AOAD/M_T Choke Ring GPS Antenna

Absolute Phase Center Variations

Results of Absolute PCV Field Calibrations
at IfE and Geo++ ®

compiled by Falko Menge and Dr. Martin Schmitz, version 1.2

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(original AOAD/M_T Choke Ring antenna on the robot during calibration procedure)

(original AOAD/M_T Choke Ring antenna used for this calibration)

Download complete html-pages - *without PCV tables:* pdf-file (0.6 MB)

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History

Changes and updates of the AOAD/M_T web-sites:

- Version 1.0, 16.06.2000:
  - First publication of absolute PCV results (field calibration) of the AOAD/M_T.

- Version 1.1, 04.05.2001:
  - Update of Nullantenna file in IGS-Format (nullantenna.igs). There are slight changes due to the transformation procedure of the absolute field calibration results to the AOAD/M_T IGS-Offsets

    L1=+0.00000 +0.00000 +0.11000, L2=+0.00000 +0.00000 +0.12800 (north, east, height in meter).

    Originally, the horizontal Offsets L1=+0.00060 -0.00046, L2=-0.00010 -0.00062 (north, east in meter) were also used within the transformation. This was not rigorous, since the azimuthal PCV described by the Offsets (e.g. L1-north: 0.6 mm) were introduced. Elevation dependent PCV cannot take up azimuthal PCV. Now, the field calibration result is only transformed to the IGS-height of the AOAD/M_T (L1=110 and L2=128 mm), while keeping the horizontal Offsets. Afterwards, all Offsets again are set to zero.

    The downloadable pdf-file of this publication is not affected by the changes.

    More theory and details of the Nullantenna will be presented in an extra chapter in this publication soon.
  - History list (this file), in order to show all changes and updates of theses web-sites.

- Version 1.2, 17.05.2001:

  Extension of publication list (incl. downloadable files).

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1. PCV Calibration of GPS Antennas - *General Overview*

The point of reception of the GPS signal at the antenna is not homogenous. This phase error is a function of the signal’s direction and varies with azimuth and elevation. The magnitude of the phase center variations (PCV) typically spans a range of mm to cm. The neglection of this antenna behavior can lead to baseline errors between mm and cm. It can even reach up to 10 cm for the height component. The different error magnitudes of the effects are due to differences of measurement setups and following GPS processings (antenna types, mixed baselines, used linear combination, estimation of tropospheric parameters, network type, kinematic applications, used elevation angle, measurement time, engineering applications, rotated/tilted antennas, type and quality of PCV correction ...).

A widely used correction for the PCV is a ***pure offset***. But the offset estimation depends on the elevation mask and the location/constellation/multipath. Furthermore, there are different definitions of the offset (3D offsets relativ to a reference antenna, 2D horizontal absolute offsets + vertical relative offset, minimum conditions). An absolute 3D offset can only be determined with the help of rotations AND tilts of the antenna. Therefore, offsets are only a rudimentary and approximate correction. A complete correction modell including PCV should be used in precise applications.

The most common calibration type is the ***relative field calibration***. The setup is quite simple. Reference coordinates are in most cases necessary. The results for the PCV of the tested antenna are relative to a reference antenna. Per definition, the PCV of this reference antenna are set to zero and the offsets are also fixed. The typical reference antenna for the relative field calibration is the AOAD/M_T choke ring antenna (e.g. IGS/NGS). Because of the influence of site multipath and the insufficient covering of the antenna hemisphere with observations, typical results for the PCV corrections are only elevation dependent and have a minimum elevation mask of 10 degrees. Due to the "lack" of absolute PCV information, the corrections are not sufficient for networks with differently orientated antennas (large networks, engineering applications).

Absolute chamber calibrations are another possibility for the determination of GPS antenna’s PCV. The test antenna will be precisely moved within an anechoic chamber. An artificial GPS signal is used. Difficulties for this type of calibration may be the artificial signal, the precise definition of the reference point, the mechanical precision of the whole mechanical setup and, possibly, remaining multipath. It is hard to achieve a very high number of observations for a well covered antenna hemisphere.

The ***absolute field calibration*** is another calibration procedure for the determination of PCV. The technical constraints for this calibration are quite high. But through a special field setup and measurement program (rotation AND tilts of the antenna, elimination of multipath), the results are absolute and not site dependent. Azimuthal PCV can be resolved and results down to elevation zero can be determined. More detailed information on absolute PCV field calibration can be found in the next paragraph and in various publications.

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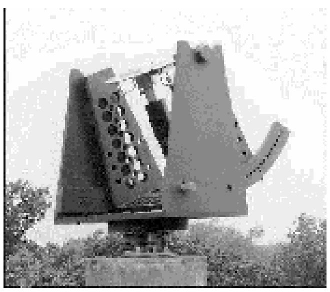
2. Absolute PCV Field Calibration - *Basics and Procedure*

Starting point for the development of this procedure was, that existing field calibrations were only relative (refering to a reference antenna) and correlated with the site (multipath influence and satellite constellation, i.e. northern hole). The goals were

- separation of multipath and PCV
- absolute results independent of a reference antenna
- high resolution of the PCV
- field procedure.

The realization has two features to handle the problems "relative" and "multipath influence". First of all, in order to get the absolute PCV information, the test antennas are rotated AND inclined. Secondly, differences between observations with identical multipath effects are used to eliminate site correlations.

Antenna Mount


a)

b)

c)

During the first development phase of the project we used the two mounts shown above (a, b). In order to achieve a better stability and precision, the current procedure makes use of a robot (c). Considerable efforts were necessary to develop an error model for the robot. The observations for this modell are derived from a tachymetric measurement system (TMS). Beside an exactly known position due to the precise robot and the high number of possible rotations and tilts, another advantage is the possibility of an automation of the calibration procedure.

