On the Relative Amplitude of Multipath A Simulation Analysis

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Motivation

Multipath is one of the dominating error sources in high precision GNSS

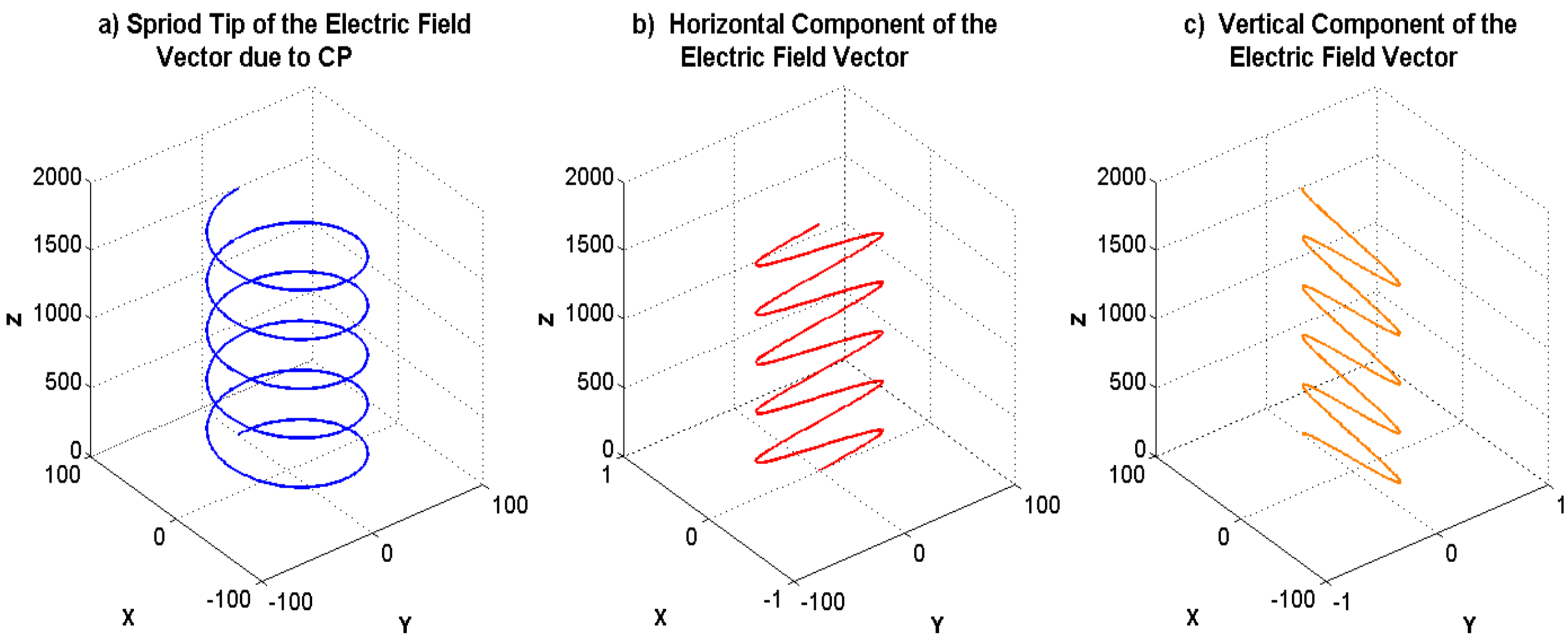
Multipath Errors in Phase, Code and Signal Amplitude domains are Characterized as functions of:

- Multipath **Relative Phase** w.r.t. LOS
  (Geometry)
- Multipath **Relative Delay** w.r.t. LOS
  (Geometry)
- Multipath **Relative Amplitude** w.r.t. LOS
  (Not Directly Accessible)

Presentation Focus:

- Description GNSS Signal Amplitudes
- Propose of an Analytical Model for GNSS Signal Amplitudes
- Model Validation

