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Antenna Group Delay Calibration with the Geo++ Robot

Extension to Code Observable

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Introduction

Absolute GNSS antenna calibrations are routinely conducted using the Geo++ absolute field calibration with a robot. The robot calibration provides phase center variations (PCV) and carrier-to-noise (CNO) decrease functions for both frequencies of GPS and GLONASS. The individual GLONASS frequencies are considered in the determination of the GLONASS PCV.

In addition to the phase also code measurements are of certain interest for GNSS applications. By theory, the antenna affects the reception of the code measurements, which is also termed as group delay variations (GDV). The group delay of an antenna is physically the change in the received phase versus the change in frequency.

The GNSS antenna calibration for code measurements is more susceptible to environmental changes compared to phase measurements. The code receiving characteristics depend for instance on the associated amplifier and band-pass filters as well as temporal changes.

Geo++ has been approached by different parties to investigate group delay variations with the Geo++ GNSS antenna calibration system. Hence, the absolute field calibration with a robot has been extended to estimate group delay variations. First experiences and results are presented.

Calibration of Group Delay Variations

The absolute antenna calibration with a robot performs in addition to the PCV determination a simultaneous group delay calibration in a separated adjustment based on the data from the same receiver. The modeling is basically the same as for phase variations. A spherical harmonic expansion is used to model the group delay variation for the antenna hemisphere. The C/A code on L1 and P-code observable on L2 are used and negative elevations up to 5 deg are allowed. Main difference compared to the phase calibration are the parameters of the code multipath modeling in the adjustment.

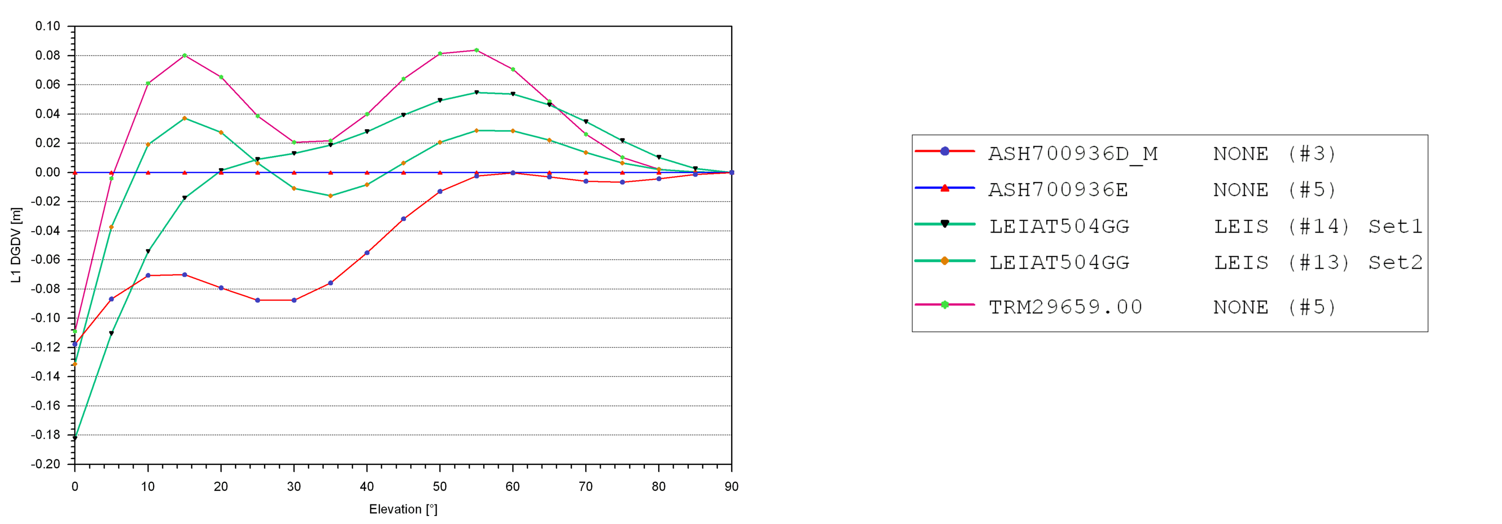
Significance of Group Delay Variations from a Sample

