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Near-field Effects on GNSS Sites

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Analysis using Absolute Robot Calibrations and Procedures to Determine Corrections

Introduction

The phase centre and variations (PCV) of an GNSS antenna can be precisely determined using the Geo++® Absolute Field Calibration with a robot. The PCV are determined free or significantly reduced of any mutipath effects depending on the antenna type. However, there are remaining multipath effects caused by the actual setup and the environment on the GNSS site, which can significantly modify the phase variations.

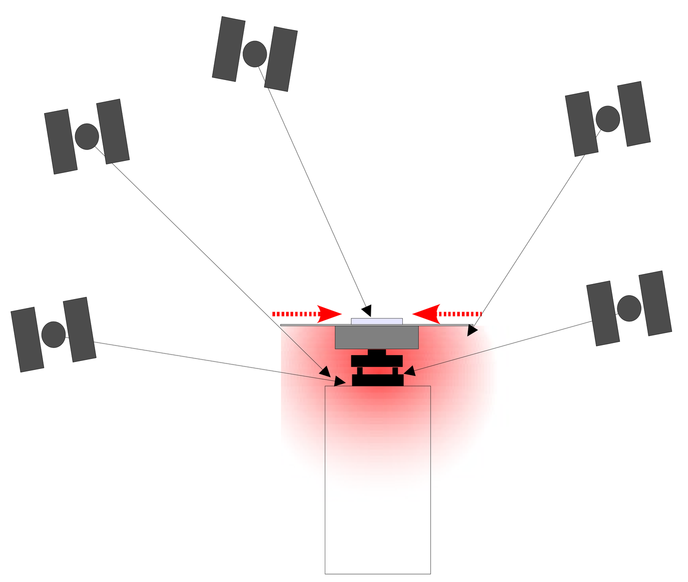
The site multipath influence itself can be separated into **near-field** and **far-field** effects, which do have different properties. Near-field effects cause a systematic bias especially in the coordinate height component. Far-field effects can be averaged out by sufficient length of observation data.

The absolute antenna calibration with the robot is an excellent instrument to investigate near-field 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 the very long-periodic multipath in the close vicinity and electro-magnetic interaction of the antenna, the phase variation pattern change. Therefore, the near field effect of the antenna can be determined and investigated.

Theory

For an isotropic antenna (point form) and an unlimited horizontal reflector the near-field effect is a function of

- mainly satellite elevation
- detour path rsp. height
- reflection coefficient
- signal frequency



The near-field effects are caused by the antenna setup, e.g. pillar, tripod, adaption, etc.

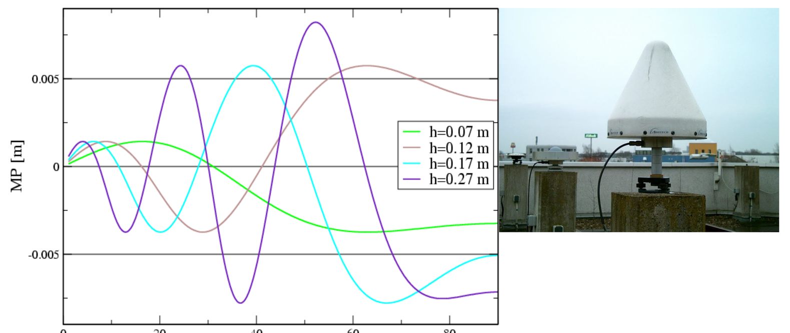
The signal is influenced by:

- diffraction
- reflection
- imaging
- electro-magnetic coupling

The constant geometry of antenna and close surrounding cause a systematic change of the reception characteristics of the antenna. There is no averaging of this near-field multipath over time and it will mainly bias the height component.

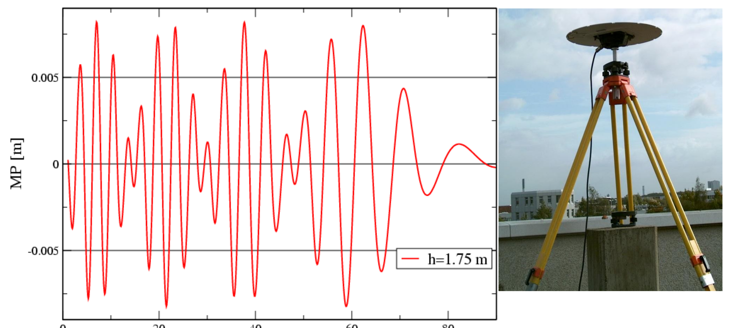
The near-field multipath has been computed for different scenarios:

Pillar Setup



- low frequency
- effect in high elevation
- systematic influence (bias)
- elevation dependent, but also azimuth dependent for non-symmetric setups

Tripod Setup



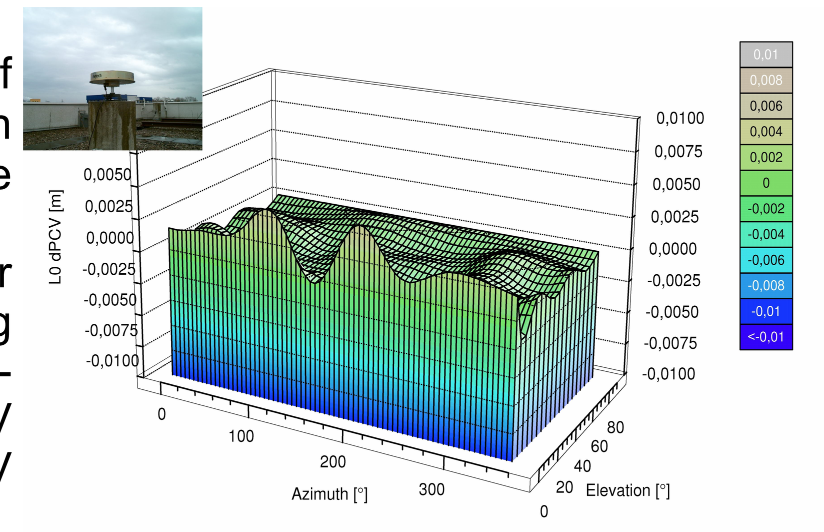
- high frequency
- influence „smaller“
- transition into far-field effect

Calibration of the Near-field effect

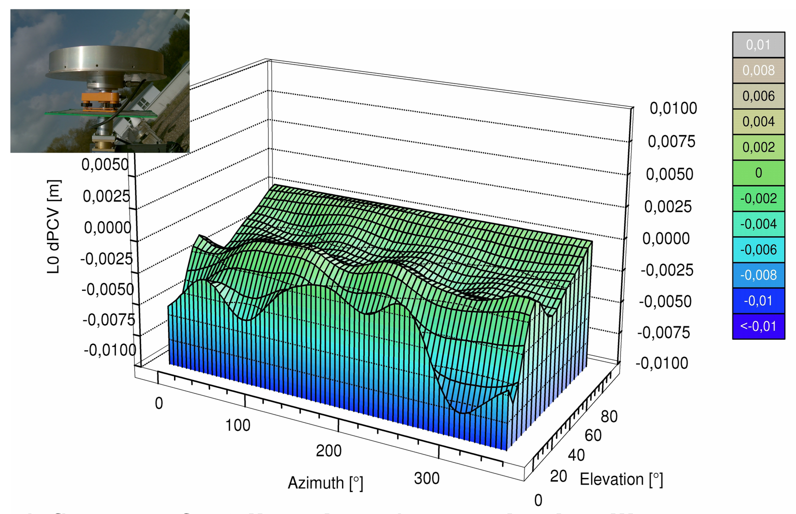
The near-field effect can be described like antenna PCV. For a constant geometry between antenna and near-field (tripod, pillar) the estimated PCV include the sum of both errors. The robot is limited in weight and dimension of the tested antenna setup. However, re-construction of the near-field causing setup are possible to calibrate.

The graphics show PCV differences of the ionopheric-free linear combination **L0** for the **same** Dorne Margoline type antenna (ASH700936D_M).

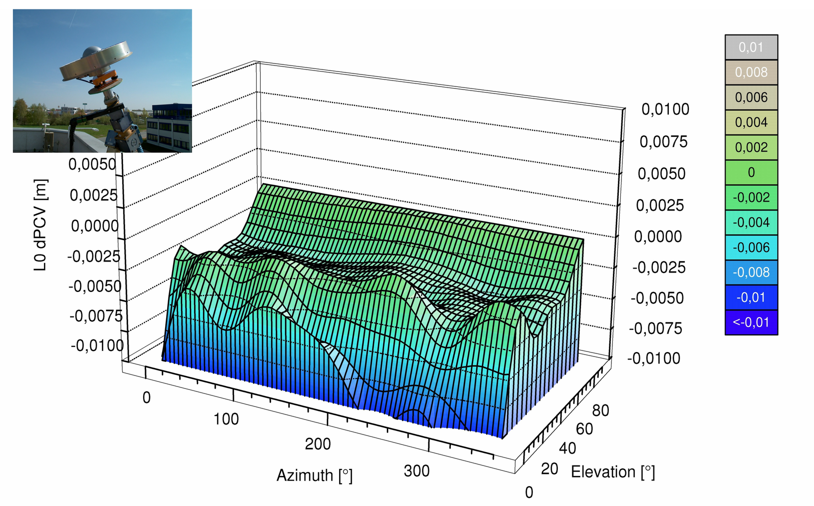
The repeatability is generally better than 2mm, except for the horizon (0deg elevation). The influence of the re-constructed near-field on the PCV reaches up to 10mm. These PCV differences are the near-field influence.



