Development and Production of the Onboard Radiometric Calibration References for the Next Generation of European Weather Forecasting Space Instruments

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A Legacy of Successful & Critical Flight Hardware

- SCISAT ACE-FTS
- SUOMI-NPP CrIS Sounder
- GOSAT-1 Tanso-FTS
- GOSAT-2 Tanso-FTS
- JPSS-1 CrIS-J1 Sounder
- JPSS-2 CrIS-J2 Sounder
- JPSS-3 CrIS-J3 Sounder
- JPSS-4 CrIS-J4 Sounder
- MTG FCI F1
- MTG IRS F1
- METOP IASI-NG F1
- MTG FCI F2, F3 & F4
- MTG IRS F2
- IASI-NG F2 & F3
- METimage F2 & F3

Timeline:
- 2000
- 2005
- 2010
- 2015
- 2020

Countries:
- Canada
- USA
- Japan
- Confidential customer
- Europe
- Germany
**Genesis of the Next-Gen Calibration Sources**

From a prototype for CSA …

- In 2011, ABB developed with CSA support a new generation of blackbody.
- This initiative was to provide:
  - compact and cavity free calibration sources with emissivity higher than 0.99.
  - Calibration facility allowing thermal sensor calibration with the following parameters:
    - Accuracy better than 30 mK (3 \( \sigma \)).
    - Possibility to calibrate in ambient or vacuum.
    - Calibration traceable to ITS-90.
  - Radiometric facility in order to determine radiance with BT accuracy lower than 300 mK and emissivity determination lower than 0.005.
Genesis of the Next-Gen Calibration Sources

Design Details

- Blackbody is based on circular concentric grooves
- Grooves patterns results in a 10 to 20 more absorptive surface compared to bare planar surface.
- This geometry allows blackbody sources in different range of size.
  - Diameter:
    - From 50 mm diameter for MTG-FCI.
    - Up to 450 mm diameter for new upcoming Thermal Imaging mission.
  - Thickness:
    - From few mm thick to few cm thick depending on mission requirements.

### Genesis of the Next-Gen Calibration Sources

#### Design Details - Generic Advantages

<table>
<thead>
<tr>
<th>Compact</th>
<th>Low mass</th>
<th>Non polarized emission</th>
<th>Thermal load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Could be a baffle-less platform</td>
<td>Consequence of the compactness</td>
<td>Due to good thermal homogeneity on grooves</td>
<td>No restriction on heating load</td>
</tr>
<tr>
<td>Down to few mm thick for extreme compact case</td>
<td>About 5 to 10 g/cm²</td>
<td>Main drawbacks of asymmetric specular cavity</td>
<td>From cryogenic temperature to 600 K</td>
</tr>
</tbody>
</table>
Genesis of the Next-Gen Calibration Sources

Design Details - Performance Advantages

- **Homogeneous temperature**
  - Not a cavity
  - Thermal load located on a plate

- **High emissivity BB**
  - Higher than 0.995
  - Higher than 0.999 with baffle

- **Improved radiometric performance**
  - Selective reflected environment.
  - Low diffusion behaviour with specular coating
Genesis of the Next-Gen Calibration Sources

List of blackbody using ABB developed technology

- MTG-FCI blackbody
- MTG-IRS Blackbody
- IASI-NG FTS blackbody
- IASI-NG cloud imager blackbody
- METImage blackbody
- Other prospects
  - OGSE.
  - Commercial IR imager constellation.
Critical Points in a High-End Blackbody

Key points to take care of when developing high-end blackbodies

- Temperature Knowledge
- Optical Properties Knowledge
- Radiometric Knowledge
Critical Points in a High-End Blackbody Calibration

**Thermal Sensor Calibration**

- **Measurement Equipment**
  - High end bridge used in several NML.
  - Absolute calibration of resistance references.
  - Absolute calibration of SPRT.

- **Conditioning Equipment**
  - Good thermal and stable bath (< 10 mK).
  - Thermal design of the system allowing good thermal transfer.