Multipath Elimination and PCV Estimation

The satellite constellation repeats after a mean sidereal day. In case of identical conditions (geometry, weather, surfaces ...), also multipath effects repeat with the same period. Thus, with the pre-conditions fulfilled, day time differences eliminate the multipath influence. Since the PCV information is elimated also, the antenna has to be rotated and tilted on one of the two measurement days. The difference of the PCV between the rotated/tilted position and the fixed position will be the observable for the PCV determination. **- NEW -** The multipath elimination approach has been improved within the second phase of the project. The current calibrations are a real-time procedure without a static reference day. The multipath conditions between close measurement epochs are identical. Therefore, the difference between epochs can eliminate the effects (the realization within the software uses the correlation in time of the multipath). Finally, with both possibilities for the multipath elimination/reduction, spherical harmonic functions serve for the PCV estimation.

Advantages of the Absolute PCV Field Calibration

There are several advantages of the absolute PCV field procedure:

- absolute PCV (L1, L2, GPS, Glonass) in real-time
- independent of reference antenna and reference coordinates
- elimination of multipath
- precise robot, exactly known reference point (pivot)
- very good coverage of the whole antenna hemisphere with observations
- automated measurement program
- PCV down to elevation zero
- significant azimuthal PCV.

The high resolution of the PCV and the possibility to estimate reliable and repeatable azimuthal PCV is based on the automation of the measurement program. With the help of the robot, there are between 4000 and 7000 different positions (standard procedure) of the antenna. The measurement program changes with the actual satellite constellation. Thus, a total coverage of the whole antenna hemisphere is reached. Furthermore, a dynamical elevation mask is used (only satellites in high elevations) within the observation procedure.

With the presented procedure (especially through the use of a highly precise and calibrated robot and the automation of the measurements), very precise and reliable PCV corrections can be derived (e.g. see AOAD/M_T results), even down to elevation zero and also for azimuthal PCV. The results have been independently confirmed through measurements

- with different robots
- at different sites
- on different days.

More detailed information can be found in several publications.

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3. Discussion of Absolute PCV - *Effects, Large Networks, Engineering Applications*

The consideration of absolute PCV corrections plays an important role for precise GPS coordinate determination in several fields of application. Within large networks, simultaneously received satellite signals differ in their directions, because of the baseline length and the different orientation of the antennas. Absolute PCV are needed for this observation constellation. Relative PCV information is not sufficient (relative PCV are zero for identical antenna types, but no corrections are obviously insufficient for differently orientated antennas). The other main advantage of absolute PCV is their high resolution (-1- repeatability, -2- significant results for azimuthal PCV, -3- PCV information down to elevation zero). This information is needed for a variety of precise GPS applications, as for example in engineering surveys (e.g. inclined antennas in railroad surveying or machine guidance), in reference networks with mixed antenna types of user and provider and also for "standard" processing of regional networks (observations lower than 10 degree elevation contribute to a better separation of troposphere and height).

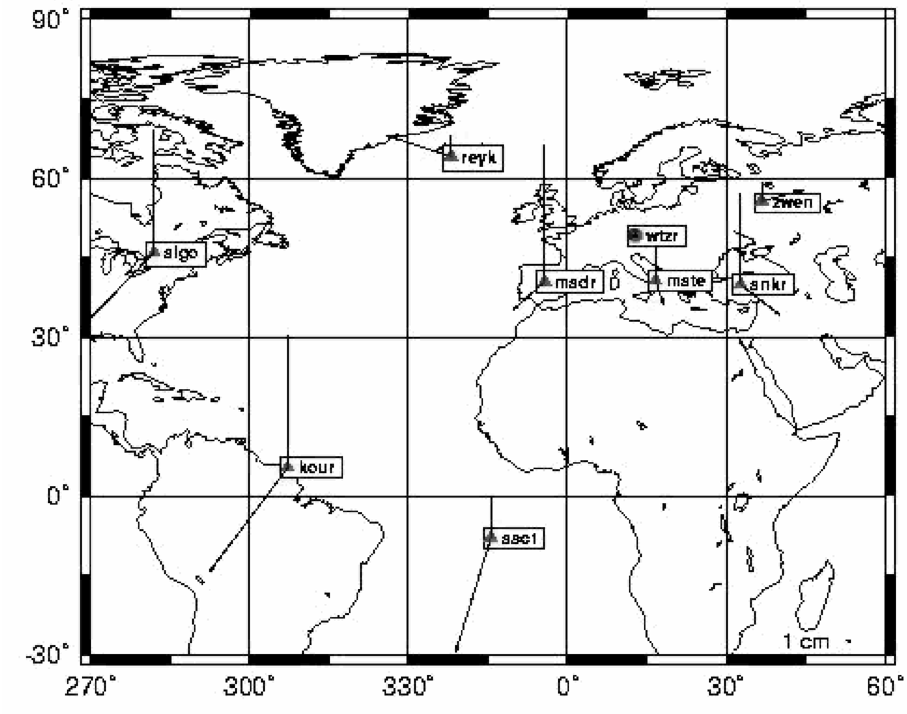
The AOAD/M_T choke ring antenna is the most common antenna type within the global network of the International GPS Service (IGS). Furthermore, it serves as the reference antenna for relative PCV calibrations. This group already presented some examples with absolute PCV for the AOAD/M_T (beside other mixed antenna applications) verifying the functionality and the effects of absolute PCV (e.g. ION GPS-98, see publications).

