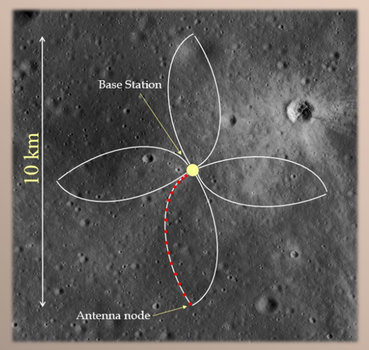
Are non co-located linearly polarized antennas advantageous for FARSIDE?

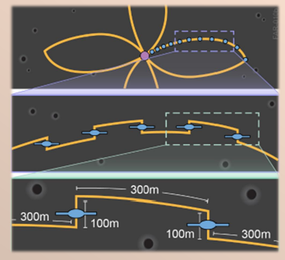
Nivedita Mahesh, Judd. D. Bowman and Bharat Gehlot, School of Earth and Space Exploration.

FINESST Award: ASTRO19-0089

FARSIDE Notional Layout

FARSIDE is a Probe class concept to place a low radio frequency interferometric array on the farside of the Moon.



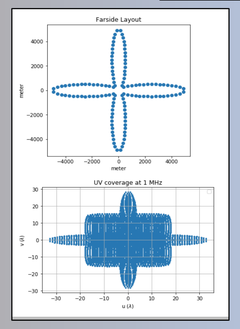


Parameter	Value
No. of Antennas	128
HB – Range	1 – 40 MHz
HB – Dipole	5 m
HB – Deployment	Stacers
LB – Range	100 kHz – 2 MHz
LB – Dipole	100 m
LB – Deployment	Embedded in tether
Petal Arm length	5 km
Petal arm width	10 km

Deployment of a 50m arm with stacer cannot be done.

- X *Not intended for dual polarization measurements.*
- X *No Circular polarization data.*
- X *Longer integration time (2x).*

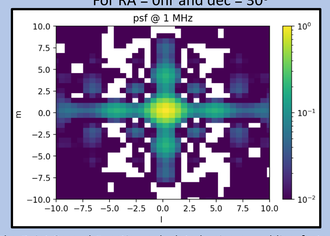
Ellipses for Petal Layout



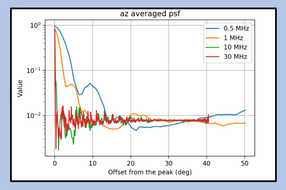
A simulated FARSIDE layout using the proposed dimensions. The four arms of the array are designed using ellipses with a major axis = 5 km and a minor axis = 1 km.

- The nominal elliptical configuration was slightly modified so that the central antennas do not overlap.
- For all *f*, the 1st sidelobe of the psf < 30x the peak.
- We find that doubling the petal width reduces the sidelobe level by factor of 2.

For RA = 0hr and dec = 30°

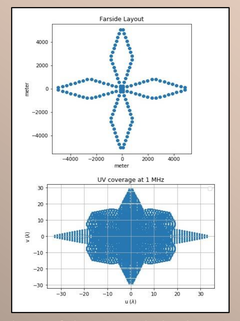


The Point Spread Function calculated using a padding factor of ~1.3 (upto +/-50 lambda).



A comparison of azimuthally averaged profiles of PSFs at 4 different frequencies for the elliptical arms layout.

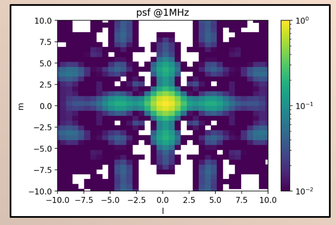
Rhombus Configurations



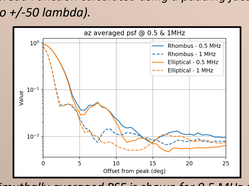
The layout of the array with rhombuses instead of ellipses, its uv-coverage at 1MHz.

- Nominal elliptical petal layout does not provide sufficient spacing between antennas to stagger the X & Y dipoles.
- So we investigate the staggered positions with Rhombus layouts.
- The psf from the rhombus configuration is compared with 1km width elliptical arms.
- The rhombus configuration seems to increase the level of far side-lobes (>10 degrees).

For RA = 0hr and dec = 30°



The Point Spread Function calculated using a padding factor of ~1.3 (upto +/-50 lambda).

