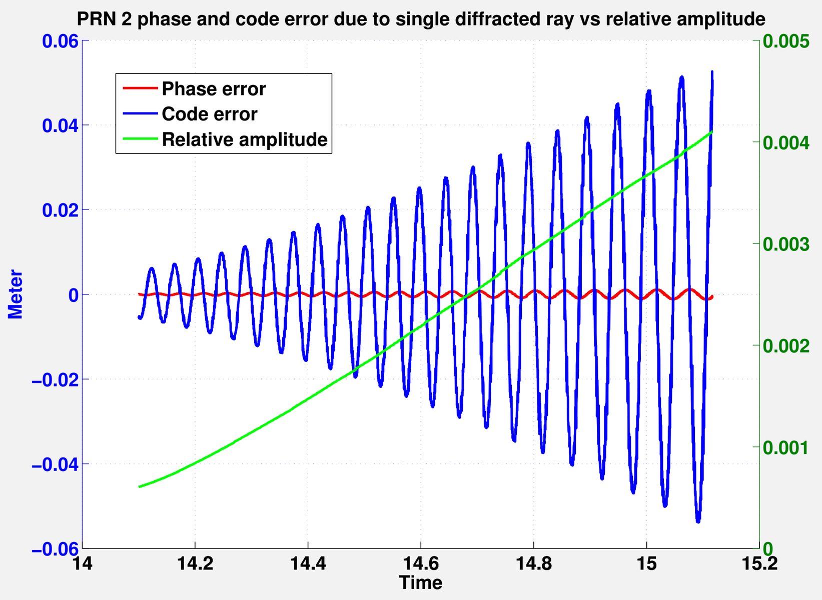
Station specific Biases in PPP and Reference Station Networks: Investigations at the Institut für Erdmessung

Steffen Schön, Tobias Kersten, Nico Lindenthal, Marios Smyrnaios, Ulrich Weinbach
Institut für Erdmessung | Leibniz Universität Hannover

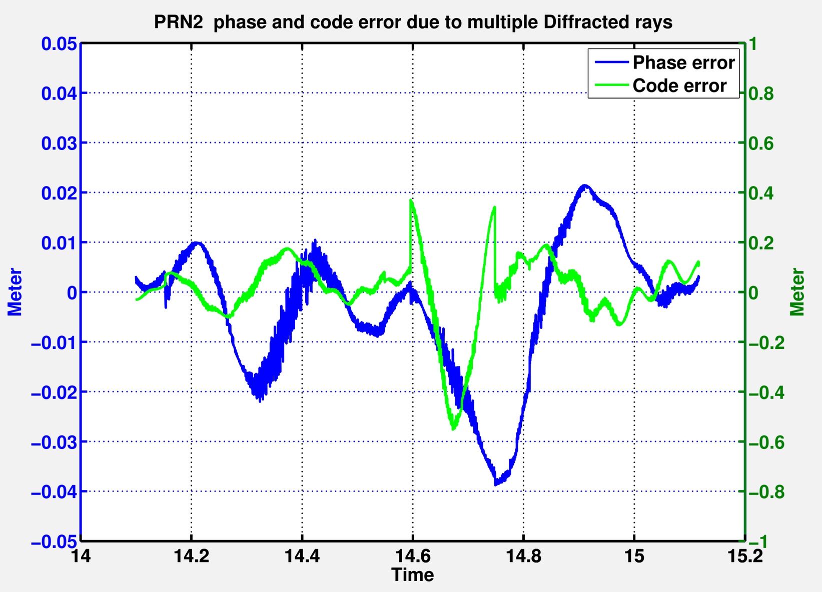
Multipath Propagation Modeling using Ray-Tracing and GNSS Receivers

At IfE, multipath propagation and its impact on phase and code observations are characterized through ray-tracing simulation and software receivers.

- **Input**: Description of the physical environment in which the receiver is placed, receiver-transmitter coordinates and antenna diagrams (both orthogonal polarizations).
- **Output**: Detailed description of geometrical, physical and electromagnetic properties of each ray.



(a)



(b)

Fig. 1: PRN 2 Phase vs. code errors for a single diffracted ray (a) and for multiple diffracted rays (b).

