Impact of Different Individual GNSS Receiver Antenna Calibration Models on Geodetic Positioning

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Introduction

Since April 2011, the igs08.atx antenna calibration model is used in the routine IGS (International GNSS Service) data analysis. The model includes mean robot calibrations to correct for the offset and phase center variations of the GNSS receiver antennas. These so-called "type" calibrations are means of the individual calibrations performed by Geo++ [Wübbena et al., 2006] and are available for a specific antenna/radome combination.

The GNSS data analysis performed within the EUREF Permanent Network (EPN) aims at being as consistent as possible with the IGS analysis. This also applies to the receiver antenna calibrations. However, when available, individual antenna calibrations are used within the EPN analysis, see Figure 1, instead of the "type" calibration. When these individual calibrations are unavailable, then the EPN analysis falls back to (type) calibrations identical as the ones used within the IGS (igs08.atx).

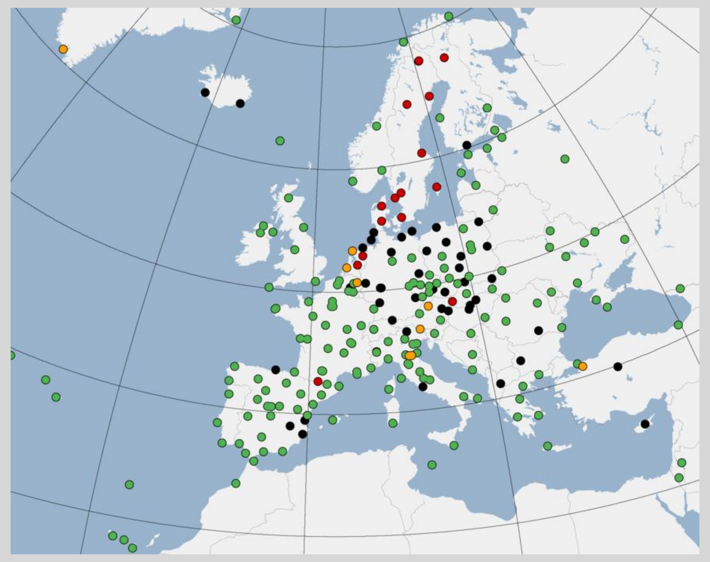

Figure 1. Map of the calibration available at each EPN station at the present date (245 stations).
- *Black dots: antenna/radome pairs with absolute individual calibrations (15.98%)*
- *Green dots: antenna/radome pairs with true absolute type calibrations (69.26%)*
- *Orange dots: antenna/radome pairs with absolute calibrations converted from relative values (6.56%)*
- *Red dots: antenna/radome pairs without absolute calibrations. In this case, the radome is neglected and the calibration values of the antenna with radome 'NONE' is used (8.20%).*

Aim of this study:
- Evaluate the significance of the offset caused by using different receiver antenna calibration models on the station position, using the PPP (Precise Point Positioning) technique.
- Investigate the differences in positioning obtained when switching between:
  1. Individual antenna calibrations and type calibrations.
  2. Individual calibrations from different calibration methods.

1. Antenna Calibration Methods

Different calibration methods are used. Their usage in the EPN is summarized in Table 1. Each technique is different:
- Robot calibration: the antenna is fixed on a moving robot and observes the signal from the satellites. The robot allows to rotate the antenna in order to determine accurately the azimuth-dependent phase center variation (PCV).
- Chamber calibration: the antenna is in an anechoic chamber and observes a simulated signal. It can also rotate for the determination of the azimuth-dependant PCV.
- Field calibration: the antenna observes the satellites and the differences are made with respect to a calibrated antenna.

Institute	Method	# of antenna calibrated
Geo++ Gmbh	ROBOT	40
SenStadt BERLIN	ROBOT	11
IfE	ROBOT	1
Lwa (TU-Dresden)	FIELD	1
UniBonn	CHAMBER	0*

Table 1. Known calibration institutes providing individual calibrations for EPN stations, including the calibration method and number of calibrations available within the EPN in April 2011.

**Some calibrations have been added since, like the individual calibration of BRUX performed by UniBonn.*

	GEO++	UniBonn
Technique	robot	anechoic chamber
Source	real observed satellite signals	generated sine wave
Frequencies	only observed frequencies	any (future) frequency
Equipment	GNSS receiver	Vector Network Analyser
Multipath	Not attenuated	Attenuated by absorbers
Environment	variable	stable
Duration	Long (wait for all GNSS signals)	Short (limited by positioner speed)

Table 2. : Comparison of calibration techniques at UniBonn and Geo++.

