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).

- **Stationary**
- **Cyclostationary**
- **Polycyclostationary**
- **Nonstationary**

### 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)

### Stationarity in wide-sense

\[ m_x = m_x(t_1) = m_x(t_2) \]
\[ R_{xx}(\tau) = R_{xx}(t_1, t_2) = R_{xx}(t_2 - t_1) \]

### 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

Impact of correlation on the fading phenomenon

$$A_f = \sqrt{I^2 + Q^2}$$
Stationary, Cyclostationary and Nonstationary Analysis of GNSS Signal Propagation Channel
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)

Stationary, Cyclostationary and Nonstationary Analysis of GNSS Signal Propagation Channel
Open Sky with Single Reflector (3/3)
Open Sky with Multiple Reflector (1/2)

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- **Static Antenna, PRN:28, Coherent Integration =20 ms**
  - Signal Level (dB) graph showing signal level over time (s) for static antenna with coherent integration of 20 ms.

- **Moving Antenna, PRN:28, Coherent Integration =20 ms**
  - Signal Level (dB) graph showing signal level over time (s) for moving antenna with coherent integration of 20 ms.

- **PRN:28, Moving Antenna, Coherent Integration = 20 ms**
  - Density graph with amplitude values on the x-axis and density on the y-axis for moving antenna with coherent integration of 20 ms.

- **PRN:28, Static Antenna, Coherent Integration 20 ms**
  - Density graph with amplitude values on the x-axis and density on the y-axis for static antenna with coherent integration of 20 ms.

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Open Sky with Multiple Reflector (2/2)

Figure 9.18  Series corresponding to diffraction and multipath

(Fontan, 2008)
Foliage: Static/Dynamic

Static Antenna under Foliage, PRN:13 and 19, Coherent Integration = 60 ms

Moving Antenna under Foliage, PRN:10 and 13, Coherent Integration = 60 ms

PRN 10 (Dynamic)
PRN 13 (Dynamic)
Indoor Data(Lab): Static/Dynamic

NavLab, Static, Coherent Integration = 200 ms

Conference Room, Dynamic, Coherent Integration = 200 ms
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.