BERTA - Project

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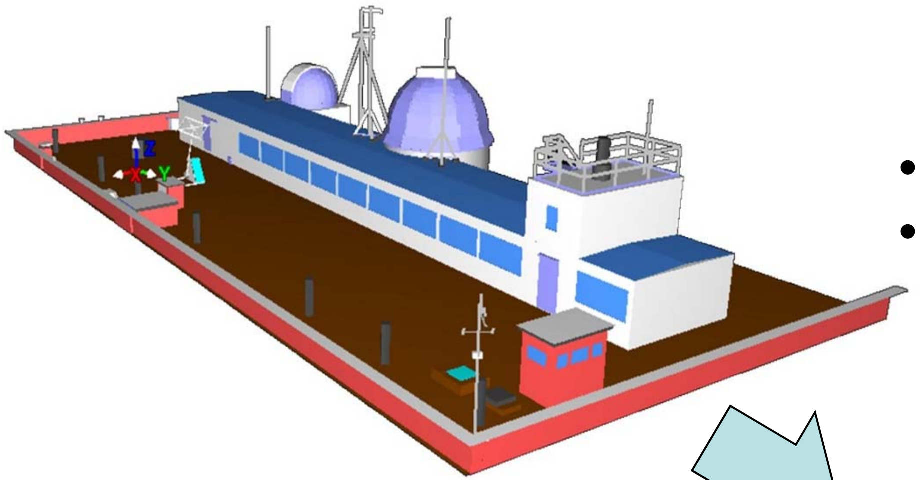
Hannover 22.07.2014

Overview

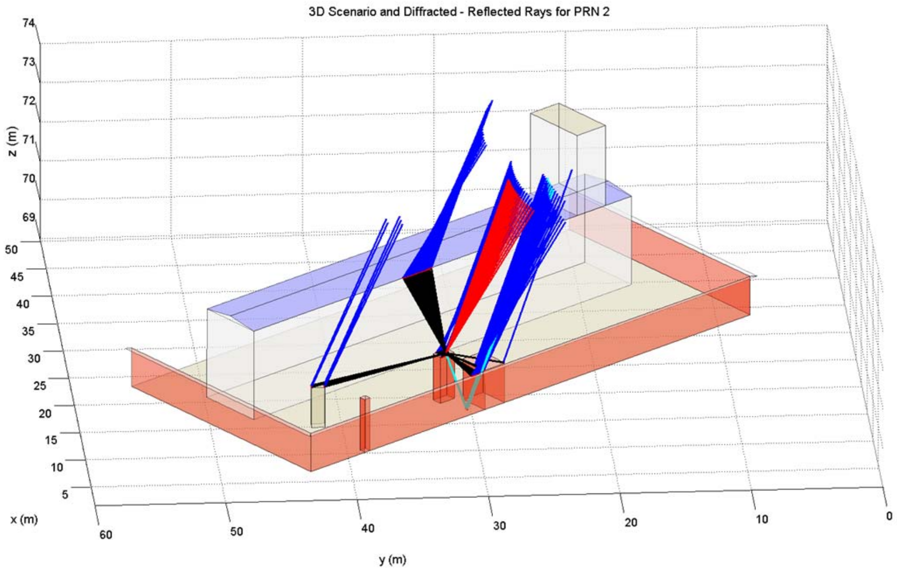
- GIH Rooftop Experiment
- PTB Experiments
- Sea Gate Experiment
- Indoor Experiment
- Outlook

GIH Rooftop Scenario



3D Model Measured with Terrestrial Laser Scanner (GIH):

- Coordinates of all planes
- Material properties of all planes



Visualization of Simplified Scenario and Ray-Tracing Results

GIH Rooftop Measurement Campaign

<u>Investigation w.r.t.:</u>

- **Sidereal Repeatability** of multipath effects
- Impact of different **Receivers/Antennas**
- Impact of different **C/N_0 estimation algorithm**
- Impact of different **Tracking Schemes**

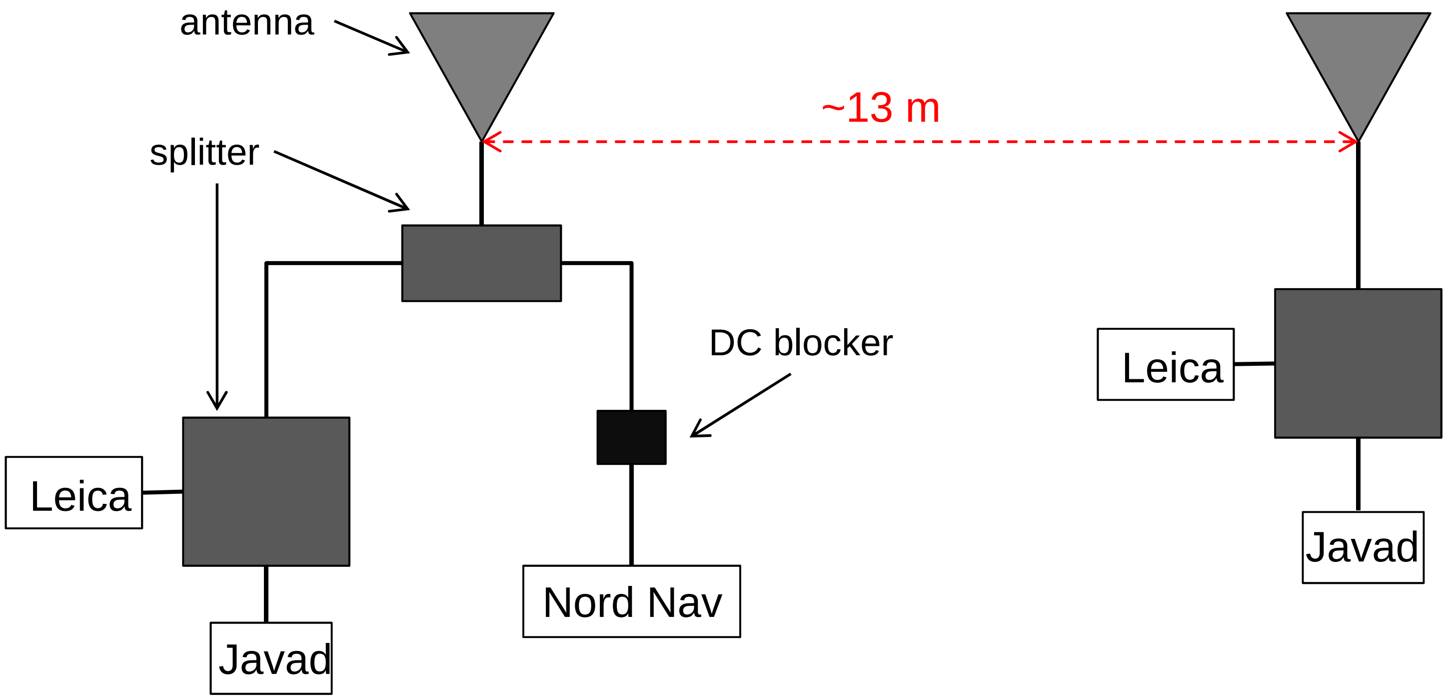
Date	Data
03.03.2011	Raw observations + IF
04.03.2011	Raw observations + IF
07.03.2011	Raw observations + IF

Javad G3T Delta

Leica GRX1200 +GNSS

Nord Nav R30

Experiment setup



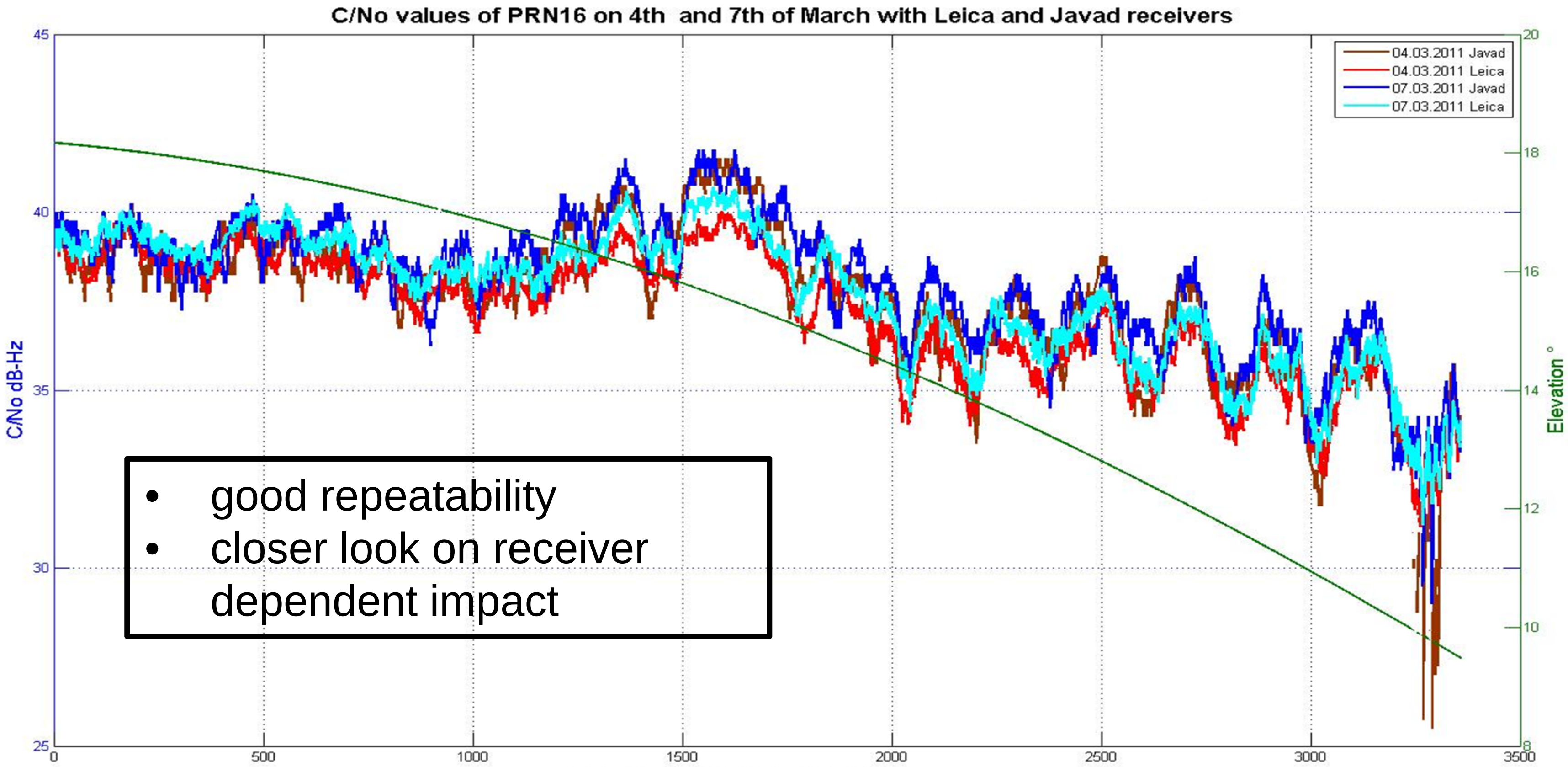
RINEX data processing:

- Matlab-based modules developed at Institut für Erdmessung

IF data pocessing:

- Nord Nav firmware
- Matlab-based software receiver modules for C/N_0 estimators and carrier phase discriminators developed at Institut für Erdmessung

Sidereal repeatability of Multipath Effects



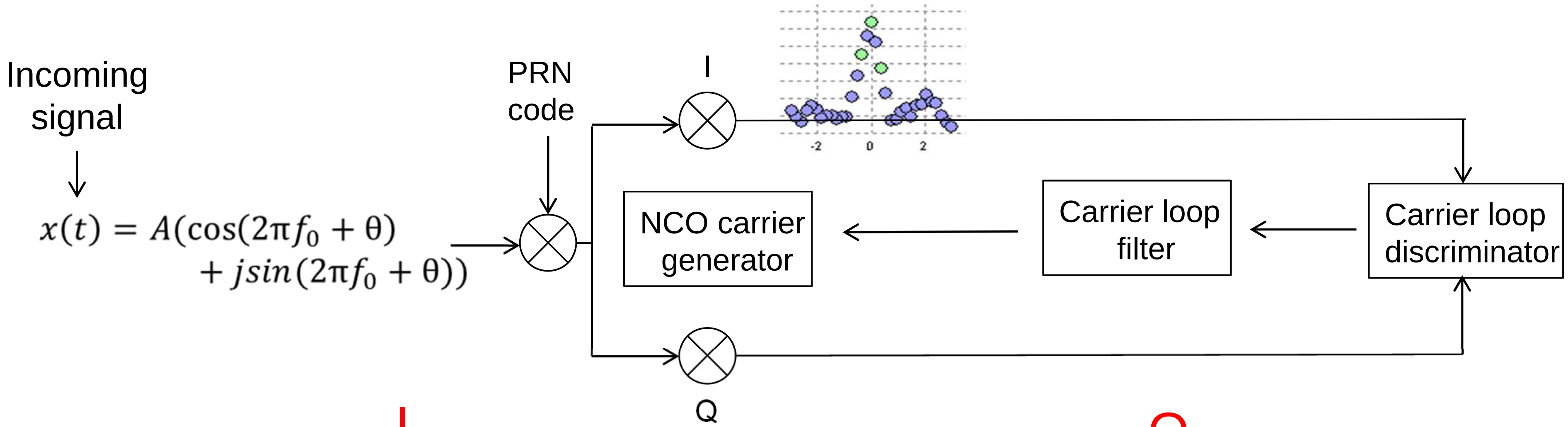
- good repeatability
- closer look on receiver dependent impact

