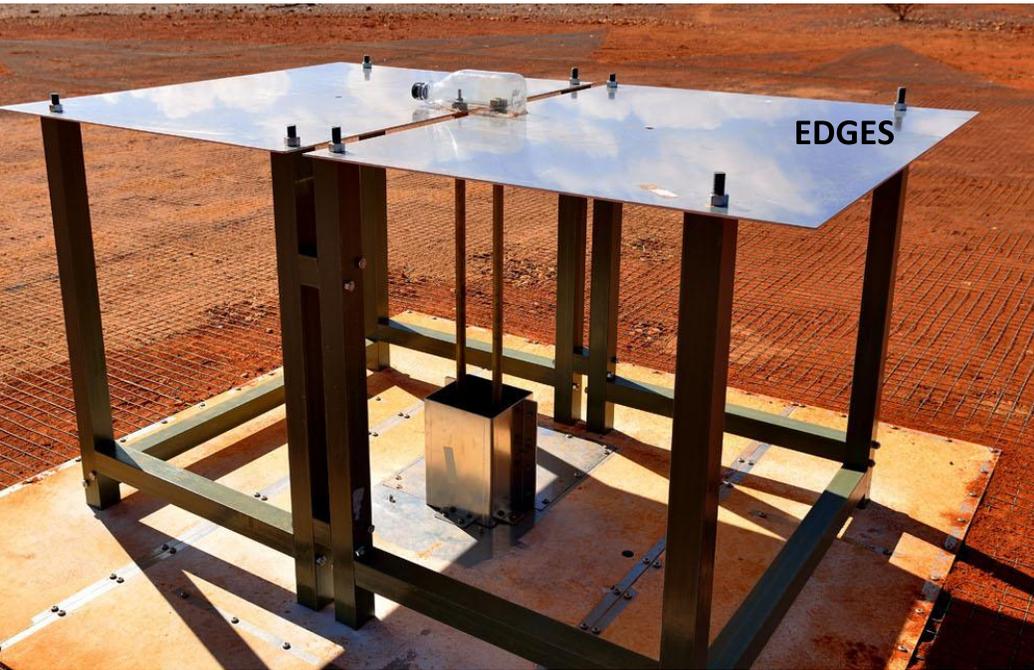


REACH

LEDA



Global 21-cm Experiments

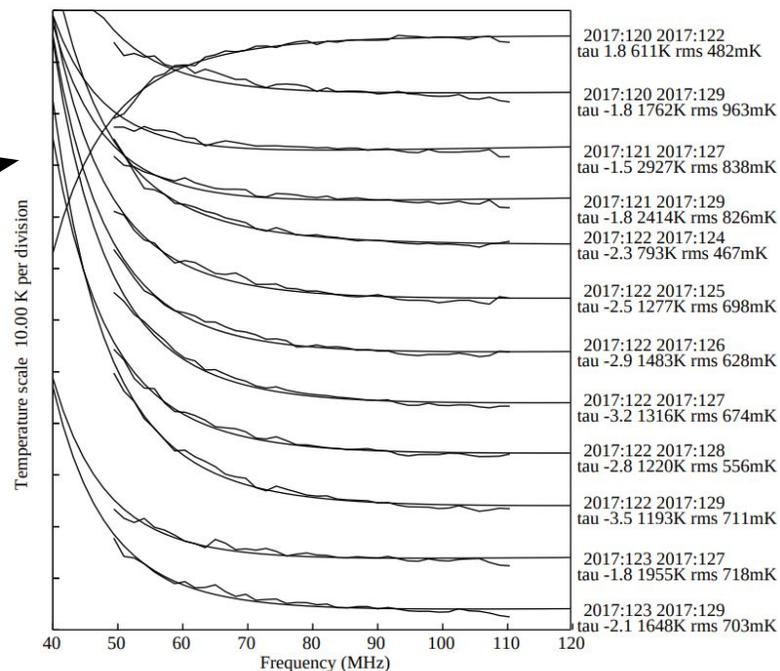


- **Measurement:** Sky-averaged radio spectrum below 200 MHz
- **Requirement:** Knowable instrument response at 0.01%
- **Instrument design:** Widefield, wideband radio spectrometer
 - Compact antenna and embedded receiver
 - Temperature controlled receiver with internal references to provide a time-invariant response.

