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Bistatic Radar Observations of the Moon Using the Arecibo Observatory & the Mini-RF Instrument on LRO

D. B. J. Bussey (1), R. Schulze (1), C. V. Jakowatz (2), M. Nolan (3), R. Jensen (1), G. W. Patterson (1), F. S. Turner (1), D. E. Wahl (2), D. A. Yocky (2), J. T. S. Cahill (1), C. Neish (1), R. K. Raney (1), P.D. Spudis (4), and the Mini-RF Team,
(1) Applied Physics Laboratory, Laurel MD USA, (2) Sandia National Laboratory, Albuquerque NM USA, (3) Arecibo Observatory, Arecibo PR USA, (4) Lunar and Planetary Institute, Houston TX USA (ben.bussey@jhuapl.edu)

Abstract

The Mini-RF team is conducting a bistatic radar imaging campaign that will test the hypothesis that permanently shadowed areas near the lunar poles contain water ice. Additionally these measurements can be used for studies of the composition and structure of pyroclastic deposits, impact ejecta and melts, and the lunar regolith. These bistatic observations involve the Arecibo Observatory Planetary Radar (AO) transmitting a 12.6 cm wavelength signal, which is reflected off of the lunar surface and received by the Mini-RF instrument on LRO. These observations will be the first lunar non beta-zero radar images ever collected.

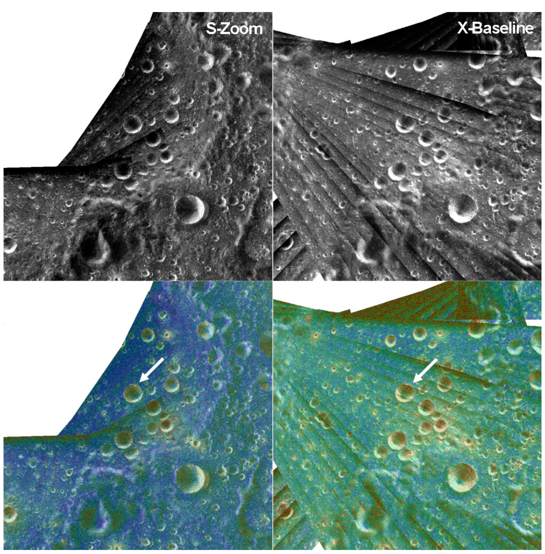

Figure 1. Mini-RF mosaics showing multiple small craters on the floor of Peary crater which have elevated CPR values only in their interiors (Arrow points to one example). These represent prime candidates for the location of ice deposits. The elevated CPR is seen in both the 12.6cm (S) and 4.2 cm (X) radar bands.

1. Introduction

Typically, orbital radar observations use the same antenna to both transmit and receive a signal. The angle between the transmitted and received signals (the bistatic, or beta angle) for these observations is therefore zero and they are referred to as monostatic observations. By using the AO radar as the transmitter and Mini-RF as the receiver, we have the opportunity to collect data for the Moon with beta angles other than zero. These measurements provide the best possible test of the water ice hypothesis with current assets at the Moon or from Earth-based measures.

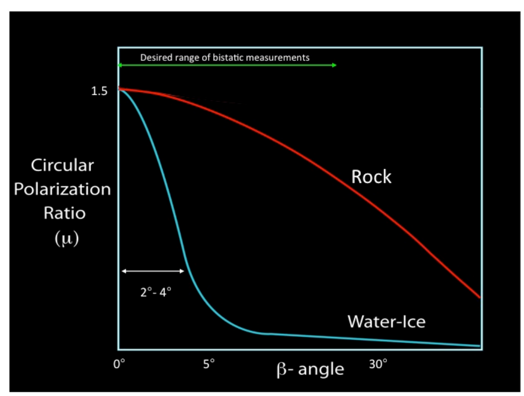

Figure 2. Predicted behavior of CPR versus beta angle for both rock terrains and an ice/regolith mixture.

The Circular Polarization Ratio (CPR) is the ratio of the powers of received signal in the same sense transmitted divided by the opposite sense. Mini-RF transmits a left circular polarized (LCP) signal; a normal reflection from a dry randomly rough surface is dominated by Bragg backscatter, hence it results in RCP since in effect it is "single-bounce". Typical dry lunar surface has a CPR value less than unity [1].

