Stationary, Cyclostationary and Nonstationary Analysis of GNSS Signal Propagation Channel

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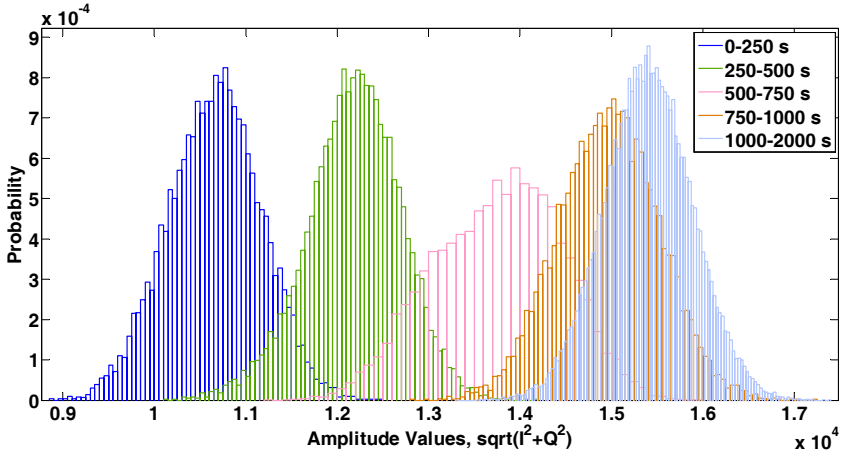
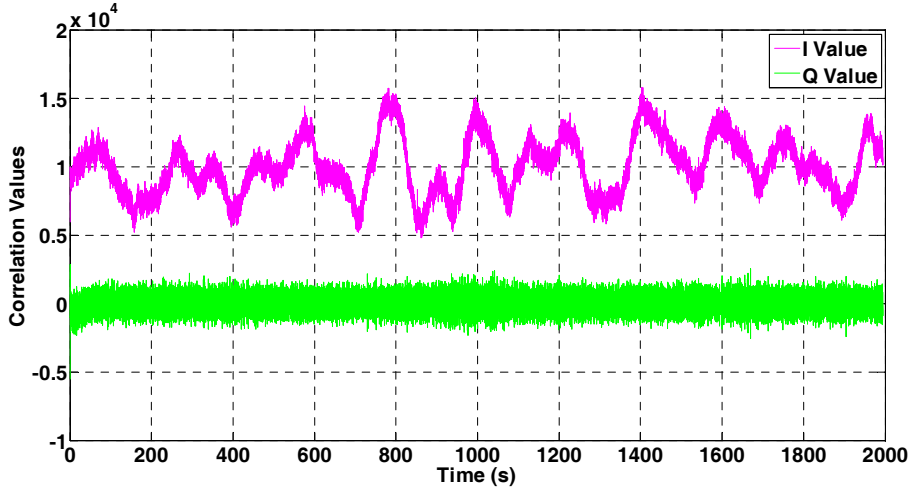
Objectives

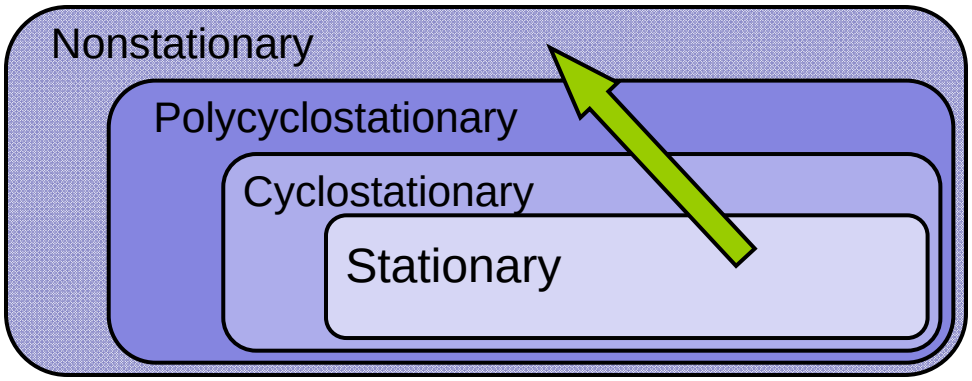
- Empirical characterization of GPS signal amplitude under various scenarios such as urban, semi urban, foliage and indoors
- Empirical validation of statistical models for signal amplitude such as single and multiple state models
- Stationary, cyclostationary and nonstationary analysis of GPS signal amplitude under harsh environments





Background

- Classes of Stochastic Processes (Gardner, 1994).



- Stationarity in wide-sense

$$m_x = m_x(t_1) = m_x(t_2)$$

$$R_{xx}(\tau) = R_{xx}(t_1, t_2) = R_{xx}(t_2 - t_1)$$

- Cyclostationarity in a wide-sense

$$m_x(t) = m_x(t + nT_0)$$

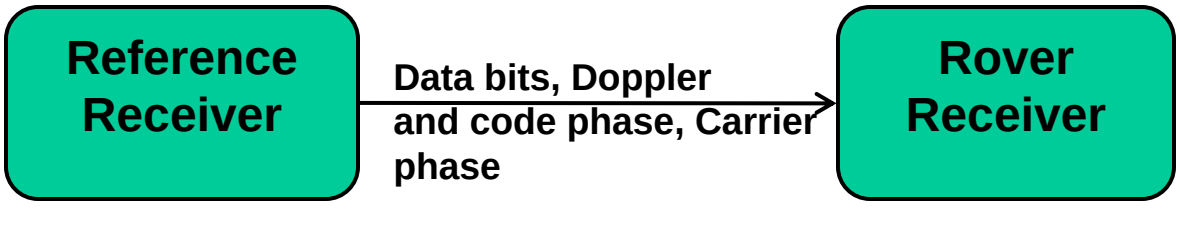
$$R_{xx}(t, \tau) = R_{xx}(t + nT_0, \tau)$$

  - Cyclic Autocorrelation Function (CAF)
  - Spectral Correlation Density function (SCD)

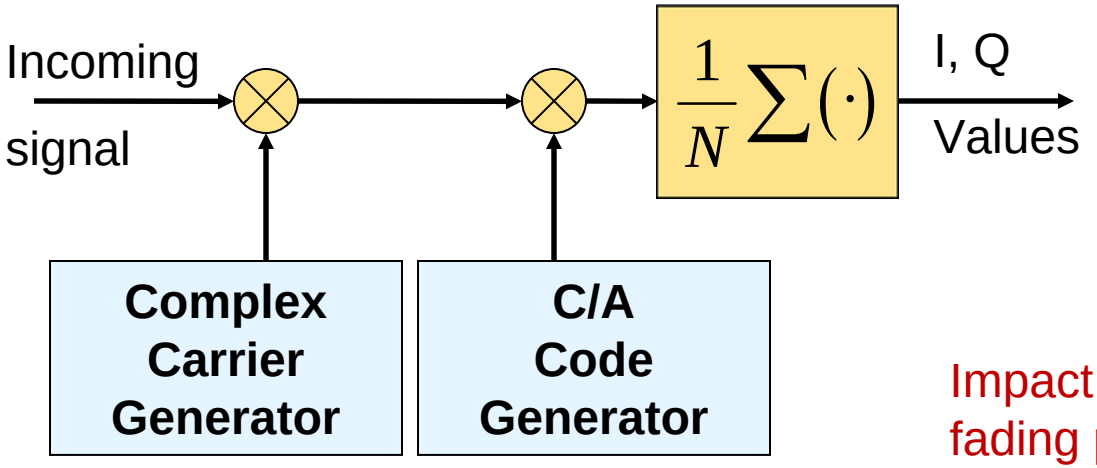
- Non-stationary signals
  - Short-Time Fourier Transform
  - Wigner-Ville Distribution

Methodology

- Data aiding from a reference receiver. Synchronous data were collected from two receivers with one antenna in a relatively open sky condition and another being in harsh environment.



