A Study on MIMO Mobile-To-Mobile Wireless Fading Channel Models

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Presentation

- Objectives
- Introduction
- MIMO M2M Channel Modelling
- Geometric-Based Stochastic Model (GBSM)
- Geometric Elliptical Model and Properties
- Mathematical Representation of the MIMO M2M Elliptical
- Results of the MIMO M2M Channel Modelling Statistical Properties
- Conclusion
- Future work

MIMO M2M Wireless Fading Channel Model

Objectives

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

MIMO M2M Wireless Fading Channel Model

What is MIMO

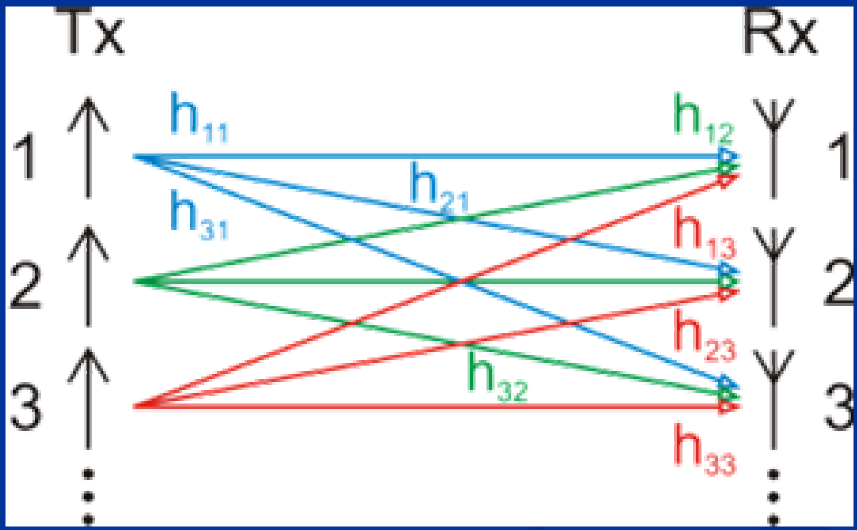
- Multiple Input Multiple Output (MIMO)
  - Contrast to conventional communication systems
  - Multiple antennas

  - Improve communication performance
  - Increases in data throughput
  - Link range without additional bandwidth or transmit power

MIMO M2M Wireless Fading Channel Model

What is MIMO

- Method of transmitting and receiving two or more unique data streams through a single radio channel,
- Increasing the maximum data rate achievable on every single radio channel.



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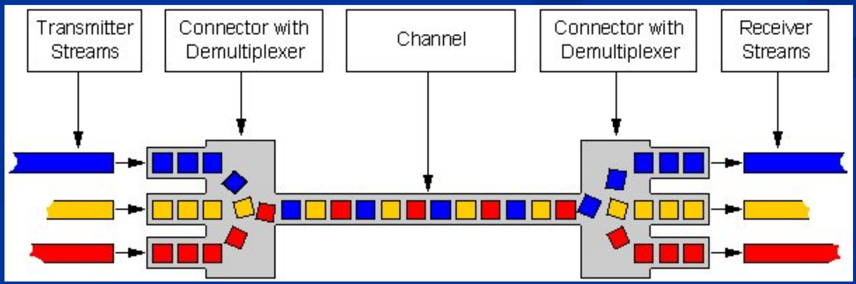
MIMO Properties

- Diversity means that the system provide a receiver with multiple replicas (copies) of the same information bearing signal, the duplicated signals are slightly changed by fading.
  - Space Diversity

    Antenna elements are sufficiently spaced apart to achieve independence between the transmitted and received signals. The spatial separation needs to be at least half the wavelength to obtain desired results of independence
  - Time Diversity – without wasting bandwidth

    Same information is transmitted in different Time slots
  - Frequency Diversity

    Same information is transmitted on different carrier frequencies
- Multiplexing
  - Rate of transmission



