Antenna calibrations

A. Villiger

1Astronomical Institute, University of Bern, Bern, Switzerland

e-mail: arturo.villiger@aiub.unibe.ch

Tour de l’IGS, 17. February 2021
IGS Antenna related files

- The IGS coordinates the antenna and receiver names among the calibration facilities, site managers, and ACs (→ rcvr_ant.tab)
- The IGS coordinates the definition of the antenna reference points (ARP) and north orientation (→ antenna.gra)
- The IGS coordinates with the Antenna Working Group and Reference Frame Group the antenna calibration patterns (→ igs14.atx)

https://files.igs.org/pub/station/general
Why do we need antenna calibration patterns?

\[ L_i^k = |x^k - x_i| + T_i^k - I_i^k + c\delta_i - c\delta^k + \lambda N \]

- \( x^k \): Satellite \( k \) position
- \( x_i \): Station \( i \) position
- \( T_i^k \): Troposphere
- \( I_i^k \): Ionosphere
- \( \delta_i, \delta^k \): clock correction
- \( \lambda, N \): Wavelength, phase ambiguity
Antenna pattern

Transition from reception point to the antenna reference point (ARP)
- Account for phase variations (PV)
- Account for phase center offset (PCO)
- Local tie from ARP to marker position

The antenna pattern are:
- Frequency dependent
- Direction dependent
Antenna pattern

PCO  Phase Center Offset: nadir and azimuth independent

PV  Elevation and azimuth dependent part
    The combined PCO and PV reflect the full correction. The separation is completely arbitrary.

Note: PCO is defined in such a way that the 90° zenith angle of the PV is 0. An other options would be a zero mean condition over all PV or even only PV (PCO = 0)
Example: Antenna TRM59800.00 NONE

<table>
<thead>
<tr>
<th>Freq.</th>
<th>$x$-PCO</th>
<th>$y$-PCO</th>
<th>$z$-PCO</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>0.65</td>
<td>1.35</td>
<td>89.35</td>
</tr>
<tr>
<td>L2</td>
<td>-0.24</td>
<td>0</td>
<td>117.76</td>
</tr>
<tr>
<td>IF</td>
<td>2.03</td>
<td>3.44</td>
<td>45.44</td>
</tr>
</tbody>
</table>
Example: Antenna LEIAR25 NONE

<table>
<thead>
<tr>
<th>Freq.</th>
<th>x-PCO</th>
<th>y-PCO</th>
<th>z-PCO</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>1.41</td>
<td>1.00</td>
<td>155.34</td>
</tr>
<tr>
<td>L2</td>
<td>-0.15</td>
<td>0.29</td>
<td>164.00</td>
</tr>
<tr>
<td>IF</td>
<td>3.82</td>
<td>2.10</td>
<td>141.95</td>
</tr>
</tbody>
</table>
Why do we need antenna calibration patterns?

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Distance satellite - station

The scale of the coordinate frame (station height) is highly correlated with the receiver and satellite z-component of the phase center offset:

Receiver: the PCO defines the vector between the physical marker and the actual reception point of the antenna.

Satellite: the PCO defines the vector between the center of mass and the exact emission point in the antenna.

Given: The satellite height is given due to celestial mechanics.
Example: Galileo E101 (Nadir: 14°)

<table>
<thead>
<tr>
<th>Freq.</th>
<th>x-PCO</th>
<th>y-PCO</th>
<th>z-PCO</th>
</tr>
</thead>
<tbody>
<tr>
<td>E01</td>
<td>-169.37</td>
<td>29.63</td>
<td>811.77</td>
</tr>
<tr>
<td>E05</td>
<td>-169.80</td>
<td>25.85</td>
<td>791.85</td>
</tr>
<tr>
<td>IF</td>
<td>-168.83</td>
<td>34.40</td>
<td>836.88</td>
</tr>
</tbody>
</table>
Example: Galileo E210 (Nadir: 20°)

<table>
<thead>
<tr>
<th>Frq.</th>
<th>x-PCO</th>
<th>y-PCO</th>
<th>z-PCO</th>
</tr>
</thead>
<tbody>
<tr>
<td>E01</td>
<td>121.33</td>
<td>-8.01</td>
<td>724.14</td>
</tr>
<tr>
<td>E05</td>
<td>122.14</td>
<td>-9.38</td>
<td>636.31</td>
</tr>
<tr>
<td>IF</td>
<td>120.31</td>
<td>-6.28</td>
<td>834.86</td>
</tr>
</tbody>
</table>
Origin of antenna calibration pattern

**Receiver antenna pattern**
- Robot calibrations: Calibrated using robot system
- Chamber calibrations: Calibrated in anechoic chambers

