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

Philipp Zeimetz, Heiner Kuhlmann
Institute of Geodesy and Geoinformation
University of Bonn

Antenna Model

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

Idea of the laboratory procedure

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

result

phase measurement

antenna pattern
(effect of PCO and PCV)
2 Examples

Typical GNSS-antenna properties:
- PCV values up to several mm
- Elevation: large elevation-dependent effects
- Azimuth: Often a very symmetrical characteristic
Requirements

GNSS observation accuracy: $\sigma = 0.3\text{mm} - x \text{ cm}$ (zenith to horizon)

antenna effects should be small in comparison to other errors

Required calibration accuracy: $\sigma = 0.1\text{mm} - 1\text{mm}$ (zenith to horizon)

Repeatability of the calibration results (Precision):

$\sigma = 0.1 - 0.2\text{ mm}$ (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

Test-Campaign 2009

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
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 $\sigma = 1\text{mm}$
→ 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 $s = 0.8\text{mm}$
- no visible systematic effects
Accuracy of the height determination

- 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

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”
Results

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

Empirical standard deviations

\[ \sigma_{L1} = 0.8\text{mm} \]

for height differences

\[ \sigma_{L2} = 1.0\text{mm} \]

determination with GPS

\[ \sigma_{L0} = 1.6\text{mm} \]

\[ \Rightarrow \sigma = 1\text{mm} \text{ accuracy level is possible for the height-component if} \]
- 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
  \[ \Rightarrow \text{The analysis of a near-field situation is possible.} \]

2 Results:
- An \( \sigma = 1\text{mm} \) accuracy level is possible for the height-component
- The calibration results are valid.
Thank You!

Anechoic chamber Bonn

- **Walkable absorber**
- **Test area**
- **Absorber**
- **Transmitter**

Dimensions:
- Width: 270 cm
- Length: 600 cm
- Height: 195 cm
- Height of absorber: 870 cm

XXIV FIG International Congress 2010, Sydney

04/05/2010
Accuracy of the height determination

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

Standard deviation without red Baselines

Setup A

Setup B

XXIV FIG International Congress 2010, Sydney
04/05/2010