Separation of absolute PCV from other errors (satellite antenna / troposphere / coordinates)

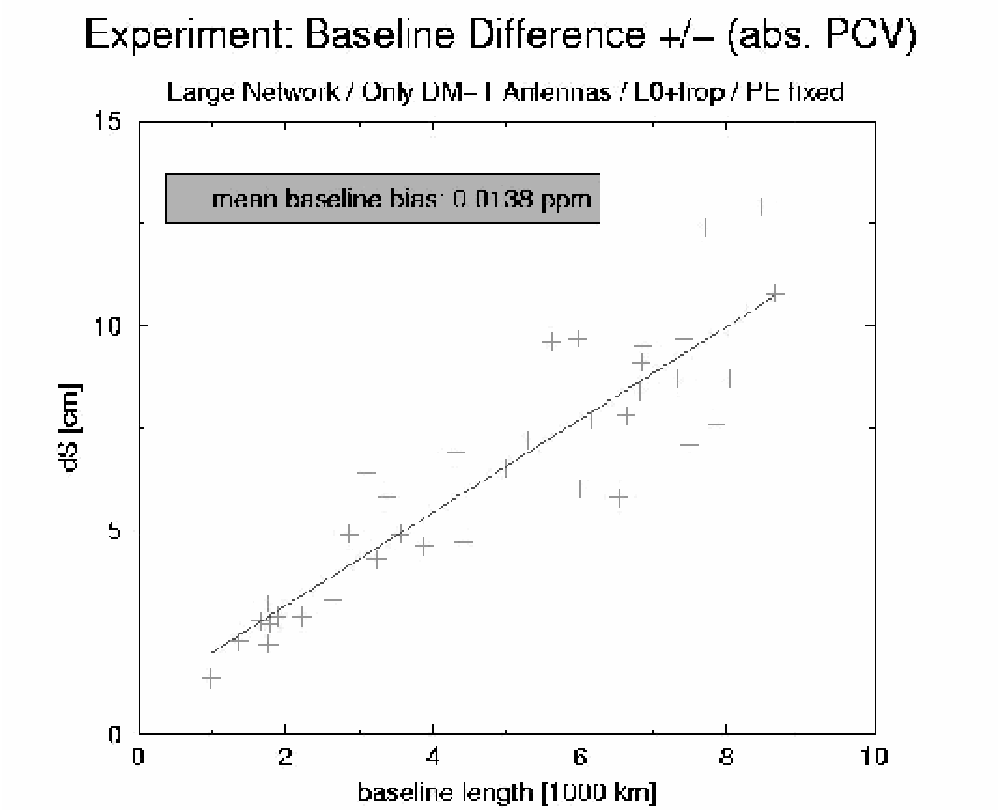
For the verification of the absolute PCV our group did not carry out direct comparison of network results with ITRF, since the ITRF implies VLBI, Laser *AND* also GPS results. It is almost impossible to separate the individual error terms from PCV effects and a (sub-) mm true reference is generally not available. Our subsumtive way to verify the absolute PCV - correctness and effects - always avoids most error components and refers to a well known reference:

- *Mixed short baseline:* Mixed short baseline applications, including use of the ionospheric free linear combination and estimation of tropospheric parameter, and the comparison with the precisely known reference coordinates (e.g. ION GPS-98, see publications, additional experiments will be carried out).

- *Large network processing:* Comparison of two solutions of large network processing (identical antennas AOAD/M_T, precise ephemeris, ionospheric free linear combination, tropospheric parameter). The only difference in the processing (identical options/parameter) are the introduced absolute PCV in one solution. The difference reveals a sort of scale in the order of 0.014 ppm (still, it is a first order effect for long observations; there are also constellation dependencies), which shows the effect of neglected absolute PCV information (e.g. ION GPS-98, see publications, additional experiments will be carried out).



(AOAD/M_T IGS network, difference of +/- absolute PCV solutions)

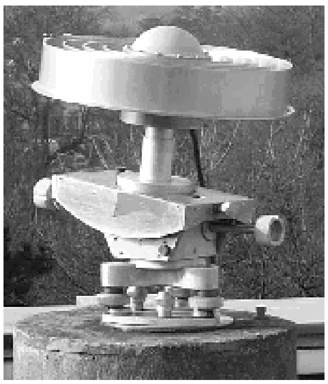


(AOAD/M_T IGS network, different lenght of baselines +/- absolute PCV solutions)

- *Large network simulation:* In order to compare the coordinates of a large network with a true reference, we conducted a simulation with a rotated and inclined antenna on a known short baseline. There are no effects due to other error sources (satellite, atmosphere, coordinates). Therefore, a separation of the effect can be easily done, while comparing the results using absolute PCV with precisely known reference coordinates. Height differences are shown in the next table. The AOAD/M_T antenna was inclined +/- 5 degree (roughly corresponding to about 550 km network extension) and also rotated (using an antenna mount; will be repeated with a more extensive measurement program with the robot). We compared the solution with no corrections (comparable to actual processing using relative PCV in a network like IGS) as well as the one with introduced absolute (**orientated!**) PCV with known reference coordinates. Errors in the range of 1 cm showed up without absolute PCV. Using the absolute PCV, only differences in the mm-range compared to the reference coordinates can be seen.

Two choke ring antennas, 24h observation, L0+trop-solution, -pcv (no PCV), +pcv (orientated absolute PCV), height differences to truth:

az = 030 °, zenith = 85 °	- pcv (difference to truth)	15 mm
	+ pcv	3 mm
az = 345 °, zenith = 95 °	- pcv	19 mm
	+ pcv	4 mm



(inclined and rotated AOAD/M_T on antenna mount)

The results of all these tests underline the correctness of the absolute PCV, show their influence on GPS network solutions and verify the succesful separation of the absolute PCV antenna effect.

More tests and examples for diverse areas of applications with new absolute PCV results will be shown and published soon.

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4. Absolute PCV Calibration of AOAD/M_T - *Details, Accuracy, Precision*

Absolute PCV Results of AOAD/M_T

The Allen Osborne Associates Dorne Margolin Model T (AOAD/M_T), serial number (SN) 404 has been extensively calibrated using the automated real-time absolute PCV field calibration method by IfE and Geo++®.

There were in total 42 calibrations, which were combined using the complete variance-covariance matrix of the individual results for a combined PCV estimation.