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What is M2M

- Mobile-to-Mobile
  - Difference between Mobile-to-Mobile and the Mobile-to-Base
  - Communication between a mobile transmitter and a mobile receiver over a wireless medium
- Example
  - One vehicle in a given location of a city tries to communicate to other moving vehicle in other location
  - Police car or emergency vehicle

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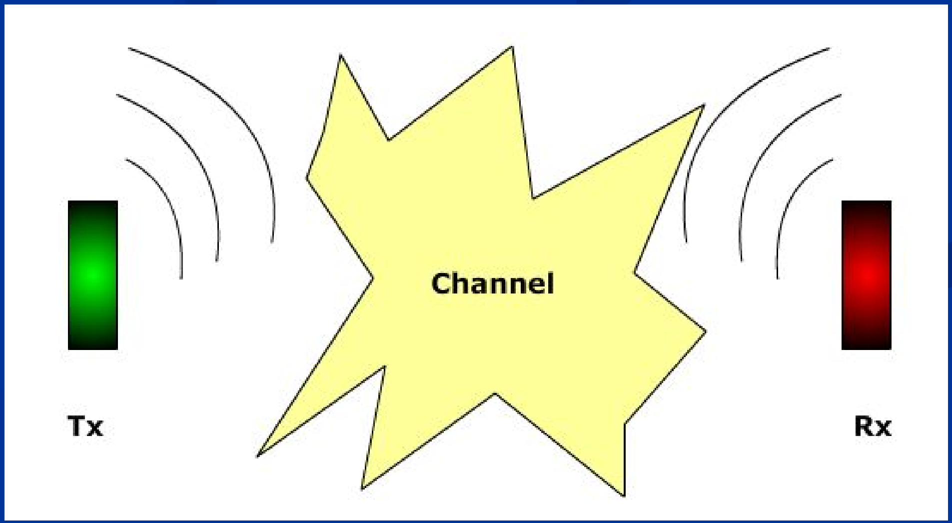
Why study the Channel in MIMO M2M

- Channel
  - In radio signals channel is the transmission medium.
  - Sometimes the signal is incorrect
  - Predict the signal
  - Design better Tx and Rx
  - So the data is transmitted and received Faster and Accurate



MIMO M2M Wireless Fading Channel Model

Channel modelling

- Mathematical model that describes a Channel
- Response, behaviors to different input conditions

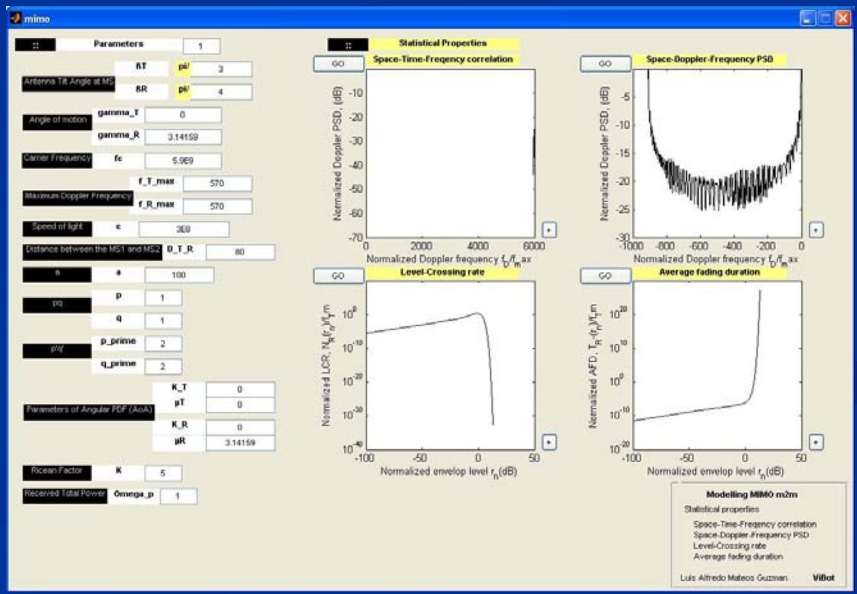
- Accuracy
  - Quality of the model
- Efficiency
  - Complexity of the model

