The RO instrument onboard MetOp Second Generation

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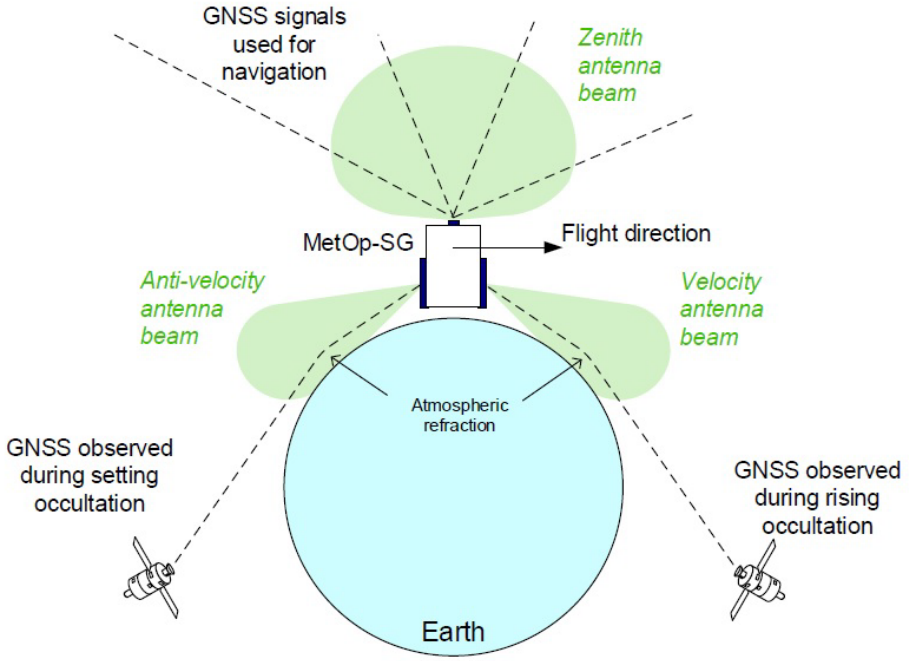
Radio Occultation Principle



Three antennas:

- Zenith side for position&Velocity
- Velocity for Rising Occultation
- Anti-Velocity for Setting Occultation

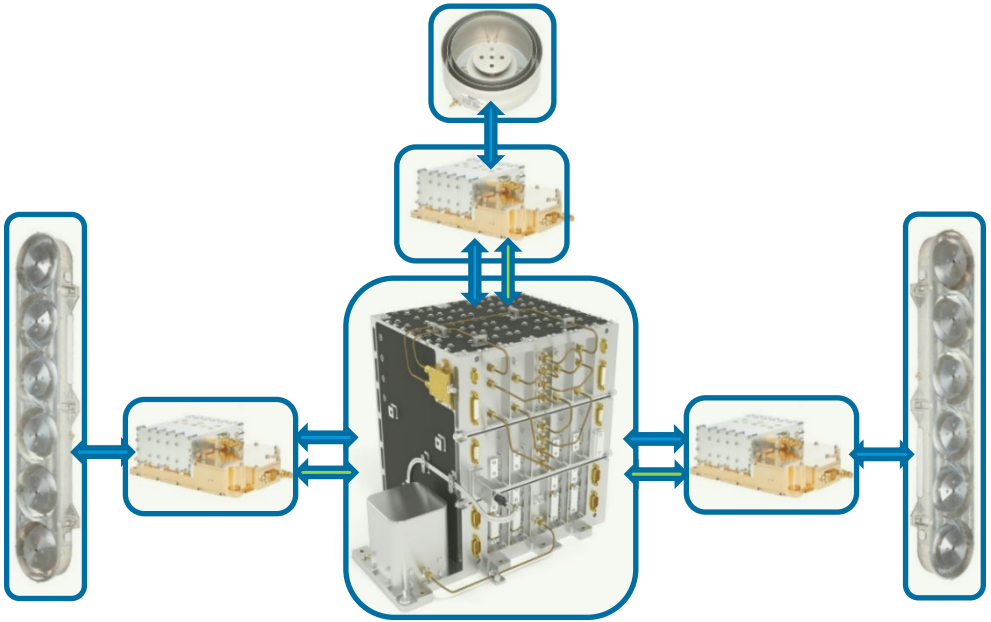
The Earth atmosphere bends and delays the GNSS signals received proportionally to its characteristics.

Needs dual frequencies, very accurate satellite velocities, Frequency short-term stability.

