Ray-tracing Approach versus Double Difference, Multipath Characterization in a Multiple Ray Scenario

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Motivation

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

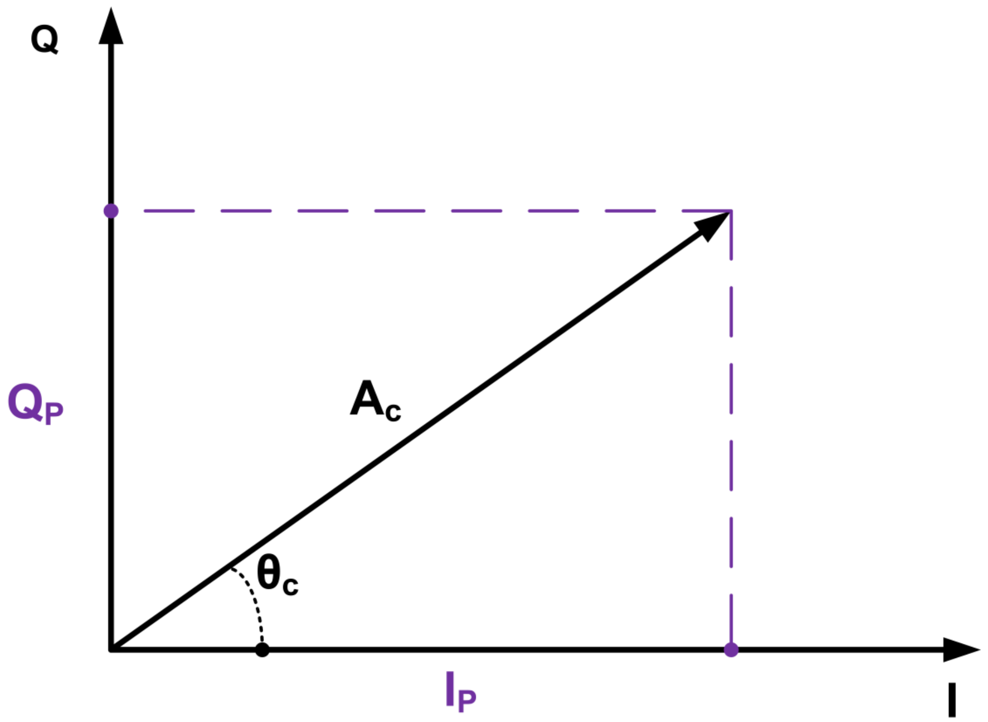
- Multipath effects in observation domain are characterized as functions of:

  ✓ carrier **Frequency**
  ✓ **Geometry** related parameters
  ✓ **Signal Amplitudes** of the involved signal components (both LOS and MPCs)

Presentation Focus:

- Signal Amplitude Epoch-wise Modeling
- Novel Ray-Tracing Approach for the Characterization of a Multiple-Reflection/Diffraction Environment

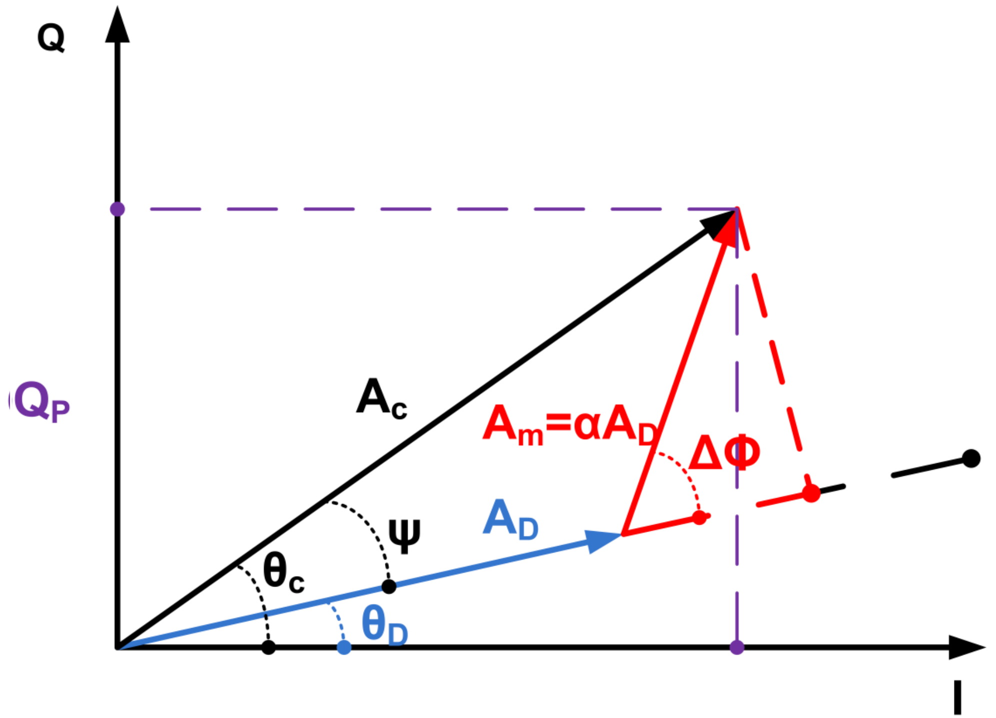
Multipath Characterization



Multipath errors in the Observation domains are **characterized** as functions of:

- Multipath **Relative Phase** w.r.t. LOS **ΔΦ** *(geometry)*
- Multipath **Relative Amplitude** w.r.t. LOS **α** *(Not directly accessible)*

Multipath Characterization



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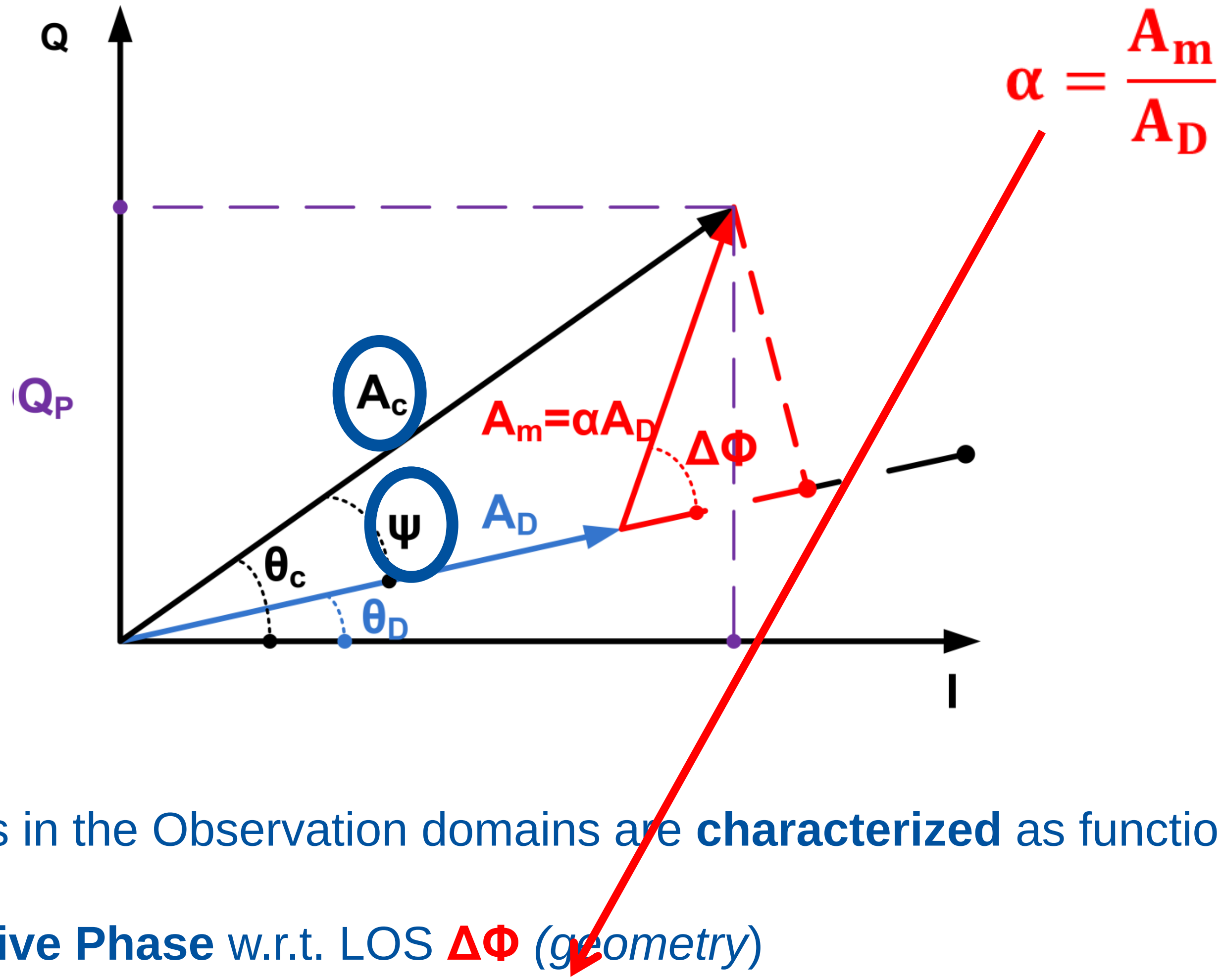