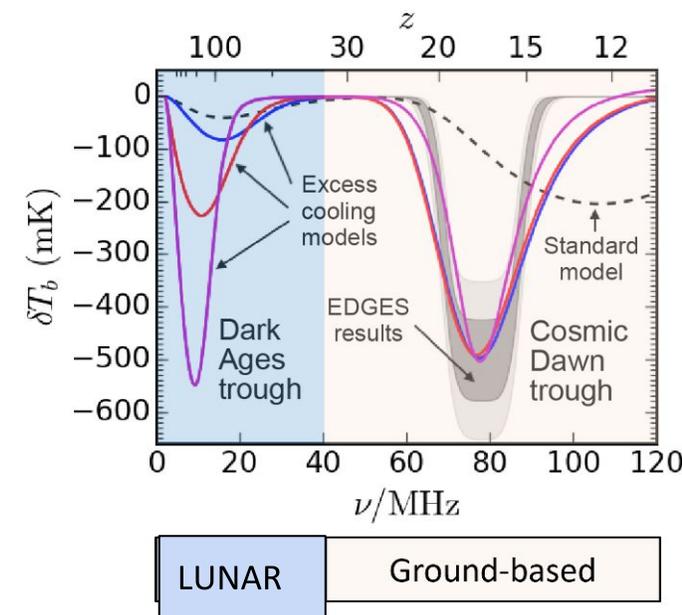
Aiming for the Moon

Advantages:

- 1.) No Terrestrial RFI
- 2.) No ionosphere
- 3.) Can probe the Dark Ages
- 4.) Avoid Solar Radio flux



A.E.E Rogers et. al. 2015



Possible strategies

Orbiter mission

- 1.) No ground/soil effects
- 2.) Avoid reflections and multipath propagations

Lunar surface

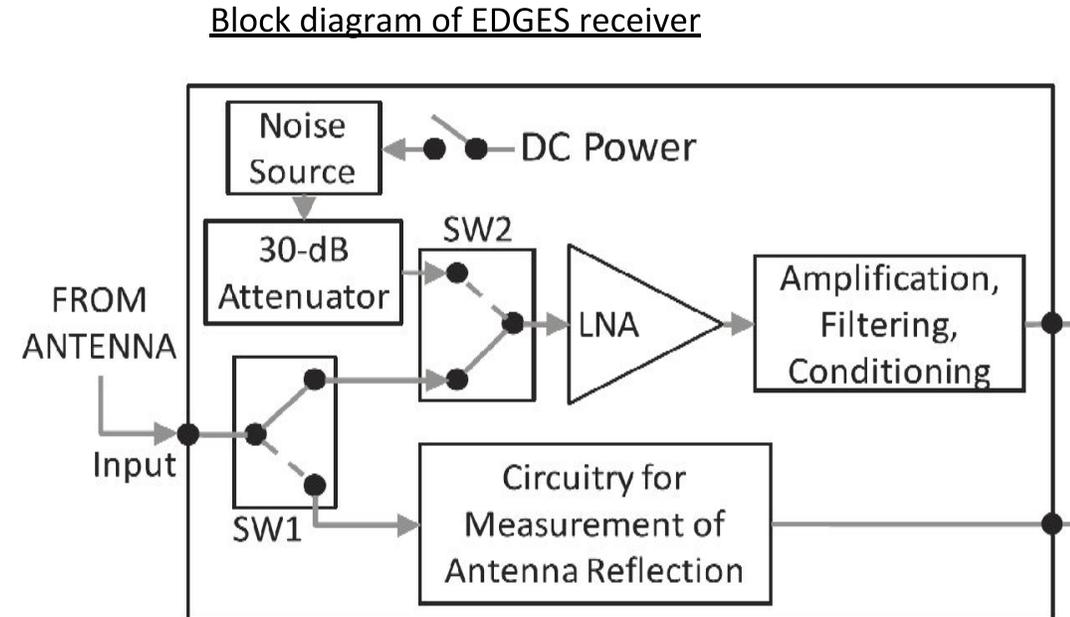
- 1.) Unchanging environment
- 2.) More space.
- 3.) Less interference due to electronics

