The Impact of Different GPS Antenna Calibration Models on the EUREF Permanent Network

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Abstract

It is generally known that the phase center of a GPS antenna is not a stable point coinciding with a mechanical reference. The phase center depends on the direction of the received signal. Models for the correction of the phase center variations (PCV) of GPS antennas have been available for some years. The first relative calibration methods used a standard reference antenna (Dorne Margolin Type, e.g. AOAD/M_T), which was supposed to have no direction dependent phase center variations. Relative calibration models have been used for many years now. Today also absolute calibration models are available. The influence of using different calibration models will be shown on the subnetwork processed by the Bayerische Kommission für die Internationale Erdmessung (BEK).

Introduction

Even though relative PCV calibration models are widely used within GPS standard processing, it does not mean that they are correct for each application scenario. The use of relative models rather reflects the difficulty to estimate the correct absolute phase pattern due to the up to recently unavailable methods. First absolute calibrations, i.e. by SCHUPLER and CLARK (1994), have been carried out in an anechoic chamber. These calibrations indicated already that the Dorne Margolin Type, e.g. the AOAD/M_T antenna, has significant elevation dependent phase centre variations . Nevertheless, this type of antenna has been approved of being the "Zero" antenna forming a standard, with elevation dependent variations set to zero referring to a fixed mean offset.

A new absolute field calibration method has been developed in a joint project by IfE and Geo++ (WÜBBENA et al. 1996, 2000), which uses a robot to estimate elevation and azimuth dependent PCV with high resolution and precision down to the antenna's horizon. Even though these absolute models have also been approved by a variety of institutions (e.g. ROTHACHER and SCHMID 2002) it is still not used within the IGS community due to the following reasons:

– the IGS standard (adopted by EUREF) stipulates relative models
– the use of absolute models leads to discrepancies between the coordinates of GPS and other space techniques (scale factor)

The later reason is obviously the main reason for the GPS community, which prevents the introduction of the new absolute models as a general standard. It is assumed that applying absolute antenna models disclose a problem with the GPS satellite antenna offsets and its associated PCV. As a recent study by MADER and CZOPEK (2001) has shown, the phase centre offsets of the GPS IIA satellites are not in agreement with the widely used standard.

We will show in this paper the impact of applying different PCV correction models on a part of the EUREF network, which is processed by the BEK. It is also of importance to notify, that different antenna domes have an impact on the GPS antenna's receiving characteristics. Therefore we apply correction models for the different antenna domes to picture this widely known but so far unconsidered effect.

Absolute Field Calibration

The absolute field calibration has been developed by Geo++ and the Institut für Erdmessung (IfE) of the University of Hannover, Germany, (WÜBBENA et al. 1996, 2000, MENGE et al. 1998).The main goal of this procedure was to develop a method that allows the estimation of PCV, which are independent of a reference antenna. Another advantage is that the effect of multipath is eliminated, thus one yields station independent PCV. Without the separation of the antenna's inherent PCV and the other station dependent effects (multipath, diffraction, scattering etc.), other calibration methods are often influenced by these signals, which is a major drawback of relative calibrations.

Today the absolute field calibration method is matured to a real time system using a robot (see figure 1) that carries out rotations of the antenna to estimate the direction dependent PCV.

The robot carries out fast rotations on different axes, which increases the efficiency considerably. Besides the efficiency the precision of the robot is a relevant aspect. Advantages of the absolute antenna calibration are summarised as follows:

– absolute 3D-offset and PCV
– high resolution and precision (0.2-0.3 mm, 1?)
– free of multipath
– PCV from 0°-90° elevation, also azimuthal PCV
– site and location independent.

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Figure 1: Robot for real time antenna calibration with test antenna.

Figure 2 shows the elevation dependent PCV of an AOAD/M_T antenna based on the mean offsets approved by the IGS as a result of the calibration with the robot. It is clearly visible that the elevation dependent PCV are different from zero and vary up to 3 cm for the ionosphere free linear combination L0 (LC).