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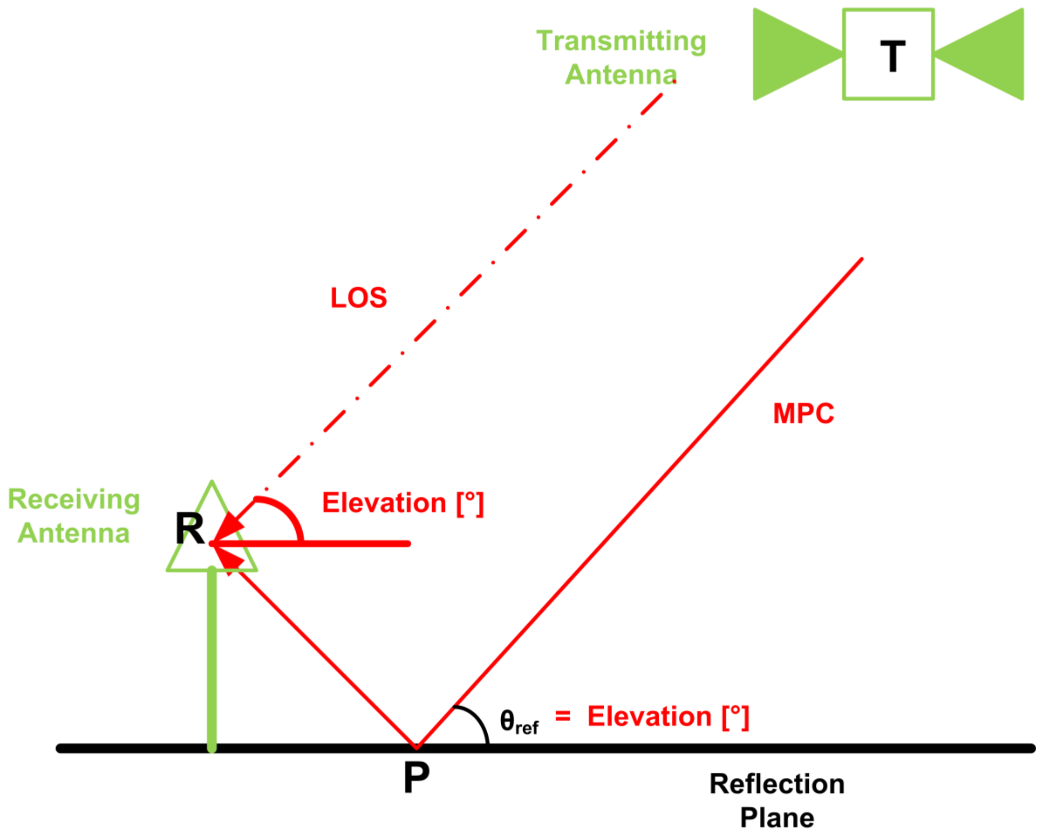
Analytical GNSS Signal Amplitude Model (1)

- Ground Multipath Scenario Investigation (i.e. known geometry)
- Two Signal Components: LOS and Ground MPC



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Analytical GNSS Signal Amplitude Model (2)

- Ground Multipath Scenario Investigation (i.e. known geometry)
- Two Signal Components: LOS and Ground MPC

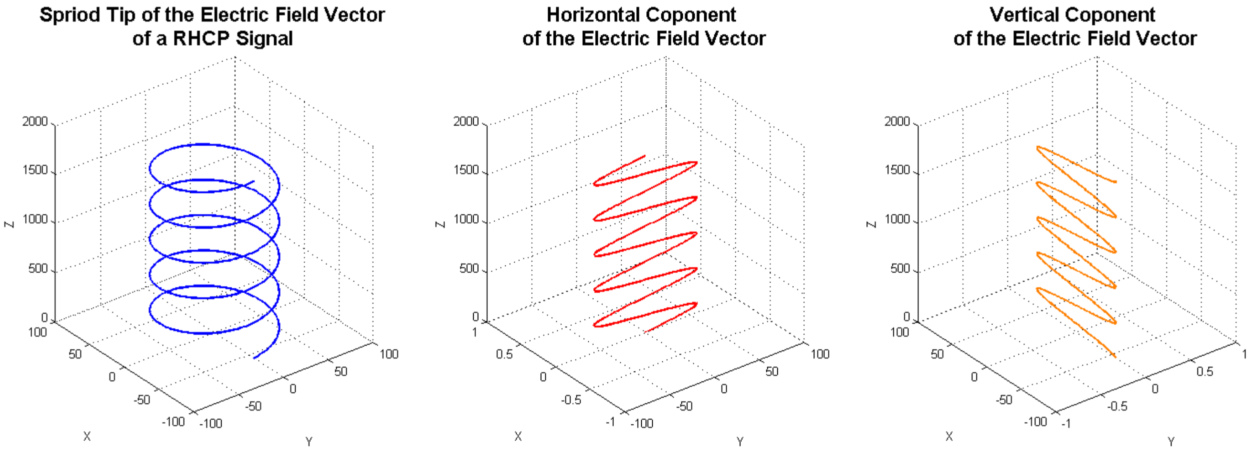
Signal Amplitude Model:

Transmitted Signal Polarization

Transmitted Signal is Modeled
As **R**ight **H**and **C**ircular **P**olarized
(by the appropriate **Jones vector)**

Reflection Process

Receiving Antenna



Analytical GNSS Signal Amplitude Model (3)