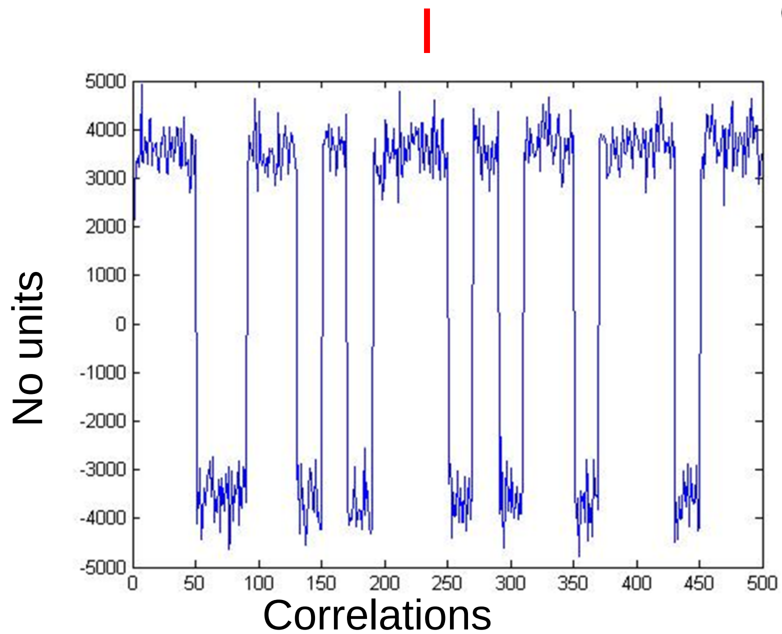
Mean offset value: 1.038 dB-Hz and σ=0.443 dB-Hz

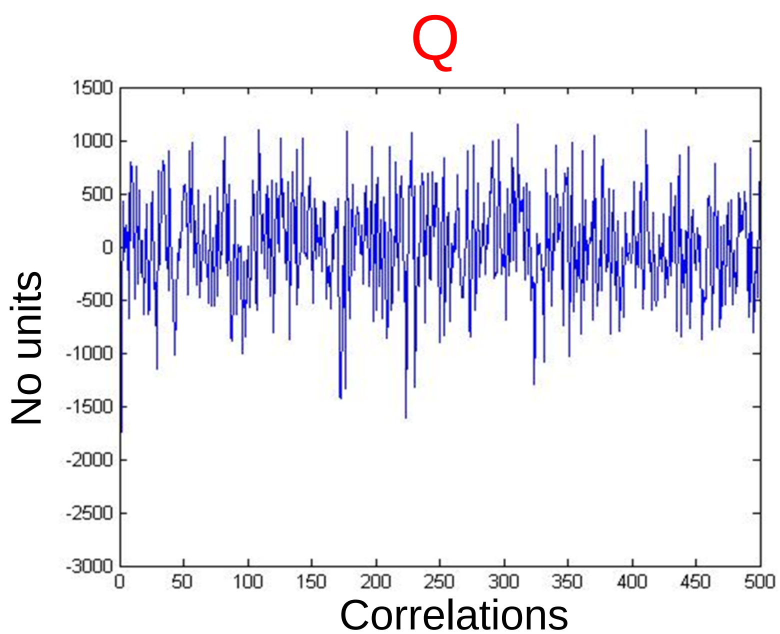
Date	Start time	End time
04.03.2011	14:22:08	15:18:53
07.03.2011	14:09:56	15:06:41

GNSS Signal Processing - Overview

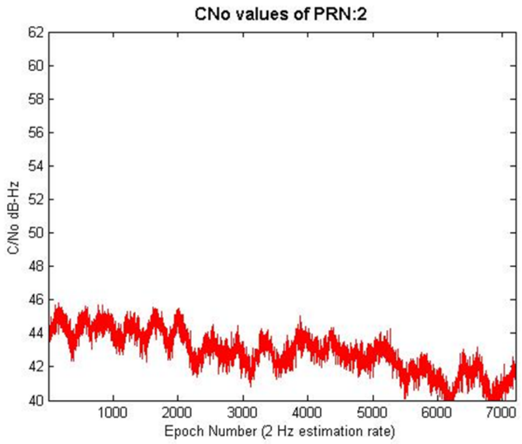
But due to multipath and noise the discriminator is never zero



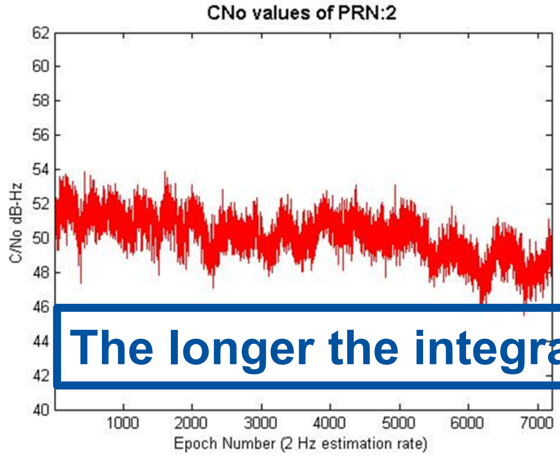




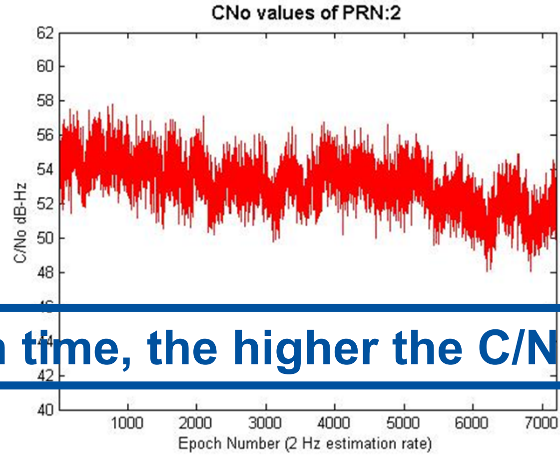
Different integration times and averaging periods



T=1msec, rate=0,5 sec

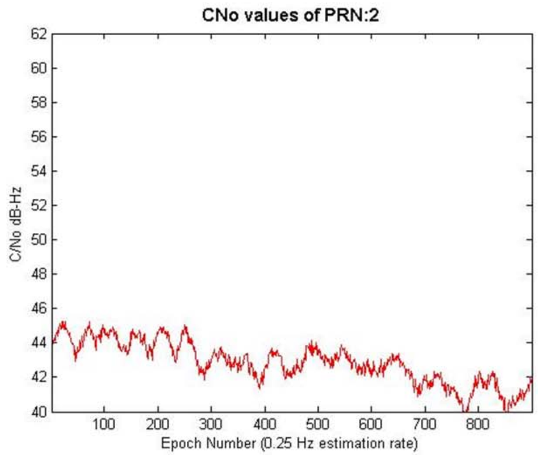


T=5msec, rate=0,5 sec

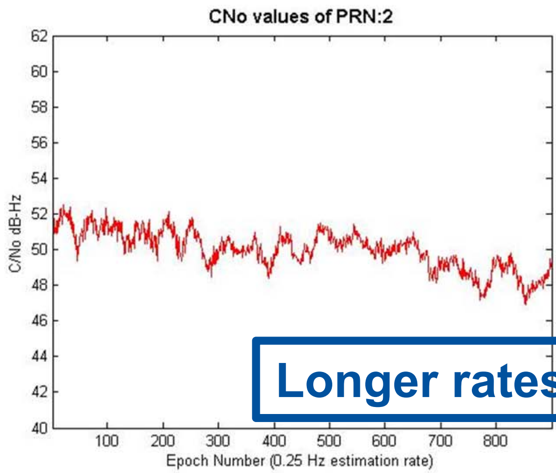


T=10msec, rate=0,5 sec

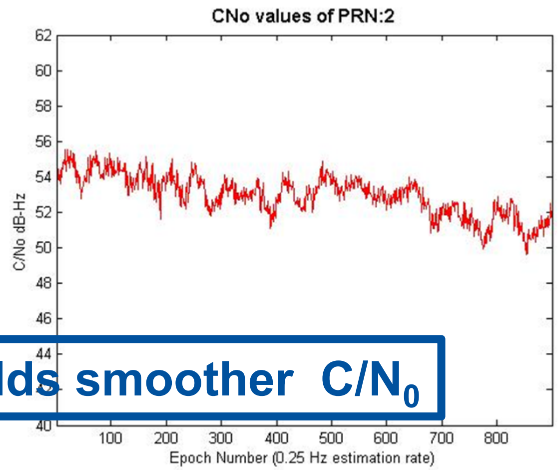
The longer the integration time, the higher the C/N_0



T=1msec, rate=4 sec



T=5msec, rate=4 sec

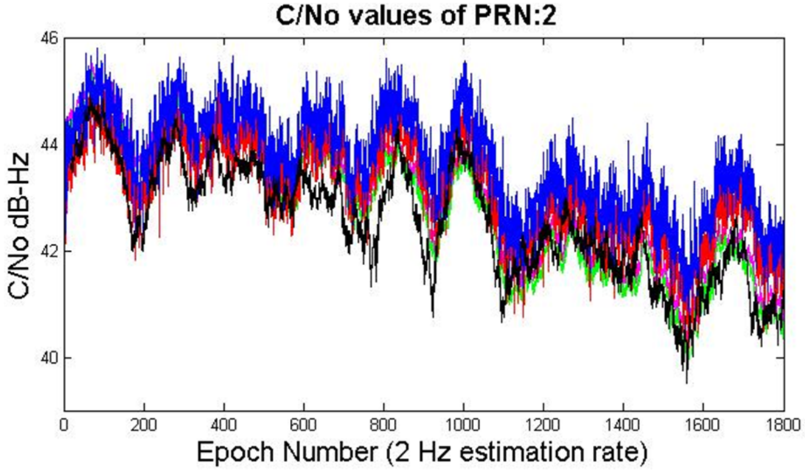


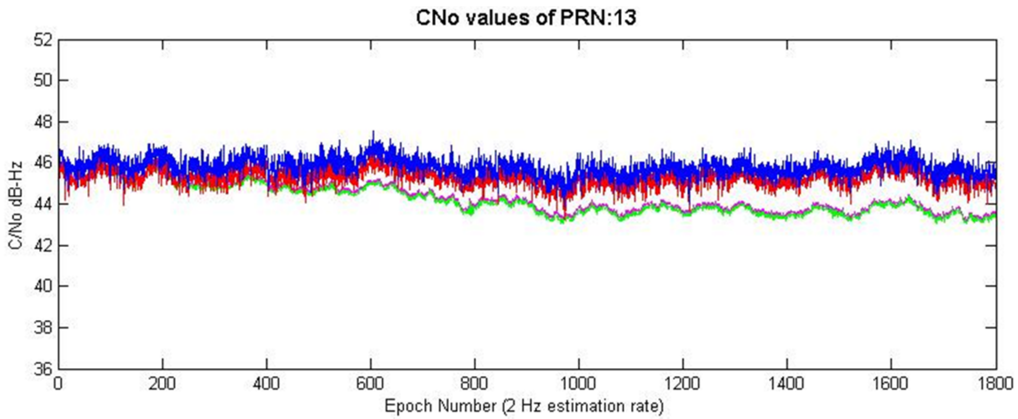
T=10msec, rate=4sec

Longer rates yields smoother C/N_0

Variance Summing estimator (1 hour IF data set)

C/N$_0$ Estimator - Comparison





- Different noise impact
- Slightly different trends

Nord Nav R30

vs

Power Ratio estimator

vs

Variance Summing estimator

vs

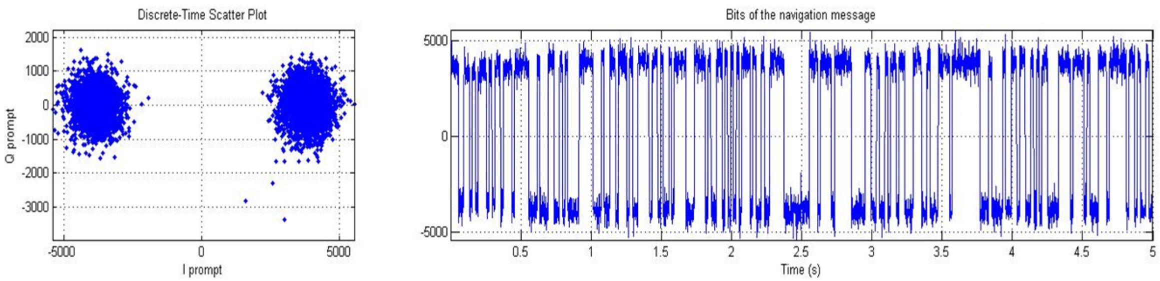
Squaring estimator

vs

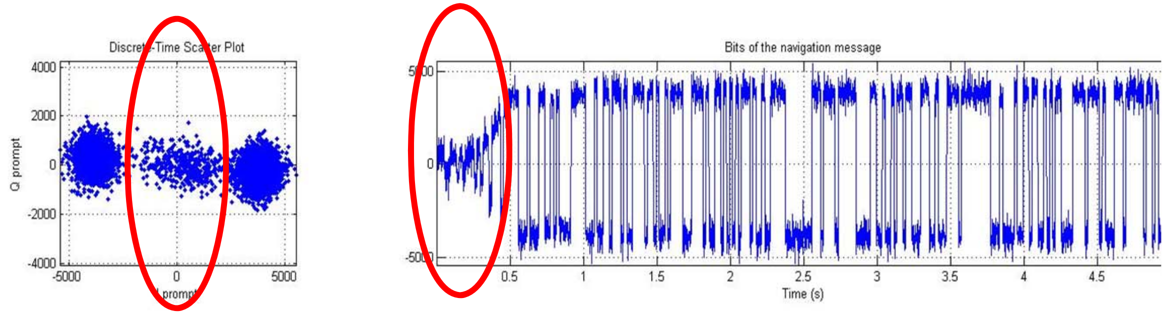
Differential estimator

High Resolution Correlator

The HRC was implemented only for Phase Tracking



Prompt Correlator



HRC Correlator

Drawback
- Reduction of Signal Strength (1/20 of the original Peak)
- Tracking Problems
- Phase and Code observation Quality degradation

Findings

Data analysis showed:

- Different receivers same multipath contamination (short delay multipath)
- Repeatability of multipath effects due to the repetability of the satellite orbits
- Each satellite has a unique repetition period (few seconds difference)

Signal Processing in software receiver showed:

- Filter out long delay MPCs
- No improvement for short delay MPCs (< 30 m)
- Increase processing capacity (HRC)
- Decreace signal quality (HRC)
- Power Ratio estimator and Variance Summing estimator C/N_0 algorithms give noiser observations
- Usage of longer signal snapshots results in better signal quality
- Longer average periods filter out noise