RO Instrument Overview

RO units:

- GNSS Electronic Unit:
  - GPS, Galileo, BeiDou (optional GLONASS)
  - Dual frequency L1/L5
  - Frequency Domain Adaptive Filter (FDAF) FPGA (FRODO)
  - Ultra Stable Oscillator (USO)
- RO occultation antennas (x2) and POD navigation antenna
- External LNAs (x3)



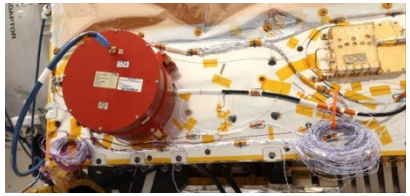
Main interface data:

- Mass: 25 kg
- Power: 40 W
- Data Rate: 1.1 Mb/s

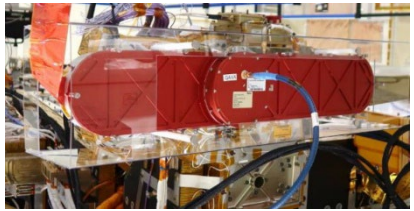
RO Instrument Status

- The RO Proto Flight Model (PFM) test campaign was completed in 2020 with excellent results and was the first instrument delivered to Satellite-A Prime in October 2020. It has been fully integrated and tested onto the satellite-A PFM.
- The RO FM2 was fully tested and delivered to Satellite-B Prime in April 2021, integrated and is under final testing.
- The RO FM3 has been fully tested in October 2021 and is under test with BeiDou SW.
- The RO FM4 has been updated with BeiDou SW and full functional and performance tests have been completed.
- The RO FM5 & FM6 are assembled and will be tested.
- The qualification testing of the SW including Beidou constellation has been completed. PFM and FM2 will be retrofitted and verified at satellite level.

