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First Results of Relative Field Calibration of a GPS Antenna at BCAL/UFPR (Baseline Calibration Station for GNSS Antennas at UFPR/Brazil)

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Abstract

The precise and accurate determination as well as the usage of individual calibration values of GNSS (Global Navigation Satellite Systems) antennas are of fundamental importance for state-of-the-art GNSS positioning at millimeter accuracy level, especially concerning the precise determination of the height component. Calibration values can be determined in various ways (relative vs. absolute, chamber vs. field). Within the transnational research project "PROBRAL: Precise positioning and height determination by means of GPS – Modeling of errors and transformation into physical heights", the first relative antenna calibration field of Latin America was established.

One main goal of this cooperation was to establish a relative receiving antenna calibration field for GNSS instrumentations on the roof top of the "Astronomical Laboratory Camil Gemael" called BCAL/UFPR (http://www.lage.ufpr.br/), situated on the Polytechnic Campus of the Federal University of Paraná in Curitiba (Brazil).

The status of the calibration field as well as recent results are going to be presented within this paper, e.g. a TRM22020.00+GP antenna was calibrated in three sessions of 24 h, with a data sampling rate of 15 s. The software WaSoft/Kalib was used to process the GPS phase observations. Carrier phase center offset values and carrier phase center variation values were determined relatively with respect to a Leica Choke Ring antenna.

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92.1 Introduction

The NAVSTAR GPS (Navigation System with Timing and Ranging – Global Positioning System), popularly known as "GPS", is able to contribute to various applications. One of them is to determine point coordinates with mm-precision. In order to fulfill this

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goal, systematic errors have to be taken into account. Within the evaluation of GPS measurements, the receiving antenna is a possible source of systematic errors.

Within the functional model of GPS data estimation, the location of the frequency-dependant phase center for GPS antennas is divided in two parts: PCO (phase center offset) and PCV (phase center variations), details see Sect. 92.2.

The subject "GNSS antenna calibration" has been investigated and analyzed by different international working groups for nearly two decades. Various studies, e.g. on receiver and satellite antenna phase center variations (e.g. Schmid et al. 2007) and on the influence of the dominant reflectors in the vicinity of the receiving antenna (e.g. Dilßner et al. 2008), have been carried out by the GNSS community recently. Due to the continuous improvement of the functional GNSS model (e.g. orbit determination, atmospheric modeling), site-specific effects are playing nowadays a more important role in GNSS positioning.

The intention for establishing a GNSS antenna calibration basis in Brazil emerged because there was no antenna calibration service in Latin America existing. The establishment of this calibration basis in Brazil (BCAL/UFPR: Baseline Calibration Station for GNSS Antennas at UFPR) is therefore the first one and was made possible especially due to technology transfer from Germany within the international cooperation PROBRAL: Precise positioning and height determination by means of GPS – Modeling of errors and transformation into physical heights, which was funded by CAPES (Brazil) resp. DAAD (Germany).

PROBRAL is a joint project between the Department of Geomatics (DGEOM), Federal University of Paraná (UFPR), Curitiba (Brazil) and the Geodetic Institute (GIK), Karlsruhe University (TH) resp. Karlsruhe Institute of Technology (KIT), Karlsruhe (Germany). The aim of the research project is to validate and improve the quality of GNSS-based positioning, especially of the height component. The joint project, which started in 2006, is founded by the Brazilian academic exchange service CAPES and by the German academic exchange service DAAD.

BCAL/UFPR was established at the Centro Politécnico on the campus of Paraná Federal University in the city of Curitiba, on the roof top of the "Camil Gemael" astronomical observatory (Fig. 92.1), at the annex auditory alongside of LAGE (Spatial Geodesy Laboratory) with respect to logistic aspects (e.g. power supply, security) and signal quality at the site (e.g. multipath effects). Due to the fact that, multipath effects can cause significant errors when determining GPS antenna calibration values, these effects have to be taken into account, when choosing an appropriate calibration site location.