The differences between robot and chamber calibrations are summarized in Table 2 and the differences between the calibration values are shown in Figure 4.

References

P. Rebischung, J. Griffiths, J. Ray, R. Schmid, X. Collilieux, B. Garayt, *IGS08: the IGS realization of ITRF2008,GPS Solution*, DOI 10.1007/s10291-011-0248-2, december 2011

G. Wübbena, M. Schmitz, G. Boettcher, C. Schumann, *Absolute GNSS Antenna Calibration with a Robot: Repeatability of Phase Variations, Calibration of GLONASS and Determination of Carrier-to-Noise Pattern*, Proc. of the IGS Workshop, May 8-12, 2006, ESOC, Darmstadt, Germany

2. Methodology

To evaluate the influence of different receiver antenna calibration models on precise positioning, a similar approach was followed as the one used by Rebischung et al., 2011:
- Two separate PPP runs were made in which all processing options (satellite antenna calibrations, orbits and clocks, etc…) are identical except for the receiver antenna calibration model.
- For the receiver antenna calibration model, the igs08.atx and individual calibrations were used.
- The difference between the daily positions obtained by the different PPP runs will give us a daily estimate of the position offset caused by the changed receiver antenna calibration model.
- **The final position offset** of a station is then obtained by taking the mean of the daily estimates over the considered data set of that station (corresponding to the time frame a specific antenna/radome combination was installed).

Two data sets are analyzed here
- **The 53 EPN stations with individual calibration**, from the beginning (2003 for the first individual calibration in the EPN) to April 2011. They are compared to the type calibrations from igs08.atx.
- **The six antennas installed at Royal Observatory of Belgium (ROB)**. Each of those antennas have been individually calibrated by both Geo++ and UniBonn. The impact of the calibration method on the positioning is investigated by comparing the two calibrations for each antenna.

3. Impact of Individual Calibration with Respect to igs08.atx

Figure 2 presents the histogram of the position offsets between individual calibrations and igs08.atx calibrations, referred here as type calibrations.

Results 1
- Horizontal position offsets show values with a distribution around 0 mm but with a great dispersion, values up to 4 mm.
- Vertical component position offsets show no normal distribution around 0 mm and values up to 10 mm.

The position offsets tend to have a greater impact on the vertical component. This is confirmed here and allows to explain the absence of normal distribution in this component.
There are 4 position offsets equal to 0 mm in all three components. This is explained by the fact that the igs08.atx calibrations for those antenna are made with one individual calibration.

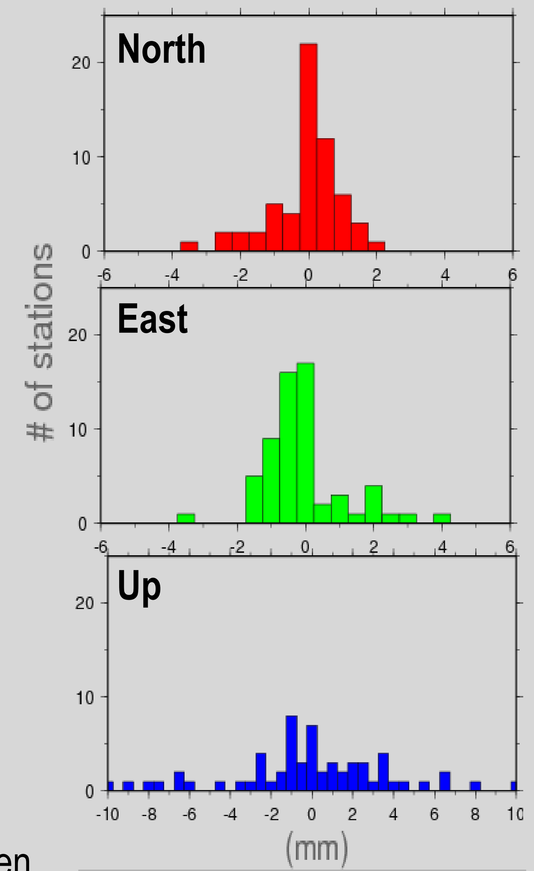

Figure 2. Histograms of position offsets induced by the difference between individual receiver antenna calibrations and igs08.atx calibrations for the 53 station/antenna+radome pairs individually calibrated in the EPN.

