# Antenna calibrations

A. Villiger

[1]*Astronomical 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?

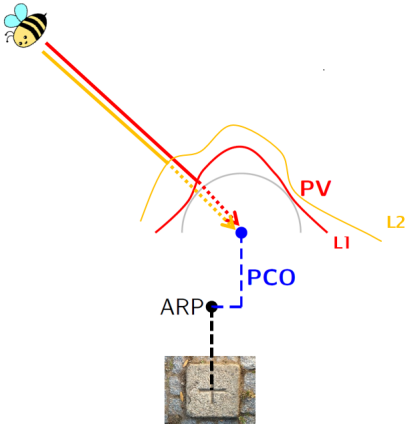
$$L_i^k = \left|\mathbf{x^k} - \mathbf{x_i}\right| + T_i^k - I_i^k + c\delta_i - c\delta^k + \lambda N$$

| | | |
|---|---|---|
| $\mathbf{x^k}$ | Satellite $k$ position | Center of Mass |
| $\mathbf{x_i}$ | Station $i$ position | Antenna marker |
| $T_i^k$ | Troposphere | |
| $I_i^k$ | Ionosphere | |
| $\delta_i, \delta^k$ | clock correction | |
| $\lambda, N$ | Wavelength | phase ambiguity |

# Antenna pattern

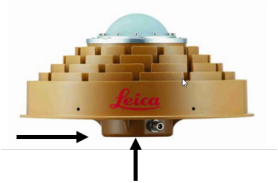
Transition from reception point to the antenna reference point (ARP)

- Account for phase variations (PV)
- Account for phase center offset (PCO)
- Local tie from ARP to marker position




**The antenna pattern are:**

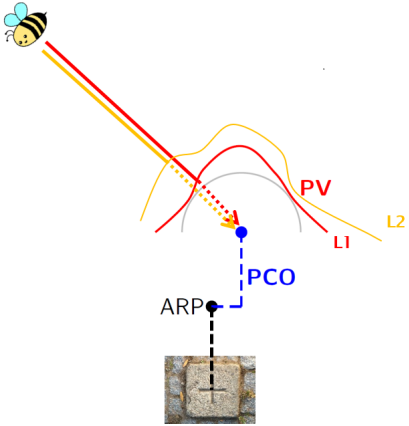
- Frequency dependent
- Direction dependent



# Antenna pattern

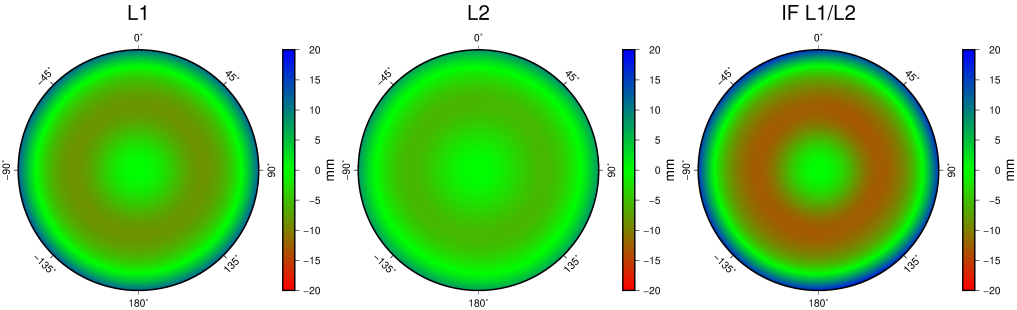
PCO Phase Center Offset: nadir and azimuth independent

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



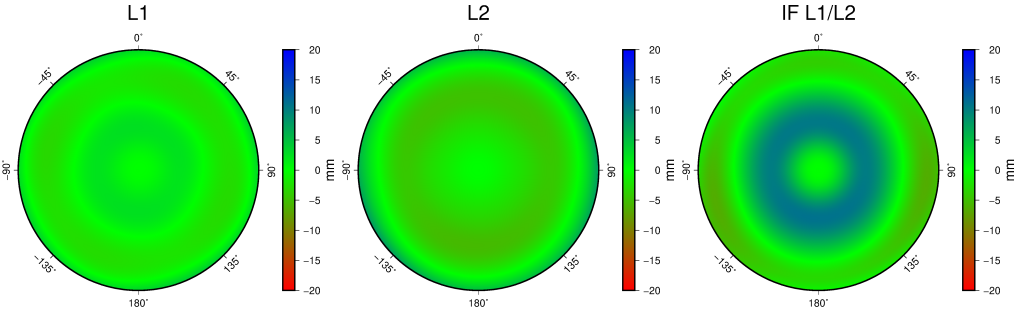

*Note: PCO is defined in such a way that the 90° zenith angle of the PV is 0. An other options would be a zero mean condition over all PV or even only PV (PCO = 0)*

