Synergistic Use of Telecommunications Systems to Conduct Bistatic Radar

Principal Investigator: David Bell (337)

Daniel Nunes (322), Harvey Elliot (337), Zaid Towfic (337), Curtis Jin (337), Abigail Fraeman (322)

Program: Spontaneous Concept

Project Objective:

The goal of this project is to evaluate the ability to conduct bistatic radar experiment with the use of the Mars helicopter and Mars 2020 rover. This effort focused on the use of the helicopter's telecommunication subsystem as a source, with the receiver being the Radar Imager for Mars' Subsurface Exploration (RIMFAX) instrument on the Mars 2020 rover, which is a ground-penetrating radar). Fortunately, the telecommunication subsystem of the helicopter overlaps with the operational frequencies of the RIMFAX instrument to make this concept feasible.

However, prior to effort, the useful science that may be ascertained from such an experiment was not clear. Major factors impacting that result depends on the geometry of the experiment and surface properties. In this effort, we address these issues.

Benefits to NASA and JPL and Significance of Results:

This effort studied the performance of a bistatic radar experiment between the Mars helicopter and the RIMFAX GPR onboard the Mars 2020 rover, using the Mars helicopter telecommunication system as a source. The effort concentrated on two problems:

1. The characterization of surface layer properties from Brewster Angle
2. The detection of medium change in the subsurface layers

For the first problem, we explored the characterization performance against the surface properties. We have shown that it is possible to utilize the existing communication waveform to achieve successful characterization. In fact, the determination of the surface permittivity can be done in an extremely fine scale with our current approach, compared with traditional approaches. However, one caveat we encountered is that a bistatic experiment involving the Helicopter and a rover is relegated to areas of high surface permittivity and/or high Helicopter altitude (> 30 m) for current operational separation tolerance. Alternatively, the operational separation tolerance for the two vehicles needs to be reduced to ~10 m or less.

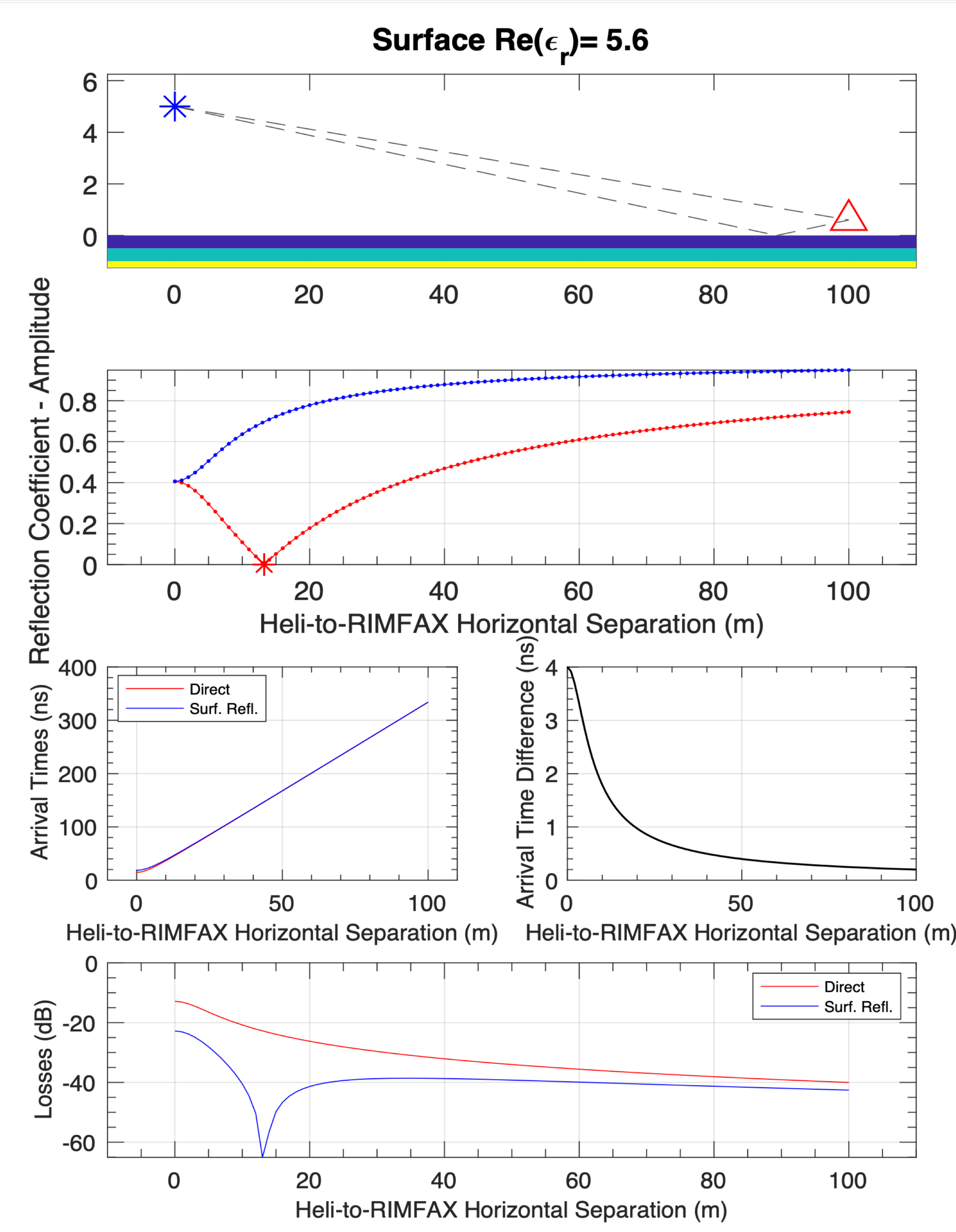
For the second problem, we demonstrated successful detection of a sub-surface medium change via a bistatic experiment utilizing the helicopter telecom waveform and the RIMFAX receiver up to 100cm in depth for when the helicopter-rover distance is 100m. The detection of the depth of the interface can be obtained by sweeping the helicopter height up to 50m and comparing the profile to that shown in Fig. 4. Again, the caveat is that the helicopter height should be up to 35m (to detect the deeper interfaces).