Figure 3 presents the position offsets for the TRM55971.00 TZGD:
- Installed in 11 EPN stations and each of these antennas have been individually calibrated
- All the individual calibrations for this antenna have not been performed by the same institute
- The type calibration is the mean of Geo++ calibration of 8 antennas

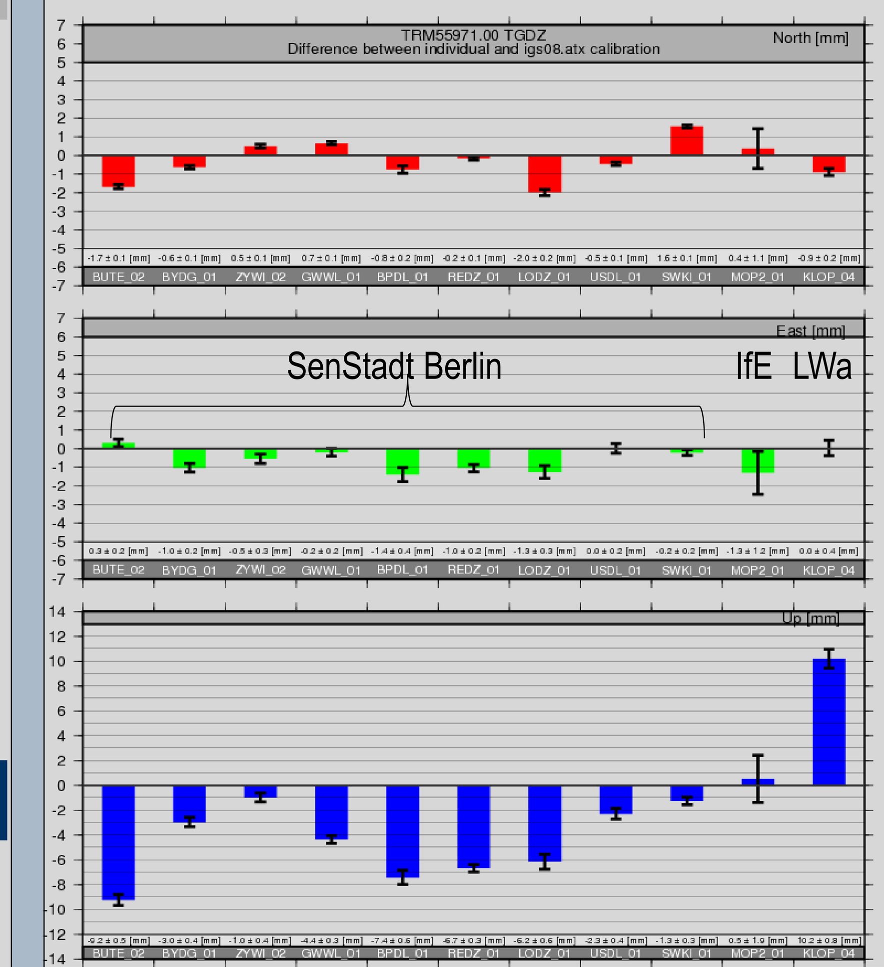

Figure 3. Position offsets between the individual calibrations and the type calibration for 11 different TRM55971.00 TZGD antennas.

Horizontal position offsets induced by two different individual calibrations reach 2 mm (for the north). The vertical position offsets are more pronounced: -9 mm for BUTE and 10 mm for KLOP.
The antenna of KLOP is the only field calibration, and performed by a different institute than for BUTE. Moreover, the differences between each calibration and the type calibration on L_3 already show that the impact on each observation can reach more than 6 mm, depending on the elevation and the azimuth of the satellite over the station.

4. Impact of the Calibration Method on Positioning

To study the impact of the calibration method on geodetic positioning 6 antennas have been installed at ROB. 5 of the 6 antennas are TRM59800.00 NONE, the other one is a LEIAR25.R3 NONE. All those antennas have been calibrated by Geo++ and UniBonn.

