IGS AC Workshop 2019

April 15 – April 17, 2019
Potsdam, Germany

GNSS antenna calibration
in the anechoic chamber

Florian Zimmermann
16.04.2019
Key points and questions

- Brief description of the calibration procedure
- Precision/accuracy of individual chamber calibrations?
- Precision/accuracy of chamber type-mean patterns?
- Consistency between chamber and robot calibrations?
- Calibration patterns for whole frequency range?
The anechoic chamber

- Designed and established during PhD of Philipp Zeimetz (2010)
  'Zur Entwicklung und Bewertung der absoluten GNSS-Antennenkalibrierung im HF-Labor'
  DGK-Reihe C, Nr. 682, München 2012

- Operated in cooperation with District Government Cologne (Geobasis NRW)
  Responsible for parts of the German SAPOS network (www.sapos.de)

Currently at the IGG...

- one member of technical staff in charge of antenna calibrations
  (amongst other things)
- no member of scientific staff involved in chamber calibrations
- no scientific research in the field of antenna calibration
The anechoic chamber

Chamber calibrations used by IGG for:

– High-precision static and kinematic short baseline applications (<1km)
  – Accuracy requirements at a few millimeters to submillimeter range

– Experimental calibrations

Chamber calibrations used by District Government Cologne for:

– SAPOS permanent station network
  – Accuracy requirements: 5mm horizontal, 8mm vertical
The anechoic chamber
The anechoic chamber

- Transmitting antenna (0.9GHz-1.6GHz)
- Absorbing material
- GNSS antenna
- Robotic positioner
**Calibration procedure**

- **Network analyzer (NWA)** performs frequency sweep between 1.15GHz and 1.65GHz (sinusoidal signal)

- **Signal is attenuated** by 30-40dB to avoid an overload of the amplifier in the receiving antenna

- **NWA measures phase shift** of received signal at every antenna position

- **Antenna is rotated** in 5 degree steps in elevation and azimuth
  1. Elevation 0° → azimuth 0°...360°
  2. Elevation 5° → azimuth 0°...360°
  3. ...
 Calibration procedure

- **sphere fit** to NWA measurements
  - center of sphere defines **PCO**
  - residuals to fitted sphere define **PCV**
**Pros:**

- GNSS frequency spectrum completely available
- Fast calibration procedure  
  \[ \text{duration} \approx 1-2 \text{ hours} \]
- Not influenced by atmospheric effects or satellite errors
- 'Controlled' measurement environment
Calibration procedure

Cons:

- Assumption of a parallel wave front
  - short distance between transmitting and receiving antenna (≈ 6.5m)
  - theoretically fulfilled

- absorbers perfectly working?
  - no influence of reflected signals?
  - effectivity depends on incidence angle

- Identification of systematic errors
  - extremely difficult

- common 'near-field' problem
Key points and questions

– Brief description of the calibration procedure

– Precision/accuracy of individual chamber calibrations?

– Precision/accuracy of chamber type-mean patterns?

– Consistency between chamber and robot calibrations?

– Calibration patterns for whole frequency range?
How accurate/precise are chamber calibration patterns?

Antenna: TRM55971.00_NONE (24 repeated calibrations)

Analysis:
– Determination of PCC (phase center corrections) for each calibration pattern

\[ PCC(\alpha, \beta) = PCO \cdot e_0(\alpha, \beta) + PCV(\alpha, \beta) \]

– Determination of standard deviations \( \sigma_{PCC}(\alpha, \beta) \)

– Results for frequencies
  – G01 (1575.42 MHz) \( \rightarrow \) identical to E01/S01/J01
  – G02 (1227.60 MHz) \( \rightarrow \) identical to J02
  – G05 (1176.45 MHz) \( \rightarrow \) identical to E5a/S05/J05/I05
Precision of calibration pattern
(TRM55971.00.NONE - 24 calibrations)

G01 (1575.42 MHz)

G02 (1227.60 MHz)

G05 (1176.45 MHz)

F. Zimmermann - IGG chamber calibration - IGS AC Workshop 2019
Precision of chamber calibration type-mean patterns?

Antenna: LEIAR25.R4_LEIT (34 calibrations)

Analysis:
– Determination of PCC (phase center corrections) for each calibration pattern

– Determination of type-mean calibration pattern

– Determination of differences to type-mean pattern

– Analysis of standard deviations $\sigma_{PCC}(\alpha, \beta)$ of differences
Precision of chamber type-mean patterns
(LEIAR25.R4_LEIT - 34 calibrations)

G01 (1575.42 MHz)

G02 (1227.60 MHz)

G05 (1176.45 MHz)
Consistency between robot and chamber calibration patterns?

