Variability of GPS Errors On-site

Investigations of Antenna PCV and Multipath Towards a Station Calibration

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1) INTRODUCTION

Diverse GPS applications require accuracies at the mm-level, for example reference station networks and high precision engineering surveys. With the improving GPS precision the whole error budget on-site demands increased attention, especially with respect to the antenna behavior (the phase center variations PCV) and to multipath (MP).

The error resulting from using different (or also differently orientated) antenna types due to the PCV is in the mm-cm range. The worst effect can be found in large networks (using the L0 linear combination and modelling a troposheric scale factor), which can reach several cm in height. So far, known calibration procedures are the relative field calibration, the absolute calibration in anechoic chambers and the absolute field calibration. There exist also tests for an in-situ calibration of the sum of the station dependent errors PCV+MP.

A further error source on-site is multipath, that also has an effect on the measured carrier phase resultant of the direct and reflected signal. Multipath signals originate from specular and diffuse reflection and diffraction. Various fields of research for methods to reduce this effect concern the antenna-based mitigation (gain pattern, choke rings),the receiver technology (correlator techniques) and the data processing and analysis for MP modeling. Still, the impact of MP on the carrier phase remains as an important site dependent limiting error source with a need for further research.

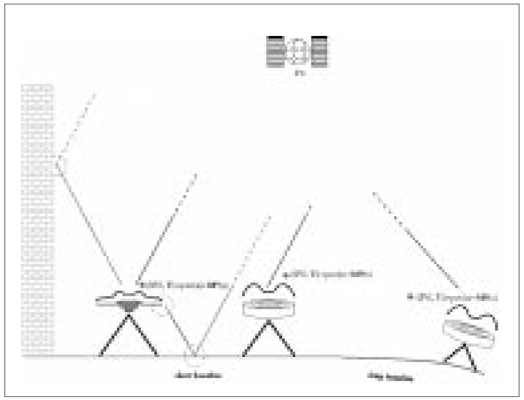

Fig. 1: Errors on-site - impact of PCV+MP

Within this project our aim is to separate the PCV and MP errors. The first step is the calibration of the station independent absolute PCV. The next step will be a calibration/modeling of the site MP.

2) ABSOLUTE PCV

The absolute field calibration makes use of the repeated satellite constellation after a mean sidereal day. For the case of stable conditions and unchanged geometry (reflectors) the MP influence will cancel out in the observation difference between two days. The PCV information can be re-obtained through rotations and tilts of the test antenna on one of the two days and will be modeled with a spherical harmonic functions. Finally, one yields azimuth- and elevation-dependent PCV. Features of the procedure are the MP elimination/ reduction (site independence); the possibility of an absolute calibration without reference antenna and coordinates; the PCV estimation without a separation of offset and pattern; the well covered antenna hemisphere with observations.

Fig. 2: Robot

The feasibility and also the functionality of the basic ideas and the procedure itself have already been demonstrated.The PCV were evaluated for different antenna types in a small reference network and compared with the results of calibration sets of other groups. Still, all calibrations have not finally reached the aimed 1mm-level. Due to the considerable efforts for this calibration procedure, we are currently striving for an automation with a precise robot (calibration, programming), which also will be used for the second step, the MP investigations.

3) VARIABILITY OF MULTIPATH

The GPS receiver/antenna receives both the direct and reflected signals. The phase error induced by the reflected signal can be characterized by:

$$\Delta\Psi = \arctan\left(\frac{\alpha\cdot\sin(\varphi)}{1+\alpha\cdot\cos(\varphi)}\right);\alpha[0,1] \quad \text{reflection factor}$$

Hence a maximum error of about 5 cm can be expected. MP varies in dependence of the transmitted signals and their angles of incedence, of the reflectors (geometry, surface) and of the antenna and receiver techniques. The daily repeatability of the MP, prerequisite for the PCV calibration procedure, is depicted in Fig. 3.

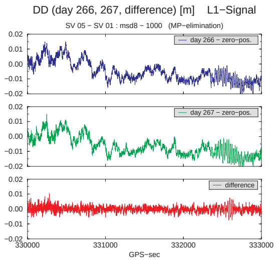

Fig. 3: MP and time - daily repeatability

Still, even in case of an unchanged reflector geometry, there can be differential changes in MP from day to day e.g. (Fig. 4) because of the surfaces (rain). This fact should be taken into consideration for modelling of MP and the applications of possible models.

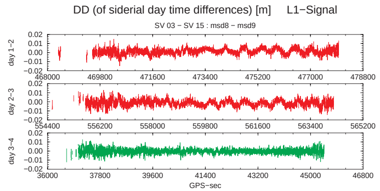

Fig. 4: MP and reflector surface - differential changes (rain on day 2)

In order to analyse the MP on-site, to scan the variations, tests were carried out in which the 'outside' satellite-reflector-geometry remained unchanged, but the antenna itself was shifted (3D) precisely around a zero-position.

These precise spatial variations of the antenna were used to investigate the variations of the carrier phase (e.g. Fig. 5). With this 'artificial geometry change', but with an unchanged reflector geometry on-site, a recording of MP will be possible.

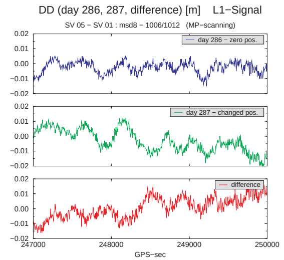

Fig. 5: MP-scanning - carrier phase changes

Also the signal-to-noise ratio (SNR) contributes to the elucidation of the impact of MP on-site (Fig. 6).

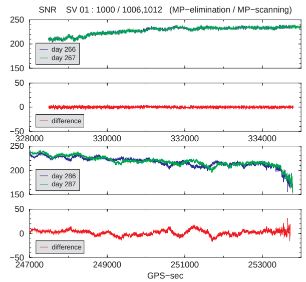

Fig. 6: SNR showing MP

4) OUTLOOK, FUTURE GOALS

The goal of the project is to reach the complete correction/reduction/consideration of absolute PCV- and MP-errors on-site (one important area of application will be reference station networks transmitting differential carrier corrections).
The PCV calibration is currently in a stage of automation and further evaluations. Precise spatial variations of the antenna (thus different MP carrier phase errors between the positions) will help to develop the mitigation modell for MP.

Acknowledgments
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