- Signal analysis at the correlator output level

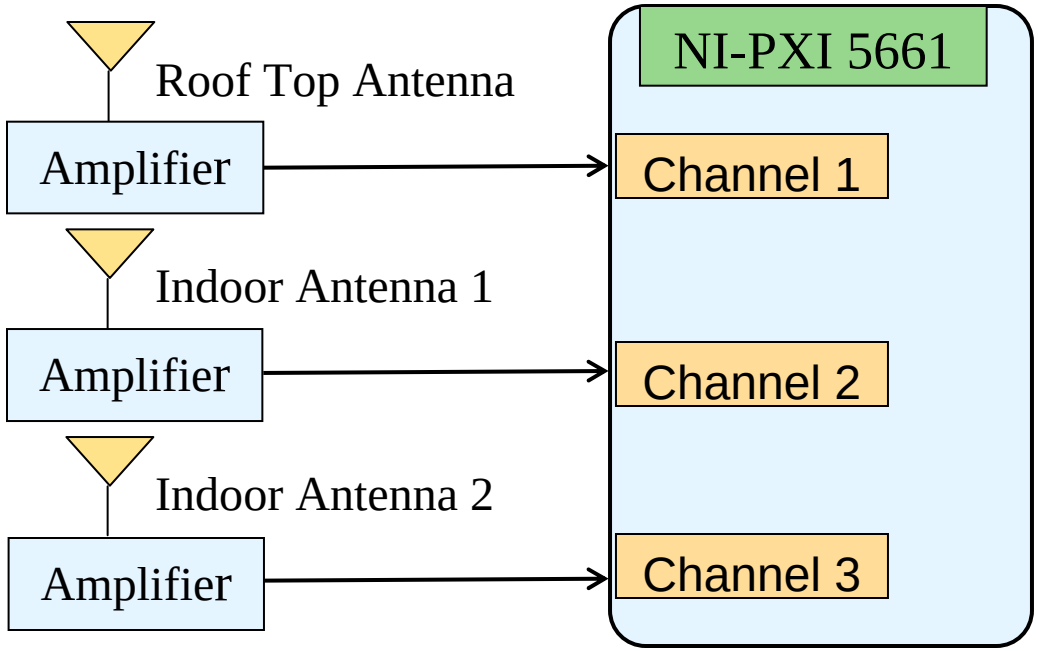


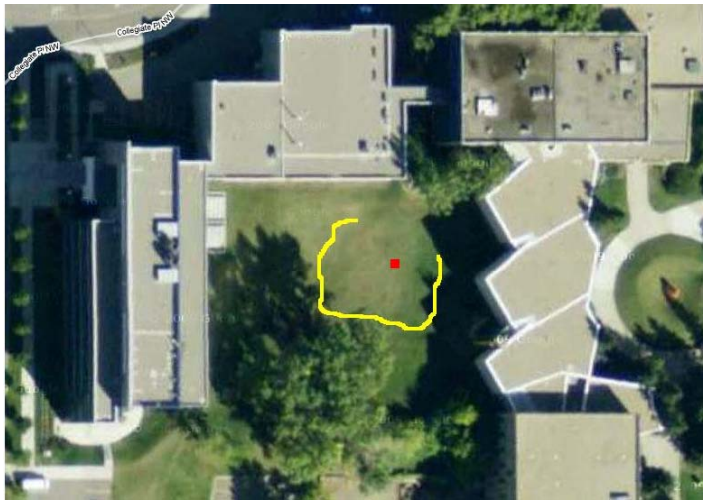
Amplitude of the signal is computed as

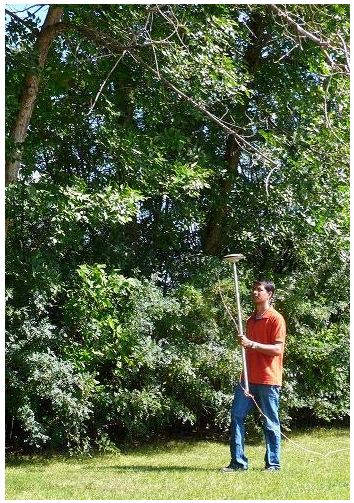
$$A_f = \sqrt{I^2 + Q^2}$$

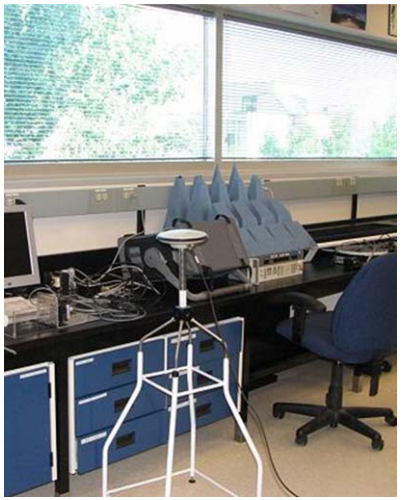
Impact of correlation on the fading phenomenon

Test Setup

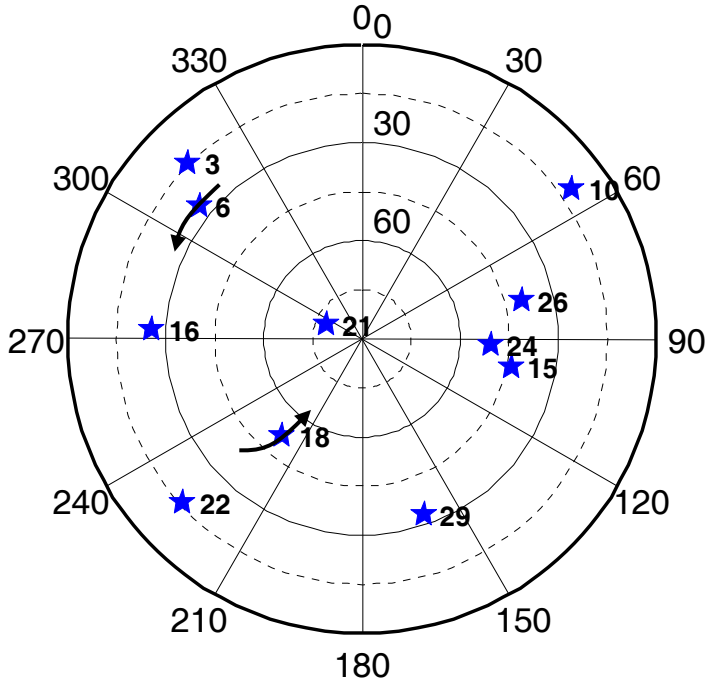

Roof Top Antenna
Amplifier
Indoor Antenna 1
Amplifier
Indoor Antenna 2
Amplifier
NI-PXI 5661
Channel 1
Channel 2
Channel 3

