The RO Instrument for MetOp-SG Engineering Model Test Results

Anders Carlström, Joel Rasch, Jacob Christensen, Thomas Liljegren
RUAG Space, Göteborg, Sweden
ROMSAF-IROWG 2019
Introduction

- Instrument overview
- Main characteristics
- Open Loop Tracking using 10 Correlators
- RO Engineering Model Results
  - Antennas, LNAs, Receiver Modules
  - End-to-end test results
  - End-to-end simulation results
- Conclusion
Two Instrument Generations

**GRAS on MetOp**
- 700 occultation measurements per day (GPS L1&L2)
- Altitude coverage: 0 to 85 km
- MetOp-B Launch: Sep 2012
- MetOp-C Launch: Sep 2018
- Design life time: 5 years (+ long term storage)

**GRAS-2 : RO on MetOp-SG**
- 2500 occultations per day (GPS/Galileo/Beidou/QZSS L1&L5)
- Altitude coverage: 0 to 500 km
- Design life time: 7.5 years (+ long term storage)
MetOp-SG RO
Main Characteristics

- Galileo, GPS, Compass/BeiDou & QZSS Occultations:
  - Glonass K may replace QZSS in the future
  - Modernized GNSS signals: L1, L5
  - 2500 occs/day per instrument
- Bending angle accuracy <0.5 µrad
- Altitude coverage: 0 to 500 km
- Full open loop tracking with 10 correlators in lower troposphere
- “Frodo” device for DME/TACAN protection

<table>
<thead>
<tr>
<th></th>
<th>DME (green)</th>
<th>TACAN (red)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak pulse power (W)</td>
<td>1000</td>
<td>3500</td>
</tr>
<tr>
<td>Antenna peak gain (dBi)</td>
<td>9.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Frequency range (MHz)</td>
<td>962-1213</td>
<td>962-1213</td>
</tr>
<tr>
<td>Number of stations</td>
<td>3826</td>
<td>417</td>
</tr>
</tbody>
</table>
MetOp-SG RO
Internal Units

- GOA x2
- GZA
- LNA x3
- GEU incl. PIM x2
- RF & DC Harness
RO: From Antenna to Bending Angle

[Diagram showing the RO Instrument for MetOp-SG, with labels for GOA, LNA, GRM, FGM, and GPP, and a flowchart illustrating the process from Antenna to Bending Angle.]
Open Loop Tracking using 10 Correlators

- Model based tracking:
  - On-board algorithms incl. Doppler & Range models
  - Open loop tracking where data from 10 correlators are output (the standard method is to output 1 correlator)
- Algorithm to retrieve the correlation peak from 10 correlators is implemented in ground processing
- Allows for rising signal tracking from the surface
- Advanced tracking: is especially useful to cope with:
  - Large range uncertainty (e.g. ionosphere)
  - Signals with narrow autocorrelation function (i.e. GPS L1C, L5, Galileo E1bc, E5a & Beidou B1C, B2a)
RO Engineering Model Results
Antenna Gain Pattern Results

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Req.</th>
<th>BB</th>
<th>SN001 (EM)</th>
<th>SN002 (EQM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOA gain margin L1</td>
<td>&gt;0 dB</td>
<td>0.56 dB</td>
<td>0.39 dB</td>
<td>0.36 dB</td>
</tr>
<tr>
<td>GOA gain margin L5</td>
<td>&gt;0 dB</td>
<td>0.87 dB</td>
<td>0.47 dB</td>
<td>0.43 dB</td>
</tr>
</tbody>
</table>
## Low Noise Amplifier (LNA) Results

<table>
<thead>
<tr>
<th>Req.</th>
<th>EBB01</th>
<th>EBB02</th>
<th>EBB03</th>
<th>SN101</th>
<th>SN102</th>
<th>SN103</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNA noise figure L1</td>
<td>&lt;2.0 dB</td>
<td>1.56 dB</td>
<td>1.56 dB</td>
<td>1.60 dB</td>
<td>1.57 dB</td>
<td>1.57 dB</td>
</tr>
<tr>
<td>LNA noise figure L5</td>
<td>&lt;2.2 dB</td>
<td>1.98 dB</td>
<td>1.95 dB</td>
<td>1.96 dB</td>
<td>2.01 dB</td>
<td>2.02 dB</td>
</tr>
</tbody>
</table>
## GNSS Receiver Module Results

<table>
<thead>
<tr>
<th>Requirement</th>
<th>SN02</th>
<th>SN03</th>
<th>SN05</th>
<th>SN07</th>
<th>SN08</th>
<th>SN09</th>
<th>SN10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementation loss L1</td>
<td>&lt;1.3 dB</td>
<td>0.45 dB</td>
<td>0.75 dB</td>
<td>1.20 dB</td>
<td>0.55 dB</td>
<td>1.23 dB</td>
<td>0.25 dB</td>
</tr>
<tr>
<td>Implementation loss L5</td>
<td>&lt;1.7 dB</td>
<td>0.98 dB</td>
<td>1.25 dB</td>
<td>1.65 dB</td>
<td>1.08 dB</td>
<td>1.16 dB</td>
<td>0.82 dB</td>
</tr>
</tbody>
</table>
End-to-end Performance Evaluation

EUMETSAT test data set & “Classic 55”

IDS → GPP → Δ

GNSS simulator → RO → GPP → Δ

Bending angle error

Together ahead. RUAG
Environmental tests (Vibration, shock, TV, EMC) were successfully performed. No performance degradation.

• **FDAF EQM:**
  Maximum DME/TACAN Interference is applied
  
  - Budget analysis based on specified parameters:
    0.46 urad RMS (35-80 km)
  - Analysis based on measured units:
    0.36 urad RMS (35-80 km)
Conclusion

- MetOp-SG RO instrument Engineering Model testing is successfully completed
- Excellent performance of all tested units: antennas, LNAs, receiver modules
- End-to-end test demonstrates a bending angle accuracy of 0.4 urad RMS (at 35-80 km)
- PFM manufacturing is ongoing
- 6 flight-models to produce