- To balance Accuracy and Efficiency there must be a trade-off between both

MIMO M2M Wireless Fading Channel Model

Accurate Channel modelling

- Modelling needs to be Accurate and Practical
- Different conditions
- So we can predict
- Simulate
- Design high-performance communication systems



MIMO M2M Wireless Fading Channel Model

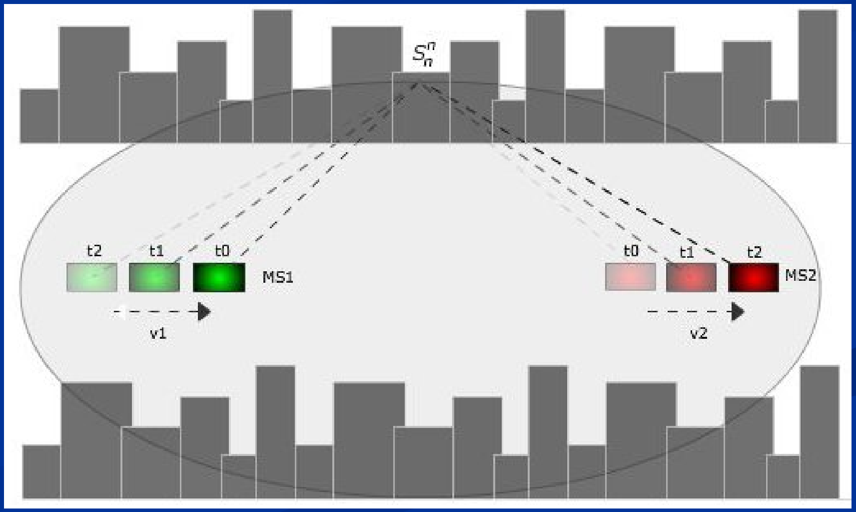
MIMO M2M Geometric-Based Stochastics Model (GBSM)

- GBSM
  - The impulse response is characterized by the laws of wave propagation
  - Describe the double-directional multi-path propagation
  - Multi-paths due to various phenomena such as reflection and refraction
  - Scatterer geometries
  - Stochastic (random)
  - Describe the characteristics of the radio channel by means of the joint Probability Density Function (PDF)
  - One-ring, Two-ring and the Elliptical model

