Analysis of the Impact of Rotating GNSS Antennae in Kinematic Terrestrial Applications

TS04E - Laser Scanners, Friday, 20 May 2011

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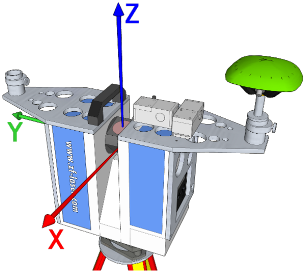
FIG Working Week – *Bridging the Gap Between Cultures*
Marrakech, Morocco, May 18-22, 2011

Motivation

Transformation of local, sensor defined coordinates to absolute or global coordinates

- Typical task in terrestrial laser scanning applications
- Transformation parameters: translation and rotations (at least the azimuthal orientation) required
- Observation of transformation parameters (with additional sensors) is worthwhile

⟹ Most suitable is the use of GNSS equipment



Current realisation of the combination of laser scanner and GNSS equipment at the Geodetic Institute

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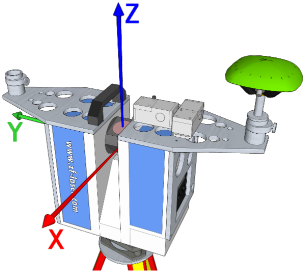


Current realisation of the combination of laser scanner and GNSS equipment at the Geodetic Institute

GNSS equipment to determine position and orientation in kinematic applications

- *Alternating orientation of an eccentrically* mounted GNSS antenna

⟹ Systematic effects:
- Polarisation of the satellite signal (Phase wind up effect)
- Phase centre corrections (offsets and associated variations)

Contents

Errors related to rotating GNSS antennae

Phase wind up (PWU) effect

- Up to one full cycle due to the signal polarisation
- PWU effect is linear in time and identical for all satellites visible in the topo-centre assuming an antenna horizontally rotating with constant velocity
- Single-differences on a short baseline
  - Constant net effect for all satellites

  $\Longrightarrow$ Absorbed by the receiver clock error

Phase centre corrections (PCC)

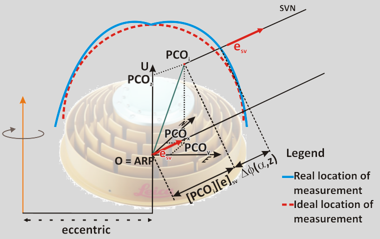
Errors related to rotating GNSS antennae

Phase wind up (PWU) effect

Phase centre corrections (PCC)

- Measurements related to electrical phase centre
- Modelling of observations in adjustment often w.r.t. antenna reference point (ARP)
- PCC described by phase centre offset (PCO) and associated elevation and azimuth depending phase centre variations (PCV) close the gap

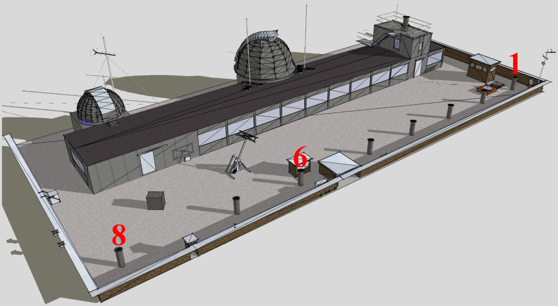
Sketch of PCC for an eccentrically (and horizontally) rotating antenna



$\Delta\phi_{ant}(\alpha,e) = [PCO_i]\,[e_i] + \Delta\phi(\alpha,e=\pi/2-z)$

Location and GNSS equipment

Location: Geodetic network with 9 pillars at the roof of the building of the GIH



GNSS equipment

Reference station (MSD08)

Antenna: LEIAR25 LEIT
Receiver: JAVAD TRE_G3T DELTA

Antenna under test (MSD06)

Antenna: JAV_GRANT-G3T
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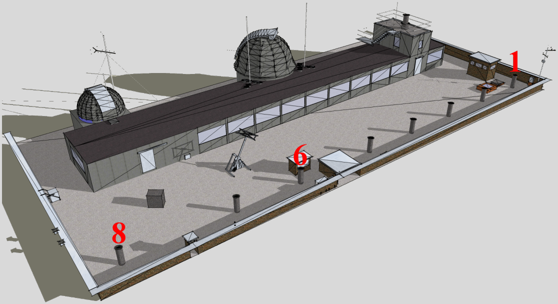

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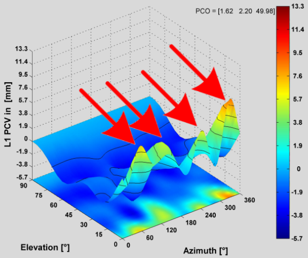
GNSS equipment – investigation strategy