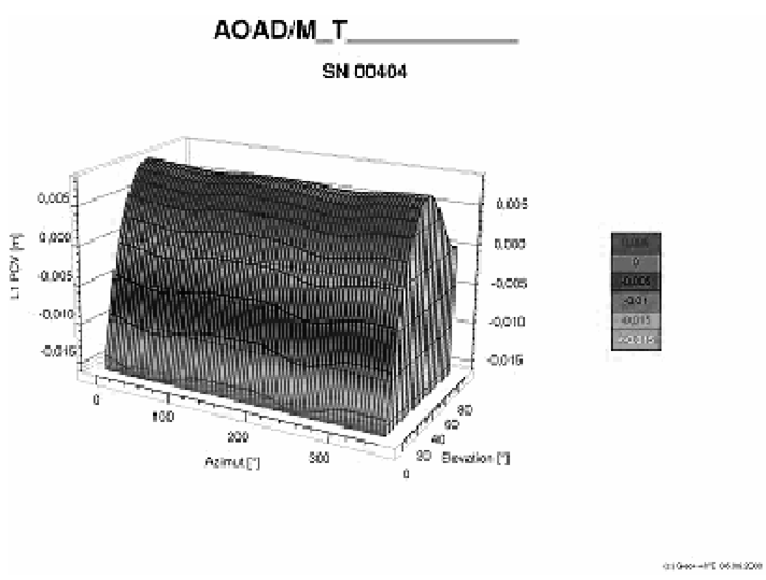
The calibrations differ by location, constellation (robot, satellites, weather, ...) and date. Spherical harmonics of degree 8 and order 5 were used for all real-time calibrations and for the final PCV model.

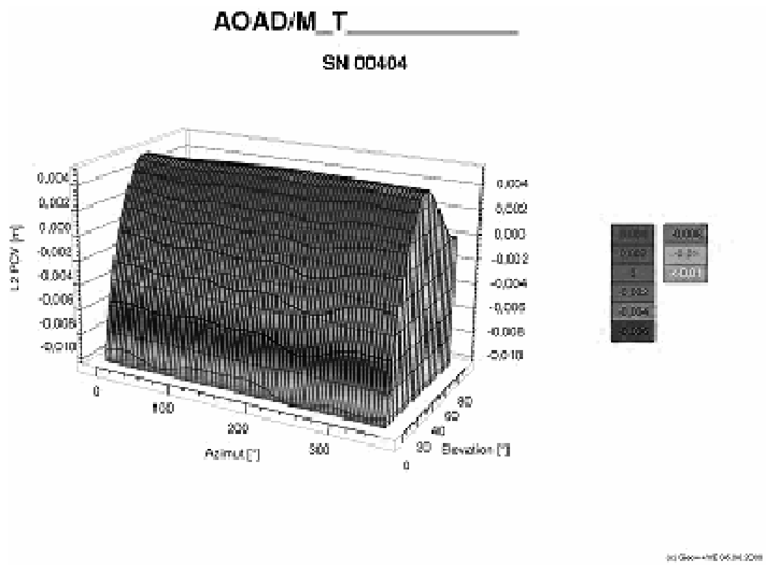
The absolute PCV are given in meter using the sign convention of the Geo++ antenna file format, which is opposite to the IGS/NGS. The graphics show the L1 and L2 PCV after removing the offset

OFFSETS L1=+0.00060 -0.00046 +0.09124
OFFSETS L2=-0.00010 -0.00062 +0.12006

(north, east, height in [m]).

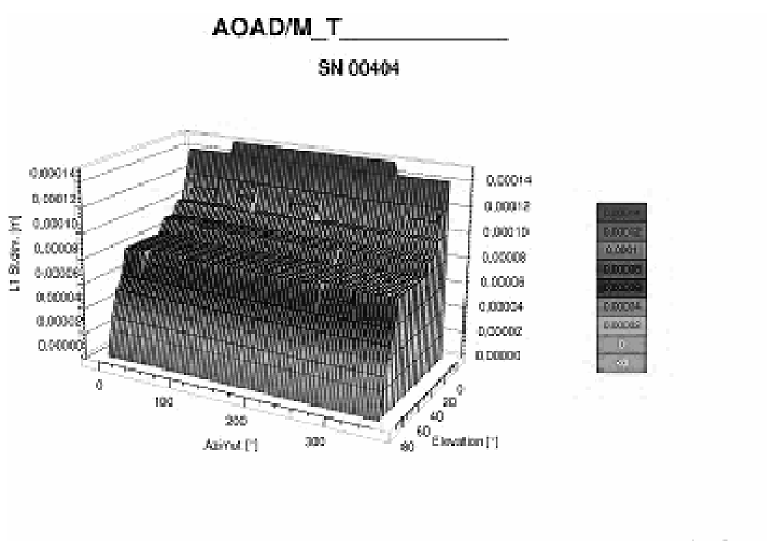
The PCV vary for L1 over a range of approximately 20 mm and for L2 over 14 mm (click on the images - L1, left / L2, right - for a high resolution jpg).