Lessons learnt from Ground based

- Receiver calibration
- Antenna beam modelling
- Study of environment
- Study of foregrounds

Receiver Calibration Schemes

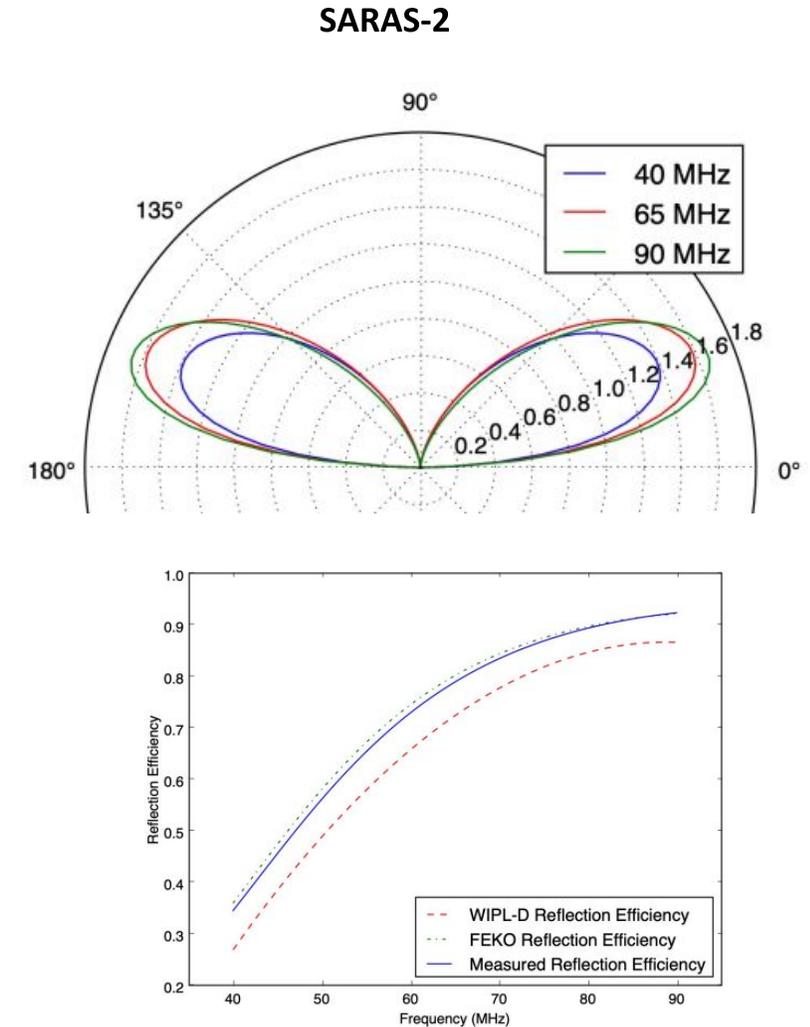
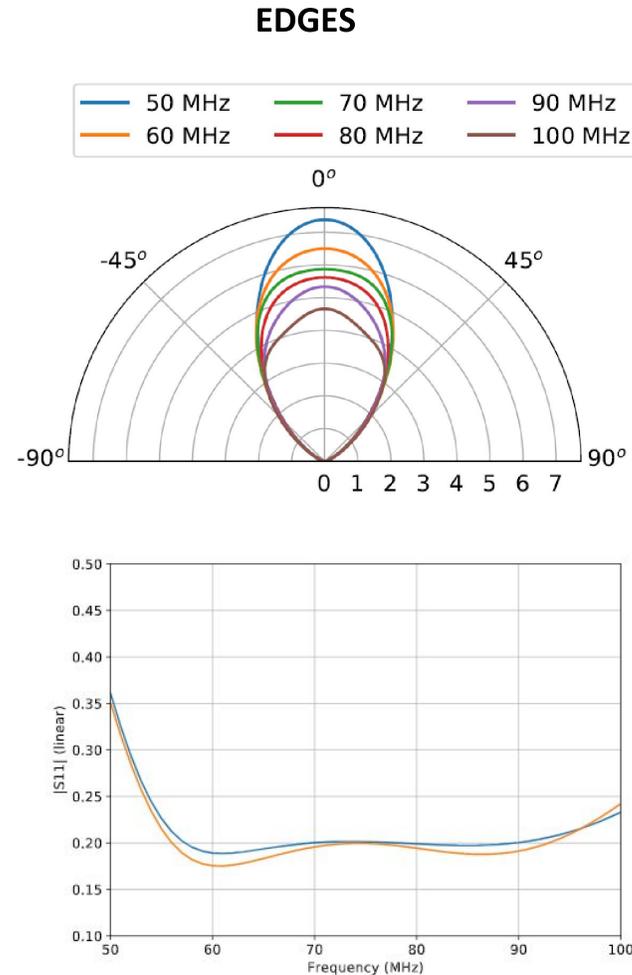
- Measure response to known inputs in the laboratory to solve for absolute temperature scale
 - Absolute accuracy to 1%
 - Relative accuracy in band to $< 0.01\%$
- In-situ measurement of antenna impedance
- Similar scheme employed by SARAS-2 - No switch - But cross correlation
- Achieve similar level of performance needed for cosmology
- Mature receiver strategies achieved by both.
- S_{11} measurement accuracy of 10^{-5} . *Saurabh et al. 2019*