<u>**GIH Scenario is very complex for in-depth multipath characterization**</u>

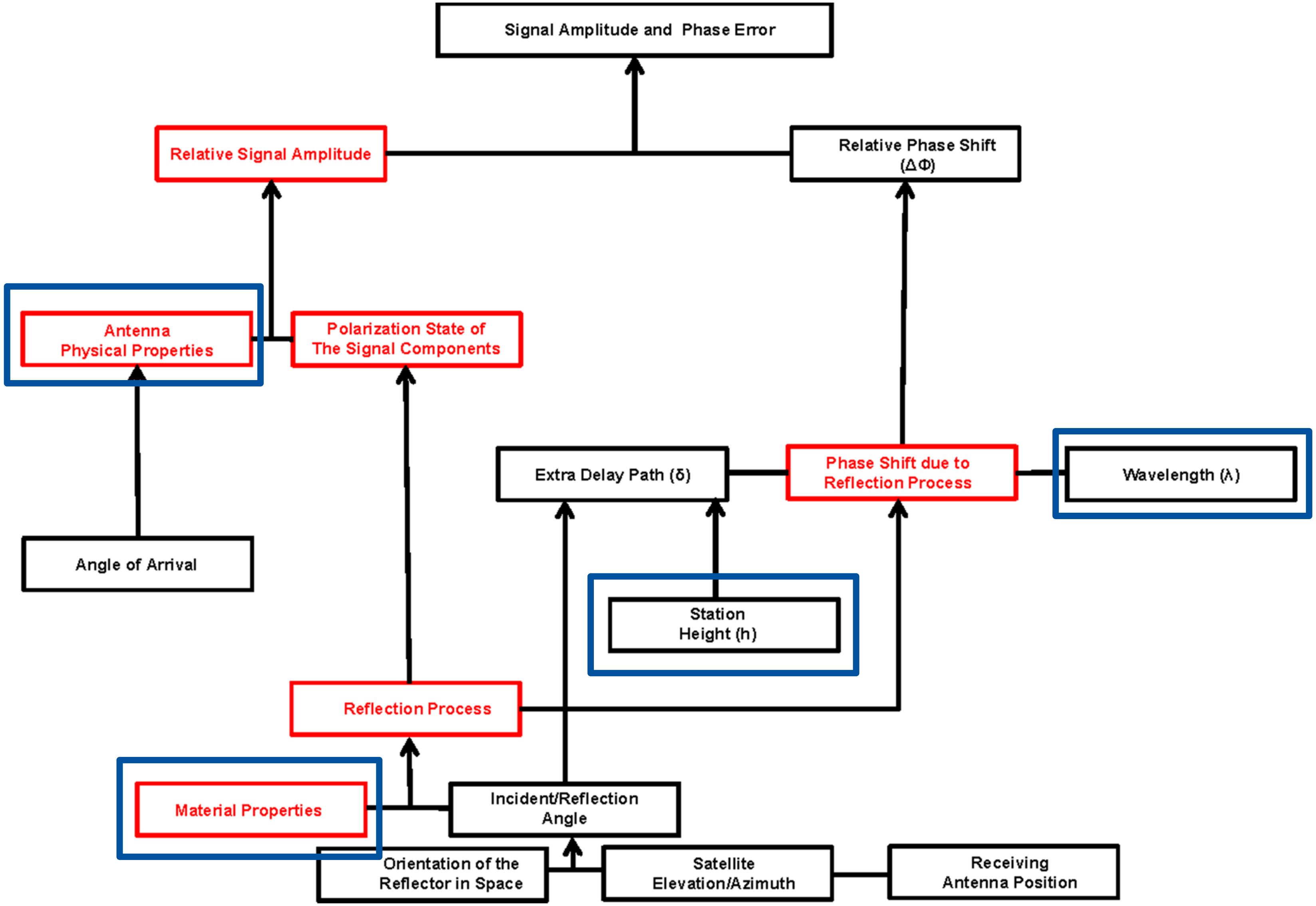
PTB ''Ground Reflector'' Experiment

- Survey of the local environment
- Short baseline Set-up
- High-Low antenna Set-up

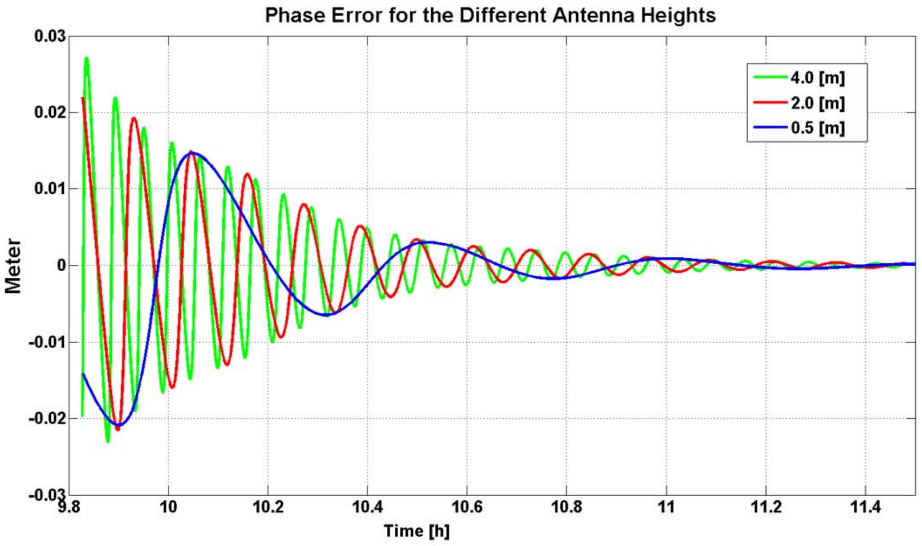
PTB ''Artificial Reflector'' Experiment

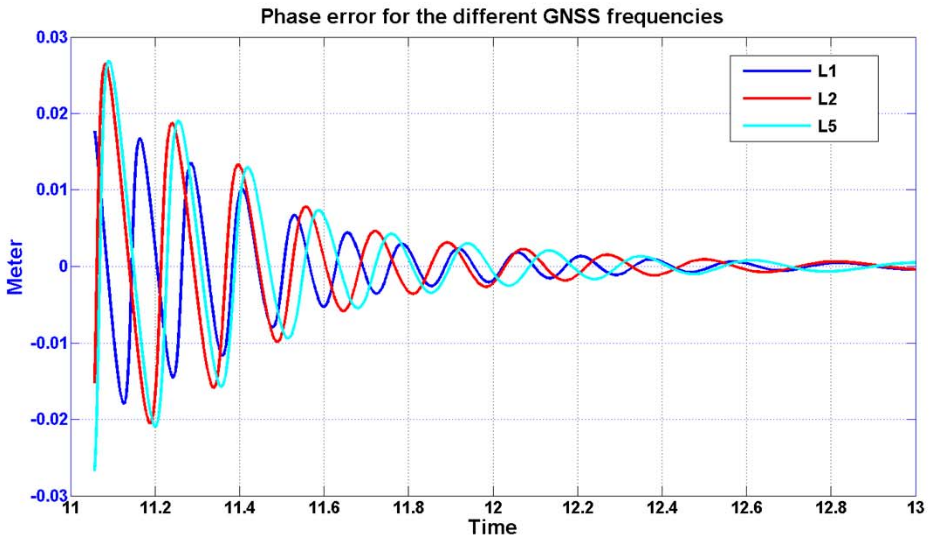
- Survey of the area
- 3 Baselines Measured
- Software Receiver
- Different Antennas
- Sidereal Repeatability

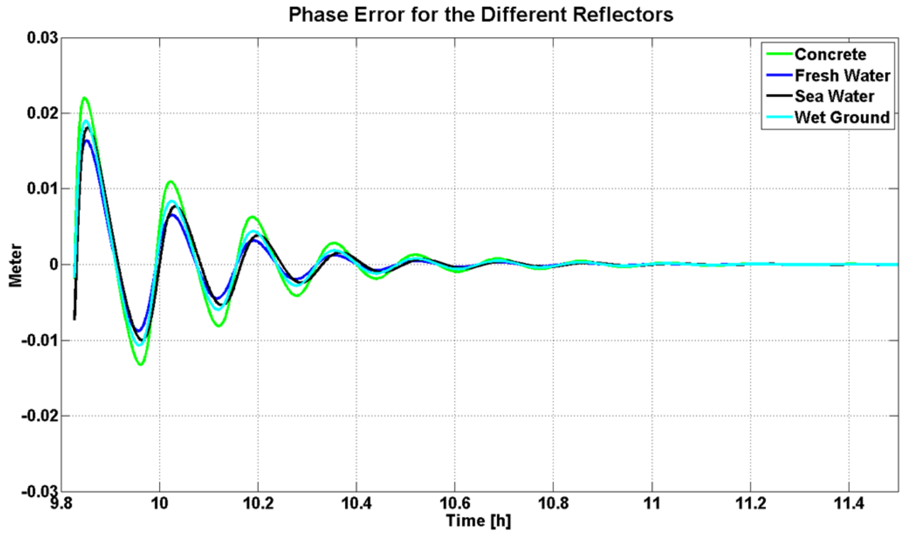
Multipath Characterization

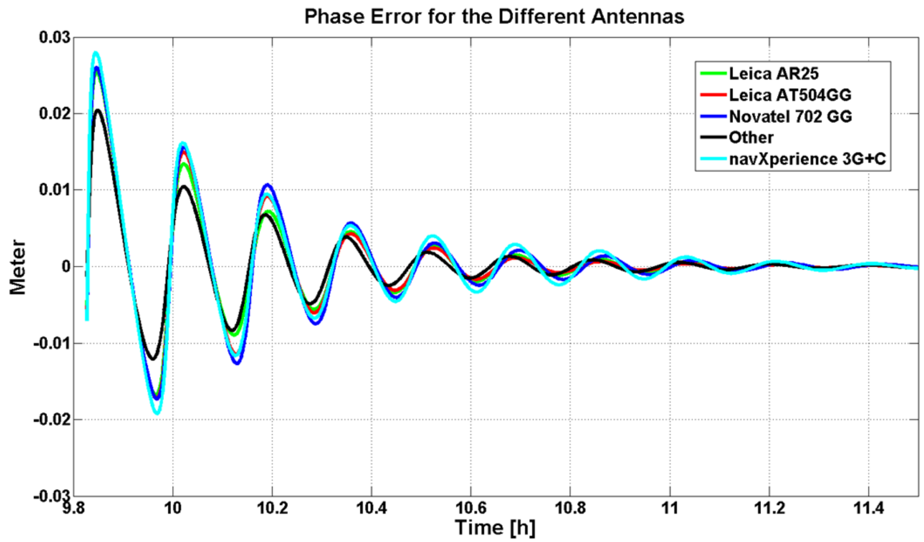


Multipath Characterization (2)

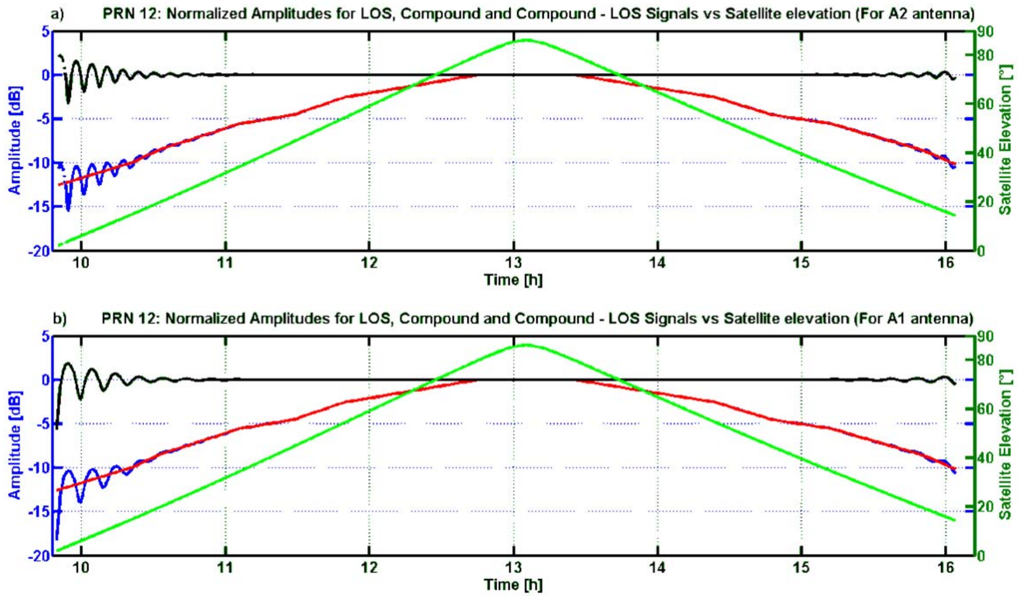


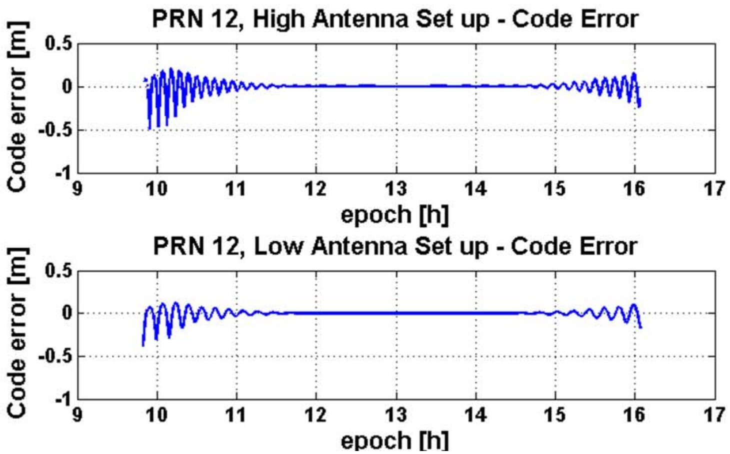


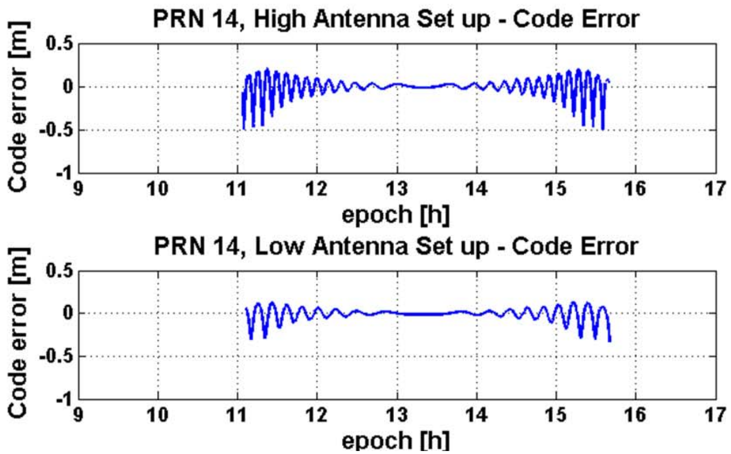




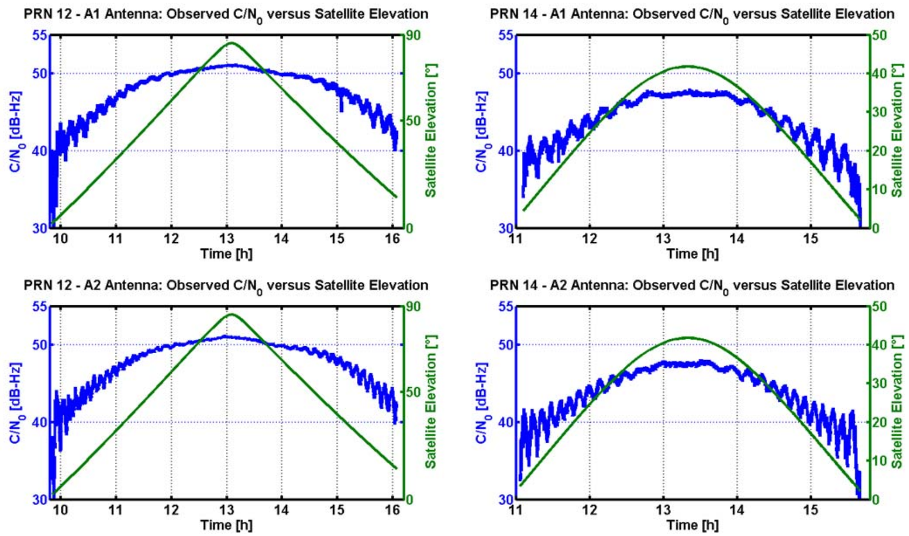
Multipath Characterization (3)