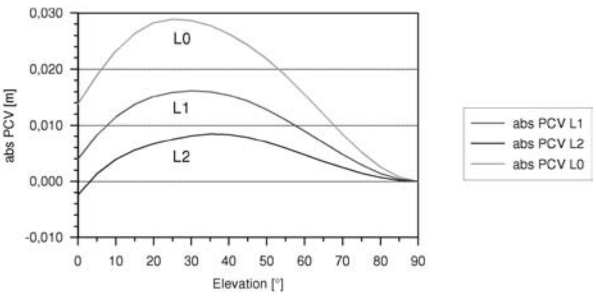

Figure 2: Elevation dependent absolute phase center correction for the Dorne Margolin AOAD/M_T (L1, L2 and LC Signal) based on the IGS offsets.

The impact of different calibration models

In order to evaluate the impact of different antenna calibration models, relative and absolute PCV corrections have to be compared. Therefore the standard processing strategy used by the BEK for its contribution to the EUREF Permanent Network as one of the Local Analysis Centres (LAC) has been used to apply absolute calibration models derived by IfE and Geo++ and the standard relative models approved by the IGS. The comparison also includes a new model for the phase centre offsets of the GPS satellite antenna based on investigations by MADER and CZOPEK (2001). Their analysis of the mean phase centre offset of the GPS Block IIA satellite antennas, without the estimation of direction dependent parts reveals a substantial difference to the phase centre offsets used so far. This offset is more than 60 cm different compared to the standard models.

The used absolute antenna calibration results consists of new phase centre offsets and the associated PCV for the different antenna types. Some of the PCV sets stem from the GEO++ database (http://gnpcvdb.geopp.de) and some from calibrations at IfE.

The standard processing strategy used by most of the LAC's implies:

– IGS orbits and pole information
– ocean loading corrections applied
– 10° elevation mask
– elevation dependent weighting function [1/cos(z)]
– Niel mapping function
– one troposphere parameter for each hour
– fix ambiguities

The network consists of 53 stations covering mostly the Mediterranean region - the area processed by the BEK (compare figure 3).

Three different processing set-ups have been chosen for the comparison in order to evaluate the impact of relative and absolute calibration models for the GPS receiver antennas as well as the impact of the mean GPS satellite antenna offset:

1. Standard model (model 1) according to the IGS: relative PCV for the GPS antennas on ground, standard IGS antenna offset for the GPS satellites
2. Model (model 2) using absolute PCV for the GPS antennas on ground, but standard IGS antenna offsets for the GPS satellites
3. Model (model 3) using absolute PCV for the GPS antennas on the ground and new mean offsets for the GPS satellites.