- **Setup Capability**
  - Accuracy down to 10 mK over 250 K to 350 K.
  - Capability to do the calibration at ambient and vacuum condition.
## Critical Points in a High-End Blackbody

**Radiometric Validation**

### Emissivity Measurement

<table>
<thead>
<tr>
<th>Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of model (analytical or Monte Carlo) to determine emissivity.</td>
</tr>
<tr>
<td>Use HDR, DDR, BRDF as inputs.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measurement Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>High end FTS capable of measuring from 2 to 20 microns.</td>
</tr>
<tr>
<td>Edwards Integrating sphere capable of looking at ranging angle.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Setup Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflectance accuracy down to 0.5%.</td>
</tr>
<tr>
<td>Emissivity accuracy down to 0.1%.</td>
</tr>
<tr>
<td>Traceable measurement using CNRC reference samples.</td>
</tr>
</tbody>
</table>
Critical Points in a High-End Blackbody

Radiometric Validation

Radiometric Performances

- Radiometric Measurement
  - Emissivity
  - Radiance stability
  - Radiance uniformity
- Radiometric Etalon Knowledge
  - 5 mK absolute accuracy
  - Thermal stability about 5 mK/hour
  - Emissivity > 0.9995
- FTS Performances
  - 8-14 µm with LN2 cooled MCT
  - NESR < 2 nW/cm²/sr/cm⁻¹
- Thermal Environment Properties
  - 1 K absolute accuracy
  - Thermal stability about 5mK/hour
- Resulting performances
  - Radiance knowledge less than 50 mK.
  - Emissivity measurement accuracy less than 0.001
# Calibration Sources In Development

Review of performances and project status

## Meteosat Third Generation

<table>
<thead>
<tr>
<th>Instrument type:</th>
<th>Temperature knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Hyperspectral imager</td>
<td>- U = 20 mK (including calibration and drifts)</td>
</tr>
<tr>
<td><strong>Project Status</strong></td>
<td><strong>Optical performances</strong></td>
</tr>
<tr>
<td>- Qualification completed with EQM</td>
<td>- Spectral range = 3.5 to 13.5 microns</td>
</tr>
<tr>
<td>- PFM delivered</td>
<td>- Emissivity &gt; 0.985</td>
</tr>
<tr>
<td>- FMs to be built in 2018</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instrument type:</th>
<th>Temperature knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>- FTS based sounder</td>
<td>- U = 20 mK (including calibration and drifts)</td>
</tr>
<tr>
<td><strong>Project Status</strong></td>
<td><strong>Optical performances</strong></td>
</tr>
<tr>
<td>- Qualification completed with EQM</td>
<td>- Spectral range = 4 to 16.95 microns</td>
</tr>
<tr>
<td>- FMs to be built in 2018/2019</td>
<td>- Emissivity &gt; 0.995</td>
</tr>
</tbody>
</table>

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This work was supported in part by the European Space Agency (ESA) funding through the Meteosat Third Generation (MTG) programme. The Blackbodies will be flying on six MTG series instruments.
Calibration Sources In Development
Review of performances and project status

METOP-SG / IASI-NG

- Instrument type:
  - Cloud imager

- Project Status:
  - Qualification completed with EQM
  - On-going performance validation with prototype
  - FMs to be built in 2018/2019

- Temperature knowledge
  - $U = 20 \text{ mK (including calibration and drifts)}$

- Optical performances
  - Spectral range = 3.5 to 15.5 microns
  - Emissivity $> 0.995$

- Instrument type:
  - FTS based sounder

- Project Status:
  - Qualification completed with EQM
  - On-going performance validation with prototype
  - FM to be built in 2018/2019

- Temperature knowledge
  - $U = 20 \text{ mK (including calibration and drifts)}$

- Optical performances
  - Spectral range = 10.5 to 12.5 microns
  - Emissivity $> 0.98$
Calibration Sources In Development
Review of performances and project status

**METOP-SG / METImage**

- **Instrument type:**
  - Multispectral imager

- **Project Status**
  - Qualification to be completed with STM
  - Performance demonstration with Proto
  - PFM and FMs to be built in 2018/2019

- **Temperature knowledge**
  - Calibration uncertainty = 36 mK (planned)

- **Optical performances**
  - Spectral range = 3 to 13.5 microns
  - Emissivity > 0.995
ABB is developing blackbodies for all the new generation European weather satellites

ABB provides high end compact blackbodies with key characteristics such as:
- Emissivity higher than 0.99.
- Temperature knowledge better than 30 mK.
- Radiometric knowledge better than 300 mK.
Follow-on with blackbody activities at ABB

- In order to keep our technological edge on IR calibration sources, ABB is currently doing internal R&D on the next generation IR calibration sources (Advanced Blackbody Technology Development):
  - Working on new coatings.
  - In-flight temperature calibration.
  - Improvement of calibration and test setup to further reduce uncertainty.
  - ... 

- This aims for ABB to provide the next generation IR calibration sources with the following key parameters:
  - Emissivity higher than 0.999.
  - Temperature knowledge better than 20 mK.
  - Possibility of on-flight recalibration.
  - Radiometric knowledge better than 100 mK.