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Objectives

Mobile-to-Mobile (M2M) communications applications can be seen in mobile ad-hoc networks, wireless sensor networks, and intelligent transport systems, these systems require direct communication between a mobile transmitter and a mobile receiver over a wireless medium. Such Mobile-to-Mobile communication systems differ from the conventional cellular radio systems, where the Base Station is stationary and only the Mobile Station is moving.

The employment of multiple antennas at both the transmitter and receiver, known as Multiple Input Multiple Output (MIMO) technologies, enables to greatly improve the link reliability and increase the overall system capacity. For the design and test of such MIMO Mobile-to-Mobile systems, we need to have a thorough understanding and an accurate modelling of the underlying channels. For this purpose, the Geometrically-Based Stochastic Model (GBSM) has been applied for narrowband MIMO Mobile-to-Mobile channel modelling. The most important GBSMs include the one-ring model, two-ring model and Elliptical-ring model, in which the Elliptical-ring model is predestinated for modelling either narrow and wideband MIMO channels in microcellular and picocellular environments.

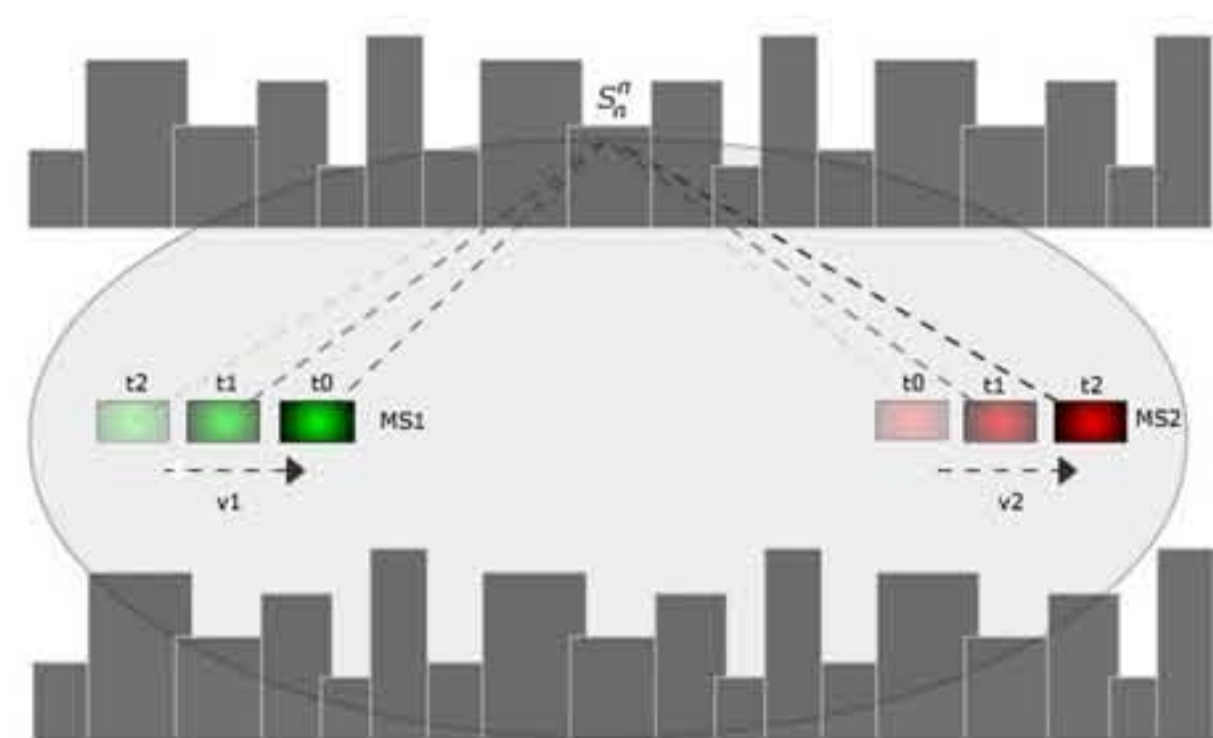
In this project, the statistical properties of narrowband MIMO Mobile-to-Mobile wireless fading channels in non-isotropic scattering environments will be investigated based on the elliptical-ring model. The interested properties include Space-Time (ST) Correlation (CF) properties, Space-Doppler-frequency (SD) Power Spectral Density (PSD), Level Crossing Rate (LCR), and Average Fading Duration (AFD).

