New anechoic chamber results and comparison with field and robot techniques

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<table>
<thead>
<tr>
<th>Institution</th>
<th>Calibration Method</th>
<th>used Software</th>
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<tbody>
<tr>
<td>University of Hannover</td>
<td>robot – absolute</td>
<td>GNPCV</td>
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<td>Geo++ Garbsen</td>
<td>robot – absolute</td>
<td>GNPCV</td>
</tr>
<tr>
<td>State Survey... Niedersachsen</td>
<td>relative field calibration</td>
<td>WaSoft/Kalib</td>
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<td>University of Bonn</td>
<td>relative field calibration</td>
<td>Bernese GPS Software</td>
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<tr>
<td>University of Bonn</td>
<td>chamber test</td>
<td>not available in spring ’02</td>
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Motivation: get better insight into the performance of different calibration methods by calibration of a set of identical antennas at different institutions
German bench mark test 2002

Results for Leica AT303

(Schmid et al. 2002)
German bench mark test 2002

Results for Leica AT303
(elevation-dependent PCV)

the robot measurements (IfE and Geo++) agree on the level of 1mm
the standard field calibrations display larger variations of 2 mm (L1) and 4mm (L2)

? Confirmation of absolute results by an independent technique and identical antenna ?
Largest anechoic chamber in Europe

- 41 x 16 x 14 m
- absorbing material suited for frequencies > 0.5 GHz
Antenna measurement setup (pilot phase) in the Greding chamber

transmitting antenna

L1/L2

s ≈ 18 m

test antenna

transmitted signal

GDI-bus

network analyser

received GPS signal

control of the motion of antenna mount
dr(α, β) = a · r₀ + λ · dφ(α, β)

with PCO: \( a(φ) = (a_x, a_y, a_z) \)

Two-Step Processing

1. Estimation of mean phase center offset (PCO) a with respect to the ARP:
   \[ \sum dφ(α, β)^2 = \text{Min!} \]

2. PCV directly (no fit required!)
Estimation of PCO and PVC

geometric situation within the Chamber setup (pilot phase)

3a. Definition of a model function for the PCV
    e.g.: harmonic function \( \text{dr}(\beta) = \sum (a_k \cos \beta + b_k \sin \beta) \), \( k = 0, \ldots, 3 \), or 5

3b. Reprocessing of step 1 and re-estimation of normalized RMS

to get information about the scatter:

\[ \text{dr} = a_y \sin \beta - a_z \cos \beta \]
\[ \Rightarrow a_y, a_z \]

\[ \text{dr} = a_x \cos(\alpha) + a_y \sin(\alpha) \]
\[ = a_x \cos(\alpha) - a_y \sin(\alpha) \]
\[ \Rightarrow a_x, a_z \]
## Tested Antenna Types

<table>
<thead>
<tr>
<th>Antenna Type</th>
<th>IGS-Code</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trimble compact</td>
<td>TRM22020.00+GP</td>
<td>with groundplane</td>
</tr>
<tr>
<td>Trimble Zephyr geodetic</td>
<td>TRM41249.00</td>
<td>stealth groundplane (anti-reflex)</td>
</tr>
<tr>
<td>Trimble geodetic</td>
<td>TRM14532.00</td>
<td></td>
</tr>
<tr>
<td>Leica AT 504</td>
<td>LEIAT504</td>
<td>Dorne Margolin Antenna with chokerings (designed after D/M T)</td>
</tr>
<tr>
<td>Leica AT 303</td>
<td>LEIAT303_LEIC</td>
<td>micropuls antenna with chokerings (identical to AT503)</td>
</tr>
</tbody>
</table>
Phase pattern L1 (Elevation - Dependence)

measured PCV values, no fitting function!

- Leica AT303
- Leica AT504
- Tr Geod
- Tr Zephyr
- Tr Compact
Phase pattern L2 (Elevation - Dependence)

Asymmetry
Phase pattern (Azimuth - Dependence)
Elevation 12.5°

Leica AT303  Leica AT504  Tr Geod  Tr Zephyr

L1

L2
Normalized RMS of PCV (mm) gives information about the scatter after implementation of a harmonic function.

**Normalized RMS of PCV**

- Leica AT504
- Leica AT303
- TRM Comp +GP
- TRM Geodetic
- TRM Zephyr

Normalized RMS of PCV gives information about the scatter after implementation of a harmonic function.

**Normalized RMS of PCV**

- Leica AT504
- Leica AT303
- TRM Comp +GP
- TRM Geodetic
- TRM Zephyr

Normalized RMS of PCV gives information about the scatter after implementation of a harmonic function.
Comparison of Phase pattern L1 (Elevation - Dependence)

Chamber (Greding) - absolut field calibration with robot (GEO++, Hannover)

Leica AT 303 (identical antenna)
Comparison of Phase pattern L2 (Elevation - Dependence)

Chamber (Greding) - absolut field calibration with robot (GEO++, Hannover)

Leica AT 303 (identical antenna)
Comparison of Phase pattern
(Azimuth - Dependence, Elevation 12.5°)

Chamber (Greding) - absolut field calibration with robot
(GEO++, Hannover)

Leica AT 303 (identical antenna)
Comparison of the Offsets between Chamber (Greding) and robot (GEO++)

Residual-Offsets from best-fit between both patterns

\[ \sigma_{\text{antcal}}^2 = \sigma_{\text{PCO/PCV}}^2 + \sigma_D^2 \]

together with definition of ARP
Comparison of PCV between Chamber (Greding) and robot (GEO++)

- **Elevation-dependent**
  - sig0(Ele-comp) L1
  - sig0(Ele-comp) L2

- **Azimuth-dependent**
  - sig0(Az-comp) L1
  - sig0(Az-comp) L2

Scatter between two different PCV patterns after best-fit

**Not available**
High potential for (receiver) antenna calibration in the anechoic chamber

• Absolute calibrations from chamber measurements and robot agree on the 1 mm-level (identical antenna)

• Significant variations in quality between antennas of different design

• Anechoic chamber and robot permit homogenous distribution of observations and quality of the PCV results with regard to the antenna hemisphere

• Direct representation of the measured PCV values (no fitting function needed)
  => possibility to study the characteristics of the patterns in detail

Future: Develop operational procedure for chamber measurements by improved control of the motion of antenna mount
  => measure the whole hemisphere in an automatic mode