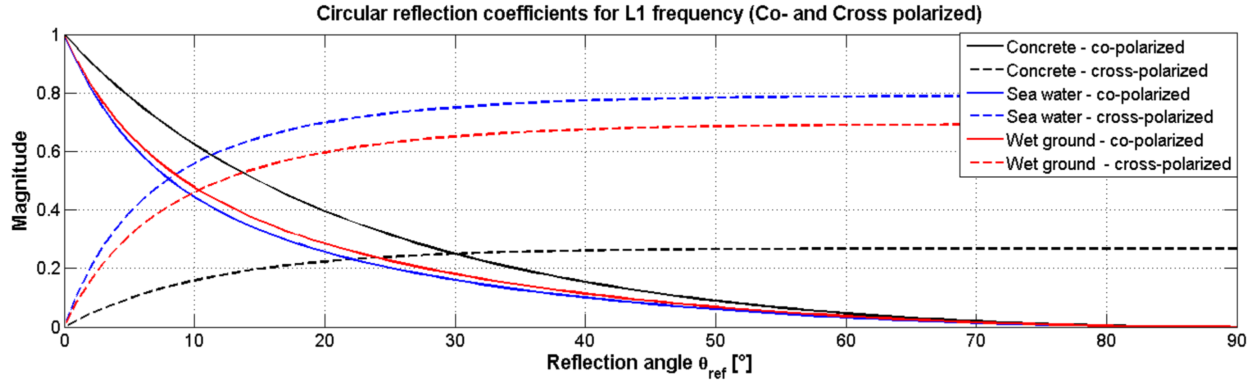
Polarization State of GNSS Signals/Antennas (1)

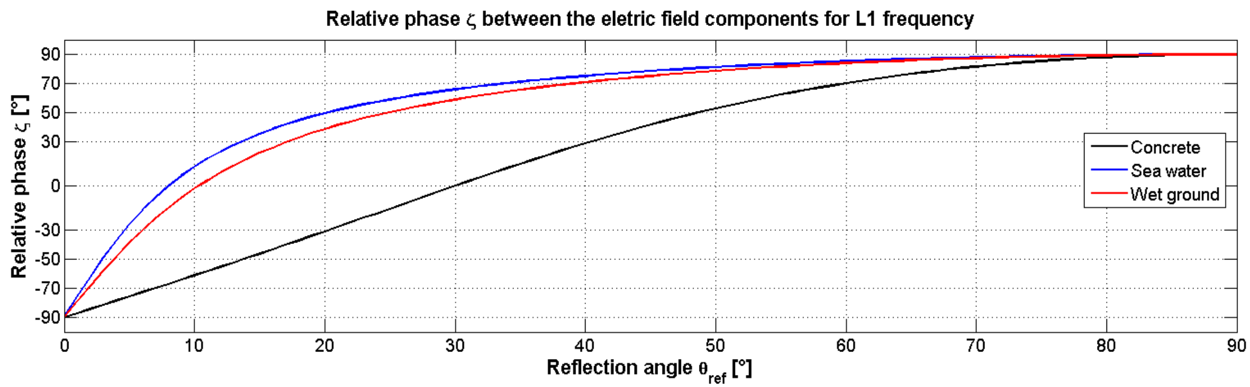


$$\vec{E}(t) = E_1 cos\omega t\vec{x} + E_2 \cos(\omega t + \zeta)\vec{y}$$

Circular Polarization:	
Spatial orthogonallity	$\vec{x} \perp \vec{y}$
Time quadrature	$\zeta = \frac{\pi}{2}\ (LH), -\frac{\pi}{2}\ (RH)$
Equal amplitude	$E_1 = E_2$

