Characterization of GOCE GPS Antennas

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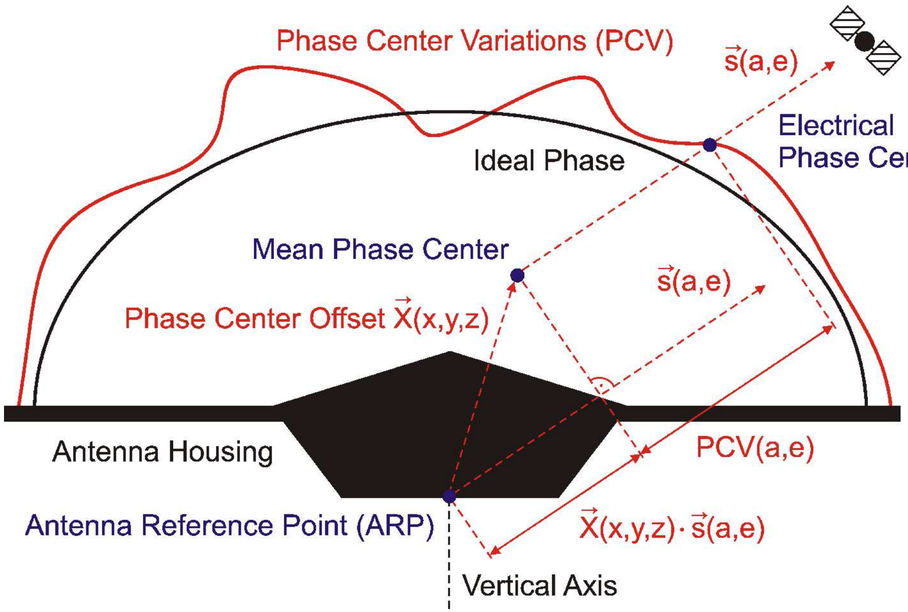
Fundamentals - Antenna Phase Center

- GPS measurements refer to electrical phase center (PC), which is neither a physical nor a stable point → PC (a, e, L_i)
- Vector from PC to mechanical antenna reference point (ARP) has to be determined by calibration
- PC is defined by mean phase center offset + variations (PCV)

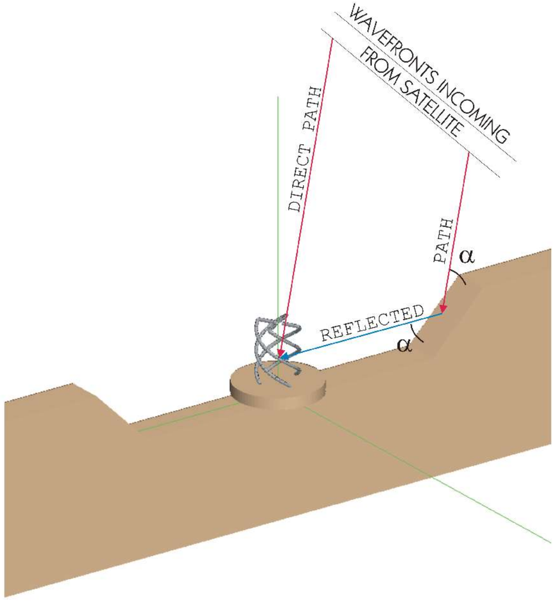


Fundamentals - Automated Absolute Field Calibration

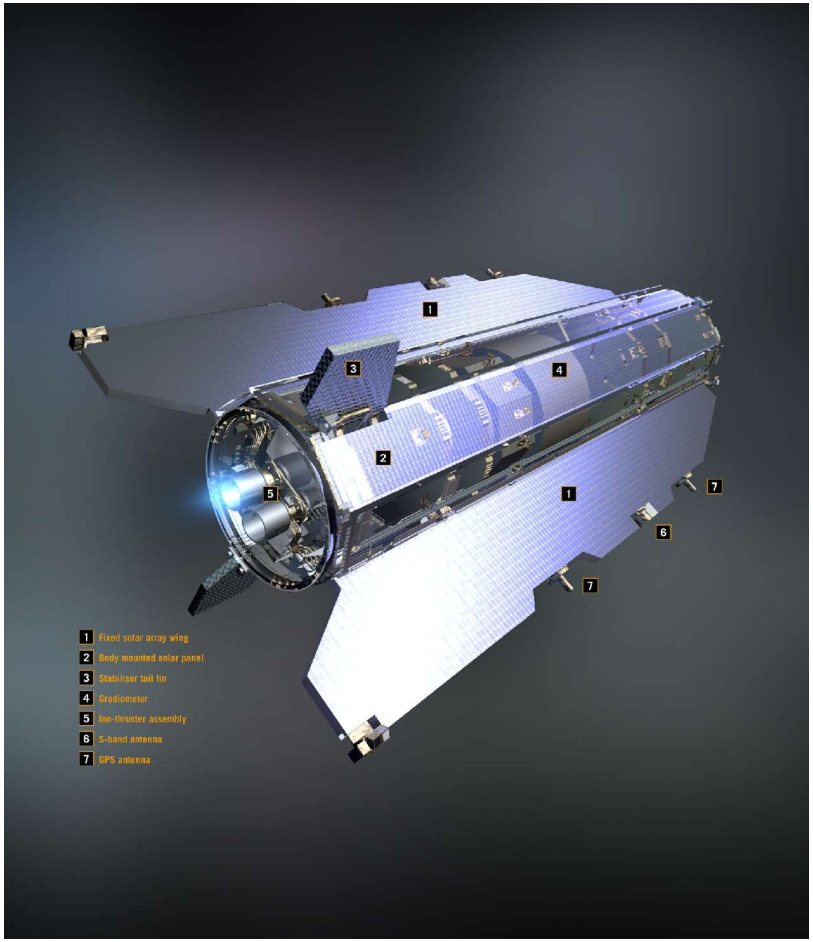
- Developed by the Institut für Erdmessung (IfE) and Geo++®
- Rigorous separation between phase center variations and site dependent multipath effects
- Antenna will be tilted and rotated by means of a precisely calibrated and fast moving robot
- Since time differences between consecutive epochs amount just a few seconds, environment multipath error is highly correlated and can be well described as a stochastic process
- PCV signal is free of systematic effects ($\rightarrow$ „absolute“ PCV)
- Spherical harmonic expansion (8,5) is used for modelling PCV and C/N_0 data over whole antenna hemisphere
- Suitable technique for investigation of near field effects

Fundamentals - Antenna Near Field Effects

- Mainly caused by long-periodic multipath inferences induced by the close vinicity of the receiving antenna (e.g. surface of pillars, tribachs, groundplanes, satellites…)
- Effects tend to be much stronger than multipath coming from more-distant objects because of less spreading loss
- Receiver mitigation techniques can not distinguish between direct and reflected signal in case of short excess signal path (< 30 m)
- Near field effect will also *not* be eliminated by the robot calibration
- Robot calibration results describe inherent PCV pattern *together* with near field influence!



