S-1 MPC

The in-orbit performance of the Sentinel-1A C-SAR Instrument

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Outline

1. Introduction
   • ESL INS within the S-1 MPC

2. S-1A Instrument long-term performance monitoring
   • Internal calibration:
     • PG – impact of temperature
     • SAR Antenna monitoring
   • Doppler Centroid
   • Burst synchronization
   • FDBAQ
ESL INS within the Sentinel-1 MPC

- Expert Support Laboratory – SAR Instrument
- Long term monitoring of key instrument performance parameters
- Investigation of anomalies:
  - Detailed analyses of raw data, Internal cal signals
  - Impact on data quality
- Support to the maintenance of the instrument configuration (RADAR DATA BASE)
- Support to the maintenance of the L1 processing configuration
Internal Calibration monitoring
Temperature increase since March 2015, related mainly to the increased instrument operation
PG gain trend: co-pol

S1A PG long term trend: pol. HH

S1A PG long term trend: pol. VV

<table>
<thead>
<tr>
<th></th>
<th>HH</th>
<th>VV</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM</td>
<td>-0.20 dB/year</td>
<td>-0.01 dB/year</td>
</tr>
<tr>
<td>IW</td>
<td>-0.26 dB/year</td>
<td>-0.04 dB/year</td>
</tr>
<tr>
<td>EW</td>
<td>-0.25 dB/year</td>
<td>-0.02 dB/year</td>
</tr>
</tbody>
</table>
PG gain trend: cross-pol

<table>
<thead>
<tr>
<th></th>
<th>VH</th>
<th>HV</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM</td>
<td>-0.16 dB/year</td>
<td>-0.01 dB/year</td>
</tr>
<tr>
<td>IW</td>
<td>-0.19 dB/year</td>
<td>-0.09 dB/year</td>
</tr>
<tr>
<td>EW</td>
<td>-0.18 dB/year</td>
<td>-0.07 dB/year</td>
</tr>
</tbody>
</table>
PG gain drift investigation

- PG drift of approx 0.2dB/year for rx-H polarization
- Investigation of the single elements’ drift has been carried out

\[ PG = \frac{TX \cdot RX \cdot TA}{EPDN \cdot APDN} \]

Considering coefficients trends in [dB/year] the following relationship applies:

\[ PG_{\text{TREND}} = TX_{\text{TREND}} + (RX_{\text{TREND}} - EPDN_{\text{TREND}}) + (TA_{\text{TREND}} - APDN_{\text{TREND}}) \]
Tx chain from IntCal

### Trends calculated from 7th April 2014 to 31st May 2015

<table>
<thead>
<tr>
<th>Mode</th>
<th>Tx H trend</th>
<th>Tx V trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM</td>
<td>-0.36 dB/year</td>
<td>-0.22 dB/year</td>
</tr>
<tr>
<td>IW</td>
<td>-0.35 dB/year</td>
<td>-0.25 dB/year</td>
</tr>
<tr>
<td>EW</td>
<td>-0.38 dB/year</td>
<td>-0.21 dB/year</td>
</tr>
<tr>
<td>WV</td>
<td>-0.38 dB/year</td>
<td>-0.29 dB/year</td>
</tr>
</tbody>
</table>
RX H and V show a common stable trend, with a jump related to instr. Rx gain change occurred in September 2014
TA chain from IntCal

- TA V-pol shows a significant positive trend, compensating the TX negative trend
PG trend last 4 months

S1A PG long term trend: pol. HH

S1A PG long term trend: pol. VV

S1A PG long term trend: pol. VH

S1A PG long term trend: pol. HV
Internal calibration - summary

• PG drift of approx 0.2dB/year for rx-H polarization up to March 2015
• No drift for the rx-V polarization
• Investigation on the «source» of the drift indicates that:
  – The TX chain shows a negative trend
  – The RX chain shows a stable trend (except for a jump related to the instrument gain reconfiguration)
  – The TA V shows a positive trend (especially for V-pol), «compensating» the negative TX trend
• The increased instrument utilization since March 2015 (also seen from the increased temperature analysis) mitigates the drifts.
• The drift is captured by the internal calibration: no impact on data quality
SAR Antenna TRMs status

Error matrix for delta RX, H incl. FM status

Error matrix for delta RX, V incl. FM status

Error matrix for delta TX, H incl. FM status

Error matrix for delta TX, V incl. FM status
## Antenna TRMs status evolution:

<table>
<thead>
<tr>
<th>Date</th>
<th>TILE</th>
<th>ROWs</th>
<th>TX/RX – H/V</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-May-2014</td>
<td>4</td>
<td>11,12</td>
<td>TX H, TX V, RX V</td>
<td>Failure</td>
</tr>
<tr>
<td>9-Jun-2014</td>
<td>4</td>
<td>12</td>
<td>RX H</td>
<td>Failure</td>
</tr>
<tr>
<td>29-Apr-2015</td>
<td>4</td>
<td>11</td>
<td>RX H</td>
<td>Failure</td>
</tr>
<tr>
<td>16-18 Apr 2015</td>
<td>12</td>
<td>16</td>
<td>TX V, RX V</td>
<td>Intermittent failure</td>
</tr>
<tr>
<td>20-28 Apr 2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01-04 May 2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-May-2015, 22:33:36 UT</td>
<td>12</td>
<td>16</td>
<td>TX V, RX V</td>
<td>Failure</td>
</tr>
<tr>
<td>18 Oct 2014 to 20 Jan 2015</td>
<td>5</td>
<td>1-20</td>
<td>RX H, RX V</td>
<td>Intermittent failure</td>
</tr>
<tr>
<td>18-20 Mar 2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26-28 Mar 2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>18-24 Apr 2015</td>
<td></td>
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<tr>
<td>25-30 Apr 2015</td>
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<tr>
<td>05-06 May 2015</td>
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<td></td>
<td></td>
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<tr>
<td>26-27 May 2015</td>
<td></td>
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<tr>
<td>06-14 July 2015</td>
<td></td>
<td></td>
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<tr>
<td>17-21 July 2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22 July 2015</td>
<td>5</td>
<td>1-20</td>
<td>RX H, RX V</td>
<td>Switch to redundancy (RDB#5)</td>
</tr>
</tbody>
</table>
Closer look to Tile#5

