PALSAR RADIOMETRIC AND GEOMETRIC CALIBRATION

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Contents of presentation

1. Calibration summary of the PALSAR three year performance
2. Radiometric accuracy
3. Geometric Accuracy
4. Polarimetry
5. Change detection examples
6. Conclusions
• Update history (SIGMA-SAR)

• Jan. 24, 2006: ALOS launch
• May. 16, 2006: Initial calibration starts
• Oct. 23, 2006: Operation Start

• July, E, 2008: Antenna Pattern update (FBD 343 HV)
  • ScanSAR update (antenna pattern, radiometric equation)

• Jan. B, 2009: Recalibration of all the strip modes using Amazon (and CRs)
  • Calibration of the HV modes
L1.0 data (raw data)

Telemetry analysis and correction (ATT)

Doppler/Doppler rate analysis

Range compress (Chirp rate correction)

Range antenna pattern correction

Range migration

Azimuth compression (SRC)

Specan

Multilook

16 bits

\[ DN = \sqrt{z \cdot z^* / B} \]

IEEE four byte complex, POLCAL (Distortion correction)

multilook + 16 bits

\[
\begin{pmatrix}
Z_{hh} & Z_{hv} \\
Z_{vh} & Z_{vv}
\end{pmatrix}
\]

[full pol]

\[
\begin{pmatrix}
1 & \delta_3 \\
\delta_4 & f_2
\end{pmatrix}
\begin{pmatrix}
Z_{hh} & Z_{hv} \\
Z_{vh} & Z_{vv}
\end{pmatrix}
\begin{pmatrix}
1 & \delta_1 \\
\delta_2 & f_1
\end{pmatrix}
\]

[others]

\[
\begin{pmatrix}
Z_{hh} & Z_{hv} / f_1 \\
Z_{vh} / f_2 & Z_{vv} / f_1 \cdot f_2
\end{pmatrix}
\]

① L1.5  ② L1.1  ③ L1.5

④: DN-\(\sigma^0\) conversion

\[ \sigma^0 = 10 \log_{10} \langle DN^2 \rangle + CF \]
Transmission power monitor

Variation of the Pt Over 80 TRM

Std Dev. Of Pt
No variation of the distortion matrix on time confirmed!

Using the Amazon CRs deployed by ASF, IBGE, and JAXA

Distortion matrix was not updated from the operation start.
Polarimetric Calibration Accuracy

Target: CRs at the Rio Branco, Brazil

Amplitude (VV/HH)  Phase of (VV/HH)

Amplitude ratio of VV/H-H

Phase difference between VV and HH (deg)

Mean: 1.0134
std: 0.0619

Mean: 0.0612 (deg)
std: 2.6613 (deg)
Radiometric calibration using the CRs Mode and time dependency over last three years

- Calibration Factor (dB)
  - Data points

- Days
  - CF (mean) = -83.0 dB
  - Std dev = 0.762 dB

Graph 1:
- CF(FBS215)
- CF(FBS343)
- CF(FBD343)
- CF(FBS415)
- CF(FBD415)
- CF(PLR215)

Graph 2:
- CF(FBS215)
- CF(FBS343)
- CF(FBD343)
- CF(FBS415)
- CF(FBD415)
- CF(PLR215)
Update of the FBD HV antenna pattern and validation using the Amazon data
Table 2  Representative gamma-naught measured for the Amazon forest

