EM Modeling of Resistively Loaded Antennas on Lunar Regolith

Team 42 Lumen

Jose Ayon, Sohum Saraswat, Benjamin Fernandez, Jacob Poland, Fabian Reyes

Mentor: Judd Bowman

Purpose

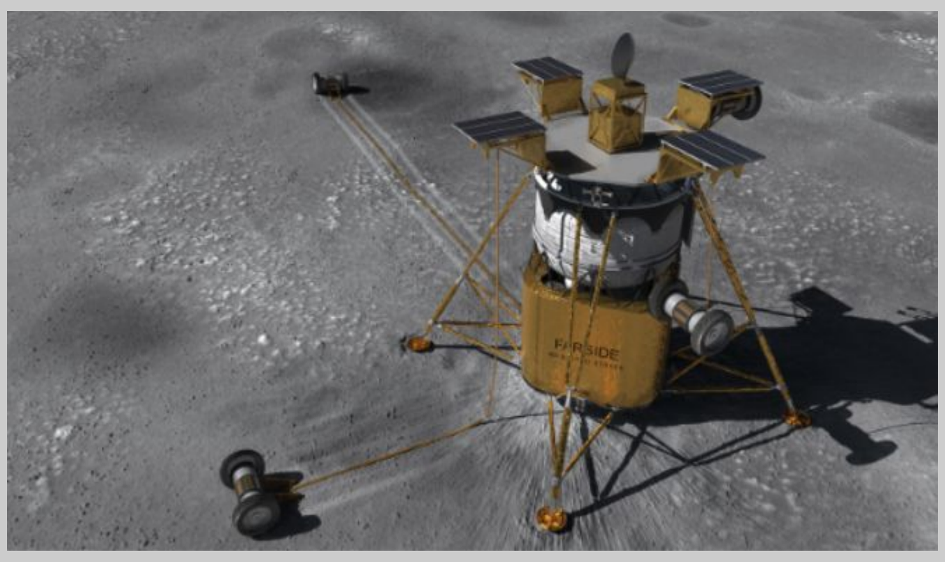
FARSIDE (Far-side Array for Radio Science Investigations of the Dark Ages and Exoplanets) focuses on detecting very weak radio signals from space that cannot be observed on Earth due to interference and noise. The far side of the Moon provides a quiet environment for these observations. In this project, we studied how our antenna behaves to ensure it can effectively detect these faint signals.

Introduction

The FARSIDE mission, developed by NASA's Jet Propulsion Laboratory and the University of Colorado Boulder, This system uses autonomous rovers to lay out long antenna-embedded tethers across the lunar surface, forming a large distributed radio telescope.

A key feature of this design is the use of ferrite materials within the antenna to control electromagnetic behavior. Prior work showed that ferrite loading can isolate sections of the antenna, improving performance by reducing unwanted effects.

Building on this, this project focuses on modeling ferrite-loaded dipole antennas to understand how different loading methods affect signal behavior. This provides a clearer understanding of dipole performance and supports the development of reliable antenna designs for future lunar radio astronomy.



Ferrite Shrouding

Ferrite shrouding places ferrite material around sections of the antenna to control how current flows along the dipole. The ferrite introduces frequency-dependent impedance that increases at higher frequencies, suppressing unwanted currents. This reduces sidelobes and helps maintain a cleaner, more stable radiation pattern across the frequency range.

Results & Analysis

Conceptual

- Lunar regolith causes losses and shifts in performance
- Unloaded antenna shows multiple lobes at higher frequencies
- Ferrite loading suppresses unwanted currents
- Continuous loading gives a clean, stable response

Physics

- Antenna is highly reactive at low frequencies
- Regolith increases electrical length and loss
- Ferrite adds R + jX, lowering Q and smoothing response
- Controlled current distribution gives improved radiation pattern