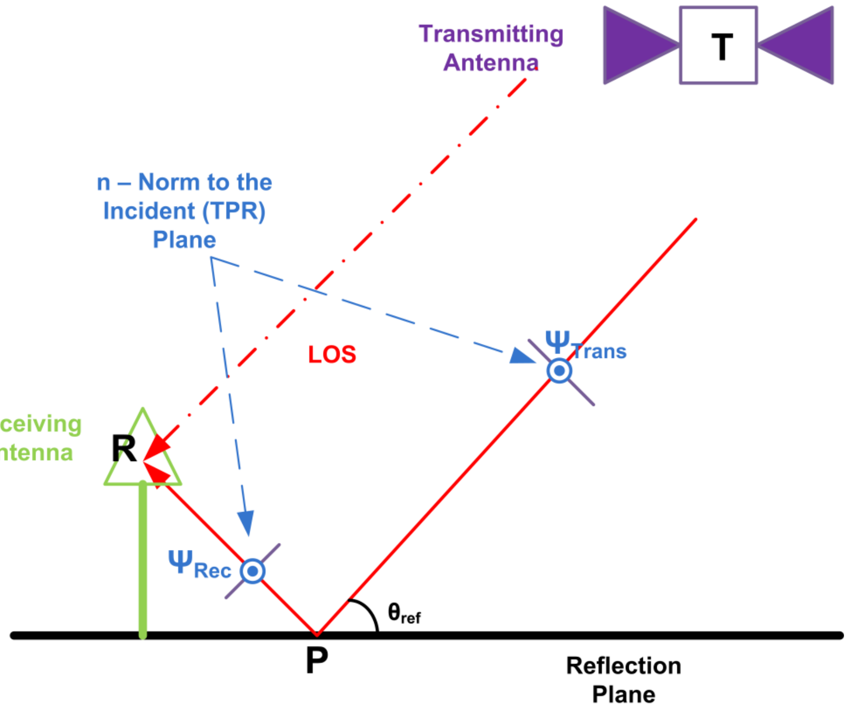
Reflection Process





Material	RHCP	RHEP	LP	LHEP	LHCP
Concrete	0°	1° ≈ 29°	30°	31° ≈ 89°	90°
Sea Water	0°	1° ≈ 8°	8°	9° ≈ 89°	90°
Wet Ground	0°	1° ≈ 11°	11°	12° ≈ 89°	90°

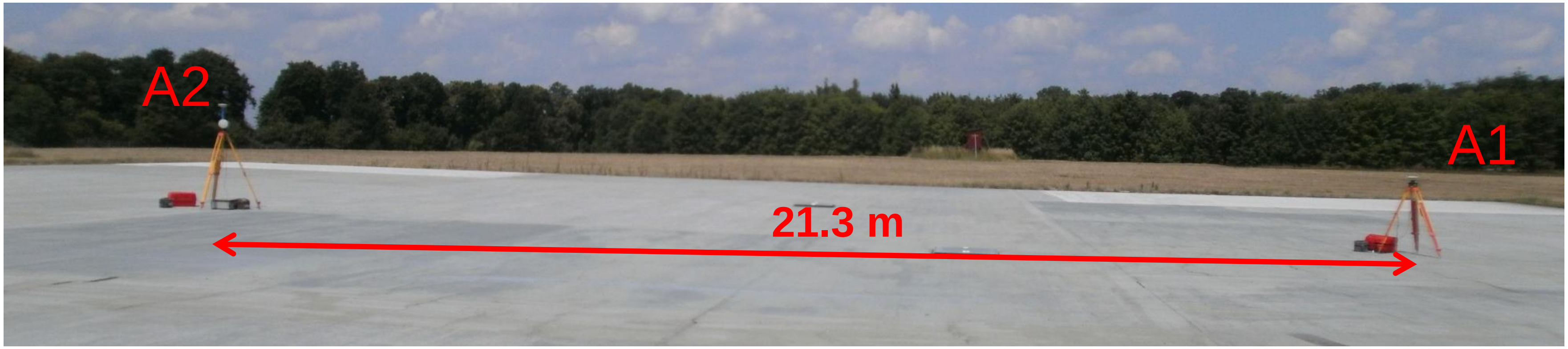
Signal Amplitude Proposed Model (e.g. Ground - Reflection)



GNSS Signal Amplitude Model:

$$S_{MPC/LOS} = \begin{pmatrix} \text{Receiving} \\ \text{Antenna} \\ f(\text{Gain}_{el}) \end{pmatrix} * \begin{pmatrix} \text{Reflection} \\ \text{Coefficients} \\ f(\theta_{ref}, \text{material}) \\ \Psi_{rec}, \Psi_{Trans} \end{pmatrix} * \begin{pmatrix} \text{Transmitting} \\ \text{Antenna} \\ (\text{RHCP}) \end{pmatrix}$$