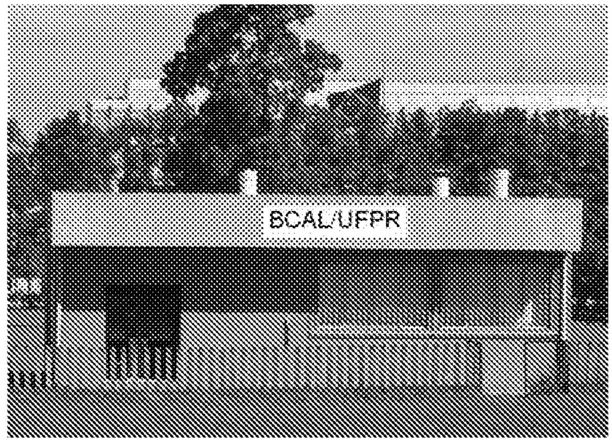

Fig. 92.1 BCAL/UFPR; antenna calibration field

92.2 Receiving Antenna Calibration Values

The location of satellite signal reception related to a GNSS antenna is called phase center.

Dealing with phase centers, one has to distinguish between the two terms: component-related mechanical phase center and electrical phase center, whereas the electrical phase center is identical to the direction-related signal reception point. This phase center is in most cases neither located at the antenna's rotation axis nor necessarily coincident with the geometric center of the antenna. The PCO is a 3d displacement vector between the average frequency-dependant phase center and the antenna reference point (ARP), see *P* of Fig. 92.2. The PCV are additional systematic displacements of the phase center of the antenna. PCV are elevation-dependent, see Fig. 92.2. The phase center will vary as function of the satellite signal direction change. Ignoring the variations of the phase center

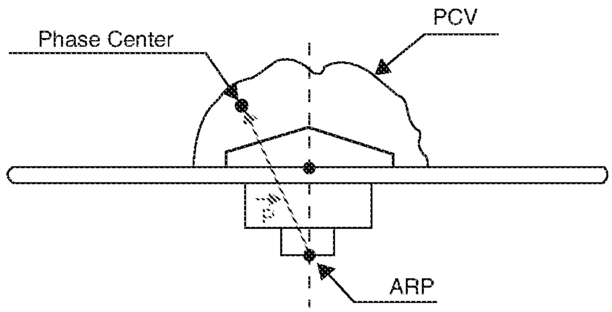

Fig. 92.2 Modeling schema, phase center

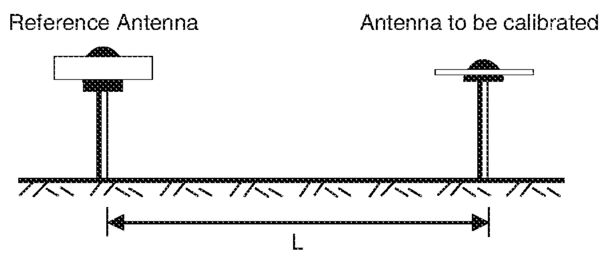

Fig. 92.3 Relative field calibration

can lead to significant vertical errors, which can even reach up to 10 cm (e.g. Menge et al. 1998).

92.3 Relative Field Calibration of GNSS Antennas

A short baseline, usually a few meters long, is chosen for the relative field calibration approach for GNSS receiving antennas in order to minimize orbital errors and atmospheric influences (Freiberger 2007). The baseline has to be well defined and determined with high precision. Both sites of the baseline should be affected with minimum multipath effects.

Within the relative calibration approach two antennas are used (see Fig. 92.3): The reference antenna is usually of Dorne/Margolin Choke Ring antenna type. The calibration values (PCV, PCO) of the second antenna are determined with respect to the reference antenna relatively. This antenna type is used by the NGS (National Geographic Service, Silver Spring, MD, USA) for relative field calibration (e.g. Mader 1999).