Conclusion

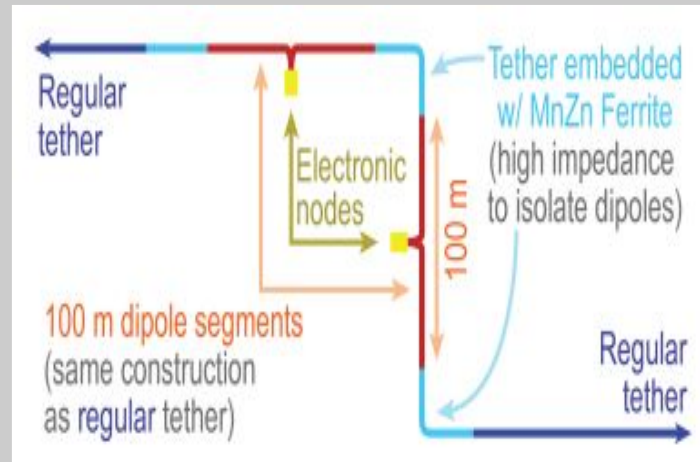
Ferrite loading was shown to improve antenna performance by reducing sidelobes and producing a more stable, broadband response, with continuous loading providing the most consistent results. The lunar environment plays a significant role in shaping antenna behavior, affecting efficiency, resonance, and overall signal quality. However, these findings are based on simulations that depend heavily on assumed conditions such as material properties and surface characteristics. As a result, variations in these assumptions can lead to different outcomes, highlighting the need for more refined modeling and experimental validation to confirm performance in real-world lunar conditions.

Requirements & Problem

- Must detect very weak low-frequency signals(100Khz - 40 Mhz)
- Antenna must operate effectively over a wide frequency range
- Performance is affected by the lunar surface (regolith)
- Traditional antennas create multiple unwanted lobes at higher frequencies
- Need a design that maintains a clear, stable signal response
- System must be simple, reliable, and suitable for lunar deployment

Solution

- Use a long dipole with ferrite loading
- Ferrite controls unwanted currents
- Reduces extra lobes for a cleaner signal
- Compared point vs continuous loading
- Goal: single, stable response across frequencies

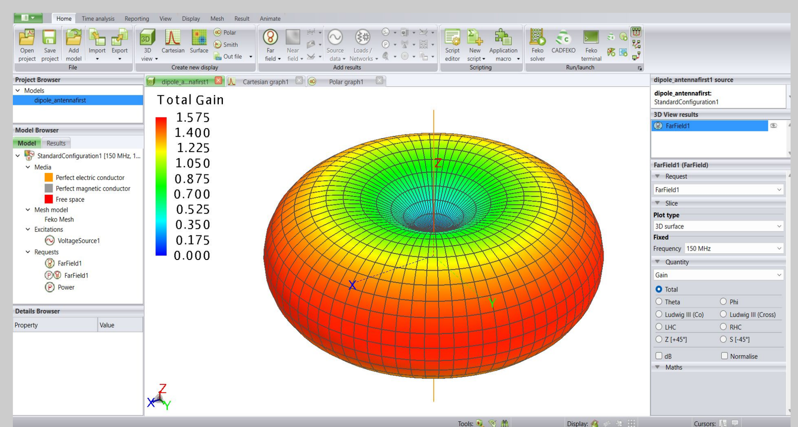


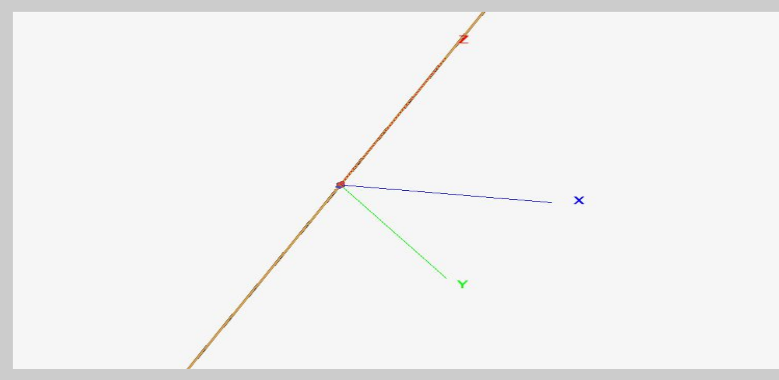
Design Approach & Team Methodology

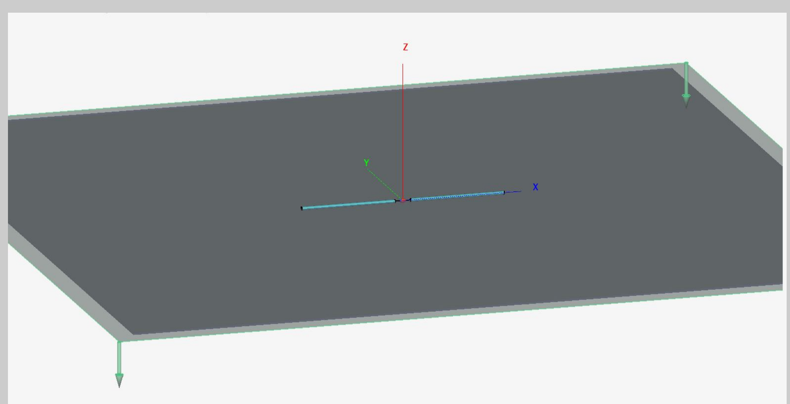
Approach Mindset: We followed a step-by-step process, starting from a simple baseline and gradually adding real-world lunar conditions and enhancements to understand their impact on antenna performance.