Antenna: TRM55971.00_NONE

Individual antenna calibrations available from
- Geo++ (robot)
- IfE Hannover (robot)
- IGG (chamber)

Analysis:
- Determination of PCCs for every calibration pattern
- Determination of PCC differences $\Delta PCC(\alpha, \beta)$
- Results for frequencies
  - G01 (1575.42 MHz)
  - G02 (1227.60 MHz)
robot (Geo++) vs. robot (IfE)

(TRM55971.00_NONE)

G01 (1575.42 MHz)

G02 (1227.60 MHz)
robot (Geo++) vs. chamber (IGG)
(TRM55971.00_NONE)

**G01 (1575.42 MHz)**

robot (Geo++) vs. chamber (IGG)

- $\Delta PCC$ for every azimuth direction
- Mean $\Delta PCC$

**G02 (1227.60 MHz)**

robot (Geo++) vs. chamber (IGG)

- $\Delta PCC$ for every azimuth direction
- Mean $\Delta PCC$
IGS (igs14.atx) vs. IGG type-mean pattern (LEIAR25.R4_LEIT)

**G01 (1575.42 MHz)**

- **Differences to IGS type-mean**
  - ΔPCC for every azimuth direction
  - Mean ΔPCC

**G02 (1227.60 MHz)**

- **Differences to IGS type-mean**
  - ΔPCC for every azimuth direction
  - Mean ΔPCC

F. Zimmermann - IGG chamber calibration - IGS AC Workshop 2019

April 16, 2019
How do the calibration patterns differ over the frequency range?

Antennas: LEIAR25.R4_LEIT and TRM55971.00_NONE

Analysis:
- **NOAZI patterns** for all GPS, GLONASS and Galileo frequencies
- Determination of PCCs
NOAZI for all frequencies
(LEIAR25.R4_LEIT)

absolute values

- G05/E5a (1176.45 MHz)
- E5b (1207.140 MHz)
- E6 (1278.75 MHz)
- E5a+b (1191.795 MHz)
- G02 (1227.60 MHz)
- G01/E1 (1575.42 MHz)
- R03 (1202.025 MHz)
- R02 (1246.00 MHz)
- R01 (1602.00 MHz)

NOAZI PCC [mm] vs. Elevation [°]

LEIAR25.R4_LEIT

TRM55971.00_NONE
NOAZI for all frequencies (LEIAR25.R4_LEIT)

→ after removing mean value at each elevation angle

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>1176.45 MHz</td>
<td>G05/E5a</td>
</tr>
<tr>
<td>1207.140 MHz</td>
<td>E5b</td>
</tr>
<tr>
<td>1278.75 MHz</td>
<td>E6</td>
</tr>
<tr>
<td>1191.795 MHz</td>
<td>E5a+b</td>
</tr>
<tr>
<td>1227.60 MHz</td>
<td>G02</td>
</tr>
<tr>
<td>1575.42 MHz</td>
<td>G01/E1</td>
</tr>
<tr>
<td>1202.025 MHz</td>
<td>R03</td>
</tr>
<tr>
<td>1246.00 MHz</td>
<td>R02</td>
</tr>
<tr>
<td>1602.00 MHz</td>
<td>R01</td>
</tr>
</tbody>
</table>

LEIAR25.R4_LEIT

TRM55971.00NONE
Precision of chamber calibrations (standard deviations)?
- Individual patterns: 0.3mm to 0.5/0.6mm
- Type-mean patterns: 0.5mm to 1.3mm
- Slightly decreasing for lower elevations and lower frequencies

Consistency between chamber and robot calibrations (differences)?
- Individual patterns: -3.0mm to 3.0mm
- Type-mean patterns: -2.5mm to 5.0mm
- Systematic effects apparent
- Biggest differences at lower elevations

Calibration patterns for whole frequency range (PCC values)?
- NOAZI patterns differ in the range of -6.0mm to 5.0mm
- Differences in lower and upper L-Band smaller
Thank you!

M.Sc. Florian Zimmermann
Institute of Geodesy and Geoinformation
University of Bonn
zimmermann@igg.uni-bonn.de
How accurate/precise are chamber calibration patterns?

Antenna: LEIAT504GG_NONE (8 repeated calibrations)

Analysis:

– Determination of PCC (phase center corrections) for each antenna and each calibration pattern
\[
PCC (\alpha, \beta) = PCO \cdot e_0 (\alpha, \beta) + PCV (\alpha, \beta)
\]

– Determination of standard deviations \( \sigma_{PCC} (\alpha, \beta) \) for each antenna

– Results for frequencies
  – G01 (1575.42 MHz)  identical to E01/S01/J01
  – G02 (1227.60 MHz)  identical to J02
  – G05 (1176.45 MHz)  identical to E5a/S05/J05/I05
Precision of calibration pattern
(LEIAT504GG_NONE - 8 calibrations)

G01 (1575.42 MHz)

G02 (1227.60 MHz)

G05 (1176.45 MHz)
G05 frequency attenuated due to transmission characteristics of antenna