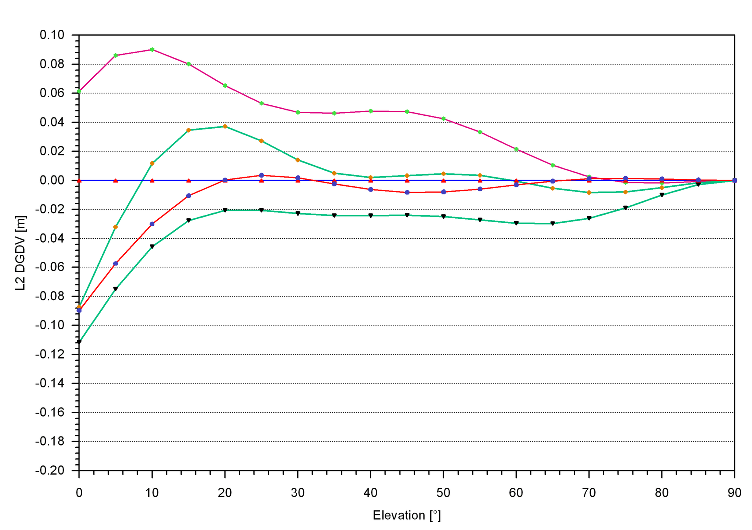
Individual antennas have been calibrated several times, but the repeatability of a single GDV calibration is currently not sufficient. However, a large sample of calibrations or individual antennas allow the determination of a type mean group delay variation.

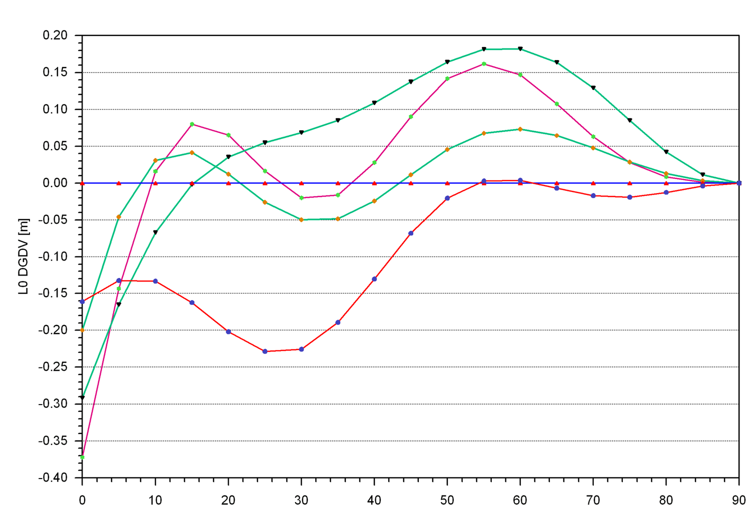
The significance of a GDV type mean is demonstrated while comparing

- set 1: computed from 14 individual LEIAT504GG LEIS antennas
- set 2: computed from 13 individual and different LEIAT504GG LEIS antennas
- additional Dorne Margolin (DM) type antennas (Ashtech, Trimble)

The following figures show the relative DGDV against the type mean of the ASH700936E NONE antenna:





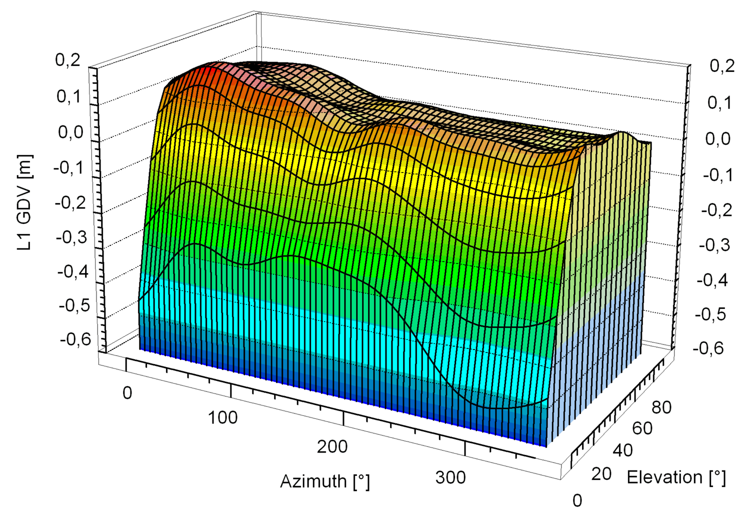


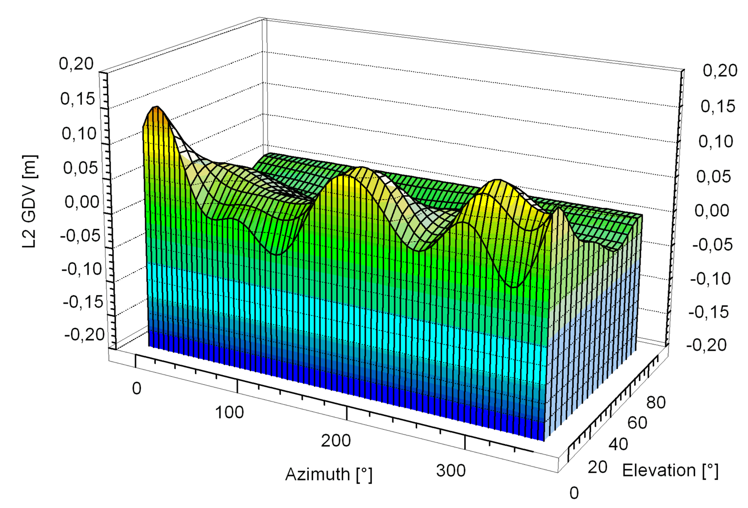
The agreement of the two Leica sets is in the order of 5 cm for L1 and L2, which is supported by the standard deviations of about 4 cm for one single GDV computation. The differences to other antenna models of DM-type is in the range of +/- 10 cm.

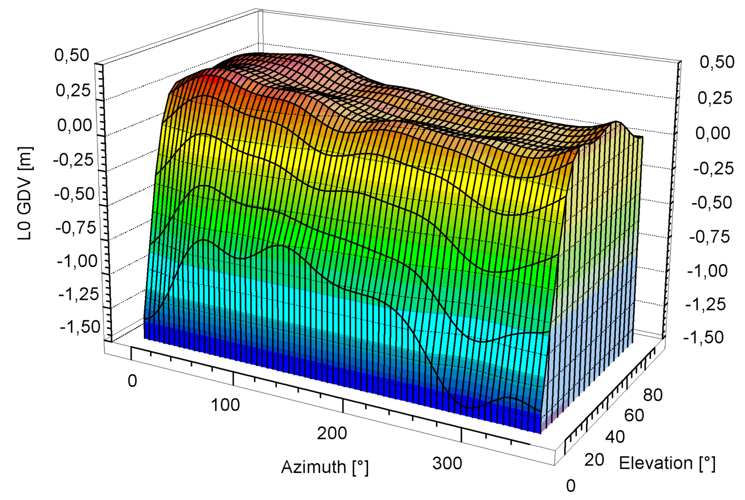
Absolute Group Delay Variations

The magnitude of absolute GDV are displayed for the LEIAT504GG LEIS with a larger sample of 27 individual antennas and 54 calibrations. The GDV show

- significant increase in magnitude below 25 deg elevation
- up to 10 cm in higher elevation for L1
- smaller effects for L2
- up to 1 m at low elevations for ionospheric free signal L0