Introduction

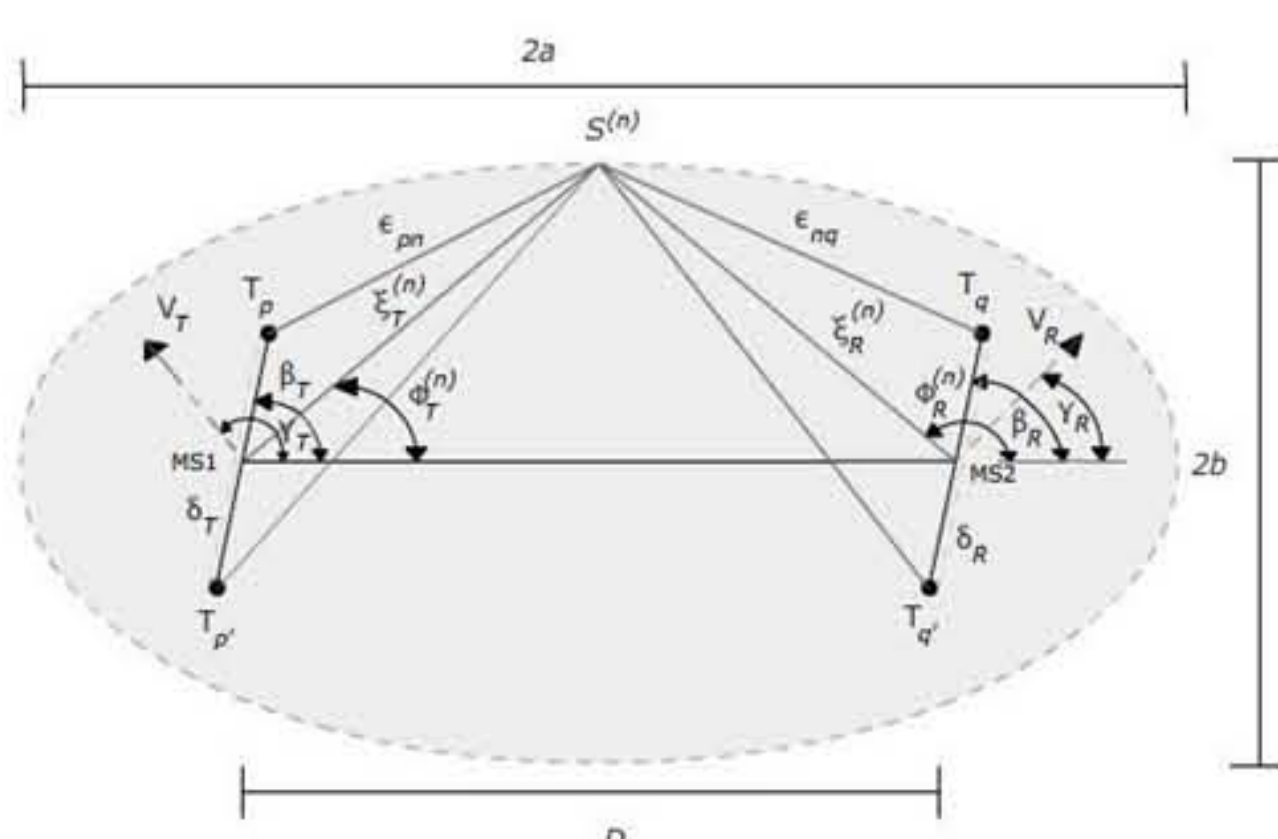
In MIMO M2M channel modelling, it is important take into consideration the several issues that affect propagation within the channel like variation in time, multipath phenomena and Doppler shifts, angle of arrival of the received signals, and also the effects of using multiple carrier frequencies [4].

