The frozen sea area: a reference case study for inversion problem

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CO.RI.S.T.A. recently faced with the problem of data inversion by using SHARAD data.

For a starting point a simple situation has been chosen as reference study case: the frozen sea.

The goal is better understand the electromagnetic interaction with surface and sub-surface by using a step-by-step approach, starting from simplified model for layer characterisation and electromagnetic interaction.
The area under investigation:

- **BOX Frozen sea**
  - Lon 151.5°E : 152.5°E
  - Lat 4.5°N : 5.5°N

- **BOX Medusae Fossae**
  - Lon 150.5°E : 155°E
  - Lat 1.5°N : 2.5°N
Subsurface investigation

Fresnel equation (only reflection)

Homogeneous low-loss medium

Two medium (two interfaces)

Parallel and flat interfaces
With this hypothesis it is possible to estimate the permittivity of the sub-surface material (medium 3) only from the power ratio of surface and sub-surface, given the permittivity and attenuation of the first one (medium 2).

\[
\varepsilon_{r3} = \frac{(1 - M)^2}{(1 + M)^2} \varepsilon_{r2}
\]

\[
M = \pm \sqrt{\frac{P_4}{P_1}} \left(1 - \varepsilon_{r2}\right) \frac{1}{4\varepsilon_{r2}} e^{\alpha d}
\]
The dielectric constant can be estimated by correcting the signal time delay.
The loss tangent can be estimated by comparing power ratio corresponding to different depths

\[
\alpha = \frac{1}{2(d_2 - d_1)} \ln \left( \frac{P_2^2}{P_4} \frac{P_4^1}{P_2^4} \right)
\]
Subsurface investigation

<table>
<thead>
<tr>
<th>dielectric constant</th>
<th>P₄/P₁</th>
<th>dist1</th>
<th>P₄/P₁</th>
<th>dist2</th>
<th>tgd estimated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>r_0589803_001_SS19_700_A</strong></td>
<td>3</td>
<td>1.69</td>
<td>44.8</td>
<td>0.47</td>
<td>485.8</td>
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<td>0.0069388</td>
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<td>3</td>
<td>1.32</td>
<td>61.6</td>
<td>0.41</td>
<td>424.3</td>
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<td>0.007668</td>
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</tbody>
</table>
Then the dielectric constant of the sub-surface can also be estimated (under North-Hill area).

The application of Fresnel equation gives unfeasible values.

Therefore an additional term should be considered in the surface/sub-surface power ratio.

This term takes into account the different scattering behavior of surface and sub-surface.
Possible geological interpretation suggests that statistical characteristics of subsurface under North-Hill can be inferred by analyzing the area just outside it (Frozen Sea).

To this aim simulation tool developed within Level 2 activities can be used.
Subsurface investigation

Geologic unit map
Subsurface investigation

Ratio of about 0.1

Scattering at nadir

Simulation

Level 1b
Subsurface investigation

The results under North Hill

<table>
<thead>
<tr>
<th>Orbit</th>
<th>r_0341902_001_SS19_700_A</th>
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</thead>
<tbody>
<tr>
<td>diel cons surf</td>
<td>Rugosity factor</td>
</tr>
<tr>
<td>3</td>
<td>0.1</td>
</tr>
<tr>
<td>distance[m]</td>
<td>dielectric constant subsurf</td>
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<tr>
<td>424.3122</td>
<td>4.8167</td>
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<thead>
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<tr>
<td>distance[m]</td>
<td>dielectric constant subsurf</td>
</tr>
<tr>
<td>485.8727</td>
<td>5.1287</td>
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</tbody>
</table>
The frozen-sea area is fully covered by SHARAD

Preliminary analysis has been performed with 9 products with near tracks

r_0186301_001__ss19_700
r_0207401_001_SS19_700
r_0264101_001_SS19_700
r_0320802_001_SS19_700
r_0341902_001_SS19_700
r_0363001_001_SS19_700
r_0398601_001_SS19_700
r_0625403_001_SS19_700
r_0661003_001_SS19_700
Subsurface investigation

Peaks isolation in defined areas

Record: 400 – 1200
Subsurface investigation

The results under Frozen-sea

<table>
<thead>
<tr>
<th>Dielectric Constant Subsurface</th>
<th>tgd=0.007</th>
<th>tgd=0.01</th>
<th>Sublayer Distance[m]</th>
<th>Total records</th>
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</thead>
<tbody>
<tr>
<td>4.8</td>
<td>11.89</td>
<td>12.26</td>
<td>54.14</td>
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<tr>
<td>5.1</td>
<td>13.24</td>
<td>13.75</td>
<td>52.52</td>
<td>13015</td>
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</table>
Even the very simple model applied the results are compatible with possible materials and with analogous results already published.

Further activities are related to:

- Inclusion of processor effects in terms of centroid variation and sub-surface defocusing
- Estimation of different statistical characteristics of surface/sub-surface from data
- Compatibility of estimated values with materials