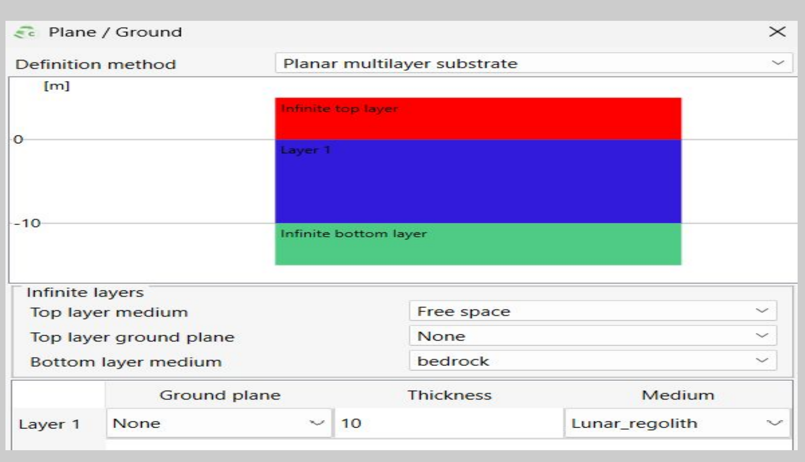
1. Base Antenna Design (Earth Simulation)

- Designed a half-wave dipole antenna in Earth environment
- Simulated performance to establish a reference for gain, impedance, and radiation pattern
- Verified expected behavior at resonance and across frequencies
- Used this as a control case for comparison with later conditions







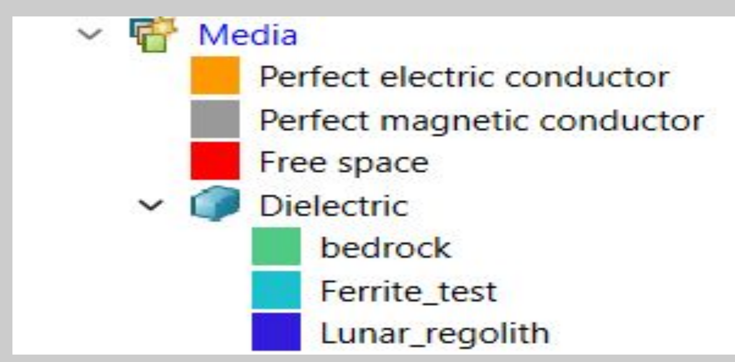


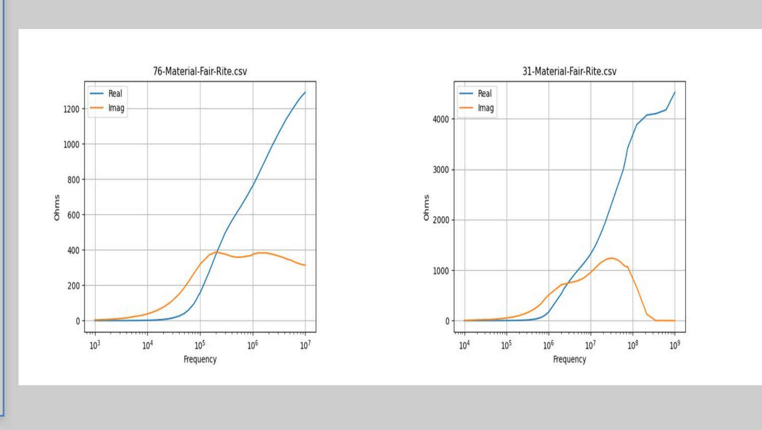
2. Lunar Environment Modeling

- Introduced lunar regolith properties into the simulation
- Modeled antenna placement close to the lunar surface
- Analyzed how the Moon's surface affects signal propagation and losses
- Compared results with Earth simulation to observe performance degradation and pattern changes

3. Ferrite Loading Implementation

- Studied different ferrite materials (Mix 31 and 76) and their impedance behavior
- Explored loading strategies (point vs continuous along the antenna)
- Incorporated ferrite effects into Altair Feko simulations
- Evaluated impact on radiation pattern, sidelobes, and signal stability
- Identified configurations that produce a cleaner, more controlled response





Ira A. Fulton Schools of Engineering

Arizona State University