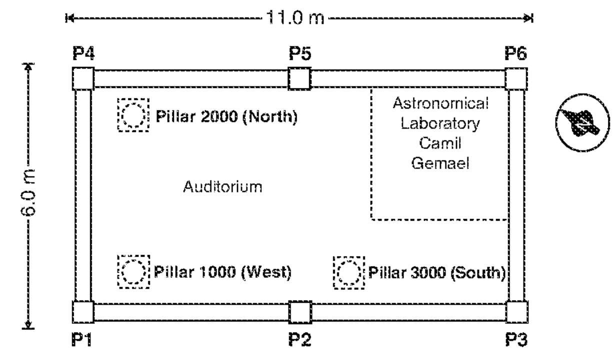

Fig. 92.4 Location of the three pillars of the BCAL/UFPR and the six leveling control points (P1 ... P6)

92.4 Baseline Calibration Station for GNSS Antennas at UFPR

The research described here, was carried out at Centro Politécnico of Federal University of Paraná in the city of Curitiba (Brazil) as part of a PROBRAL project, where transfer of technology is one main goal.

The BCAL/UFPR (Baseline Calibration Station for GNSS Antennas at UFPR) is actually equipped with three pillars (1000, 2000, and 3000) on the roof top of the "Astronomical Laboratory Camil Gemael". The monumentation is based on a core of steel and concrete with a height of approx. 1.3 m, measured from the base of the block. Based on experiences concerning the establishment and monumentation of geodetic network points gained at the Geodetic Institute of the Karlsruhe University (TH) three stable pillars could be constructed consisting of material with a long expected lifetime.

In order to monitor the behavior of the building, a leveling line (control points P1...P6, see Fig. 92.4) was established and is observed at least two times per year. Until now, the differences between the leveling runs were considerably small.

92.5 Multipath Analysis of BCAL/UFPR

In order to analyze the multipath impact on potential calibration sites, measurements were carried out using different dual-frequency GPS receivers in 2008. The data were collected in several sessions of 24 h with a data rate of 15 s.

The software WaSoft/Multipath 3.2 was used to detect and localize carrier phase multipath (Wanninger 2009a). Therefore, various GPS networks consisting of a maximum of five reference stations were analyzed. According to Wanninger and May (2000) and Wanninger (2005) the multipath detection algorithm is based on the following characteristics and assumptions:

- Dominant multipath periods range from 10 to 45 min and depend mainly on the distance between reflector and receiver antenna.
- Ionospheric refraction is eliminated using the ionosphere-free linear combination.
- The software WaSoft/Multipath 3.2 was developed to check multipath effects of GNSS reference stations. Due to the location of the receiver antennas (e.g. top of roofs), it could be assumed that all reflectors are situated at low elevation angles. Thus, it is appropriate to expect that satellite signals with low elevation angles (e.g. below 50°) are affected and signals received from higher elevations (e.g. above 50°) show little or no multipath effects.
- Due to the fact that multipath effects are site-specific, multipath effects of different network stations are uncorrelated.
- In detail, the software is based on undifferenced residuals of the ionosphere-free linear combination