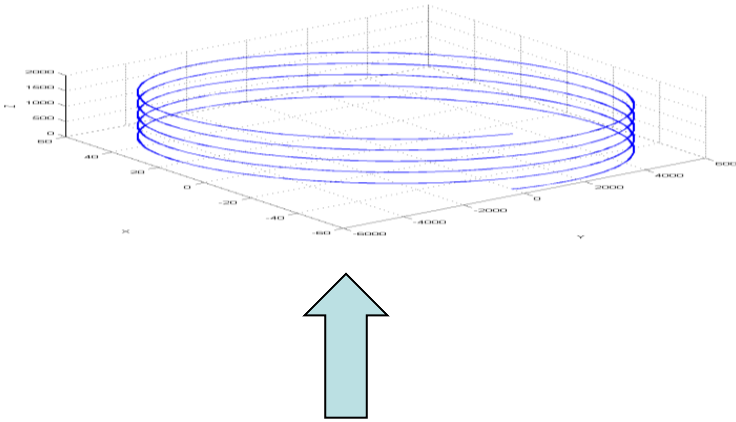
- Ground Multipath Scenario Investigation (i.e. known geometry)
- Two Signal Components: LOS and Ground MPC

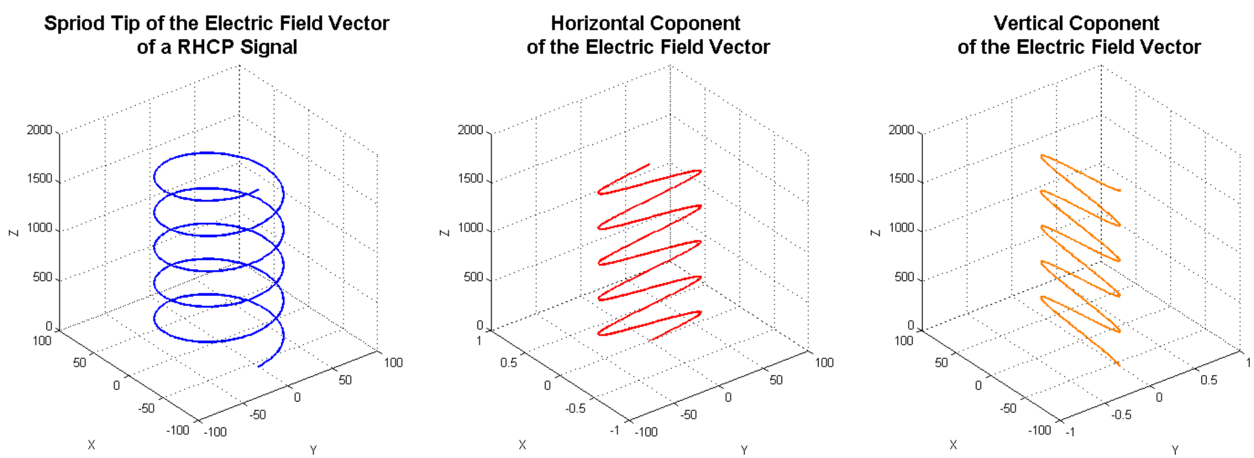
Signal Amplitude Model:

Transmitted Signal Polarization

Reflection Process

Receiving Antenna





Analytical GNSS Signal Amplitude Model (4)

- Ground Multipath Scenario Investigation (i.e. known geometry)
- Two Signal Components: LOS and Ground MPC

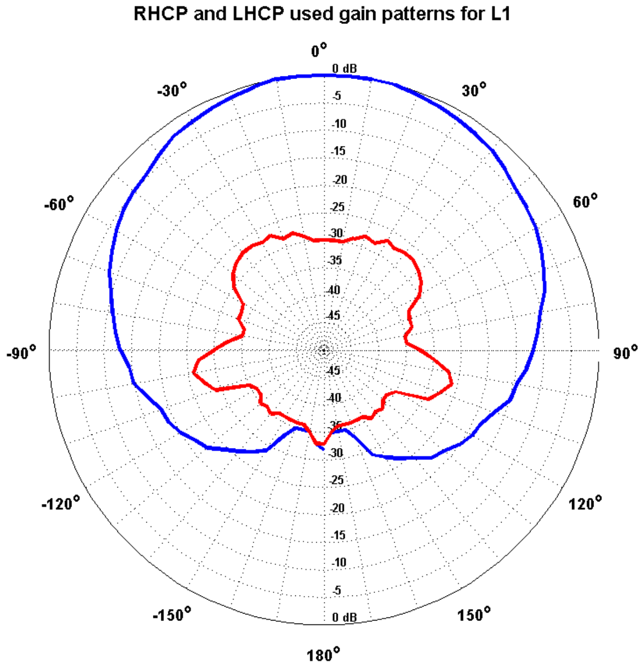
Signal Amplitude Model:

Transmitted Signal Polarization

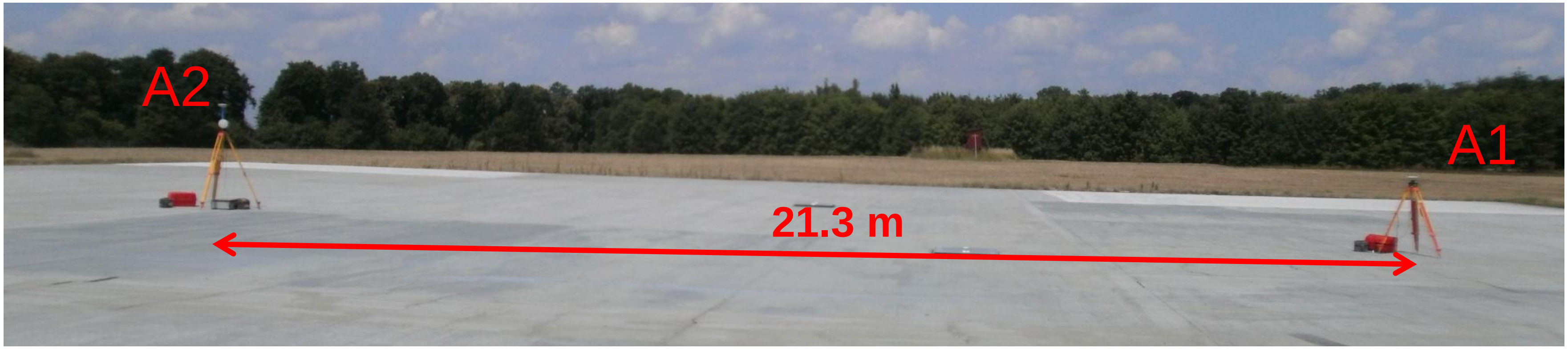
Reflection Process

Receiving Antenna

Modeling the **Receiving Antenna** by taking into account the **Elevation Dependence** of the **Gain Patters** (by the appropriate **Jones vector**)



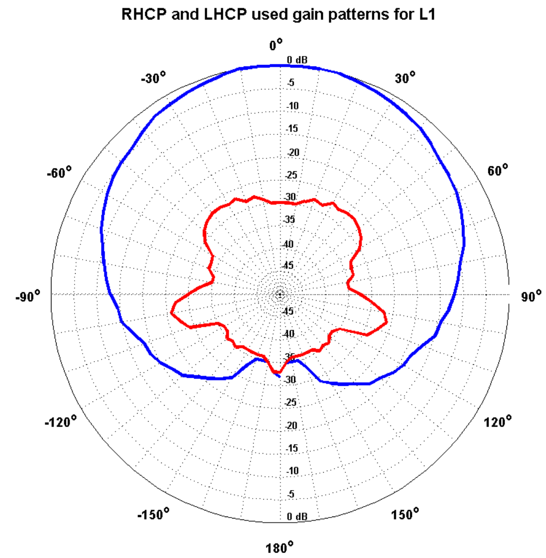
Model Validation: Experimental Set-Up



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.