***Repeatability** of two calibration with the same setup*



*Influence of a **tribrach** and a **quadratic pillar** re-construction, edge 30cm*



*Influence of a **tribrach** and a **round pillar** re-construction, diameter 20cm*

Station Dependent Errors

The PCV and Multipath are most important station dependent errors:

PCV + MP

Station calibration with robot is generally possible, but problems with spatial coverage (constellation), changing environment, weather influences (reflection coefficient), efforts and costs, etc.

Therefore MP is divided in near-field and far-field effects, which leads to

$PCV + MP_{near\text{-}field} + MP_{far\text{-}field}$

Antenna

PCV: elevation and azimuth dependent Phase Centre Variation
=> **Calibration of PCV** with robot

Multipath

near-field: long-periodic, systematic effect, bias
=> **Calibration of near-field effect** together with PCV using robot and re-construction of antenna setup

far-field: short-periodic, systematic effect
=> average over time or station calibration

Site stability

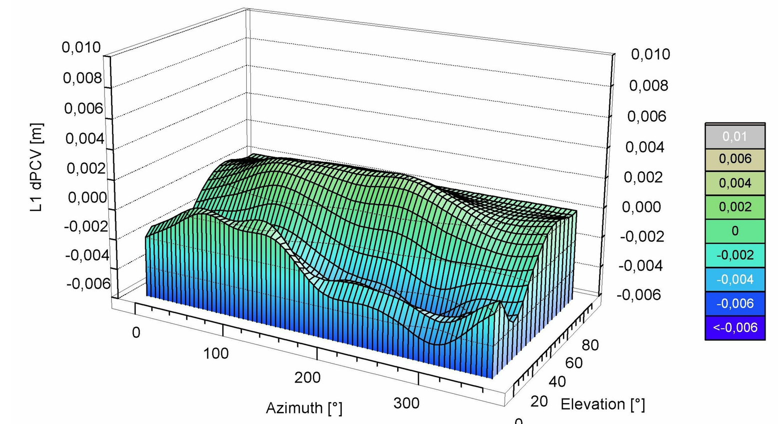
stable monument and site for antenna
=> analysis of time series, but affected by PCV and $MP_{near\text{-}field}$

Acknowledgement: Results and graphics from NETPOS were kindly provided by Kadaster, the Netherlands.

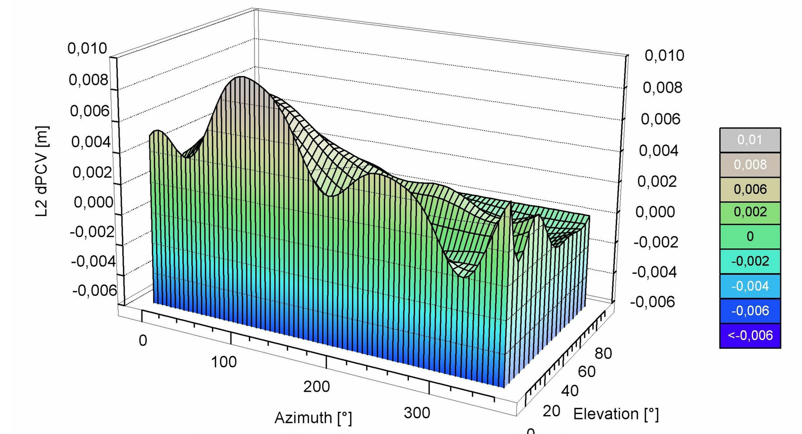
Experience from a RTK network

The TPSPG_A1 antenna, a small rover antenna without ground plane and choke rings, are mounted on a steel pipe mast. The near-field effect will have a significant influence for such a antenna setup causing especially height errors in positioning. A calibration of the antenna including (the upper part of) the mast was executed with the robot to determine the near-field effect together with the antenna's PCV.

