Geo++® White Paper

Near Field Effects of a Car Roof on TPSHIPER_PLUS Phase Variations

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Introduction

The phase variations (PCV) of an GNSS antenna can be precisely determined using the Geo++® Absolute Field Calibration with a Robot. However, there may be remaining effects caused by the setup and the environment of the antenna in the actual surveying application, which can significantly modify the phase variations.

The absolute antenna calibration with the robot is an excellent instrument to investigate such remaining effects on phase variations. A particular antenna setup mounted on the robot will be constantly rotated and tilted by the calibration procedure, but the geometry between received satellite signals and setup will not change. Due to very long-periodic multipath in the close vicinity and electro-magnetic interaction of the antenna, the phase variation pattern change. Therefore, the term near field effect on the antenna is used.

Absolute Antenna Calibration with a Robot

The Geo++® calibration method determines the absolute antenna offsets in horizontal and vertical position as well as absolute elevation and azimuth dependent PCV for both GNSS frequencies. The determined PCV are completely independent from the antenna used on a second station in order to enable precise differential GNSS. The absolute calibration approach allows the complete modeling of the receiving characteristic of the antenna under investigation.

Basic concept of the calibration method is the separation between multipath and phase variation. A special observation procedure with fast changing antenna orientations through the robot is used for the estimation of absolute PCV and for the elimination of multipath. The fast precisely know orientation changes are essential for the calibration.

The accuracy of the Automated Absolute Field Calibration with a robot has been analyzed intensively. The standard deviation is in the range of 0.2 to 0.4 mm (1 sigma level), which corresponds to the demonstrated repeatability of approximately 1 mm for individual antenna. The repeatability has also been verified using results from absolute chamber calibrations of identical antennas.

The processing is done in real-time. Therefore the complete results are available after the calibration. The calibration results cover the complete reception area of the antenna down to elevation angles of 0 degree.

Determination of Near Field Effects

The near field effects are mainly caused by very long-periodic multipath, which is caused by reflecting surfaces close to the antenna. Such reflectors can be mounting devices (e.g. tribrach), the surfaces of pillars, or roofs of platforms in kinematic applications. In the following investigation, a car roof will be used to demonstrate the influence of an antenna mounted on the roof on PCV.

The robot is limited concerning dimensions and/or weight of the antenna construction mounted. It is often not possible to investigate the complete actual environment, because the constructions are too heavy or too large. In these cases, only a representative, but limited copy of the environment gives an indication of the effects present. It will not perfectly show the overall effects.

For the analysis of car roof effects, an approximately round part of a roof was cut out from a car. The most important geometry is the vertical separation of the antenna from the reflecting (approximately horizontal) surface. The antenna height of the antenna reference point above the car roof cut-out was 54 mm. A round tribrach was used in the setup (see Fig. 1 and Fig. 2). The roof cut-out, tribrach and antenna was mounted as a setup on the robot for calibration.

The antenna setup can now be calibrated on the robot, while the geometric properties of the cut-out will be constant during the calibration procedure. The antenna setup is tilted and rotated, but the effective geometry for the long-term multipath will be constant and will cause a variation of the estimated phase variations. The near field effect will not be eliminated by the applied multipath elimination technique, because it repeats after orientation changes for the same incoming GNSS signal. The difference of the car-roof setup and a regular calibration of the antenna reveals the effect of the setup.

Antenna Used in Investigation

The investigation uses an integrated receiver/antenna GNSS system manufactured by Topcon Positioning Systems, which is named after the IGS naming convention TPSHIPER_PLUS. For convenience in this text, the setup of the TPSHIPER_PLUS on the car roof cut-out will be called TPSHIPER_PLUS^{roof}, which is not an official naming.

The TPSHIPER_PLUS has a quadratic housing. A TNC adapter for an optional UHF antenna whip is located at the top and center of the antenna cover. The calibration has been done without any UHF antenna. Effects of the UHF antenna on the PCV are already documented (Schmitz et al 2002).

