RO Instrument Design Considerations for the New GNSS Signals

IROWG-2 Workshop

Estes Park, Co USA, 2012

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- The future: GRAS-2
- New GNSS Signals: Galileo
- RO simulation results
- Conclusion

Magnus Bonnedal
Anders Carlström
Thomas Lindgren
Jacob Christensen

GNSS Receiver Development

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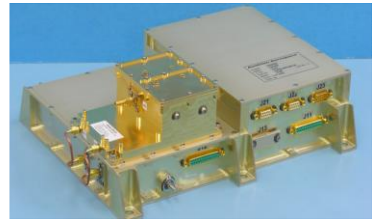

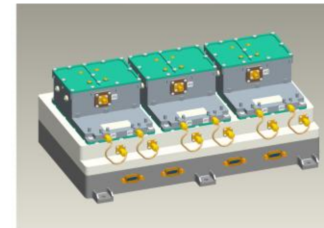

RO

GRAS MetOp A
B
C

Operational

RO

GPSOS
NPOESS

EDU

POD

SWARM

Production Phase
6 units

New Generation:
- Modular
- Compact
- Front end RFASICS
- UART i/f
- Compact antenna

POD

Sentinel-1 A
Sentinel-2 A
Sentinel-3 A

Production Phase
6 units

New Features:
- 1553 i/f
- Dynamic Nav solution
- Choke ring antenna
- S/C multipath analysis

POD

Sentinel-1 B
Sentinel-2 B
Sentinel-3 B

2:nd
generation ordered
6 units

EartCARE

POD

Sentinel-1 C
Sentinel-2 C
Sentinel-3 C

3:rd
generation anticipated
6 units

RO

GRAS-2

GPS: L1 C/A + L2 Codeless tracking

GPS L2C

Galileo, Compass, Glonass CDMA

GRAS Performance

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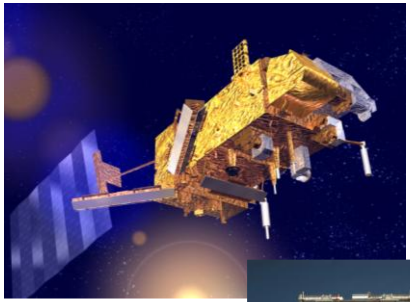
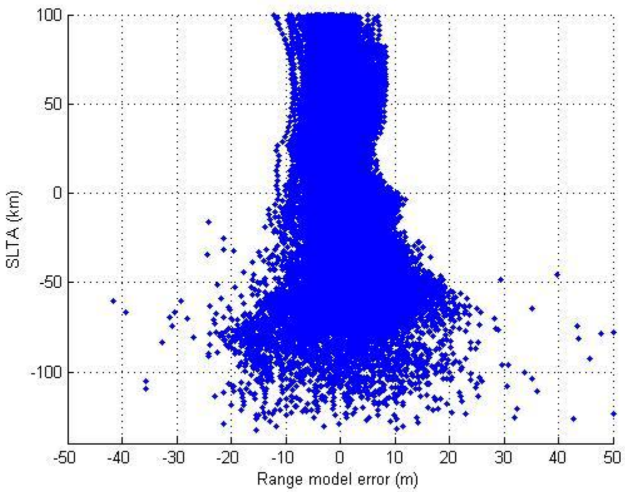


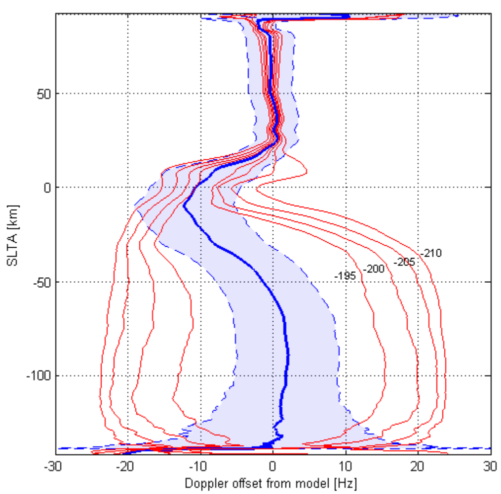
Characteristics:

- 650 occ/day
- Ultra stable frequency reference < 1e-12
- Wide coverage high gain antennas
- Excellent RFI rejection
- OL sampling at 1 kHz (high observability)

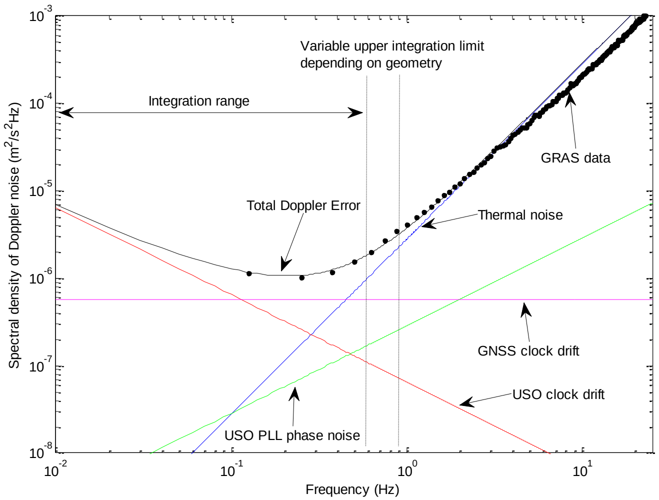
Range model performance



Doppler model performance



Doppler measurement performance



GRAS-2 Performance

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Characteristics:

- 1300-2400 occ/day
- Ultra stable frequency reference < 0.5e-12
- Wide coverage high gain antennas
- Open loop sampling for continuous measurements

Requirements:

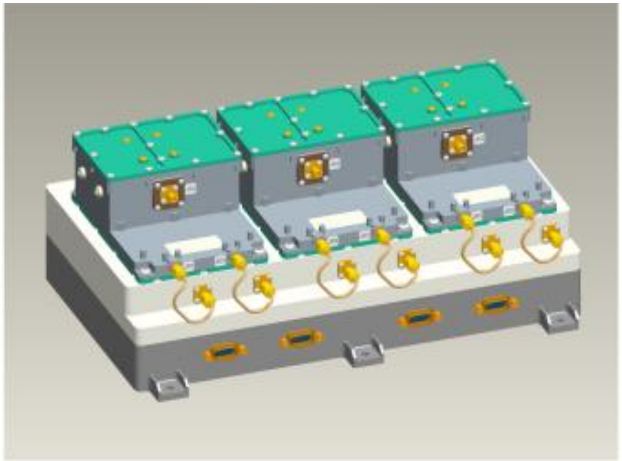
GPS L1, L5

GALILEO E1, E5

COMPASS

GLONASS CDMA

0.5 μrad bending angle accuracy

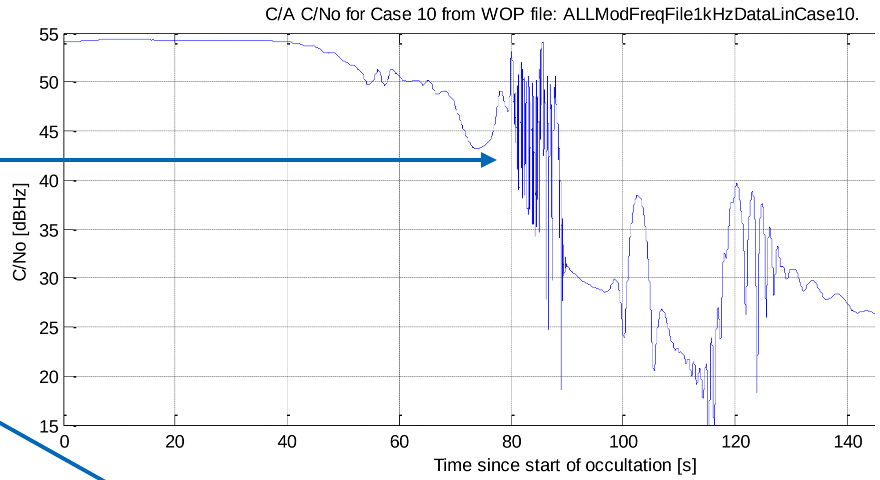


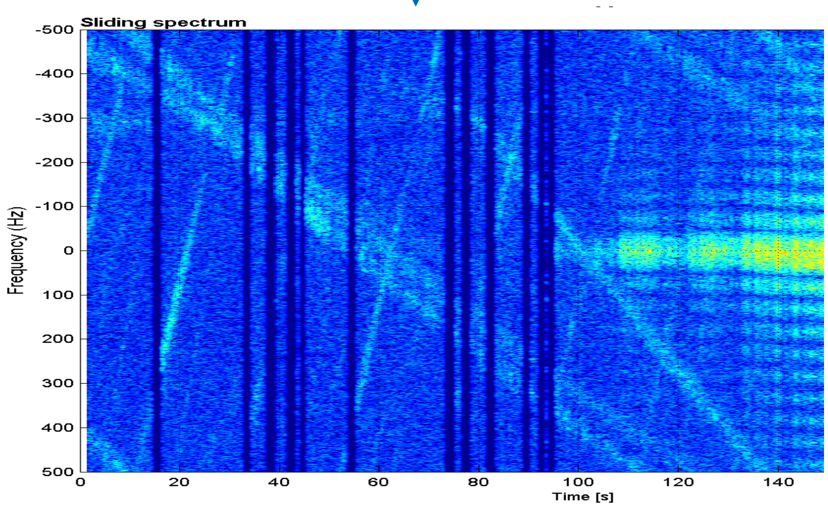
Nominal data:

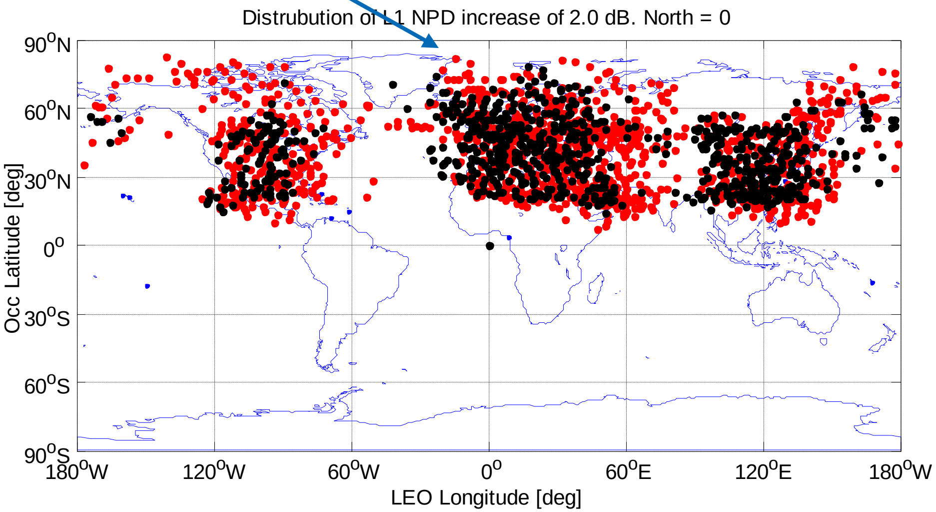
- Mass: 8 kg
- Power: 25 W
- Data rate: 200 kbps – 1 Mbps