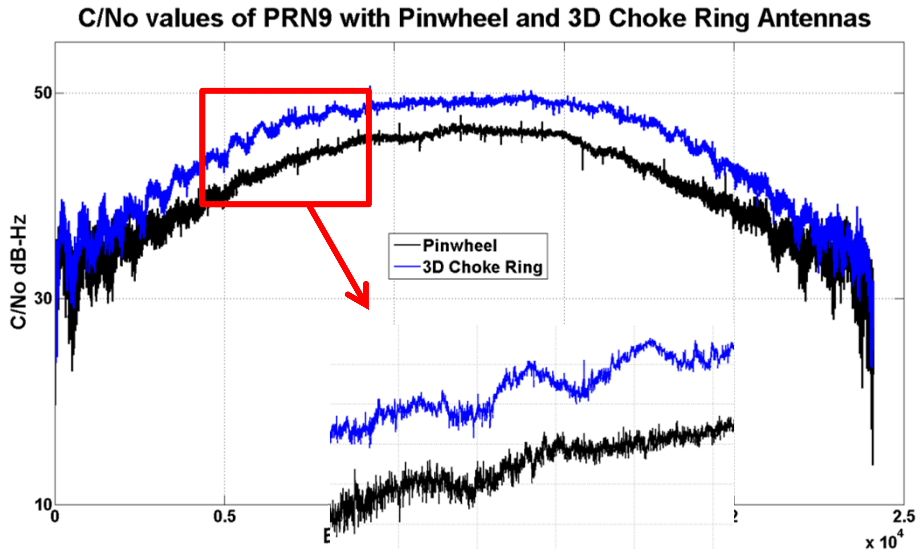


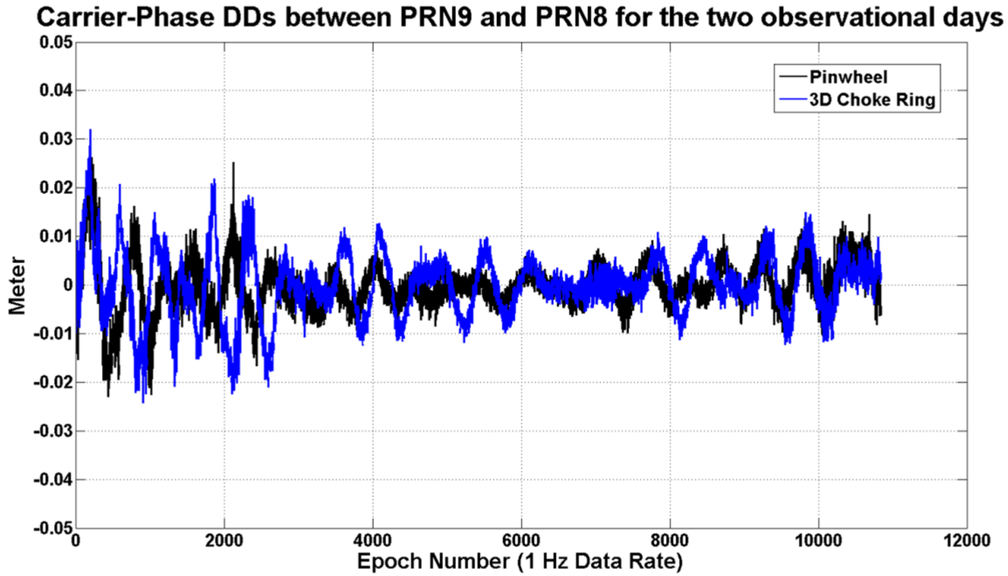




Data Analysis (1)

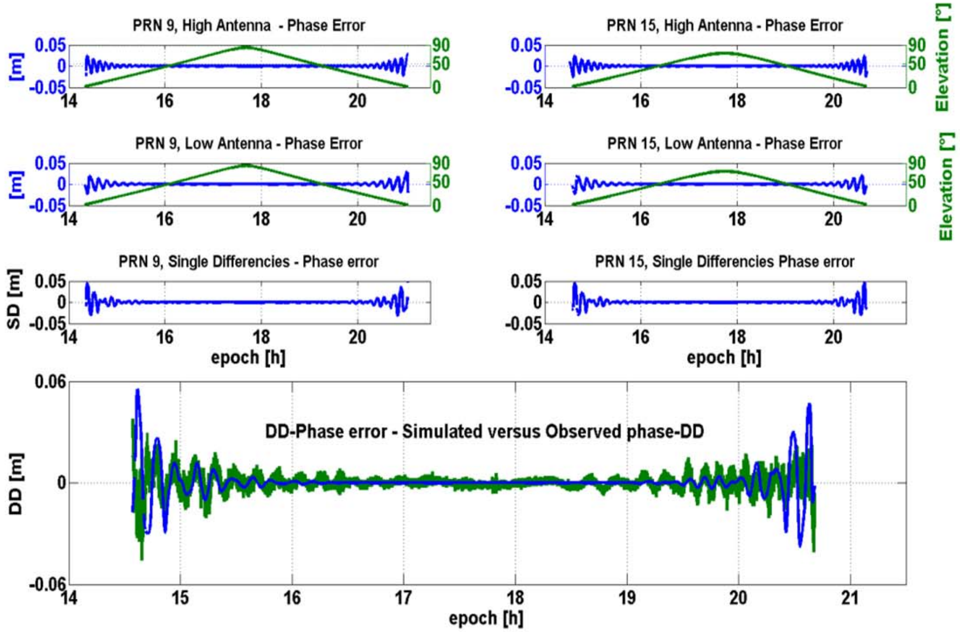


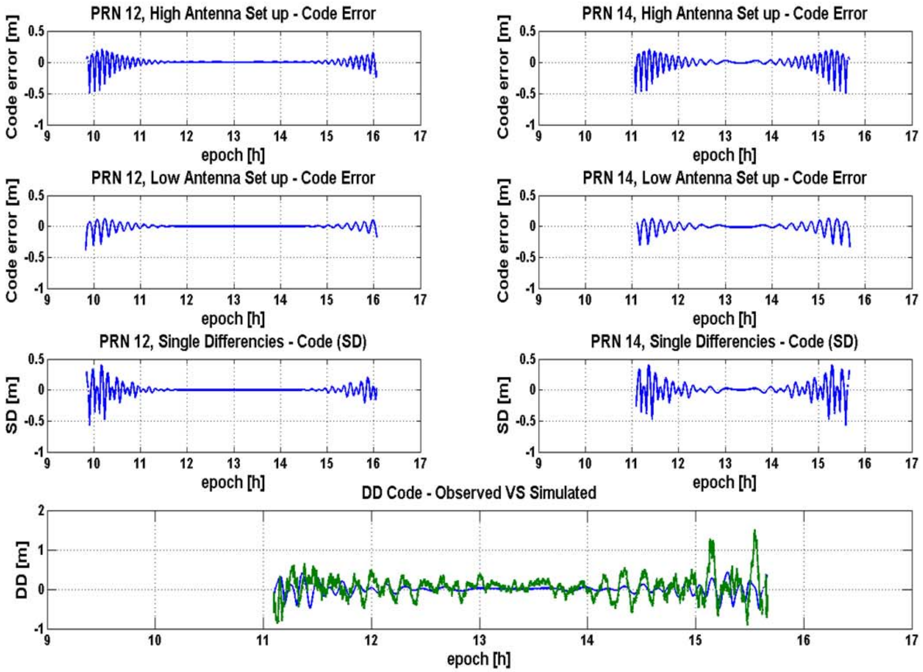




- RMS of the DD residuals with the **Choke ring** antenna: 0.0066 m
- RMS of the DD residuals with the **Pinwheel antenna**: 0.0062 m

Simulations vs Obaservations





PTB Experiments - Findings

- Derivation of new equations (phase, code and signal amplitude) for multipath characterization.
- Generation of realistic multipath signatures that occur in the GNSS observables.
- Distance from the reflector is related to the frequency of the interference pattern.
- Lower Carrier-Frequencies result in larger error envelopes.
- Different antennas results in different multipath signatures.
- Data analysis showed a slightly better overall performance of pinwheel antennas compared to 3D Choke ring antenna.
- The impact of short delayed multipath components is very similar for different receivers connected to the same antenna.

