

Taking Advantage of the Radio Quiet Lunar Farside with the FARSIDE Radio Array. Neil Bassett¹, Jack O. Burns¹, David Rapetti^{1,2,3}, and Keith Tauscher¹, ¹University of Colorado Boulder, Boulder, CO ²NASA Ames Research Center, Moffett Field, CA ³Universities Space Research Association (USRA), Mountain View, CA

Introduction: The Farside Array for Radio Science Investigations of the Dark Ages and Exoplanets (FARSIDE) is a probe-class, NASA-funded concept study, which takes advantage of the unique radio environment of the lunar farside. By deploying 128 antennas across a 10 km x 10 km area, FARSIDE will be able to image the 10,000 square degrees of sky visible from the lunar farside from 200 kHz to 40 MHz [1]. The instrument consists of a central base station with the antenna nodes deployed along 8 spokes in an asymmetric petal configuration. The nodes are connected by a tether, which provides power and data transfer.

The infrastructure required for the mission includes a commercial lander (in which the base station is integrated) and a rover used to carry and deploy the antenna nodes. The total mass of the landed payload is 1,750 kg, well within the expected capabilities of future commercial landers such as Blue Origin's Blue Moon lander. The requirement for the landing site is simply that it be within the radio quiet region of the lunar farside (see Figure 1). The deployment of the instrument would be entirely robotic, not requiring human astronauts on the surface. The rover would deploy each petal over the course of a lunar day (requiring 4 days total), returning to the base station each time. In order to survive lunar night, FARSIDE would be equipped with radioisotope thermoelectric generators to provide heat. The low radio frequency observations that FARSIDE will be able to perform will enable a wide range of science. FARSIDE will be able to monitor nearby stars and detect coronal mass ejections and bursts caused by other magnetic events, identify auroral radiation from the magnetospheres of possibly habitable exoplanets, and measure the 21-cm spectrum from the Dark Ages between recombination and the formation of the first stars and galaxies. Additionally, FARSIDE will be able to provide observations of our own solar system, including the possible Planet 9, as well as sounding of the lunar subsurface down to ~2 km.

Lunar Radio Environment: Ground based measurements at low radio frequencies are limited by both ionospheric effects and the presence of human generated radio frequency interference (RFI). The ionosphere contains free electrons due to the ionization by solar radiation and acts as a plasma. Below ~30 MHz ionospheric effects distort incoming radio signals well above the level expected for the 21-

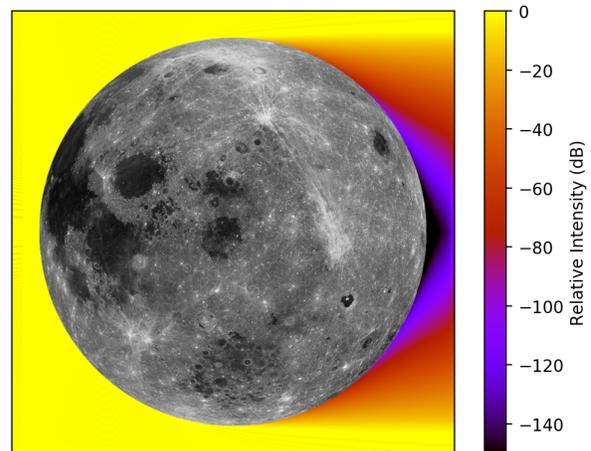


Figure 1: Results of a 4000 x 4000 km numerical simulation of the lunar radio environment at 30 kHz [3]. RFI incident from the left is attenuated behind the Moon on the right. Higher frequencies exhibit even greater levels of attenuation due to the decreasing effect of refraction around the limb of the Moon. An image of the Moon is overlaid for illustrative purposes.

cm signal as well as other sensitive astronomical signals [2]. Below the plasma frequency, which depends on the electron density but is generally ~10 MHz, the ionosphere is effectively opaque to electromagnetic radiation. Even above Earth's ionosphere, terrestrial RFI may still contaminate observations at low radio frequencies. These RFI signals include power communications transmitters with unpredictable spectral signatures. The farside of the Moon, however, offers a unique radio quiet environment above the ionosphere where both terrestrial RFI and Earth's auroral radiation are occluded by the Moon [3]. Numerical simulations of the electromagnetic environment confirm the radio quiet nature of the lunar farside (see Figure 1). Low radio frequency experiments can take advantage of this quiet region by placing an instrument directly on the surface of the farside.