FY19 Results:

Problem 1: Characterization of Surface Layer Properties from Brewster Angle

We modeled the bistatic surface reflection coefficient according to Ulaby (1982) for a range of surface permittivity values and geometries to assess the feasibility of the experiment, while adopting the Mars Helicopter telecom frequency of 914 MHz. The geometry is defined by the altitude of the helicopter antenna from the ground, the height of the RIMFAX antenna above the ground, and the horizontal separation between the Helicopter and the RIMFAX antenna. In the landed configuration, the helicopter antenna is ~0.4 m above the ground, and we assume a helicopter altitude (Z_h) envelope between 1 m and 50 m. The latter is greater than that planned for the actual flight of the Mars Helicopter, but it allows for a better characterization of the conditions under which future experiments will need to take place in order to yield useful science. The height of the RIMFAX antenna above the ground is fixed at 0.6 m. The real part of the surface layer permittivity (ε_r') depends primarily on its density. Unconsolidated regolith is very porous, with densities between 1500 kg/m^3 and 1900 kg/m^3, which translate to real relative permittivity values between 2.8 and 3.3. Here we adopt 2.5 and 3.2 as a plausible regolith range. A zero-porosity real relative permittivity value of basalt from shergottites is 8.8, which we employ as the uppermost bound. We also adopt a 5.6 intermediate value for the real relative permittivity of sedimentary and volcanic rocks.

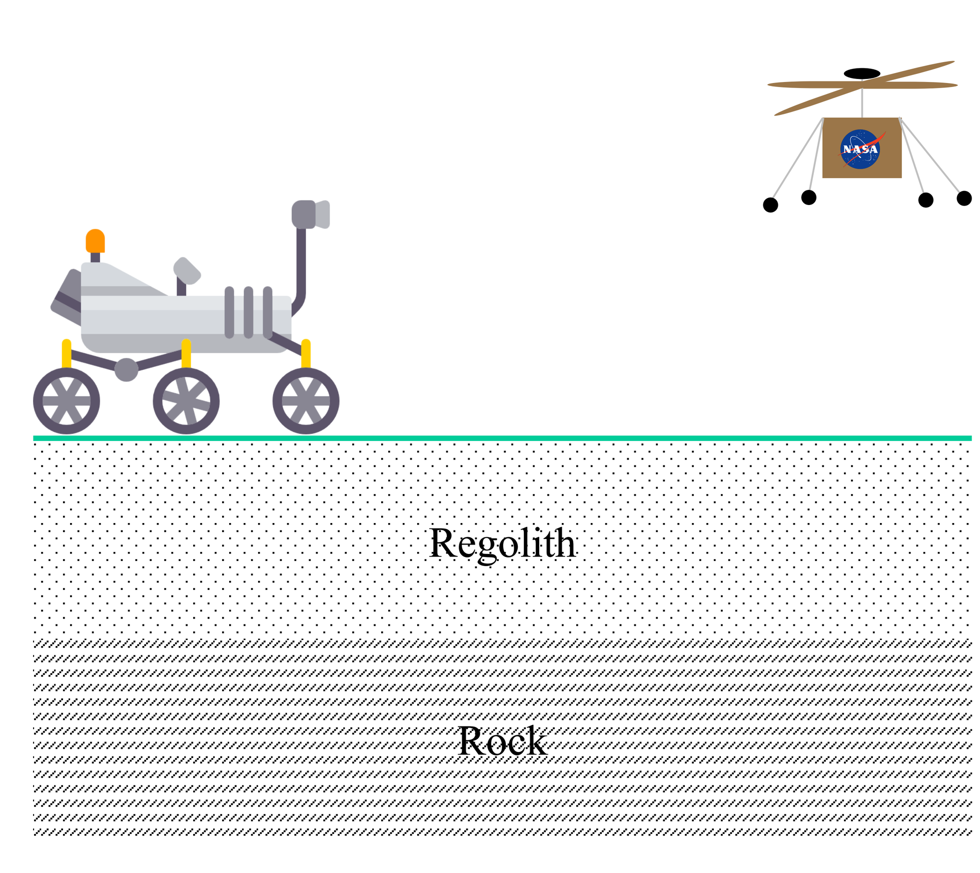
The surface reflection coefficient is the sum of the horizontal (RH) and vertical (RV) polarization components. The Brewster angle is the particular incidence angle at which RV drops to zero and R to a minimum value (R_{min}). We computed the Brewster angle for the parameter envelope assumed for this Problem 1, and convert it to a "Brewster separation", or the value of the horizontal separation between Helicopter and RIMFAX at which RIMFAX would observe R_{min}. The reflection loss in dB is calculated from the reflection coefficient and combined with spherical expansion loss. The figure on the right shows the output from our model for a single permittivity and helicopter altitude (ε_r' , Z_h) set, and separations ranging from 1 to 100 m.