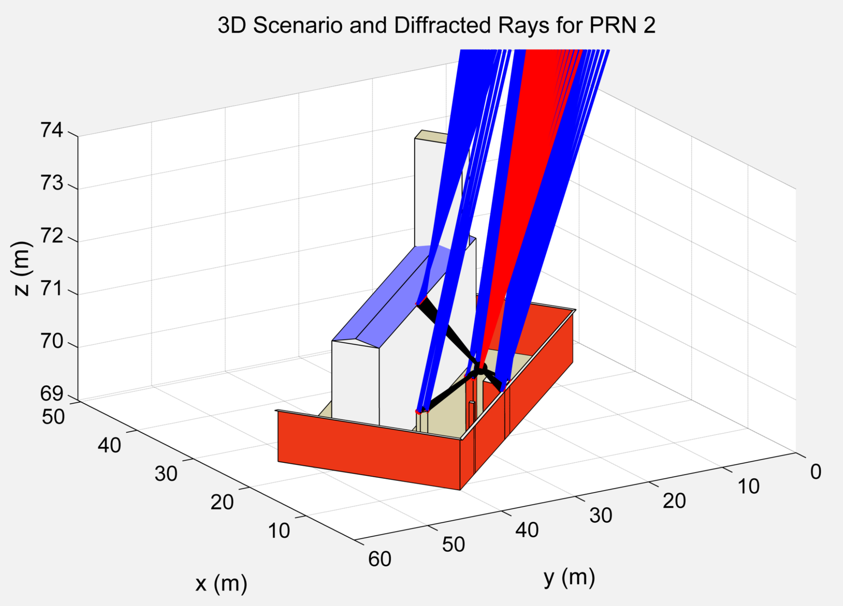


Fig. 2: Ray-tracing results of PRN 2. The direct ray is colored in red, the incident rays in blue and the diffracted rays in black.

Findings:

- Validation of multipath theory based on channel estimation from simulations.
- For one multipath component, phase and code error characteristics are as expected from theory (cf. Fig. 1(a)).
- Multipath relative amplitude is not constant but changing during observational period (cf. Fig. 1(a)).
- For multiple multipath rays, the 90° shift between phase and code errors is not occurring (cf. Fig. 1(b)).

Acknowledgement

This project is funded by the Federal Ministry of Economics and Technology (BMWI) based on a resolution of the German Bundestag.

Advanced receiver clock modeling in PPP

If the internal oscillator of the receiver is replaced by a highly stable atomic clock, e.g. a H-maser, the GNSS receiver clock offset can be modeled rather than estimated epoch-wise independently.

Findings:

- The analysis of GPS data of several IGS stations equipped with H-maser indicate that receiver clock modeling can improve the RMS of the height component of a kinematic PPP solution by up to 70 %.
- In contrast, the impact on static PPP solutions is generally negligible.
- The clock modeling for kinematic PPP of the two GRACE satellites (BlackJack GPS receivers connected to Ultra Stable Oscillators (USOs), with frequency stabilities of σ_y=1 - 3$\times 10^{-13}$ up to 1000 s was successfully demonstrated.

