Validation of the Laboratory Calibration of Geodetic Antennas based on GPS Measurements

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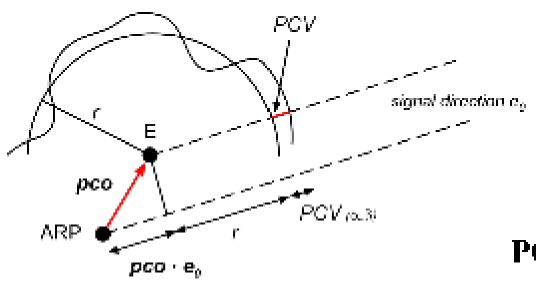
Antenna Model



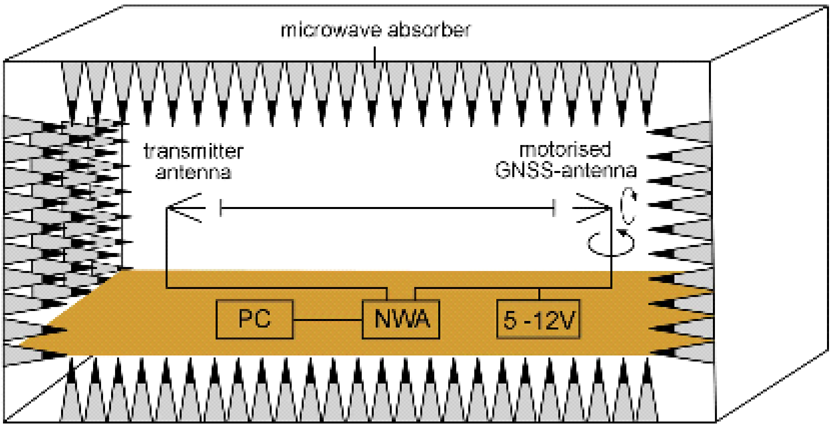
$$\mathbf{PCO} \cdot \mathbf{e}_0 + \mathbf{PCV}(\alpha, \beta)$$

The antenna effects:

1st: The phase measurements refer to the phase center E.
The position of the phase center is unknown.
→ First task of the calibration: find the phase center

2nd: The position of the phase center depends on the direction of the signal.
→ Second task of the calibration: determine the phase center variations

Calibration Setup



- NetworkAnalyser (NWA): measurement of the phase variations
- 2-axis-Positioner: rotation of the GNSS-antenna in order to change the direction of the incoming signal
- Absorber: Using absorbers in order to reduce multipath effects

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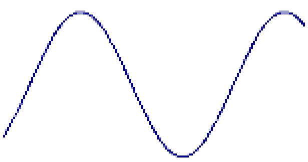
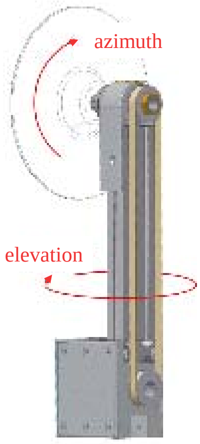
Idea of the laboratory procedure

1st	2nd	3rd
transmit a test signal (non-modulated signal)	rotate the antenna change signal direction	phase measurement





phase measurement

result

antenna pattern
(effect of PCO and PCV)

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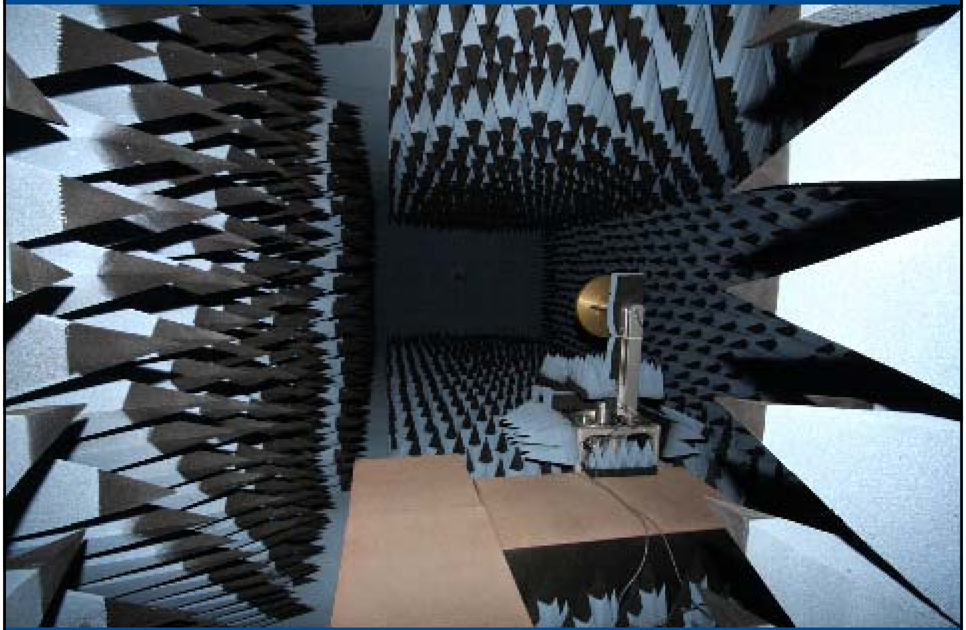
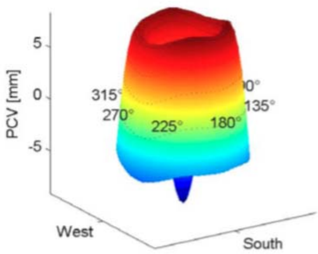
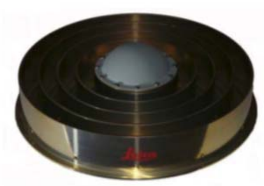
Absorber Room