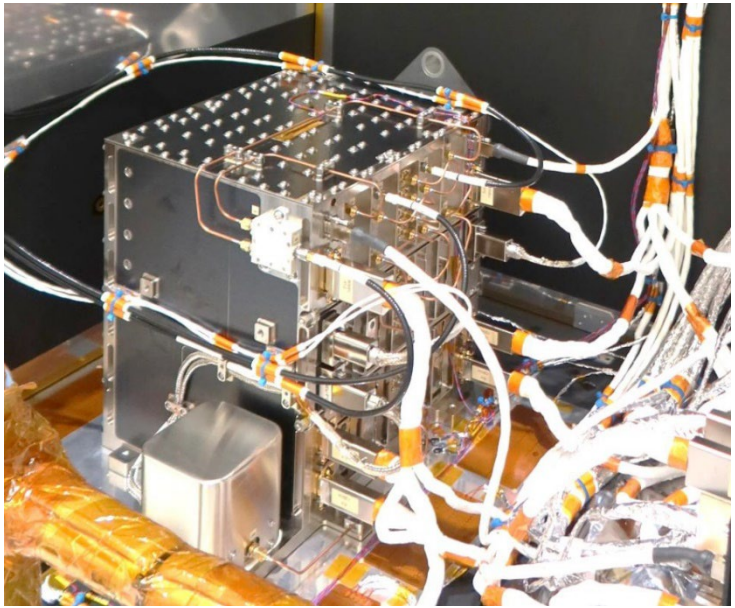
RO PFM on Satellite A1



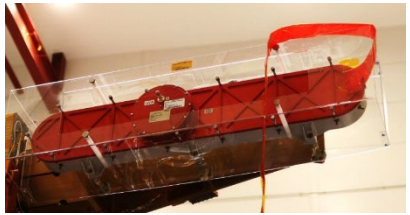
Zenith Antenna



Anti-Velocity Antenna



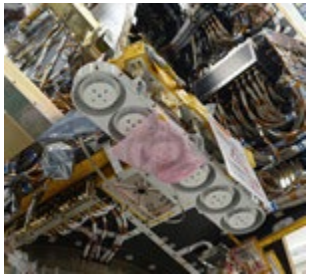
Electronics Unit and USO



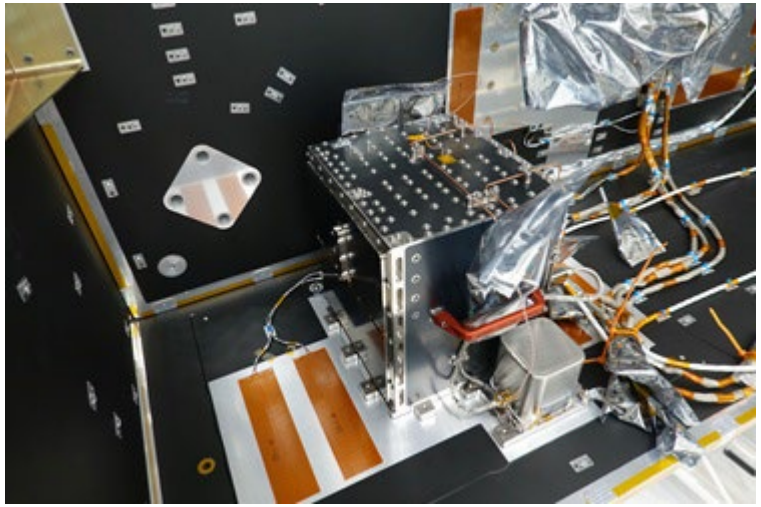
Velocity Antenna

RO FM2 on Satellite B1

Zenith Antenna



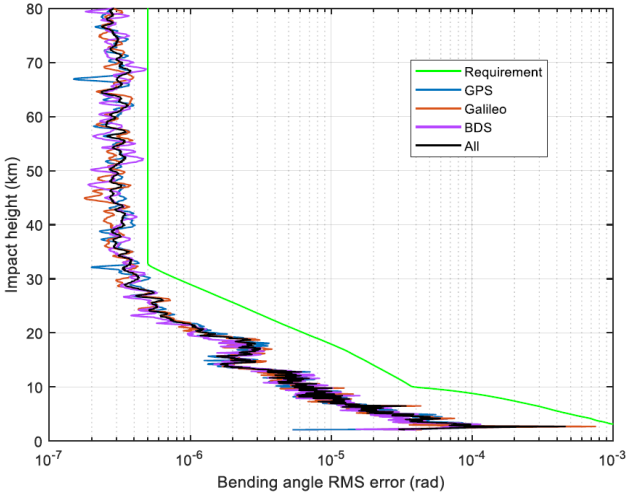
Anti-Velocity Antenna

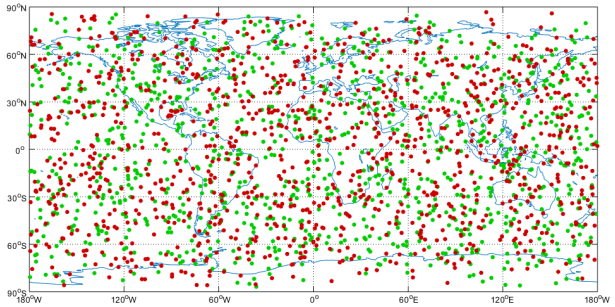


Electronics Unit and USO

Velocity Antenna

RO Performances and Processing





1 day Coverage

- About 2000 occultations/day/instrument by tracking simultaneously Galileo, GPS and BeiDou,
- From Surface to 500km altitude
- Bending Angle RMS error about 0.3-0.4 microradian in the upper atmosphere,
- Interference mitigation in L5.

- Ground Processing Algorithms finalised and tested

Level2 products: (high resolution vertical profiles)
- Atmosphere: Refractivity, Temperature and Humidity
- Ionosphere: Electron density

From GRAS to RO instrument

	GRAS on MetOp	RO on MetOp-SG
Nb of instruments	3 (1 per satellite)	6 (1 per satellite)
Nb of constellations	1 (GPS)	3-4 (Galileo, GPS, BeiDou, resources for 4th one)
Nb of occultations	~650/day/instrument	~2000/day/instrument
Bending Angle [rms]	1μrad or 0.4% (90%)	0.5μrad or 0.2% (1σ)
Vertical profile	1-80km	0-80km, 80-500km
USO Allan variance	1e-12	5e-14
Interferences Protection	None	L5 Freq Adaptive Filter
Reliability	0.8 over 5 years	0.85 over 7.5 years

Conclusions

- The heritage of RO is the GRAS instrument on MetOp-A/B/C, reference instrument for Numerical Weather Forecasting and Climate Monitoring.
- The RO will outperform these performances with about 2000 occultations per day per instrument (Galileo, GPS, BeiDou) and 0.3-0.4 microradian Bending Angle in the upper atmosphere. A 4th constellation tracking is possible.
- The first two RO instruments are already accommodated on the first two satellites.
- Six instruments have been built, one on each of the MetOp-SG satellites.
- The testing of the SW with BeiDou constellation has been completed and will be uploaded on all instruments.

- RO, together with the European built MetOp-SG instruments, will provide the best ever Scientific Products, measured simultaneously over the same area.