Mini-RF monostatic data shows many craters with high CPR values. Most of these features are associated with fresh, young craters and display elevated CPR both inside and outside their rims. Some permanently shadowed craters near both poles show elevated CPR inside the crater rims but low CPR outside the crater rim (Figure 1). These properties are consistent with RF backscatter caused by surface roughness in the former case and water ice in the latter [2].

The physics of radar scattering predict that high CPR caused by a rocky surface will be relatively insensitive to the beta angle, whilst high CPR caused by ice will be very sensitive to beta, with elevated CPR values dropping off abruptly at beta angles greater than about 1-2° (Figure 2). The exact shape of the CPR-β curve for an ice-regolith mixture is a function of the amount and purity of the ice. However we do not need to measure this curve to differentiate between high CPR from rocks versus ice, by measuring at beta angles in the 5°-10° range we are definitely in the right hand portion of this plot, i.e. a rocky surface will have a significantly higher CPR than an ice/regolith mixture. Acquiring observations of high CPR at beta angles larger than about 5° would validate the theoretical physics that predicts such behavior. Once validated, then this offers robust ice/non-ice discrimination by radar measurements.

2. Bistatic Campaign

Mini-RF has instigated an Arecibo high-power bistatic campaign. This involves imaging both polar, and non-polar targets that have high monostatic CPR values. By acquiring non beta zero data of equatorial high-CPR regions (which we can safely assume have high CPR due to the presence of surface rocks) we can confirm the hypothesis that high CPR caused by rocks is reasonably invariant to the beta angle (red curve in Figure 2). A low-power test to validate the concept was successfully completed in April 2011 (Figure 3).

The plan is to conduct multiple observations of polar craters that show enhanced monostatic CPR values in their interiors. To first order we will be looking to see if regions that have high CPR values in the monostatic data have high or low values in the bistatic data. If we find areas that become low only in the bistatic data then this provides strong

Initially we will attempt to acquire data in the β=~5-10° range. At these angles we expect there to be a clear high-low difference in CPR values for rocks versus ice.

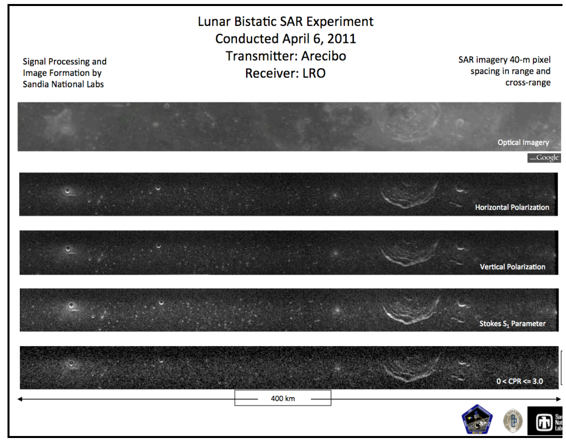

Figure 3. Low-power bistatic data images including both polarizations, S1 and CPR products. The top image is a Clementine mosaic of the same region associated with a bistatic collect.

Additionally we will be imaging other scientific targets of interst, including pyroclastic deposits. Acquiring non beta zero data of these deposits will provide information on their characteristics.

3. Conclusions

Using Arecibo and Mini-RF we have the opportunity to collect the first ever planetary bistatic radar images at non β=0 angles. These data will provide a unique new piece of evidence to determine if the Moon's polar craters contain ice. We have a technically sound approach and have validated the concept by conducting the AO low-power test. Essentially we have now demonstrated a completely new instrument mode, capable of exciting and quite different science. This has not been done before for other planets, and will provide information on both polar ice and lunar surface roughness/dielectric constants.

References

[1] Campbell B., et al., Earth-based 12.6-cm wavelength radar mapping of the Moon: New views of impact melt distribution and mare physical properties, Icarus, 2010.

[2] Spudis P. D. et al.,Initial results for the north pole of the Moon from Mini-SAR, GRL 2010.