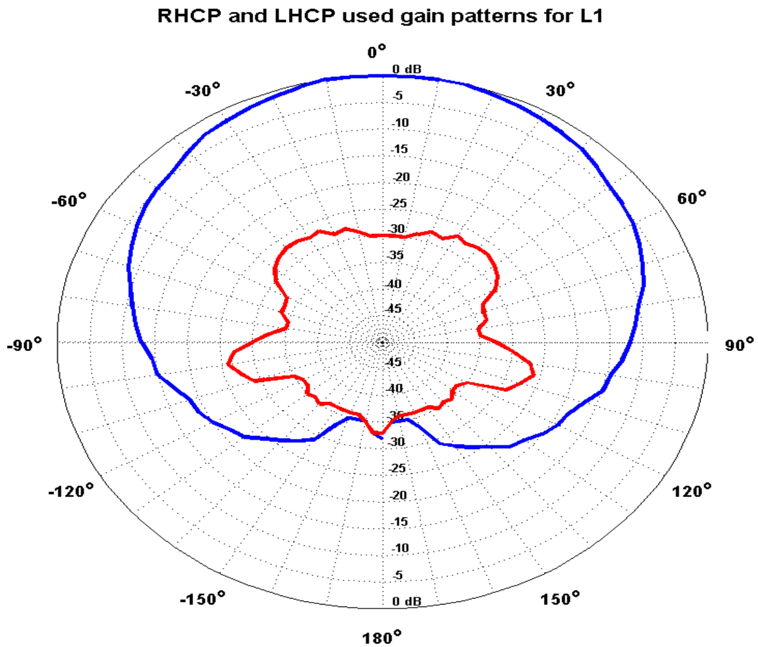
Experimental Set Up for Model Validation



Controlled environment at the PTB antenna test facility in Braunschweig

- Two antennas with different height (A2=2.053 m, A2=1.358 m)
- The antennas were spaced about 21.3 m
- The observational period lasted for about 7 hours
- Cut- off angle of 0°
- The data rate was 1 Hz.
- One pair of AX1202GG Leica antennas
- One pair LEICA GRX1200+GNSS receivers.