GRAS Experience

- Complex atmosphere
- Ground interference
- Co-channel interference







Galileo Signals

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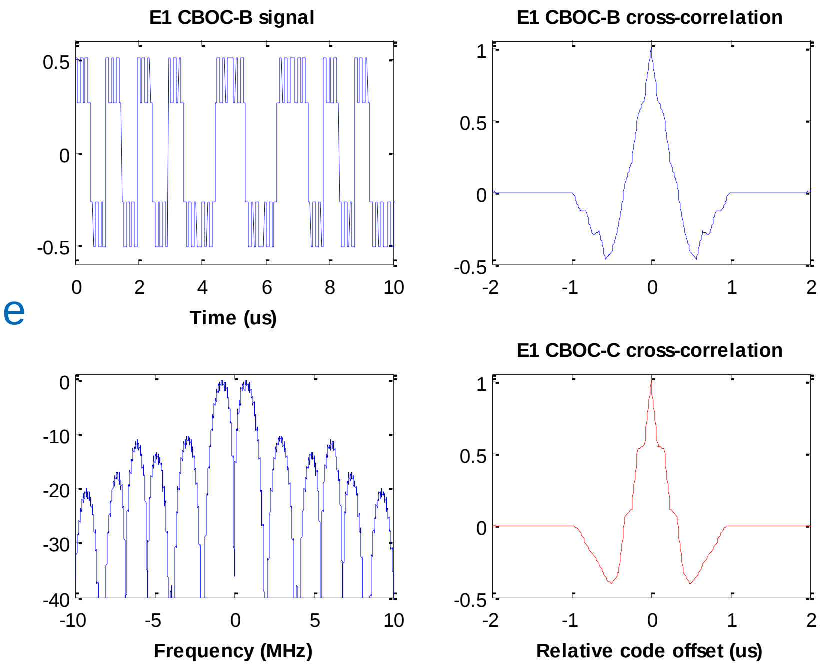
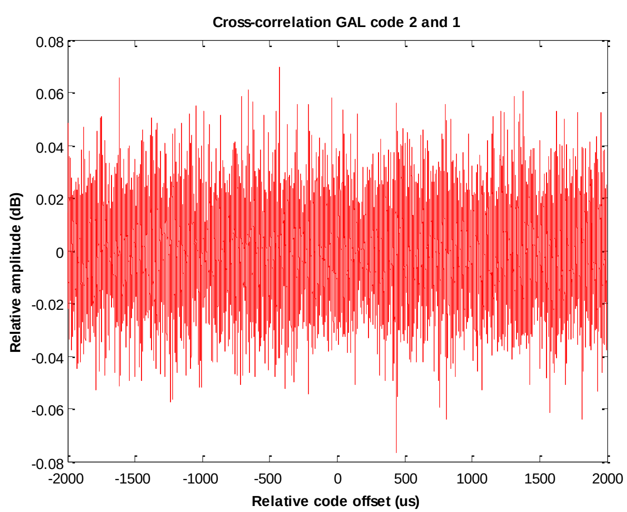
- Signals of particular interest for GRAS-2:
  - E1 (CBOC) data 250 Hz (-B) and pilot (-C)
  - E5 (BPSK 10 MHz)
- Cross-correlation between signals varies over time due to the relative motion between them.
- Experience from GRAS is that cross-correlation interference may be up to 5 dB above thermal noise, interfering with the acquisition process.





- Cross-correlation between Galileo E1 CBOC (B and C):
  - -24 dBc peak relative to signal being tracked (B or C) (~3 dB better than GPS C/A)
  - -38 dBc average (~6 dB better than GPS C/A)

Galileo Signals:
Bending Angle Accuracy

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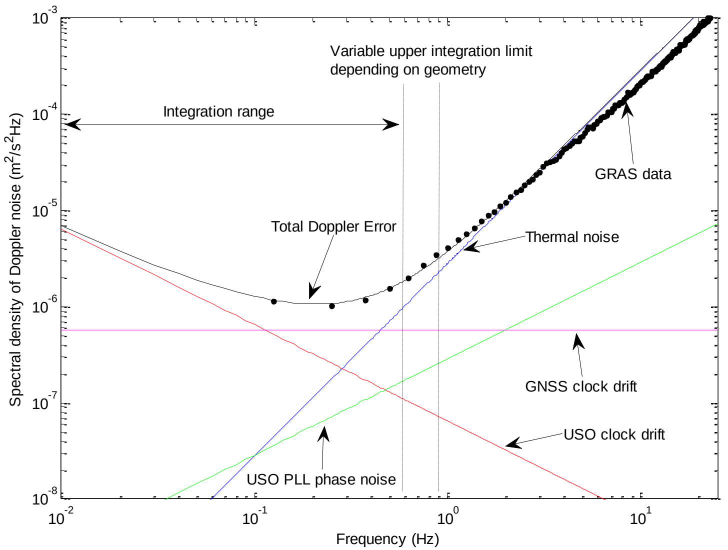
- RMS budget at 35 km
- Interference between Galileo/GPS/Compass/Glonass signals accounted for
- Signal power increases (no codeless tracking)
- More co-channel interference
- GNSS clock improvements



