LunaRAX and Mini-RF+

Radar team: C. Neish, B. Malphrus, S. Byrne
Ice has unique radar properties, with high values of the circular polarization ratio ($\text{CPR} = \frac{\text{SC}}{\text{OC}}$)

$\text{SC} = \text{radar with same polarization as transmitted beam}$

$\text{OC} = \text{radar with opposite polarization as transmitted beam}$

Multiple bounce backscattering on a rough surface randomizes polarization ($\text{OC} \approx \text{SC}$)

**MODERATE CPR** (~0.5 - 1)

Forward scattering in ice preserves polarization ($\text{OC} \ll \text{SC}$)

**HIGH CPR** (> 1)

~10\(\lambda\)
Ice has unique radar properties, with high values of the circular polarization ratio ($\text{CPR} = \frac{\text{SC}}{\text{OC}}$)

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Forward scattering in ice preserves polarization ($\text{OC} \ll \text{SC}$)

HIGH CPR ($> 1$)

~10$\lambda$
N. Pole of Mercury

Harmon et al., 2011
**HOWEVER**, high CPR can also be explained by extremely blocky surfaces (\( \text{CPR} = \frac{SC}{OC} \))

\[ SC = \text{radar with same polarization as transmitted beam} \]
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Multiple bounce backscattering on a rough surface randomizes polarization (\( OC \approx SC \))

**MODERATE CPR (~0.5 - 1)**

Blocky surfaces may act as corner reflectors, causing double bounce backscatter (\( OC << SC \))

**HIGH CPR (> 1)**
**HOWEVER**, high CPR can also be explained by an extremely blocky surface \((\text{CPR} = \frac{\text{SC}}{\text{OC}})\)

SP Flow in northern Arizona, as observed by AIRSAR

<table>
<thead>
<tr>
<th></th>
<th>CPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

**radar**
At a beta angle of zero, high CPR is not a unique indicator of water ice. Rough, blocky surfaces can also produce CPR > 1. Need a **bistatic measurement** to distinguish between the two possibilities.
At a beta angle of ~10°, we can distinguish rocky surfaces from buried ice.
Mini-RF is currently conducting these experiments...

**Incidence Angle**

**Emission Angle**

**Phase Angle**

**S1 (total backscattered power)**

2012-220: Cabeus (Aug. 7)

Patterson et al., NLSI, 2013
Permanently shadowed regions
(using LOLA 120 mpp DTM)

85-90 South

85-90 North
Hidden from the Earth
(when located at the equator)

85-90 South

85-90 North
PSRs visible from the Earth (when located at the equator)

85-90 South

85-90 North
### Summary:

<table>
<thead>
<tr>
<th></th>
<th>85-90 S</th>
<th>85-90N</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSR Area</td>
<td>7847 km²</td>
<td>6390 km²</td>
</tr>
<tr>
<td>PSR Area Visible</td>
<td>3362 km²</td>
<td>2394 km²</td>
</tr>
<tr>
<td>%PSR Visible</td>
<td>43%</td>
<td>37%</td>
</tr>
</tbody>
</table>

Southern visible PSR sections are in big contiguous sections whereas northern areas are made up of many small fragments.
What’s the next step?

- Mini-RF is limited to one observation a month at most. *Need better coverage.*
- Mini-RF is limited to S-Band (12.6 cm) coverage. A *P-Band radar could probe deeper deposits of ice.*
- Not all PSRs are visible from Earth. A *two spacecraft radar mission would allow us to more effectively probe the PSRs.*
Option #1: LunaRAX

Transmit P-Band radar from Arecibo, receive at ‘LunaRAX’, a cubesat based on the RAX design.

Specifications:

- **Payload**: Bistatic radar receiver, 426-510 MHz
- **Attitude control**: Passive magnetic, Three axis gyros
- **Processing**: 8 GB of storage
- **Power system**: Solar panels (8 W), Lithium-ion batteries (4.4 Ahr)
- **Communications**: UHF transceiver
- **Structure**: Standard 3U CubeSat
- **Mass**: 2.6 kg
Problems:

1. Arecibo operates as a pulsed radar to increase resolution. Accompanying pulse-processing is too big for a CubeSat.

2. Hard to point high-gain antennas with a CubeSat. “It’s like the tail wagging the dog.”

3. A CubeSat like RAX could not receive both polarizations at the same time.

Bottom line: LunaRAX wouldn’t work. RAX worked because it was a lot closer to its transmitter and required a lot lower resolution.
Option #2: Mini-RF+

Transmit S-Band radar from one spacecraft and receive at a second spacecraft (could be LRO).
Option #2: Mini-RF+

Pros:
• It would actually work!
• Better coverage of PSRs
• Better resolution

Cons:
• Some areas already covered by Mini-RF
• Likely to be more expensive (microsat range)

**QUESTION:** How much would it cost to fly LRO if it were only supporting Mini-RF at S-Band alone?

**Specifications:** 150 W / 15 kg / 1 m²
Table 1. 

<table>
<thead>
<tr>
<th>Wavelength (µm)</th>
<th>Brightness (Jy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.8</td>
<td>1.0</td>
</tr>
<tr>
<td>9.2</td>
<td>1.5</td>
</tr>
<tr>
<td>10.4</td>
<td>1.8</td>
</tr>
<tr>
<td>12.0</td>
<td>1.2</td>
</tr>
<tr>
<td>13.3</td>
<td>1.3</td>
</tr>
<tr>
<td>14.7</td>
<td>1.1</td>
</tr>
</tbody>
</table>

**Notes:**
- The brightness values are obtained from the radar data.
- The wavelength range is from 7.8 to 14.7 µm.
- The brightness is expressed in units of Jy (Jansky).

**Figure 1:**
- The images represent the radar brightness at different wavelengths.
- Each image corresponds to a specific wavelength, indicated at the bottom of the image.
- The images show variations in brightness across the spectrum.

**Discussion:**
- The observed variations in brightness suggest different surface properties.
- Further analysis is required to correlate these variations with specific geological features or phenomena.
Distribution of Water on Mars: Overlay of water equivalent hydrogen abundances and a shaded relief map derived from MOLA topography. Mass percent of water were determined from epithermal neutron counting rates using the Neutron Spectrometer aboard Mars Odyssey between Feb. 2002 and Apr. 2003.


The neutron spectrometer aboard Mars Odyssey, a component of the Gamma-ray Spectrometer suite of instruments, was designed and built by the Los Alamos National Laboratory and is operated by the University of Arizona in Tucson. The Mars Odyssey mission is managed by the Jet Propulsion Laboratory.
SHARAD on the Moon?