# Example: Antenna TRM59800.00 NONE




| Frq. | $x$-PCO | $y$-PCO | $z$-PCO |
|---|---|---|---|
| L1 | 0.65 | 1.35 | 89.35 |
| L2 | -0.24 | 0 | 117.76 |
| IF | 2.03 | 3.44 | 45.44 |

# Example: Antenna LEIAR25 NONE



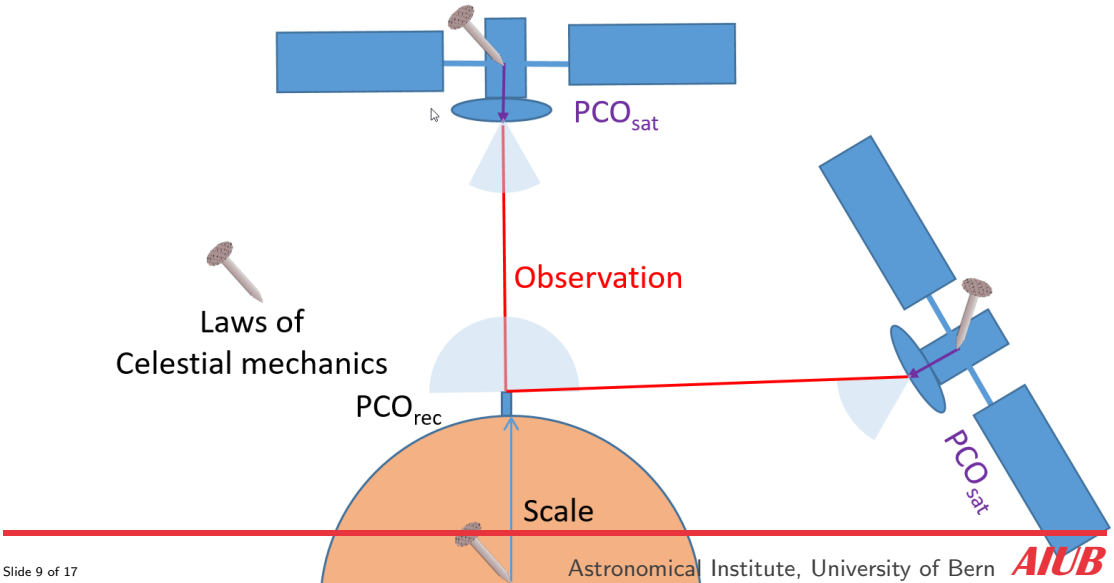

| Frq. | $x$-PCO | $y$-PCO | $z$-PCO |
|---|---|---|---|
| L1 | 1.41 | 1.00 | 155.34 |
| L2 | -0.15 | 0.29 | 164.00 |
| IF | 3.82 | 2.10 | 141.95 |

# Why do we need antenna calibration patterns?

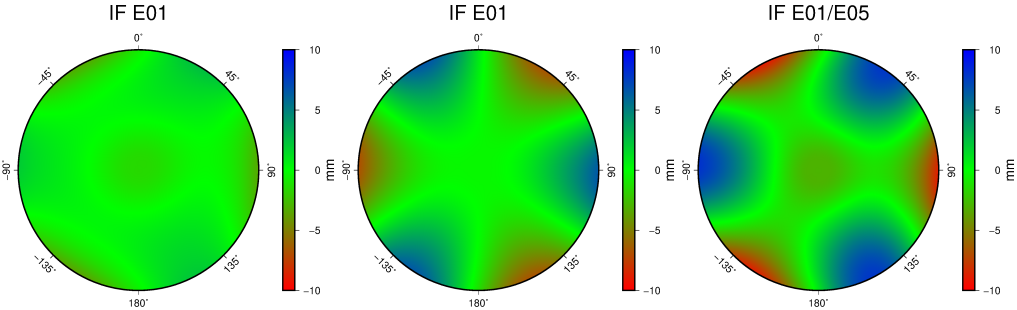
$$L_i^k = \left|\mathbf{x^k} - \mathbf{x_i}\right| + T_i^k - I_i^k + c\delta_i - c\delta^k + \lambda N$$

| | | |
|---|---|---|
| $\mathbf{x^k}$ | Satellite $k$ position | Center of Mass |
| $\mathbf{x_i}$ | Station $i$ position | Antenna marker |
| $T_i^k$ | Troposphere | |
| $I_i^k$ | Ionosphere | |
| $\delta_i, \delta^k$ | clock correction | |
| $\lambda, N$ | Wavelength | phase ambiguity |