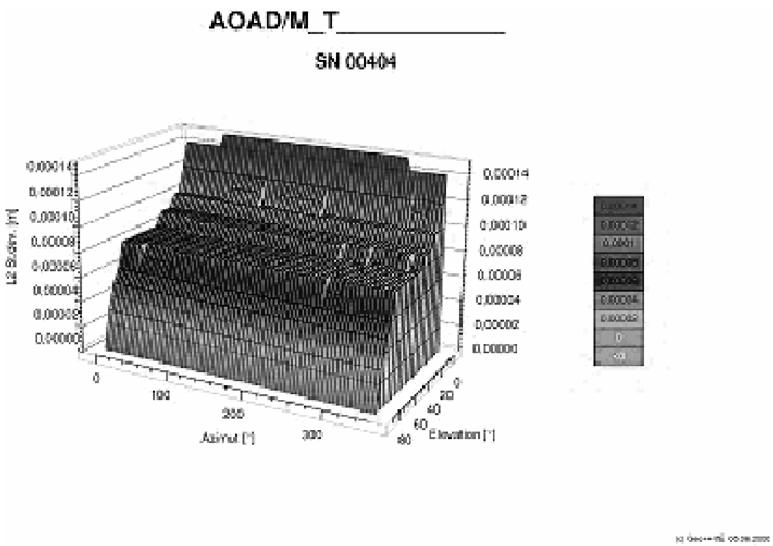




Standard Deviation

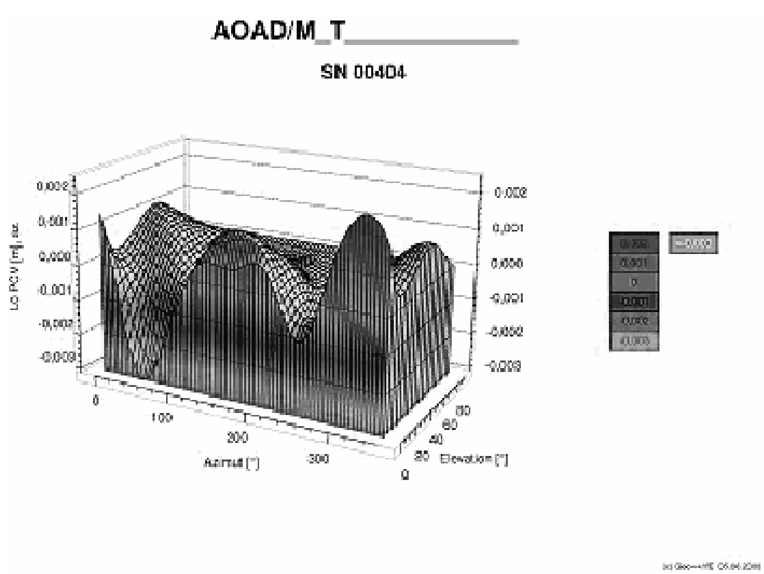
The standard deviation is generally homogeneous for all azimuths and is in the order of 0.3-0.5 mm for most of the elevation ranges with a slight degradation to 1-2 mm for elevations below 5 deg. The large number of combined calibrations of the AOAD/M_T gives a too optimistic standard deviation well below 0.1 mm, but with the same elevation dependent degradation (click on the images - L1, left / L2, right - for a high resolution jpg). Nevertheless, the overall standard deviation of the 42 combined calibrations is at the 0.2 mm level.





Azimuthal Variations

The azimuthal variations in the PCV are generally below 1 mm for the AOAD/M_T. However, the effect in L0 (ionospheric free signal) reaches values of 1 mm, even for the elevation range from 90 to 10 deg (click on the image for a high resolution jpg). At lower elevations, the azimuthal variations are even higher.



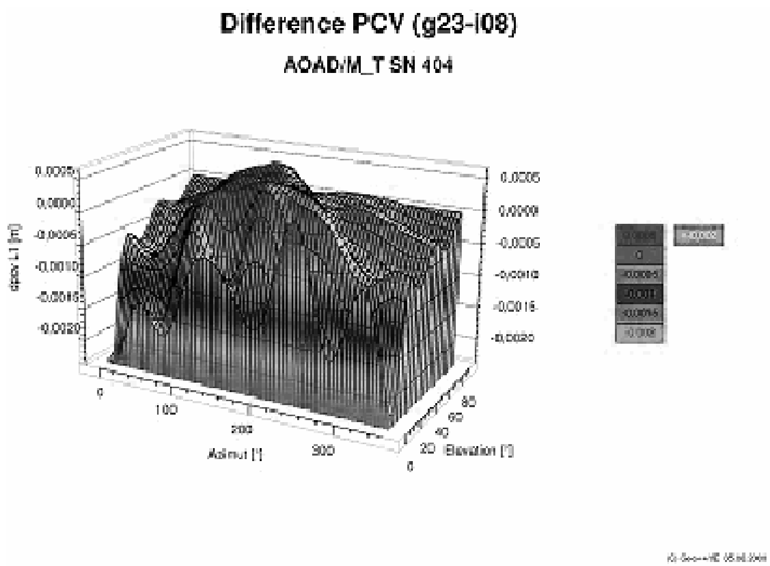
Azimuthal PCV L0 (offset and elevation dependent terms removed)

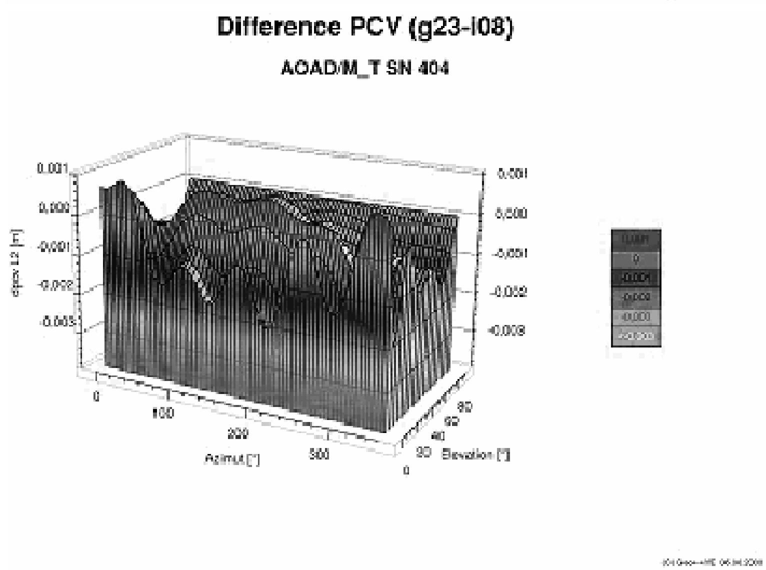
Repeatability

The repeatability is derived from independent calibrations at two sites (identical antenna). The repeatability gives values between 0.5 to 1 mm in the elevation range from 90 to 10 deg. For the elevation range from 10 to 0 deg the repeatability shows higher differences above 1 mm, which can individually amount to some mm at the horizon. However, the mean repeatability is generally at the 0.5 to 1 mm level.

The following graphics are the difference in PCV from one calibration done by IfE and one by Geo++®. The robots, the locations and the general conditions were different. The calibrations were selected by chance. For an operational calibration always two calibrations are combined, which gives a better repeatability than presented here. For the repeatability, the PCV were reduced to the same height offset (combined solution) with no horizontal offsets (included in the PCV).