<table>
<thead>
<tr>
<th>Off-nadir angle</th>
<th>Mode</th>
<th>1-Gamma-naught (dB)</th>
<th>2-Gamma-naught (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.9⁴</td>
<td>FBS-HH</td>
<td>-6.255 (0.228)⁴</td>
<td>-6.389 (0.219)⁴</td>
</tr>
<tr>
<td>21.5⁴</td>
<td>FBS-HH</td>
<td>-5.960 (0.112)⁴</td>
<td>-6.510 (0.242)⁴</td>
</tr>
<tr>
<td>34.3⁴</td>
<td>FBS-HH</td>
<td>-6.550 (0.142)⁴</td>
<td>-6.550 (0.141)⁴</td>
</tr>
<tr>
<td>34.3⁴</td>
<td>FBD-HH</td>
<td>-6.318 (0.228)⁴</td>
<td>-6.517 (0.222)⁴</td>
</tr>
<tr>
<td>41.5⁴</td>
<td>FBS-HH</td>
<td>-6.082 (0.107)⁴</td>
<td>-6.502 (0.107)⁴</td>
</tr>
<tr>
<td>41.5⁴</td>
<td>FBD-HH</td>
<td>-5.764 (0.317)⁴</td>
<td>-6.504 (0.317)⁴</td>
</tr>
<tr>
<td>50.8⁴</td>
<td>FBS-HH</td>
<td>-6.202 (0.400)⁴</td>
<td>-6.502 (0.400)⁴</td>
</tr>
<tr>
<td>Average-strip</td>
<td></td>
<td>-6.201 (0.326)⁴</td>
<td>-6.515 (0.219)⁴</td>
</tr>
<tr>
<td>18-42⁴</td>
<td>SCAN-HH</td>
<td>-6.65 (0.4)⁴</td>
<td>-6.65 (0.4)⁴</td>
</tr>
</tbody>
</table>


Table 3  Gain offset table referred to 34.3 FBSHH (dB)

<table>
<thead>
<tr>
<th>Beam (off nadir angles, degrees)</th>
<th>FBS ⁴</th>
<th>FBD ⁴</th>
<th>PLR ⁴</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.9⁴</td>
<td>-0.4025⁴</td>
<td>-0.4025⁴</td>
<td>-⁴</td>
</tr>
<tr>
<td>21.5⁴</td>
<td>-0.427⁴</td>
<td>-0.427⁴</td>
<td>0.223⁴</td>
</tr>
<tr>
<td>34.3⁴</td>
<td>-0.200⁴</td>
<td>0.200⁴</td>
<td>-⁴</td>
</tr>
<tr>
<td>41.5⁴</td>
<td>-2.050⁴</td>
<td>-1.690⁴</td>
<td>-⁴</td>
</tr>
<tr>
<td>50.8⁴</td>
<td>-2.600⁴</td>
<td>-2.600⁴</td>
<td>-⁴</td>
</tr>
</tbody>
</table>
Incidence angle dependence of the gamma naught
Evaluation conducted using the Amazon data

- Strip modes
- ScanSAR data

\[
\text{Gamma-naught} = -6.515 \text{ dB} \\
\text{standard dev.} = 0.219 \text{ dB}
\]

\[
\text{Gamma-naught(Average)} = -6.65 \text{ dB} \\
\text{Standard deviation} = 0.4 \text{ dB}
\]
Geometric calibration using the CRs Mode and time dependency over last three years

![Graph showing data points and error metrics with labels for different datasets and error values.](image)
Noise Equivalent Sigma-Zero (NESZ) shows lowest values of the sigma-naught.
Update of the Calibration Factor (CF) : Recalibration

\[
\sigma^0 = 10 \cdot \log_{10} \left( D N^2 \right) + CF [dB]
\]

Table 4  History of CF (dB)

<table>
<thead>
<tr>
<th>Date</th>
<th>Before Jan 6, 2009</th>
<th>After Jan 7 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>FBS099HH</td>
<td>-83.16</td>
<td>-83.0</td>
</tr>
<tr>
<td>FBS215HH</td>
<td>-83.55</td>
<td>-83.0</td>
</tr>
<tr>
<td>FBS343HH</td>
<td>-83.4</td>
<td>-83.0</td>
</tr>
<tr>
<td>FBD343HH</td>
<td>-83.2</td>
<td>-83.0</td>
</tr>
<tr>
<td><strong>FBD343HV</strong></td>
<td><strong>-80.2</strong></td>
<td><strong>-83.0</strong></td>
</tr>
<tr>
<td>FBS415HH</td>
<td>-83.65</td>
<td>-83.0</td>
</tr>
<tr>
<td>FBD415HH</td>
<td>-83.19</td>
<td>-83.0</td>
</tr>
<tr>
<td><strong>FBD415HV</strong></td>
<td><strong>-80.19</strong></td>
<td><strong>-83.0</strong></td>
</tr>
<tr>
<td>FBS508HH</td>
<td>-83.30</td>
<td>-83.0</td>
</tr>
<tr>
<td>PLR215</td>
<td>-83.40</td>
<td>-83.0</td>
</tr>
</tbody>
</table>