**Satellite antenna pattern**
- Estimated by the IGS ACs: PCO and block-wise estimated PV (nadir dependent, no azimuth dependency, up to ± 1-2cm)
  Note: the PV and PCO are based on the ionosphere-free linear combination \( \rightarrow L1 = L2 \)
- Chamber calibrations: Disclosed by the GNSS agencies (Galileo, QZSS, PCO only: BeiDou, GPS (BLOCK IIIA))
  \( \rightarrow \) all frequencies
**IGS antenna pattern: IGS14 vs IGS20**

<table>
<thead>
<tr>
<th>GNSS</th>
<th>Frq</th>
<th>IGS14</th>
<th>IGS20</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sat. Rec</td>
<td>Sat Rec</td>
</tr>
<tr>
<td>GPS</td>
<td>L1</td>
<td>(IIIA )</td>
<td>(IIIA )</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>(IIIA )</td>
<td>(IIIA )</td>
</tr>
<tr>
<td></td>
<td>L5</td>
<td></td>
<td>(III )</td>
</tr>
<tr>
<td>GLO</td>
<td>G1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>G2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>G3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GAL</td>
<td>E1</td>
<td>(L1)</td>
<td>(L1)</td>
</tr>
<tr>
<td></td>
<td>E5a</td>
<td>(L2)</td>
<td>(L2)</td>
</tr>
<tr>
<td></td>
<td>E5b</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>E5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>E6</td>
<td></td>
<td></td>
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**IGS20 (realization of ITRF2020)**

- Not yet released
- Scale corrections might be applied
- Update of the receiver calibrations
- Galileo disclosed full antenna pattern
- GPS disclosed PCOs for BLOCK IIIA satellites

- **new**
- **estimated**
- **calibrated**
- **guess**
Multi-GNSS example

Different PPP solutions using Repro3 products:

Station: ZIM3
Antenna: TRM59800.00 NONE

\[
\begin{array}{|c|c|c|c|c|c|}
\hline
\text{Solution} & \text{GRE} & \text{GPS} & \text{GLO} & \text{GAL} & \text{GAL} \\
\hline
\text{N} & 0.00 & 0.56 & -2.04 & 2.12 & 1.88 \\
\text{E} & 0.00 & -1.45 & 1.33 & 0.48 & -0.5 \\
\text{U} & 0.00 & 1.22 & 0.42 & -1.51 & 13.08 \\
\hline
\end{array}
\]

\( x, \ y, \ \text{and} \ z \ \text{PCO of the used antenna pattern:} \)

\[
\begin{array}{|c|c|c|c|}
\hline
\text{Frq.} & x-\text{PCO} & y-\text{PCO} & z-\text{PCO} \\
\hline
\text{L1} & 0.65 & 1.35 & 89.35 \\
\text{L2} & -0.24 & 0 & 117.76 \\
\text{IF} & 2.03 & 3.44 & 45.44 \\
\hline
\text{R1} & 0.98 & 1.51 & 86.86 \\
\text{R2} & -0.16 & -0.2 & 114.47 \\
\text{IF} & 2.73 & 4.13 & 44.58 \\
\hline
\text{E1} & 0.65 & 1.35 & 89.35 \\
\text{E5} & -0.12 & -0.04 & 127.6 \\
\text{IF} & 1.62 & 3.10 & 41.13 \\
\hline
\text{L1}/\text{L2} & 1.77 & 3.05 & 53.54 \\
\hline
\end{array}
\]
Multi-GNSS example

Different PPP solutions using Repro3 products:

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<tr>
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<td>-1.51</td>
<td>13.08</td>
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Using igs14.atx → for a GPS-Only solution: height difference of about -9mm!

$x$, $y$, and $z$ PCO of the used antenna pattern:

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<td>L1/L2</td>
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- Official IGS receiver and antenna names (rcvr_ant.tab)
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- Schematic antenna graphics defining the Antenna reference point (antenna.gra)
  
  NRP: North Orientation Mark
  ARP: Antenna Reference Point
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LEIAR20

\[
\begin{align*}
&\text{NOM} = \text{NRP (north orientation mark)} \\
&\text{BAM} = \text{ARP (bottom of antenna mount)} \\
&0.3200 \quad 0.0000 \quad 0.0013 \quad 0.0323 \quad 0.1113 \quad 0.1613 \\
\end{align*}
\]
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Summary

• The IGS products are based on the IGS antenna models
• It is important to use consistent IGS ANTEX file and IGS products (currently igs14.atx)
  → the IGS14 scale is part of the igs14.atx
• The antenna pattern are azimuth and elevation dependent, so take the antenna orientation into account (they should be aligned to North)
• The antenna pattern are frequency dependent, (e.g. do not use L2 for E05)

→ https://files.igs.org/pub/station/general

Model name: rcvr_ant.tab
ARP definition: antenna.gra
Antenna pattern: igs14.atx