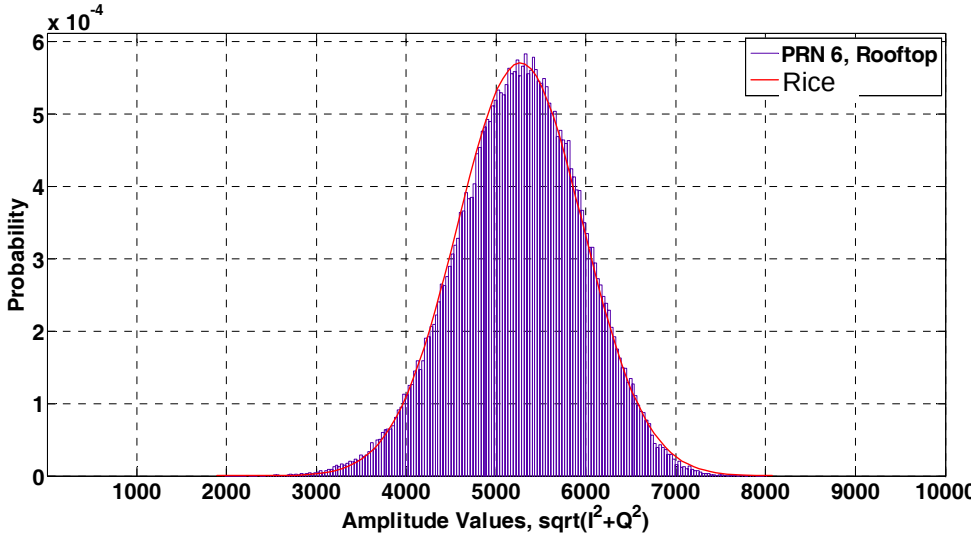


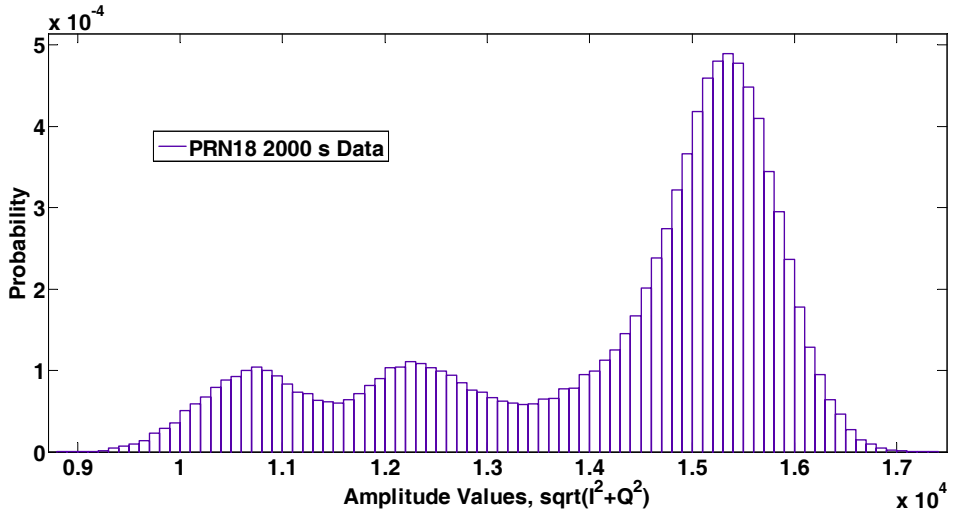


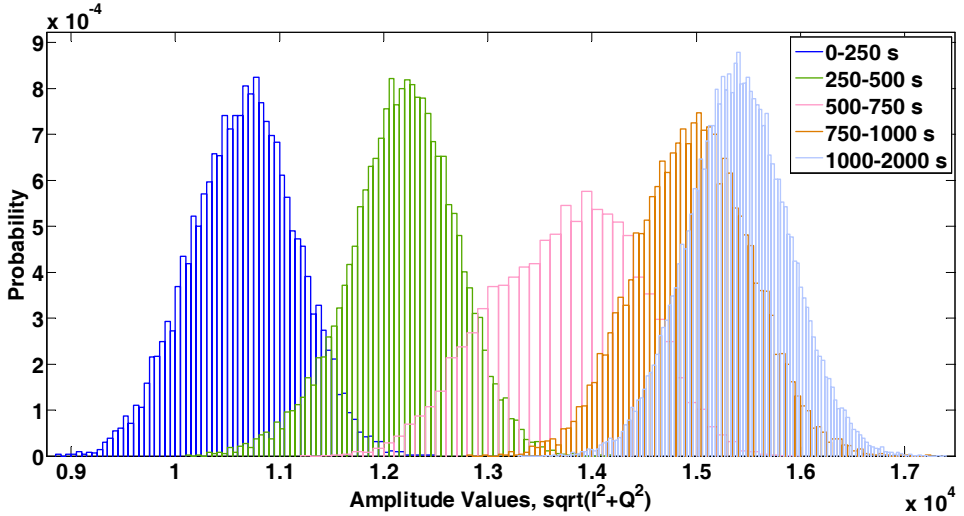


Open Sky Scenario





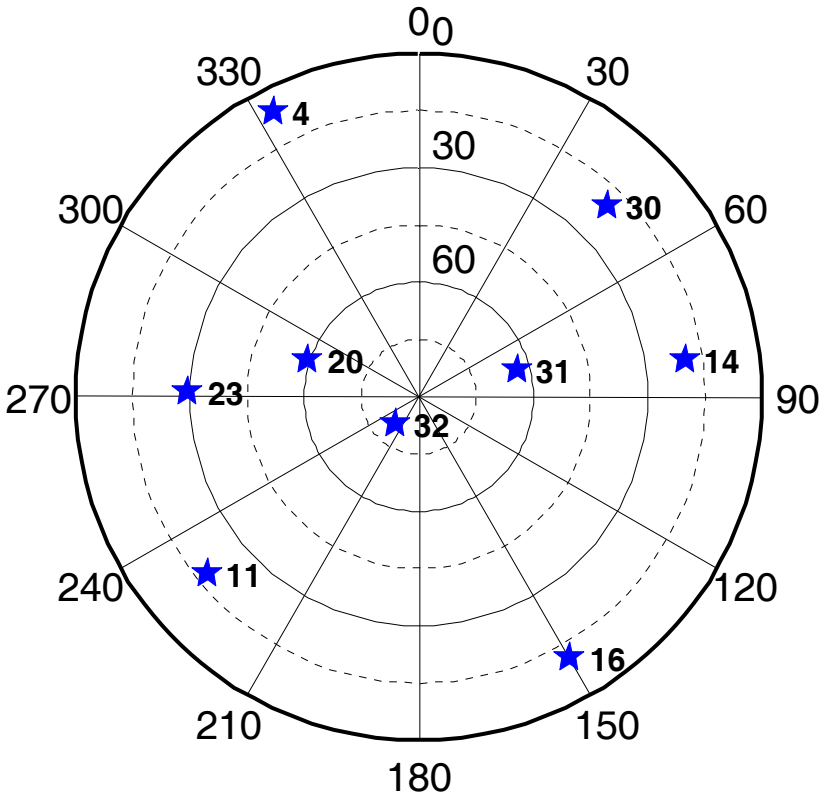


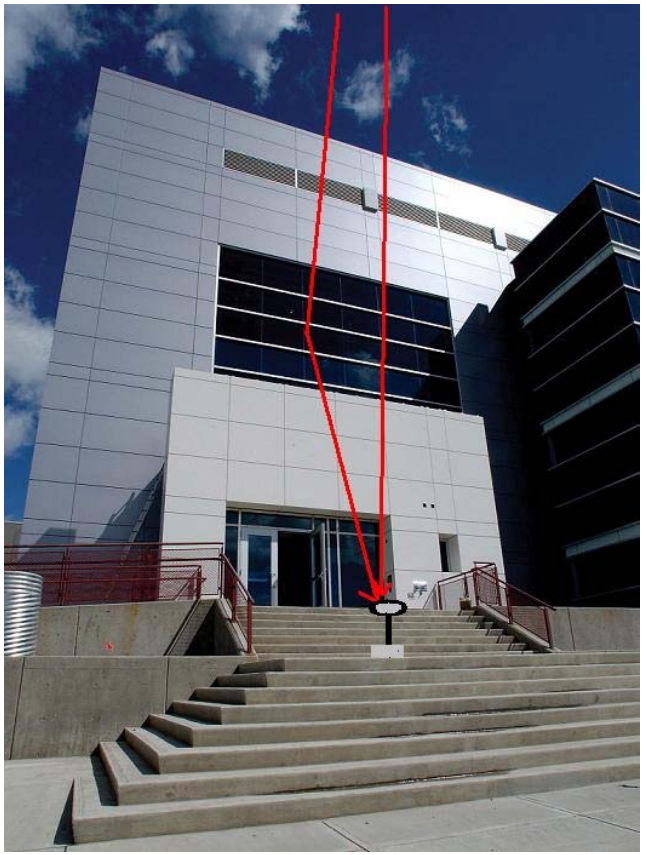


Open Sky with Single Reflector (1/3)