Simulations - Assumptions

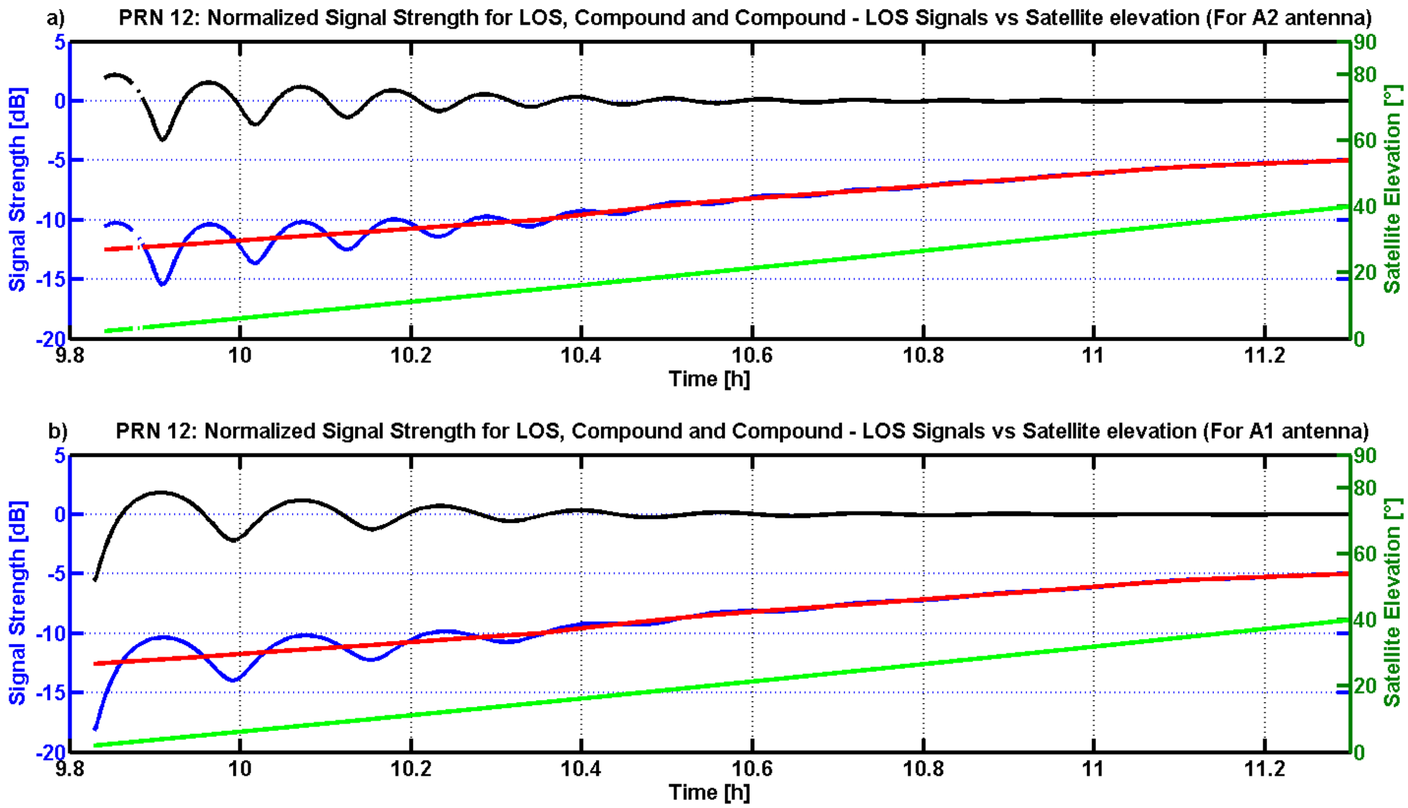


Adopted from: http://webone.novatel.ca/assets/Documents/Papers/GPS701_702GG.pdf.

Assumptions used for the simulations:

- The receiving antenna gain patterns of NOV702GG antenna was used (assumed to be similar to the AX1202)
- The normalized gain patterns were assumed symmetrical in azimuth (Polarization state for all possible azimuths and elevation)
- The satellite antenna/signals was/were assumed perfect RHCP
- Angles ψ_{rec} and ψ_{trans} were assumed to be equal and constant
- Horizontal Reflector

