Initial Polarimetric Calibration of PALSAR

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1. Background

Progress of ALOS

(1) Launch of HII-A (January 24, 2006)
(2) Initial mission check phase (January 24 ~ May 25, 2006)
(3) Calibration phase (May 25 ~ October 23, 2006)
(4) Operation phase (October 24, 2006 ~)

ALOS mission objectives:
- Map making
- Regional observation
- Disaster monitoring
- Resource survey
- Technology development

ALOS Sensors:
- PRISM
- AVNIR-2
- PALSAR

PALSAR observation mode ⇒ FBS, FBD, DSN, PLR, SCAN

PALSAR is the first space borne polarimetric L-band synthetic aperture radar and its data is expected to be utilized in various remote sensing applications.

A polarimetric calibration is an important issue.
2. Polarimetric Calibration (1/2)

- Polarimetric calibration: To remove the polarimetric distortions caused by the radar hardware and the propagation in the measured scattering matrix.

\[
\begin{pmatrix}
Z_{HH} & Z_{VH} \\
Z_{HV} & Z_{VV}
\end{pmatrix} = A \frac{1}{r} e^{-j \frac{4 \pi r}{\lambda}} \begin{pmatrix}
1 & \delta_1 & \cos \Omega & \sin \Omega \\
\delta_2 & f_1 & \sin \Omega & \cos \Omega
\end{pmatrix} \begin{pmatrix}
S_{HH} & S_{VH} \\
S_{HV} & S_{VV}
\end{pmatrix} \begin{pmatrix}
1 & \delta_3 & \cos \Omega & \sin \Omega \\
\delta_4 & f_2 & \sin \Omega & \cos \Omega
\end{pmatrix} + \begin{pmatrix}
N_{HH} & N_{HV} \\
N_{VH} & N_{VV}
\end{pmatrix}
\]

- \( Z \): Measured Scattering Matrix
- \( S \): True Scattering Matrix
- \( R, T \): Distortion Matrix
- \( N \): System Noise
- \( F \): Faraday Rotation Effect
- \( \delta \): Cross-talk
- \( A \): Amplitude Calibration Parameter
- \( f_1, f_2 \): H/V imbalance

Calibration \( \Rightarrow \) Estimation of Distortion Matrices \( R, T, F \)
2. Polarimetric Calibration (2/2)

Faraday rotation angle:

$$\Omega = \frac{k}{f^2} \times B \cos \psi \sec \theta_0 \times TEC \quad \text{[radians]}$$

- $k$: Constant of value ($2.365 \times 10^4$)
- $B$: Magnetic flux density
- $f$: Frequency
- $\psi$: Angle between earth’s magnetic field and radar wave
- $\theta_0$: Incident angle
- $TEC$: Total electron content

- Example of Total electron content (TEC)
  - Time variation
  - Year variation

http://www.aiub.unibe.ch/ionosphere/

- Predicted faraday rotation angle

3. Objective and analysis method

- Polarimetric calibration (POLCAL) parameter of PALSAR is estimated by Quegan method.
- An influence of faraday rotation is examined by comparison between Amazon and Tomakomai data.
- PALSAR data is compared with Pi-SAR (L-band) data.

**Analysis data**

- Rio branco (Brazil): $\psi \approx 90$ [deg.]
- Tomakomai (Japan): $\Omega \approx 0$ [deg.]

<table>
<thead>
<tr>
<th>No.</th>
<th>Obs. date</th>
<th>Path (D/A)</th>
<th>Off-nadir angle[deg.]</th>
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</tr>
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<td>10/21, 2006</td>
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<td>D</td>
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<td>A</td>
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<td>D</td>
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<td>6</td>
<td>10/7, 2006</td>
<td>A</td>
<td>23.1</td>
</tr>
</tbody>
</table>

**Estimation method of POLCAL parameter**

- Quegan method ($\Omega=0$): $\begin{pmatrix} Z_{HH} & Z_{HV} \\ Z_{VH} & Z_{VV} \end{pmatrix} = \begin{pmatrix} 1 & \delta_1 & S_{HH} & S_{HV} \\ \delta_2 & f_1 & S_{VH} & S_{VV} \end{pmatrix} \begin{pmatrix} 1 \\ \delta_3 \\ \delta_4 \\ f_2 \end{pmatrix}$ $\leftarrow$ PALSAR’s POLCAL model