Fig. 1: Absolute robot calibration of a TPSHIPER_PLUS mounted on a round car roof cut-out

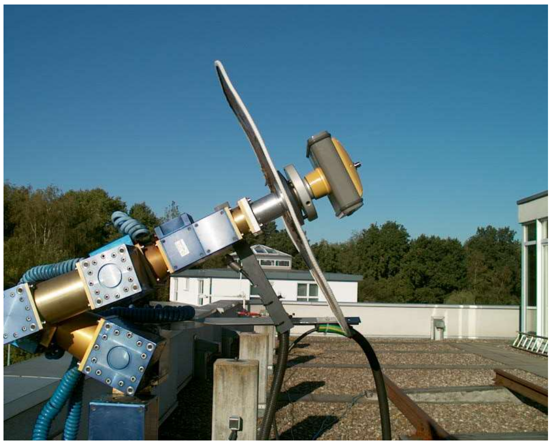

Fig. 2: TPSHIPER_PLUS mounted on a round car roof cut-out

An additional whole in the car roof cut-out was required for cables of the power supply and the data link of the integrated receiver. For safety reasons, the edges of the cut-out were sealed with a removable plastic cover. Fig. 1 and Fig. 2 give an impression of the setup on the robot.

Absolute PCV Pattern

The complete PCV model of a Geo++ antenna calibration correspond to a spherical harmonic expansion of degree and order (8, 5), which is used in the Automated Absolute Field Calibration. The PCV are therefore azimuth and elevation dependent. These PCV are the best possible model for the calibrated antenna.

The L0 signal is the ionosphere free linear combination of L1 and L2, which is also often called L5. In most applications and software packages, the L0 linear combination is representing the overall PCV influence on the application or it is directly used to estimate coordinates. The PCV differences on L0 are greater by a factor of 3 compared to L1 and L2. This is expected by theory for L0.

Fig. 4 depicts the absolute L0 PCV of the TPSHIPER_PLUS. The PCV vary from +5 mm to -10 mm and the edges of the antenna housing show up in the figure. The PCV of the TPSHIPER^{roof} in Fig. 3 are completely different. There is a systematic change with a large gradient of the PCV visible at the 50 deg elevation range. The edges of the housing are this time not obviously. The systematic effect is mainly due to the round car roof cut-out in the TPSHIPER^{roof} setup.

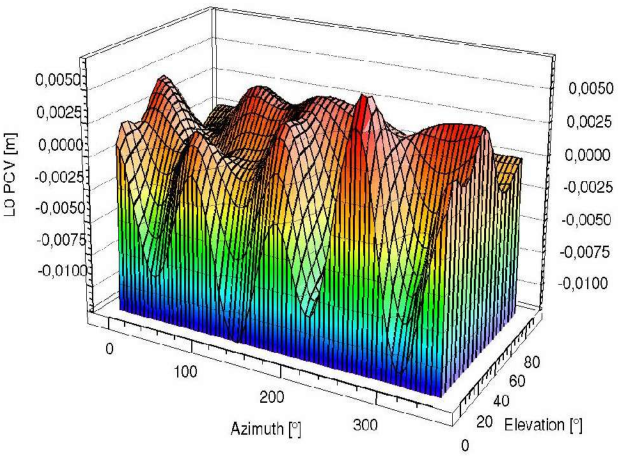

Fig. 3: L0 PCV of TPSHIPER_PLUS

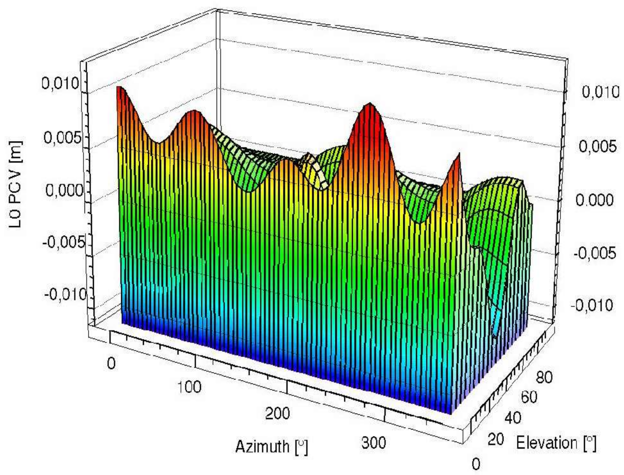

Fig. 4: L0 PCV TPSHIPER_PLUS^{roof}

Difference of Absolute Offsets

Offsets are by no mean a precise measure to compare antennas. The offset computation is up to now not standardized and is depending on several parameters:

- absolute or relative calibration
- absolute or relative offsets
- used cut-off angle (only for relative calibration)
- geographical location of site used for calibration (only for relative calibration)
- reference antenna (only for relative calibration)
- minimum condition for PCV for offset determination
- remaining multipath effects (only for relative calibration)
- processing strategy and use of relative antenna definition
  while transferring between absolute and relative PCV and vis versa

Effects from these factors affect the interpretation of offset differences. However, the offset reflects a kind of mean effect of the phase variations. The calibration and processing of the two setup TPSHIPER_PLUS was identical. Therefore, Tab. 1 shows the differences of the offsets for the individual calibration of the TP-SHIPER_PLUS and the setup on the car roof cut-out. The differences are neglect able for the horizontal components, but amounts for the L2 height component to 7 mm.

Offset Difference	*dN [m]*	*dE [m]*	*dH [m]*
L1	0.00076	-0.00050	-0.00212
L2	0.00053	0.00000	- 0.00733

Tab. 1: TPSHIPER_PLUS offset differences in car roof environment

The offsets are a mean values determined over the complete hemisphere of the antenna. A comparable satellite coverage is never available in practical applications. Therefore more analysis must be placed on the actual PCV pattern to get insight into possible effects for short observation times or kinematic applications.

Difference of Absolute PCV Pattern

The PCV differences between the TPSHIPER_PLUS and the TPSHIPER_PLUS^{roof} are in the range of +/- 20 mm. Fig. 5 and Fig. 6 show the differences from two different views. Fig. 5 shows the regular view startin g with the horizon in the front, while Fig. 6 gives a view from the zenith line in the fromt of the figure to show the large gradient present in the PCV difference, i.e the car-roof setup influence. To be precise, the visible influence includes also the effects caused by the round tribrach.

The main influence is an elevation dependent change in the PCV. This is related to the round cut-out used in the setup. The visible azimuthal variations are mainly caused by the housing edges in the PCV of the regular setup.