GOCE Mission - Overview

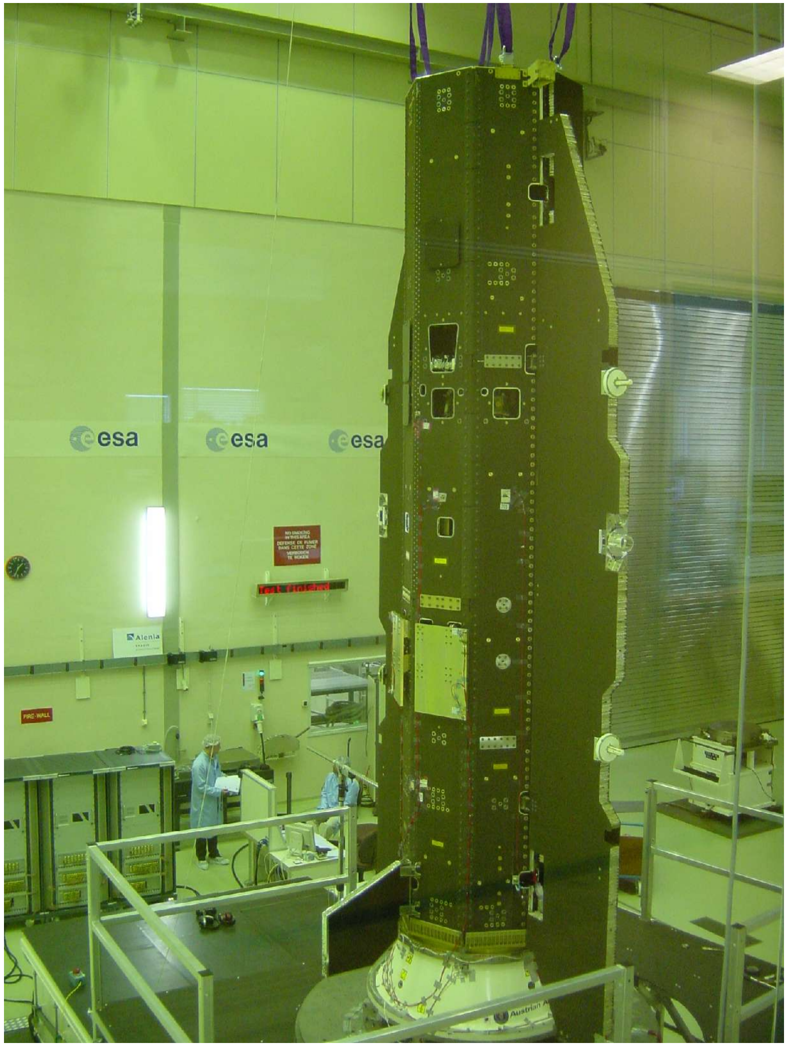


Mission Objectives:
- Determination of gravity-field anomalies with ±1 mGal
- Determination of geoid with ±1 cm
- Spatial resolution better 100 km

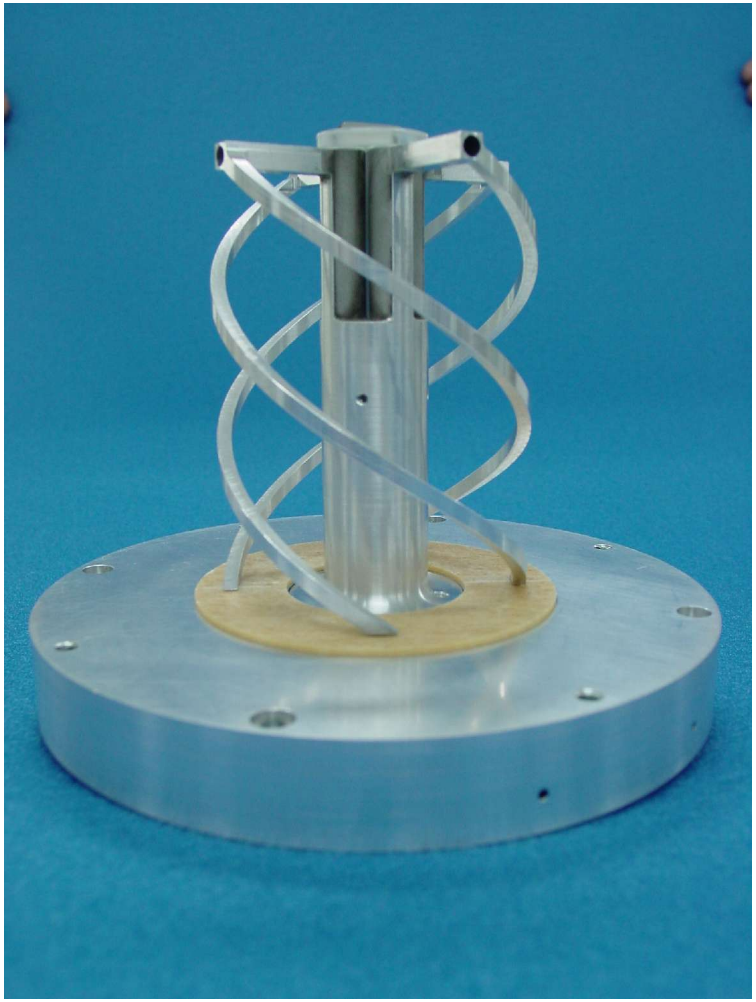
Mission Details:
- Launch in 2007
- Duration of 20 months
- Mean orbital altitude of 250 km

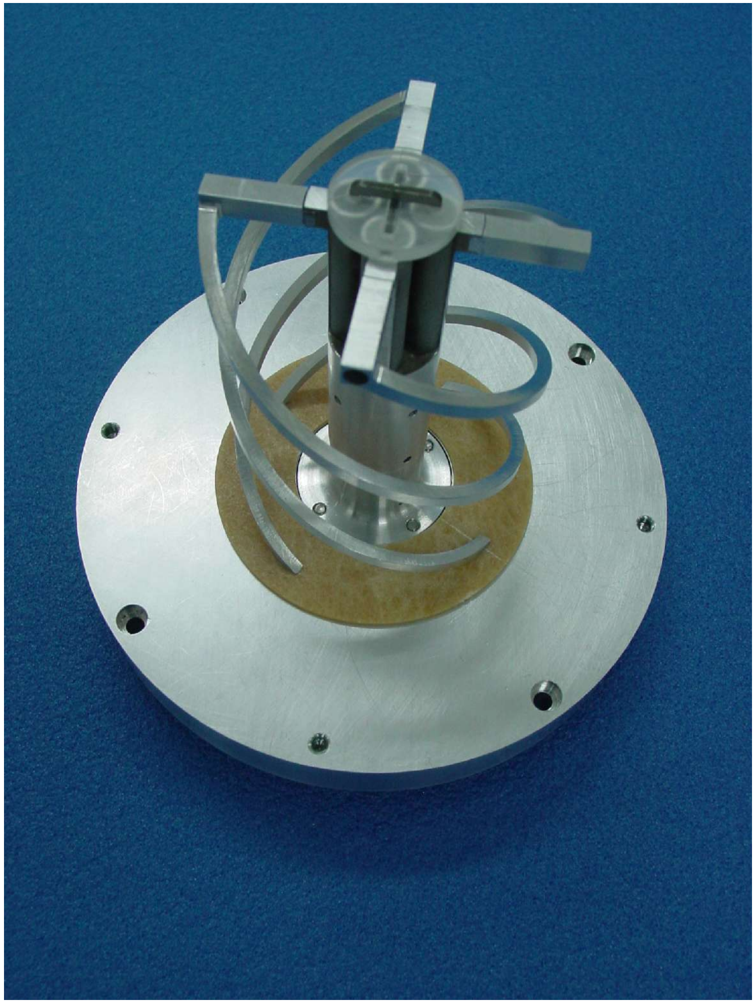
Payload:
- Electrostatic Gravity Gradiometer
- Satellite-to-Satellite Tracking Instrument (SSTI)
- Laser retroreflectors