- Intermittent failure of complete tile (RX only, both polarizations)
Antenna coefficients from RFC (average over rows)
Since launch – H pol

RX H abs mean [dB]

RX H phase mean [deg]

Tile 1
Tile 2
Tile 3
Tile 4
Tile 5
Tile 6
Tile 7
Tile 8
Tile 9
Tile 10
Tile 11
Tile 12
Tile 13
Tile 14

Tile 5
Investigation of the impact on data quality

- Impact on antenna directivity ➔ reduction close to 13/14 (0.7 dB)

- The effect impacts the PG, which shows a consistent power variation ➔ The radiometric accuracy of the data is not impacted

- The NESZ is increased by the same amount

![Graph showing antenna directivity and 1/PG (applied by IPF)]
22 July 2015 – Switch to redundancy

RX H abs mean [dB]

RX H phase mean [deg]

22/07/2015
Switch to redundancy
Antenna status - summary

- The antenna status is daily monitored through the dedicated RFC mode.
- 10 failures in total since launch:
  - 2 TX H-pol
  - 3 TX V-pol
  - 2 RX H-pol
  - 3 RX V-pol
- Switch to redundancy on the 22 July 2015 resolved the issue.
Doppler Centroid
Doppler centroid evolution over 1 cycle

Cycle 58
6th to 18th September:
ascending orbits
Doppler centroid evolution over 1 cycle

Cycle 58
6th to 18th September: descending orbits
DC evolution during Zero Doppler period

S1A Doppler Centroid evolution

Increasing trend?

6 SST changes
STT 1+3

+ 25 Hz

STT 1+2

+ 7 Hz

STT 2+3

- 10 Hz

STT 1+2

+ 12 Hz

STT 2+3
Quaternions at work

- acquisition with YSL disabled during S1A unavailability is “seen” by the quaternions
Doppler Centroid - summary

• The Doppler Centroid over land is limited within 50 Hz, confirming the effectiveness of the Zero-Doppler steering law.

• The Star Trackers re-configuration events impact the overall bias of the Doppler Centroid and can be estimated from data. (No impacts on L1 data quality)
Burst Synchronization
Burst synchronization evolution

- Burst synch within nominal values

Synchronization issue on 18th and 19th May captured by OBS processor

Cycles from 43 to 51 w.r.t. cycle 42

98.9% of DTs with synch. better than 99%

96.8% of DTs with a synch. better than 99%
FDBAQ
Recall of the FDBAQ concept

Lower bound for SNR with quantization included

\[ SNR = \frac{\sigma_0}{\sigma_{0,\text{min}}} \quad \sigma_{0,\text{min}} = -22\text{dB} \]

Thermal noise only SNR

\[ SNR = \frac{\eta_{\text{foc}} \sigma_0}{N_T} \]

SNR with BAQ-3 quantization included (SQNR)

\[ SNR = \frac{\sigma_0}{N_T + \left( \frac{\sigma_0}{Q} + \frac{N_T}{\eta_{\text{foc}}} \right)} \]

SNR with FDBAQ quantization included

\[ SNR = \frac{\sigma_0}{N_T + \left( \frac{\sigma_0}{Q} + \frac{N_T}{\eta_{\text{foc}}} \right)} \]

\[ \hat{\sigma}_{0,k} = \left[ \left( Q \cdot \frac{\sigma_{0,\text{min}}}{\eta_{\text{infoc}}} - \frac{N_T}{\eta_{\text{infoc}}} \right) \cdot \text{SQNR}_k \right] + \frac{N_T}{\eta_{\text{infoc}}} \]
FDBAQ at work: example
Data SNR statistics

Land scenario with cities

Forest scenario

SNR [dB] # blocks

FDBAQ, 2.8165 bit/sample
BAQ-3, 3 bit/sample
ECBAQ, ~3 bit/sample

SNR [dB] # blocks

FDBAQ, 3.0261 bit/sample
BAQ-3, 3 bit/sample
ECBAQ, ~3 bit/sample
FDBAQ - summary

- The FDBAQ quantization scheme performs correctly and provides an improved SNR for high-reflectivity targets.

- The long-term statistics over the acquired data show that the average Mbit/s is:
  - [271.5 213.36 222.56 188.58 208.04 178.39] For Stripmap
  - 194.89 For IW
  - 62.32 For EW
  - [11.8 6.7] For WV

- The average bit/sample is <3.5, lower than BAQ4, with improved SNR.
Thank you