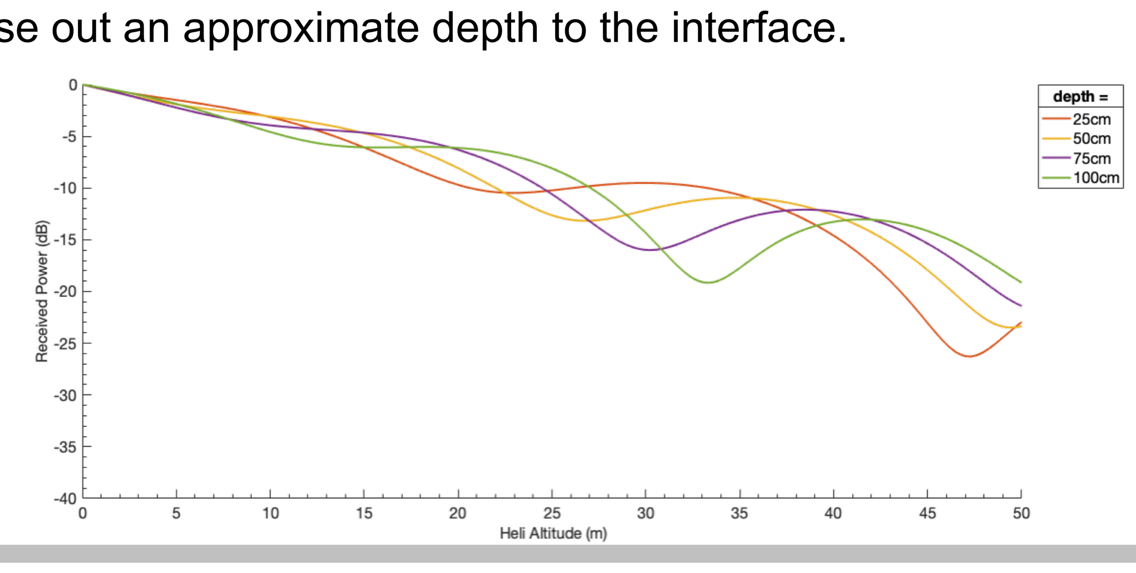


Problem 2: Detection of medium change at depth:

Using the same model as described in Problem 1 we also wanted to explore the potential of using the Mars Helicopter to detect a change in medium under the surface. This could be thought of as a layer of rock under sand, subsurface ice, or any other media which would change the relative permittivity. For the sake of simplicity, we will also assume this layered media is in the form of a plane parallel bed with a distinct interface between the two layers. In this example we model a top layer of regolith with a relative permittivity of 3.0 and a bottom layer of rock with a relative permittivity of 5.6. We will also assume that the helicopter is at a fixed separation distance of 100m and can fly to a maximum altitude of 50m. The figure below shows the results for this model for a regolith depth of 25, 50, 75, and 100 cm.

Assuming that the Mars Helicopter is able to operate in this flight envelope it shows promising results for detecting a medium change in the first few meters of the regolith. Whereas Problem 1 produced a smooth curve with a single defined null a layered bed would produce more of a sinusoidal response. The number and location of the minima of these sinusoidal signals can be used to tease out an approximate depth to the interface.





National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

PI/Task Mgr. Contact Information:
David J. Bell
David.J.Bell@jpl.nasa.gov
(818) 354-8041

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