Simulations
Two Different Antenna Set Ups



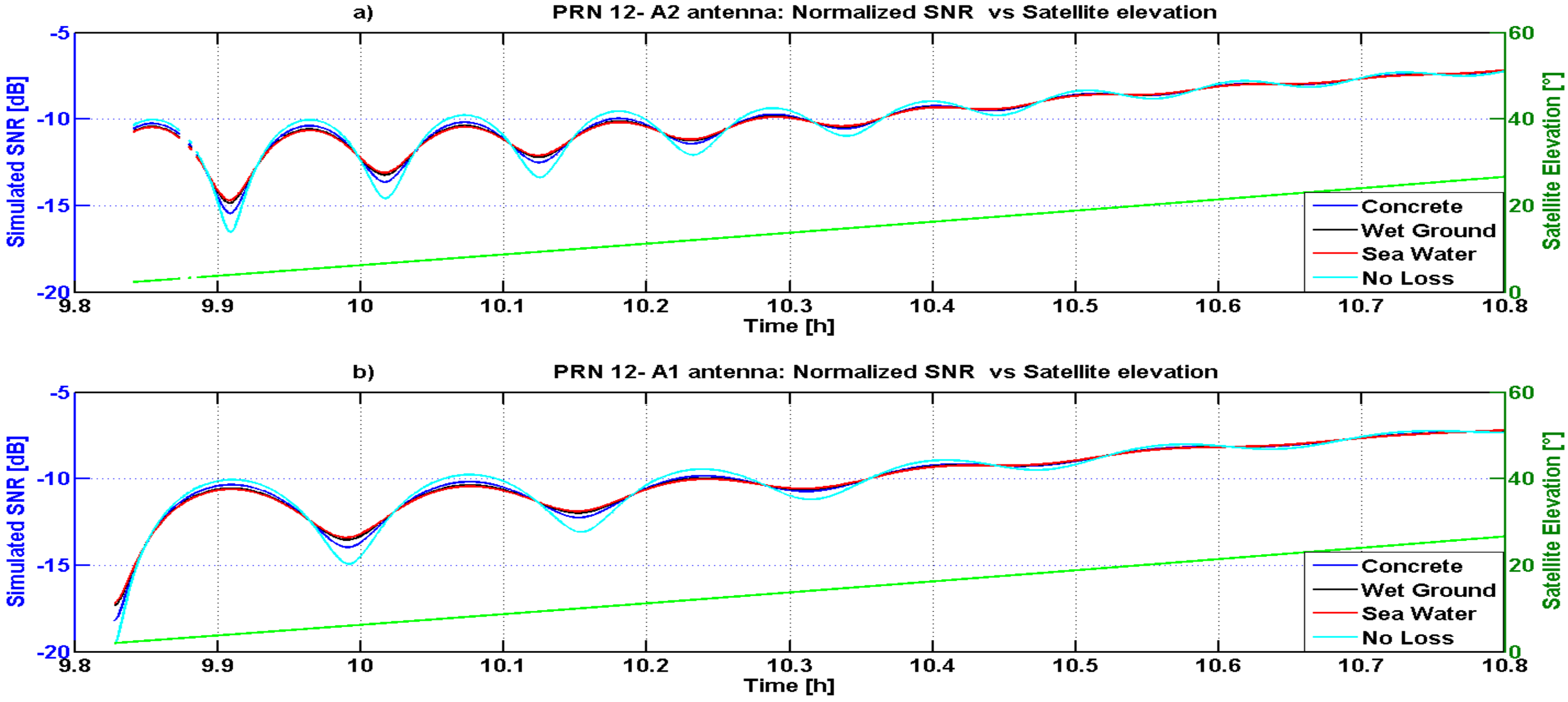
- **LOS Contribution:**
A smoothed curve mainly determined by the gain pattern of the receiving antenna.

- **Multipath Contribution**
shows the typical amplitude variations of few dB depending on the material properties of the reflector

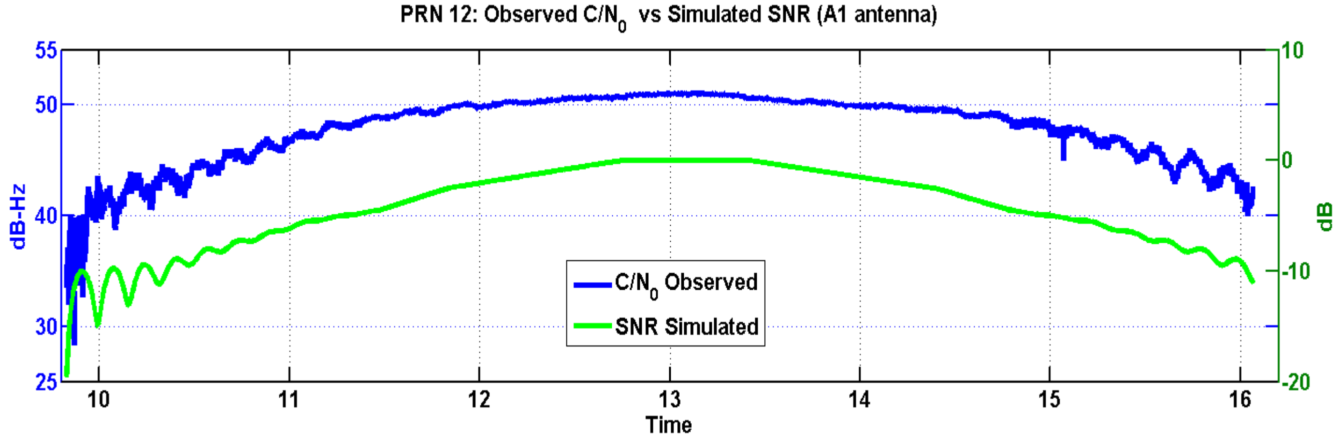
- **Compound SNR**
shows a superposition of both features