MIMO M2M Wireless Fading Channel Model

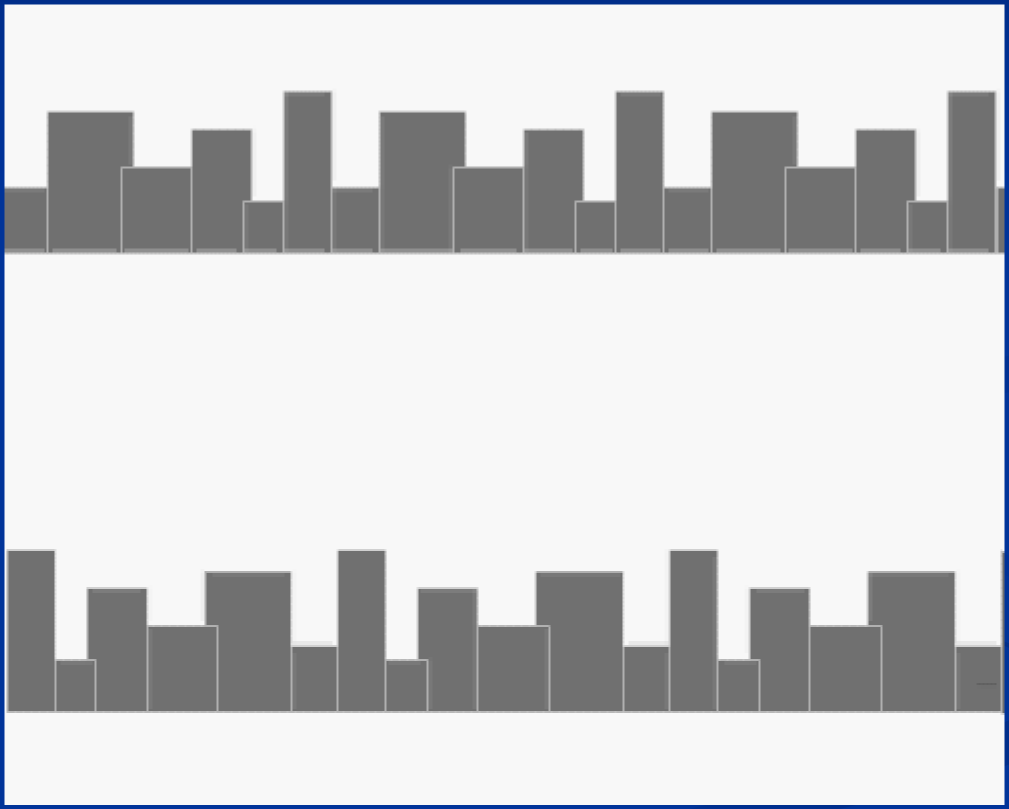
MIMO M2M Geometric Elliptical Model

- The signal statistics depends on
- Position of the Mobile Stations (MS1, MS2)
- Geometrical distribution of the scatterers around the two Mobile Stations
- The MS1 and MS2 are closer to each other (pico-cell 400m)
- Same vertical heights
- Scatterers exist on the ellipse surrounding both the MS1 and MS2, each positioned at the focal points of the Ellipse



MIMO M2M Wireless Fading Channel Model

Reference model of the MIMO M2M Elliptical



MIMO M2M Wireless Fading Channel Model

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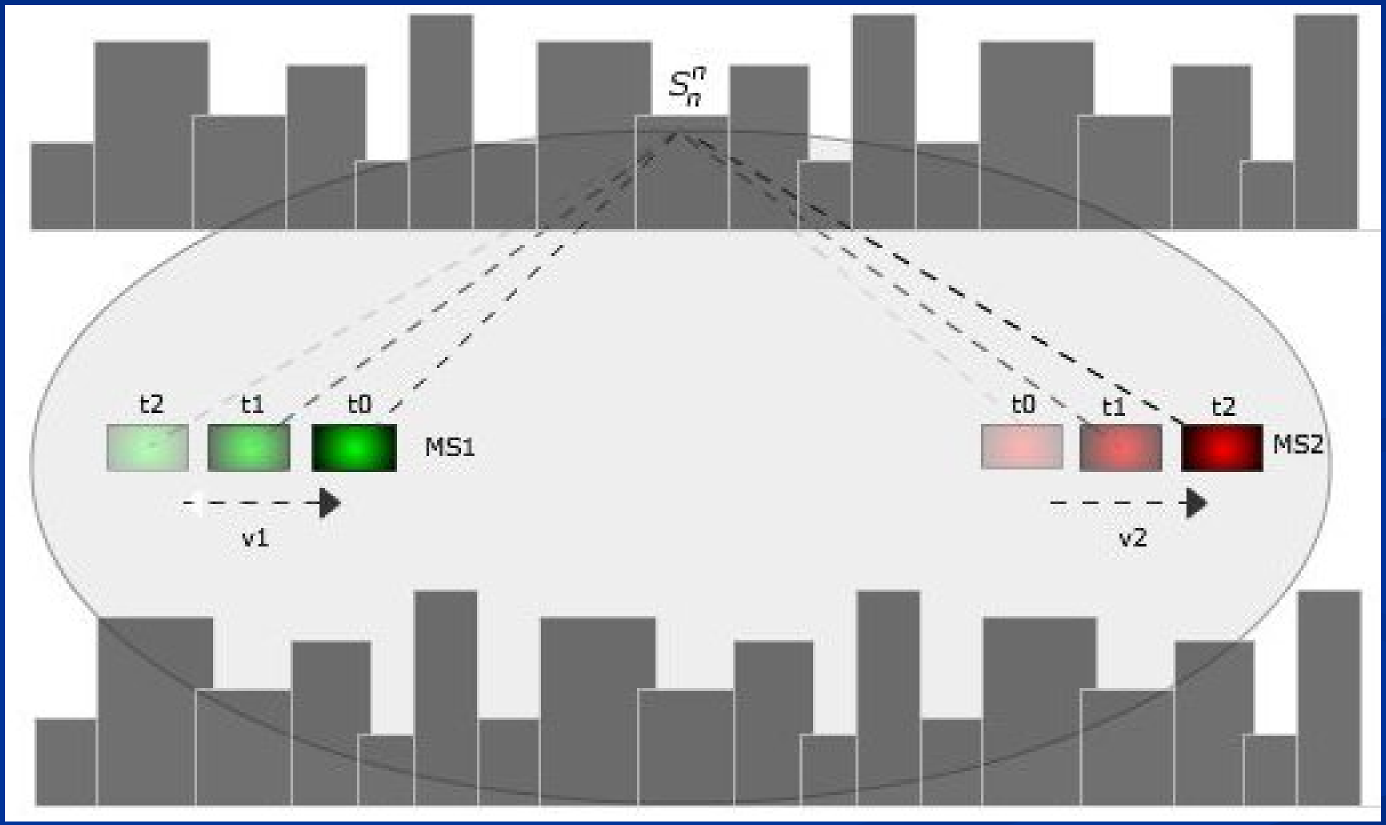

