Modeling Planar Dipoles on Lunar Regolith for a Radio Array on the Lunar Far-side. N. Mahesh[1] and J.D. Bowman[1], [1]School of Earth and Space Exploration, ASU, Tempe, 85282, (Nivedita.mahesh@asu.edu).

Some of the most pressing questions in astrophysics can be addressed by a low-frequency radio array telescope on the lunar surface. The key science goals of such an array include: 1) detection of exoplanet radio emission to characterize exoplanet habitability and 2) probing the growth of structure and thermal history of the universe during the cosmological dark ages using the 21cm line of hydrogen.

Existing radio astronomy antenna designs optimized for Earth-based arrays need to be modified for use in lunar radio telescope to cover the desired frequency range between ~1-30 MHz and to account for the properties of the lunar regolith. Further, to meet the desired sensitivity of the key science, the array would need thousands of dipoles. With deployment on the lunar surface as one of the main constraints, we explore configurations that involve planar dipoles as envisioned in the ROLSS concept. As a first step to optimize dipole antenna designs for a lunar telescope, we use the well-understood beam patterns of the Experiment to Detect the Global EoR Signature (EDGES) low-band planar "blade" antenna as a reference.

Here, we report simulated properties of blade dipoles placed directly on lunar regolith compared to dipoles above a ground plane. We observe that the impedance of an antenna differs when it is on regolith compared to above a ground plane, hence the operational bandwidth differs between the two scenarios by 11%. In addition, the antenna's beam will differ. For an antenna on a finite ground plane, the beam response generally has its maximum near zenith and little of the response will be below the horizon, whereas for an antenna directly on the regolith, the primary response of the beam is seen to be toward the nadir. Thus, there is an associated reduction in efficiency, roughly 45%, for a dipole directly on regolith compared to over a ground plane. We investigate these differences by considering several variations with and without ground planes, as well different dipole antenna sizes. Calculations indicate that an antenna that is two times larger than EDGES low-band blade has a sufficient SNR of ~ 2.8 at low frequencies ~ 10 MHz. But the reflection coefficient (S11) of this antenna is ~0.96 at 10 MHz, making the performance sensitive to small changes in regolith properties or calculation errors.

We explore ways to improve the return loss of planar dipoles by 1) increasing the electrical path length for the currents on the surface and 2) by breaking the planarity requirement of the antenna, lifting the dipole panels at an angle from the regolith. Our preliminary analyses considered constant regolith electrical properties with frequency ($\epsilon_r = 2 \ \& \ \sigma = 3e^{-5}\ S/m$). We further plan to consider more realistic conditions of the regolith which would include layers of rocks other than frequency dependent material properties. After obtaining a reasonably optimized final design, we will extend the analysis to include both the linear polarizations of the antenna as that would be essential for exoplanet studies.

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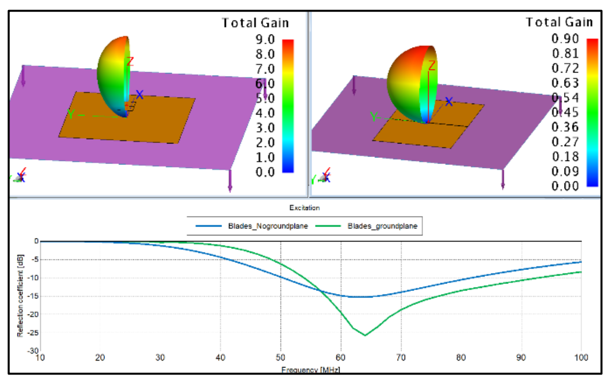

Figure: The top two panels show the 3D models of the EDGES low-band blade antenna. In the left panel the antenna is not visible, only the PEC ground plane (brown). The right panel shows the scenario with the antenna placed straight on the regolith. Here the antenna is shown in brown. The purple substrate indicates the Lunar regolith model used in the simulations. Overlaid on the models are their respective 3D beam patterns at 40 MHz. The max gain is 9.0 for the ground plane case Vs 0.9 for the no ground case. The bottom plot is return loss Vs frequency for the above two cases. The no ground plane case (blue) is seen to have a lower bandwidth where S11 < -10dB compared to the ground plane case (green). The improved S11 at 40 MHz compensates the drastic reduction in gain resulting in overall reduction of the efficiency by only 45%.