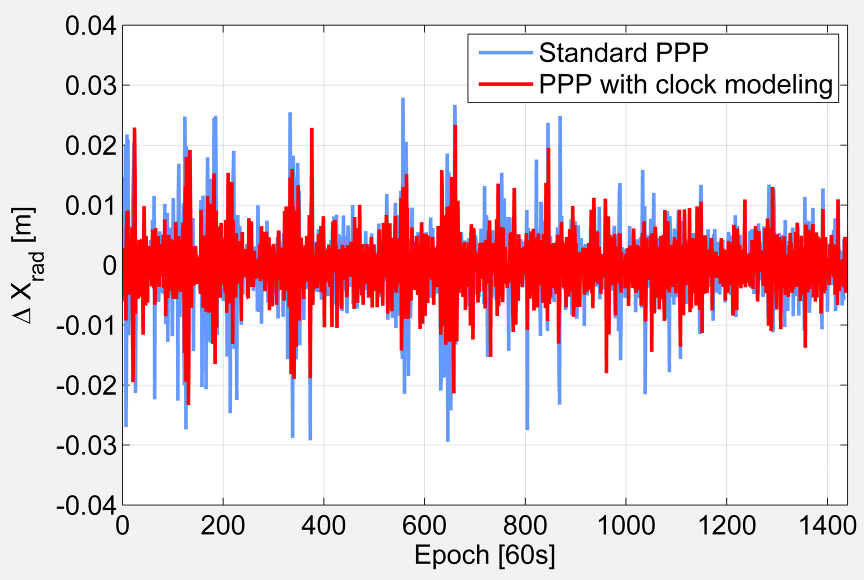
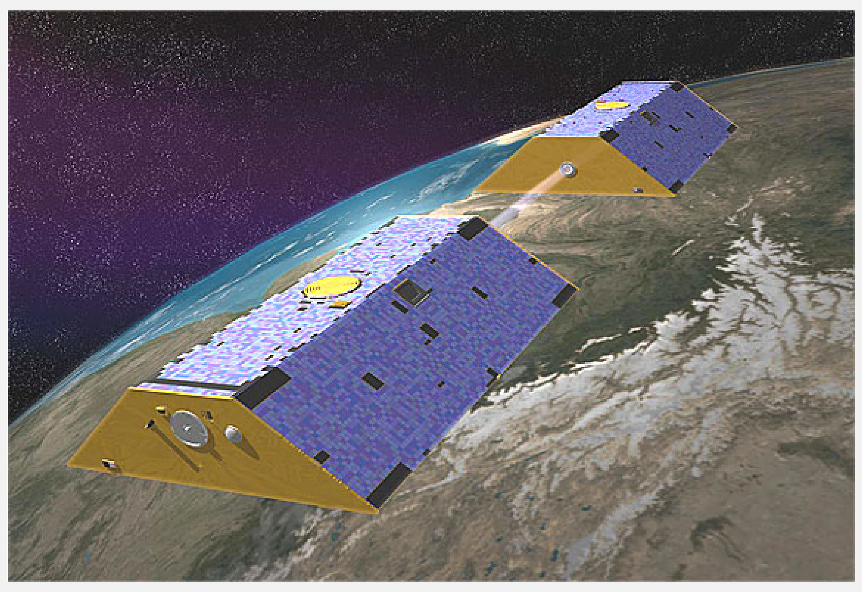


Fig. 3: High-frequency kinematic radial position residuals for GRACE A w.r.t. to a reduced-dynamic orbit (Jan 4, 2008).



© NASA

Fig. 4: The twin satellites of the Gravity Recovery And Climate Experiment (GRACE) mission in orbit.

- PPP simulations and code-only solutions indicate a possible improvement of the radial orbit precision of about 50 %.
- In addition clock modeling allows position estimation even if only 3 satellites are observed.
- For PPP with real GRACE data, comparisons with reduced dynamic orbits show indeed a significant reduction of the high frequency noise in the radial component.

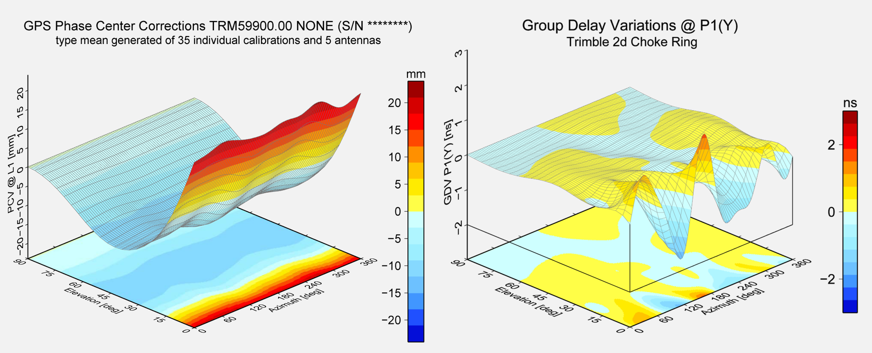
Acknowledgement

This work is part of and funded by the Quantum Engineering and Space Time Research Excellence Cluster QUEST.