Budget Parameters	Metop-GRAS		Galileo signals Pilot only		Galileo signals Pilot + Data	
Signal component	L1 C/A	L2 P(Y)	E1c	E5a-Q	E1b,c	E5a-I,Q
Received signal power at lower frequency (dBm)	-115	-119	-118	-119	-115	-116
Noise and interference power density (dBm/Hz)	-171	-173	-168	-171	-168	-171
C/No (dBHz)	55	47	49	50	52	53
GNSS Allan deviation @ 1 s gate time	2e-12		1e-12		1e-12	
USO Allan deviation @ 1-10 s gate time	1e-12		1e-12		1e-12	
LO phase noise at 1 Hz offset (dBc/Hz)	-55		-55		-55	
Bending angle accuracy budget						
Thermal Noise Error (mm/s)	0.70		0.84		0.59	
GNSS Allan Deviation Error (mm/s)	0.67		0.35		0.35	
USO Allan Deviation Error (mm/s)	0.53		0.57		0.57	
LO phase noise error (mm/s)	0.30		0.33		0.33	
Total Doppler Meas. Error (mm/s)	**1.14**		**1.13**		**0.96**	
Bending angle Doppler sensitivity (urad mm^{-1} s)	0.40		0.40		0.40	
Total Bending Angle Meas. Error (urad)	**0.46**		**0.46**		**0.39**	

RO Simulator Environment

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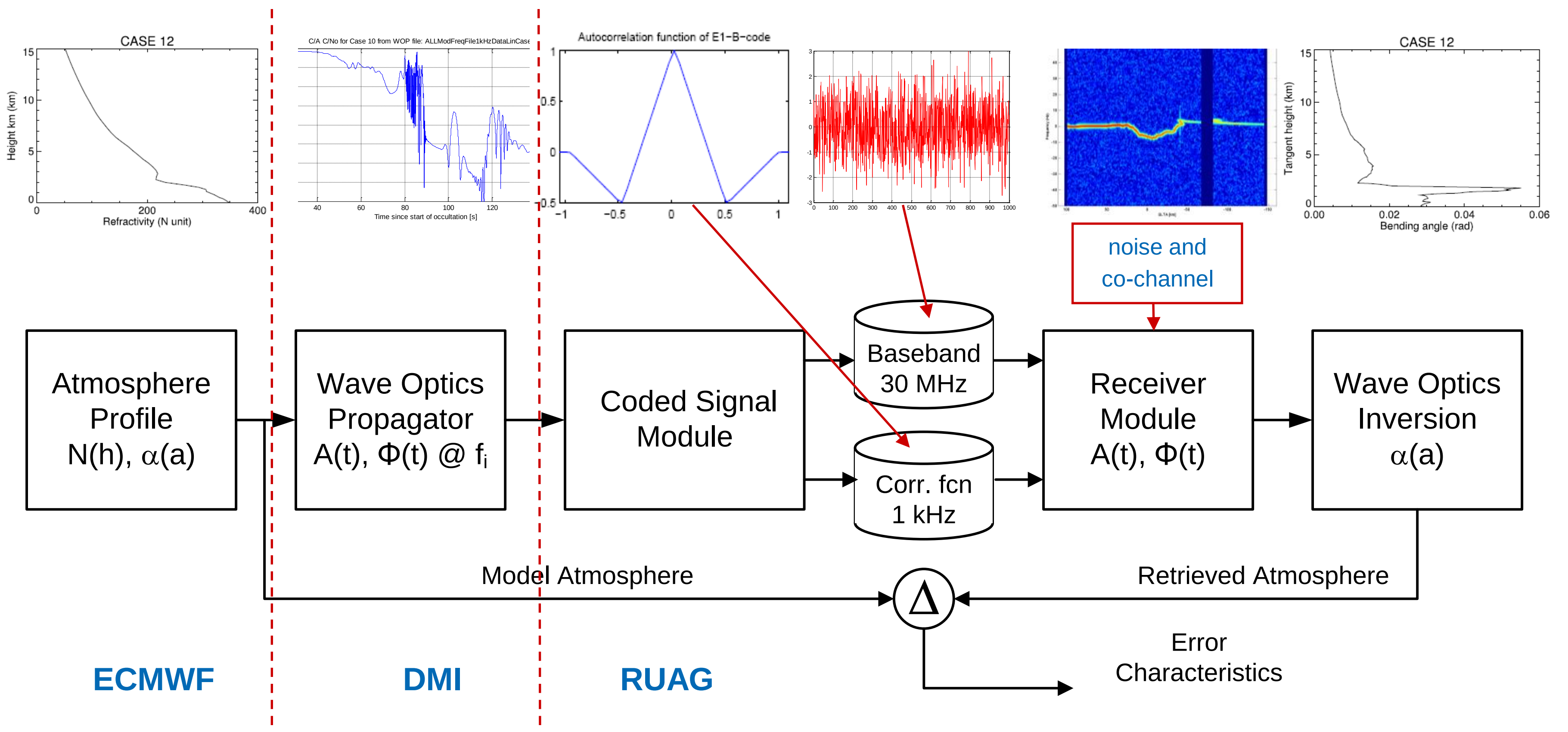
Objective: (EUMETSAT Study)