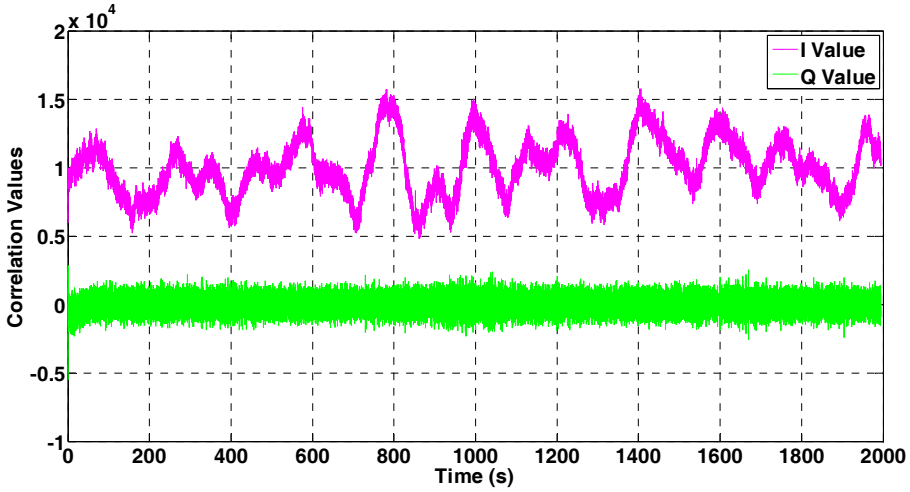
20 Feb 2009, 7:30 pm (1 hour)

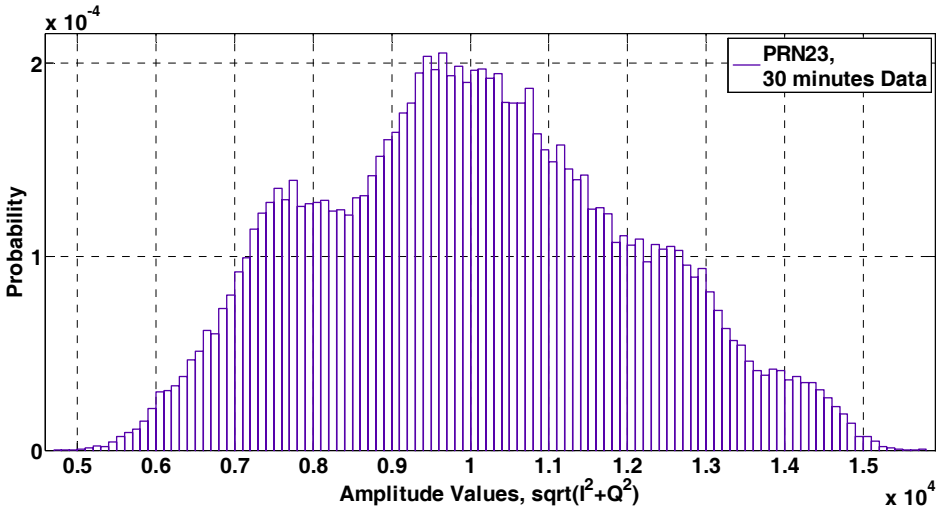
West Gate, CCIT

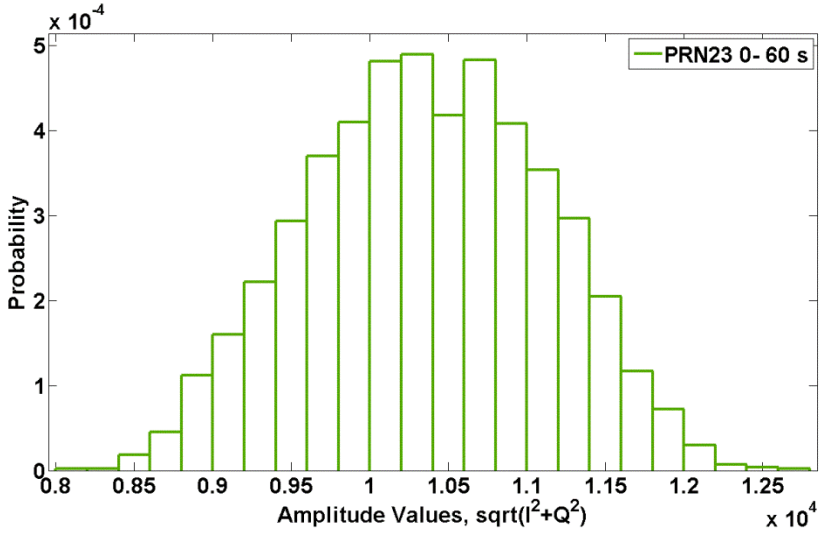


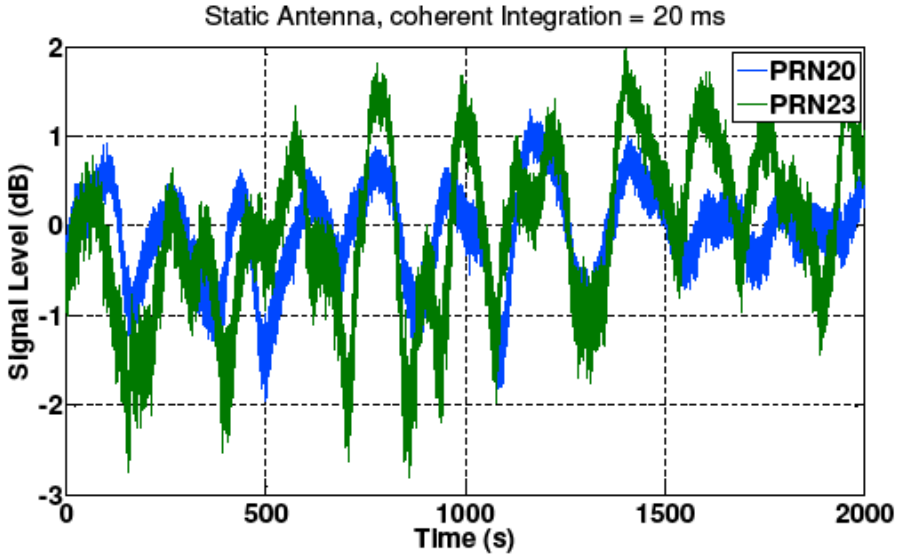


Open Sky with Single Reflector (2/3)