Monsalve et al. 2017, Rogers & Bowman 2012

Modeling Chromatic Antenna Beams

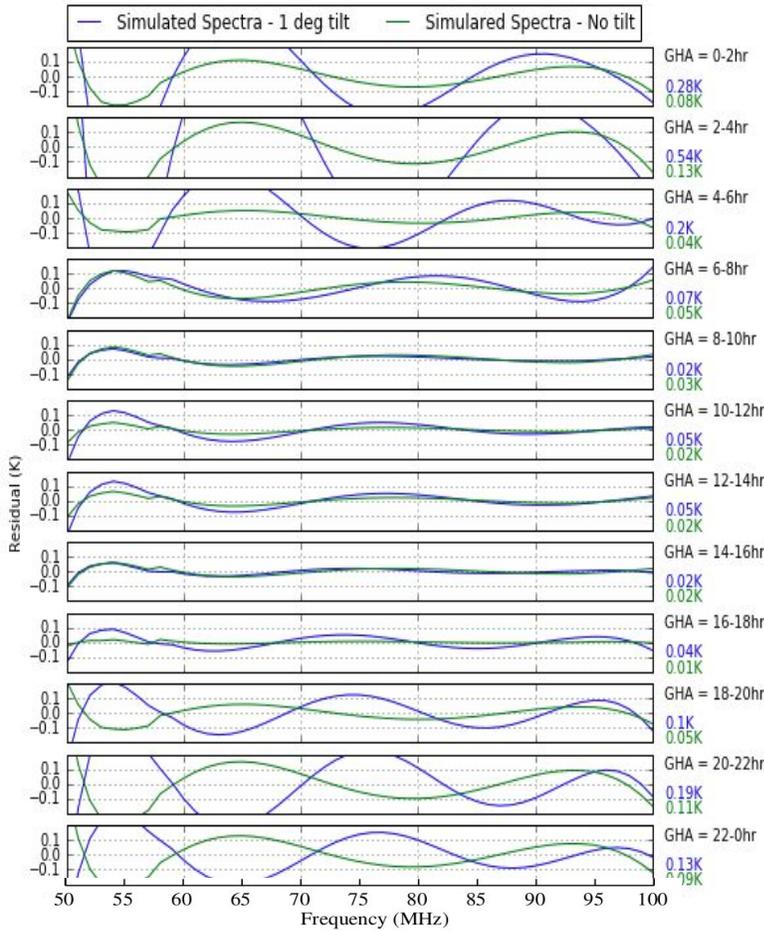
- Antennas are chromatic – their properties depend on frequency. This couples angular sky structure into observed spectrum
- Cannot presently measure antenna beam with sufficient accuracy
- Need extremely accurate electromagnetic antenna models to capture these effects
- Developed modeling techniques for EDGES and verified across three numerical solvers. Validated by comparing EDGES data and simulated observations