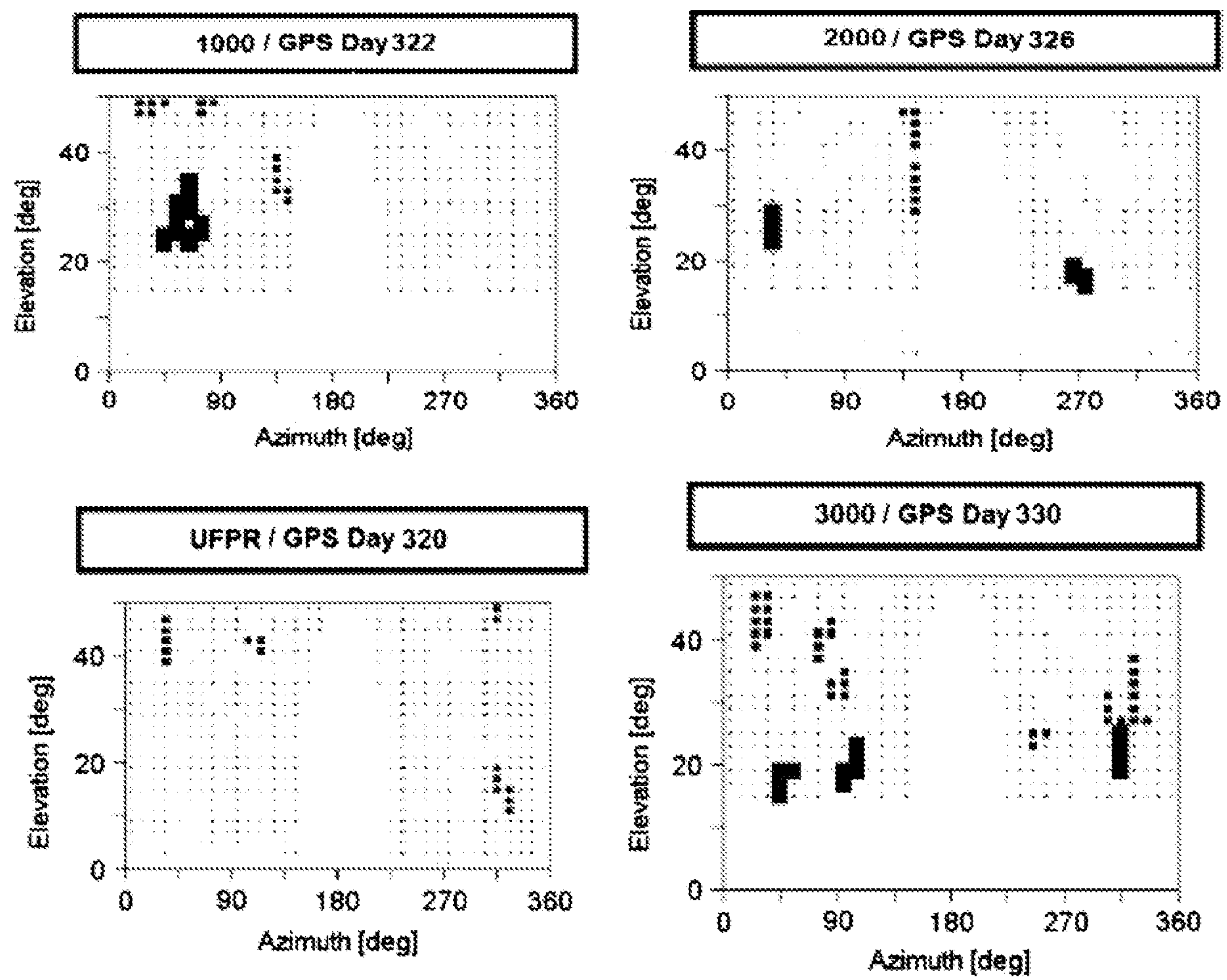

Fig. 92.5 Representative results of multipath case study of four sites (UFPR, pillars 1000, 2000 and 3000)

L3, calculated for 20 min blocks. Using undifferenced residuals time series, double-differences of simultaneous observations of the highest and a low satellite of one site are calculated and compared based on correlation coefficients to the corresponding observations collected at other sites of networks consisting of at least three sites. By means of averaging techniques carrier phase ambiguities, remaining tropospheric effects, and the influence of orbit errors are reduced.

The program WaSoft/Multipath 3.2 needs 24 h data, with an interval not bigger than 60 s. In this case study, RINEX data sets collected with different dual-frequency GPS instrumentations were used. Broadcast ephemerides were introduced, too. The network limits are smaller than 100 km. The coordinates of the stations are known in the WGS84 reference frame with a precision in the range of a few centimeters (Wanninger 2005).