PCV pattern L1: *Javad Grant G3T* antenna



Investigation strategy

GNSS equipment – investigation strategy

PCV pattern L1: *Javad Grant G3T* antenna

Investigation strategy

- Simultaneous acquisition of GNSS and reference trajectories
- Creation of reference trajectories

(1) Theoretic one: Computed based on the known geometry of the GNSS antenna mount on top of the laser scanner

(2) Experimental one: Tracking of a *Leica GRZ122* 360° prism with a *Leica TS30* tacheometer

- Data analysis in observation and coordinate domain

GNSS equipment – investigation strategy

PCV pattern L1: *Javad Grant G3T* antenna

Investigation strategy

In the following study we used

- *Wa1* software using single-differences between receivers to eliminate
  - Orbit errors,
  - Satellite clock errors and
  - Errors due to propagation delays in the atmosphere
- A small baseline of about 14 $m \Longrightarrow$ eliminates all atmospheric effects

Pre-investigations - measurements with a non-rotating antenna (DOY049 and 041)

Performance of the used antenna for estimating coordinates with non-rotating antenna

- Similar combination of antenna, 360° prism and height above pillar
- DOY049: Standard tripod on pillar 6
- DOY041: Additional use of the wing adaption for mounting on a laser scanner
- ΔT for DOY049 and 041 corresponds to difference of sidereal and solar day length

$\Longrightarrow$ Get a rough idea about the influence of the wing adaption

Antenna setup without wing adaption

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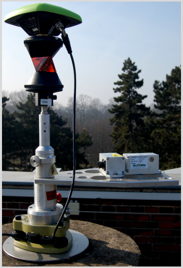

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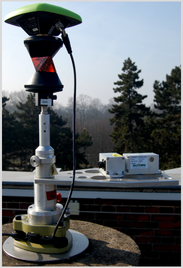
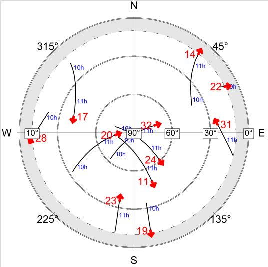


Skyplot DOY049 – 09:50:38 - 11:25:38



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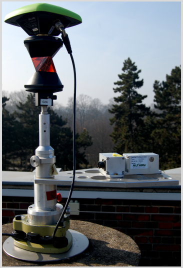

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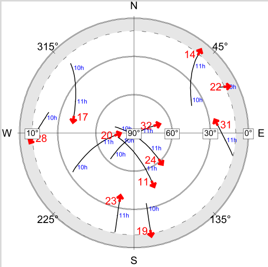

Kinematic measurements with an eccentrically rotating antenna (DOY025)

Analyse the impact of rotating GNSS antennae in kinematic terrestrial applications

- Measurements with a laser scanner rotating about its vertical axis (duration for full circle $\approx$ 13 min, vertical rotation speed $\approx 12.5\,Hz$)
- ΔT for DOY025, 049 and 041 corresponds to diff. of sidereal and solar day length
- Weight compensation for GNSS antenna and prism
- Laser scanner is oriented to the direction of gravity; for observation of remaining spatial residuals inclinometer were used
- All observations (GNSS and tacheometer) are synchronised by an external computer

Used equipment

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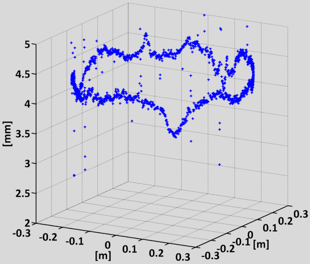
Used equipment and sample trajectory in local geodetic coordinates



Analysis of the impact of the PCC by calculation of range corrections

For every epoch a new set of PCC for an eccentrically rotated antenna is calculated and projected into the line of sight to the individual satellites

$$\mathrm{PCO}_c = f(PCO, \alpha_0, \mathrm{r}, \Delta\alpha)$$

$$\mathrm{PCV}_c = f(PCV, \alpha_0, \mathrm{r}, \Delta\alpha)$$

$$\Phi^j_{c_i} = \Phi^j_i - \mathrm{PWU}^j_{c_i} + \mathrm{PCO}^j_{c_i} - \mathrm{PCV}^j_{c_i}$$

mit :

$i :=$ Frequenz L1/L2

$j :=$ Satellit No.