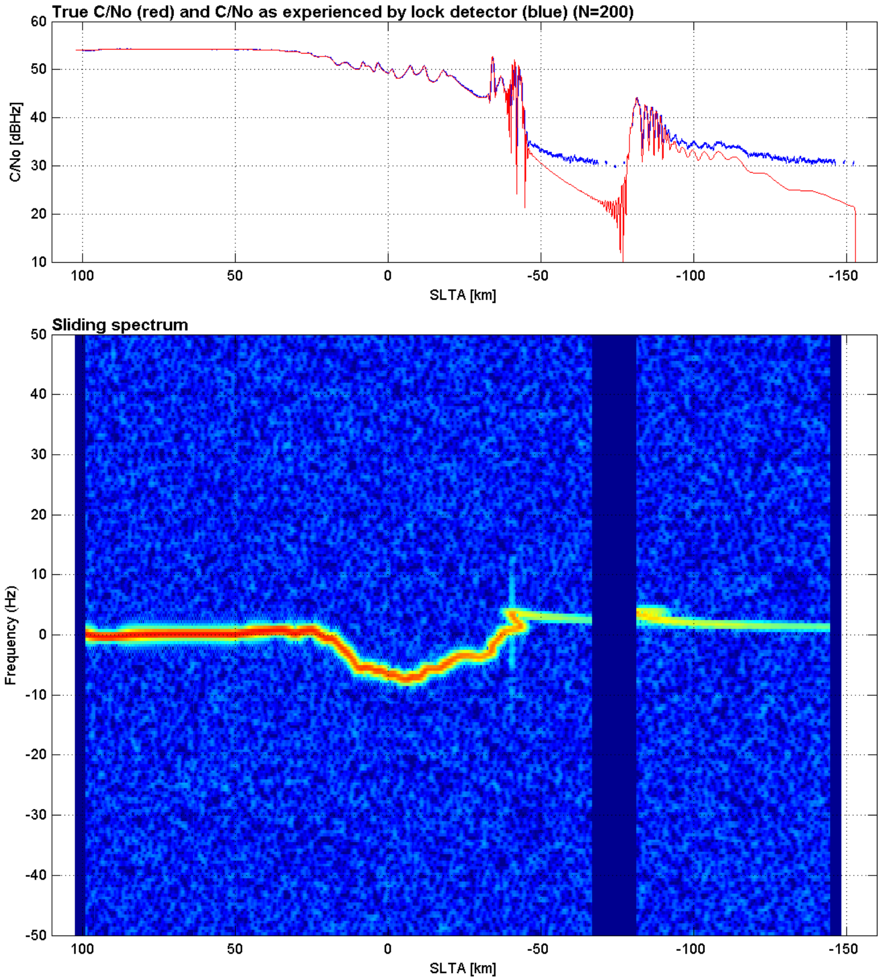
- Relate instrument characteristics to bending angle performance.
- Establishing GRAS-2 acquisition and tracking strategies.
- Validating S/W patches for GRAS enhancements.



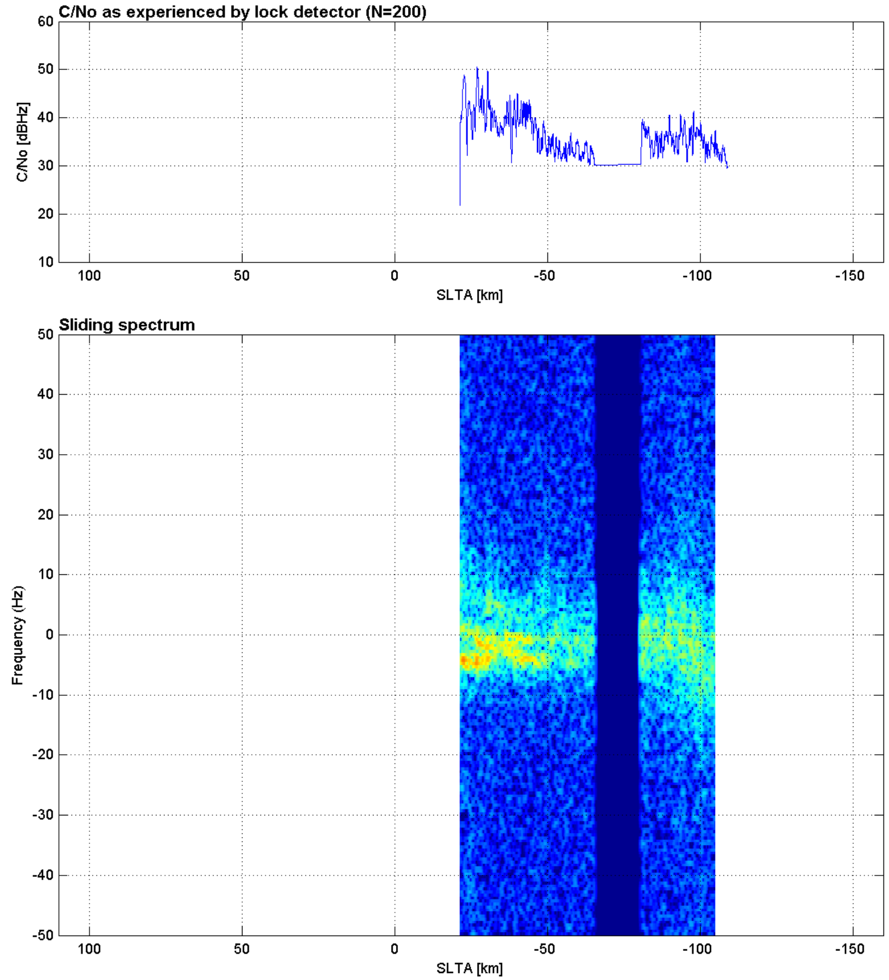
Simulation Model Results

(ESA study)

