Differences between GPS receiver antenna calibration models and influence on geodetic positioning

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Outline

• Individual antenna calibration methods
• Methodology
  • Precise Point Positioning
  • Data sets
• Impact on computed station position
• Summary and conclusions
• Computed GPS station position: Antenna Reference Point (ARP)
• GPS signal measured at the virtual phase center of the receiving antenna
• Phase center corrections = Difference between ARP and phase center of the antenna
• Determined by the calibration and divided in 2 parts:
  – Phase center offset (PCO): independent of satellite position
  – Phase center variation (PCV): depend on the azimuth and elevation of the satellite over the antenna

\[ \text{PCC}(\alpha, z) = \text{PCO} + \text{PCV}(\alpha, z) \]
Individual calibration methods

Robot calibrations

Anechoic chamber calibrations

Geo++(D)
Also NGS(USA), Ife(D), SendStadt Berlin(D)

Uni-Bonn(D)
# Individual calibration methods

<table>
<thead>
<tr>
<th>Robot Calibrations</th>
<th>Anechoic chamber calibrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use real GNSS signals</td>
<td>Use generated sine wave</td>
</tr>
<tr>
<td>Only observed signals</td>
<td>Any frequency</td>
</tr>
<tr>
<td>GNSS receiver</td>
<td>Vector Network Analyzer</td>
</tr>
<tr>
<td>Multipath mitigated by intelligent positioning sequence</td>
<td>Multipath mitigated by the chamber</td>
</tr>
<tr>
<td>Used to generate type mean calibrations in the IGS</td>
<td>Can be used to generate type mean calibrations</td>
</tr>
<tr>
<td></td>
<td>since the igs08.atx</td>
</tr>
</tbody>
</table>
How to compare 2 calibrations

\[ \Delta PCC(\alpha, z) = (PCO_1 - PCO_2) + (PCV_1(\alpha, z) - PCV_2(\alpha, z)) \]

But PCV are not aligned:
- Geo++: Zenith PCV = 0
- Uni-Bonn: PCV = direct phase measurement

To compare:
- Shift Uni-Bonn PCC -> Zenith PCV = 0
- PCC(\alpha, z) equivalent to PCC(\alpha, z) + constant for all directions (for positioning)

Adding a constant: no position offset
- Only station clocks affected
- Equivalent to adding cable length
Individual calibration on $L_3$

- Differences of PCC between Geo++ and Uni-Bonn calibrations for a Trimble antenna on $L_1$ and $L_2$ and the resulting $L_3$ calibration

- Differences on $L_1$ and $L_2$ at the mm level but amplified in $L_3$
- In this study: only $L_3$ used
Individual calibration models
PCC differences between Geo++ and Uni-Bonn

- Six antennas installed at ROB.
- Each individually calibrated by both GEO++ and Uni-Bonn.

- What is the impact of the calibration model on computed station position?
Individual calibration models
PCO differences between Geo++ and Uni-Bonn

- Six antennas installed at ROB.
- Each individually calibrated by both GEO++ and Uni-Bonn.

<table>
<thead>
<tr>
<th>Station</th>
<th>North ΔPCO (mm)</th>
<th>East ΔPCO (mm)</th>
<th>Up ΔPCO (mm)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTBR 2</td>
<td>0.1</td>
<td>0.0</td>
<td>8.3</td>
</tr>
<tr>
<td>RTBT 2</td>
<td>0.7</td>
<td>1.0</td>
<td>-5.3</td>
</tr>
<tr>
<td>RTBT 3</td>
<td>1.4</td>
<td>0.6</td>
<td>-6.5</td>
</tr>
<tr>
<td>RTBQ 1</td>
<td>1.3</td>
<td>0.5</td>
<td>-6.3</td>
</tr>
<tr>
<td>RTBR 3</td>
<td>1.2</td>
<td>1.0</td>
<td>-5.0</td>
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<tr>
<td>RTBS 1</td>
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<td>1.4</td>
<td>-3.7</td>
</tr>
</tbody>
</table>

(*) PCO of Uni-Bonn adapted for zenith PCV = 0 (approximation: horizontal neglected)

- What is the impact of the calibration model on computed station position?
How to estimate the impact on computed station position

- Impact on computed station position not direct:
  - PCO+PCV (PCC) will affect each satellite differently at each epoch
How to estimate the impact on computed station position

- Daily RINEX files
- 2 Precise Point Positioning:
  - Identical processing options (10° elevation cut-off, satellite antenna calibrations, orbits and clocks, etc...)
  - 2 different receiver antenna calibrations:
    - Geo++
    - Uni-Bonn

⇒ Daily Position offsets

Final position offset = Mean daily position offsets (100 consecutive days)

Position offsets for Brussels

- Horizontal:
  - Trimble: -1 mm in the North and between 0 and -1 mm in the East
  - Leica: -0.1 mm in the North and 0 and -1 mm in the East

- Vertical:
  - Between -4 and -7 mm
Latitude dependency of the position offsets

- On a globally distributed set of stations (IGS08 core stations)
  - Assumption: all stations equipped with the same antenna
  - PPP for 2 antennas (using Geo++ and Uni-Bonn calibrations)
  - Position offset as function of latitude
Latitude dependency of the position offsets

- Latitude dependent model (spherical harmonics) computed
- Horizontal range: 0.4 mm
- Vertical range: 3.5 mm
Latitude dependency of the position offsets

- $\Delta \text{PCO}$
Latitude dependency of the position offsets

- $\Delta PCO$ and $\Delta PCO$

TRM59800.00 NONE
SN: 54146

TRM59800.00 NONE
SN: 54193

AGU Fall Meeting, December 2012, San Francisco
Latitude dependency of the position offsets

- $\Delta PCO$ and $\Delta PCO$

- $\Delta PCO = \text{Mean horizontal offset} \pm 0.1 \text{ mm}$

- Latitude dependency weak

- Up component ?
Position offsets for Brussels
Link with the $\Delta$PCO

- Differences of PCC (PCO+PCV) in all three component
- Link between $\Delta$PCO and horizontal component position offset?
  - Differences between igs08.atx and igs05.atx seem to show similar behaviour
Summary

• Station positions computed with Geo++ and Bonn calibrations for 6 antennas in Brussels:
  – Horizontal position offsets
    • Reach 1 mm and differences between Trimble and Leica antenna
  – Vertical position offsets
    • Between 3 and 7 mm

• Station positions computed with Geo++ and Bonn calibrations for 2 antennas on a globally distributed set of stations:
  – Weak latitude dependency position offsets
  – Horizontal position offsets
    • $\Delta PCO = \text{Mean } \pm 0.1 \text{ mm and variations of 0.4 mm to the mean}$
  – Vertical position offsets
    • Variations of 3.5 mm to the mean
Summary

• Impact of different calibration models on the computed station position not yet fully understood:
  
  – Up component?
  
  – Which level of agreement to reach between receiver antenna calibrations for positioning?