MIMO M2M Wireless Fading Channel Model

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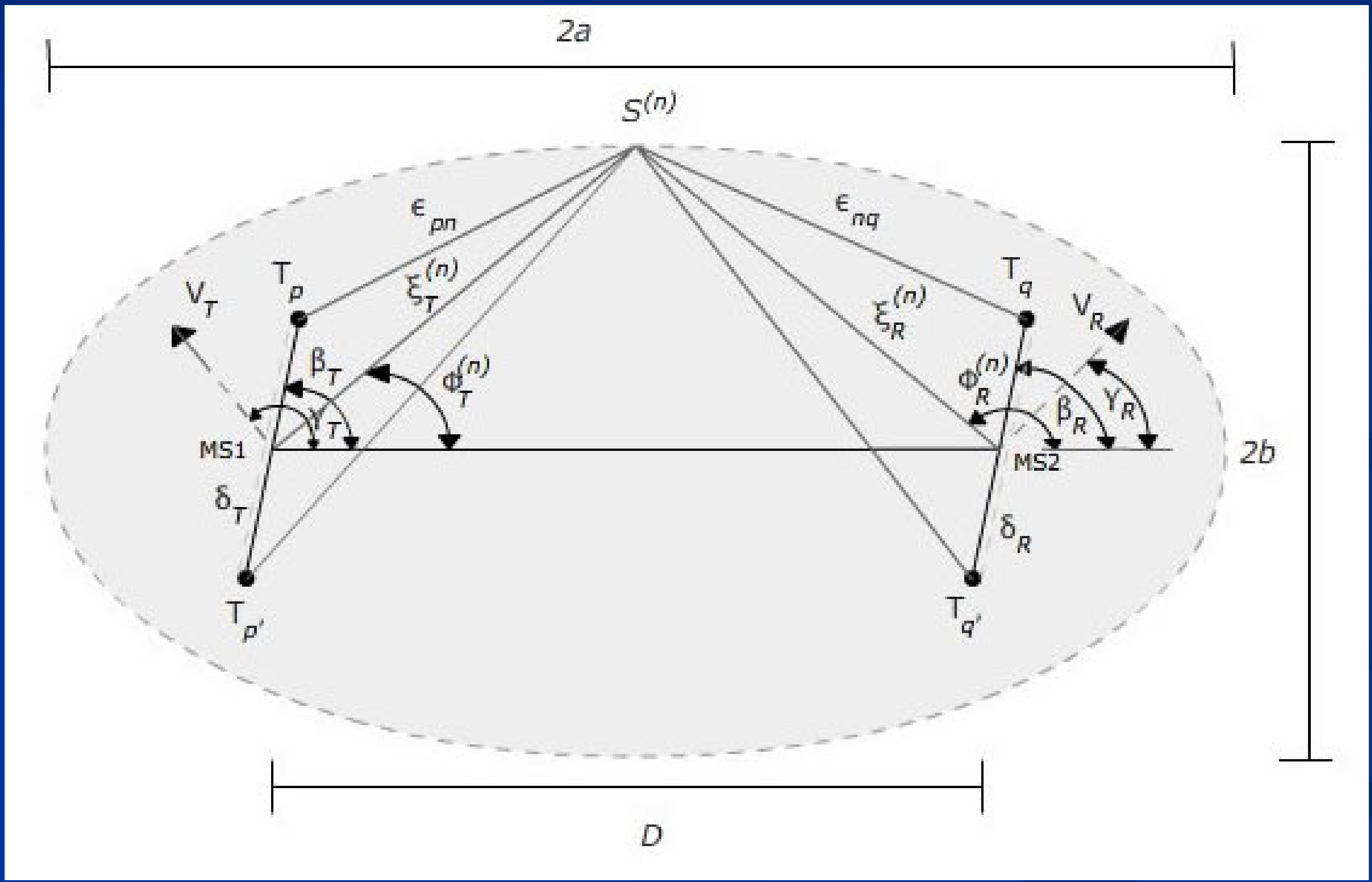