Mahesh et al. (submitted to AJ, 2020)

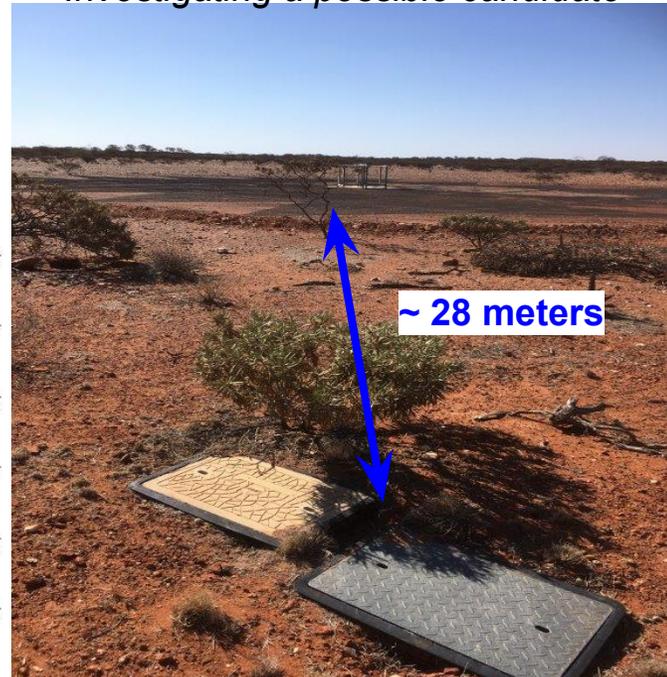
Examples of Antenna Environment

Considering tilt effects for **SARAS** as it floats on water



- Multipath/ reflections
- Soil Properties
- Ambient weather conditions
- Unmodelled imperfections in ground plane