A subset of the analyzed network consisting of four stations (UFPR, pillars 1000, 2000, 3000) has been selected and WaSoft/Multipath was used to analyze the data in terms of multipath conditions (see Fig. 92.5).

The used symbols of Fig. 92.5 are relating to multipath impact

- Blank: no observation data.
- Dots: no multipath effects detected (standard deviation based on L3 < 5 mm).
- Small squares: minor multipath effects (standard deviation based on L3: 5–15 mm).
- Completely black: major multipath effects (standard deviation based on L3 > 15 mm).

Figure 92.5 shows highest carrier phase multipath effects resulting from signals with a low angle of incidence from east directions and from an elevation of 0° to 50°. All other signals show minor or no multipath errors.

Pillar 3000 seems to be more affected by multipath effects than the pillars 1000 and 2000. Nowadays, all pillars are less affected by multipath due to the fact that obstacles – detected within the above described case study – were eliminated. With this analysis it could be ensured that the BCAL/UFPR was built at an appropriate location for relative calibration of GNSS antennas.

92.6 Results of the First Relative Field Calibration Experiments

First calibration experiments were carried out in order to gain calibration values for GPS TRM22020.00+GP antennas. Based on the above described multipath case study, pillar 1000 (pillar 2000) was chosen as location for the reference antenna (antenna to be calibrated).

The antenna to be calibrated was rotated with the so-called DRB device. DRB was developed by the Technical University of Dresden (Germany) to meet the needs of scientific experiments, especially in GNSS antenna calibration (Frevert et al. 2003). This automatic device rotates the antenna to be calibrated scheduled. Within this case study the antennas were rotated within 60 s from north direction (measurement: T = 0 s) to south direction (measurement: T = 15 s). Fifteen seconds later the antenna pointes to west direction (measurement: T = 30 s) and finally at T = 45 s the antenna points to east direction and is than rotated back to the north direction. This cycle is repeated each minute.

The collected data was post-processed using the software Wasoft/Kalib (Wanninger 2009b), which was developed to determine GNSS antenna parameters for relative calibration consisting of PCO and PCV.

A two-frequency geodetic equipment (Leica GPS1200 receiver, Leica Choke Ring antenna (AT504), see Fig. 92.6, left) was used as reference antenna. The antenna to be calibrated (Trimble TRM22020.00+GP) is shown in Fig. 92.6 (right) as well as the DRB device. The measurements were

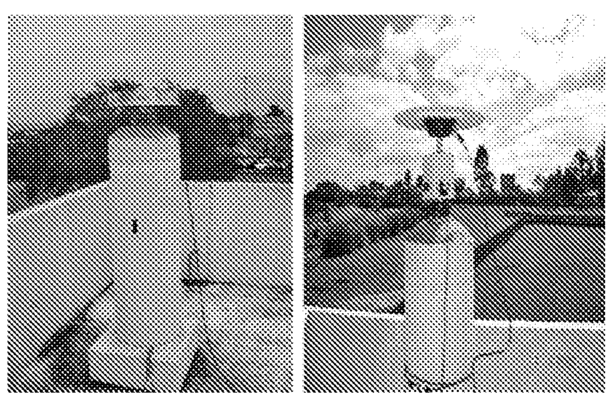

Fig. 92.6 Relative field calibration at the BCAL/UFPR, left: reference antenna, right: DRB device and calibration antenna

Table 92.1 PCO values (north, east and up components) and corresponding standard deviations

PCO (mm) Antenna: TRM22020.00+GP (SN 12347)				
	L1	Standard deviation	L2	Standard deviation
1st experiment – GPS Day 245-2008				
North component	0.1	0.0	−0.3	0.1
East component	−2.1	0.0	2.7	0.1
Up component	53.0	0.1	60.0	0.2
2nd experiment – GPS Day 247-2008				
North component	0.2	0.0	−0.5	0.1
East component	−2.0	0.0	2.5	0.1
Up component	53.1	0.0	59.9	0.2
3rd experiment – GPS Day 248-2008				
North component	0.3	0.0	−0.6	0.1
East component	−2.0	0.0	2.6	0.1
Up component	52.8	0.0	59.5	0.2

carried out in three sessions of 24 h, with a data recording interval of 15 s.