A finite difference grid algorithm was used to propagate the electromagnetic waves through the simulation and model their interaction with the lunar material, including its electromagnetic properties. Topographical data from the Lunar Orbital Laser Altimeter (LOLA) was included in the simulation and

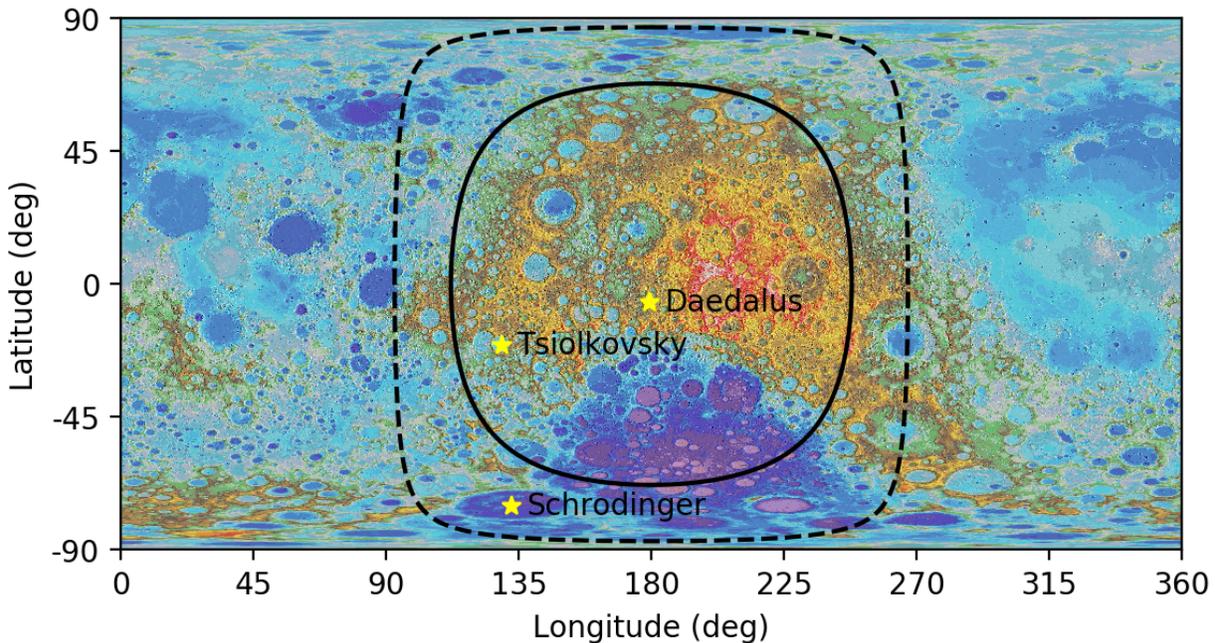


Figure 2: Elevation map from the Lunar Reconnaissance Orbiter Camera (LROC). Yellow stars signify several craters that may be of interest to low frequency radio experiments and/or lunar studies. The solid black curve denotes the ≥ 80 dB quiet region as determined from FDTD simulations at 100 kHz, while the dashed black curve is the ≥ 80 dB quiet region at 10 MHz extrapolated from the model.

showed that the topography of the Moon has only a small effect on the overall attenuation of radio waves on the farside.

Above ~ 100 kHz, direct simulations become computationally expensive due to the required grid resolution. The width of the quiet region at lower frequencies is fit well by a power law model, which can be combined with the known behavior of the system at infinite frequency (due to the geometry of the system) to extrapolate the size of the quiet region to higher frequencies.

The map of the Moon shown in Figure 2 reveals the large area of the farside covered by the radio quiet region. Even at frequencies as low as 100 kHz, RFI signals will be attenuated by at least 80 dB over a large portion of the farside. When the frequency is increased to 10 MHz, the quiet region covers nearly the entire farside including the South Pole Aitken Basin. The large size of the radio quiet region provided by the farside is encouraging because of how close the region comes to the lunar poles. Due to the discovery of the presence of water-ice in the permanently shadowed region near the poles, there is an increased desire to send upcoming missions to the poles. This presents an opportunity for low radio frequency experiments to be deployed in conjunction with human or robotic missions to the poles or other locations on the farside of the Moon.

References:

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