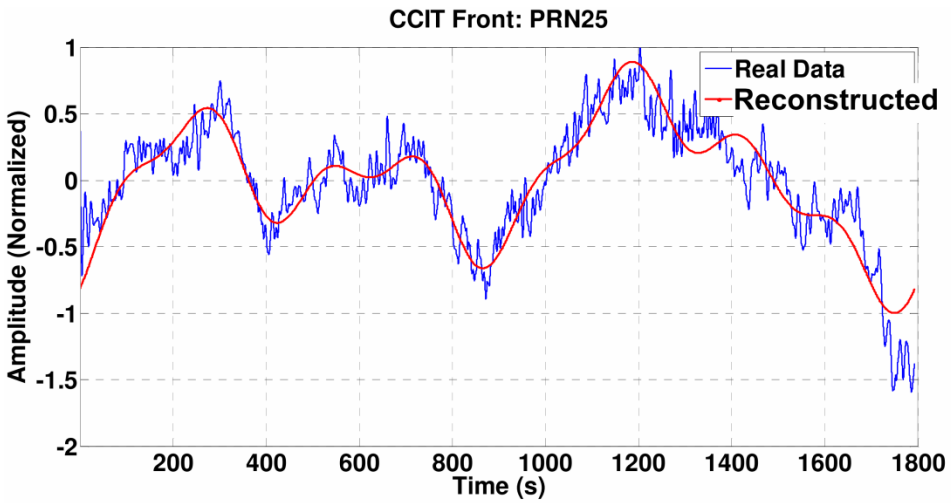


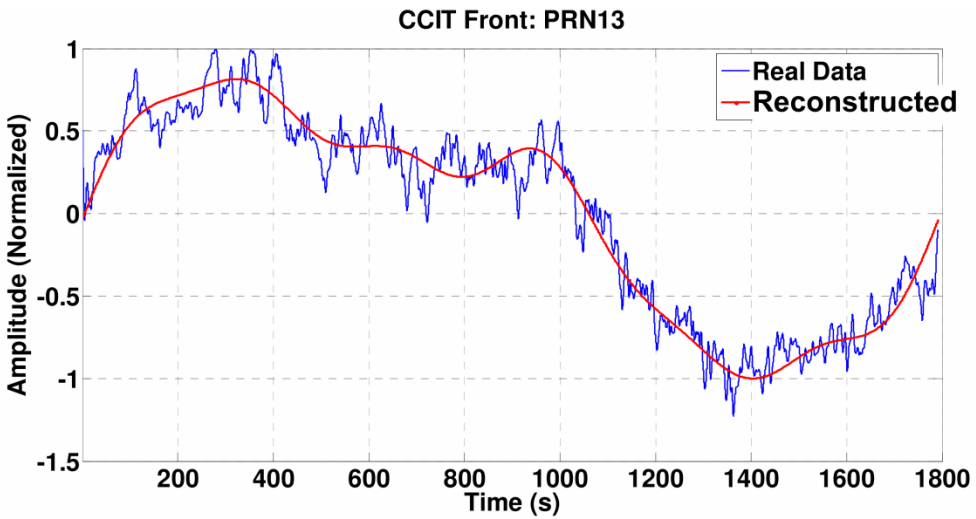


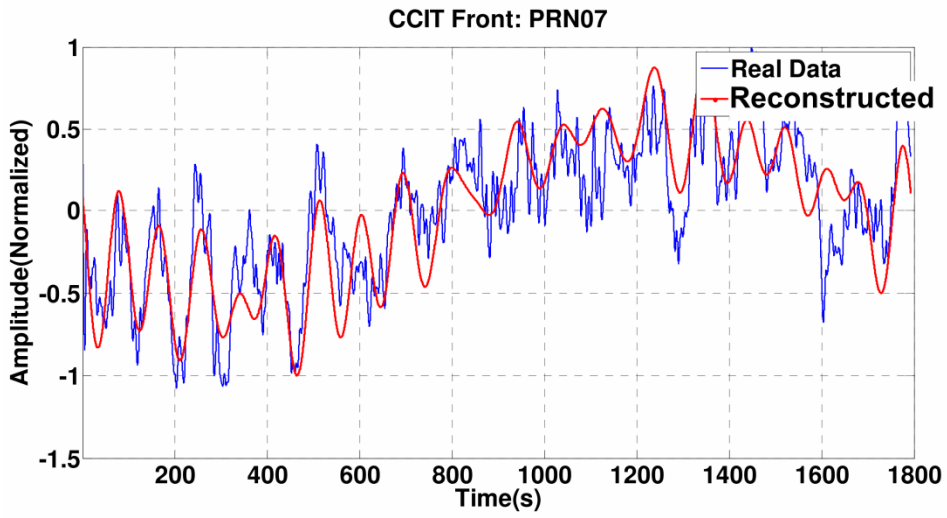


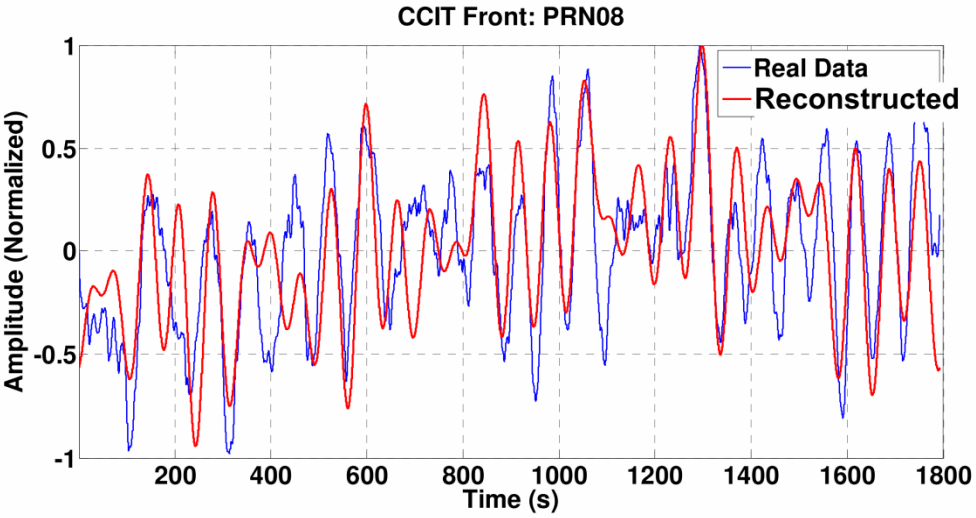


Open Sky with Single Reflector (3/3)

