Earth Observation from a Moon based SAR: Potentials and Limitations

F. Bovenga¹, M. Calamia²,³, G. Fornaro⁵, G. Franceschetti⁴, L. Guerriero¹, F. Lombardini⁵, A. Mori²

¹ Politecnico di Bari - Dipartimento Interateneo di Fisica, Via Amendola 173, Bari
² University of Florence - Department of Electronics and Telecommunications, via di Santa Marta 3, Firenze
³ IACSA (International Advanced Center for Space Applications), Corso garibaldi 76, Montelupo Fiorentino
⁴ University of Naples - Department of Electronic Engineering and Telecommunication - via Claudio 21, Napoli
⁵ CNR-IREA, Via Diocleziano, 328 80124 Napoli
⁶ University of Pisa - Department of Information Eng, Via G. Caruso 16, Pisa
What a Moon Based SAR can do and what cannot do in Earth observation wrt to standard LEO satellite ??
What standard LEO sat. SAR sensors do: imaging at high resolution

Resolution = \( \frac{\text{wavelength}}{\text{aperture}} \) \( \frac{\text{distance}}{\text{aperture}} \)

Resolution = \( \frac{\text{aperture}}{2} \)

Flight trajectory

Ground swath

Metric resolution
What standard LEO sat. SAR sensors do: interferometry (3D)

The coherent nature of radiation makes it possible to use the phase signal to measure the traveled path, i.e., the target to sensor distance.
What standard LEO sat. SAR sensors do: differential interferometry with repeated passes

ERS-1/2 Descending Data (1995-2002)

S. Jose

Raimond Fault

Water

Oil

Def. cm

mm/anno


conservation [cm]

Year

IACSA

IREA


conservation [cm]

Year

>10

<-10
Potentialities of Earth vision from a Moon based SAR

Advantageous w.r.t. LEO artificial satellite:

- On the surface of the Moon some restrictions on the transmitted power, on the antenna dimensions and on the number of antenna and their relative distances are not applicable.
- A Moon-based SAR can collect data from a very large portion of the surface of the Earth (ex Italy or the Mediterranean basin)
- Data from a resolution cell with a different aspect and incidence angle can be collected, almost at the same time.
- The temporal difference between repetition passages is one day for most of the time.
Geometrical considerations for Interferometric applications

Maximum allowed elevation angle difference for distributed scattering

<table>
<thead>
<tr>
<th></th>
<th>C Band (5.3GHz - 5.6cm)</th>
<th>L Band (1.6GHz -18cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20MHz Bandwidth</td>
<td>0.2 deg</td>
<td>0.5 deg</td>
</tr>
<tr>
<td>100 MHz Bandwidth</td>
<td>0.9 deg</td>
<td>2.7 deg</td>
</tr>
</tbody>
</table>

\[ \Delta \vartheta < \frac{\text{wavelength}}{2 \times \text{resolution} \times \tan \vartheta_{el}} \]
Considerations for Single pass Interferometry

<table>
<thead>
<tr>
<th>Bandwidth</th>
<th>C Band</th>
<th>L Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>20MHz Bandwidth (12m)</td>
<td>0.2 deg</td>
<td>0.5 deg</td>
</tr>
<tr>
<td>100 MHz Bandwidth (2.3m)</td>
<td>0.9 deg</td>
<td>2.7 deg</td>
</tr>
</tbody>
</table>

[Diagram showing MOON and EARTH with measurements of 500Km and 1m]
Focusing and Azimuthal Resolution

C – Band (5.6cm)
Antenna = 100m
Footprint = 210Km

A synthetic antenna 60 times larger that the footprint can be synthesized!

Resolution = 50m

Resolution = 84cm

Synthetic Antenna = 12600Km
Earth SAR imaging From the Moon: a possible solution

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>0.056 (C band)</td>
</tr>
<tr>
<td>Antenna dimension in cross-track direction</td>
<td>65 m</td>
</tr>
<tr>
<td>Antenna dimension in along-track direction</td>
<td>100 m</td>
</tr>
<tr>
<td>Reference elevation angle</td>
<td>50 degrees</td>
</tr>
<tr>
<td>Transmitted Bandwidth</td>
<td>100 MHz</td>
</tr>
<tr>
<td>Ground range resolution</td>
<td>2.3 m</td>
</tr>
<tr>
<td>Doppler Bandwidth</td>
<td>540Hz</td>
</tr>
<tr>
<td>Integration time</td>
<td>8 min</td>
</tr>
<tr>
<td>Azimuth resolution</td>
<td>up to 83cm</td>
</tr>
<tr>
<td>Average Power</td>
<td>About 200KW</td>
</tr>
</tbody>
</table>
Conclusions & Recommendations

The integration time for full focusing is rather large: this side prevents the possibility to image fast moving scene, such as sea surface, but on the other side it allows implementation of moving target detection even starting from single pass data.

Due to a peculiar imaging effect due to Earth rotation, a Moon based SAR can overcame the limit of half antenna length resolution and thus it can achieve high resolution capabilities, up to one meter azimuth resolution.

Moon orbits make difficult the implementation of repeat pass InSAR. Single pass InSAR, as well as along track interferometry and tomographic imaging with more than two antennas (only one transmitting) can be affordable.

While some interesting and promising configurations can be designed for a mission which fully exploits the Moon surface, the present constraints on the power supply and on the weight of apparatus (antenna and sensor) make unrealistic any applications based on SAR imaging.