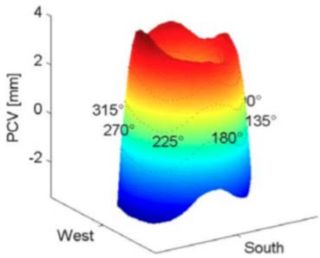
2 Examples





Typical GNSS-antenna properties:

- PCV values up to several mm
- Elevation: large elevation-dependent effects
- Azimuth: Often a very symmetrical characteristic



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Requirements

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GNSS observation accuracy: σ = 0.3mm – x cm (zenith to horizon)

⇩ antenna effects should be small in comparison to other errors

Required calibration accuracy: σ = 0.1mm – 1mm (zenith to horizon)

Repeatability of the calibration results (Precision):

σ = 0.1 – 0.2 mm (empirical standard deviation)

Total error budget (including systematic effects, accuracy)

- Comparison with field calibration procedures (e.g. Geo++)
- GNSS-measurements in small GNSS-test-sites

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Test-Campaign 2009

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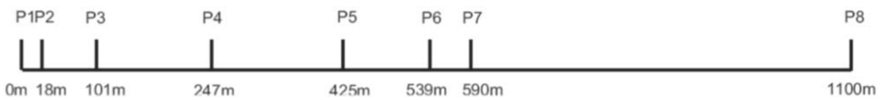
Description of the test-site



3 antenna types: LEICA AT504GG, Trimble Zephyr Geodetic (Type 1& 2)
9 individual calibrated antennas (3 of each antenna type)
8 pillars: distances between 18 and 1100m
2 different near-field-situations
4 to 10 hrs observation-time
122 measured baselines

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Test-Campaign 2009

Comparison: GPS (height-component) and precise levelling

(German Combined Quasi-Geoid-Model 2005 enables conversion between ellipsoidal heights (ETRS89) and normal heights)

Direct levelling:

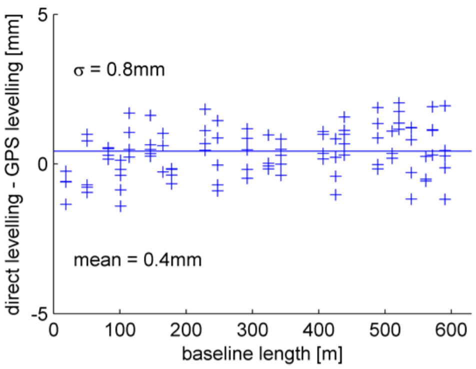
Accuracy is much better than σ = 1mm

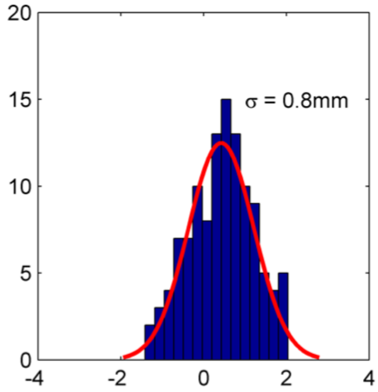
→ Reference solution for GPS

GPS-Differences from the reference solution
- are the results of the GPS uncertainties (including antenna effects)
- are indicators for the calibration accuracy

Accuracy of the height determination

- Frequency: L1
- no effects depending on the baseline length
- accuracy of s = 0.8mm
- no visible systematic effects





Accuracy of the height determination

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• Frequency: L2
• significant effects in case of one antenna/near-field combination

Red BL: one antenna with mounting B
Green BL: both antennas with mounting B
Blue BL: other combinations

