SMOS Calibration: Approach and Expectations

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- Calibration Approach
- Visibilities Calibration
- Level-1 Processor Overview
- Performance over Temperature
- Sensitivity
Calibration Approach

Cold Sky View (1 orbit)

Long Calibration (1 orbit)

24 h TBC

Short Calibration (28 epochs)

LO Phase Track (4 epochs)
The in-orbit calibration of SMOS is based on the following strategy:

1.- Calibration of NIR and CAS based on 2 calibration standards;

2.- Injection of known signals (CAS) right after the antenna (through an RF switch);

3.- On-ground characterisation of antenna and RF switch;

4.- Temperature correction of all parameters in-between NIR/CAS calibrations.

**ASSUMPTION:** ANTENNA PATTERNS REMAIN CONSTANT
SMOS is using two standards for in-orbit calibration:

a) The **Cold Sky**

Realised by inertial pointing of MIRAS to the galactic poles.

b) One **Matched Load**

It is placed in NIR. Its physical temperature is ambient and is well monitored.
Visibility Key Elements

\[ V_{kj} = \sqrt{\frac{T_{\text{sys},k}}{G_{kj}}} \frac{T_{\text{sys},j}}{M_{kj}} \]
Visibilities Calibration

Phase Calibration

RAW CORRELATIONS

0 – 1 UNBALANCE

0 – 1 CORRELATIONS

0 – 1 UNBALANCE

QUADRATURE

IQ SELF-CORRELATIONS

DICOS

IN-PHASE

HOT-WARM NOISE INJECTION

CAS

PHASE CORRECTED CORRELATIONS
Visibilities Calibration

Amplitude Calibration (I)

COLD SKY + LOAD

NIR NOISE DIODE OK

CAS NOISE DIODES OK

NIR-AR Mode

COLD SKY VIEW

PHYSICAL TEMPERATURE

NIR NOISE DIODE

NIR-R Mode

PHYSICAL TEMPERATURE

Visibilities Calibration

Amplitude Calibration (II)

- NIR Tsys
- LICEF Tsys
- Fringe Washing Function
- AMPLITUDE CORRECTED CORRELATIONS

NIR-A Mode
- PHYSICAL TEMPERATURE

HOT-WARM NOISE INJECTION
- CAS 4-point method

NIR NOISE DIODE

-1, 0, +1 CORRELATIONS

DICOS
Visibilities Calibration

Offset Calibration

- **Amplitude and Phase Corrected Correlations**
- **Calibrated Visibilities**
- **Image Reconstruction**

- **U-Noise Injection**
  - **LICEF**

- **Tud Antenna Patterns**
  - **Tud**

- **IVT Test**
  - **Estec**
Level-1 Processor Overview

Corbella Equation

\[ V_{ij}^{pq}(u,v) = 2k_B \sqrt{B_i B_j} \alpha_i \alpha_j \frac{1}{\sqrt{\Omega_i^p \Omega_j^q}} \times \]

\[ \iint_{\xi^2 + \eta^2 \leq 1} F_{n,i}^{\alpha,p}(\xi,\eta) F_{n,j}^{\beta,q*}(\xi,\eta) \frac{T_B^{\alpha\beta}(\xi,\eta) - \delta_{\alpha\beta} T_r}{\sqrt{1 - \xi^2 - \eta^2}} \]

\[ \sim r_{ij} \left( -\frac{u\xi + v\eta}{f_o} \right) e^{-j2\pi(u\xi + v\eta)} \ d\xi \ d\eta \]
Level-1 Processor Overview

Flat Target Response (1)
Level-1 Processor Overview

Flat Target Response (2)

Brightness Temperature

RMS Brightness Temperature

< 0.1 K
Flat Target Transformation

\[ \tilde{V}_{ij}^{pq}(u,v) = V_{ij}^{pq}(u,v) - \frac{T_r - \overline{T}_B}{T_r' - T_P} V_{ij}^{pq}(u,v; T_p - T_r') \]
Level-1 Processor Overview