Before Calibration: Mode dependent variation

After Calibration: Constant values

Question: How about the phase update for FBD (HV) ?
Table 7 Polarimetric distortion matrices

<table>
<thead>
<tr>
<th>Item</th>
<th>Value s (real</th>
<th>imaginary)</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission distortion matrix</td>
<td>(1.000 0 0 0e +0 0 , 0.00 0 0 0e +0 0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.427 0 2 9e -0 3 , 1.29 3 0 1 9e -0 2)</td>
<td></td>
<td>δ₁</td>
</tr>
<tr>
<td></td>
<td>(-1.1 4 7 2 4 0e -0 2 , -6.2 2 8 2 3 0e -0 3)</td>
<td></td>
<td>δ₂</td>
</tr>
<tr>
<td></td>
<td>(9.5 7 2 1 6 9e -0 1 , 3.8 2 9 5 6 3 e -0 1)</td>
<td></td>
<td>f₁</td>
</tr>
<tr>
<td>Reception distortion matrix</td>
<td>(1.000 0 0 0e +0 0 . 00 0 0 0e +0 0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-6.2 6 3 3 9 2 e -0 3 , 7.0 8 2 8 6 3 e -0 3)</td>
<td></td>
<td>δ₁</td>
</tr>
<tr>
<td></td>
<td>(-6.2 9 7 0 7 4 e -0 3 , 8.0 2 6 6 8 5 e -0 3)</td>
<td></td>
<td>δ₂</td>
</tr>
<tr>
<td></td>
<td>(7.2 1 7 1 1 7 e -0 1 , -2.3 6 7 6 8 3 e -0 2)</td>
<td></td>
<td>f₂</td>
</tr>
</tbody>
</table>

Current data
f₁=1.030979981/21.80501612(degrees)
f₂=0.722099971/-1.878998903
δ₁=-25.538(3.09)/79.36933594
δ₂=-25.385(0.077)/-151.5032329
δ₃=-25.077(3.107)/131.4864021
δ₄=-25.897(2.416)/-1.878998903

PolCal table in the SAR processor (SIGMA-SAR)

CAL of FBD

\[
\begin{pmatrix}
Z_{hh} & Z_{hv} / f_1 \\
Z_{vh} / f_2 & Z_{vv} / f_1 / f_2
\end{pmatrix}
\]

Phase term is only 2 degrees.
Update information for the other beams:

FBD30.8  Will be updated by July E, 2009
FBS38.8
PLR19.2
PLR25.1

FBD43.3

These beams have not been used by now. No affection to users.