(Click on the images - L1, left / L2, right - for a high resolution jpg)





Individual Sets of PCV Calibrations

The following survey indicates the individual calibrations, which were input to the combined solution of absolute PCV for the AOAD/M_T, SN 404. The number of epochs differ due to different options in the automated guidance of the real-time calibrations. Listed are an internal counter, date, local time, number of epochs and the standard deviation of weight unit of the simulataneous real-time processing of both GPS frequencies for the AOAD/M_T GPS antenna.

IfE Calibrations of AOAD/M_T, SN 404

4 Date: 2000-04-12 10:27:15 Epochs: 13347 s0: 0.662
5 Date: 2000-04-13 08:28:51 Epochs: 11463 s0: 0.670
6 Date: 2000-04-14 07:43:06 Epochs: 16068 s0: 0.712
7 Date: 2000-04-15 14:39:25 Epochs: 10697 s0: 0.640
8 Date: 2000-04-17 12:34:08 Epochs: 11847 s0: 0.611
9 Date: 2000-05-22 14:21:46 Epochs: 6987 s0: 0.702

Geo++® Calibrations of AOAD/M_T, SN 404

1 Date: 2000-04-29 10:26:10 Epochs: 11957 s0: 0.743
2 Date: 2000-04-29 15:03:43 Epochs: 6311 s0: 0.850
3 Date: 2000-04-29 22:15:24 Epochs: 11239 s0: 0.800
5 Date: 2000-04-30 20:12:03 Epochs: 12937 s0: 0.697
6 Date: 2000-05-01 01:02:46 Epochs: 6465 s0: 0.745
8 Date: 2000-05-01 13:53:15 Epochs: 15594 s0: 0.672
9 Date: 2000-05-02 03:55:00 Epochs: 6655 s0: 0.854
10 Date: 2000-05-23 12:56:17 Epochs: 11711 s0: 0.732
11 Date: 2000-05-23 16:55:27 Epochs: 7433 s0: 0.888
12 Date: 2000-05-23 19:20:23 Epochs: 7103 s0: 0.919
13 Date: 2000-05-24 11:34:19 Epochs: 7267 s0: 0.674
14 Date: 2000-05-24 13:57:43 Epochs: 6779 s0: 0.830
15 Date: 2000-05-24 17:36:01 Epochs: 5721 s0: 1.013
16 Date: 2000-05-24 19:51:57 Epochs: 5829 s0: 0.612
17 Date: 2000-05-24 21:55:43 Epochs: 5235 s0: 0.600
18 Date: 2000-05-24 23:42:41 Epochs: 5573 s0: 0.675
19 Date: 2000-05-25 01:34:12 Epochs: 6120 s0: 0.915
21 Date: 2000-05-25 13:04:55 Epochs: 7127 s0: 0.651
22 Date: 2000-05-25 15:32:38 Epochs: 3283 s0: 0.861
23 Date: 2000-05-25 18:01:14 Epochs: 10867 s0: 0.724
24 Date: 2000-05-25 22:02:56 Epochs: 6575 s0: 0.636
25 Date: 2000-05-26 00:25:17 Epochs: 6347 s0: 0.750
26 Date: 2000-05-26 10:18:44 Epochs: 6145 s0: 0.792
27 Date: 2000-05-26 12:24:13 Epochs: 5599 s0: 0.641
28 Date: 2000-05-26 14:17:33 Epochs: 7711 s0: 0.807
29 Date: 2000-05-26 16:50:23 Epochs: 5879 s0: 0.826
30 Date: 2000-05-26 18:45:02 Epochs: 6151 s0: 0.721
31 Date: 2000-05-26 20:58:25 Epochs: 7193 s0: 0.597
32 Date: 2000-05-26 23:32:22 Epochs: 6865 s0: 0.728
33 Date: 2000-05-27 10:46:42 Epochs: 11933 s0: 0.635
34 Date: 2000-05-27 15:15:16 Epochs: 6977 s0: 0.886
35 Date: 2000-05-27 17:39:17 Epochs: 7159 s0: 0.836

36 Date: 2000-05-27 20:07:39 Epochs: 6399 s0: 0.655
37 Date: 2000-05-27 22:25:35 Epochs: 6845 s0: 0.663
38 Date: 2000-05-28 00:42:42 Epochs: 8019 s0: 0.809
39 Date: 2000-05-28 03:24:06 Epochs: 6217 s0: 0.861

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5. Absolute PCV Results of AOAD/M_T - *Download Area*

From our point of view, some improvements and enhancements in the format definition of the PCV table used by IGS/NGS are recommendable (e.g. identical header information). Furthermore, the format should be extended in order to represent also azimuthal PCV. Some explanations and discussions can be found here:

Standard and Extension of Antenna PCV Exchange Formats.

In general, confirmed by our absolute results of several other antenna types, a complete set of individual azimuth- and elevation dependent PCV should be used preferably. The Dorne Margolin type is one of the seldom antenna types with almost none or only minor azimuthal PCV.

You will find five result files with PCV tables for the AOAD/M_T, SN 404, antenna:

1) Azimuth- and elevation dependent PCV table (Geo++ -format, ant-file)

> The ant-file corresponds to the spherical harmonic development, which was also used for the real-time calibration of degree 8 and order 5. The PCV are therefore azimuth and elevation dependent. The results of the ant-file are the best possible model of the PCV for the calibrated antenna.

2) Elevation dependent PCV table (Geo++ -format, ane-file)

> The ane-file contains only elevation dependent PCV, which were determined using an elevation dependent spherical harmonic develepment of degree 8. These PCV have been computed, because most of currently available RT-systems and post-processing software cannot handle azimuthal PCV. Existing azimuthal variations will distort the elevation dependent PCV and will degrade the accuracy of the PCV correction.