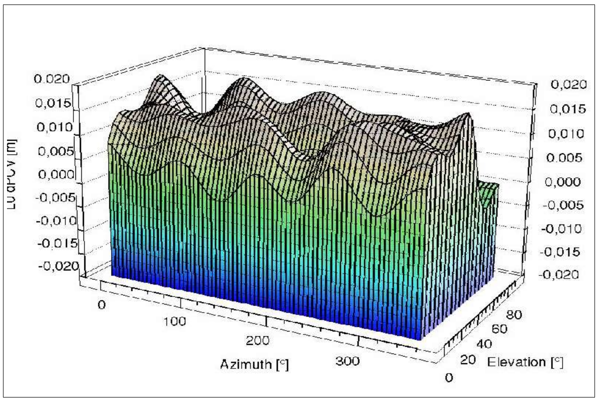

Fig. 5: L0 PCV difference (horizon in front) TPSHIPER_PLUS/TPSHIPER_PLUS^{roof}

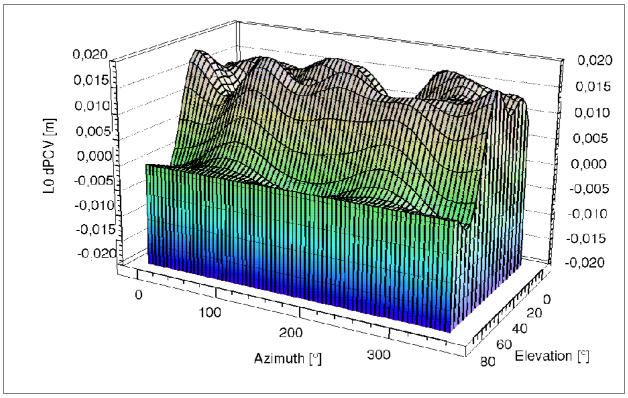

Fig. 6: L0 PCV difference (zenith in front) TPSHIPER_PLUS/TPSHIPER_PLUS^{roof}

Difference of Elevation Dependent PCV

The elevation dependent PCV are computed using a primarily elevation dependent spherical harmonic expansion of degree and order (8, 0). The actually used model is not exactly described by the above expansion (8, 0), because the coefficients for the offsets are also estimated. Existing azimuthal variations distort the elevation dependent PCV model and will degrade the accuracy of pure elevation dependent PCV correction (especially for antennas with large azimuthal variations).

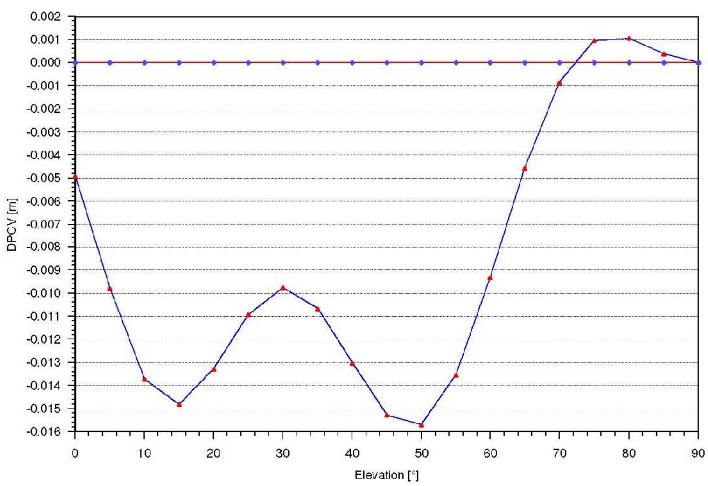

Fig. 7: elevation dependent L0 PCV differences TPSHIPER_PLUS (reference) and TPSHIPER_PLUS^{roof}

Nevertheless, elevation dependent corrections are often applied in kinematic applications without knowledge of the orientation of the antenna. Fig. 7 show the pure elevation dependent difference between the regular TPSHIPER_PLUS setup and the TPSHIPER_PLUS^{roof} setup. The horizontal line represents the TPSHIPER_PLUS. The range of the PCV difference can more easily derived from the figure, which are in the range of 17 mm for the ionospheric free linear combination L0.

Consequences for Users

The effect on GPS positional accuracy is defined in terms of the standard deviation of position s_P and the standard deviation of phase measurements s_R , together with a measure of the satellite geometry, the position dilution of precision (PDOP), as follows:

$$s_P = s_R * PDOP$$

The differences in the PCV due to near field effects can be considered in a first approximation as an additional noise on the observable. This is not a perfect assumption, because the influence does have systematics.

However, with a PDOP value of 1 to 3, differences in the PCV of 10-15 mm and more give rise to positioning uncertainties in the range of about 10 to 45 mm and more. For high precision applications this is not sufficiently accurate. The best possible modeling of the combined influence of PCV and near field effects is therefore required for an application.

Conclusion

A robot together with the absolute calibration procedure has been used to investigate the effect of a horizontal reflector in the near filed of the antenna. A regular TPSHIPER_PLUS has been compared to a particular setup, which reveals differences in the estimated PCV up to 17 mm for the ionospheric free linear combination.

For precise applications, the question is also often posed whether individual antenna calibrations are necessary, rather than a general calibration for an antenna type. The same question applies to the differences between individual antenna setups in environments such as the investigated car roof cut-out. The effects on the coordinate estimation can be significantly.

References

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Most of the references are available for download at http://www.geopp.com/publications.