The resulting PCO values (north component, east component, up component) and the standard deviations for L1 and L2 of the antenna TRM22020.00+GP (SN 12347) can be found in Table 92.1.

The same antenna shows slightly different PCO behavior for both L1 and L2. The largest variations are on L2 carrier, due to lower transmitted energy (Freiberger 2007). For L1, the largest variation found is 0.2 mm for the experiments 1–3 in the north component. For L2, the largest variation found is 0.3 mm for the experiments 1–3 in the north component. In the up component for L2, the largest variation found is 0.5 mm. Comparing the north, east and up components, for both carriers (L1 and L2), the largest variations show up for the L2 carrier. All results show good repeatability.

92.7 Conclusions and Future Work

First results of relative field calibrations of GPS antennas at BCAL/UFPR (Baseline Calibration Station for GNSS Antennas at UFPR) were obtained. Such values can now be provided for Brazil and all countries of Latin America for the first time.

Analyzing the experiment's results, small variations were found, which proof that the calibration method was applied correctly.

It is intended to do further calibration experiments in different seasons of the year in order to verify the behavior of north, east and up PCO components. In addition, the PCV are going to be analyzed.

Experiments using absorber material in order to reduce pillar-reflected multipath are planned. Investigations on the influence of meteorology on phase multipath effects will be carried out, too.

Acknowledgements PROBRAL – the recent cooperation between the Geodetic Institute, University Karlsruhe (TH) resp. Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany and the Department of Geomatics, Federal University of Paraná, Curitiba, Brazil – is funded by the German academic exchange service DAAD and the Brazilian academic exchange service CAPES.

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References

Dilßner F, Seeber G, Wübbena G, Schmitz M (2008) Impact of near-field effects on the GNSS position solution. International technical meeting, ION GNSS-08, Savannah, Georgia, USA

Freiberger J Jr (2007) Investigações para a calibração relativa de antenas de receptores GNSS. Thesis (Doutorado em Ciências Geodésicas), Departamento de Geomática, Universidade Federal do Paraná, Curitiba, Paraná, Brazil

Frevert V, Nuckelt A, Stöcker D (2003) Beschleunigte Feldkalibrierung von GPS-Antennen. DGON-symposium POSNAV 2003, Dresden, 18./19.3.2003. Schriftenreihe des Geodätischen Instituts, TU Dresden (Germany). Heft 3:353–359

Mader G (1999) GPS antenna calibration at the national geodetic survey. GPS Solut 3(1):50–58

Menge F, Seeber G, Völksen C, Wübbena G, Schmitz M (1998) Results of absolute field calibration of GPS antenna PCV. In: Proceedings of the 11th international technical meeting of the satellite division of the institute of navigation ION GPS-98, September 15–18, Nashville, Tennessee

Schmid R, Steigenberger P, Gendt G, Ge M, Rothacher M (2007) Generation of a consistent absolute phase center correction model for GPS receiver and satellite antennas. J Geodesy 81(12):781–798

Wanninger L, May M (2000) Carrier phase multipath calibration of GPS reference stations. In: Proceedings of ION GPS2000, Salte Lake City, UT, 132–144

Wanninger L (2005) Carrier phase multipath detection and localization in GPS reference station networks. http://www.wasoft.de/e/mltp/index.html

Wanninger L (2009a) Anleitung Wasoft/Multipath. Ingenierbüro Wanninger. http://www.wasoft.de

Wanninger L (2009b) Anleitung Wa1/Kalib. Ingenierbüro Wanninger. http://www.wasoft.de