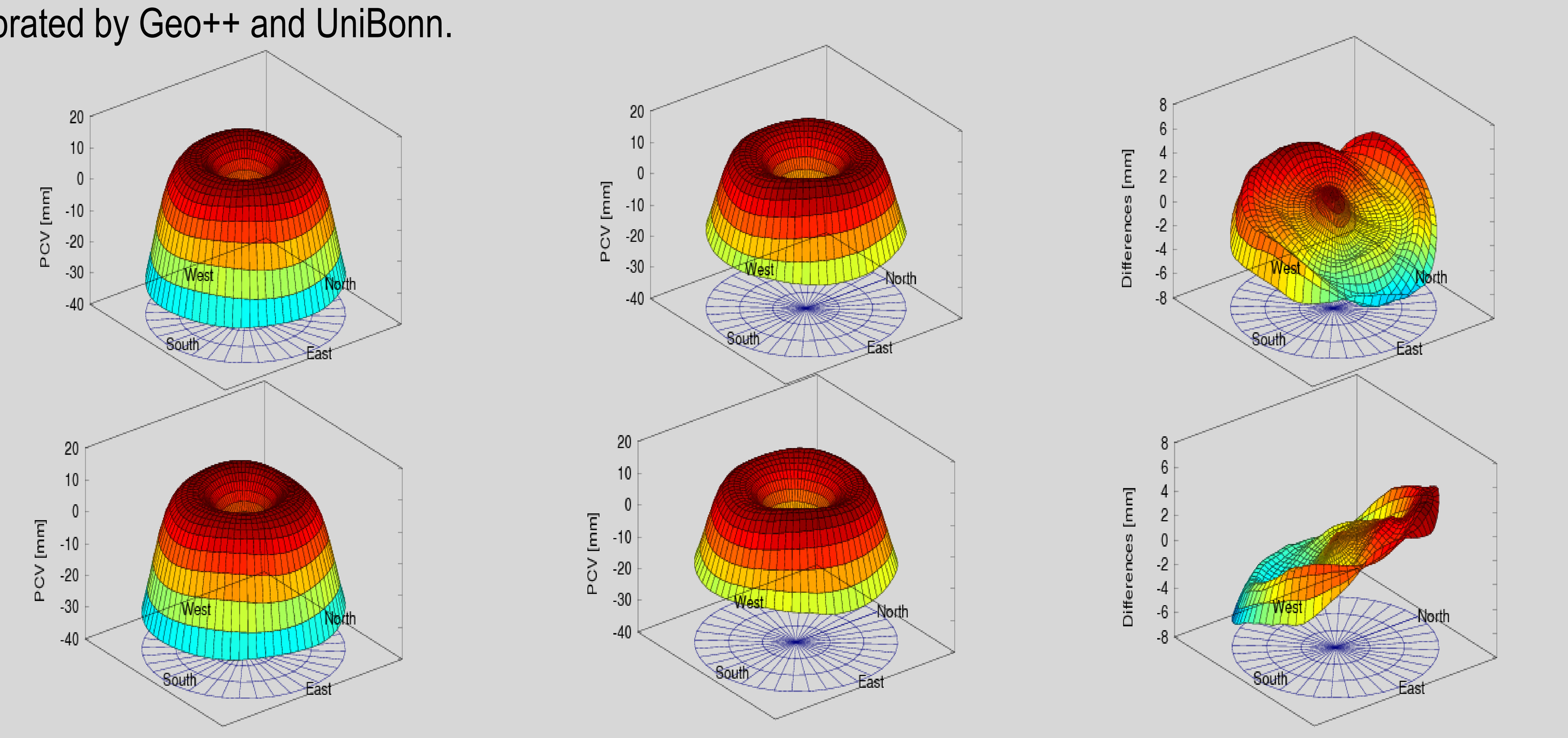

Figure 4. From left to right: Phase center variation for the ionosphere combination as measured by GEO++, UniBonn and the differences between the two. The upper plots and lower plots are both for TRM59800.00 NONE but two different antenna (installed in RTBT for the upper plots and RTBQ for the lower plots).

Figure 4 presents the phase center variation for both Geo++ and Uni-Bonn calibration for two TRM59800.00 NONE as well as the difference between the calibrations. The impact of this difference on the position can be seen on Figure 5 but **we can observe that the impact is not straight forward**. Indeed, the impact on the position will depend on the convolution of the differences between the calibration and the skyplot of the station, as shown in Figure 6..