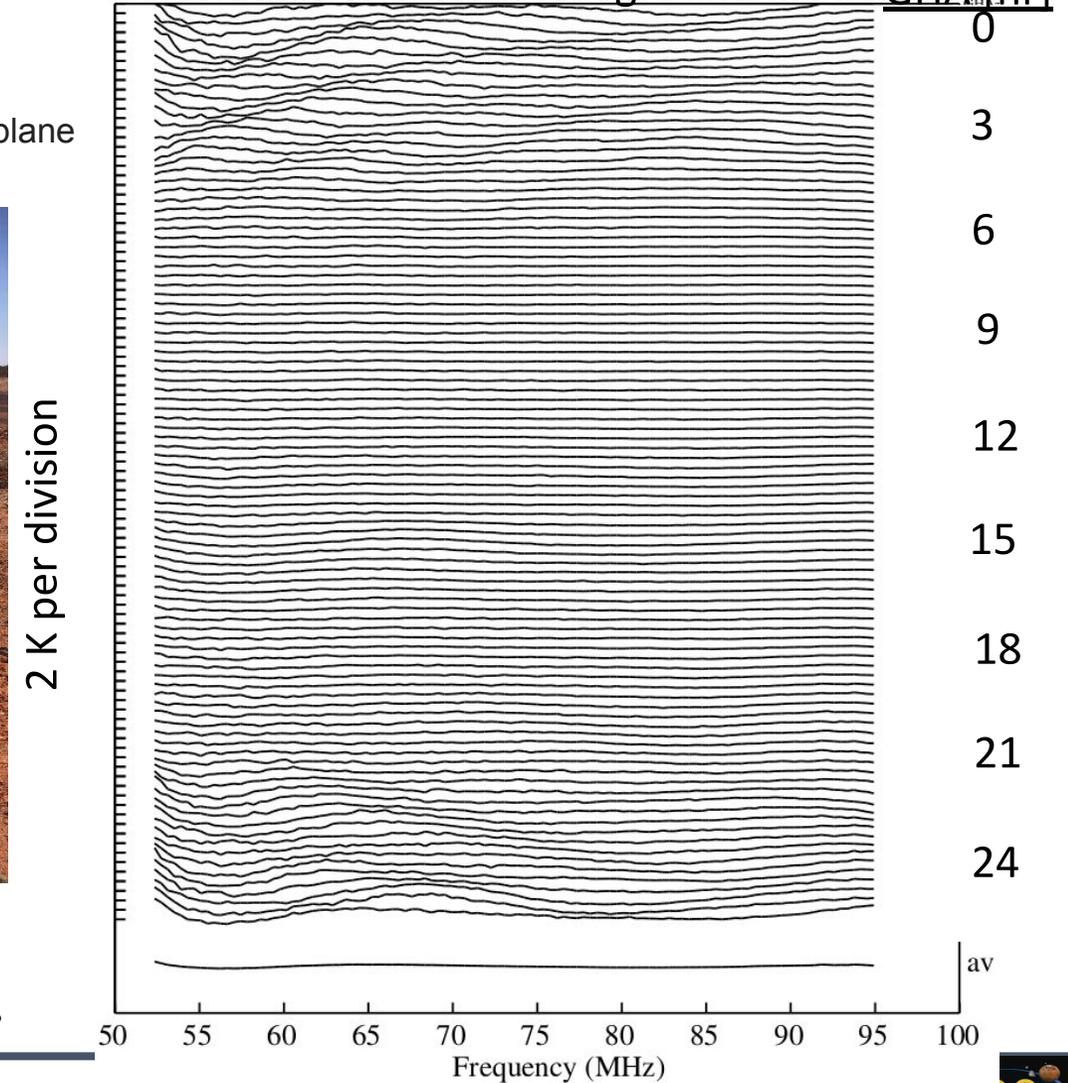
Investigating a possible candidate



A. Rogers and R. Monsalve

EDGES

Residuals to 5-term foreground model

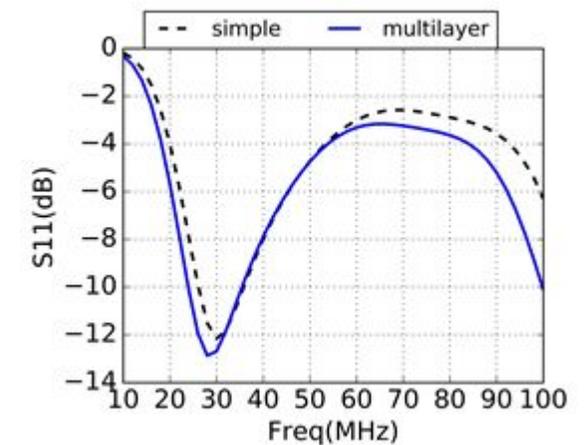
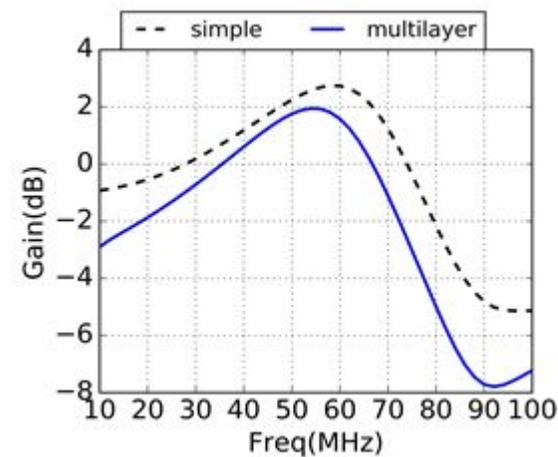
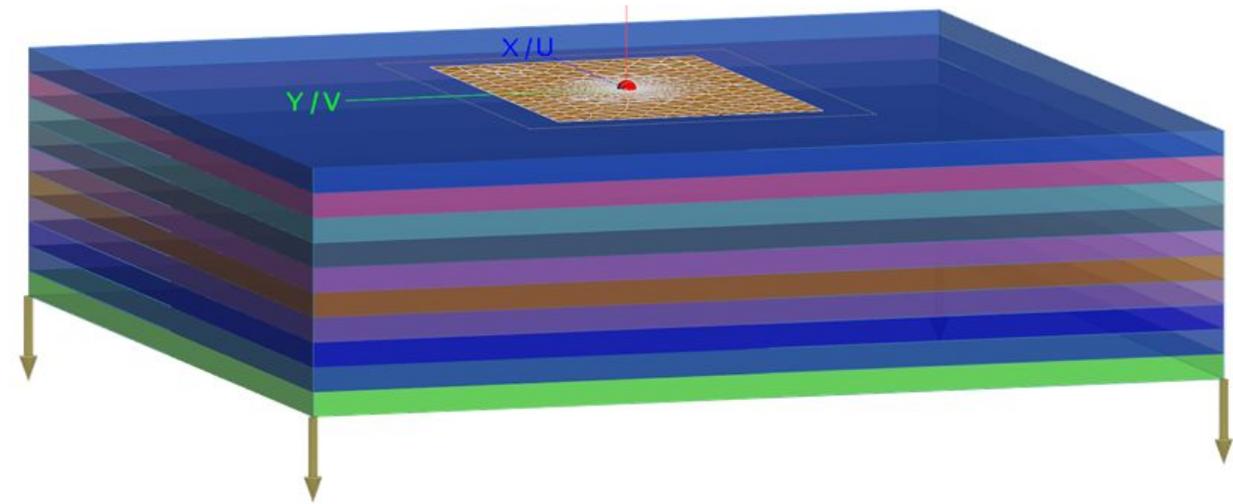