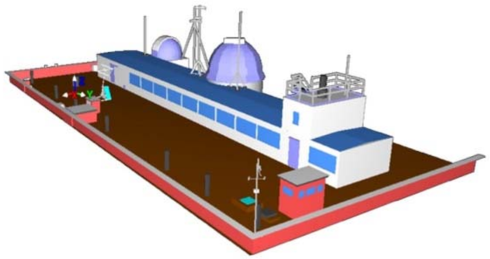
Reference Station Installation

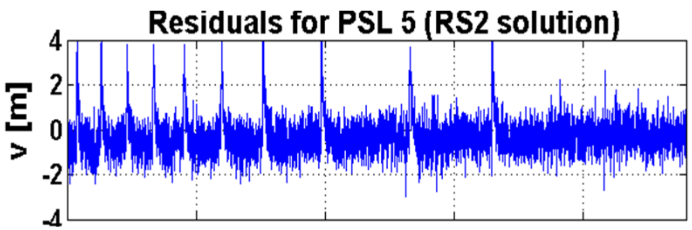
Multipath Mitigation

Site Selection and monumentation

Equipment Selection

Station Calibration

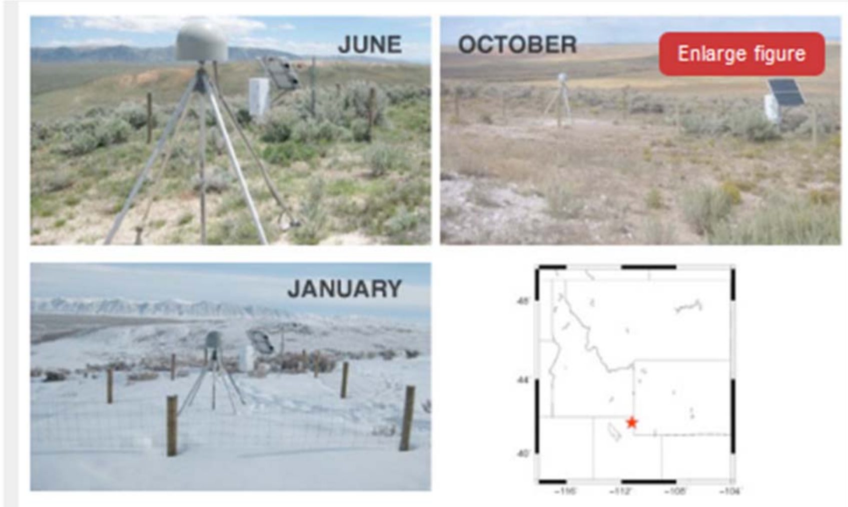




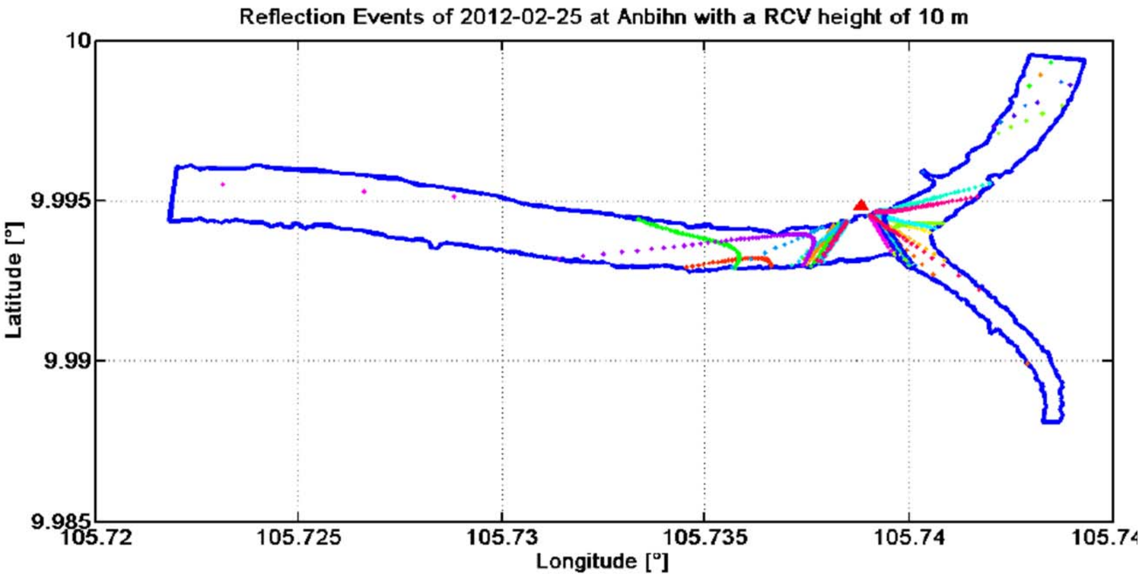
Observation weighting

Potential Applications
Geophysical Parameter Extraction

Beckheinrich et. Al 2013



Larson et. Al 2013



- Water level monitoring
- Soil moisture retrievals
- Snow height retrievals

SEA GATE Area

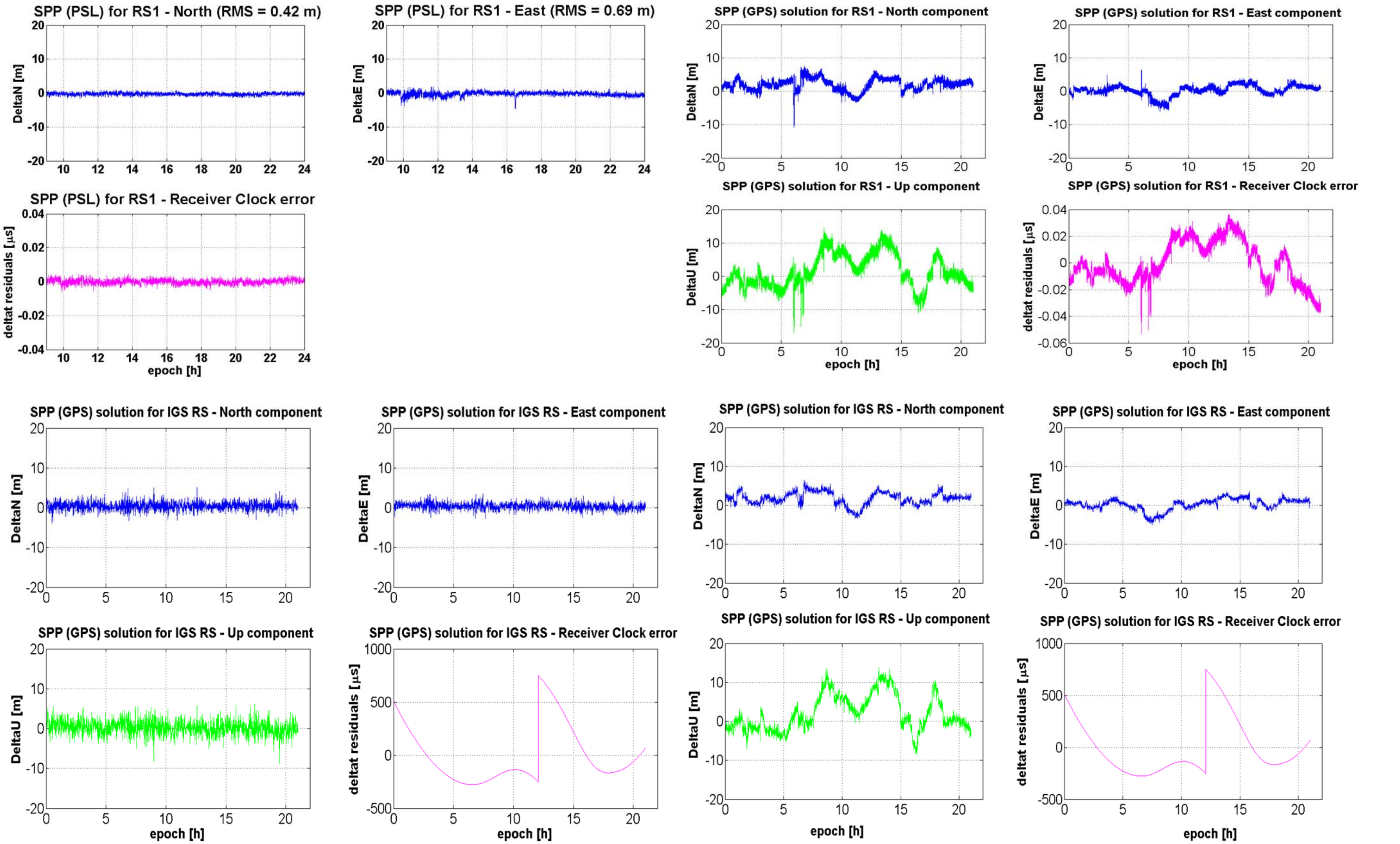
SEA GATE area in Rostock harbor is the marine Galileo test infrastructure consisting of three segments:

1. Nine Pseudolites
2. Two reference stations
3. User Segment

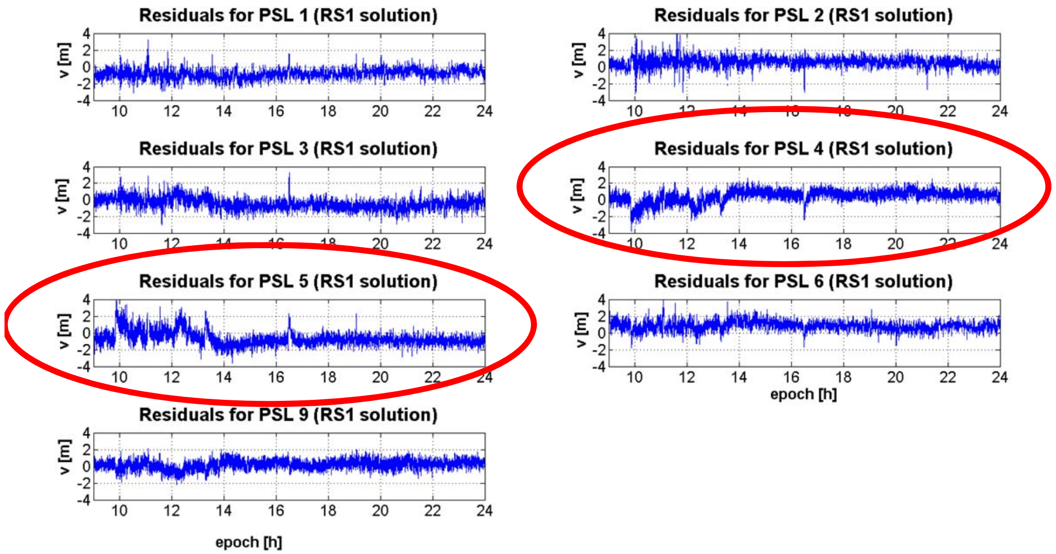
In this case the environment and the set up is not controlled by us.

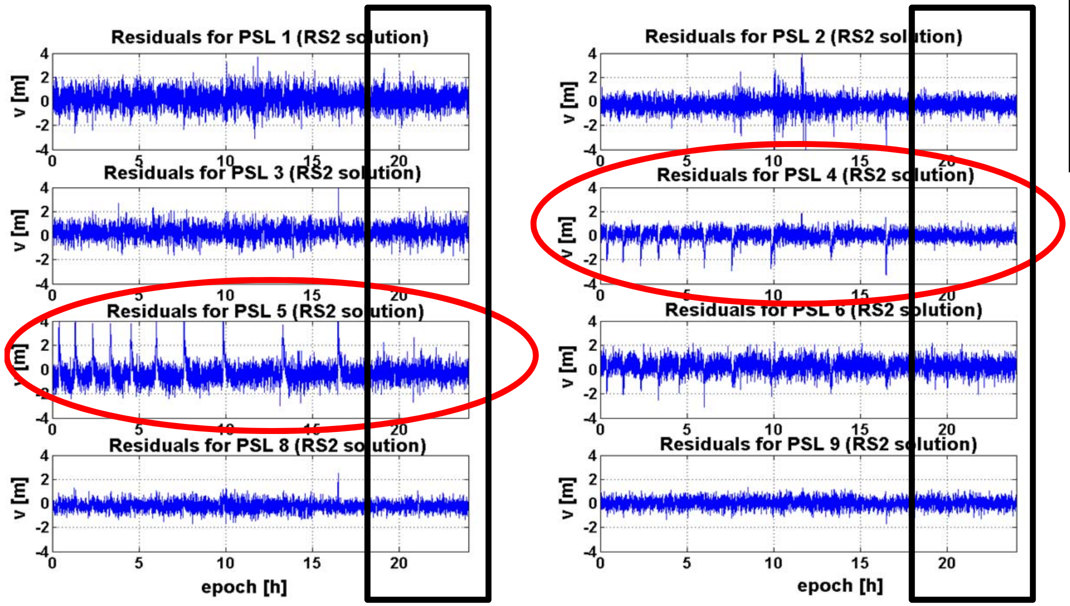
- **Data Analysis**:
  1. The two **Reference Stations**
  2. The two **Antennas on Board**

SEA GATE: Data analysis from RS (1)



SEA GATE: Data analysis from RS (2)



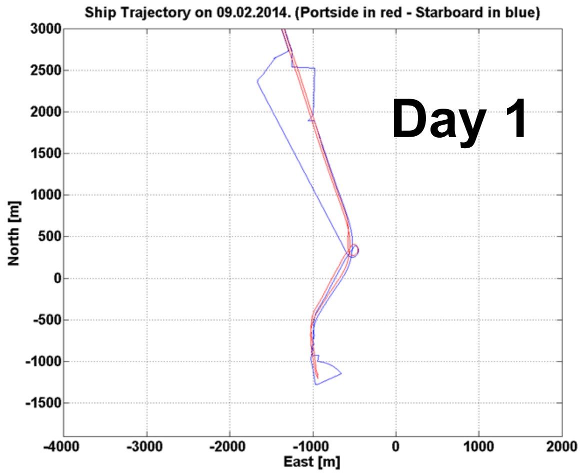


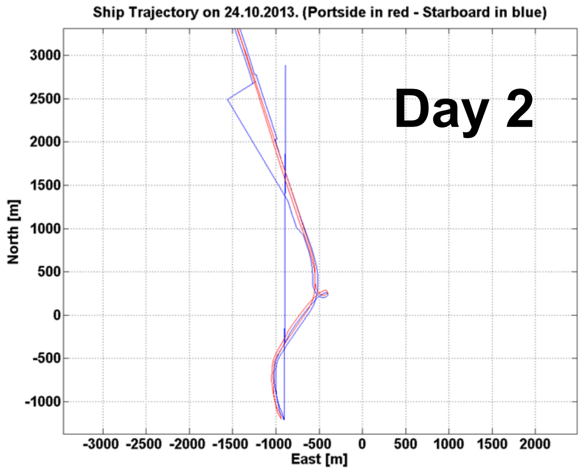
- PSL5 and PSL4 show high Multipath contamination
- After working hours multipath effects are not so frequently present in the Data Sets

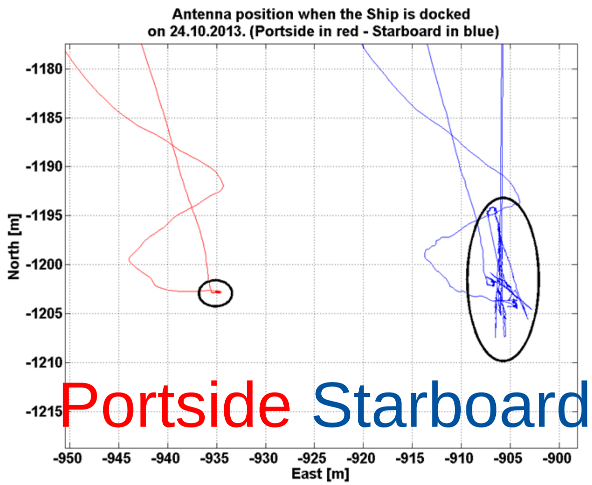
SEA GATE: Data analysis from RS (3)

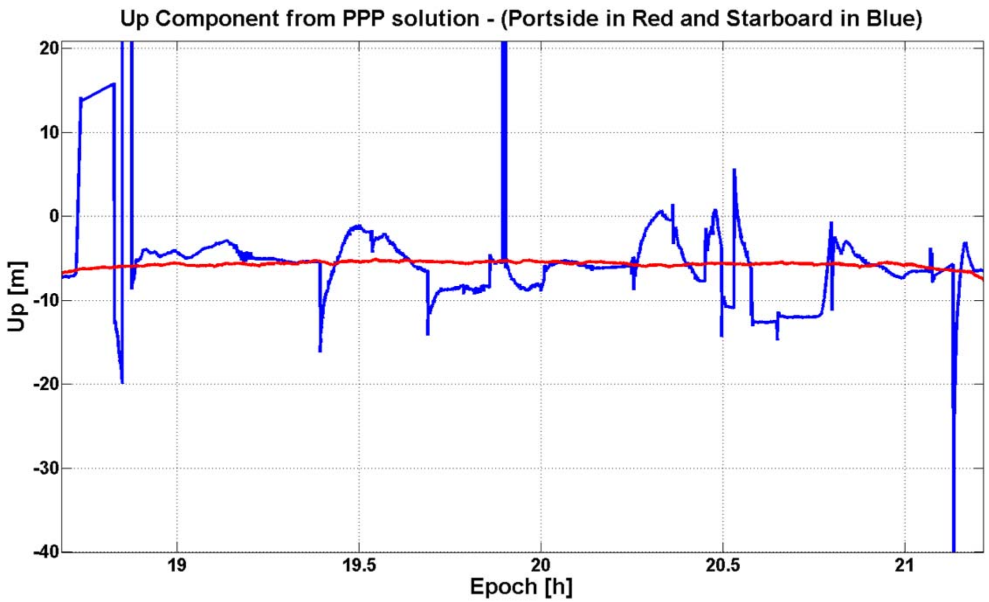
- PSL 8 observed for few epochs at RS1 on 24.10.2013.
- Obstructions of the line-of-sight at several epoch in the region enclosed by RS1, RS2, PSL 4 and PSL 5 .
- After working hours (e.g. 18:00 local time) the before mentioned effects are not so frequently present in the data sets.
- For a more critical examination of the carrier-to-noise density ratio (C/N_0) of the PSL signals more information is needed about the transmitted signal characteristics and the signal processing modules of the receiver.
- Effects present in the residuals of the observations are not present (as it was expected) in the C/N_0 time series.
- PSL-C1 solution is more precise from GPS-C1 solution due to the lack of ionospheric refraction.
- Many losses of lock or data gaps of GPS signals (C/A, L1) at RS1 and RS2.