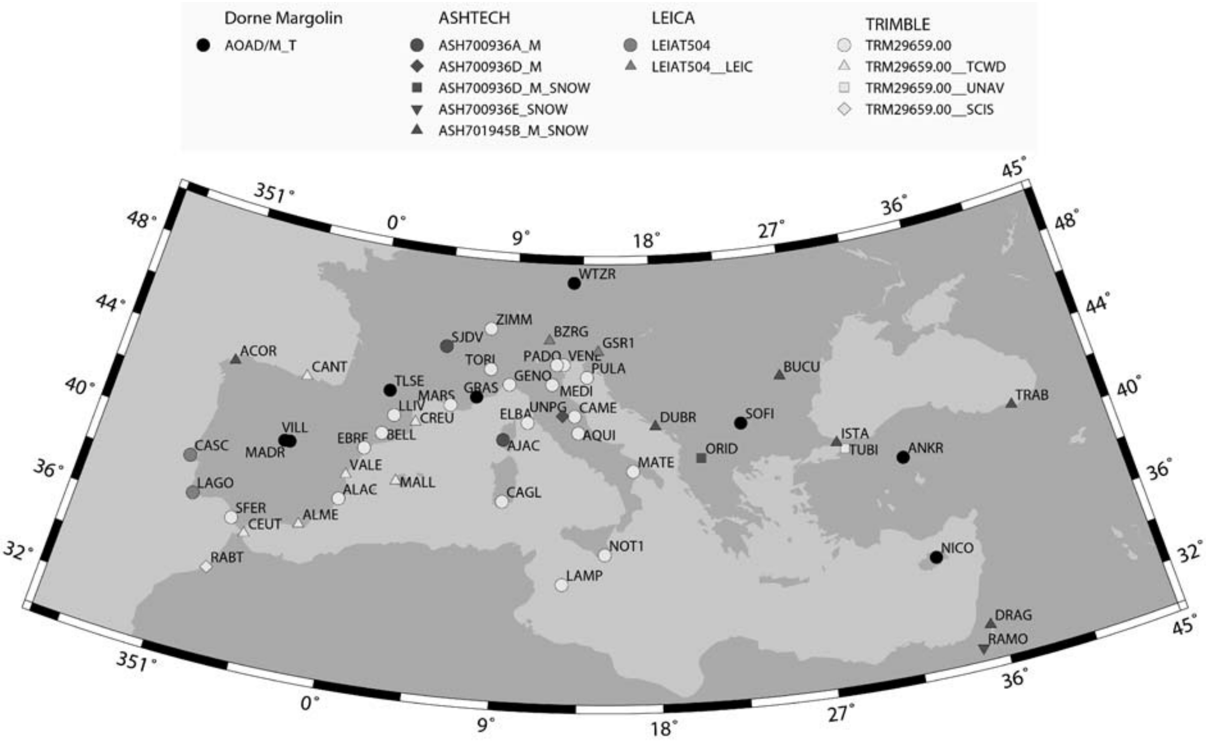

Figure 3: Map of the stations and antenna types used in the analysis

Figure 4 and 5 show the apparent horizontal and vertical position changes caused by the introduction of absolute receiver antenna PCV (compared to relative corrections). The station coordinates for Wettzell (WTZR) are kept fixed in both models for clarity to make the effect more visible. The horizontal displacements (figure 4) grow with distance from the base station Wettzell. The largest displacement can be seen at the station Mitzpe Ramon (RAMO), which amounts to 33 mm. It shows a significant vertical offset, which is almost constant over the full area. Both effects seen in these two figures are typical for a scale error. The scale error amounts for this specific network 14.9 ppb (compare table 1), which has also been reported by other groups (e.g. ROTHACHER et al. 1995) using absolute calibration models from anechoic chamber calibrations.