GOCE Mission - Overview



GOCE Mission - SSTI GPS Antennas

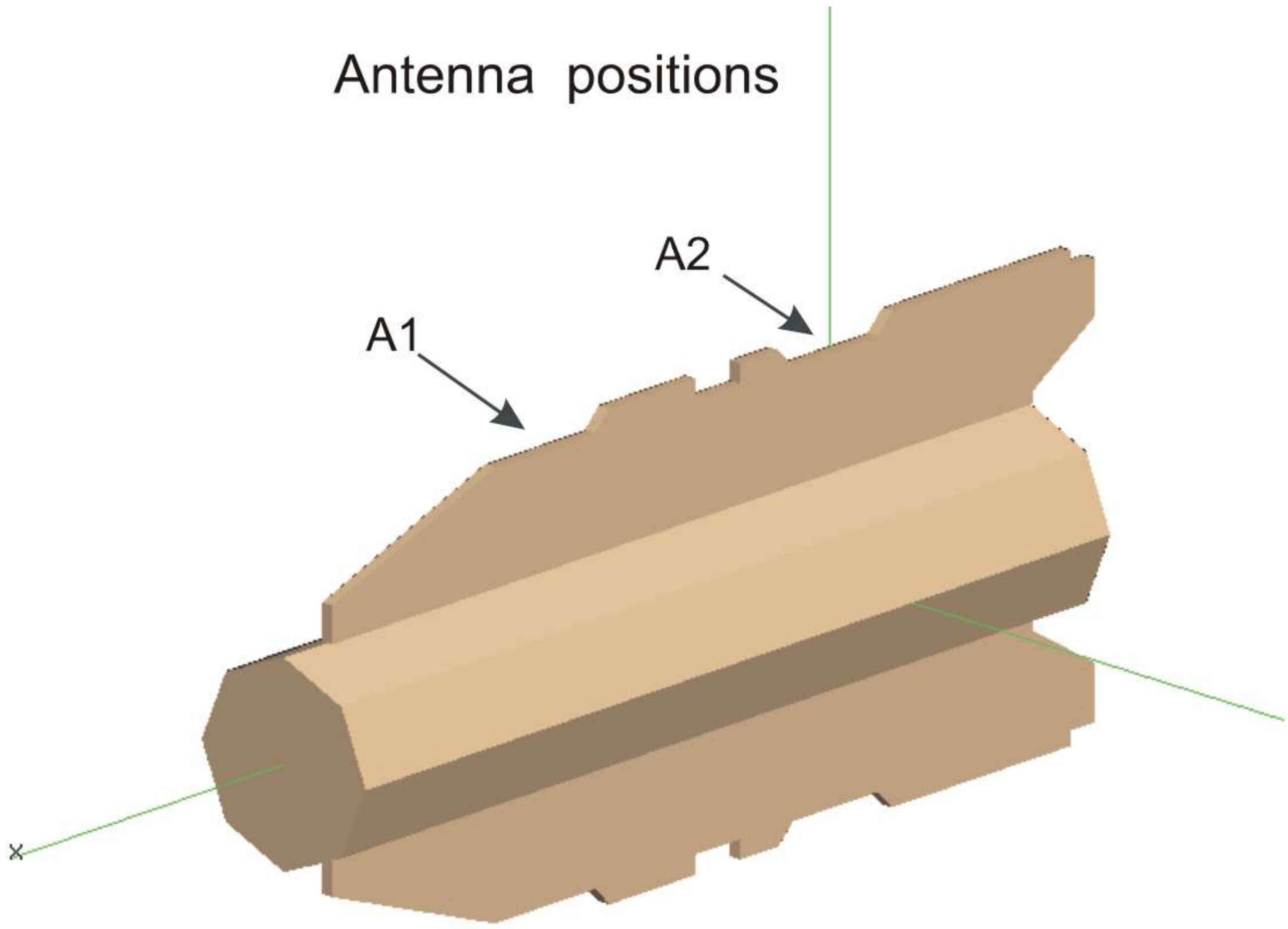




GOCE Mission - SSTI GPS Antennas

- Two Quadrifilar Helix antennas developed by RYMSA, Spain
- Broad gain pattern with very sharp drop-off near horizon
- High rejection to left hand circularly polarization (LHCP)
- Significant phase center variations (PCV) due to unsymmetrical structure of feeding part and helical arms
- Directly installed on top of GOCE solar array wing
- Positions have been optimized due to numerical simulations
- Remaining near field effects will affect PCV and C/N_0
- Most critical interactions with spacecraft will be caused by solar wing, especially for the antenna located in position A2
- COSMO Patch antenna containing Dorne Margolin DM-145-10 patch element as possible backup solution

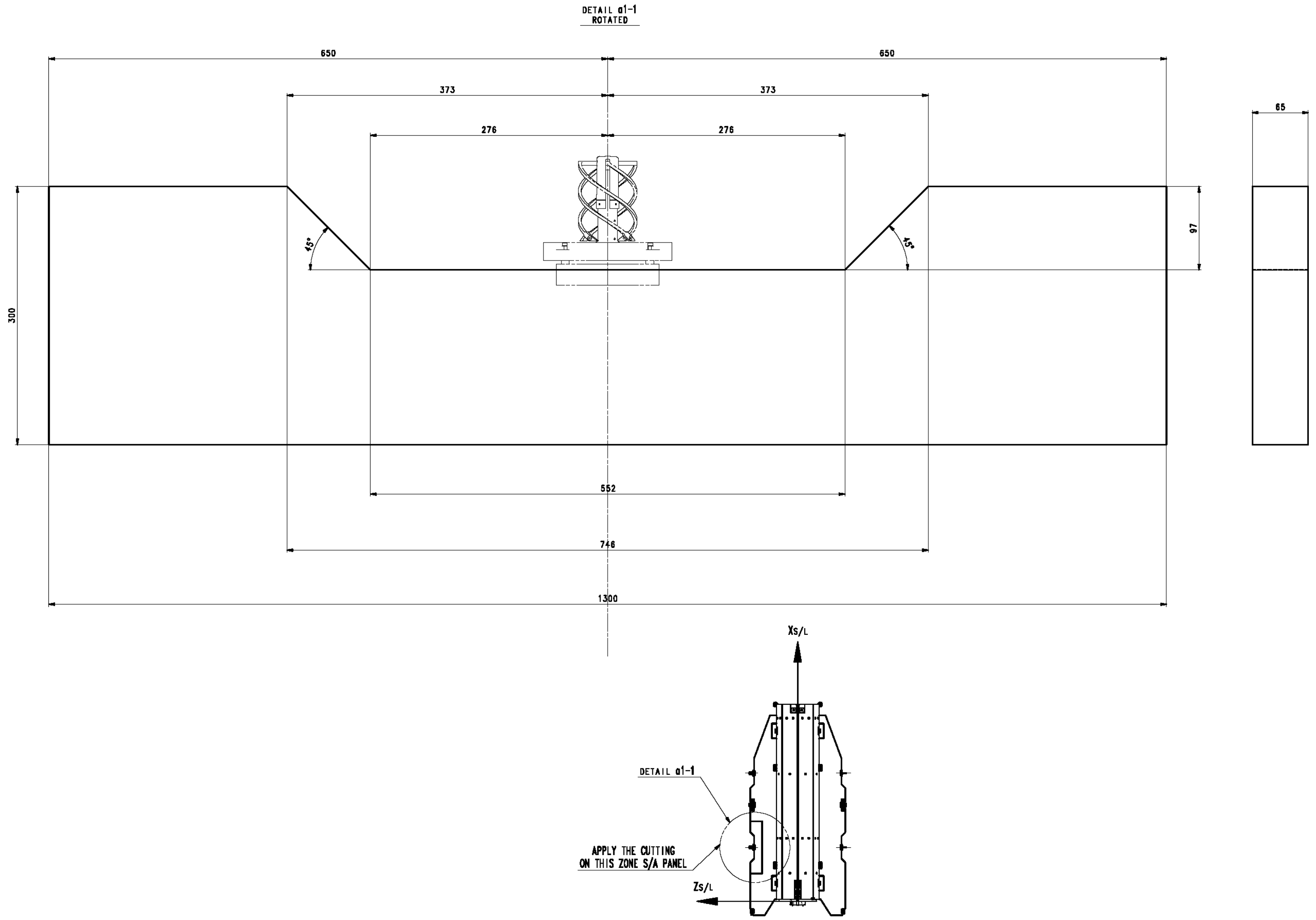
GOCE Mission - SSTI GPS Antennas



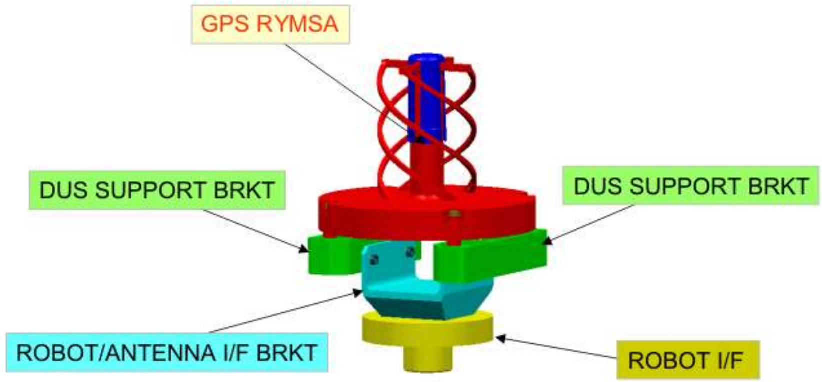
GOCE SSTI Antenna Calibration – Test Campaign

- Executed in April 2005 on the rooftop of the Institut für Erdmessung (IfE) of the University of Hannover
- Several experiments in order to characterize phase center variations as well as carrier to noise decrease as an „indicator" for the antenna gain behaviour
- Each antenna candidate was calibrated once mounted in stand-alone mode and once mounted on a simplified GOCE solar array wing model („mock-up")
- Differences of both set-ups reveal antenna near field effects
- Top surface of wing model is characterized by metallic honeycomb structure with cells of about 1-cm size
- Wing surface was also covered by flat metallic tape in order to evaluate influence of honeycomb structure