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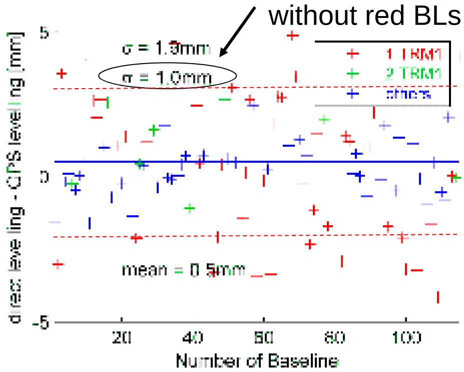
without red BLs



Setup A   Setup B

Accuracy of the height determination

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Effects:
• visible at different pillars → no multipath
• visible for each of the three TRM1 antennas → no antenna defect
• not visible for L1 → direct levelling is correct
• not visible in case of Setup A → antenna calibration is correct
→ „Near-field effects produce the observed height changes“

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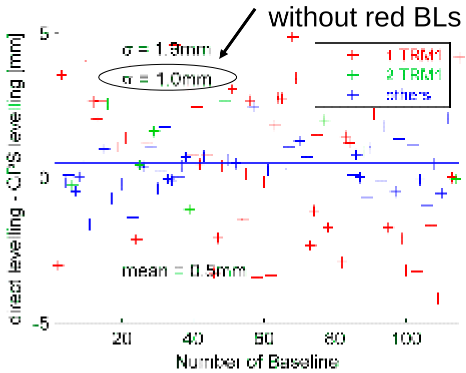
without red BLs



Setup A   Setup B

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Results

The remaining antenna effect is less than 1mm, because:

Empirical standard deviations for height differences determination with GPS

σ_{L1} = 0.8mm
σ_{L2} = 1.0mm
σ_{L0} = 1.6mm

→ σ = 1mm accuracy level is possible for the height-component if

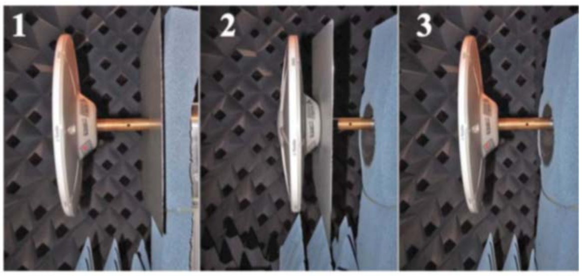
- individual antenna corrections are available
- the observation conditions are good
- near-field effects are well controlled

How to analyse near-field situations?
- by GPS-test measurements as presented here (very expensive)
- by calibrations with different antenna setups
  (effects of a tribrach, a radome, the distance to a pillar...)

Results and Summary

For example, tests with a metal plate can be used
- to simulate a pillar surface
- to show the antenna behaviour when varying the position of the plate

→ The analysis of a near-field situation is possible.



2 Results:
- An σ = 1mm accuracy level is possible for the height-component
- The calibration results are valid.

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Thank You!

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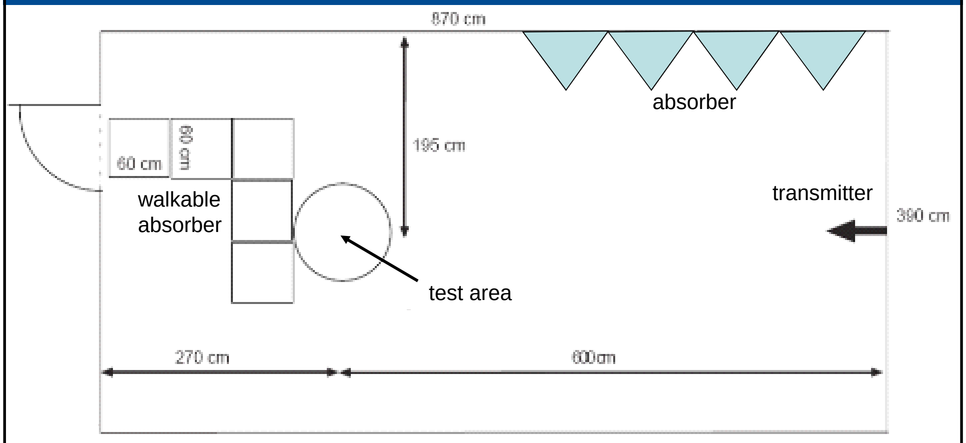