Model Validation: Simulations - Assumptions

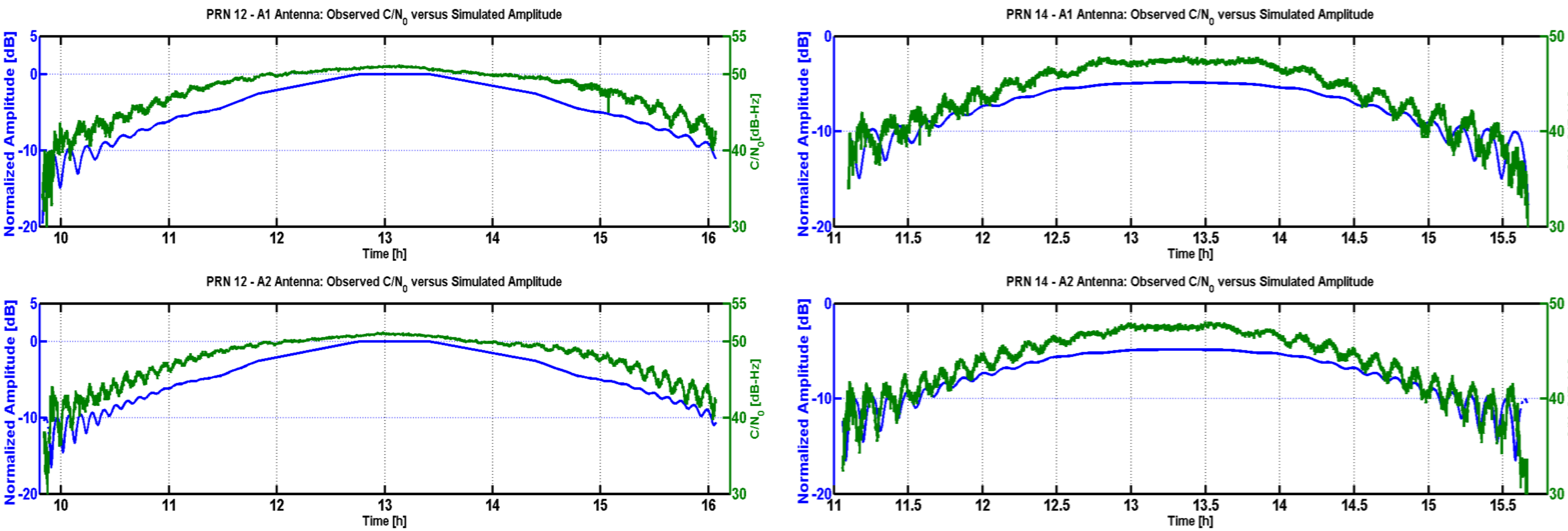


Adopted from: http://webone.novatel.ca/assets/Documents/Papers/GPS701_702GG.pdf.

Assumptions used for the simulations:

- Gain patterns of NOV702GG antenna were used (assumed to be similar to the AX1202)
- They were assumed symmetrical in azimuth
- The satellite signals were assumed perfect RHCP
- Horizontal reflector

Model Validation: Observed C/N_0 vs Simulated Signal Amplitude



Simulations can explain the main features present in the observations

Disturbances occur which are due to our simplifications e.g.:

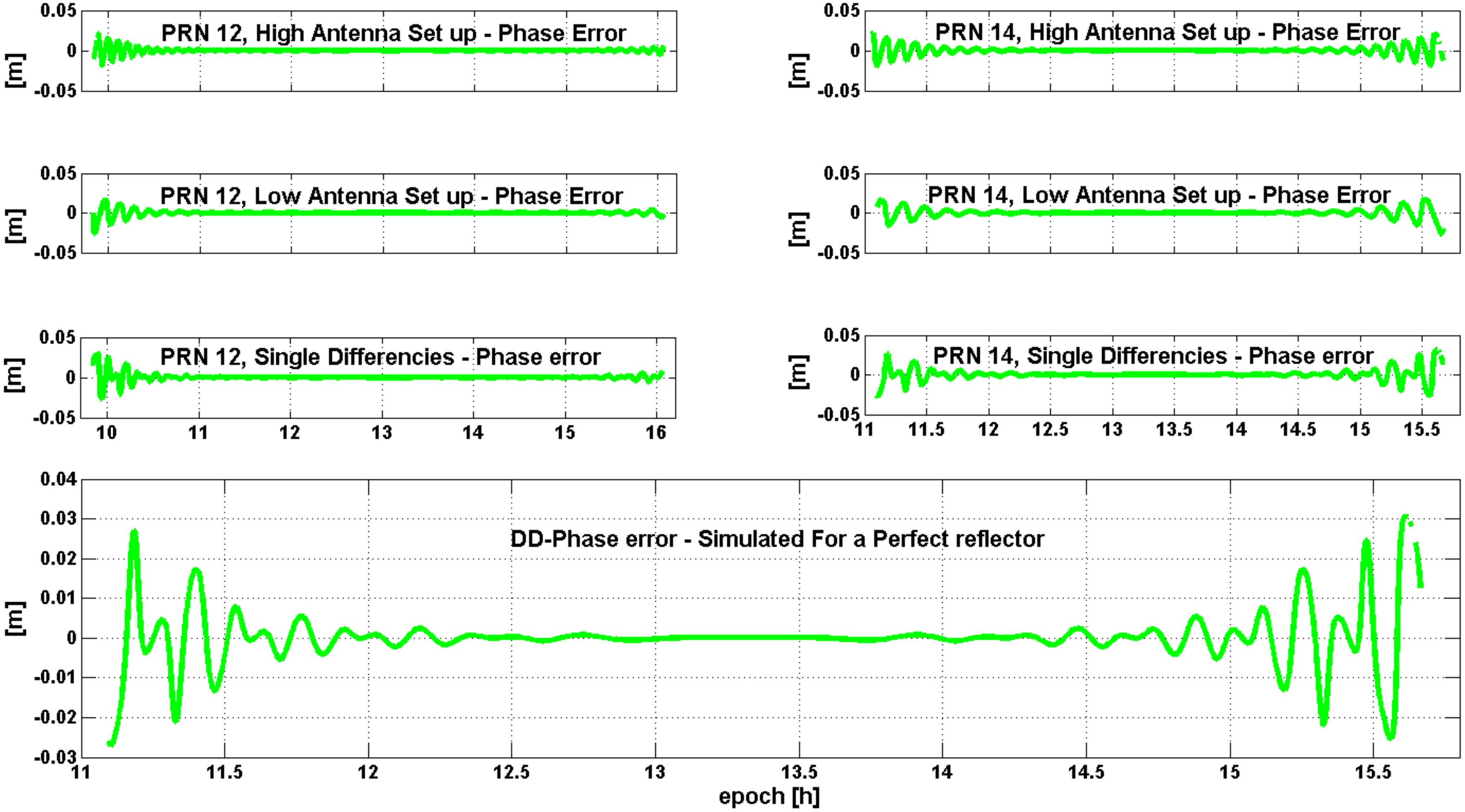
- Neglecting a small **Tilting** of the reflector => **Frequency** changes
- **Deviation** of the used from the real receiving antenna **Gain Patterns:**

1. Deviations of the **Upper Hemisphere**: Differences in the trend of the time series (LOS contribution)
2. Deviations of the **Lower Hemisphere**: Differences in the amplitude of the oscillations (MPC contribution)

- Not Considering additional **Phase Shifts** due to reflection process => **Frequency** changes, Phase Shifts

