Estimation of polarization effects on sky visibilities for FARSIDE

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The Farside Array for Radio Science Investigations of the Dark ages and Exoplanets (FARSIDE) is a Probe-class concept to place a low-frequency radio interferometric array on the far side of the Moon. The instrument will enable detection of radio emission from exoplanetary systems and serve as a pathfinder for hydrogen cosmology of the Dark Ages using the redshifted 21 cm signal of neutral hydrogen in the early Universe [2]. The current FARSIDE design architecture consists of 128 non co-spatial orthogonal pairs of antenna and receiver nodes distributed over a 10 km $\times$ 10 km area in a four arm spiral configuration. Four two-wheeled tethered rovers would be teleoperated to deploy the nodes on the four-arm spiral that remain connected to the lander by their individual tethers, providing communication, data relay, and power during deployment as well as for operations [1]. For ease of deployment, the design embeds the two 100 m dipoles sequentially in the tether for each antenna. In this scenario, the rover will deploy the tether with 90° bends along its path at each antenna location to ensure that the two embedded dipoles are aligned to orthogonal polarizations thus leading to an offset between the phase centers of the dipoles. This design provides for dual polarization measurements and circular polarization data that can help confirm exoplanet radio emissions and reduce integration time by a factor of 2.

The array configuration and deployement strategy has the caveat that the two orthogonal polarizations (labeled X and Y) for each antenna will not be co-located. This will cause the sets of XY and YX baselines to fill different regions in visibility space compared to corresponding XX and YY polarizations. We investigate the science impact of the offset between the antenna pairs in the array layout. We have estimated the polarization leakages in terms of the stokes I, Q, U and V beams of the array as a function of frequency and dipole offsets. This was done using the Muller matrix formulation presented in Kohn et. al. 2019 [3] on the beams of orthogonal 100m dipoles simulated over regolith using the FEKO software. We account for the offset differences between the phase centers of the dipoles in the Jacobian calculation of the beam. We find that the offset leads to additional mixing and leakages of Stokes U and V components of the sky into all the four different polarizations of the instrument. To quantify a few of the mixing modes; the Stokes U leakage into V of the instrument and vice versa is $\pm$ 0.4% and $\pm$1% respectively with just the beam effects and increases to $\pm$60% including the effect of offsets 2 MHz. This leakage further increases with frequency and errors in offset. In terms of offset errors, an error of 1% leads to $\pm$4% change in the Stokes U and V leakages.

Using the fourier transform of the different polarization beams and *uv*-coverage of the FARSIDE array, we then calculate the sky visibilities and produce the dirty images of the sky. We carry out this process for different sources on the sky and for different pointing directions. Using the results, we will carefully investigate levels of tolerance for errors in dipole placement, rotation and wiggles. For this complete investigation, we use a custom interferometer simulation pipeline to account for the non co-located X and Y polarizations in the FARSIDE array configuration. In the future for more realistic cases of the sky, we will combine results from our pipeline and the functionalities in pyuvsim. I will report the latest results from this effort.

References

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