MIMO M2M Wireless Fading Channel Model

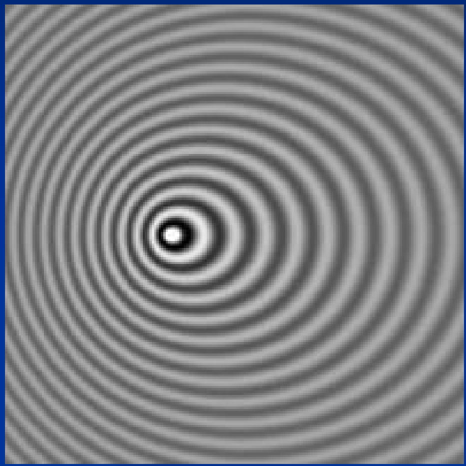
Space Time (ST) Correlation Function (CF)

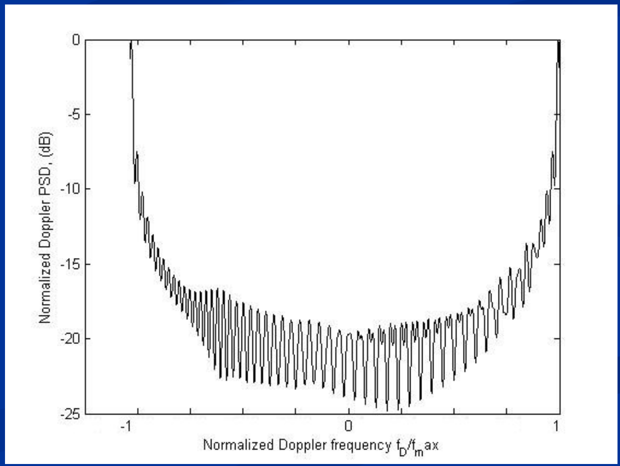
- The correlation between the frequency properties decreases when the frequencies or their differences increase
- Take into consideration the several issues that affect propagation within the channel like
  - variation in time
  - multipath phenomena
  - angle of arrival of the received signals