- Freeman method ($\delta=0$): $\begin{pmatrix} Z_{HH} & Z_{HV} \\ Z_{VH} & Z_{VV} \end{pmatrix} = \begin{pmatrix} 1 & 0 & \cos \Omega & \sin \Omega \\ 0 & f_1 & \sin \Omega & \cos \Omega \end{pmatrix} \begin{pmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{pmatrix} \begin{pmatrix} \cos \Omega & \sin \Omega \\ \sin \Omega & \cos \Omega \end{pmatrix} \begin{pmatrix} 1 & 0 \end{pmatrix}$

$\Omega = \frac{k}{f^2} \times B \cos \psi \sec \theta_0 \times TEC$
4. Analysis results (1/7)

- Channel imbalance
- Cross-talk (estimated by Quegan method)

Rio Branco (Brazil)

Amplitude

Phase [deg.]

Cross-talk [dB]

Descending (Daytime Obs.)

Ascending (Nighttime Obs.)
4. Analysis results (2/7)

- Faraday rotation angle (estimated by Freeman method)
- Polarimetric Calibration parameters averaging 6/20(A), 6/21(D), 9/4(A) and 9/5(D)

\[
\begin{pmatrix}
Z_{HH} & Z_{HV} \\
Z_{VH} & Z_{VV}
\end{pmatrix} = A \frac{1}{r} e^{-\frac{4\pi}{\lambda} \left( 1 \delta_1 \frac{S_{HH}}{f_1} + S_{HV} \delta_2 \frac{S_{HH}}{f_2} + 1 \delta_3 \frac{S_{HV}}{f_3} + N_{HH} N_{HV} \right)}
\]

- Faraday rotation angles:
  - \(\delta_1\): 0.722 \(\pm\) 1.88°
  - \(\delta_2\): 1.031 \(\pm\) 21.81°
  - \(\delta_3\): 0.001 \(\pm\) 131.49°
  - \(\delta_4\): 0.010 \(\pm\) 128.12°
  - \(\delta_5\): 0.013 \(\pm\) 79.37°
  - \(\delta_6\): 0.013 \(\pm\) 151.50°

- Un-calibration: VV/HH gain and phase
- Calibration: VV/HH gain and phase
4. Analysis results (3/7)

- Comparison between Rio Branco and Tomakomai (1/3)
  - Channel imbalance

![Graphs showing comparison between Rio Branco and Tomakomai](image-url)
4. Analysis results (4/7)

- Comparison between Rio Branco and Tomakomai (2/3)
  - Cross-talk

![Graphs showing Faraday rotation angles for Rio Branco (Brazil) and Tomakomai (Japan) with dates and angle values.](image)
4. Analysis results (5/7)

- Comparison between Rio Branco and Tomakomai (3/3)
  - Faraday rotation angle

![Graphs showing Faraday rotation angle for Rio Branco (Brazil) and Tomakomai (Japan) with descending and ascending data for different days.](image-url)
4. Analysis results (6/7)

- Comparison between PALSAR and Pi-SAR (L-band) (1/2)

Data received:
- 2006 (Year)
- 8/19 (date)
Location:
- Around Chitose

HH-VV: Red
HH+VV: Blue
HV: Green

Entropy/Alpha technique: Window size (4 by 4)

Graph showing different areas:
- Urban area
- Forest 1
- Forest 2
- Sea
- Bare soil

Comparison between PALSAR and Pi-SAR (L-band)
4. Analysis results (7/7)

- Comparison between PALSAR and Pi-SAR (L-band) (2/2)

Freeman’s decomposition technique

\[
[C] = \begin{align*}
\text{Rough surface} & \quad + \\
\text{Double bounce} & \quad + \\
\text{Canopy Layer} &
\end{align*}
\]

![Graphs showing analysis results for different land covers](image)
5. Conclusions

Polarimetric calibration parameters of PALSAR were estimated using Amazon and Tomakomai data.

- Quegan method can be used for estimating PALSAR’s POLCAL parameter from the data of Amazon where the faraday rotation angle is expected to be small.
- Tomakomai data is slightly affected by the faraday rotation.
- It is confirmed that polarimetric features of PALSAR data is similar to those of Pi-SAR data in some specific areas.

We will continue to monitor the quality of PALSAR polarimetric calibration.