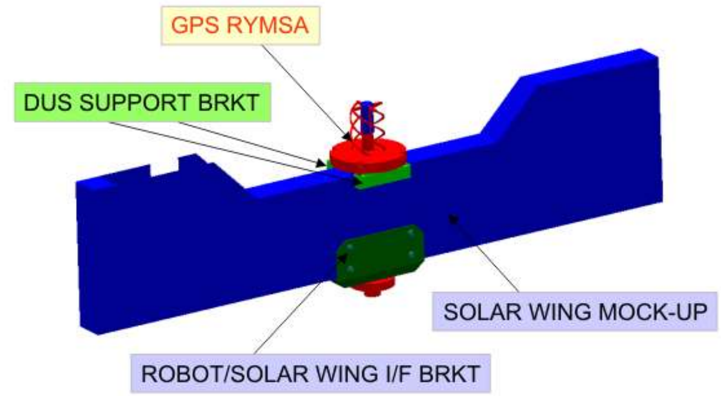
GOCE SSTI Antenna Calibration – Test Campaign



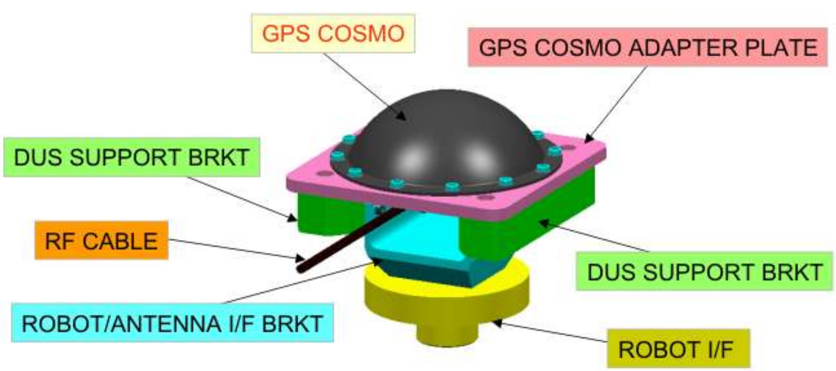
GOCE SSTI Antenna Calibration – Test Campaign



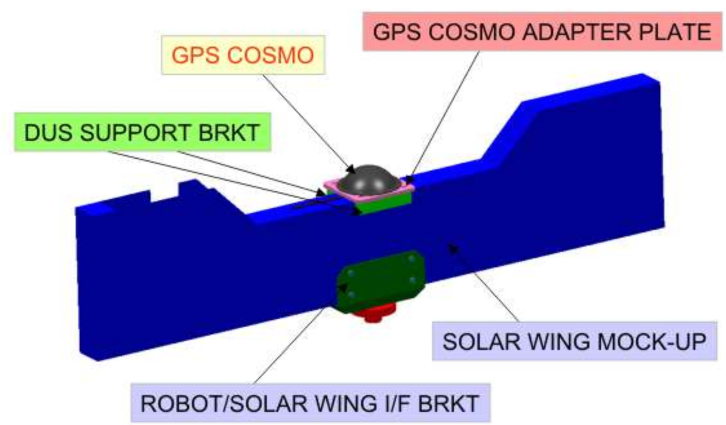
A) RYMSA QFH ANTENNA ON ROBOT INTERFACE



C) RYMSA QFH ANTENNA ON GOCE SOLAR WING MODEL



B) COSMO PATCH ANTENNA ON ROBOT INTERFACE



D) COSMO PATCH ANTENNA ON GOCE SOLAR WING MODEL

GOCE SSTI Antenna Calibration – Test Campaign

GOCE SSTI Antenna Calibration – Test Campaign

Requirements on phase center knowledge accuracy:

± 1.84 mm @ carrier signal L1
± 2.35 mm @ carrier signal L2

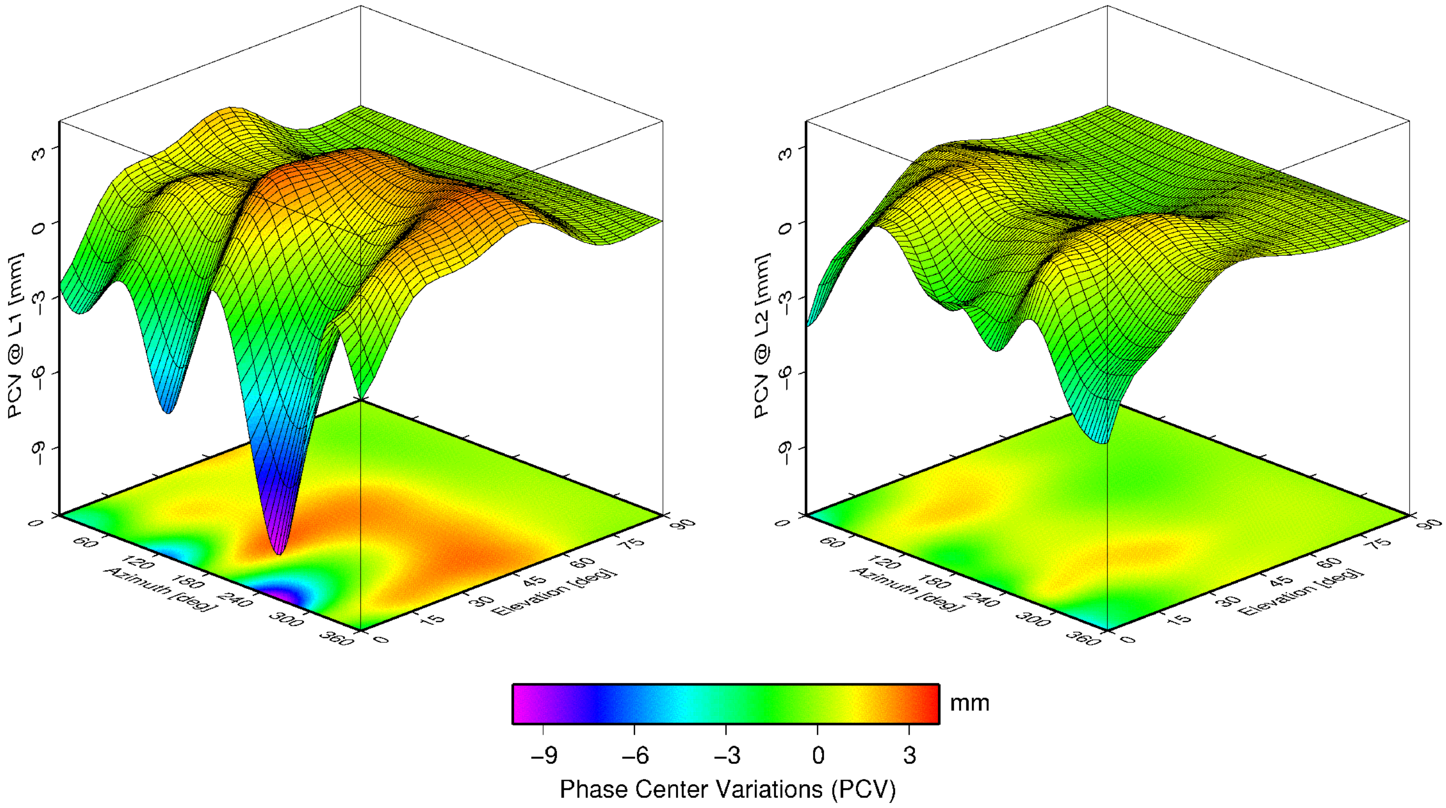
Requirements on maximum near field multipath error:

± 3.2 mm @ carrier signal L1
± 4.0 mm @ carrier signal L2

GOCE SSTI Antenna Calibration – Test Results

Characterization of RYMSA Quadrifilar Helix Antenna

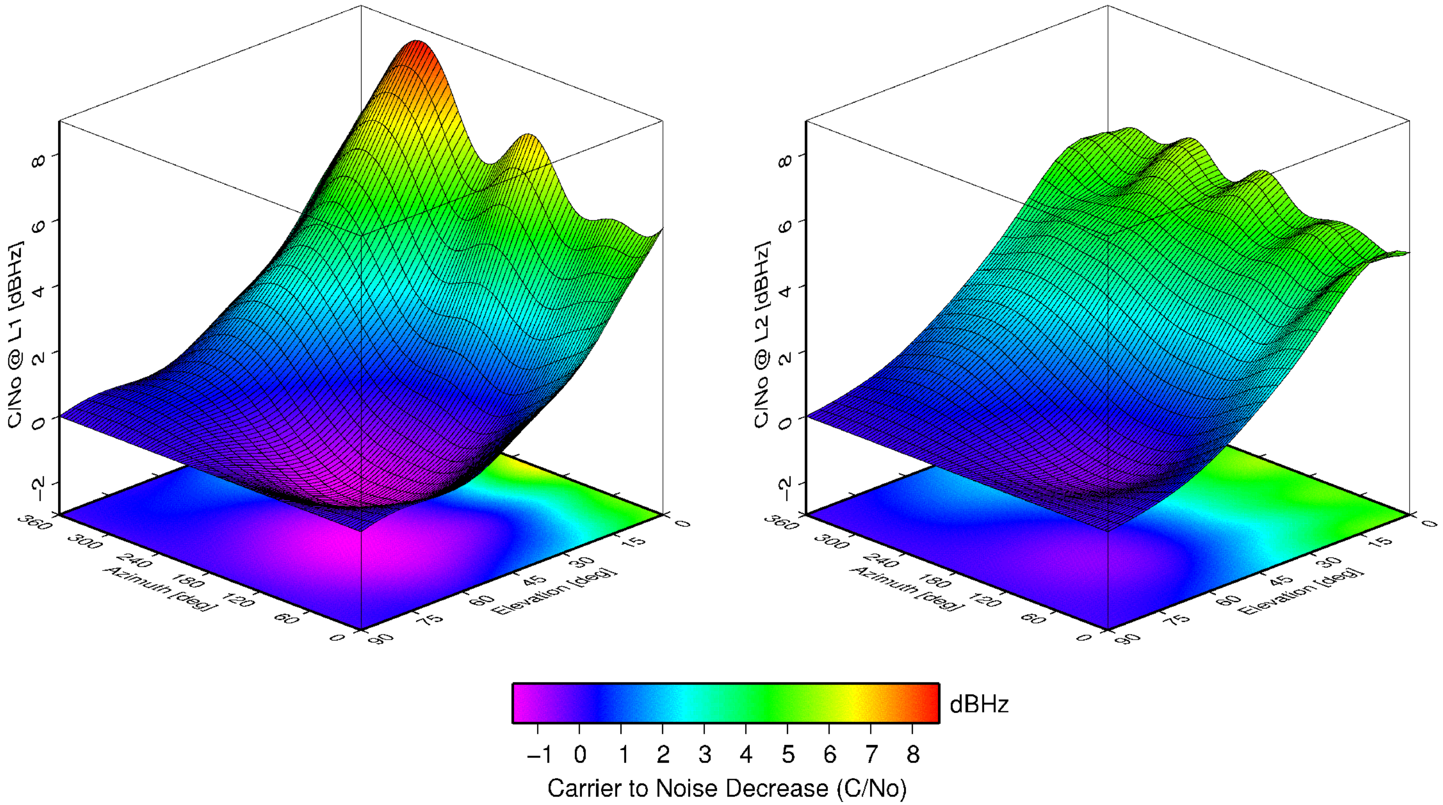
Phase Center Variations of Stand-alone Calibration



GOCE SSTI Antenna Calibration – Test Results

Characterization of RYMSA Quadrifilar Helix Antenna

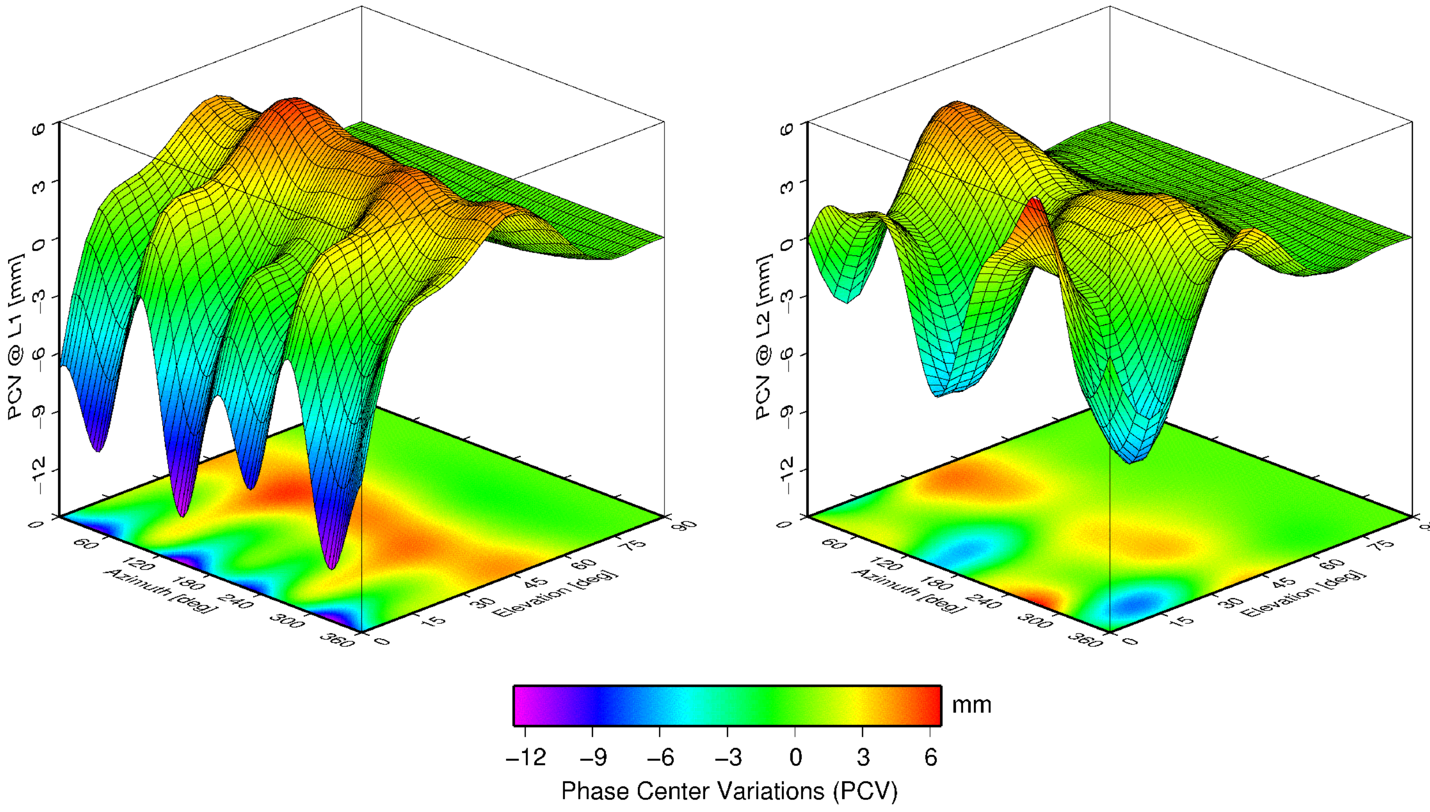
Carrier to Noise Decrease of Stand-alone Calibration