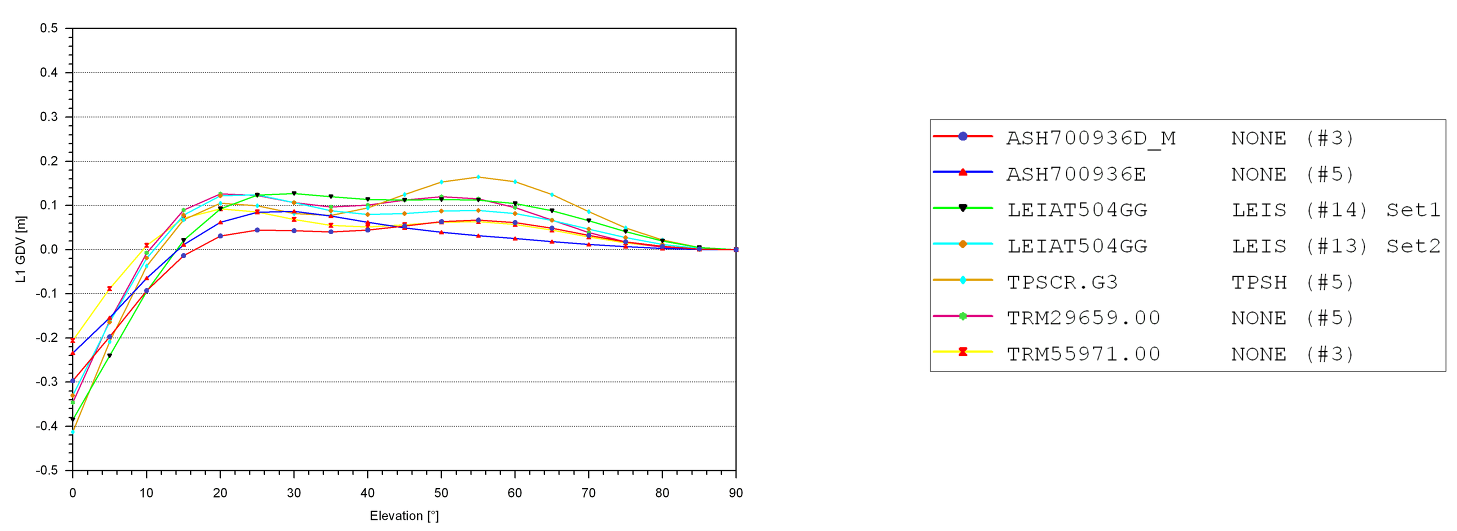


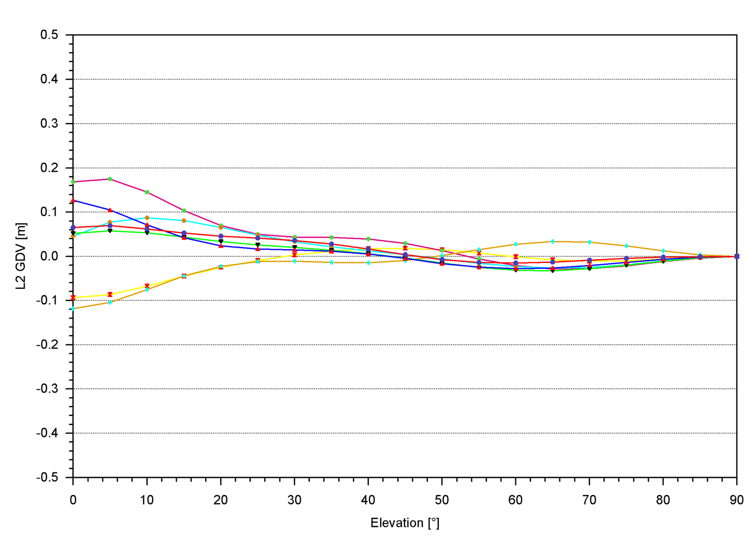


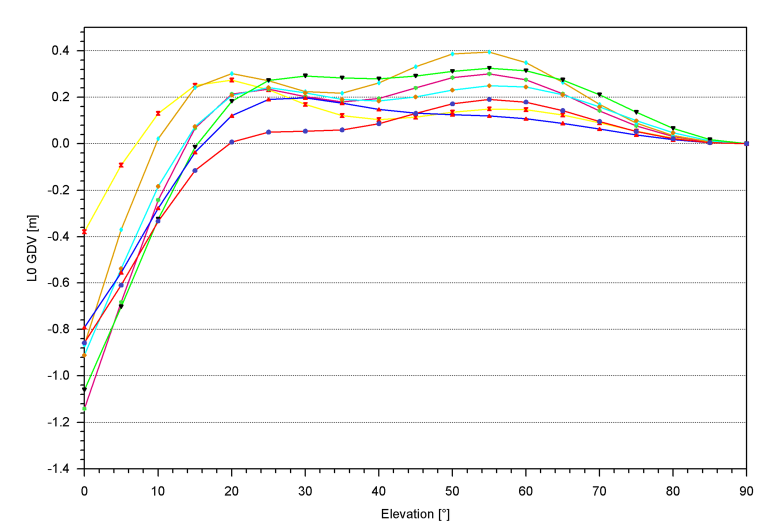


Comparison of Group Delay Variations for Different Geodetic Antenna Models

The absolute GDV are shown for some Dorne Margolin type antennas and for two differently designed geodetic antennas. The Topcon TPSCR.G3 TPSH has the same chokering construction, but