(Format GEO++ PCV table)

3) Elevation dependent PCV table (IGS-format, only minor header difference to NGS)

> identical to 2), reformatted

4) Elevation dependent PCV table (NGS-format, only minor header difference to IGS)

> identical to 2), reformatted

0) Elevation dependent PCV Nullantenna (IGS-format), for relative PCV tables

> As proposed in "Standard and Extension of Antenna PCV Exchange Formats", a Nullantenna is a convenient way to use relative and absolute PCV with currently existing relative PCV tables. Thus, a GPS user who wants to stay with relative PCV corrections can restore the missing absolute information by correcting for the

Nullantenna type.

(Definition of "Nullantenna" and Antenna Type "Nullantenna")

DOWNLOAD AREA

Download the Absolute PCV Results for the AOAD/M_T Choke Ring Antenna (without dome):

AOAD/M_T, 7490400, SN 404

1) Azimuth- and elevation dependent PCV table (Geo++ -format)

2) Elevation dependent PCV table (Geo++ -format)

3) Elevation dependent PCV table (IGS-format)

4) Elevation dependent PCV table (NGS-format)

0) Elevation dependent PCV Nullantenna (IGS-format)

We’d appreciate a short notice about who is downloading the PCV tables. Feel free to leave us your name and e-mail, any comments are welcome.

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5.1 Standard and Extension of Antenna PCV Exchange Formats

The IGS (International GPS Service) early recognized the importance of clarification of antenna types and receivers for a rigorous processing of data from networks with mixed antenna and receiver types. The clarification attemps are commonly accepted, used and referred to by other GPS users. Even real-time applications are using or intend to use the IGS tables (e.g. Radio Technical Commission for Maritime Services RTCM). Hence, the rcvr_ant.tab is generally used to define unique receiver, antenna and radome names.

However, the extented use from post-processing to real-time applications may make some enhancements necessary. This also makes it requisite for IGS to consider the requirements of real-time applications.

Beside the naming convention, the correction of phase center variations (PCV) is essential for mixed antenna use. The problem of PCV is not only restricted to large (global) network, even engineering applications with inclined antenna are faced to it. Thus, the PCV definition and correction do have an impact on regional reference station networks, real-time and precise engineering applications.

There are currently two international and freely accessible sources of PCV, IGS and NGS (National Geodetic Service), which use similar, but not identical ASCII-formats:

- IGS style (e.g. igs_01.pcv)
- NGS style (e.g. ant_info.003)

Furthermore, there are software related PCV formats:

- Geo++ antenna file
- Bernese Software PCV format
- ...

There exists differences in the individual format, e.g. the sign of the PCV. The Geo++ sign of the PCV originates from the intention to have consistant corrections for offset and PCV. The offsets of the phase center (PC) are added. Therefore the PCV should be added to a range or phase range as well. This defines the sign of the Geo++ PCV convention, which is opposite to the IGS/NGS.

The current progress in antenna calibrations and the discussions on PCV, especially in the german speaking areas (documented by two antenna workshops 1999 in Bonn and 2000 in Hannover) show that there is a vital demand for a unification and enhancement of the currently used PCV formats.

Our investigations of the international formats IGS and NGS indicated, that the numerical Offsets and PCV-values do have the same format, but the descriptive line for an antenna type is somehow different. However, it is a convention, which works quite well, but some improvements and extensions are required in order to define a more precise standard for a PCV exchange format.

From this, we suggest to define a proper format and standard, which can account for the existing PCV and should be extended by some basic information. To be discussed:

- azimuthal PCV variations
- serial number (for individual calibration)
- setup-ID (will be used by RTCM)
- flag/entry for individual calibration or type calibration
- flag/entry for relative or absolute calibration
- strict IGS rcv_ant.tab Antenna Code (IGS Codes-15 columns)
- strict IGS rcv_ant.tab Radome Code (IGS Codes-cols. 17-20)
- comment lines.

Some of the above listed requirements can be implemented using the setup-ID (relative/absolute calibration, individual/type calibration), but can also be defined as an individual flag/entry.

The enhancements are needed as more individual calibrations are used to correct PCV, absolute and relative PCV are used, and azimuthal PCV sometimes show even larger magnitude than the elevation dependent PCV. There will also be relative and absolute PCV corrections, which must enable all users for post-processing and real-time application to use and to combine both calibration types.

An easy way for the use of relative and absolute PCV with the currently existing relative PCV tables is the definition of the Nullantenna and the antenna type Nullantenna relative to the IGS/NGS reference antenna.

Another important aspect is the antenna reference point (ARP) for PCV. The ARP must be known exactly to relate offsets and PCV correctly to an antenna. Generally, the ARP is designated to the lowest not removable level (i.e. bottom) of the physical antenna. However, the ARP is not a unique height reference for all antenna types. Therefore, an ASCII file (antenna.gra) with the dimension of individual antenna types and the ARP (defined by IGS) is in use. In addition, NGS has established a data base of digital images of all calibrated antennas at NGS, which is also a good reference for an ARP definition. Nevertheless, the ARP has also to be specified in a more strict and unambiguous way.

With the above proposal it is intended to start a discussion on a more precise standard of antenna PCV exchange format.

5.2 Format of Geo++ PCV Antenna File

NAME

Geo++ antenna file

DESCRIPTION

The following text describes the format of the Geo++ antenna files.

Antenna files may contain information on the three dimensional antenna phase center offsets and antenna phase center variations (PCV). The PCV can be elevation dependent or both, elevation and azimuth dependent.

File Format

The format of the ant-file uses some keywords to indicate different data or general information. Comment lines are allowed and do have a ’#’ as the first sign of the line. However, comment lines are not allowed within the data sections (i.e. the lines of data which may follow the keyword VARIATIONS L1= and/or VARIATIONS L2=).

The meaning of the keywords is as follows. The ’=’ sign is part of the keyword and is not separated by a blank from the previous alphanumerical character.

TYPE=

is an alphanumerical description of the antenna type. The TYPE= entry generally contains the IGS Antenna Code and the IGS Antenna DOME Code.