Flat-Target-Transformed Corbella Equation

\[ V_{ij}^{pq}(u,v) = 2k_B \sqrt{B_i B_j} \alpha_i \alpha_j \frac{1}{\sqrt{\Omega_i^p \Omega_j^q}} \times T_r \to \overline{T_B} \]

\[ \int \int F_{n,i}^{\alpha,p}(\xi,\eta) F_{n,j}^{\beta,q^*}(\xi,\eta) \left( \frac{T_B^{\alpha\beta}(\xi,\eta) - \delta_{\alpha\beta}\overline{T_B}}{\sqrt{1 - \xi^2 - \eta^2}} \right) \]

\[ \tilde{r}_{ij} \left( -\frac{u \xi + v \eta}{f_o} \right) e^{-j2\pi(u \xi + v \eta)} \quad d\xi \, d\eta \]
Level-1 Processor Overview

Level-1 Processor
Main Steps

FTR → FTT → Gibbs → Foreign Sources → FTT⁻¹

\( (T_{\text{sky}} - T_B) \delta_{pq} \)

\( (T_{\text{land}} - T_B) \delta_{pq} \)

\( T_{B_\text{a}} \delta_{pq} \)
Performance over Temperature

NIR Variation over Temperature

\[ V_{kj} = \sqrt{\frac{T_{sys,k}}{T_{sys,j}}} \]

<table>
<thead>
<tr>
<th>NIR Unit</th>
<th>HOT</th>
<th>WARM</th>
<th>HOT</th>
<th>WARM</th>
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</thead>
<tbody>
<tr>
<td>AB H</td>
<td>0.15</td>
<td>0.22</td>
<td>0.11</td>
<td>0.18</td>
</tr>
<tr>
<td>AB V</td>
<td>0.02</td>
<td>0.09</td>
<td>0.02</td>
<td>0.04</td>
</tr>
<tr>
<td>BC H</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.09</td>
</tr>
<tr>
<td>BC V</td>
<td>0.07</td>
<td>0.09</td>
<td>0.02</td>
<td>0.07</td>
</tr>
<tr>
<td>CA H</td>
<td>0.07</td>
<td>0.11</td>
<td>0.04</td>
<td>0.11</td>
</tr>
<tr>
<td>CA V</td>
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<td>0.09</td>
<td>0.02</td>
<td>0.04</td>
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</tbody>
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Specification: < 0.2 K/C; 0.02 K/C with compensation

Temperature Drift for a 220 K Scene (K/C)

<table>
<thead>
<tr>
<th></th>
<th>10 C --&gt; 35 C</th>
<th>35 C --&gt; 10 C</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WARM</td>
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<tr>
<td>HOT</td>
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<tr>
<td>WARM</td>
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</table>
Performance over Temperature

NIR Accuracy (using factory values)

Antenna temperature retrieved with factory values (absorbers 293.7 K)

- \( \langle V \rangle = 293.1 \text{ K} \)
- \( \langle H \rangle = 293.7 \text{ K} \)
- \( T_{\text{abs}} = 293.7 \text{ K} \)
Performance over Temperature

PMS Variation over Temperature

\[ V_{kj} = \sqrt{T_{sys,k} \cdot T_{sys,j}} \cdot M_{kj} \]
Performance over Temperature

| Gkj | Variation over Temperature

\[
V_{kj} = \sqrt{\frac{T_{sys,k}}{T_{sys,j} G_{kj}}} M_{kj}
\]

| Gkj | < 0.3 % pp (worst baseline)

LICEF temperatures (same baseline)
Performance over Temperature

Phase of Gkj and Mkj over Temperature

Arg \{Gkj\} = 16° pp

\[ V_{kj} = \sqrt{\frac{T_{sys,k}}{T_{sys,j}}} \frac{T_{sys,i}}{G_{kj}} M_{kj} \]
LO phase variation tracking (LO calibration)

- requires periodic noise injections (LO calibration);
- objective is to have final peak-to-peak phase variations below 1°
Performance over Temperature

Correlation Offsets (1 cu = $10^{-4}$)

Specification
Sensitivity

MIRAS in the Maxwell EMC Chamber
Sensitivity

H-pol Final Image Radiometric Resolution

2.3 K

4.6 K

3 dB beam

boresight
- there are around 65 snapshots (H or V) along track;
- the along track effective sensitivity (per pass) for ocean is then

\[
\frac{(1.65+3.31)}{2\sqrt{65}} = 0.31 \text{ K}
\]