Elliptical Model

In the Elliptical Model, the Mobile Station 1 (MS1) and MS2 are closer to each other, and are placed at about the same vertical heights, and the scatterers exist on the ellipse surrounding both the MS1 and MS2, each positioned at the focal points of the Ellipse.



In a MIMO M2M wireless system, the transmitted signal in the channel has a complicated interaction with the environment. There are reflections and refractions likely to occur from large objects, diffraction of the electromagnetic waves around objects, and signal scattering. The result of these complicated interactions is the presence of many signal components, differing paths of reception or multipath signals, at the receiver [5], which can be described using their Space, Time and Frequency properties.



Mathematical Representation

The Elliptical Scattering Model describes a system where the two mobile stations MS1 and MS2 are located at the focal points of the ellipse, these mobile stations are described as a vectors, each with magnitude (speed V_T and V_R) and direction (angles of motion γ_T and γ_R) [8].

The circumference of the ellipse describe all the local effective scatterers $S_{TR}^{(n)}$ associated with the Angles of Departure of the waves bounced and designated by $\phi_{TR}^{(n)}$, this waves travel the distance

$$\xi_T^{(n)} + \xi_R^{(n)} = 2a.$$

The major axis is denoted by 'a' and the minor axis of the ellipse is the denoted by 'b'.

The received complex impulse response for T_p-R_q link is a superposition of the Line of sight (LoS) and Single Bounced rays.

$$h_{pq}(t) = h_{pq}^{LoS}(t) + h_{pq}^{SB}(t)$$

$$h_{pq}^{LoS}(t) = \sqrt{\frac{K_{pq} \Omega_{pq}}{K_{pq} + 1}} e^{-j2\pi f_c t} \times e^{j[2\pi f_{max} t \cos(\mu_T - \mu_R + \gamma_T) + 2\pi f_{max} t \cos(\mu_T^{SB} + \gamma_T)]}$$

$$h_{pq}^{SB}(t) = \sqrt{\frac{\Omega_{pq}}{K_{pq} + 1}} \lim_{N \rightarrow \infty} \sum_{n=1}^N \frac{1}{\sqrt{N}} e^{j(\psi_n - 2\pi f_c t_{pq,n})}$$

$$p = 1, 2, \dots, M_T \quad q = 1, 2, \dots, M_R$$

$$\rho_{h_{pq}^{SB}}(\tau) = \frac{n_{SB}}{2\pi I_0(K_R^{SB})} \int_{-\pi}^{\pi} e^{j\tau \cos(\theta - \mu_R^{SB})} d\theta \quad \text{Single Bounced component}$$

$$J = K_R^{SB} \cos(\phi_R^{SB} - \mu_R^{SB}) \quad \text{Non-isotropic}$$

$$T = P \cos(\phi_T^{SB} - \beta_T) + Q \cos(\phi_R^{SB} - \beta_R) \quad \text{Space}$$

$$V = f_{Tmax} \cos(\phi_T^{SB} - \gamma_T) + f_{Rmax} \cos(\phi_R^{SB} - \gamma_R) \quad \text{Time}$$

$$F\{\rho_{h_{pq}^{SB}}(\tau)\} = \int_{-\infty}^{\infty} \rho_{h_{pq}^{SB}}(\tau) e^{-j2\pi f_D \tau} d\tau \quad \text{Doppler frequency}$$

Numerical Results

The spectral shape of the Doppler spread determines the time domain fading waveform and dictates the temporal correlation and fade slope behaviors.