- Initial azimuth of antenna orientation
- Well known geometric parameters (radius and angle inc. between 2 rotation steps)
- PWU effect already treated by analysis software *Wa1* [1]

[1] Personal correspondence with L. Wanninger

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$\Longrightarrow$ Re-processing of modified observations and further analysis in the coordinate domain

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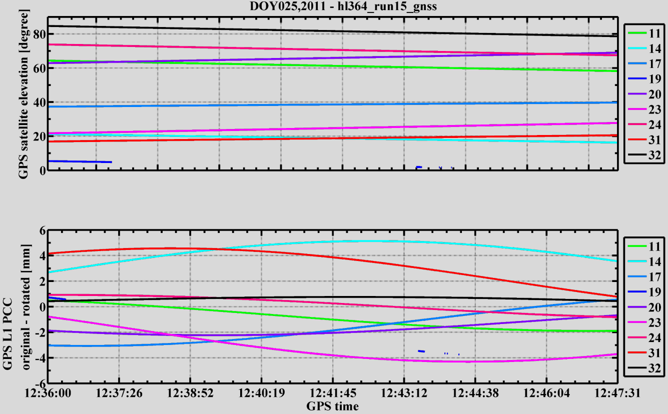
Original PCC minus rotated PCC

Original PCC minus rotated PCC for GPS L1 signals; DOY025, run15



Intermediate result

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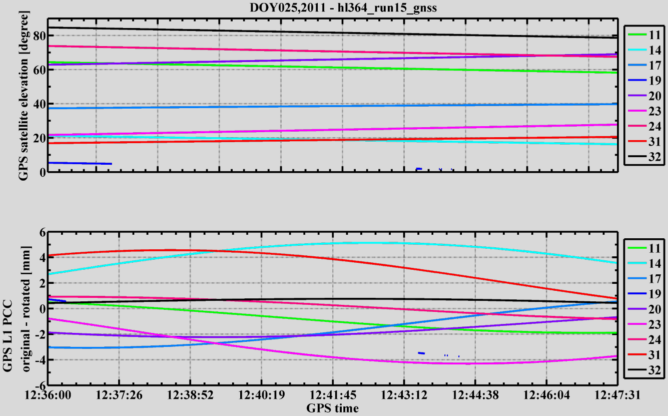
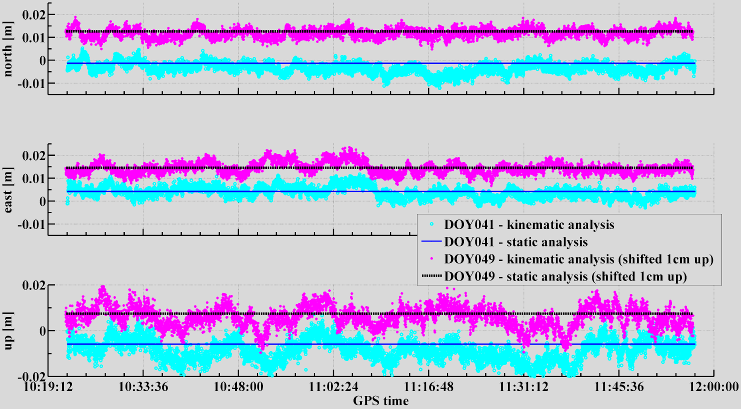


Intermediate result

$\Longrightarrow$ For GPS L1 magnitudes of up to 5 *mm* occur at low elevations

NEU coordinates of non-rotating antenna in different scenarios

Differences (to ITRF05 coordinate of pillar 6); 1 *Hz* data rate and 10° cut-off angle



Intermediate results: Kinematic coordinate estimation potential of the used GNSS antenna

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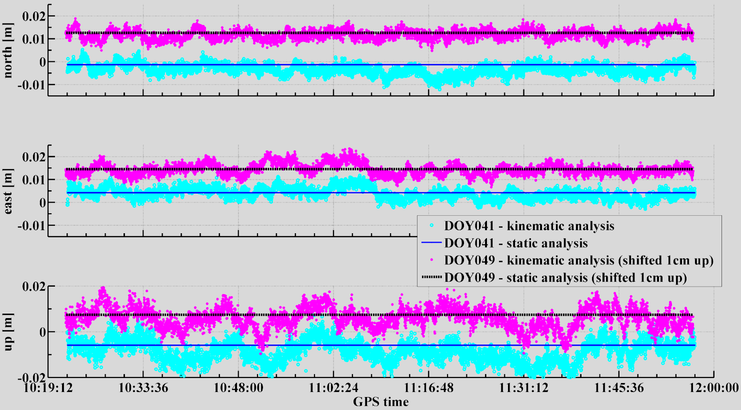


Intermediate results: Kinematic coordinate estimation potential of the used GNSS antenna

⟹ Maximum range of 1 *cm* for northing, easting and up to 2 *cm* for the up component