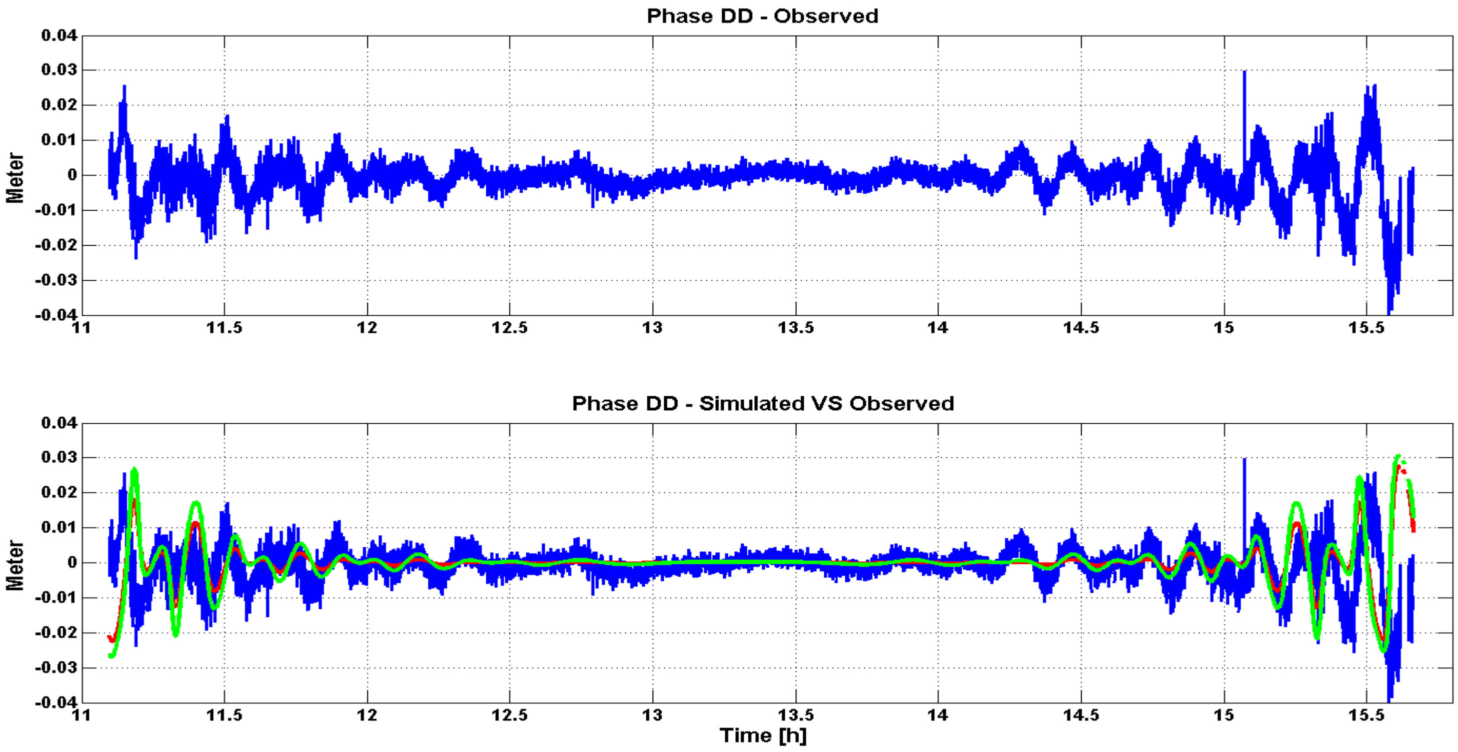
Model Validation: Phase Domain

- **Simulations: Phase-error for each of the MPCs Involved in the DD**



Model Validation: Phase Domain

- **Observed phase-DD vs Simulations phase-error-DD**



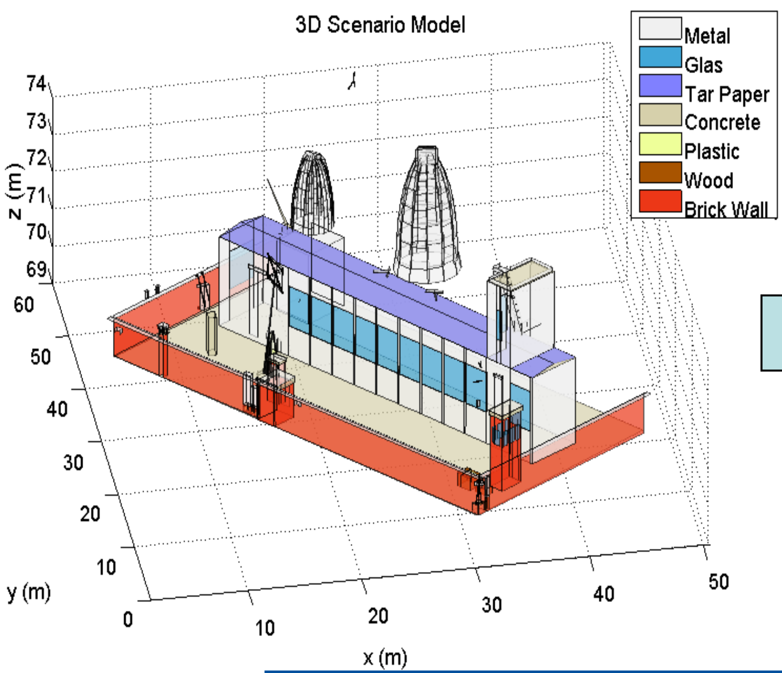
Concrete **No Loss**

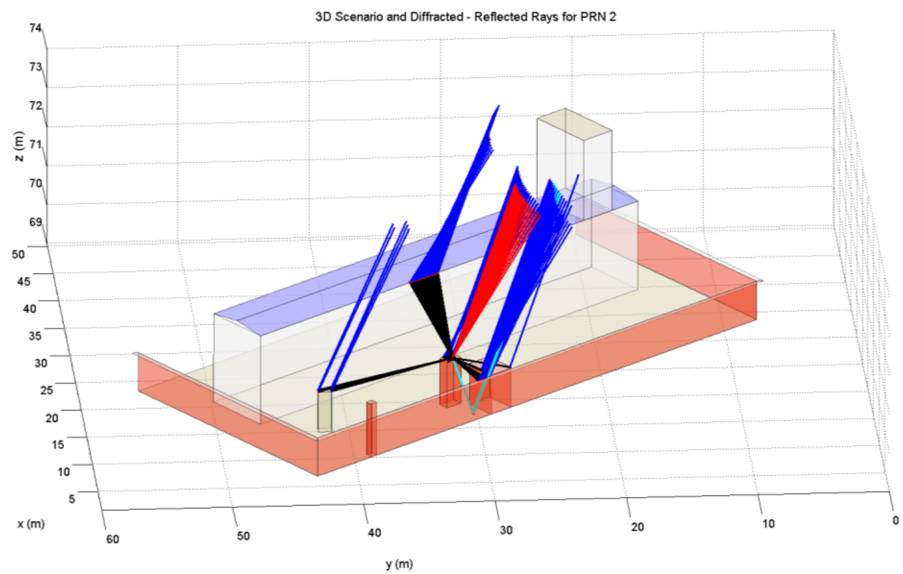
Novel Ray-Tracing Approach for Complex Geometry Scenario Characterization