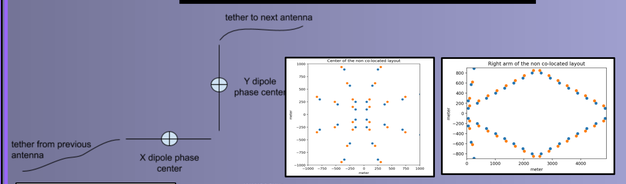


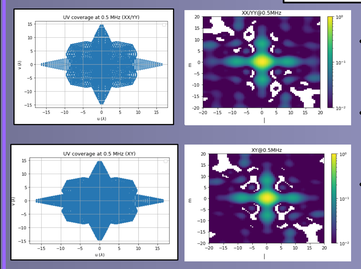
The azimuthally averaged PSF is shown for 0.5 MHz and 1 MHz.

We investigate an alternate antenna design and array layout that offers: 1.) ***dual polarization measurements*** *and 2.)* ***easy deployment*** *by eliminating the deployable stacers and embeds two dipoles sequentially in the tether for each antenna*

Non co-located Array Investigations

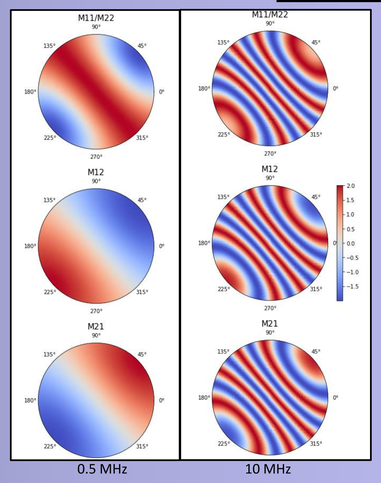
Offset X and Y Polarizations





- Each dipole is 100 meters tip-to-tip for the ➔ minimum offsets of the phase centers of the X and Y dipoles are 50 meters in each.
- These offsets lead to slightly different uv-plane coverage for cross-polarization (XY) baselines compared to the single polarization baselines (XX and YY).
- We calculate the uv-plane coverage for each set of baselines and find that the staggered layout:
  - fills the UV space more
  - results in better psf.

Estimating Stokes Leakage



The Stokes Leakage for the non-colocated dipoles is estimated using the procedure outlined in Kohn et. al 2019.

The Jones matrix for differential delay due to non-colocation is defined as:

$$J = \begin{pmatrix} 1 & 0 \\ 0 & e^{i\Delta\phi} \end{pmatrix} \qquad \Delta\phi = 2\pi(\Delta u * l + \Delta v * m)$$

Then using the Mueller matrix formulation of

$$M_{ab} = Tr\{\sigma_a \, J \, \sigma_b \, J_H\}$$

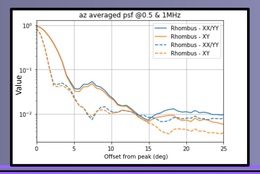
We obtain:

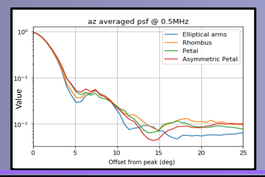
$$M_{ab} = \begin{pmatrix} 2 & 0 & 0 & 0 \\ 0 & 2\cos(\Delta\phi) & -2\sin(\Delta\phi) & 0 \\ 0 & 2\sin(\Delta\phi) & 2\cos\Delta\phi & 0 \\ 0 & 0 & 0 & 2 \end{pmatrix}$$

- Collocated array ➔ a diagonal M_{ab}
- Here for a constant antenna offset:
  - we see cross term leakage for Q and U.
  - the muller matrix terms for Stokes V leakage is zero
- The leakage term varies for different arms of the array layout.

Summary

- The Elliptical layout sidelobe < Rhombus configuration sidelobe. These psfs are also compared with the petal configuration (See A. Hegedus poster.)
- Staggered layout is feasible with the Rhombus configuration with sufficient spacing (220 m).
- The offset configurations results in different u-v coverages & point spread functions for XX/YY Vs XY/YX.
- Using the u-v coverage, the Stokes leakage was estimated which indicated cross term leakage for Stokes U & Q.
- But these leakages can be corrected using Jones matrix for fractional delay.





Future work

- Investigate more possible array layouts to optimize the rover displacement.
- Estimate the effect of error in the dipole placements.
- Estimate the effect of error on the primary beam differences
- Simulate visibilities with realistic sky models.
- Investigate the effect of the fractional offsets on the I, Q, U, V images.

This work was directly supported by the NASA Solar System Exploration Virtual Institute Cooperative Agreement 80ARCC017M0006