CF=-83.0
### Summary of the PALSAR CALVAL results

<table>
<thead>
<tr>
<th>Items</th>
<th>Measured values</th>
<th>No. of Data</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>geometric accuracy</td>
<td>9.7m (RMS): STRIP mode</td>
<td>572</td>
<td>100m</td>
</tr>
<tr>
<td></td>
<td>70m (RMS): SCANSAR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>radiometric accuracy</td>
<td>0.219 dB (1 sigma) from Amazon forest</td>
<td>572</td>
<td>1.5 dB</td>
</tr>
<tr>
<td></td>
<td>0.76 dB (1 sigma) from CRs</td>
<td></td>
<td>1.5 dB</td>
</tr>
<tr>
<td></td>
<td>0.17 dB (1 sigma: Sweden CRs)</td>
<td>16</td>
<td>1.5 dB</td>
</tr>
<tr>
<td></td>
<td>-34 dB (Noise equivalent Sigma-zero for HV)</td>
<td></td>
<td>-23 dB</td>
</tr>
<tr>
<td></td>
<td>-32 dB (as a minimum of FBD-HH)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-29 dB (as a minimum of FBS-HH)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polarimetric calibration</td>
<td>VV/HH ratio</td>
<td>81</td>
<td>0.2 dB</td>
</tr>
<tr>
<td></td>
<td>VV/HH phase diff</td>
<td></td>
<td>5 deg.</td>
</tr>
<tr>
<td></td>
<td>Crosstalk</td>
<td></td>
<td>-30 dB</td>
</tr>
<tr>
<td>resolution</td>
<td>azimuth</td>
<td>572</td>
<td>4.5m</td>
</tr>
<tr>
<td></td>
<td>range (14MHz)</td>
<td></td>
<td>10.7m</td>
</tr>
<tr>
<td></td>
<td>range (28MHz)</td>
<td></td>
<td>5.4m</td>
</tr>
<tr>
<td>Side lobe</td>
<td>PSLR in azimuth</td>
<td>572</td>
<td>-10dB</td>
</tr>
<tr>
<td></td>
<td>PSLR in range</td>
<td></td>
<td>-10dB</td>
</tr>
<tr>
<td></td>
<td>ISLR</td>
<td></td>
<td>-8dB</td>
</tr>
<tr>
<td>Ambiguity</td>
<td>Azimuth</td>
<td></td>
<td>16dB</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td></td>
<td>16 dB</td>
</tr>
<tr>
<td>Transmission power</td>
<td>Sum of 80 TRM</td>
<td>2220W</td>
<td>2000W</td>
</tr>
</tbody>
</table>

Note: (A) (B)* represents an average value of A and a standard deviation of (B). PSLR is Peak-to-Side-Lobe Ratio, ISLR is Integrated Side-Lobe Ratio.
Sample images of the SCANSAR: Desert
Sample images of the SCANSAR:Amazon
Sample images of the SCANSAR: Hokkaido and O
Sample images of the SCANSAR: Antarctica
Detection of the deforestation in the Belen, Amazon, Brazil for July 2007 ~ 2008

latitude: 0.5S ~ 2.7S
longitude: 47.6W ~ 48.8W

Red: Newly deforested area
Forest change monitoring at Central Kalimantan

Change of the biomass at Central Kalimantan for unsaturated forest.
Sea-Ice Monitoring
Conclusions

PALSAR shows very good temporal stability and higher accuracy for radiometry and geometry. (No change confirmed form the ALOS operation start)

Although the calibration shows some variation on the radiometry (using the CRs), recalibration suing the Amazon rainforest achieved the incidence angle independent radiometric performance.

PALSAR has one problem, which is a bit shift in the Polarimetry mode (POL21.5 and 23.1) very seldom since April 2007. The data can be recovered with 99.7% (un-recovered scenes 550/195,500).

From the remained fuel, the ALOS will be on orbit more than 7 years.
Polarimetry Bit-Shift issue

Bit shift occurs at POL21.5 and 23.1 sometimes.

23.1 degrees: 5% of data
21.5 degrees: 0.5% of data

Most of the data are recovered.
ALOS special issue of TGRS will come on Dec. 2009.

On these researches


3rd ALOS PI workshop at Hawaii, 2009
Due dates for abstract submission on Aug. 1, 2009
Update information

Thematic calibration (Radiometry)

Incidence angle dependence

Update of the calibration factor

Time dependence of the radiometric and geometric accuracy (including polarimetry and its cross talk).

Other parameters (e.g., NESZ)

Summary of the results
Change detection using the PALSAR

Deforestation monitoring

Carbon emission estimation

Disaster mitigation

Ice-sheet change monitoring