NO OF FREQUENCIES=

indicates the number of frequencies, which follow in the ant-file. For dual frequency antenna the entry is "2", for single frequency antenna "1".

OFFSETS L1=

contains the L1 offsets of the phase center in north, east and height component. The unit of the values is in meter [m]. The three numbers are separated by a blank.

OFFSETS L2=

contains the L2 offsets of the phase center in north, east and height component. The unit of the values is in meter [m]. The three numbers are separated by a blank.

ELEVATION INCREMENT=

is the increment of the elevation dependent PCV. The PCV are listed in a table of a discrete increment for the elevation from 0 to 90 deg. The unit of the increments are degree [deg]. The increment can be individually selected, however, a common value for the ELEVATION INCREMENT= is 5 deg.

AZIMUTH INCREMENT=

is the increment of the azimuth dependent PCV. The PCV are listed in a table of a discrete increment for the elevation and azimuth from 0 to 90 deg and 0 to 360 deg. The unit of the increments are degree [deg]. The increment can be individually selected, however, a common value for the AZIMUTH INCREMENT= is 5 deg. Only elevation dependent PCV must specify "0" for the AZIMUTH INCREMENT=.

VARIATIONS L1=

is followed in the next line by the actual PCV values of L1. The first line contains the elevation dependent PCV for azimuth 0 deg. The number of PCV values within the line is determined by "columms: 90/(elevation increment)" and start from 0 deg to 90 deg. For just an elevation dependent data set, only one line of PCV is given. Additional azimuth dependent PCV follow in a new line. The corresponding number of lines is determined by "rows: 360/(azimuth increment)+1" and starts from 0 deg to 360 deg. However, the row for 0 deg has to be repeated for the 360 deg row.

VARIATIONS L2=

is followed in the next line by the actual PCV values of L2. The first line contains the elevation dependent PCV for azimuth 0 deg. The number of PCV values within the line is determined by "columms: 90/(elevation increment)" and start from 0 deg to 90 deg. For just an elevation dependent data set, only one line of PCV is given. Additional azimuth dependent PCV follow in a new line. The corresponding number of lines is determined by "rows: 360/(azimuth increment)+1" and starts from 0 deg to 360 deg. However, the row for 0 deg has to be repeated for the 360 deg row.

DIFFERENCES to IGS/NGS FORMAT

The Geo++ antenna files are different to the IGS/NGS format in the following aspects:

- all values given in meter (instead of mm in IGS)
- all parameters (offset and PCV) with the same sign convention (different to IGS)
- sign of PCV (opposite to IGS)
- PCV listed starting from 0 to 90 deg elevation (opposite to IGS)
- azimuthal PCV (not yet possible in IGS/NGS)

The Geo++ sign of the PCV originates from the intention to have consistent corrections for offset and PCV. The offsets of the phase center (PC) are added. Therefore the PCV should be added to a range or phase range as well. This defines the sign of the Geo++ PCV convention, which is opposite to the IGS/NGS.

5.3 Definition of "Nullantenna" and Antenna Type "Nullantenna"

Definition "Nullantenna"

The Nullantenna has an absolute and isotropic characteristic. Hence, the Nullantenna has no PCV. The PCV are reduced to an antenna reference point (ARP) in order to avoid problems arising from a mean phase center (i.e. dual frequency antenna).

Realization "Nullantenna"

A realization of a Nullantenna is an actual antenna corrected by absolute PCV with its associated standard deviations.

"Nullantenna" for Absolute PCV

The absolute PCV for a Nullantenna are, corresponding to the definition, null for offsets and PCV.

"Nullantenna" for Relative PCV (refering to IGS/NGS Reference Antenna)

The relative antenna type Nullantenna (refering to the IGS/NGS reference antenna) is required for consistency with the currently existing relative PCV tables. This can be derived from an absolute PCV calibration of the IGS/NGS reference antenna (i.e. AOAD/M_T).

The PCV of the antenna type Nullantenna relative to the IGS/NGS reference antenna is derived from the AOAD/M_T, SN 404, absolute PCV field calibration in the following manner:

- the absolute PCV are reduced to the IGS/NGS height offsets and horizontal offsets set to zero:

  OFFSETS L1=+0.00000 +0.00000 +0.11000
  OFFSETS L2=+0.00000 +0.00000 +0.12800

  (north, east, height in meter)

- the sign of the PCV is altered compared to the actual absolute calibration
- only the PCV is relevant for the Nullantenna; hence, all offsets are set to null to achieve consistency with relative IGS/NGS calibrations

The antenna type Nullantenna must be incorporated into the IGS rcvr_ant.tab as well as into the IGS igs_01.pcv and into the NGS ant_info.003 relative PCV tables.

6. Summary

We intend to fill a gap with this publication containing the absolute PCV results of an AOAD/M_T choke ring antenna. The development of the Absolute Field Calibration of Antenna PCV at IfE and Geo++® reached a point, where the calibration has become a matured and highly precise procedure. With the real-time approach and the automation using a calibrated robot even azimuthal PCV can be resolved very reliably.

The missing absolute information of GPS antenna PCV is now accesible for the interested GPS user. Other groups are invited to verify these results. Results from relative field calibrations can be transformed into absolute PCV. From our side of view and based on our experiences, an individual complete absolute calibration should be prefered within precise applications (e.g. reference station networks, engineering applications, precise GPS height determination ...) due to the high resolution (azimuthal PCV, down to the antenna horizon). There are several antenna types with a magnitude of azimuthal PCV, which cannot be neglected. The AOAD/M_T type has rather small horizontal variations.

The correctness and the effects of absolute PCV have been shown in our verifications. The separation of the absolute PCV antenna effect was succesful. A next and future step should be the careful investigation of the other error sources, which are all correlated and have an integral effect (e.g. satellite antenna, troposphere ...).

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7. Absolute PCV Field Calibration - Publications of IfE and Geo++®

(Paper, Poster, Oral Presentations)

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