Ray-Tracing
Scenario and Input Parameters

Ray-tracing input parameters

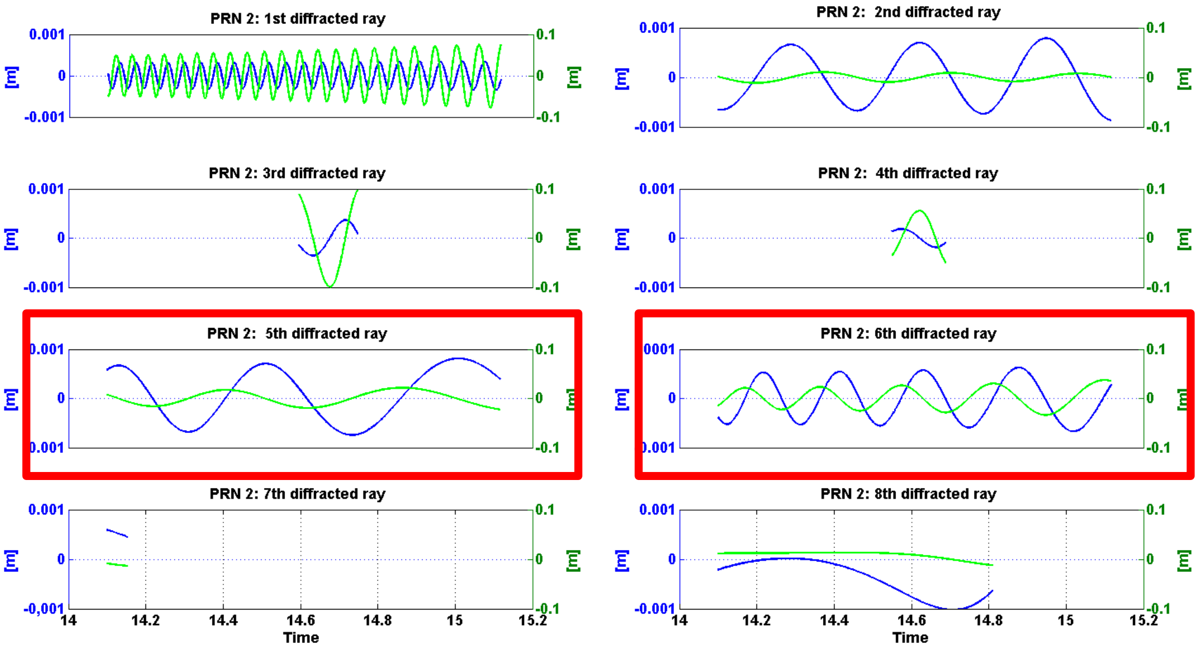
1. Description of the physical environment in which the Receiving Antenna is placed in (**Scenario**)
2. Transmitting Antenna Position
3. Receiving Antenna Position





Visualization of Simplified Scenario and Ray-Tracing Results

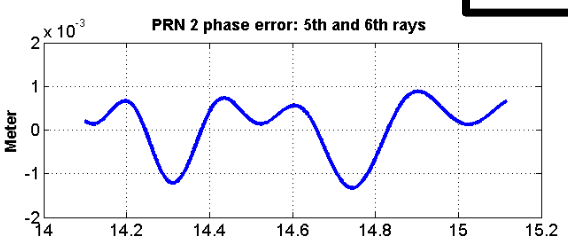
Errors in Code and Phase Domain Due to Each MPC And Due to All MPCs (1)

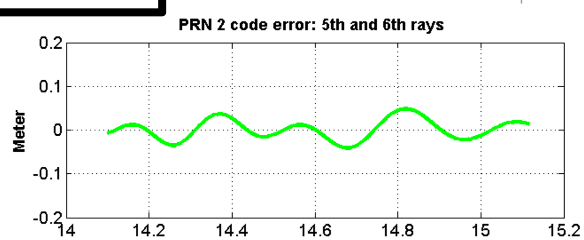


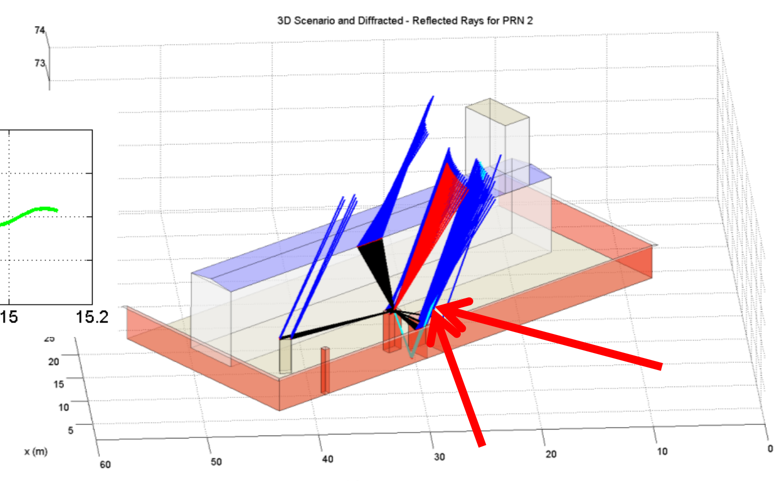
Phase and Code errors are having a 90° Shift

Phase Error

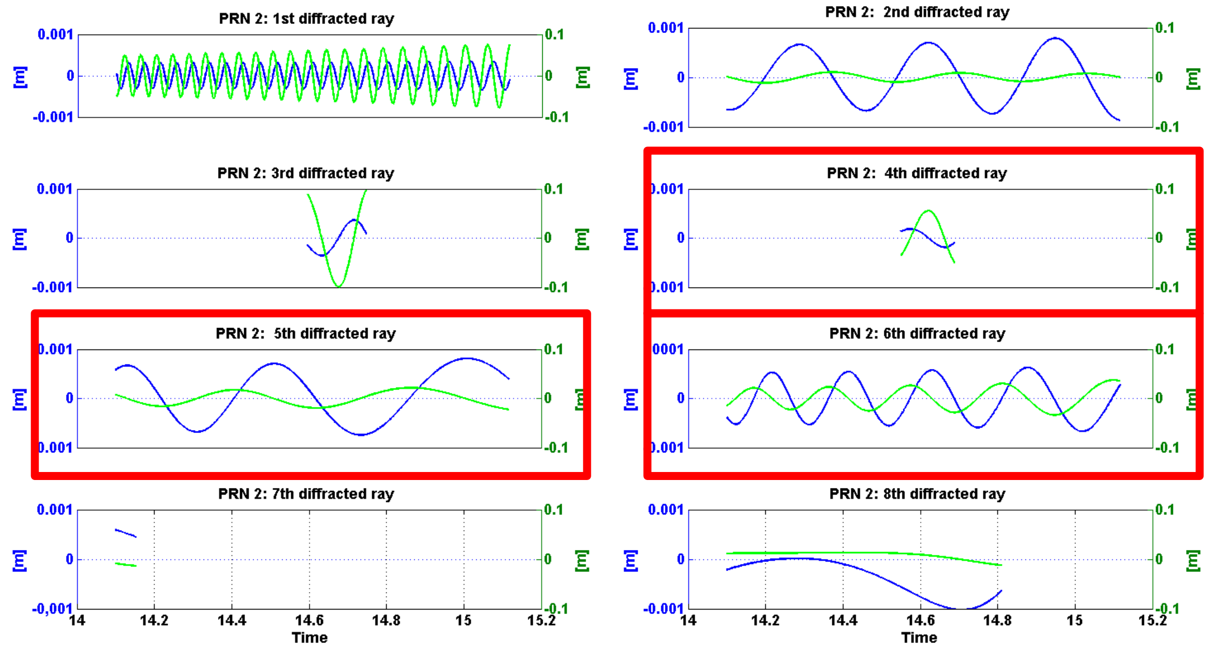
Code Error







Errors in Code and Phase Domain Due to Each MPC And Due to All MPCs (2)