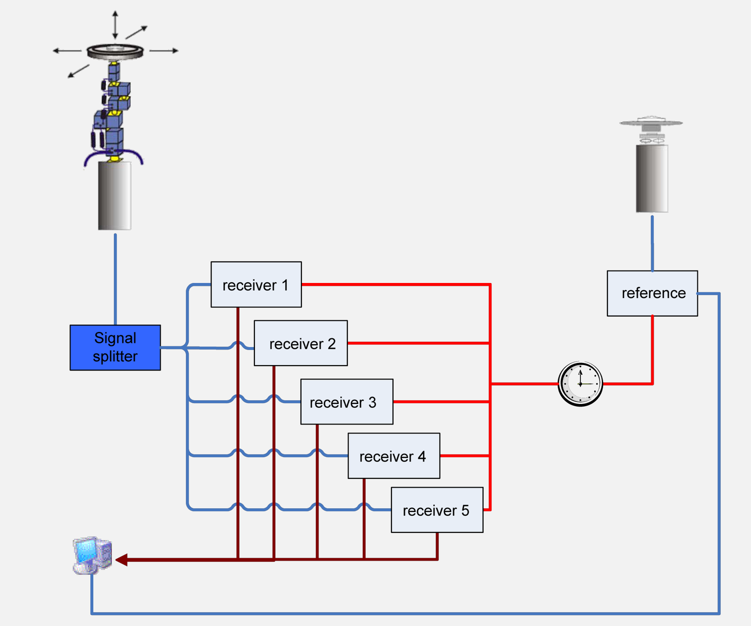
Absolute Antenna Calibration

The IfE is an official, active and IGS certificated calibration institution. The consistent set of GNSS Phase Center Corrections (PCC) of receiver antennae are determined routinely in the field using the actual signal in space and an overall accuracy of 0.2 - 0.3mm.

TRM33420.20 LEIAR25.R3 TRM5800

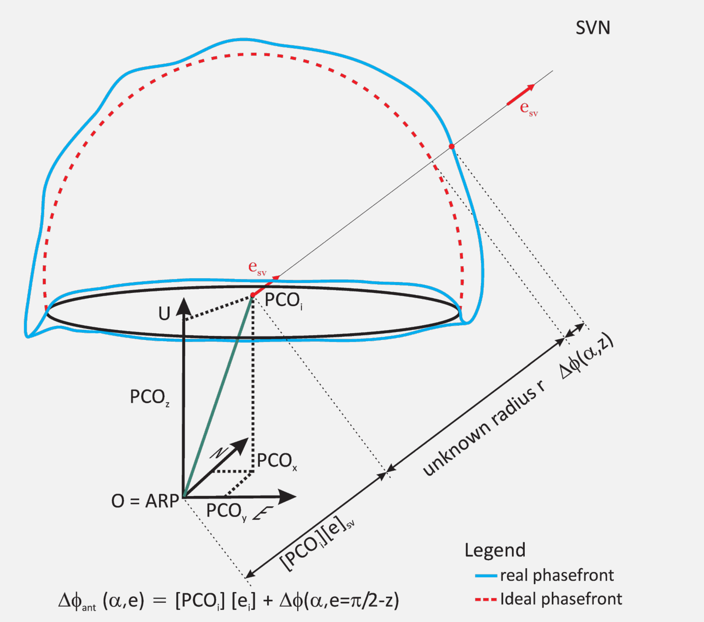


(a) (b)



(c)

Fig. 5: Typical Phase Center Variations (a), first experimental Group Delay Variations (b) and setup for the analysis of the receiver's impact on PCC determination (c).



© IfE, 2012

Current research topics:

- Interaction of the antenna w.r.t. different receiver units: equipment dependent variations on PCC could be demonstrated.
- Analysis on the interaction of the antenna's reception behavior w.r.t. antenna environment (Near field discrepancy).
- Investigations of PCC in a multi GNSS multi frequency common processing model
- Analysis of code errors by GNSS antennae.

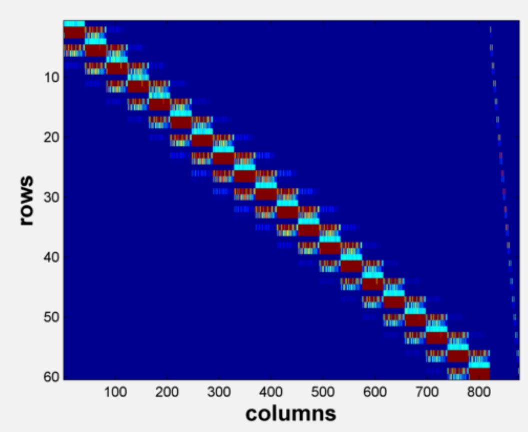
Acknowledgement

This project is funded by the Federal Ministry of Economics and Technology (BMWI) based on a resolution of the German Bundestag.