GOCE SSTI Antenna Calibration – Test Results

Characterization of COSMO Patch Antenna

Phase Center Variations of Stand-alone Calibration



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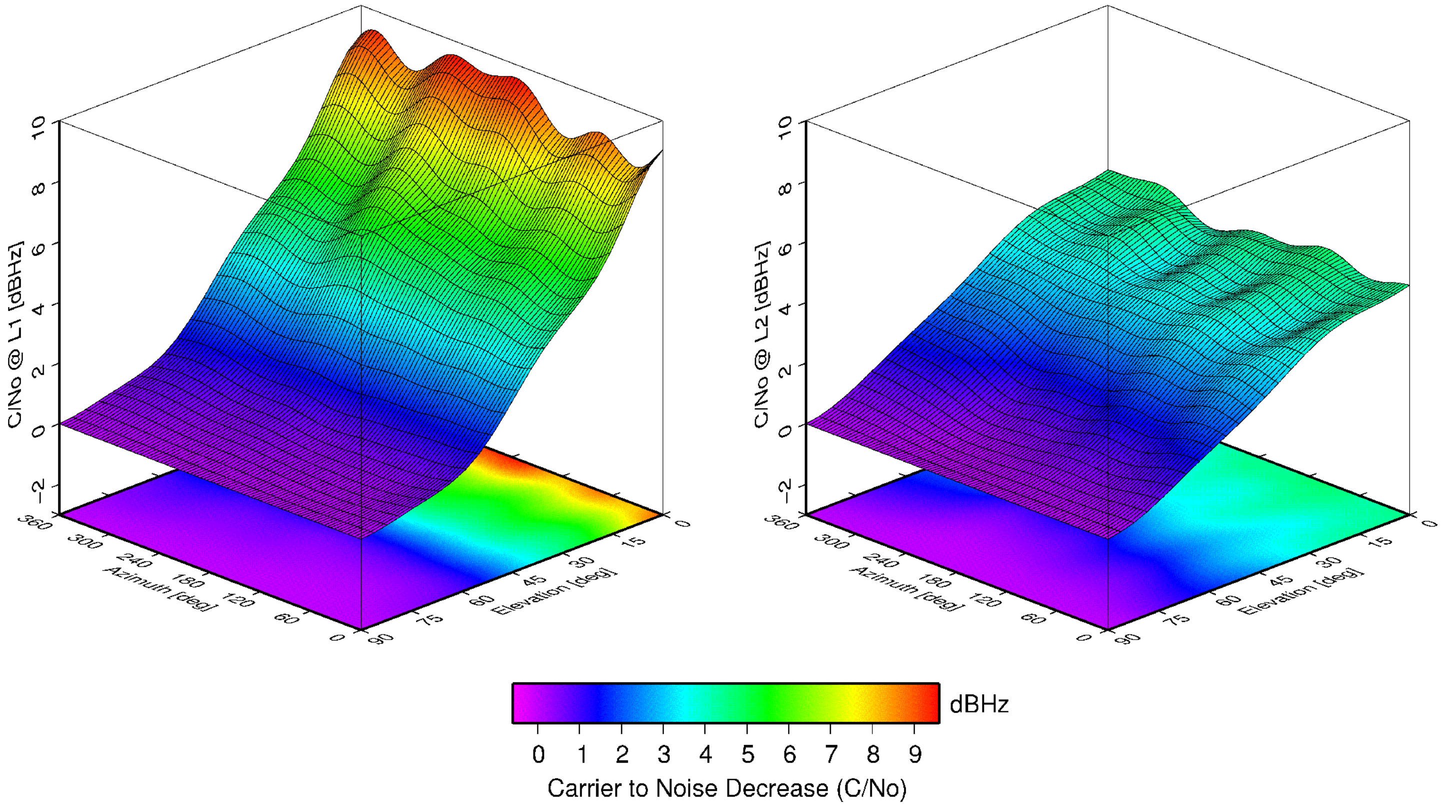
GOCE SSTI Antenna Calibration – Test Results

Characterization of COSMO Patch Antenna

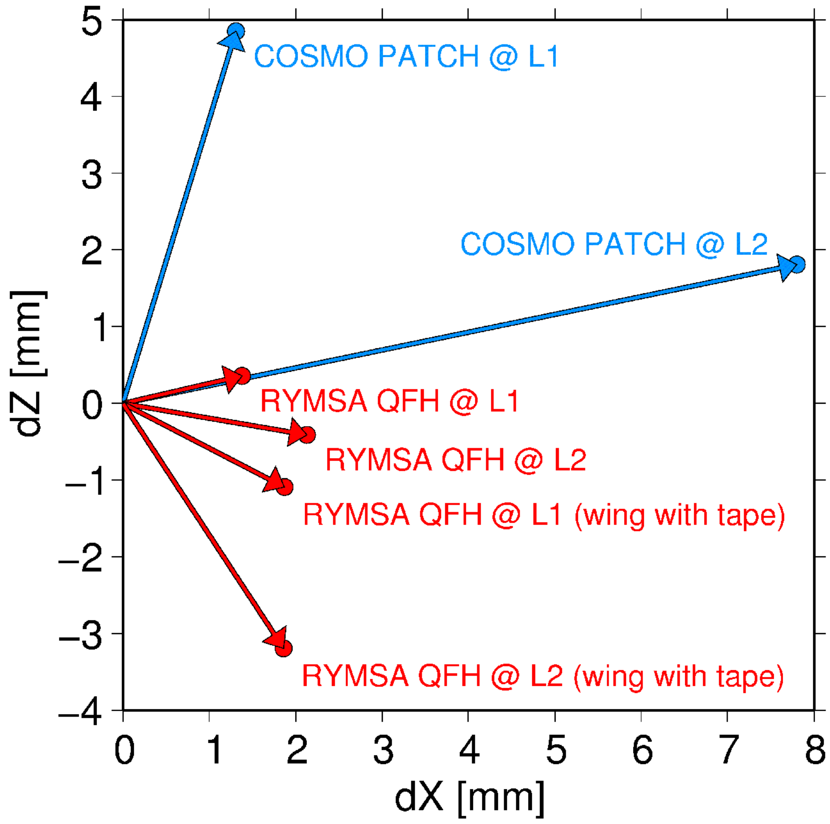
Carrier to Noise Decrease of Stand-alone Calibration



GOCE SSTI Antenna Calibration – Test Results

Influence of GOCE Solar Wing Model on Mean Phase Center

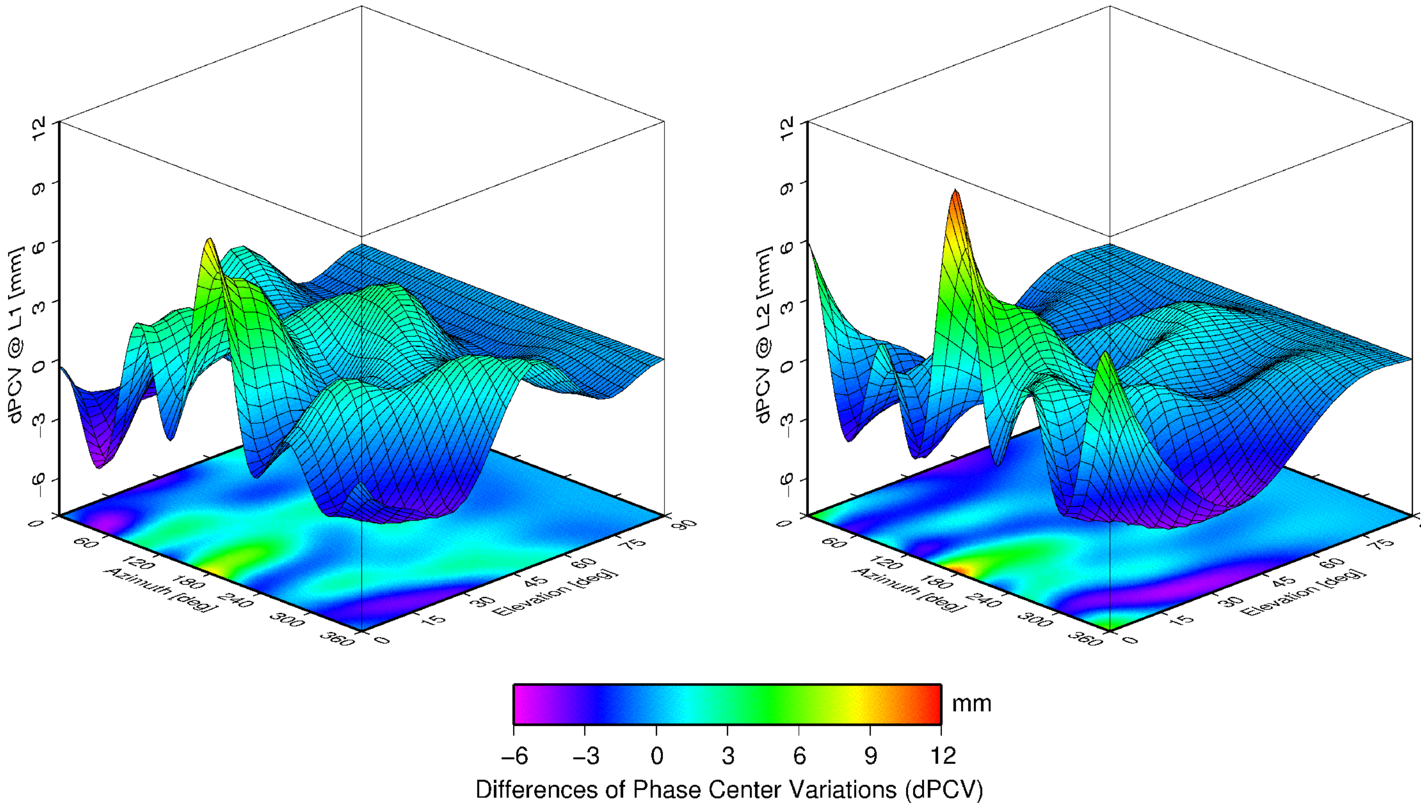
Differences of PCO between Stand-alone and Mock-up Calibration