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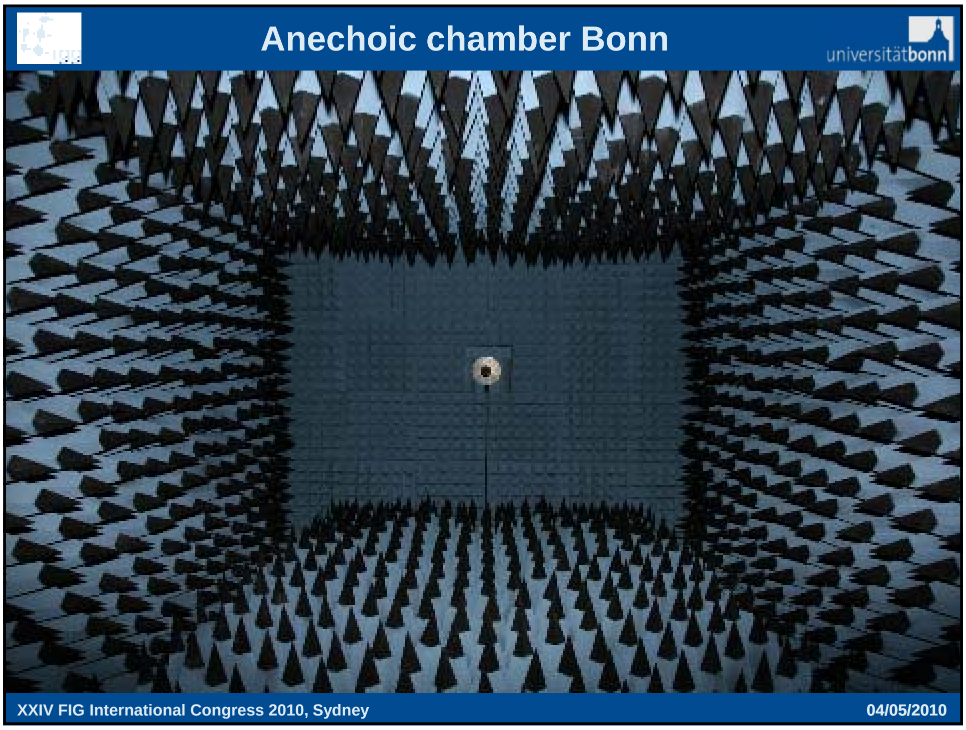
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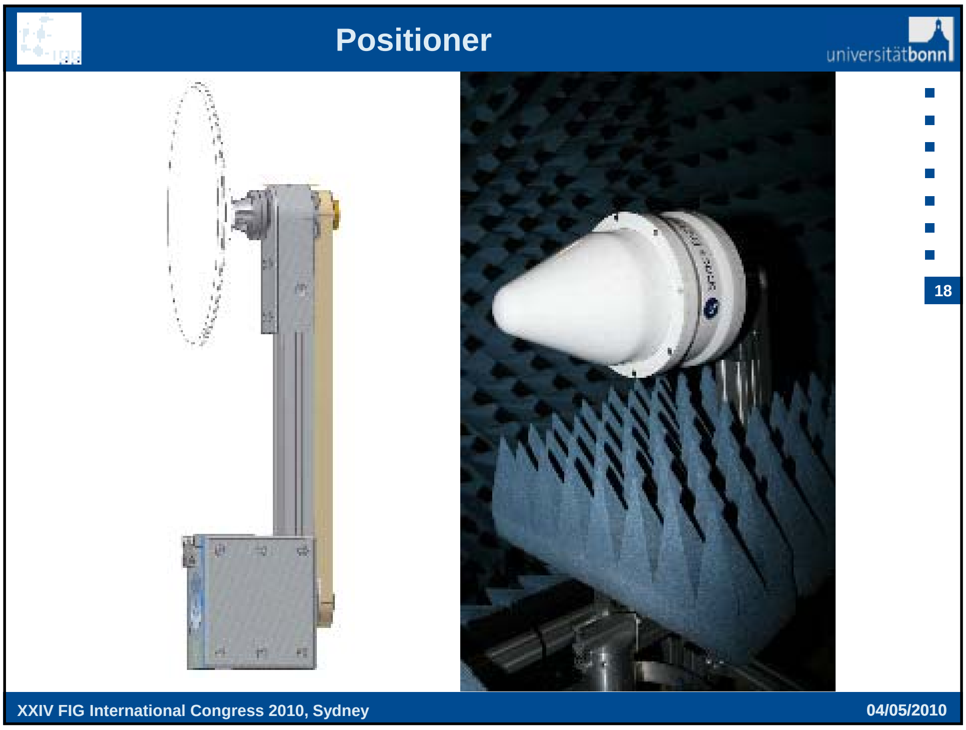
Positioner
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Accuracy of the height determination

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- Frequency: ionospheric free linear combination L0
- significant effects in combination with one antenna type

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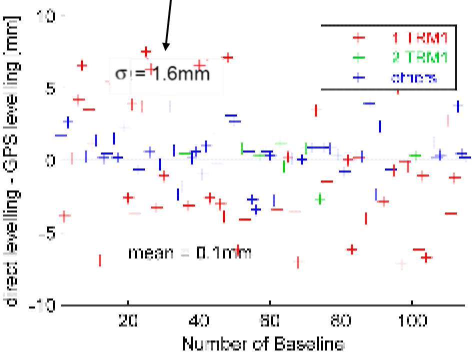
standard deviation
without red Baselines



Setup A

Setup B

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