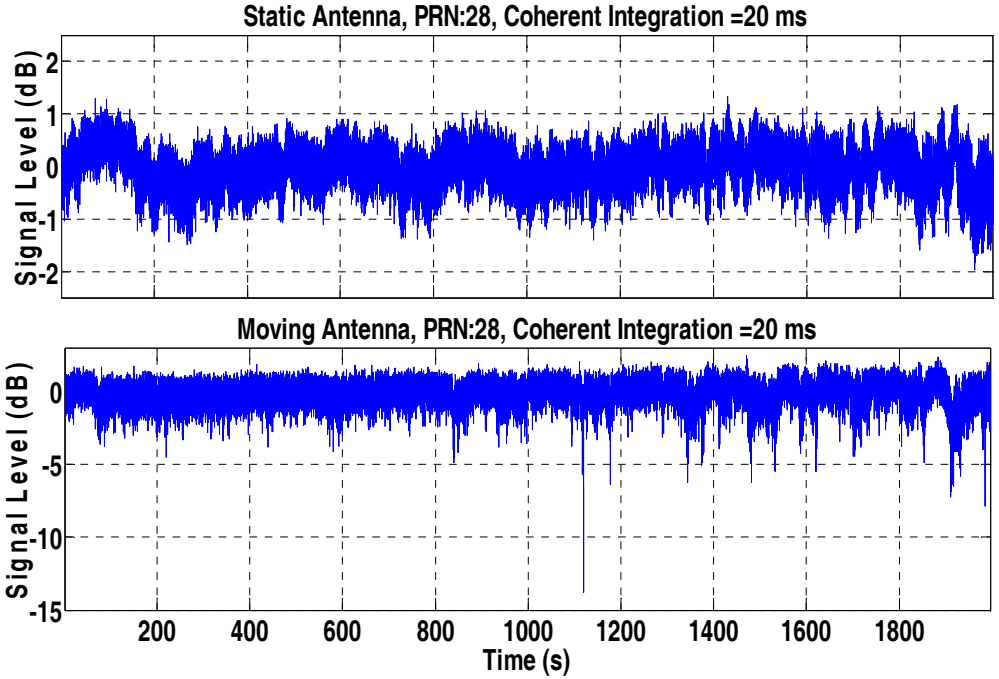


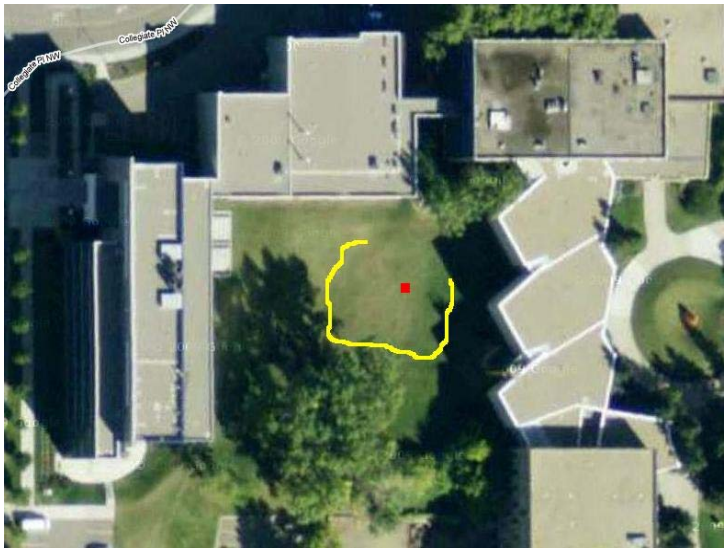


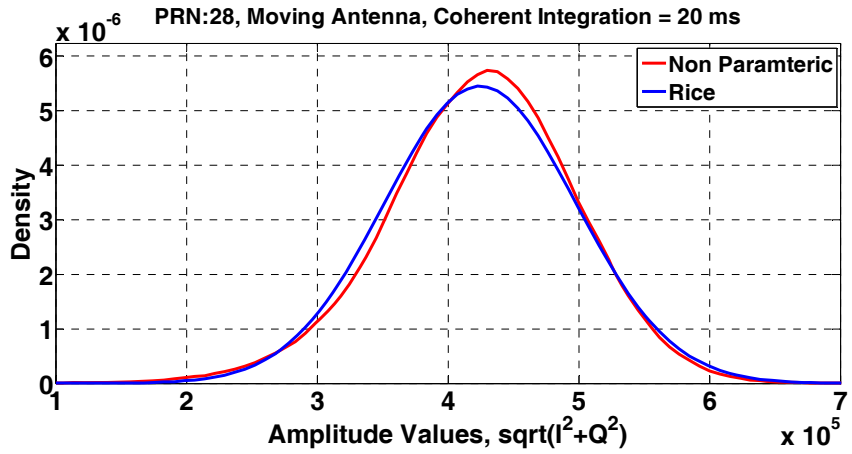


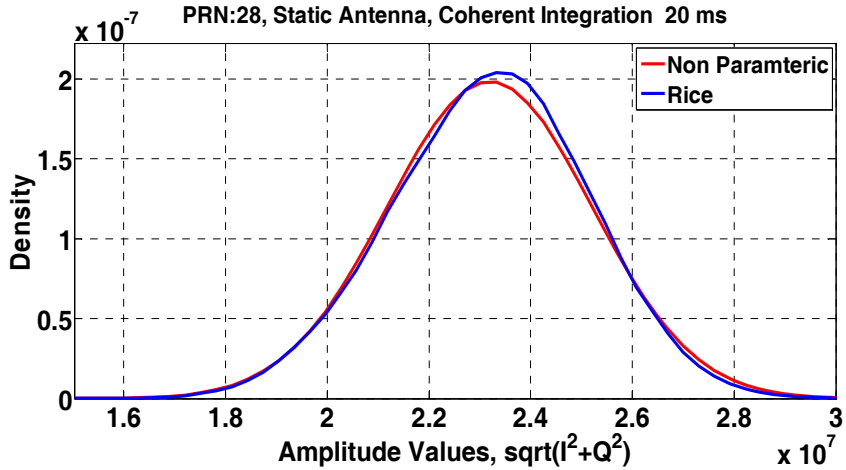


Open Sky with Multiple Reflector (1/2)









Open Sky with Multiple Reflector (2/2)