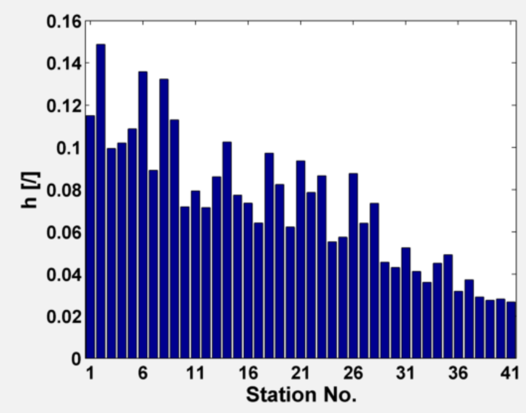
State Space Parameter in GNSS reference station networks

In GNSS reference station networks several distance dependent errors are modeled using surfaces, like e. g., *Flächenkorrekturparameter* (FKP). They are estimated in the state space together with other parameters within a GNSS network. These parameters enable to improve the user positioning by interpolating the corrections. Here, we show some FKP scenarios of the SAPOS network in Lower Saxony varying with time.

The estimatability of the state space parameters depends on the given geometry of a reference station network and the used stochastic processes. It can be analysed based on the transfer matrix $K = Q_x A'P$. Moreover it is important to check the impact factors of each station.

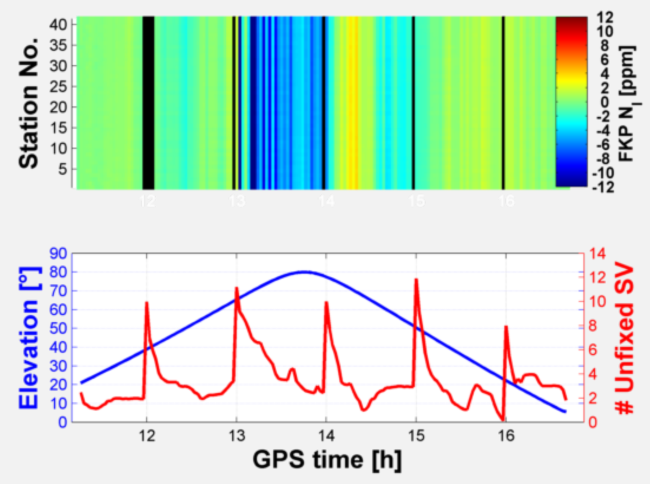


(a)

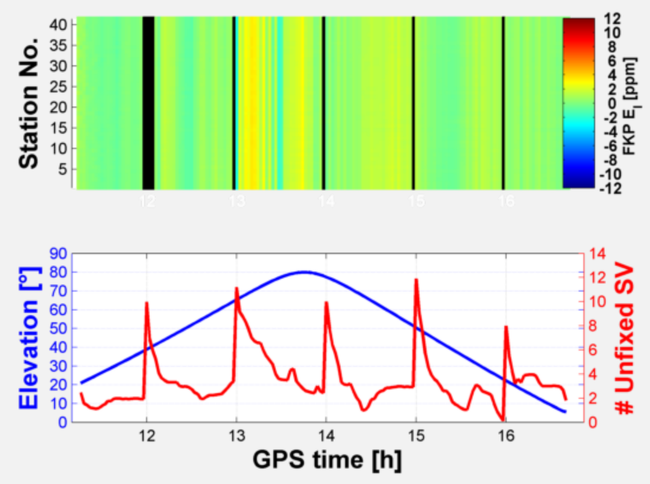


(b)

Fig. 6: Transfer matrix K (a) from batch processing and impact factors h_i (b) for the given station geometry.



(a) FKP_{NI} for PRN19



(b) FKP_{EI} for PRN19

Fig. 7: FKP for the ionosphere-free linear combination in S-N (a) and E-W direction (b).

Current research topics:

- Transfer of station geometry to state space parameters
- Identifying inter-epochal correlations
- Impact of gross errors in observations
- Estimability, reliability of parameters

Institut für Erdmessung
Schneiderberg 50
D-30167 Hannover

PPP-RTK & Open Standards Symposium
Frankfurt / Main | March, 12th-13th 2012

Steffen Schön
Tobias Kersten, Nico Lindenthal
Marios Smyrnaios, Ulrich Weinbach
www.ife.uni-hannover.de
<surname>@ife.uni-hannover.de