GOCE SSTI Antenna Calibration – Test Results

Influence of GOCE Solar Wing Model on RYMSA QFH Antenna

Differences of PCV between Stand-alone and Mock-up Calibration



GOCE SSTI Antenna Calibration – Test Results

Influence of GOCE Solar Wing Model on RYMSA QFH Antenna

Differences of PCV between Stand-alone and Mock-up calibration

Carrier Signal L1			
Cut-off [deg]	Min [mm]	Max [mm]	Std [mm]
0°	-4.8	+9.0	±1.8
15°	-3.8	+5.6	±1.4

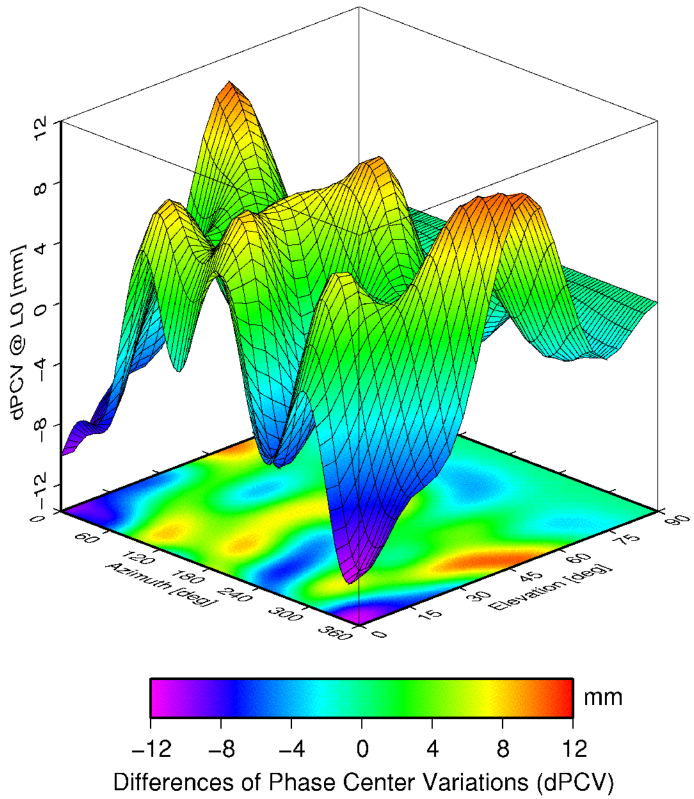
Carrier Signal L2			
Cut-off [deg]	Min [mm]	Max [mm]	Std [mm]
0°	-4.7	+11.4	±1.9
15°	-4.7	+4.7	±1.5

RYMSA QFH configuration *satisfies* requirements!

GOCE SSTI Antenna Calibration – Test Results

Influence of GOCE Solar Wing Model on RYMSA QFH Antenna

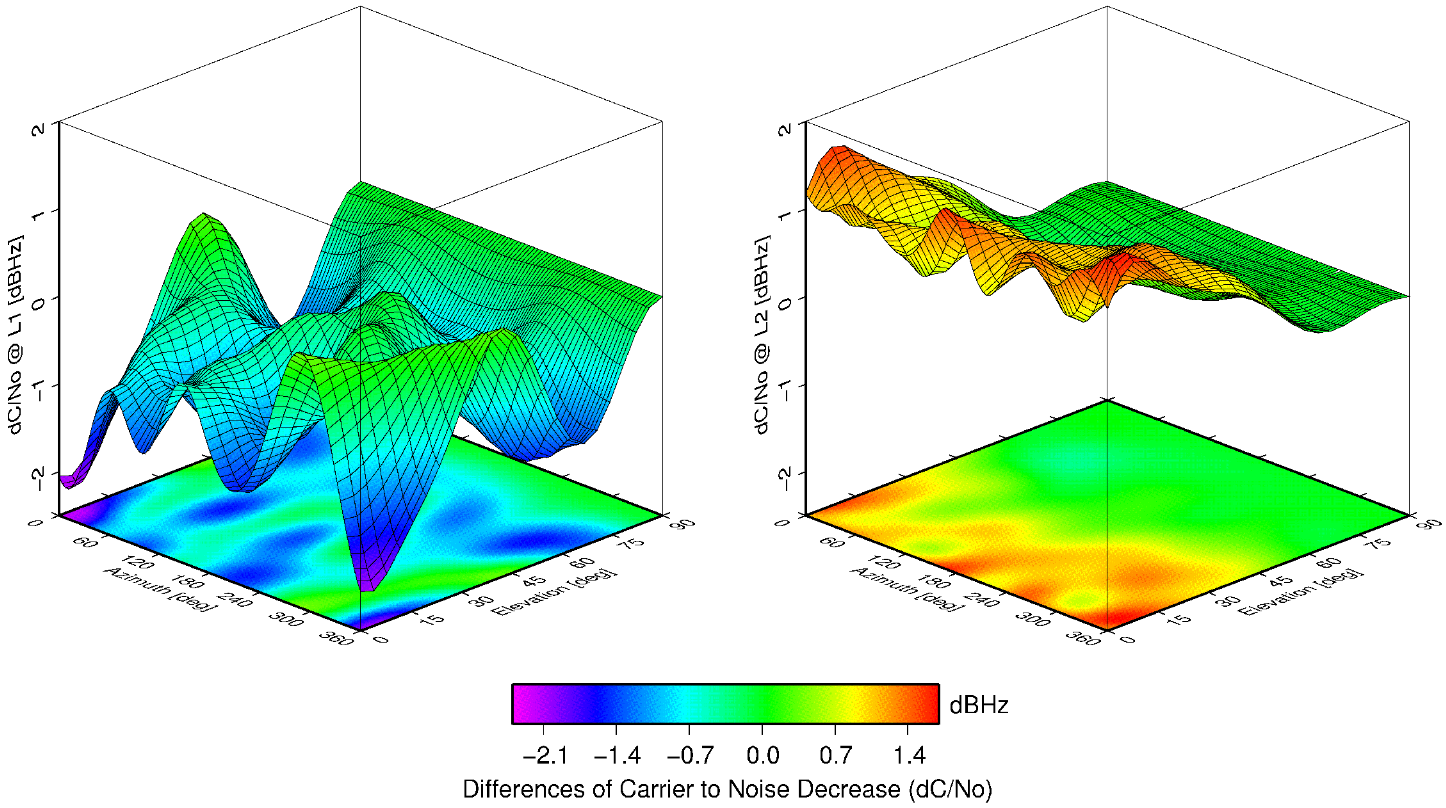
Differences of PCV in case of ionospheric-free linear combination L0