MIMO M2M Wireless Fading Channel Model

Space Doppler (SD) Power Spectral Density (PSD)

- If a transmitter is moving away from a receiver, the frequency of the received signal is lower than the one sent out from the transmitter; otherwise, the frequency is increased.
- Movement of a mobile
- Movement of objects in the background



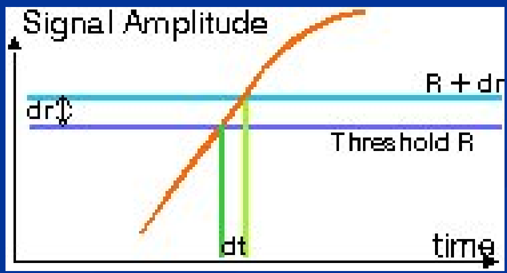


- The energy spectral density describes how the energy (or variance) of a signal is distributed with frequency.

MIMO M2M Wireless Fading Channel Model

Level Crossing Rate (LCR)

- Important second order statistics that make the Mobile-to-Mobile (M2M) channels significantly different from Fixed-to-Mobile (F2M) channels
- The Level Crossing Rate is a measure of the rapidity of the fading.
- It quantifies how often the fading crosses some threshold, usually in the positive-going direction



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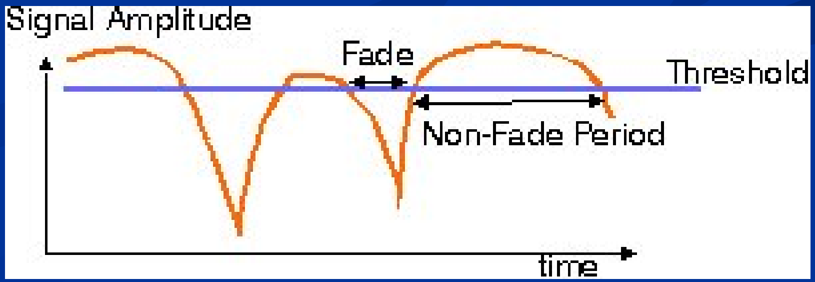
Average Fade Duration (AFD)

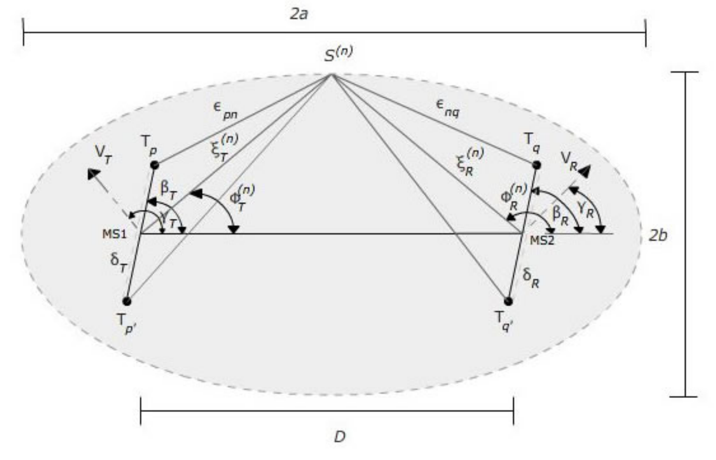
- Quantifies how long the signal spends below the threshold.
- The received signal will experience periods of:
  - Sufficient signal strength or "non-fade intervals", during which the receiver can work reliably and at low bit error rate.
  - Insufficient signal strength or "fades", during which the bit error rate inevitably is close toone half (randomly guessing ones and zeros) and the receiver may even fall out of lock.
- Channel fading occurs mainly because the user moves.
- If the user is stationary almost no time variations of the channel occur (except if reflecting elements in the environment move).
- The AFD is inversely proportional to the speed of the mobile user.