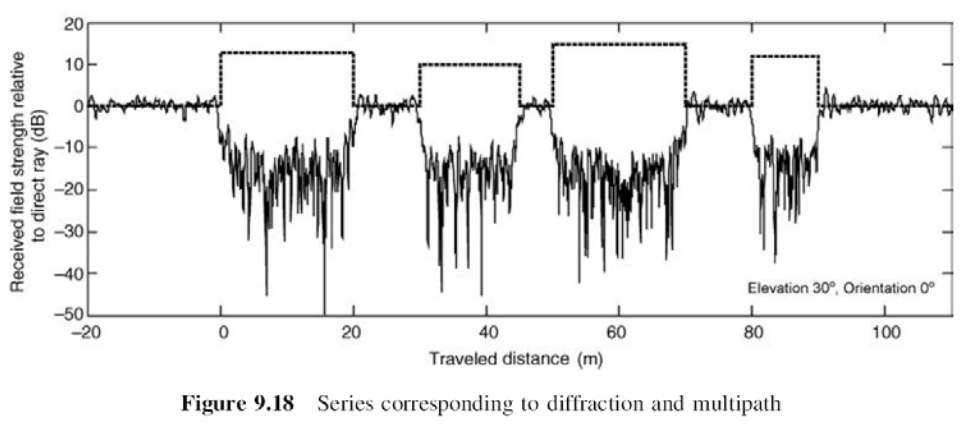
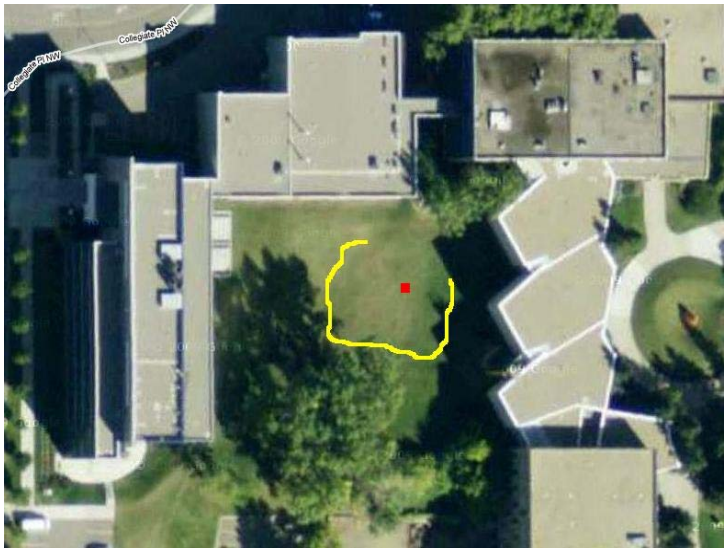
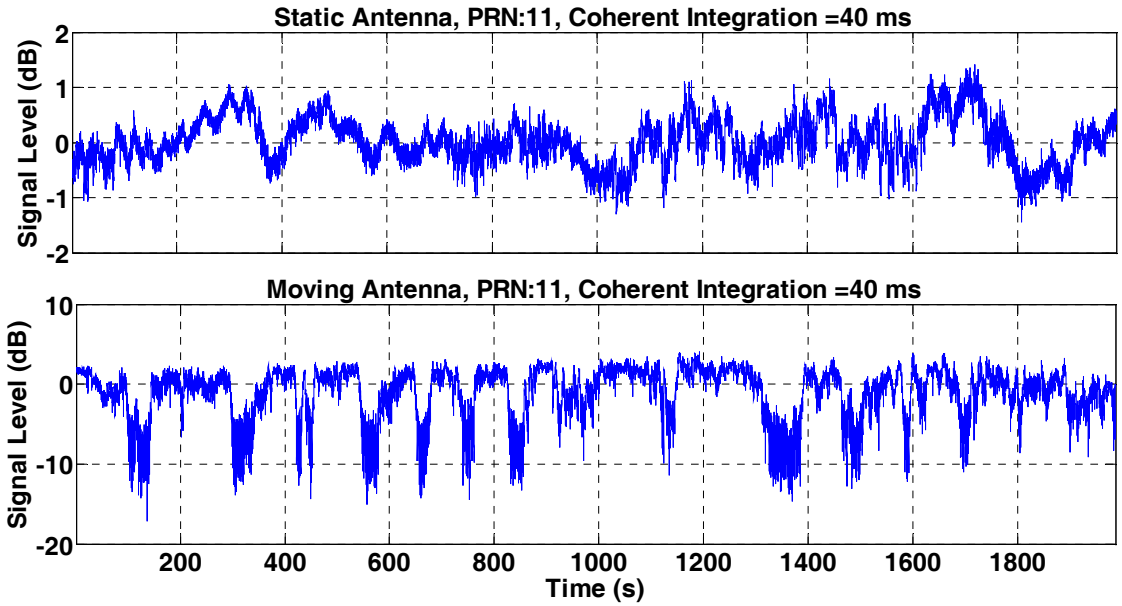
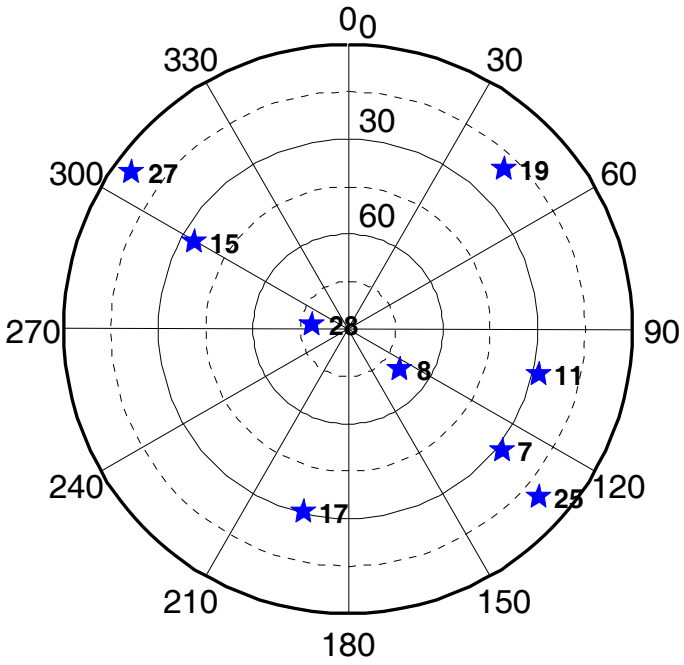


Figure 9.18 Series corresponding to diffraction and multipath

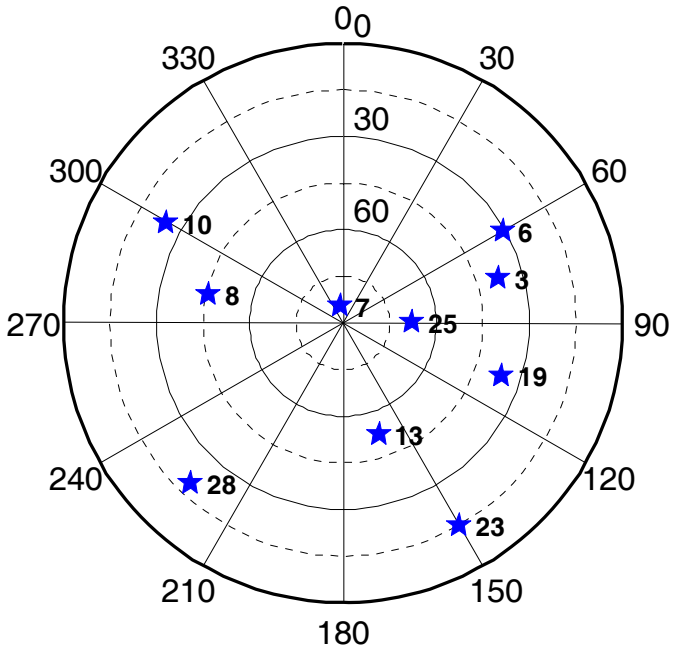
(Fontan, 2008)