GOCE SSTI Antenna Calibration – Test Results

Influence of GOCE Solar Wing Model on RYMSA QFH Antenna

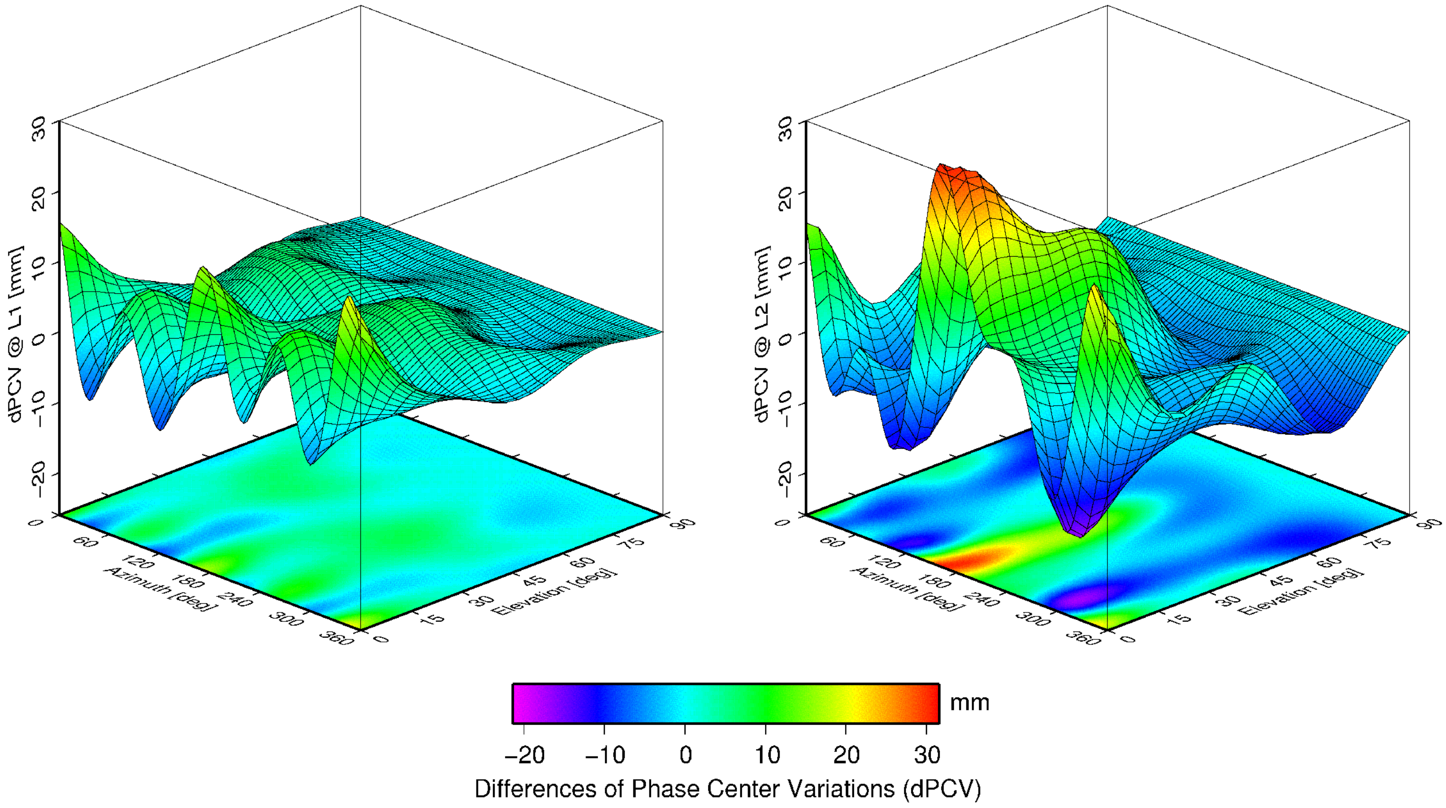
Differences of C/N_o between Stand-alone and Mock-up Calibration



GOCE SSTI Antenna Calibration – Test Results

Influence of GOCE Solar Wing Model on COSMO Patch Antenna

Differences of PCV between Stand-alone and Mock-up Calibration



GOCE SSTI Antenna Calibration – Test Results

Influence of GOCE Solar Wing Model on COSMO Patch Antenna

Differences of PCV between Stand-alone and Mock-up calibration

Carrier Signal L1			
Cut-off [deg]	Min [mm]	Max [mm]	Std [mm]
0°	-8.6	+20.9	±4.1
15°	-3.7	+8.0	±3.0

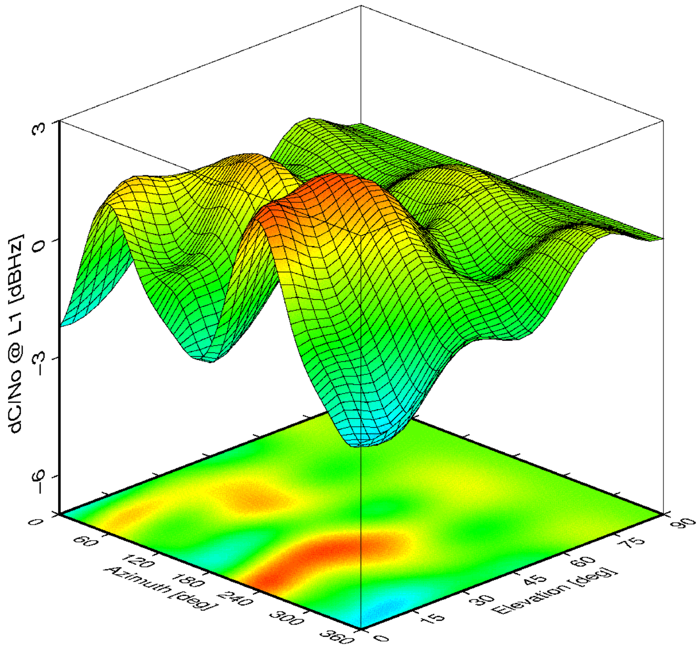
Carrier Signal L2			
Cut-off [deg]	Min [mm]	Max [mm]	Std [mm]
0°	-16.7	+31.2	±7.7
15°	-13.9	+24.1	±6.3

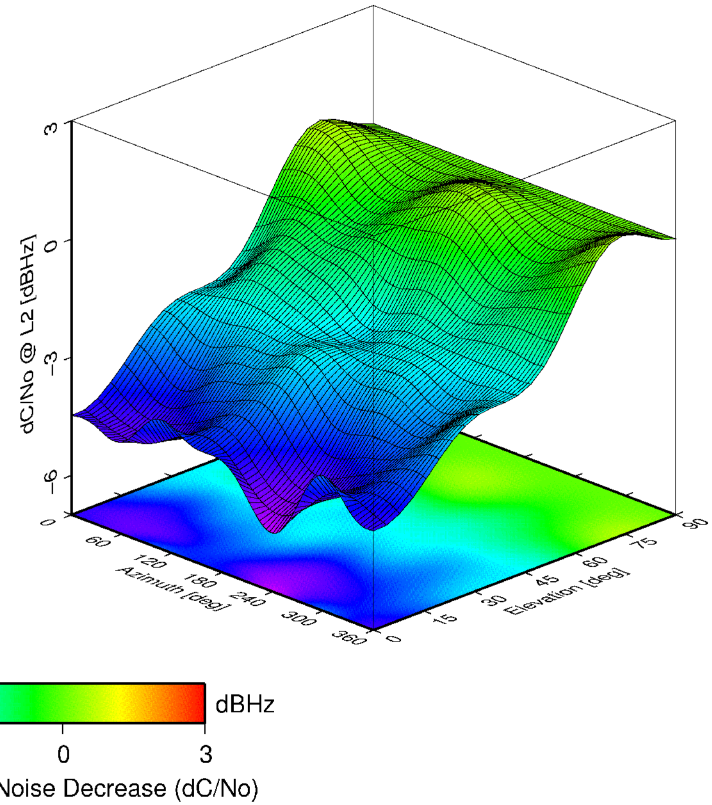
COSMO Patch configuration does *not satisfy* requirements!

GOCE SSTI Antenna Calibration – Test Results

Influence of GOCE Solar Wing Model on COSMO Patch Antenna

Differences of C/N_o between Stand-alone and Mock-up Calibration





Summary and Conclusions

- SSTI antenna calibration results are essential for achieving a 1-cm accuracy level for the GOCE POD application
- Test candidates already show PCV in azimuth and elevation of up to 1 cm when calibrated in stand-alone mode

  (→ Single mean phase center offset is consequently not sufficient for the characterization of the entire antenna)
- Presence of the spacecraft's solar array wing can cause additional near field effects like multipath of up to more than *3 cm* in phase and *5 dB-Hz* in amplitude
- As expected from theory, multipath induced phase errors tend to be stronger on carrier signal L2 than on L1
- Using a flat surface instead of rough honeycomb structure *does not* cause considerable changes in the results

Summary and Conclusions

- RYMSA QFH configuration *satisfies* GOCE SSTI requirements in terms of maximum near field multipath
- COSMO Patch configuration does *not satisfy* GOCE SSTI requirements in terms of maximum near field multipath
- Near field effects are amplified by a factor of 3 using the ionospheric-free linear combination L0, which is of particular relevance for the GOCE SSTI data processing
- Independent numerical electromagnetic simulations done at ESA-ESTEC confirm the Hannover test results