GRAS Simulation



GRAS Data



Simulation model results

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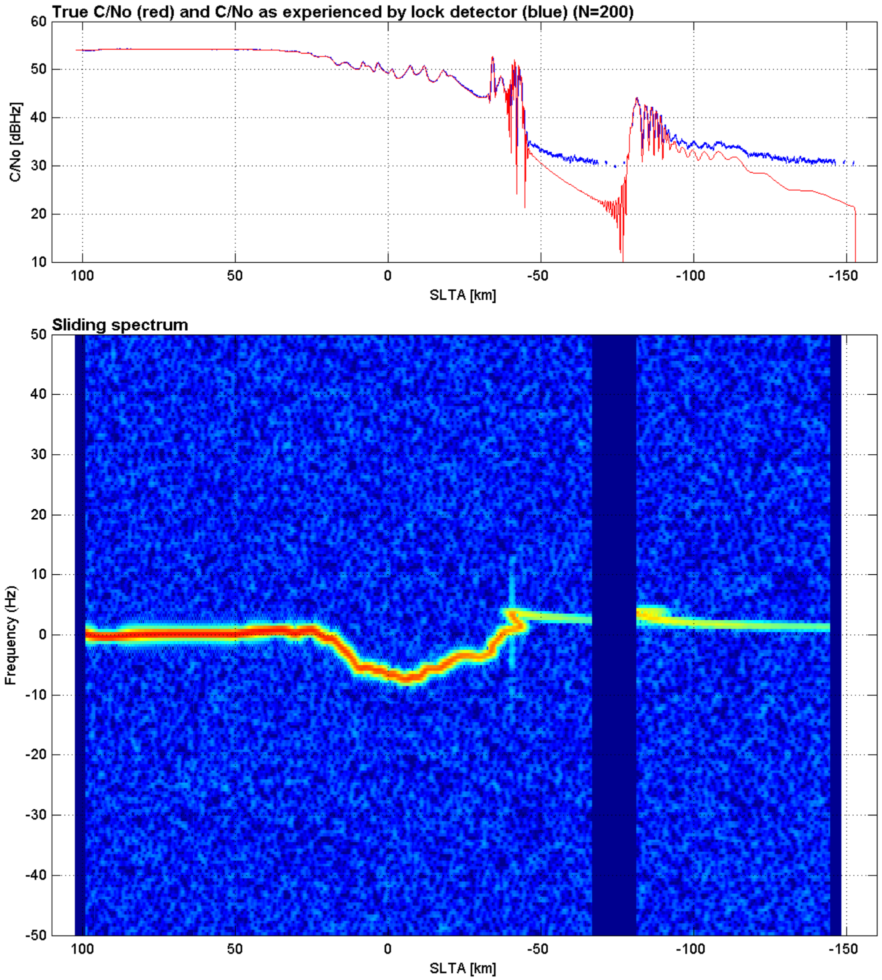
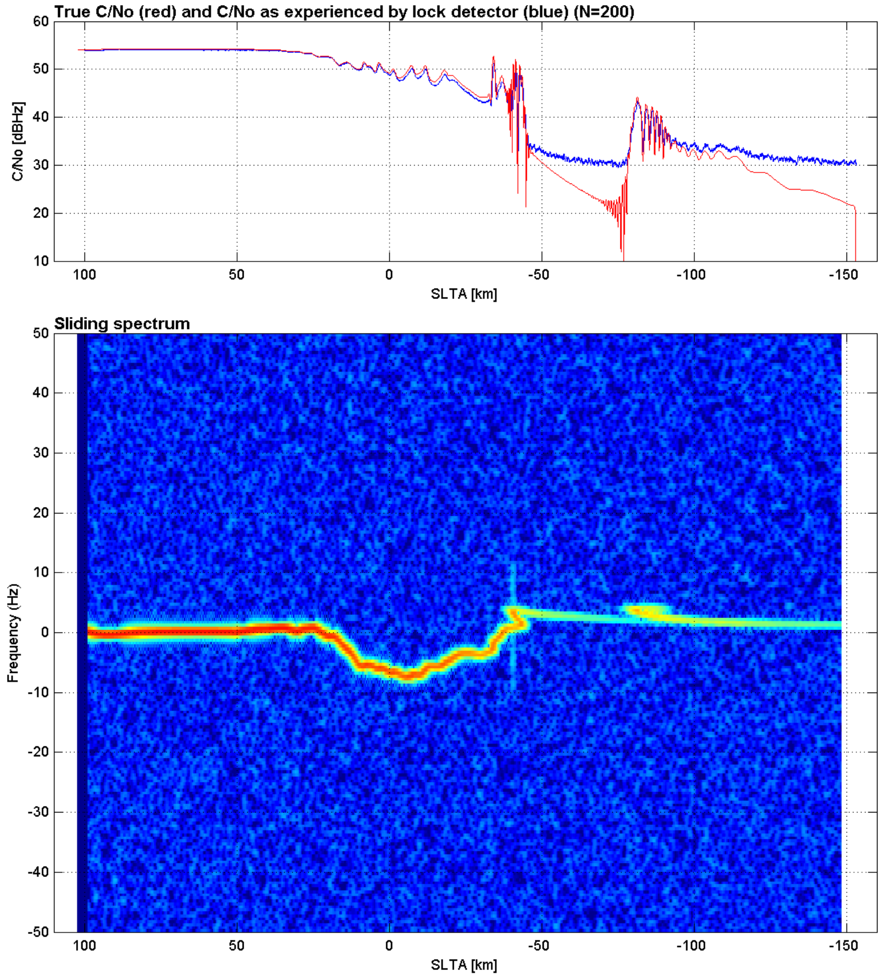
GRAS Simulation



