Field Absolute Calibration of the GPS/BDS Receiver Antenna at Wuhan University: Preliminary Results

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1 Introduction
Great demands for GNSS high accuracy applications:

- High accuracy terrestrial coordinate frame maintaining
- Continuously Operating Reference Stations (CORS)
- Precise Point Positioning (PPP)
- High accuracy level aircraft mission (Navistar, LEO)

To achieve high level accuracy, measurement and instrument biases at the cm to mm level must be understood.

One important bias is antenna phase center (APC)
In theory, the equiphase wave-front from a transmitting antenna should be perfectly spherical. However, in reality, APC is not a single point, but depends on azimuth & elevation of each frequency signal reception. APC is described by $PCO$ – Phase Center Offset and $PCV$ – Phase Center Variation.
Introduction

- **Relative PCV Calibration (Adopted by IGS in 1996)**
  
  It is reasonable for not too long baselines GNSS App.

  Disadvantages:
  
  ① Unsuitable - long distance baseline observations
  ② Unavailable - PCV with both azimuth and elevation
  ③ Unavoidable - site-dependent effects

- **Absolute PCV Calibration (Adopted by IGS in 2006)**
  
  ① Anechoic chamber
  ② Multi-axes robot (many institutes e.g. NGS, LGN Hannover, TU Dresden, University of Bonn and Geo++)
1 Introduction

PCV Calibration Platform

Relative PCV Calibration (NGS, USA)

Absolute PCV Calibration (NGS, USA)

 Calibration Robot (geo++, Germany)

Chamber Bonn Uni.
2 BDS/GPS Absolute PCV Field Calibration at WHU
Beidou Navigation System

- 15 BD2 SVs in constellation
- 16 BD3 SVs in commissioning
- 10+ BD2 SVs available in/around China
- Feasible to carry out Beidou high accuracy application

Beidou absolute PCV is a top priority for any high accuracy Applications!
Necessity for field calibration

- Pan motions
  rotations about a vertical axis aligned with local up
- Tilting motions
  tile around one horizontal axis

Advantages:
① Accelerate sample coverage
② Can reach any angle on antenna
So as to rotate and tile, we use a FANUC robot

- automatic
- 6 axes
- <0.2mm accuracy for robot frame positions (nominal)
- Difference between epochs to remove MP and separate the test antenna’s absolute PCO and PCV from DD observations.
- Unifying Time and Coordinate between GNSS and robot

Phase windup correction
2.3m - very short baseline
BDS/GPS Absolute PCV
Initial Results
Absolute Calibration Test 1

- Observation Duration: 5 sessions, about 8 hours each session
- Trimble Net R9 receivers, available for GPS/BeiDou
- Tested antenna type: TRM57971.0
  (known from igs_05.atx file, geo++ calibrated, as true values)
- PCO is first estimated, followed by PCV
BDS Absolute PCV Initial Results

- Sample Coverage
  Antenna fixed

- Sample Coverage
  Antenna with Robot
Estimated Absolute **PCO**

**GPS L1 PCO**

<table>
<thead>
<tr>
<th>PCO</th>
<th>N(mm)</th>
<th>E(mm)</th>
<th>U(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGS</td>
<td>1.19</td>
<td>-0.34</td>
<td>66.88</td>
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<tr>
<td>Estimated</td>
<td>1.11</td>
<td>-0.28</td>
<td>67.02</td>
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<td>IGS-Estimate</td>
<td>0.08</td>
<td>0.06</td>
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</table>

<1mm, compared to IGS05 type mean values
Estimated Absolute PCV

GPS L1 PCV

<1mm, compared to IGS05 type mean values
Estimated Absolute PCV (azimuth & elevation)

GPS L1 PCV (abs(IGS05 - Estimated))

<1mm, compared to IGS05 type mean values
Estimated Absolute PCO

BeiDou B1&B2 PCO

<table>
<thead>
<tr>
<th>PCO</th>
<th>N(mm)</th>
<th>E(mm)</th>
<th>U(mm)</th>
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<tbody>
<tr>
<td>B1</td>
<td>0.91</td>
<td>-0.55</td>
<td>66.47</td>
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<tr>
<td>B2</td>
<td>0.04</td>
<td>-0.02</td>
<td>57.69</td>
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</table>
BDS Absolute PCV Initial Results

Estimated Absolute PCV

PCVs range from -4 to 10 mm with zenith

IGS Workshop in Wuhan, China. Oct.29- Nov.2, 2018
Absolute Calibration Test 2

- Observation data: 5 sessions, 6 hours for each session
- Tested antenna type: DYWGNSSR044P00C (Shenzhen DingYao Co., Ltd., China)
Estimated Absolute PCO

<table>
<thead>
<tr>
<th></th>
<th>N(mm)</th>
<th>E(mm)</th>
<th>U(mm)</th>
<th>By</th>
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<tbody>
<tr>
<td>WHU</td>
<td>0.31</td>
<td>-0.25</td>
<td>139.31</td>
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<tr>
<td>NGS</td>
<td>-0.47</td>
<td>2.08</td>
<td>138.05</td>
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</table>

Difference: 1-2mm with respect to NGS
Estimated Absolute  GPS L1 PCV

PCV elev-only: diff: 2-4mm  Estimated full PCV
Estimated Absolute PCO

<table>
<thead>
<tr>
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<th>E(mm)</th>
<th>U(mm)</th>
<th>By</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.59</td>
<td>-0.24</td>
<td>150.81</td>
<td>WHU</td>
</tr>
<tr>
<td>-0.29</td>
<td>0.42</td>
<td>148.65</td>
<td>NGS</td>
</tr>
</tbody>
</table>

PCO L2 difference is 1-2mm.
Estimated Absolute GPS L2 PCV

PCV elev-only: diff: 1-2mm

Estimated full PCV
4 Conclusion
Conclusion

Trimble TRM57971/NONE was calibrated and the estimated values were further compared to the geo++ results from igs05.atx:

- <1 mm PCO calibration accuracy level can be achieved
- <1 mm PCV elevation only calibration accuracy level can be achieved
- PCV with elevation and azimuth calibration accuracy is mostly within 1mm
Conclusion

And an antenna type “DYWGNSSR044P00C” produced by Shenzhen DingYao company was calibrated and the obtained values were compared with NGS results:

- <1-2 mm GPS PCO consistency accuracy level can be achieved
- <2-4mm GPS elevation-only PCV consistency accuracy level can be achieved
Future work

- BDS/GNSS PCO/PCV models for geodetic antennas can be calibrated in the near future at WHU.

- The calibrated BDS PCO/PCV models should be validated in the high precise applications, such as PPP, and long baseline relative positioning etc.
Thanks for your attention!