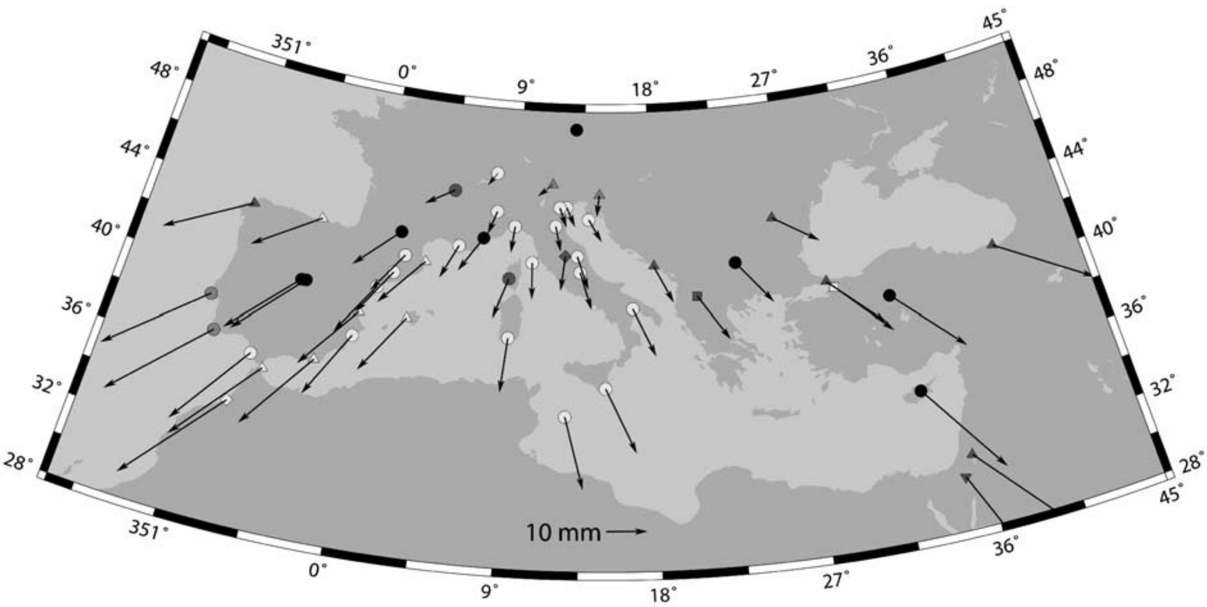

Figure 4: Apparent horizontal position changes caused by absolute PCV

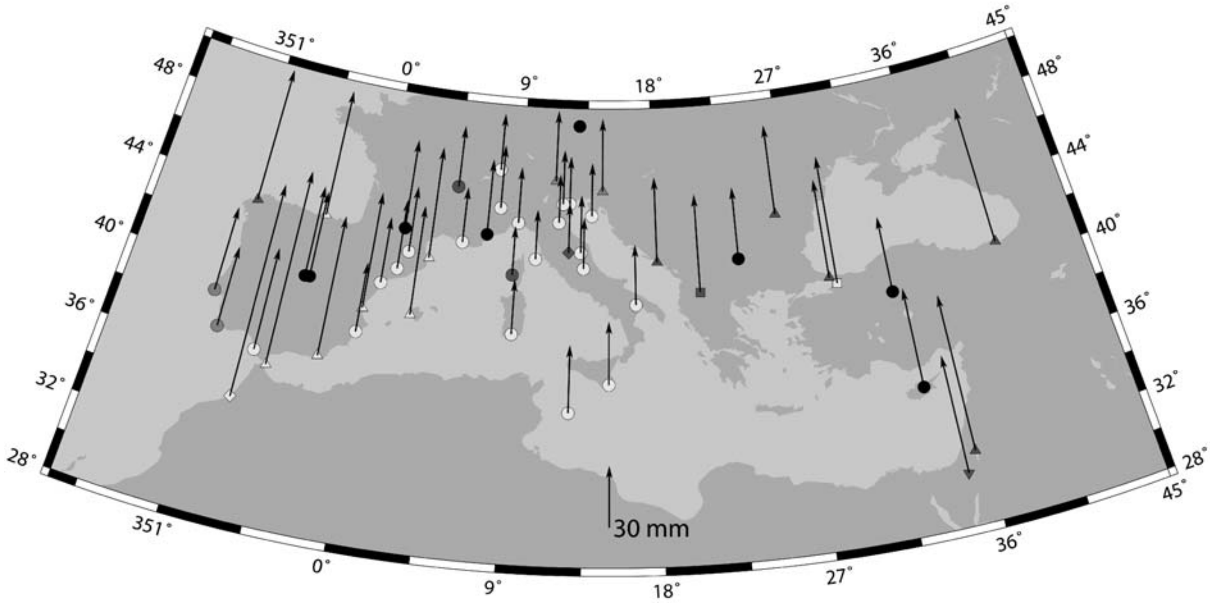

Figure 5: Apparent vertical position changes caused by absolute PCV

The second comparison takes into account that the mean GPS satellite antenna offsets determined by Mader and Czopek (2001) are more realistic than the standard values used so far. The comparison between model 1 and model 2 reveals that the effects are still the same while the size of the scale error decreases to 9.2 ppb.

Table 1: Scale factor between the different models caused by different antenna calibration models.

	Model 2	Model 3
Model 1	14.9 ppb	9.2 ppb

These results disclose a problem with the GPS satellite antennas. Obviously there are problems with the antenna offsets and as well with the PCV at the satellite antennas. Studies on these PCV are and have been carried out by ROTHACHER and SCHMID (2002) and are beyond the scope of this presentation. Nevertheless it has been proven by WÜBBENA et al. (2000) that the absolute antenna calibration models are correct and improve the results.

Influence of the antenna dome

Another aspect of antenna calibration models should be treated here as well. So far neither the IGS nor the EUREF community takes into account corrections for the different antenna domes used in their networks. It is known by the GPS community that domes have an effect mainly on the vertical position. Due to the lack of relative models, corrections are not yet applied.