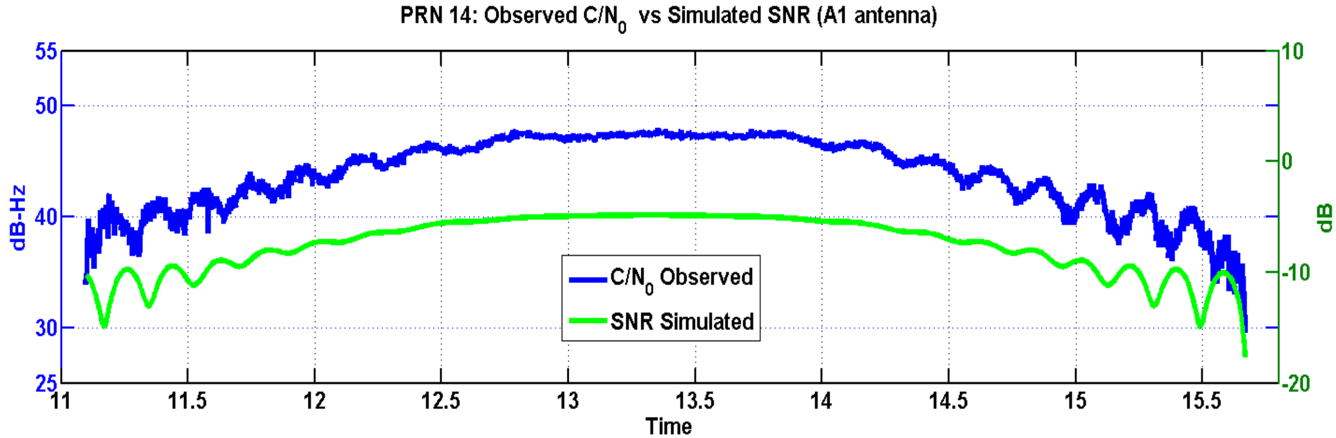
- **Frequency Difference**
of the oscillations can be noticed between the different antenna heights