The differences between the calibration of the antenna with and without the antenna with re-construction reach a magnitude of several mm for L1 and L2. For L0 the differences amplify close to 2cm. The differences are computed from type means considering more than five antenna.

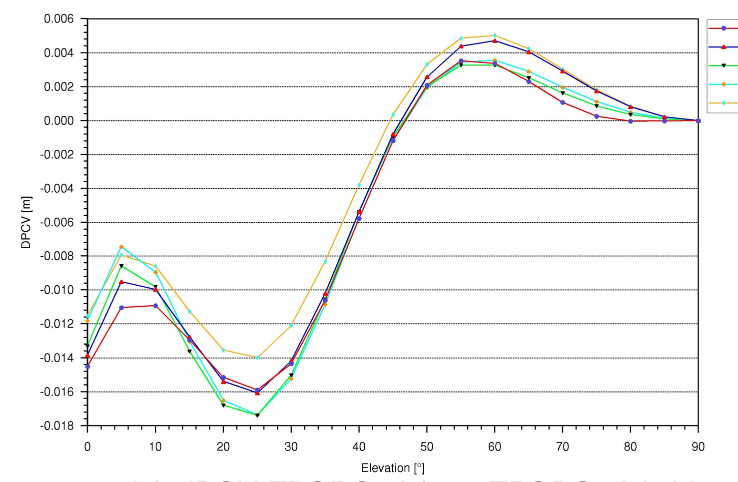


L1-dPCV: TPSPG_A1 vs. TPSPG_A1+M

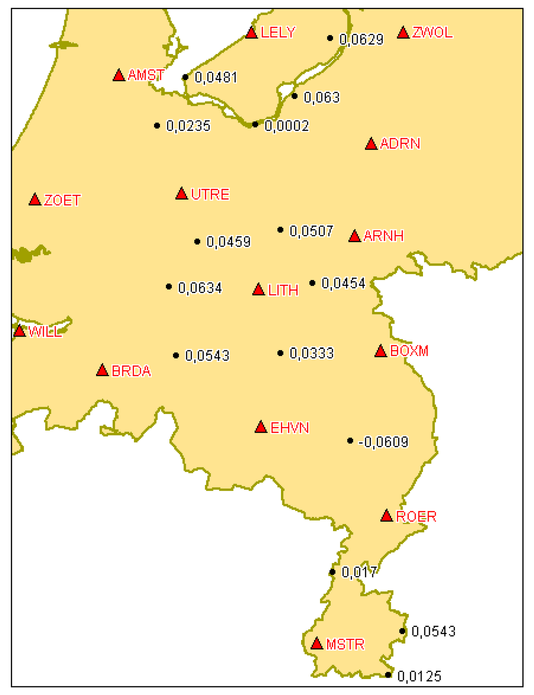


L2-dPCV: TPSPG_A1 vs. TPSPG_A1+M

The elevation dependent graph shows differences of five individually calibrated antenna with mount compared to the type mean of the antenna without any mount for the ionospheric-free linear combination L0. The repeatability of the mount influence is in the order of 4mm. The effect itself is up to 18mm.



L0-dPCV:TPSPG_A1 vs. TPSPG_A1+M



RTK positioning height errors observed in NETPOS caused by antenna near-field effects

Effect in Position Domain

The Kadaster in the Netherlands build up a RTK network called NETPOS for governmental authorities. NETPOS consists of 31 reference stations. All reference stations are equipped with the same antenna setup, like the above discussed TPSPG_A1 with steel mast. To validate the quality of NETPOS RTK measurements were executed on 81 well-known reference points, part of the Netherlands base net. A systematic height offset with a mean value of 32mm and constellation dependent variations appeared, see map.

Cause of these errors are the near field effects of the reference antennas. The effect in RTK positioning is increasing compared to the actual near-field effect due to tropospheric modelling and satellite constellation. After introducing the PCV corrections with the re-construction of the steel mast, the RTK height components are free of systematic biases and have a precision of better than 19mm.

Summary

The systematic bias caused by near-field effects can be calibrated together with the antenna's PCV on the robot. The application in an operational RTK network demonstrated the significant improvement in coordinate estimation.

Investigations are on the way to estimate the near-field antenna effects on a site with a special observation procedure in addition to the robot calibration.