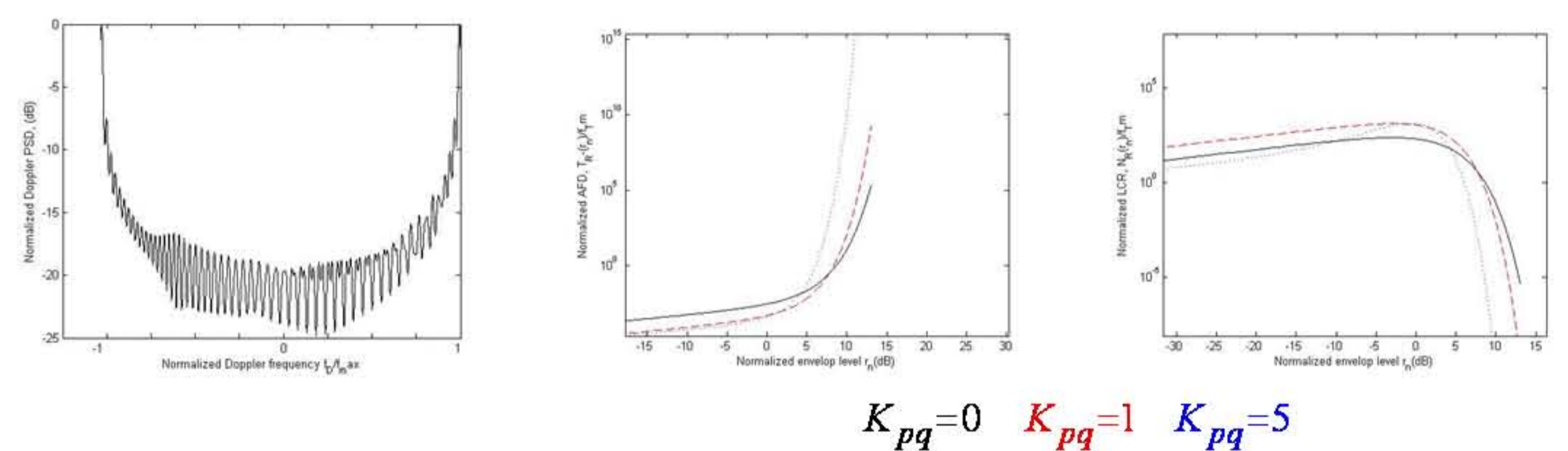
The parameters used for this numerical analysis:

$$f_c = 5.9 \text{GHz}, f_{Tmax} = f_{Rmax} = 570 \text{Hz}, \beta_T = \pi/3, \beta_R = \pi/4, a = 250 \text{m}, D = 350 \text{m}$$

$$\gamma_T = 0, \gamma_R = \pi, K_T = 0, K_R = 0, \mu_T = 0, \mu_R = \pi, K_{pq} = 5$$

The influence of the Ricean factor K_{pq} and ratio factor s (s is the ratio of the maximum Doppler frequency f_{Tmax} and f_{Rmax} , $s = f_{Rmax}/f_{Tmax}$) for a non-isotropic M2M channel on the LCR and AFD. The fades are shallower when K_{pq} is larger or s is smaller. Furthermore, the AFD tends to be larger when K_{pq} is larger or s is smaller.

The parameters used for this numerical analysis: $K_{pq} = 0, K_{pq} = 1, K_{pq} = 5$



Conclusion

In this study, the influence of the different physical parameters that determine a Multiple Input Multiple Output (MIMO) Mobile to Mobile (M2M) Elliptical ring channel were mathematically modeled and analyzed.

In this study, in order to test and analyze the Statistical properties of the mathematical model, a GUI - Simulation Environment was developed for the MIMO M2M Elliptical ring model.

The ST CF and the corresponding SD PSD for 2D non isotropic scattering environments are derived. Based on the obtained Doppler PSD for the elliptical ring model with single bounced rays and observations in [8], can be conclude that no matter what the propagation environment is, for M2M channels in non isotropic scattering environments, the single bounced rays will cause a Doppler PSD similar to the U shape.

The second order statistics of the non-isotropic MIMO M2M Ricean fading channel are considered and the analytical expressions for the LCR and AFD have been derived. Based on the derived LCR and AFD some important parameters were investigated in more detail.

The numerical simulations have revealed that the LCR and AFD are very sensitive to the angle spreads (K_T^{SB}, K_R^{SB}), mean values (μ_T^{SB}, μ_R^{SB}) of the AoA ϕ_R^{SB} and AoD ϕ_T^{SB} , and directions of motion (γ_T and γ_R) in non-isotropic scattering environments.