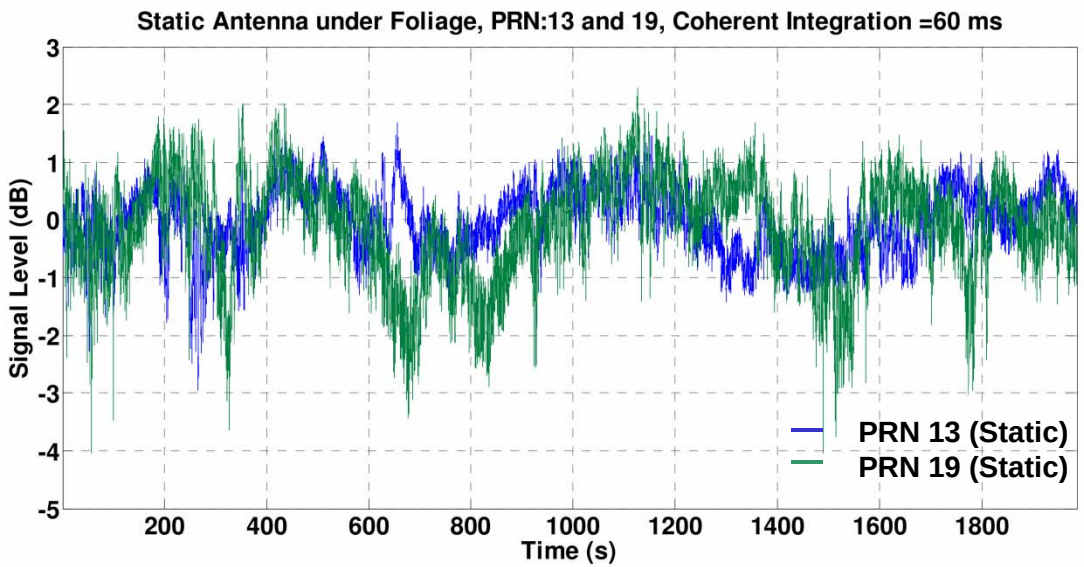


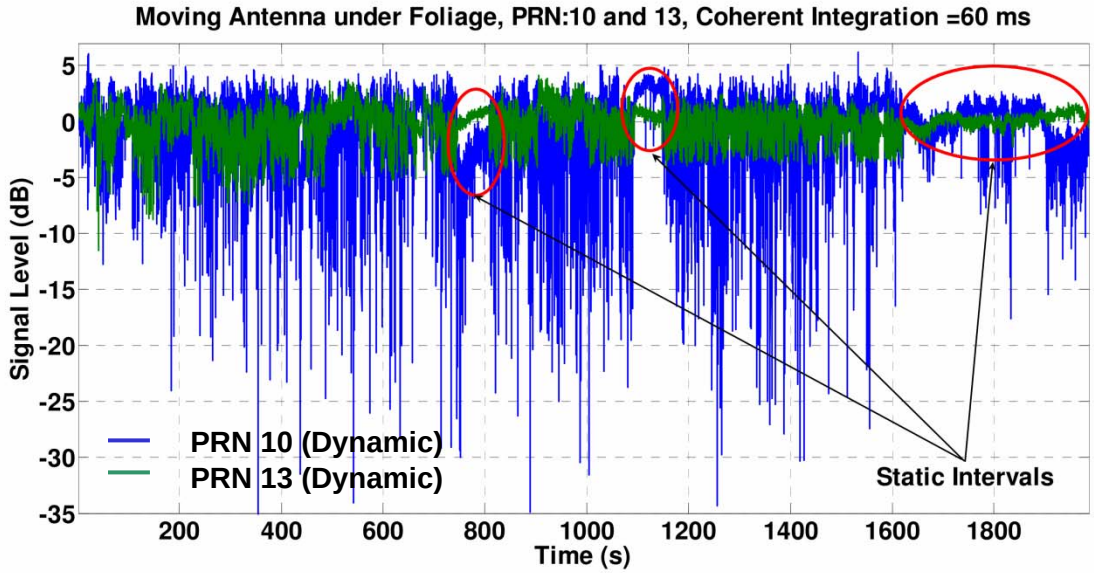




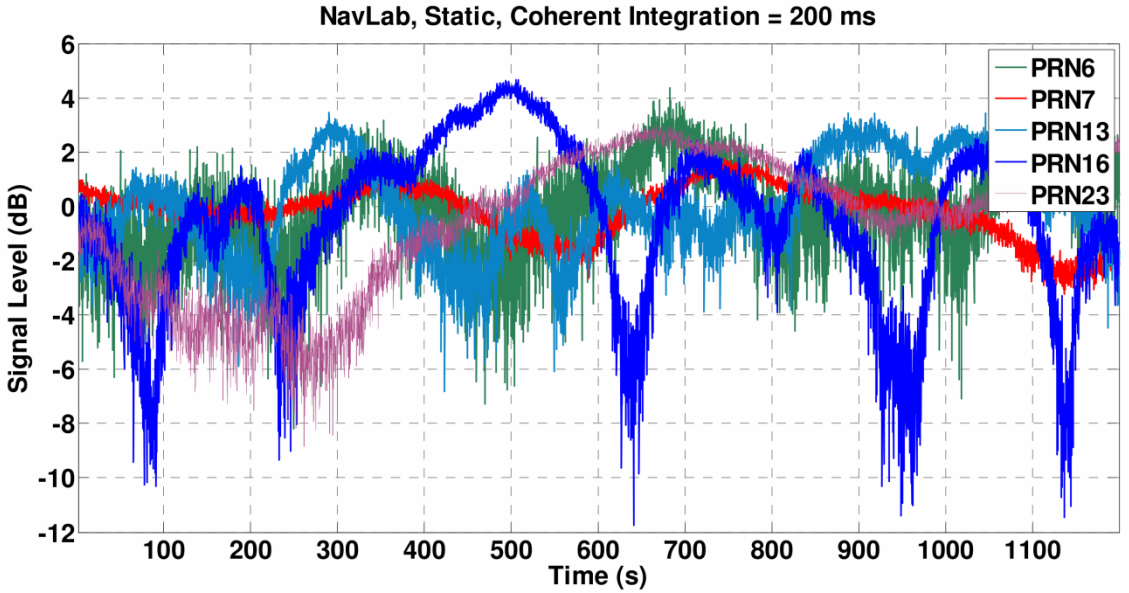
Foliage: Static/Dynamic

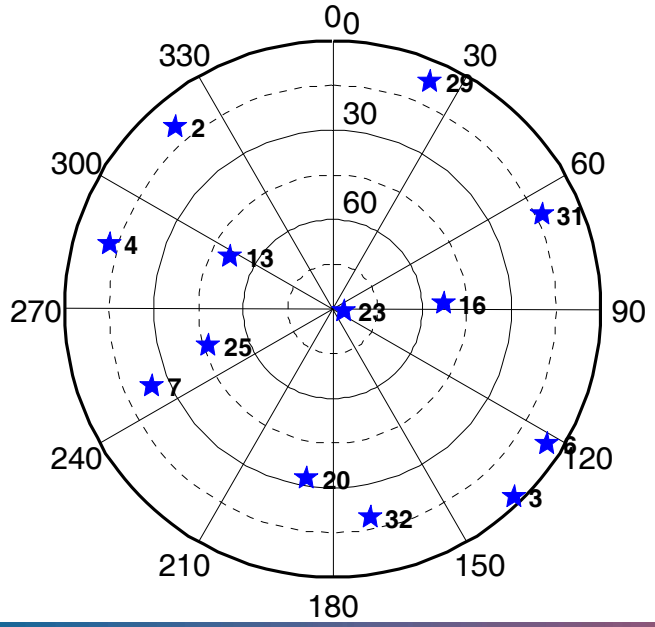


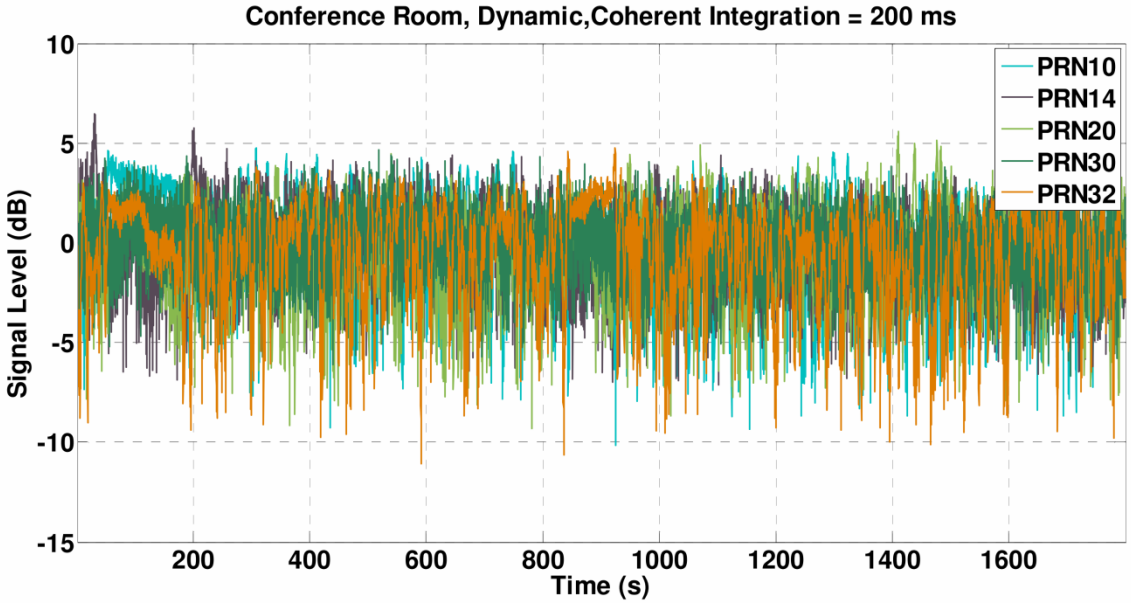




Indoor Data(Lab): Static/Dynamic







Conclusions

- Various single and multistate parametric models for signal amplitude variations were validated
- Possibility of applying cyclostationary and nonstationary analysis for the characterization of GNSS signals harsh scenarios were explored
- Under static scenarios, first order periodicities were observed in the presence of a strong reflector
- Channel coherence time of up to 4-5 minutes were observed in static scenarios.
- Signal variations become more random when the receiver is in dynamic condition and the amplitude can be more easily described using parametric models