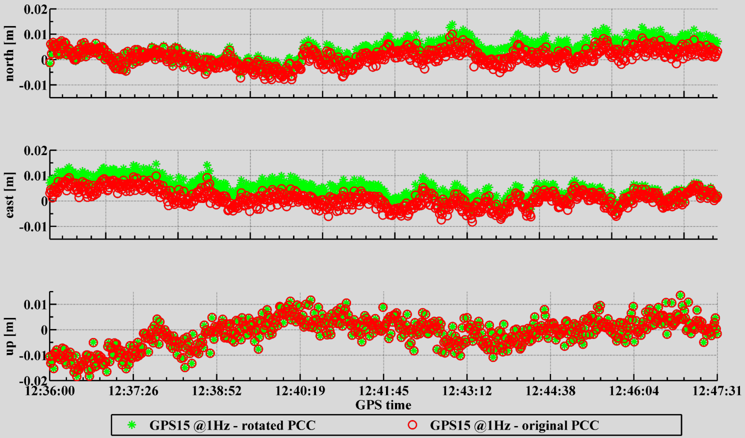
⟹ NO significant influence due to the wing adaption

NEU coordinates of rotating antenna (GPS)

Analysis of Rotating GNSS Antennae

Paffenholz et al.

Computed differences between experimental reference trajectory and rotated PCC pattern as well as original PCC pattern



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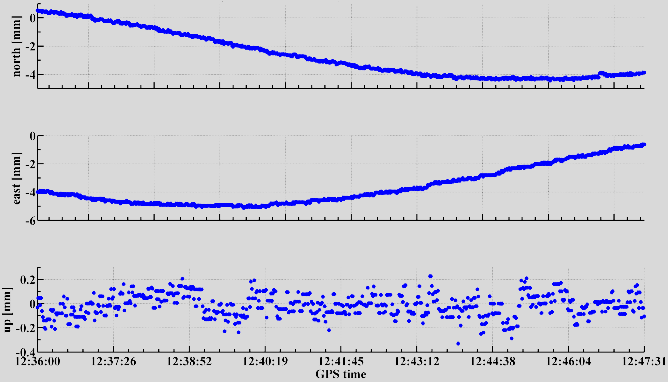
Difference between GNSS trajectories with original and rotated PCC applied



Intermediate results: PCC effect for rotating GNSS antenna

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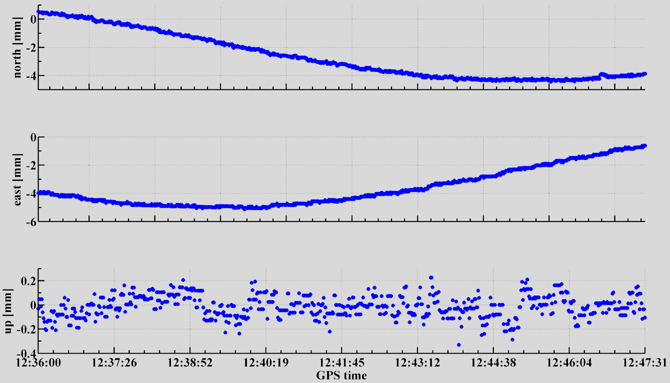
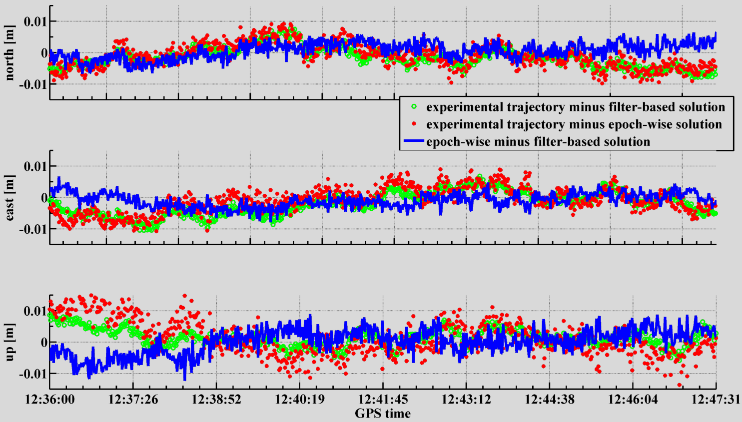


Intermediate results: PCC effect for rotating GNSS antenna

⟹ Magnitude from 0 *mm* to 4 *mm* for northing and the other way round easting as well as range of discrepancy of 0.4 *mm* for the up component

Difference of NEU coordinates of epoch-wise solution vs. filter-based solution

Differences between experimental trajectory and filter-based solution (GNSMART[2], green circles) as well as epoch-wise solution (Wa1, red bullets)



[2] GNSMART by Geo++

Special thanks go to Nico Lindenthal for the support with the kinematic GNSS analysis with GNSMART.

Conclusions and Outlook

Conclusions and sum up of the results

Observation domain

- Double differences analysis shows no significant impact of the used wing adaption in the direct vicinity (see paper)
- PWU effect is constant $\Longrightarrow$ treated like receiver clock offset in the adjustment
- Effect of up to 5 mm for rotated PCC against original PCC $\Longrightarrow$ corresponds to horizontal offset component

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Coordinate domain

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- Analysis of the impact of the rotated PCC on the derived transformation parameters

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Contact

Thank your for your attention!

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