SEA GATE: Data analysis from ferry (GPS)



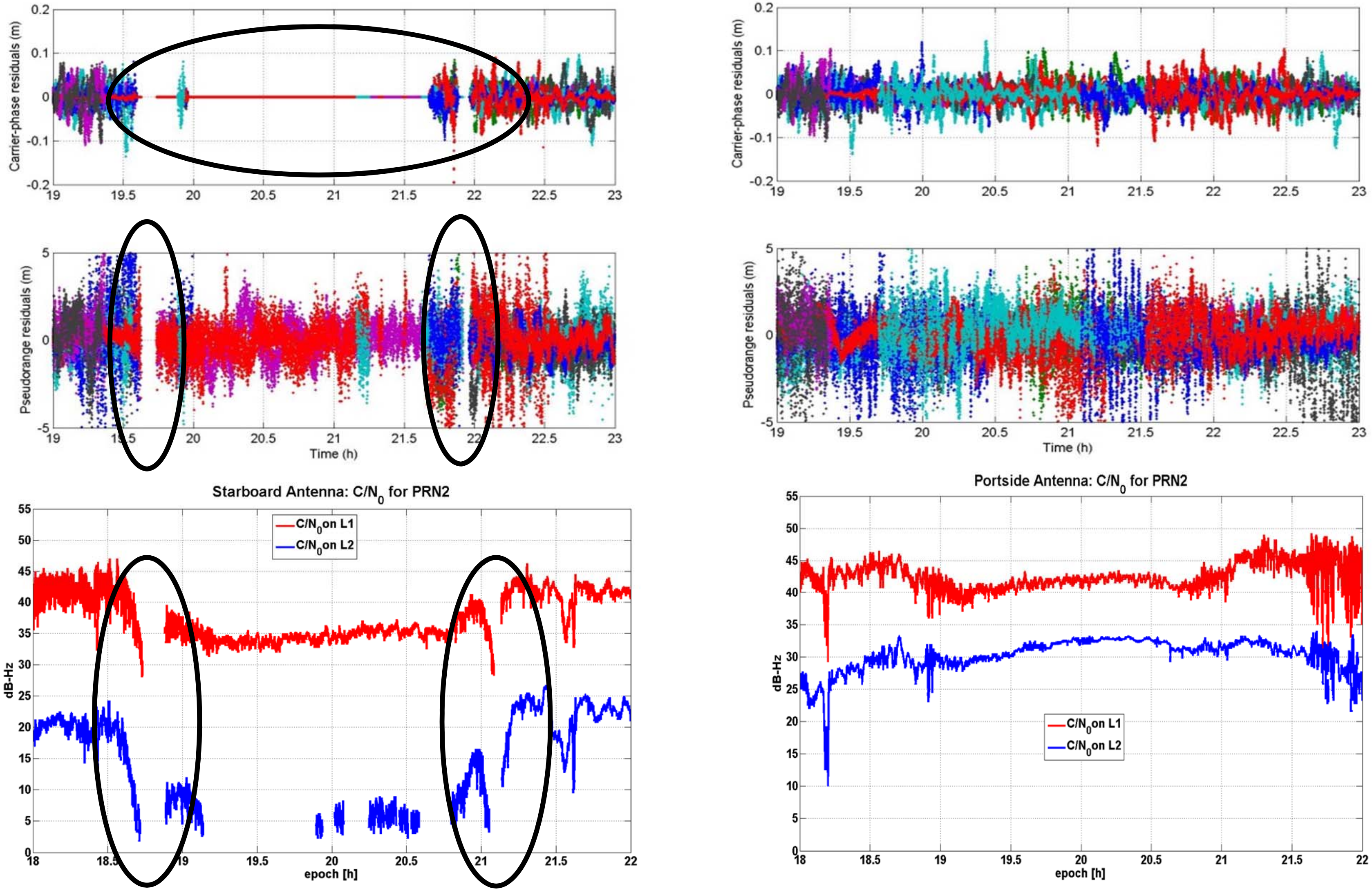




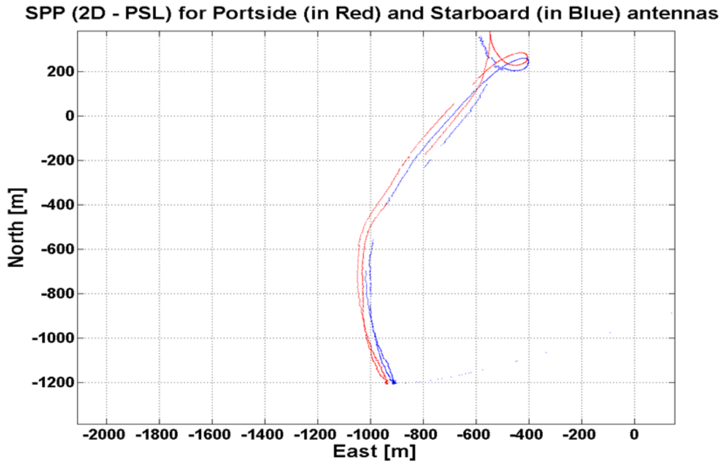


SEA GATE: Data analysis from ferry (GPS)

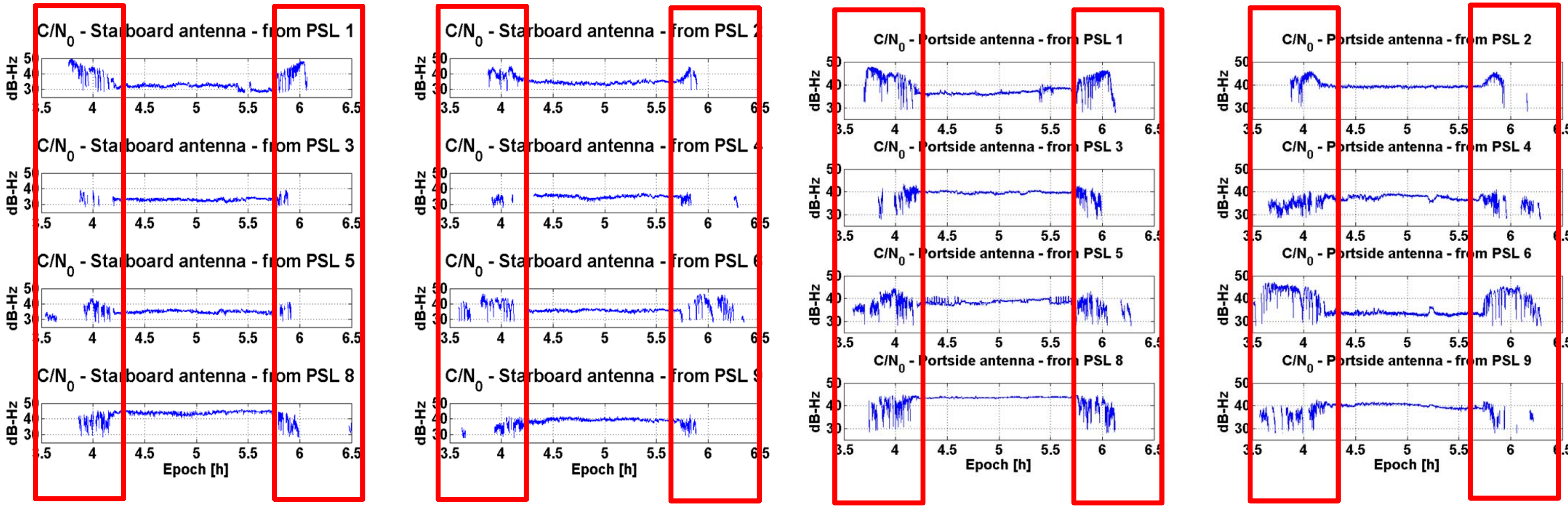
Starboard | Portside



SEA GATE: Data analysis from ferry (PSL)



- During the docking maneuvers of the ferry, the observed PSLs for several epochs are less than 3 and solution was not estimated.
- The before mentioned epochs are not common for the two antennas on board.
- During ferry entrance/exiting the port, tracking problems for all signals.



SEA GATE: Data analysis from ferry

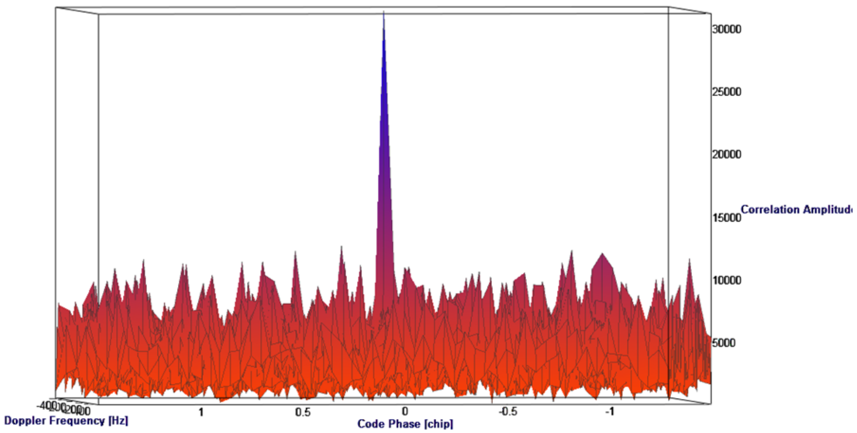
- PSL 1 and PSL 2 were not observed by both antennas on board of the ferry during the afternoon session on 24.10.2013.
- Interference like patterns present in C/N_0 time series of the PSLs for both antennas on board of the ferry, when the ferry is entering/exiting the harbor.
- Several epochs were observed, during the docking maneuvers of the ferry, were the observed PSLs are less than 3 and a solution was not estimated.
- The before mentioned epochs are not common for the two antennas on board.
- GPS signals interruption occurs during the entrance/exit of the ferry in/out Rostock harbor for signals captured with the Starboard antenna.
- The estimated trajectory, with GPS signals, with the data captured from Starboard antenna deviates significantly from the trajectory estimated with data captured from the Portside antenna. These deviations are occurring only when the ship is in Rostock harbor area.
- GPS L2 loss of lock occurs for several PRNs observed from the Starboard antenna during the presence of the ferry in Rostock harbor area.
- GPS signals quality degrades when the ferry enters the harbor area. The degradation is bigger from the signals captured with the Starboard antenna.

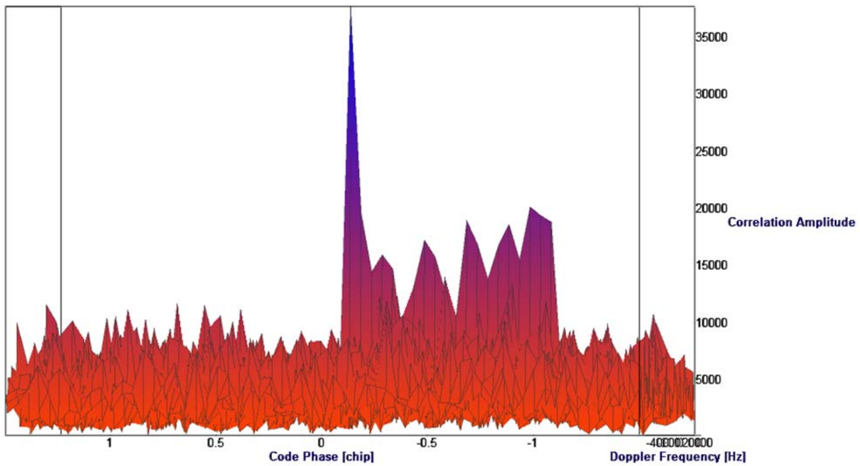
SEA GATE Data analysis - Outlook

- We are in contact with RST and Septentrio for the clarification of the problems.
- Novel Tropospheric modeling for PSL observations developed from EDM.
- Ongoing data analysis in the framework of a Bachelor Thesis and a Poster presentation in Geodetic Week.
- The investigation can be further expanded to other GATE environment (e.g. Railway).

GNSS Indoor Scenario - Challenges

- Fading behavior creates signal processing problems.
- Weak signals can not easily detectable.
- In many case reflected signals are acquired and tracked.
- Observation quality is degradated.
- Less PRNs are tracked.
- Satellite geometry is less suitable.
- Estimated positioning solution accuracy very low.



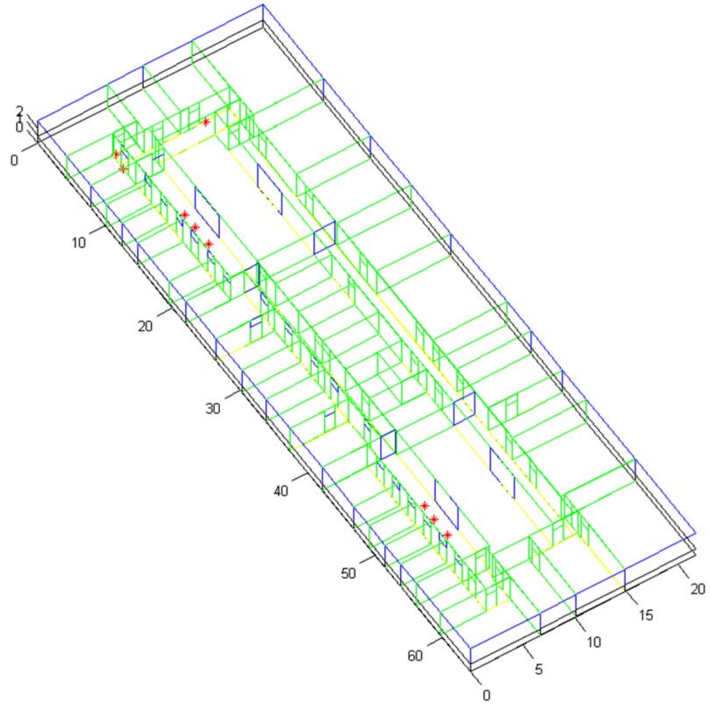


GNSS Indoor investigation

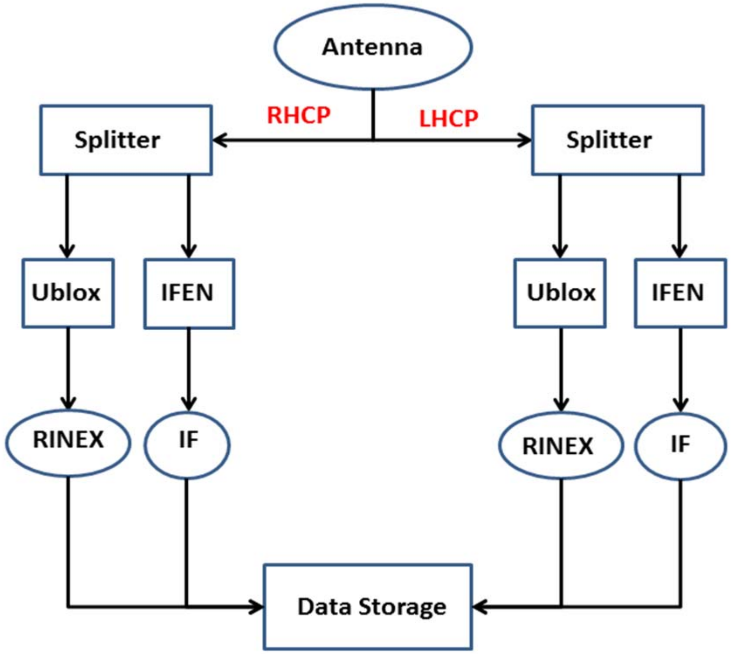
- Test **Different Tracking** schemes in indoor environment
- Compare **software-receiver** vs **high sensitivity receiver** vs **Geodetic receiver**
- Investigate the **sidereal repeatability of the fading behavior**