# Distance satellite - station

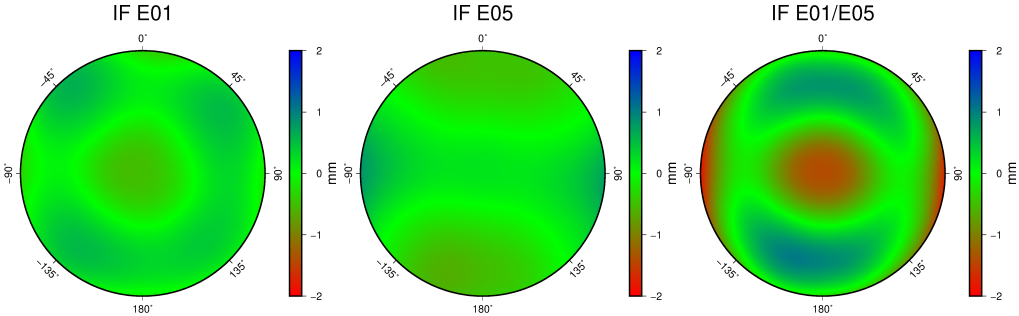


# Example: Galileo E101 (Nadir: 14°)




| Frq. | $x$-PCO | $y$-PCO | $z$-PCO |
|---|---|---|---|
| E01 | -169.37 | 29.63 | 811.77 |
| E05 | -169.80 | 25.85 | 791.85 |
| IF | -168.83 | 34.40 | 836.88 |

# Example: Galileo E210 (Nadir: 20°)




| Frq. | $x$-PCO | $y$-PCO | $z$-PCO |
|---|---|---|---|
| E01 | 121.33 | -8.01 | 724.14 |
| E05 | 122.14 | -9.38 | 636.31 |
| IF | 120.31 | -6.28 | 834.86 |

# Origin of antenna calibration pattern

**Receiver antenna pattern**

| | |
|---|---|
| Robot calibrations | Calibrated using robot system<br>Measurement of real data |
| Chamber calibrations | Calibrated in anechoic chambers |

**Satellite antenna pattern**

| | |
|---|---|
| Estimated by the IGS ACs | PCO and block-wise estimated PV<br>(nadir dependent, no azimuth dependency, up to $\pm$ 1-2cm)<br>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,<br>PCO only: BeiDou, GPS (BLOCK IIIA))<br>$\rightarrow$ all frequencies |

# IGS antenna pattern: IGS14 vs IGS20

| GNSS | Frq | IGS14 Sat. | IGS14 Rec | IGS20 Sat | IGS20 Rec |
|---|---|---|---|---|---|
| GPS | L1 | | | (IIIA ) | |
| | L2 | | | (IIIA ) | |
| | L5 | | | (IIIA ) | |
| GLO | G1 | | | | |
| | G2 | | | | |
| | G3 | | | | |
| GAL | E1 | | (L1) | | |
| | E5a | | (L2) | | |
| | E5b | | | | |
| | E5 | | | | |
| | E6 | | | | |

**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*

| Solution | GRE [mm] | GPS [mm] | GLO [mm] | GAL [mm] | GAL L1/L2 |
|---|---|---|---|---|---|
| N | 0.00 | 0.56 | −2.04 | 2.12 | 1.88 |
| E | 0.00 | −1.45 | 1.33 | 0.48 | −0.5 |
| U | 0.00 | 1.22 | 0.42 | −1.51 | 13.08 |

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

| Frq. | $x$-PCO | $y$-PCO | $z$-PCO |
|---|---|---|---|
| L1 | 0.65 | 1.35 | 89.35 |
| L2 | -0.24 | 0 | 117.76 |
| IF | 2.03 | 3.44 | 45.44 |
| R1 | 0.98 | 1.51 | 86.86 |
| R2 | -0.16 | -0.2 | 114.47 |
| IF | 2.73 | 4.13 | 44.58 |
| E1 | 0.65 | 1.35 | 89.35 |
| E5 | -0.12 | -0.04 | 127.6 |
| IF | 1.62 | 3.10 | 41.13 |
| L1/L2 | 1.77 | 3.05 | 53.54 |

# Multi-GNSS example

**Different PPP solutions using Repro3 products:**

Station: *ZIM3*
Antenna: *TRM59800.00 NONE*

| Solution | GRE [mm] | GPS [mm] | GLO [mm] | GAL [mm] | GAL L1/L2 |
|---|---|---|---|---|---|
| N | 0.00 | 0.56 | −2.04 | 2.12 | 1.88 |
| E | 0.00 | −1.45 | 1.33 | 0.48 | −0.5 |
| U | 0.00 | 1.22 | 0.42 | −1.51 | 13.08 |

Using igs14.atx → for a GPS-Only solution: height difference of about -9mm !