Applying lessons learned

Lunar surface, Measurements & EDGES-3

Lunar Surface

- Antenna beam modelling in presence of regolith
- Study gain & S11
- To minimize susceptibility to soil and nearby objects, need either:
 - Very uniform soil properties to 10s of meters depth
 - To use a large metal ground plane (ideally 100 meter diameter)
- Does a lunar surface dipole need a metal ground plane?



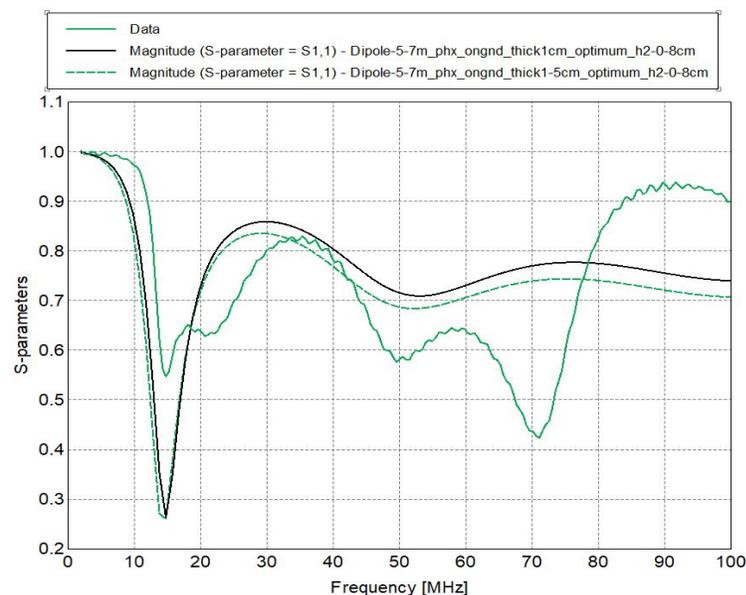
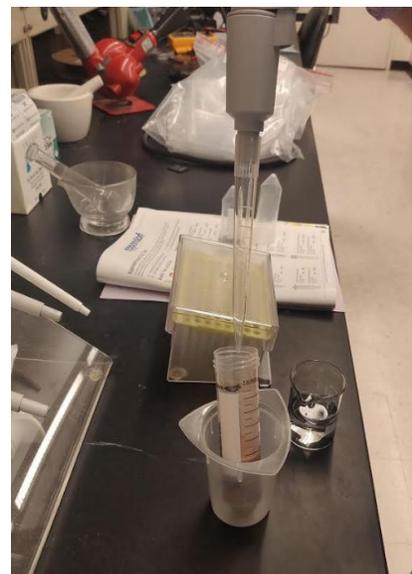
Measurements of dipoles on the ground

Aim:

- 1.) To solidify simulation results
 - 2.) To quantify ground effects
 - 3.) Needed for space missions
- A standard dipole antenna set was purchased from Com-power corporation.
 - The kit has 4 baluns that cover a frequency of 30 MHz to 1GHz.
 - The S11 measurements were made in two different sites in Tempe.
 - Soil sample was collected and conductivity was measured at the BioGeochemistry lab (Harnett's Lab)

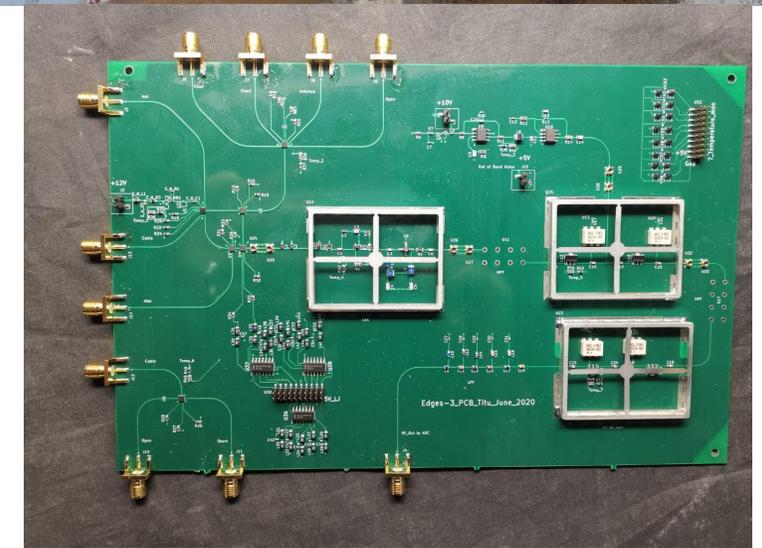
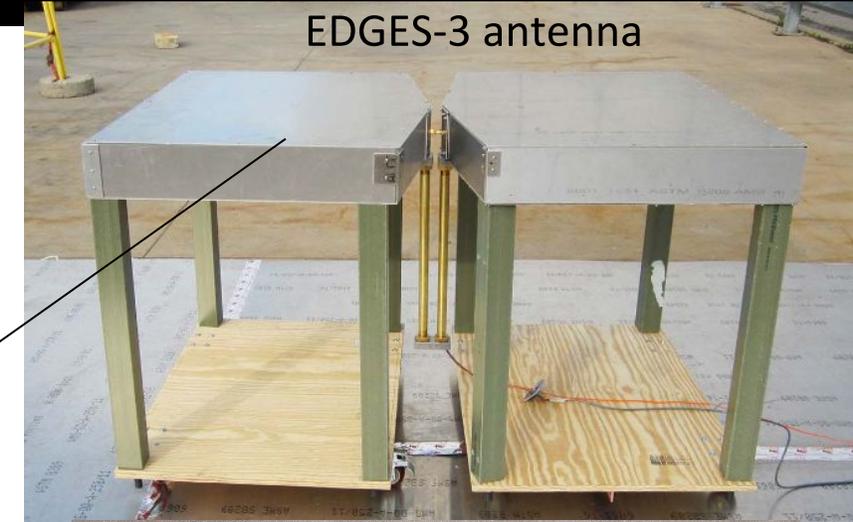


Measurement set up of the dipole on the ground at the SDFC field. The other end of the coax is connected to a VNA.



EDGES-3

- Apply lessons learned to create next-generation instrument
 - 50-meter (or no) ground plane to improve antenna beam effects
 - Integrate receiver *into* antenna to minimize electrical path length
 - Integrate calibration standards into system
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- Pathfinder for flight hardware
 - Replacing mechanical switches with solid state
 - Integrating into compact printed circuit board
 - Reducing size for better thermal management



EDGES-3 antenna

EDGES-3 test PCB

T. Samson and A. Rogers

Summary

- EDGES & SARAS have paved the way for lunar 21cm global missions
 - Established **fundamental instrument design** and calibration techniques
 - Developed accurate **instrument and antenna** modeling
 - Identified **need for knowledge of environment** and sky
- Preparing next-generation EDGES-3 and lunar instrument designs based on this validated foundation
- NASA supported **collaboration** has provided critical advances for EDGES and global 21cm experiments, including core calibration techniques and sophisticated analysis strategies