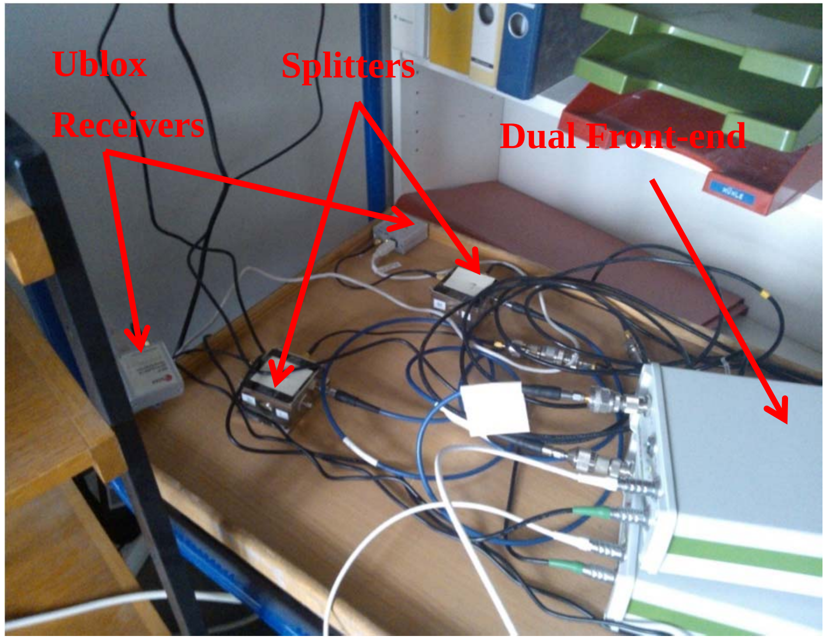
In addition:

- Usage **of LHCP and RHCP antennas** in parallel



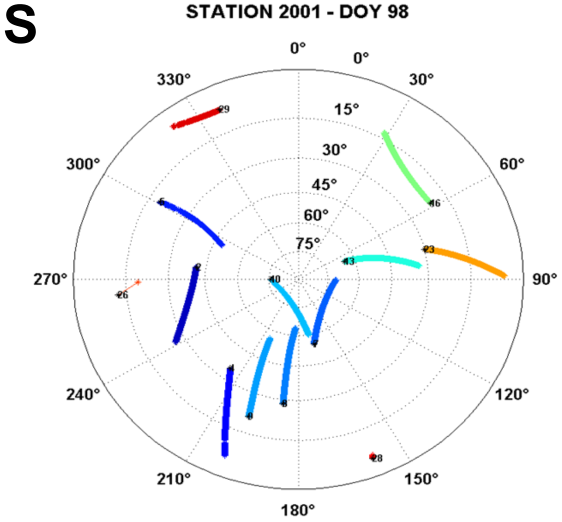
Indoor: Experiment Set-Up

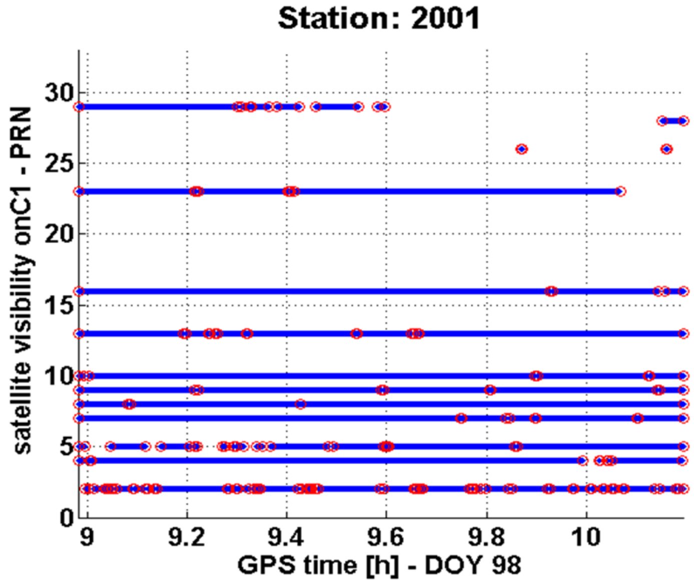




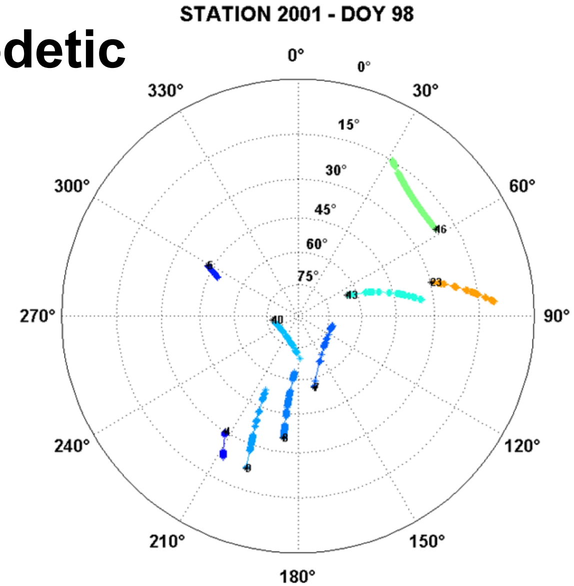
Indoor: High Sensitivity vs Geodetic Receiver

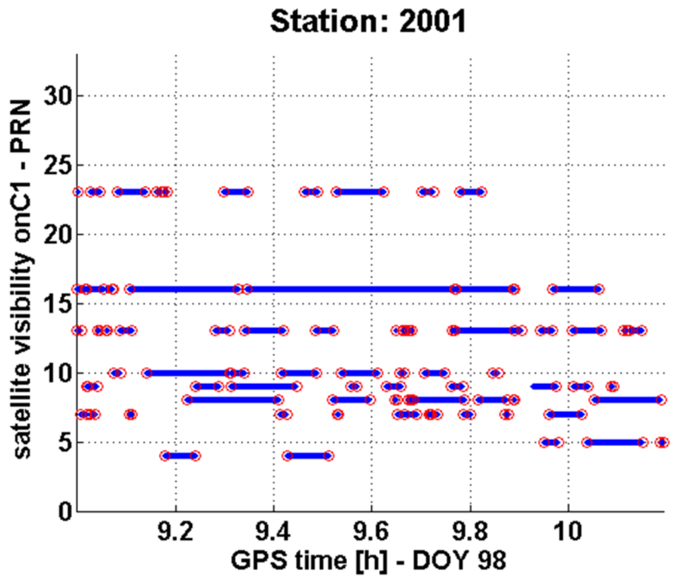
HS



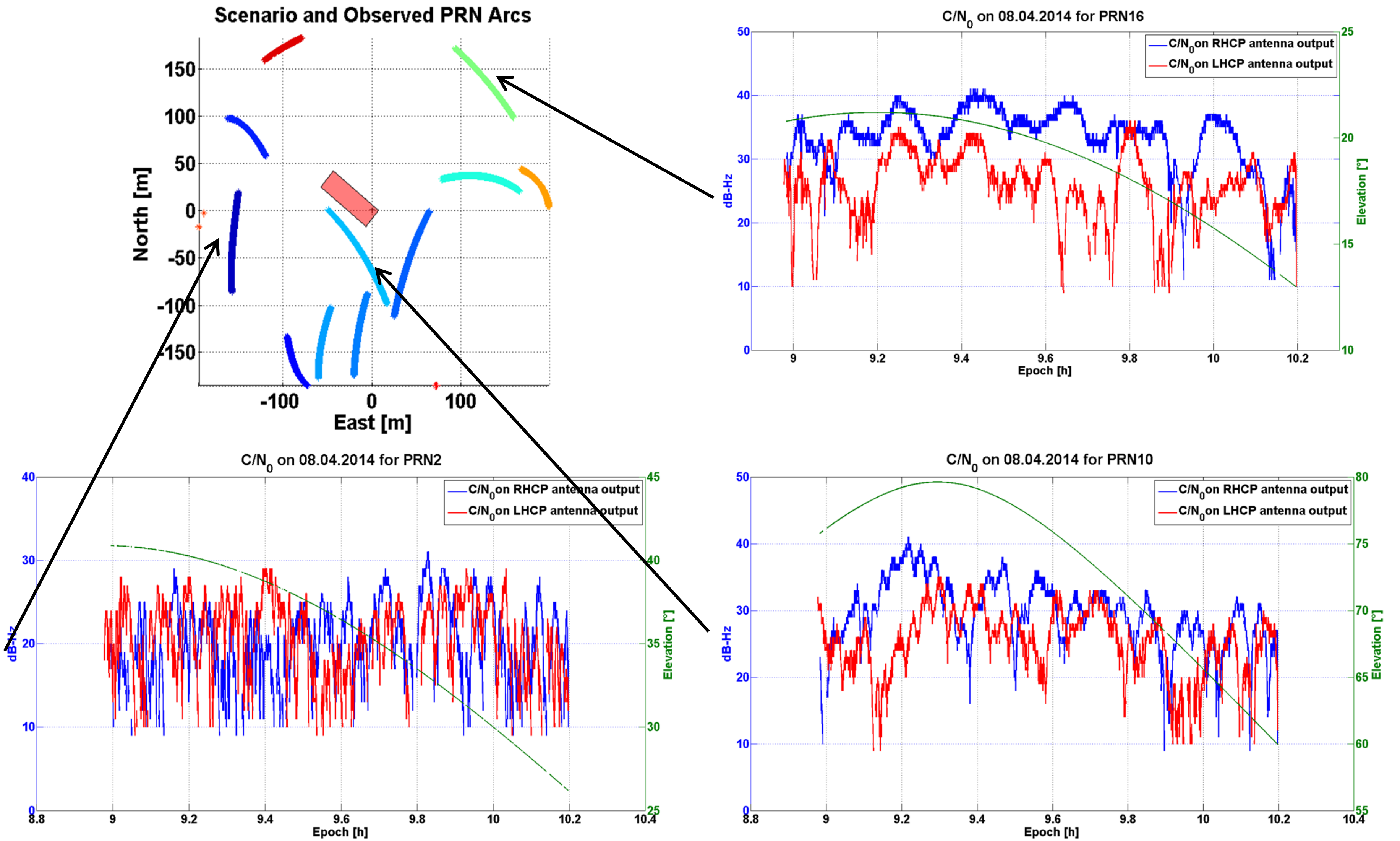


Geodetic



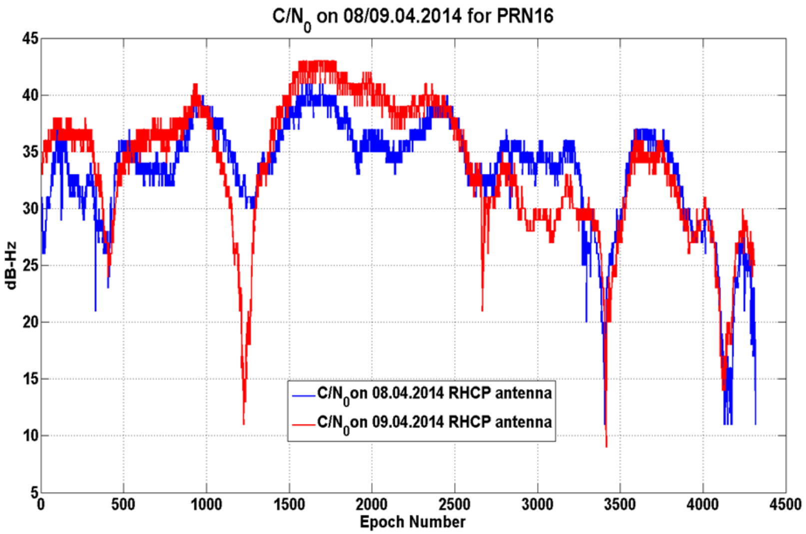


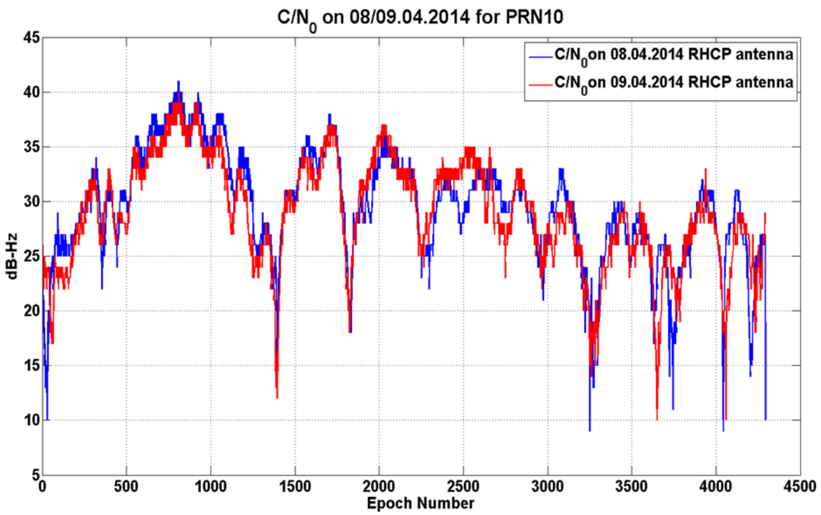
Indoor: RHCP Antenna Output vs LHCP Antenna Output