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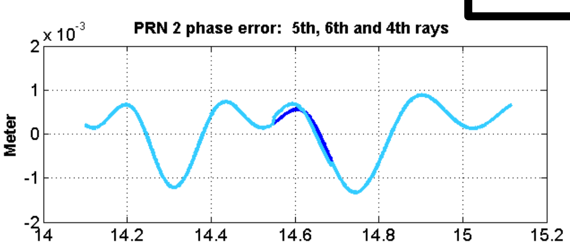
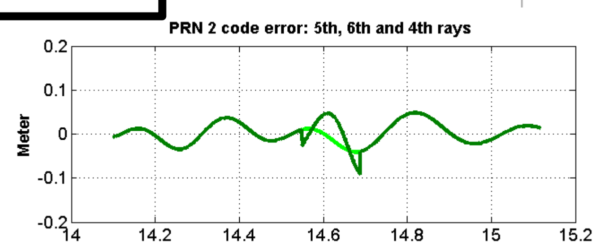
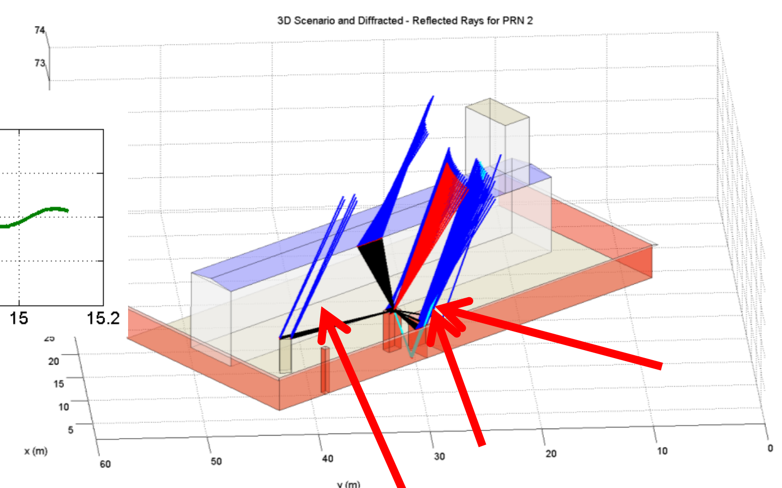
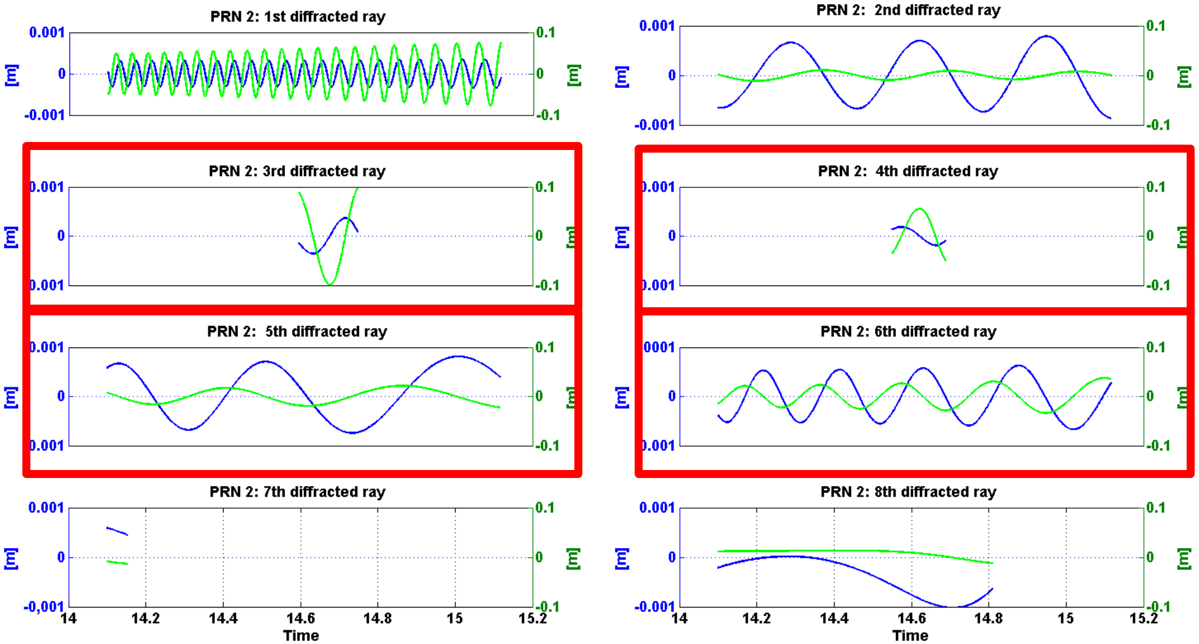
Code Error







Errors in Code and Phase Domain Due to Each MPC And Due to All MPCs (3)



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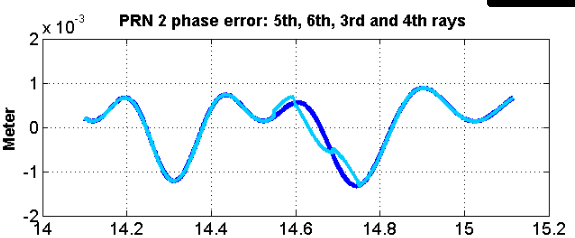