GRAS-2 Simulation



GRAS Instrument Simulations

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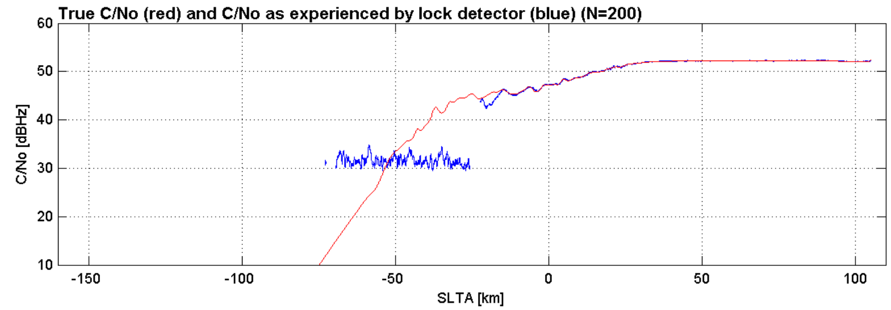
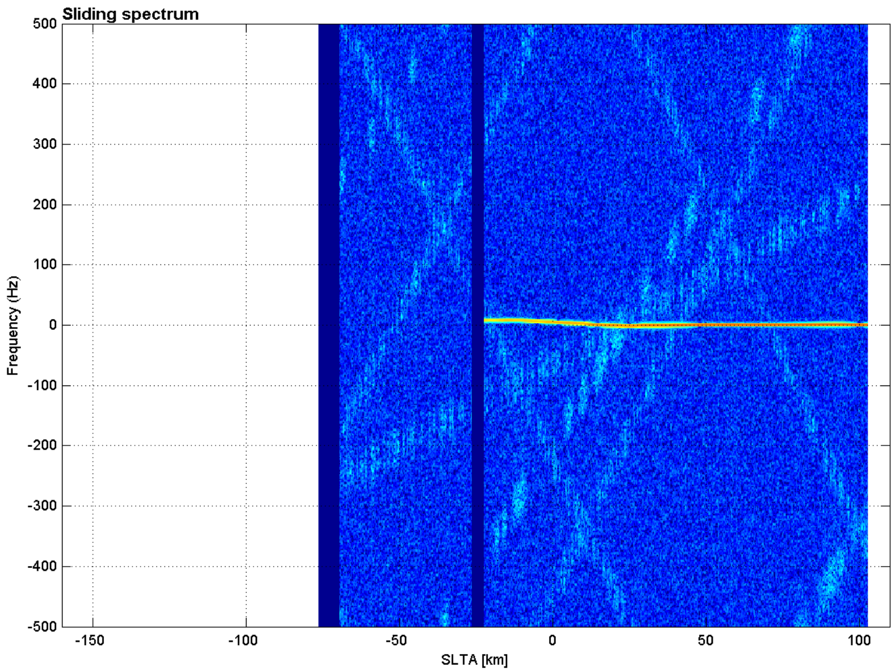
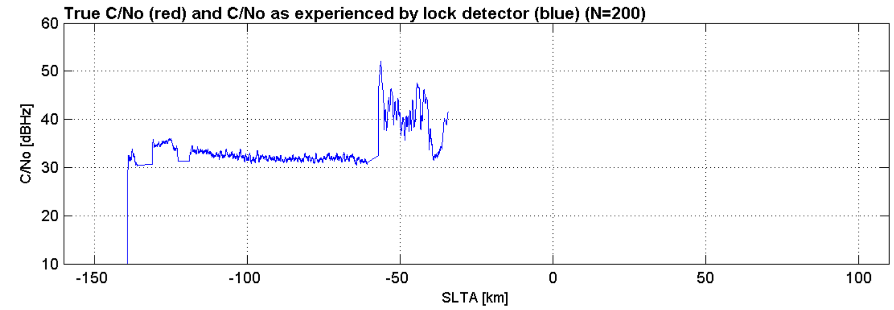
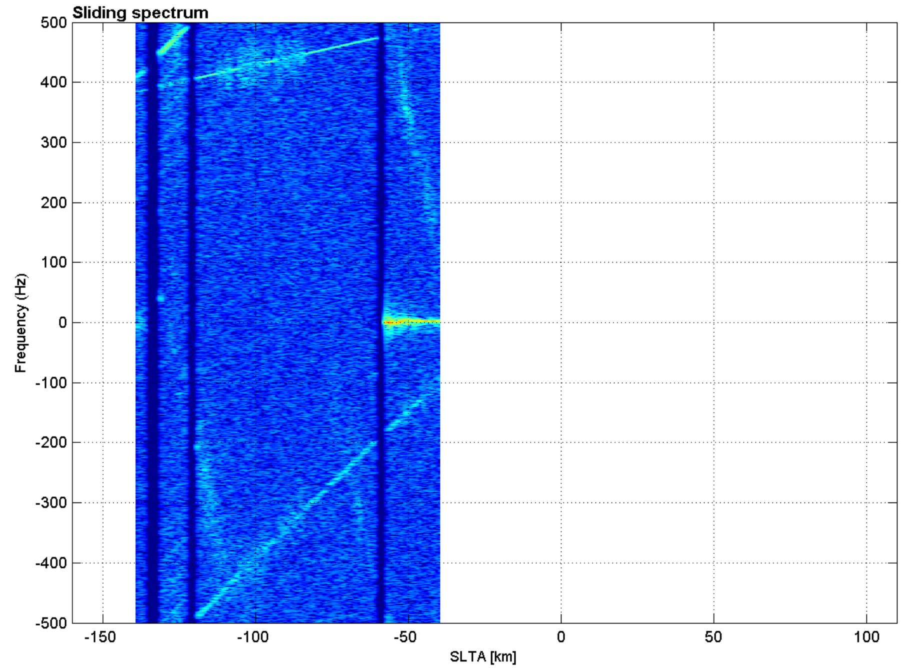
GRAS Simulation