a patch antenna reception element. The Trimble TRM55971.00 NONE has a special design to avoid multipath.







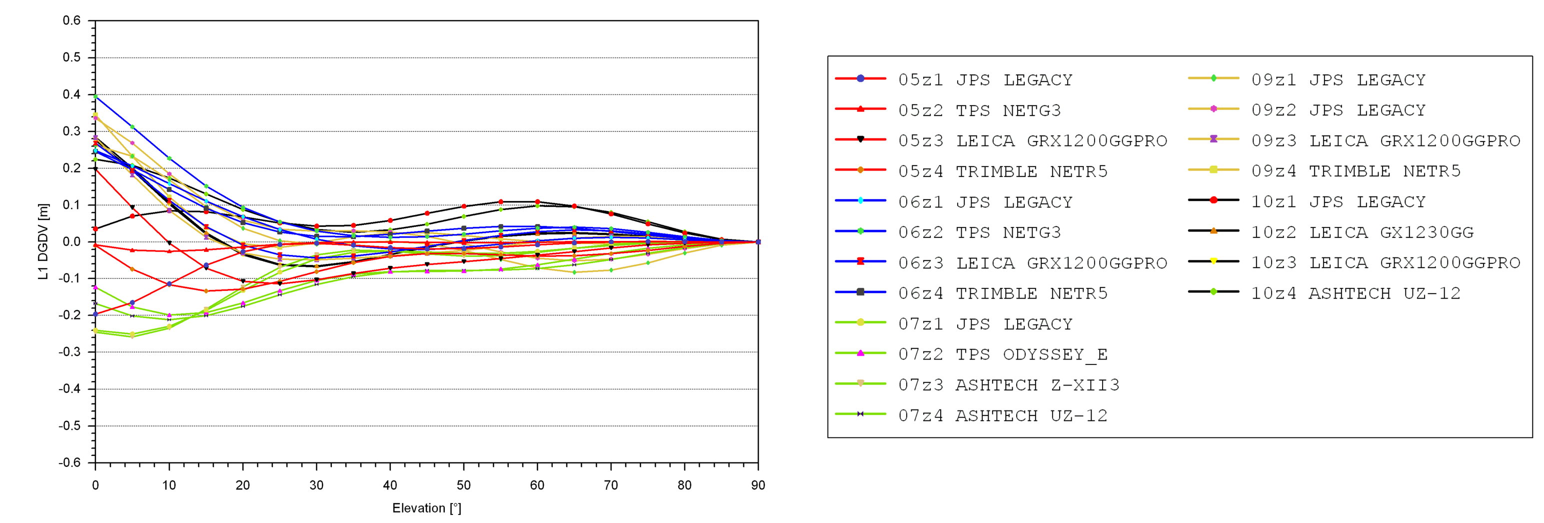
The GDV are converted to the phase offsets of the individual GNSS antenna type mean. The phase offsets are removed for the above comparisons of absolute elevation dependent GDV. It is suggested to refer GDV always to the phase offsets.