Different antennas in connection with different domes have been calibrated using the absolute field calibration. Therefore we are able to study the effect of antenna domes on the position. Again two different set-ups are used to compute this effect. In the first step a network solution has been computed using relative calibration models where only the antenna type is considered while the effect of the dome is neglected. In the second step the same network has been processed again but this time relative calibration models are used where beside the antenna type also the different types of antenna domes are taken into account (compare figure 3 for different antenna types and domes). The relative models for the second step have been estimated from absolute calibration models using the "NULLANTENNA" for a conversion on a relative PCV level *(http://www.ife.uni-hannover.de/AOA_DM_T/)*. We chose to remain on the relative level for these tests because of the not yet solved scale problem with absolute PCV and since it is still the actual standard processing strategy of the LAC.

Figure 6 shows the apparent horizontal changes caused by the different domes. The changes are generally very small. An exception is the TRM29659.00 which triggers smaller position changes of approximately 3 mm. Even though this antenna does not carry a dome the change is connected to the horizontal offsets of this antenna type which is not considered in the standard processing scheme of the IGS and EUREF.

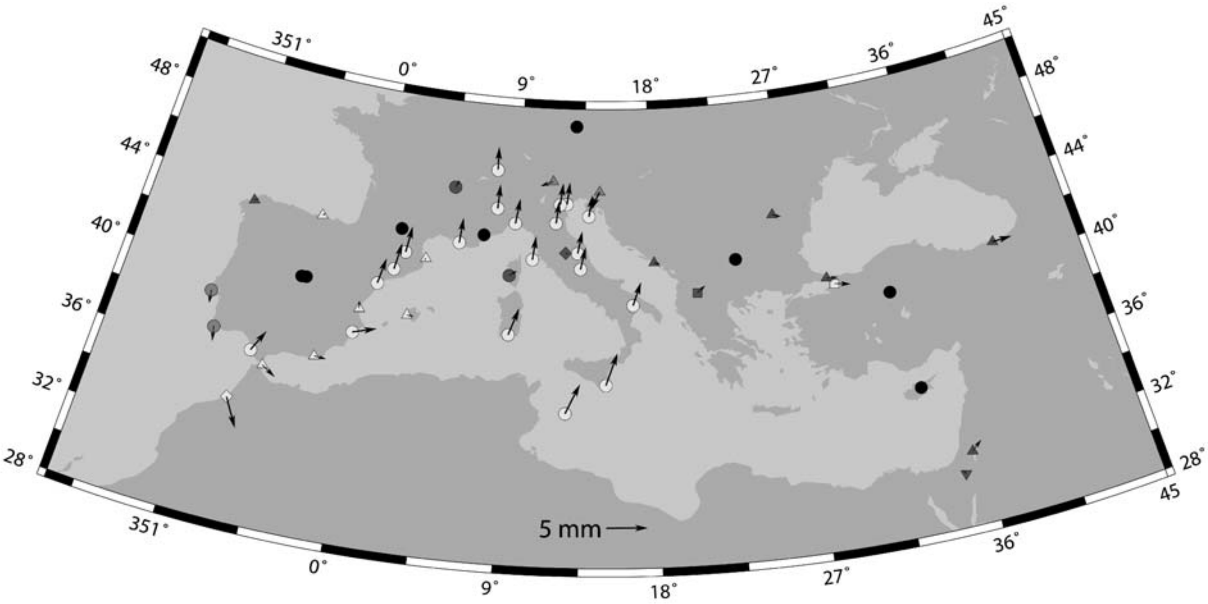

Figure 6: Apparent horizontal position changes caused by antenna domes

As seen in figure 7, the vertical position changes caused by the antenna domes are larger than the horizontal changes. Especially the Trimble TRM29659.00_TCWD causes the large vertical offsets followed by the Ashtech ASH700936D_M_SNOW and the Leica LEIAT5043__LEIC (table 2).

