Mini-RF: Imaging Radars for Exploring the Lunar Poles

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Abstract. In 2008 two imaging radars will fly to the Moon to map the polar regions and search for ice. These ice deposits would represent a significant potential resource for the manned human base that is to be set up at one of the Moon's poles late in the next decade.

The Instruments. The Mini-RF instruments are lightweight SAR radars that will fly on the Indian Space Research Organisation's Chandrayaan-1 and NASA's Lunar Reconnaissance Orbiter missions. Mini-RF will use a different analytical approach to look for ice. Classically the key parameter used to determine if ice is present is the circular polarization ratio (CPR). This is equal to the same sense (i.e. the left or right sense of the transmitted circular polarization) divided by the opposite sense polarization signals that are received. Volumetric water-ice reflections are known to have larger CPR than usually observed from surface scattering.

Mini-RF will use an hybrid dual polarization technique, transmitting a circular polarized signal (either Right or Left Circular Polarization) and then receiving Horizontal and Vertical polarization signals, as well as the phase information between the two polarizations. This is an unusual architecture, but it preserves all of the information conveyed by the reflected signals. From these data we will determine all four Stokes parameters of the backscattered field. The Stokes parameters offer a very powerful tool to investigate the nature of lunar radar backscatter. In addition to calculating the response at both circular polarizations, and therefore also the circular polarization ratio, it will also be possible to ascertain properties which should help to distinguish between multiple surface reflections versus volume scattering. This is key in trying to determine if the nature of the returned signal is due to an ice-regolith mixture, or simply rocks on the lunar surface. Examples of these key properties include the Degree of Polarization and the Degree of Linear Polarization.

The Missions. Mini-RF instruments are flying on both the Chandrayaan-1 and LRO missions, both due for launch to the Moon in 2008.

Chandrayaan-1: ISRO's lunar orbiter is scheduled for a Spring 2008 launch. It will conduct a detailed analysis of the lunar surface using eleven instruments over the course of the two year nominal mission from an altitude of 100 km. The option of operating for some of the 2 years in a 50 km orbit is also being considered.

The main goal of Mini-RF on Chandrayaan-1 is to conduct systematic SAR mapping polewards of 80° for both poles. Mini-RF will use S-band and have a spatial resolution of 75 meters per pixel. During the observation opportunities given to the instrument it will image in SAR mode both poles every orbit, covering the entire polar regions. However due to the side looking nature of SAR observations there will be a polar gap in SAR coverage immediately around both poles. The incidence angle for these observations is 35°. From the Chandrayaan-1 altitude of 100 km this corresponds to a polar image gap of approximately 2° latitude. These regions close to both poles contain some of the most promising sites for potential water deposits. We therefore have a couple of options for exploring these polar areas. The first option uses the natural wobble in the orbit inclination of the spacecraft to allow the ground track to wander. The orbit will naturally drift between 90° (pure polar orbit) and approximately 91° on a 14 day cycle. By operating Mini-RF during orbits of maximum inclination we will be able to obtain SAR strips of permanently shadowed regions within 2° latitude of both poles. The second option involves operating Mini-RF in a scatterometry or "vertical SAR" mode. In this mode the Chandrayaan-1 spacecraft is rolled so that the antenna is oriented to point to nadir. An advantage of this mode is that we can completely map the polar areas between 85° and 90° in 14 days, thus filling in the entire polar SAR gap. A disadvantage of operating in scatterometry mode is that you lose the ability to obtain high spatial resolution in the range direction. Essentially what is acquired is a profile, with 10 km width and 1 km along track resolution. However, due to the significant overlap between consecutive strips we are investigating processing techniques which improve the overall spatial resolutions of the scatterometry strips. If Chandrayaan-1 does operate for a period in a 50 km orbit, then Mini-RF will be able to obtain SAR strips of the poles.

Lunar Reconnaissance orbiter: NASA's LRO is currently scheduled for a late 2008 launch. It is carrying six instruments and the Mini-RF as a technology demonstration. It will orbit the Moon at an altitude of 50 km for a nominal mission duration of one year.

Mini-RF on LRO is an enhanced instrument relative to the one flying on Chandrayaan-1. It operates in both S band (like Chandrayaan-1) and X-band. Also as well as the baseline resolution (75 meters per pixel) it can also operate in zoom mode with a spatial resolution of 15 meters per pixel. The current allocation for Mini-RF is 20 strips of SAR data during the one-year mission. The goal will be to target areas already identified by Mini-RF on Chandrayaan-1 as potential ice deposits and use the enhanced capabilities of Mini-RF on LRO to further investigate these areas.

Mini-RF on LRO also has the capability to acquire data applicable for topographic processing. Topography products can be derived using interferometric or SAR stereo techniques. The current mission allocation permits the acquisition of 20 data takes applicable for topographic processing.

In addition to the current plans for SAR, and interferometry data collection, Mini-RF has a supplemental science plan which is a list of goals that we would like to achieve but that are not currently scheduled. These observations would become possible if Mini-RF were able to collect more data, possibly during an extended mission. One of the supplemental goals is to conduct a spacecraft to spacecraft bistatic imaging experiment (Figure 1). A signal would be transmitted from Mini-RF on Chandrayaan-1 and received by Mini-RF on LRO. Analysis of the returned backscatter signal as a function of phase angle of the same area on the Moon would provide potentially the most definitive remote technique for discriminating between ice and rock units.

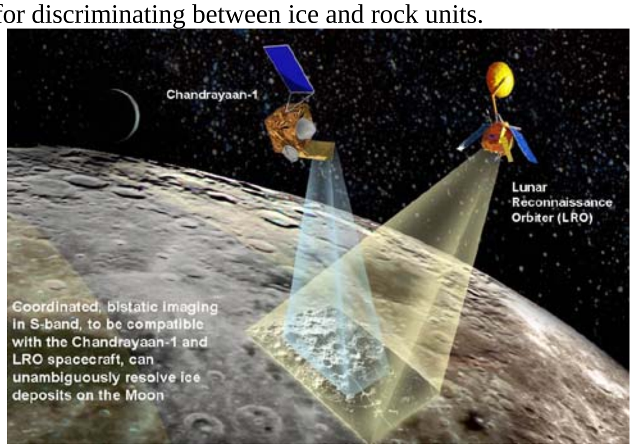

Figure 1. Coordinated bistatic imaging by two orbiting radars will help to discriminate between ice and rock units.

PRINCIPAL AUTHOR'S BIO (~50 WORDS)

Dr. Ben Bussey is a senior staff scientist at the Johns Hopkins University Applied Physics Laboratory. His area of research is primarily the lunar poles, including publishing the first quantitative illumination maps of these regions. He is deputy PI of Mini-RF on Chandrayaan-1 and LRO.