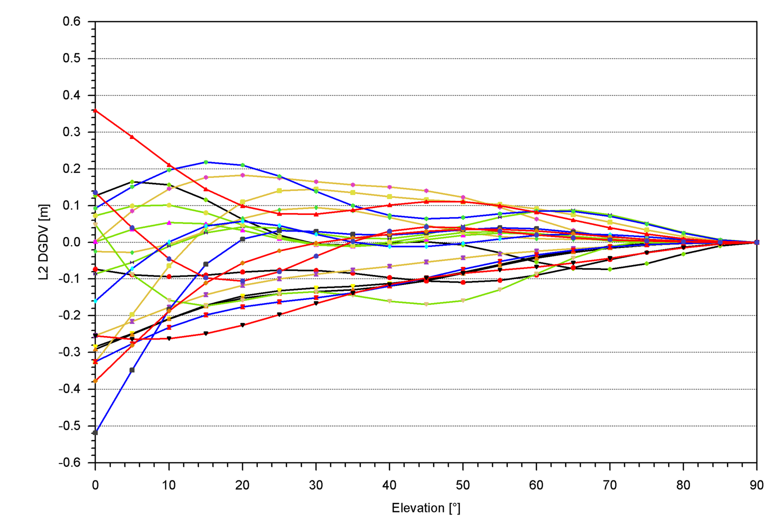
Analysis of Zero-Baseline Calibration Setups

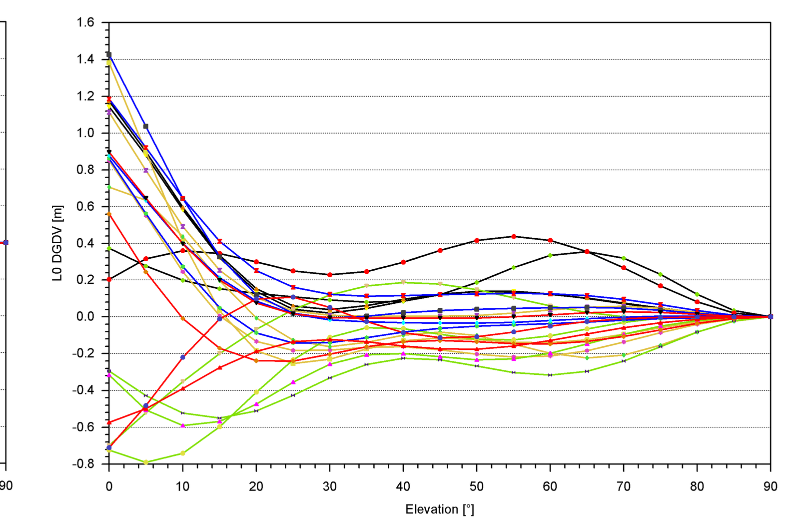
The absolute antenna calibration is used with an antenna splitter to facilitate simultaneously several GNSS receivers. It allows to investigate the impact of different receiver hardware settings or different firmwares on the GDV calibration result. The zero-baseline setup serves for

- identical antenna
- elimination of hardware effects (eg cable)
- elimination of environmental effects

Five different zero-baseline calibrations with the same individual antenna ASH700936E NONE are shown in the following graphics. From the zero-baseline tests a good agreement of the GDV pattern is obtained in some cases, although different receiver hardware and receiver settings have been used. This supports the possibility to determine repeatable GDV in an absolute antenna field calibration. The differences between the zero-baseline groups must be analysed in more details and are out of scope for this presentation.







Summary

First experiences from GPS group delay calibrations with the Geo++ absolute antenna calibration system have been presented.

The initial tests reveal a significant group delay variations for geodetic GNSS antennas. The magnitude is in the order of up to 1 m for elevations below 30 deg and the ionospheric free linear combination. Sufficient repeatability of GDV is currently not obtained from an individual antenna calibration. However, combining a large sample of GDV calibrations gives a significant type mean with an accuracy of about 5 cm.

The repeatability of the individual code calibration may be due to more sensitivity of the code observable to environmental effects (weather, temperature, hardware setup, etc). Additional investigations of parameters affecting the group delay estimation are required. Also the estimation of GLONASS GDV and the modeling of multipath in the GDV estimation will be analysed in the future.

Several GNSS applications are interested in group delay corrections. Among these are for example precise time transfer, GNSS guided precision approaches and landing systems. But also in geodetic applications the ambiguity fixing (code/carrier comparison techniques) and the general interpretation of code multipath can benefit from more insight into antenna group delay variations.