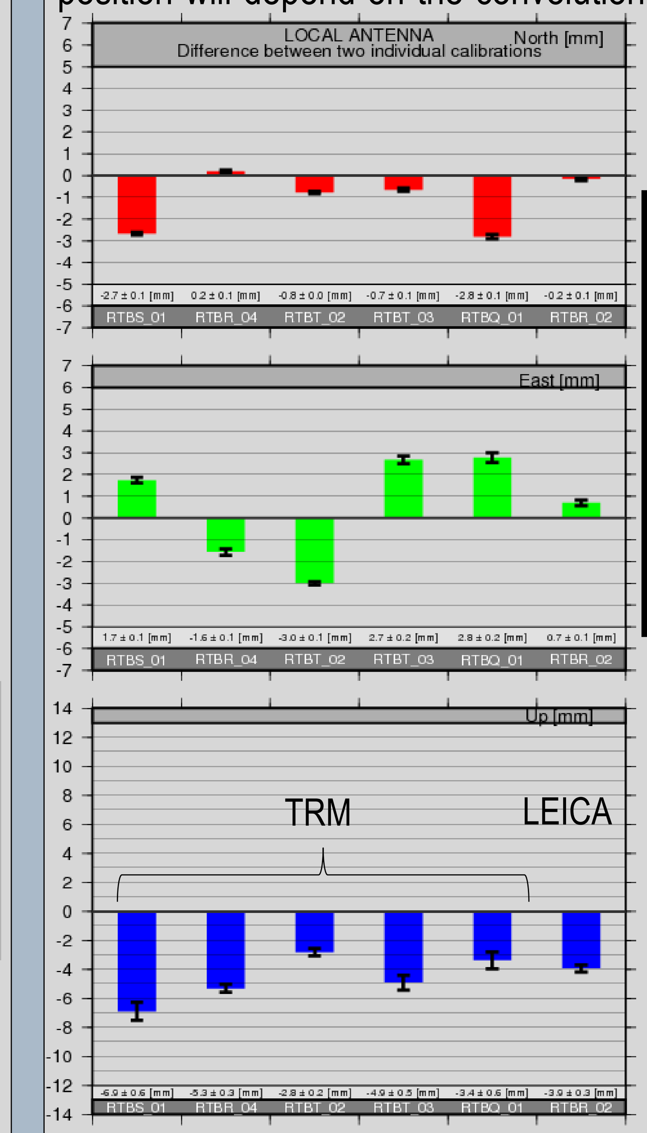

Figure 5. Position jumps for the antennas installed at ROB, resulting from the differences between GEO++ and UniBonn calibrations.

Results 2
- There is no systematic effect on the horizontal component.
- The position offsets can reach 3 mm in the horizontal component.
- There are not enough values to conclude to a negative bias in the vertical component induced by the different calibration methods.
- The vertical component is affected by position offsets up to 7 mm.
- The position offsets are equal or larger than those observed between individual and igs08.atx calibrations.

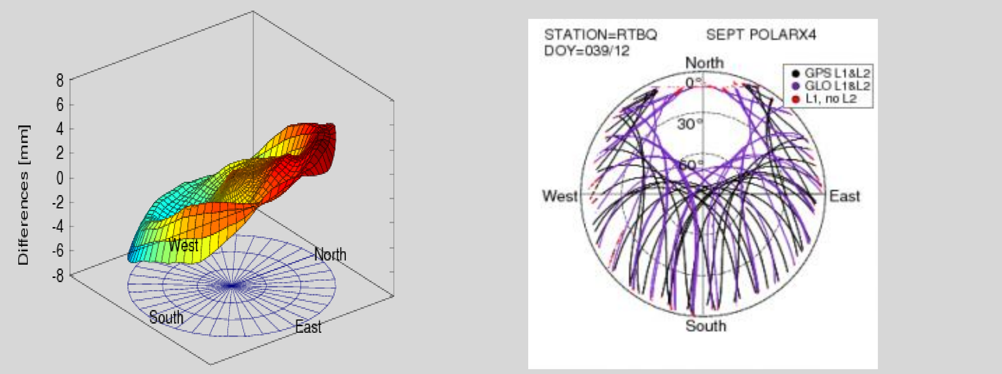

Figure 6. On the left: difference of calibration between Geo++ and UniBonn on the ionosphere-free combination for RTBQ. On the right: Skyplot of RTBQ.

Conclusions

Comparisons between station positions computed with
- Individual and igs08.atx receiver antenna calibrations show that *(results for Europe)*:
  - The position offset can reach 4 mm in horizontal component and 10 mm in the vertical component.
  - The position offsets have a greater impact on the vertical component.
  - For the same antenna model, the position offsets induced by different individual calibrations with respect to igs08.atx calibrations can reach 2 mm in the horizontal component and 10 mm in the vertical component.
- Individual receiver antenna calibrations from Geo++ and UniBonn show that *(results for 6 antennas in Brussels)*:
  - The position offsets can reach 3 mm in the horizontal component and 7 mm in the vertical component.
  - Position offsets induced by different calibration methods can be larger than those induced by the difference between an individual and type calibrations.