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

| Frq. | $x$-PCO | $y$-PCO | $z$-PCO |
|---|---|---|---|
| L1 | 0.65 | 1.35 | 89.35 |
| L2 | -0.24 | 0 | 117.76 |
| IF | 2.03 | 3.44 | 45.44 |
| R1 | 0.98 | 1.51 | 86.86 |
| R2 | -0.16 | -0.2 | 114.47 |
| IF | 2.73 | 4.13 | 44.58 |
| E1 | 0.65 | 1.35 | 89.35 |
| E5 | -0.12 | -0.04 | 127.6 |
| IF | 1.62 | 3.10 | 41.13 |
| L1/L2 | 1.77 | 3.05 | 53.54 |

# What does the IGS provide to the user?

- Official IGS receiver and antenna names (rcvr_ant.tab)

# What does the IGS provide to the user?

- Official IGS receiver and antenna names (rcvr_ant.tab)

```
+----------------------+-----------------------------------------------+
| TRIMBLE Receivers    |                                               |
| IGS Codes-20 columns |                  Description                  |
| XXXXXXXXXXXXXXXXXXXX |                                               |
+----------------------+-----------------------------------------------+
| TRIMBLE NETR9        | L1/L2+L2C/L5 GLONASS L1/L2 with 2 Maxwell-6 ASIC,  |
|                      |  eth + SBAS, 440 channel                      |

+----------------------+-----------------------------------------------+
| TRIMBLE Antennae     |                                               |
| IGS Codes-15 columns |                  Description                  |
| XXXXXXXXXXXXXX DOME  |                                               |
+----------------------+-----------------------------------------------+
| TRM59800.00          | Dorne Margolin with chokerings, Model 59800.00 |
|                      | L1/L2/L5/G1/G2/G3/E1/E2/E5ab/E6/BeiDou,       |
|                      | GPS, GLONASS, Galileo & BeiDou                |
```

# What does the IGS provide to the user?

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

# What does the IGS provide to the user?

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

```
LEIAR20

                +-------+                    <-- 0.1613
               /         \
              |           |
 +------------+-----------+------------+      <-- 0.1113  TCR
 |            |           |            |
 |            |           |            |
 |            |           |            |
 |            |           |            |
 +-+----------+-----------+----------+-+
 +------------+-----------+------------+      <-- 0.0323  BCR
              |           |
              |           |
              +-----+ +---+                  <-- 0.0013  BPA
                 +x+                         <-- 0.0000  BAM=ARP (bottom of antenna mount)
                                                         NOM=NRP (north orientation mark)
<--            0.3200                  -->
```

# What does the IGS provide to the user?

- Official IGS receiver and antenna names (rcvr_ant.tab)
- Schematic antenna graphics defining the Antenna reference point (antenna.gra)
  NRP: North Orientation Mark
  ARP: Antenna Reference Point
- Antenna calibration pattern (igs14.atx)

# What does the IGS provide to the user?

- Official IGS receiver and antenna names (rcvr_ant.tab)
- Schematic antenna graphics defining the Antenna reference point (antenna.gra)
  NRP: North Orientation Mark
  ARP: Antenna Reference Point
- Antenna calibration pattern (igs14.atx)

```
                                                                    START OF ANTENNA
JAV_RINGANT_G3T NONE                                                TYPE / SERIAL NO
ROBOT                    Geo++ GmbH                 5    03-APR-13 METH / BY / # / DATE
     5.0                                                            DAZI
     0.0   90.0    5.0                                              ZEN1 / ZEN2 / DZEN
     4                                                              # OF FREQUENCIES
IGS14_2186                                                          SINEX CODE
Number of Calibrated Antennas GPS:       005                        COMMENT
Number of Individual Calibrations GPS:   010                        COMMENT
Number of Calibrated Antennas GLO:       005                        COMMENT
Number of Individual Calibrations GLO:   010                        COMMENT
# GLONASS PCV                                                       COMMENT
#  derived from Delta PCV per 25.0 MHz                              COMMENT
#  for frequency channel number k=0                                 COMMENT
   G01                                                              START OF FREQUENCY
     +0.25      +2.24     +49.04                                    NORTH / EAST / UP
...
```

# 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 |