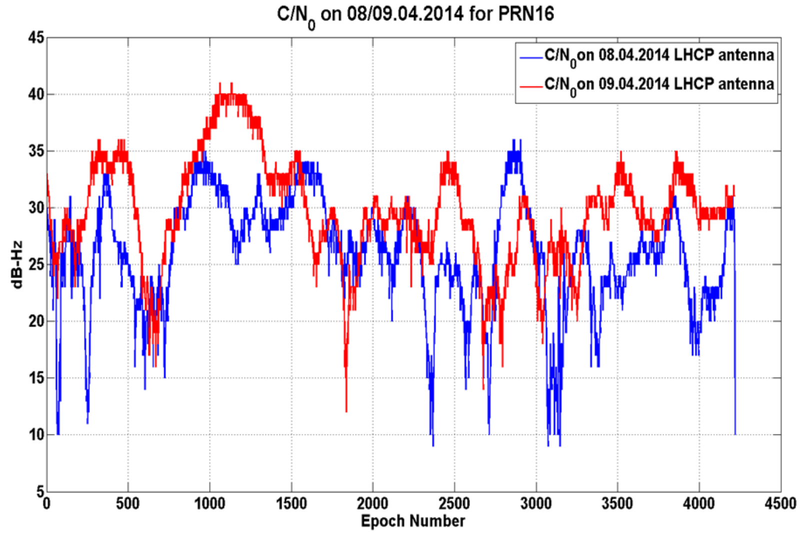
Sidereal Repeatability of Fading behavior

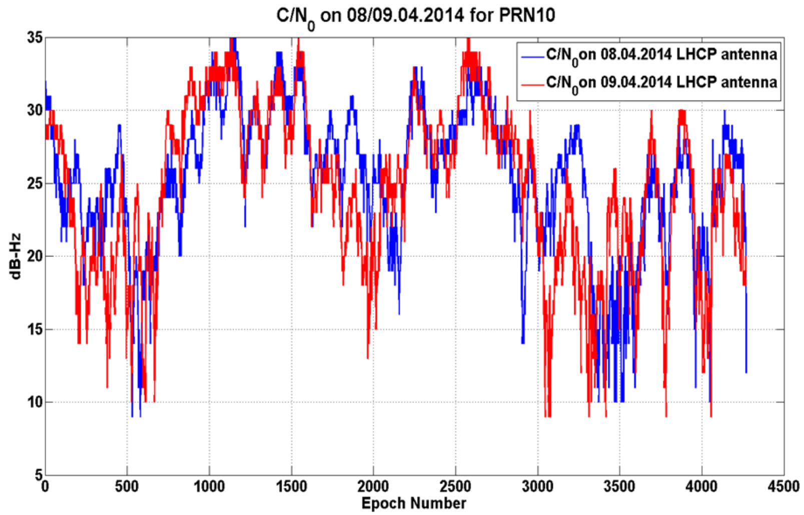
RHCP: Day1 and Day 2



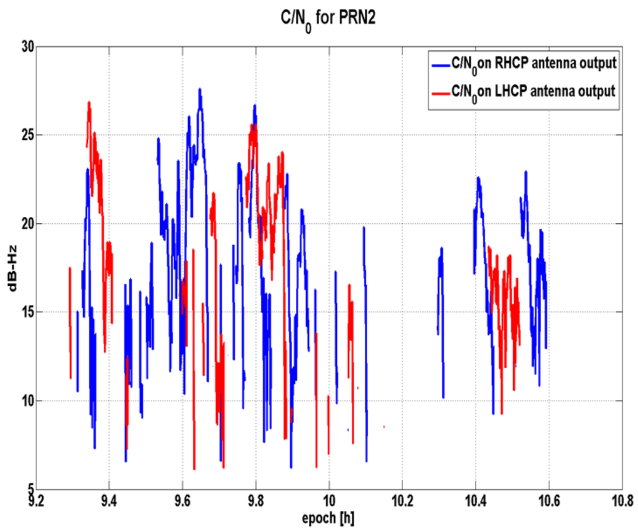


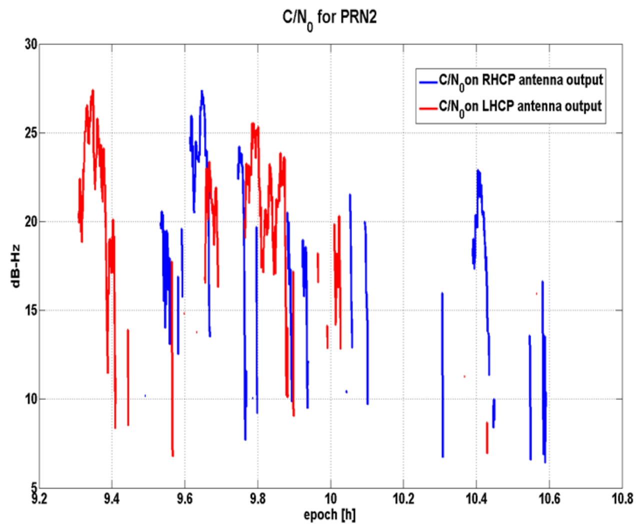
LHCP: Day1 and Day 2





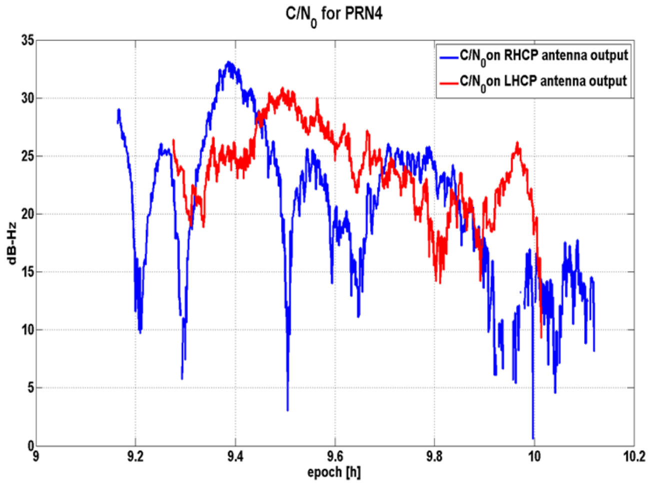
Indoor: Different tracking Schemes in Software Receiver

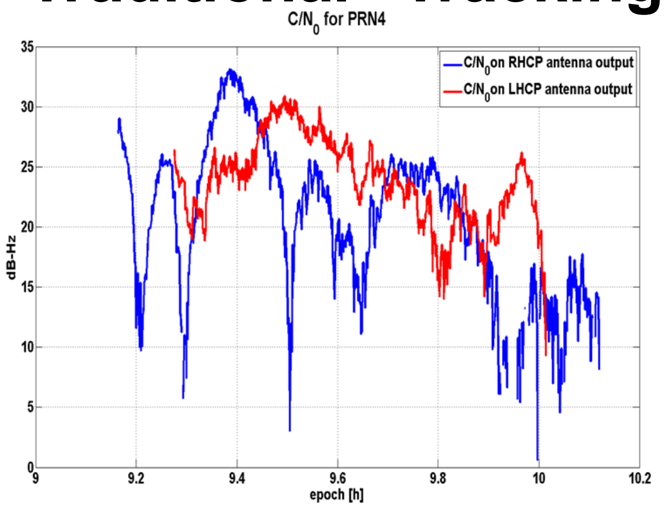




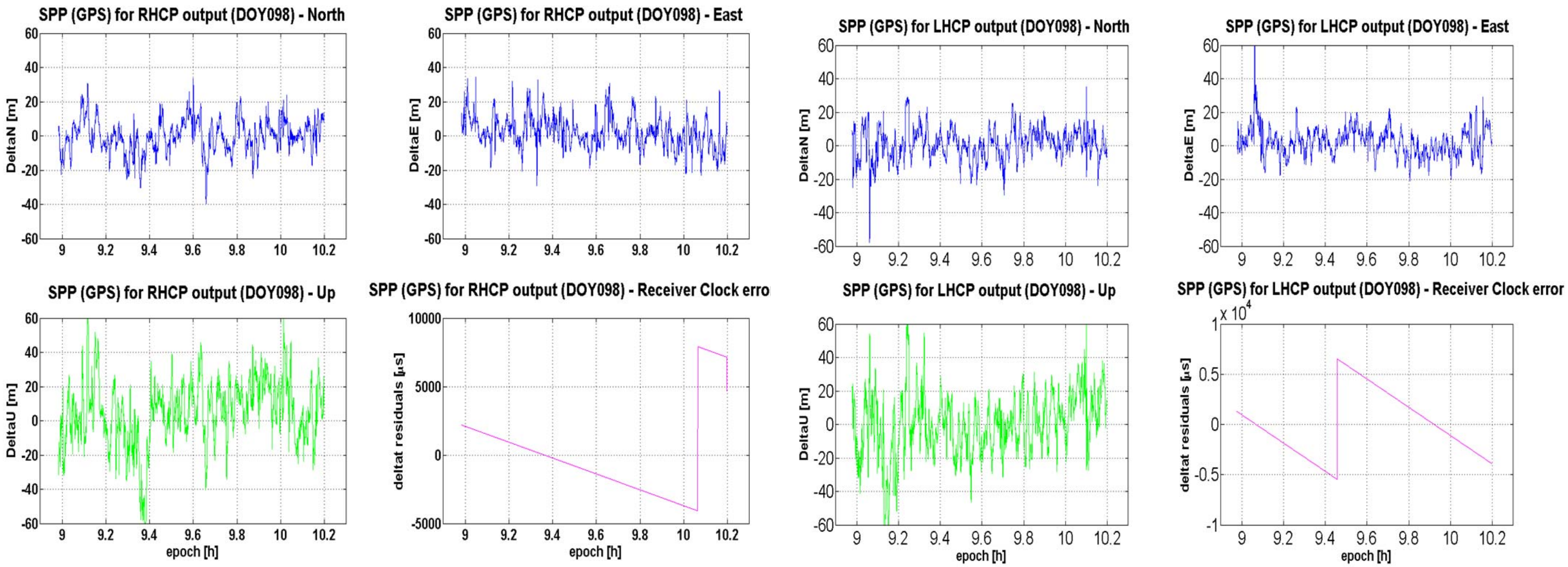
"Vector" Tracking

"Traditional" Tracking





Positioning



RHCP Antenna			
Weighting	RMS dX [m]	RMS dY [m]	RMS dZ [m]
Identity	10.91	9.98	19.94
Elevation (cos)	12.17	12.00	20.60
Elevation (cos^2)	15.08	14.25	24.25
C/N_0	10.06	9.25	18.49

LHCP Antenna			
Weighting	RMS dX [m]	RMS dY [m]	RMS dZ [m]
Identity	10.89	9.59	17.46
Elevation (cos)	12.74	10.20	19.86
Elevation (cos^2)	16.57	11.07	24.70
C/N_0	10.23	9.06	15.97

Indoor: Findings

- High sensitivity receivers outperform geodetic receivers.
- High sensitivity receiver outperform software receivers tracking signals with high sensitivity configurations.
- Sidereal repeatability of the fading behavior is occurred for only some of the observed PRNs.
- Fading behavior from the different antenna outputs is uncorrelated.
- Potential use for different antenna diversity schemes (e.g. polarization diversity) with different combining algorithms.
- C/N_0 based weighting improves the positioning accuracy.
- Poster presentation of a student indoor measurement campaign will be presented in the Geodetic Week.

Publications

Smyrnaios M., Schön S. (2014): GNSS antenna impact on the resulting multipath effects in carrier-phase and signal amplitude , Proc IAG Potsdam accepted.

Smyrnaios M., Schön S. (2013): Multipath effects on GNSS carrier-phase and signal amplitude due to different reflectors, Proceedings of IAG Scientific Assembly 2013, 150 years International Association of Geodesy (IAG), September 01.-06., GfZ - Potsdam, Brandenburg, Germany (Poster)

Smyrnaios M., Schön S., Kersten T. (2013): Epoch-Wise Modeling of GNSS Multipath Effects, Abtract #G53B-0919, AGU Fall Meeting, December 09.-13. San Francisco, California (Poster)

Smyrnaios M (2013): Multipath Effects on the GNSS Carrier-Phase, GFZ Doktorandenseminar. (Presentation)

Smyrnaios M., Schön S., Liso M. (2013): Multipath Propagation, Characterization and Modeling in GNSS , In: Geodetic Sciences - Observations, Modeling and Applications, Prof. Shuanggen Jin (Ed.), Earth and Planetary Sciences Series, InTech.

Liso, M., Smyrnaios, M., Schön, S., Kurner, T. (2013): Ray Tracing Multipath Modelling in GNSS with a Single Reflector, Antennas and Propagation (EUCAP), 2013 7th European Conference. April 2013, Gothenburg, Sweden

Smyrnaios M., Liso M., Schön S., Kürner T. (2012): Ray-Tracing Approach versus Double Difference, Multipath Characterization in a Multiple Ray Scenario, 6th ESA Workshop on Satellite Navigation Technologies & European Workshop on GNSS Signals and Signal Processing, ESA ESTEC, Noordwijk, Netherlands 05.-07.12.2012

Smyrnaios M., Liso M., Schön S., Kürner T. (2012): Ray-Tracing Approach for Multipath Characterization - Including Multiple Rays, Poster, IGS Workshop, Olsztyn, Poland, July 23-27. (Poster)

Schön, S., Kersten, T., Lindenthal, N., Smyrnaios, M., Weinbach, U. (2012): Station specific Biases in PPP and Reference Station Networks: Investigations at the Institut für Erdmessung, Poster, PPP-RTK & Open Standards Symposium, Frankfurt am Main, 12.03.-13.03.2012. (Poster)

Liso, M., Smyrnaios, M., Schön, S., Kurner, T. (2012): Investigation of diffraction effects in GNSS using ray tracing channel modelling: Preliminary results, Antennas and Propagation (EUCAP), 2012 6th European Conference. March 2012, Prague, Czech Republic

Liso M., Jacob M., Smyrnaios M., Schön S., Kürner T. (2011): Basic Concepts for the Modeling and Correction of GNSS Multipath Effects using Ray Tracing and Software Receivers, IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications, pp. 890-893, 12-16 Sept. 2011, Torino, Italy

Smyrnaios M., Schön S., Liso M., Kürner T. (2011): C/N0 as a multipath indicator: Investigation with software receivers and ray-tracing, International workshop GNSS Remote Sensing for Future Missions and Science Shanghai, 2011. (Presentation).

Smyrnaios M., Schön S., Liso M., Kürner T. (2011): On multipath characterization through software receivers and ray-tracing, Geodätische Woche Nürnberg, 2011. (Presentation)

Thank You!