GRAS Data





GRAS Instrument Simulations

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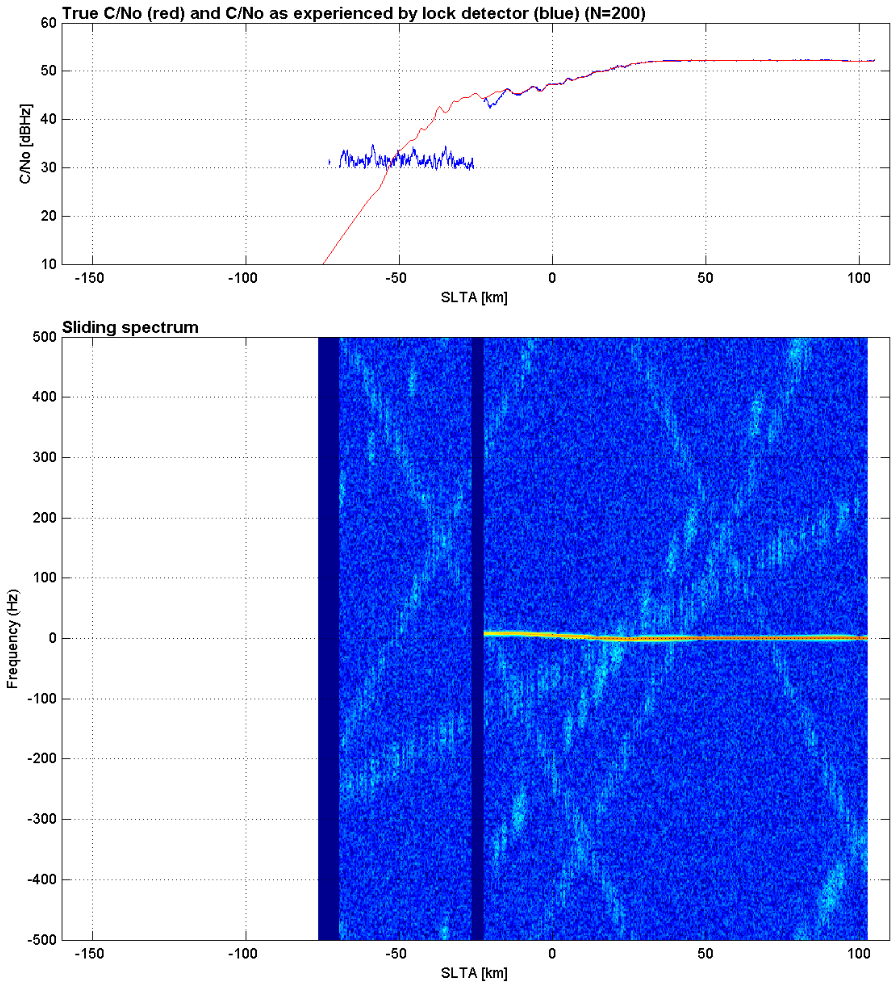
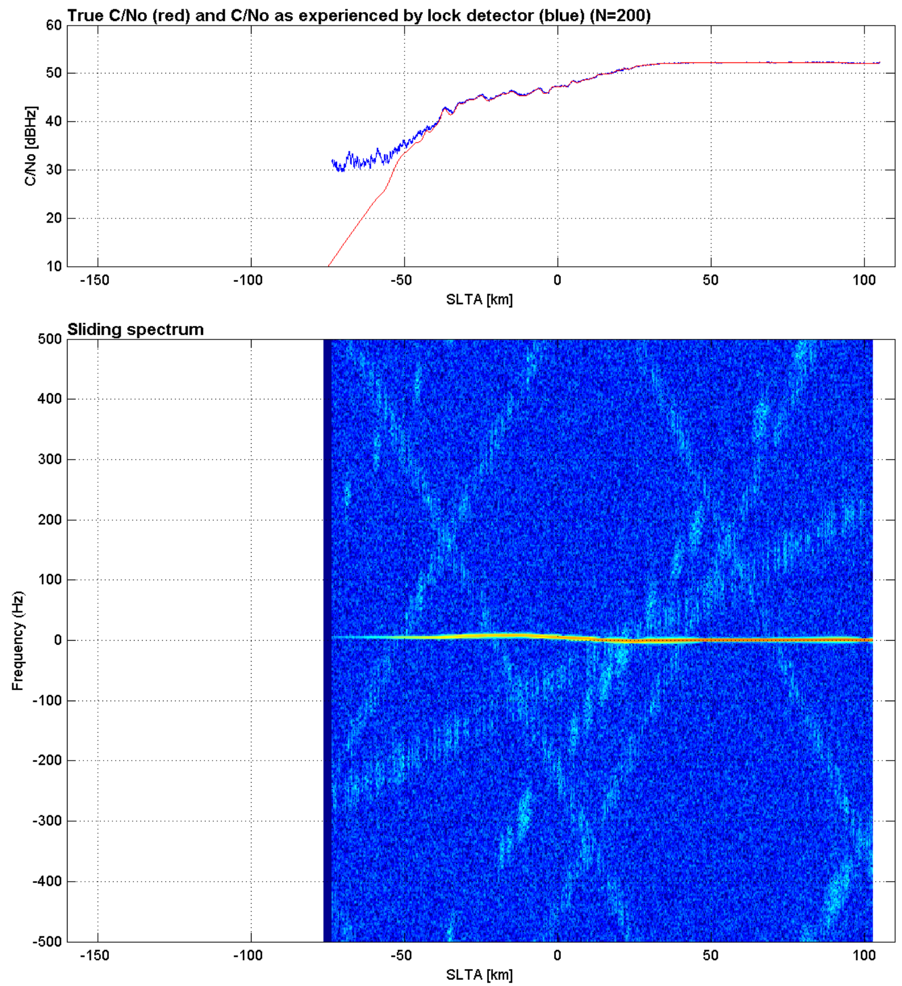
GRAS Simulation



GRAS-2 Simulation



Conclusion

- GRAS-MetOp continuous to provide valuable experience for the GRAS-2 instrument development
- New GNSS signals provide new opportunities but is also a source of increased interference in the GNSS bands
- Improved simulation tools provide realistic atmosphere cases for validating the GRAS-2 tracking principles