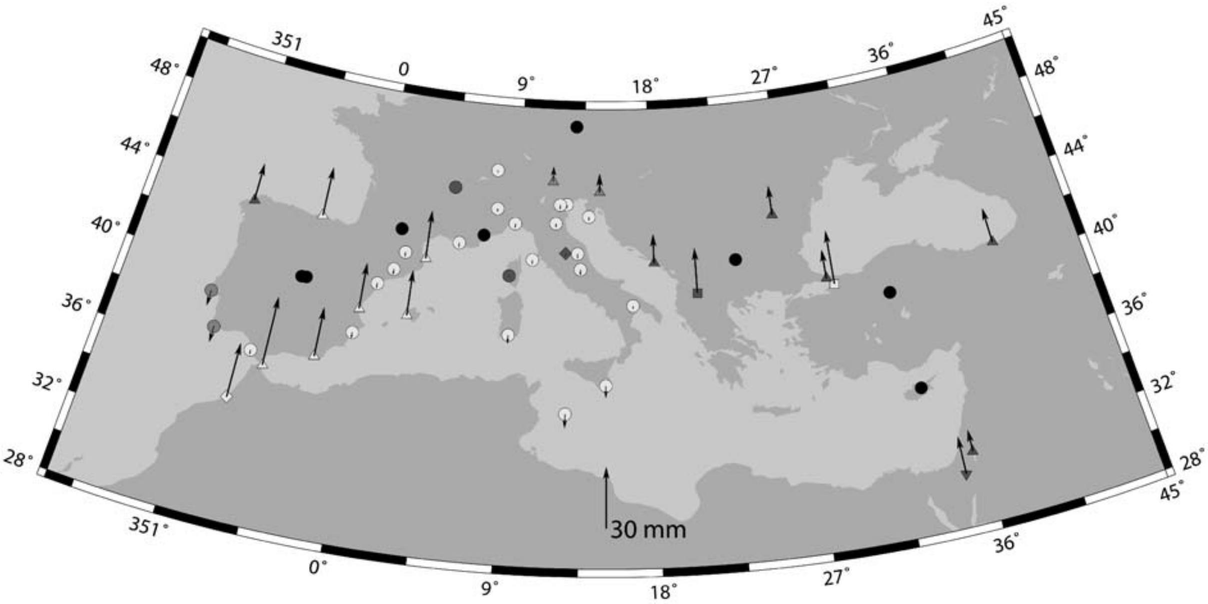

Figure 7: Apparent horizontal position changes caused by antenna domes

Table 2: Significant vertical offsets caused by antenna domes

Antenna Type	Realisations	) h [mm]
LEIAT504_LEIS	2	8.3
ASH700936D_M_SNOW	7	14.9
TRM29659.00_TCWD	6	24.7

The large effect on the Trimble choke ring antenna is caused by the ground plate which comes with this type of antenna dome. It is made from metal and changes the elevation dependent antenna characteristics significantly.

Conclusions

It has been shown that the introduction of absolute PCV calibration models lead to a significant scale error in large GPS networks. This should not lead to the assumption that the absolute PCV are incorrect since it has been proven by WÜBBENA et al. (2000) that the absolute models are true. The agreement of GPS, using relative PCV, with other space techniques like SLR or VLBI should rather be considered as being accidental, baring in mind that even the corrected mean GPS satellite antenna offsets (Block IIR) cause a scale error.

So far GPS satellite antennas had not been considered as a possible error source. Only recent studies by Mader (2001) as well as ROTHACHER and SCHMID (2002) indicate that satellite antenna PCV are a significant contributor to the scale error. Using these newly estimated satellite antenna offsets and PCV would allow to apply absolute PCV for the receiving antenna.

Dome problems are well known, but high resolution relative PCV corrections were not available until recently. It has been shown that the domes have a considerable effect on the antenna position. Mainly the height is effected whereas the horizontal effects are smaller. Still, the position error caused by domes is not a constant but depends on the satellite geometry observed at the specific site. The network used in this presentation is too small to disclose that, since the observed satellite geometry is to similar at each site.

Time series of position changes are not effected by the use of absolute or relative PCV as long as the time series are consistent. Nevertheless it should be kept in mind that the domes have a significant effect on the position. The connection between GPS heights and the gravity field will contain systematic errors as long as correct calibration models will not be used.

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