Simulations - Different Reflectors



Observed C/N_0 vs Simulated SNR



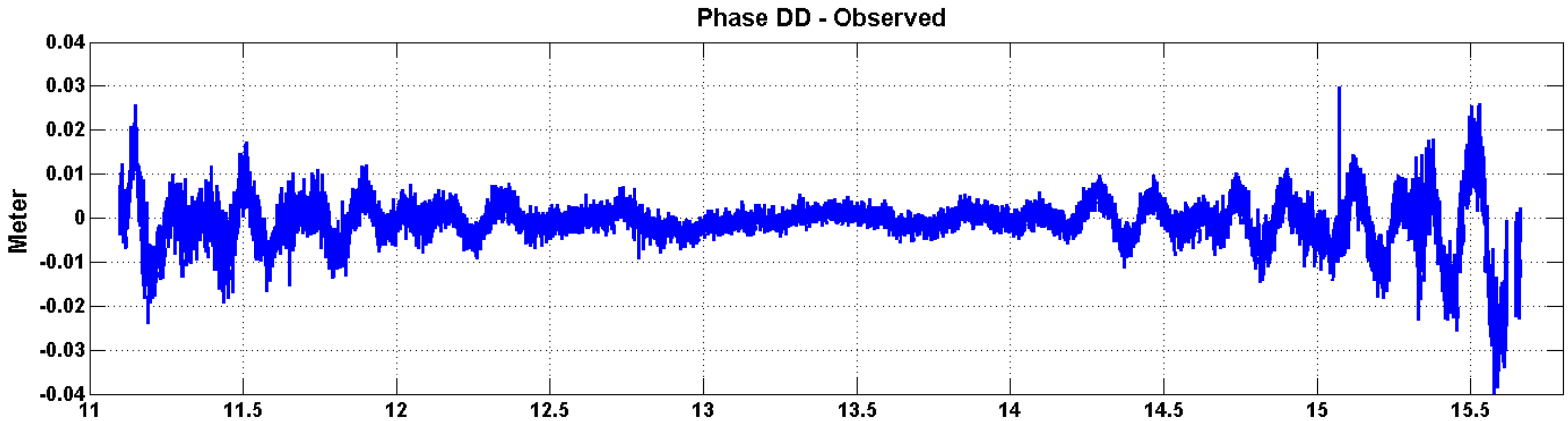


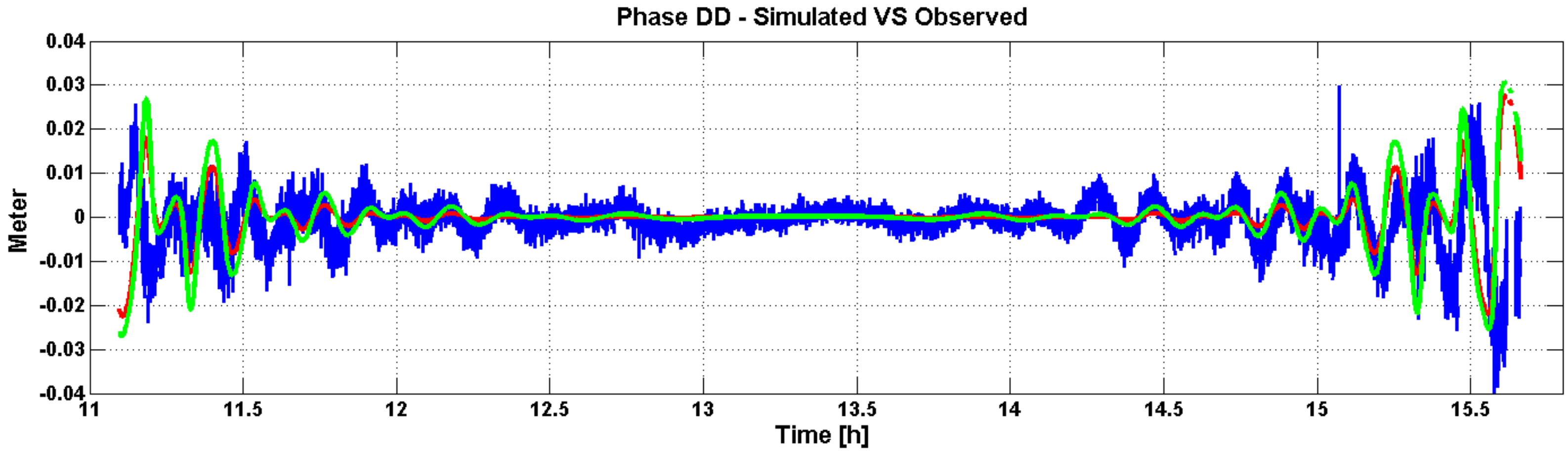
Simulations can explain the main features present in the observations

Some **Disturbances** Occur which are due to our simplifications e.g.:

- Neglecting a small tilting of the reflector
- Transmitted signal ellipticity
- Deviation of the used from the real receiving antenna gain patterns

Observed phase-DD vs Simulations phase-error-DD





Concrete

No Loss

Outlook

GNSS Signal Amplitude Model Taking into Account:

- Polarization of the Transmitting Antenna (RHCP)
- Reflection Process
- Polarization of Receiving Antenna which is modeled as a function of antenna Gain and elevation of the signal components

Simplified version but already good agreement. There are still some differences…

Future Work

- Disturbances in Frequency - (Tilting of the Reflector?)
- Disturbances in Amplitude - (Differences between used and real Gains?)
- What about the impact of the ellipticity of the transmitted signals?