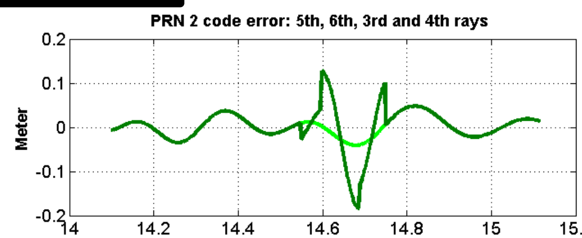

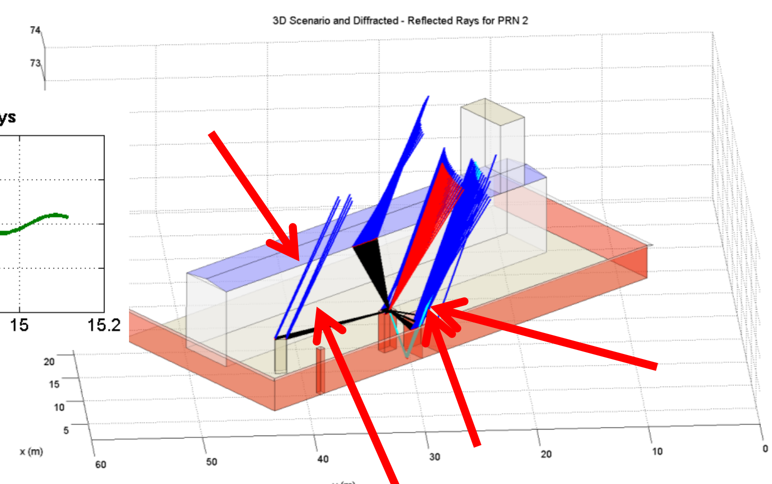

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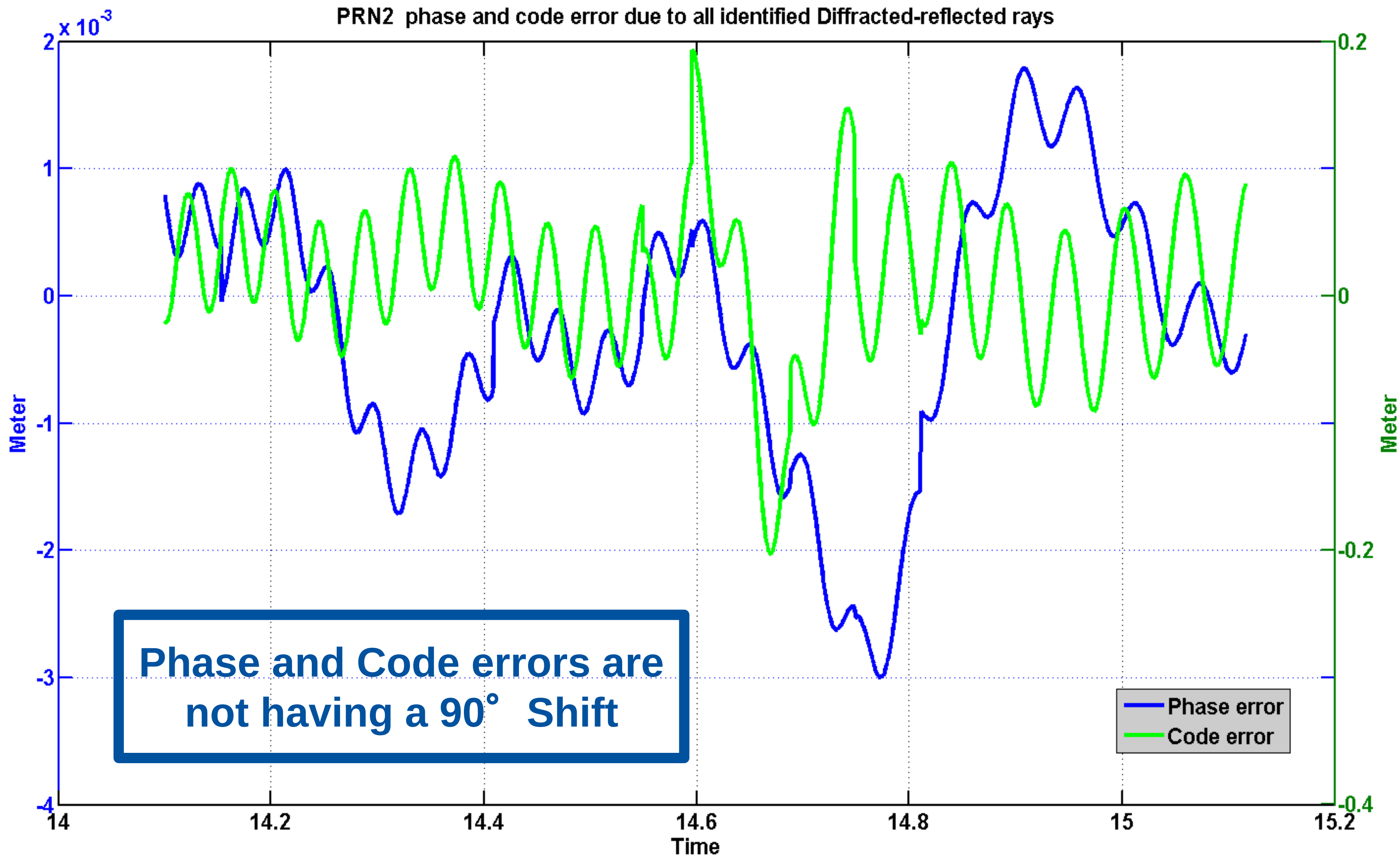


Summary

GNSS Signal Amplitude Model Taking into Account:

- Polarization of the transmitting antenna (RHCP)
- Reflection process (losses, depolarization effects, phase shifts)
- Polarization of receiving antenna which is modeled as a function of the antenna gain and the elevation of the incoming signal components

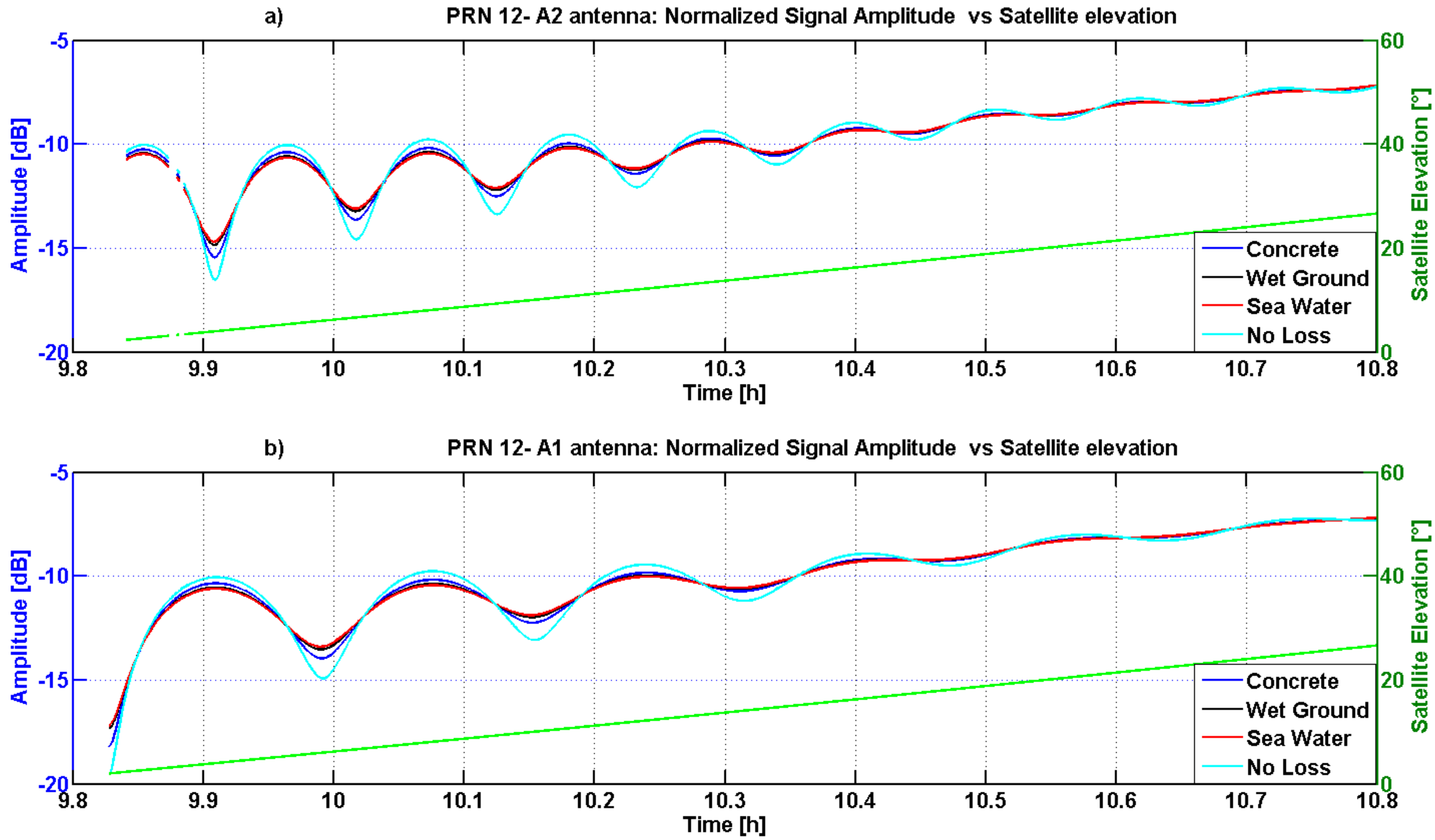
Simplified version but already good agreement. There are still some differences…

Future Work

- Improve model and reduce the assumptions
- What about the impact of the ellipticity of the transmitted signals?
- Further investigation of complex scenarios and diffraction aspects with the Ray-Tracing tool

Thank You!

Impact of Different Reflectors



Ground Reflection Scenario