MIMO M2M Wireless Fading Channel Model

Mathematical Representation of the MIMO M2M Elliptical

- The received complex impulse response for (Tp-Rq) link is a superposition of the LoS and Single Bounced rays



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

$$h_{pq}^{LoS}(t) = \sqrt{\frac{K_{pq}\Omega_{pq}}{K_{pq}+1}} e^{-j2\pi f_c \tau_{pq}} \times e^{j\left[2\pi f_{T\max} t \cos\left(\pi - \phi_{Rq}^{LoS} + \gamma_T\right) + 2\pi f_{R\max} t \cos\left(\phi_{Rq}^{LoS} + \gamma_R\right)\right]}$$

$$h_{pq}^{EI}(t) = \sqrt{\frac{\Omega_{pq}}{K_{pq}+1}} \lim_{N \to 0} \sum_{n=1}^{N} \frac{1}{\sqrt{N}} e^{j(\psi_n - 2\pi f_c \tau_{pq,n})}$$

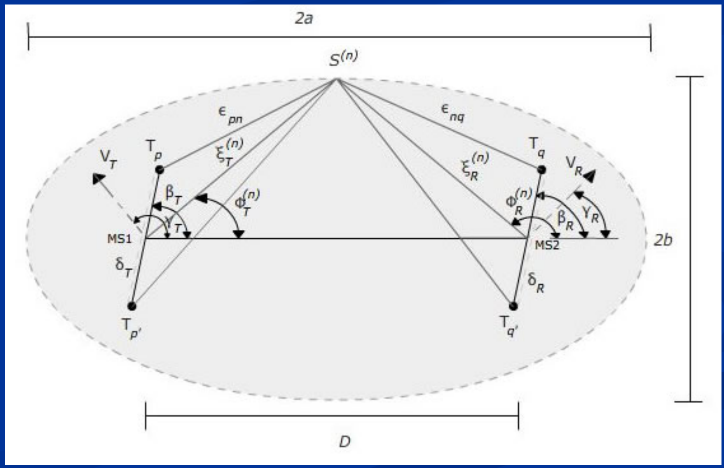
where $p = 1, 2, \ldots, M_T$ and $q = 1, 2, \ldots, M_R$

MIMO M2M Wireless Fading Channel Model

Mathematical Representation of the MIMO M2M Elliptical

- The Time delay between the MS1 and MS2 antenna elements can be deduced by dividing the distances by the speed of light

$$\tau_{pq,n} = \frac{\left(\varepsilon_{pn} + \varepsilon_{nq}\right)}{c}$$



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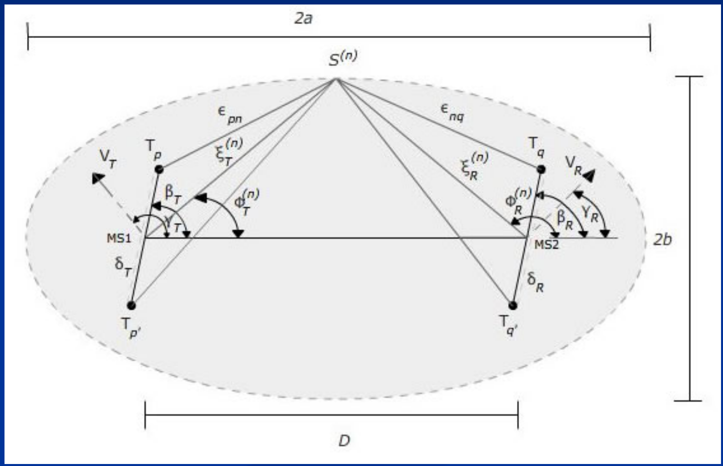
Mathematical Representation of the MIMO M2M Elliptical

- The distances between the Transmitter and the Receiver antennas to the scatterers along the ellipse, can be expressed in terms of the antenna element spacing, the Angle of Arrival and the Angle of Departure



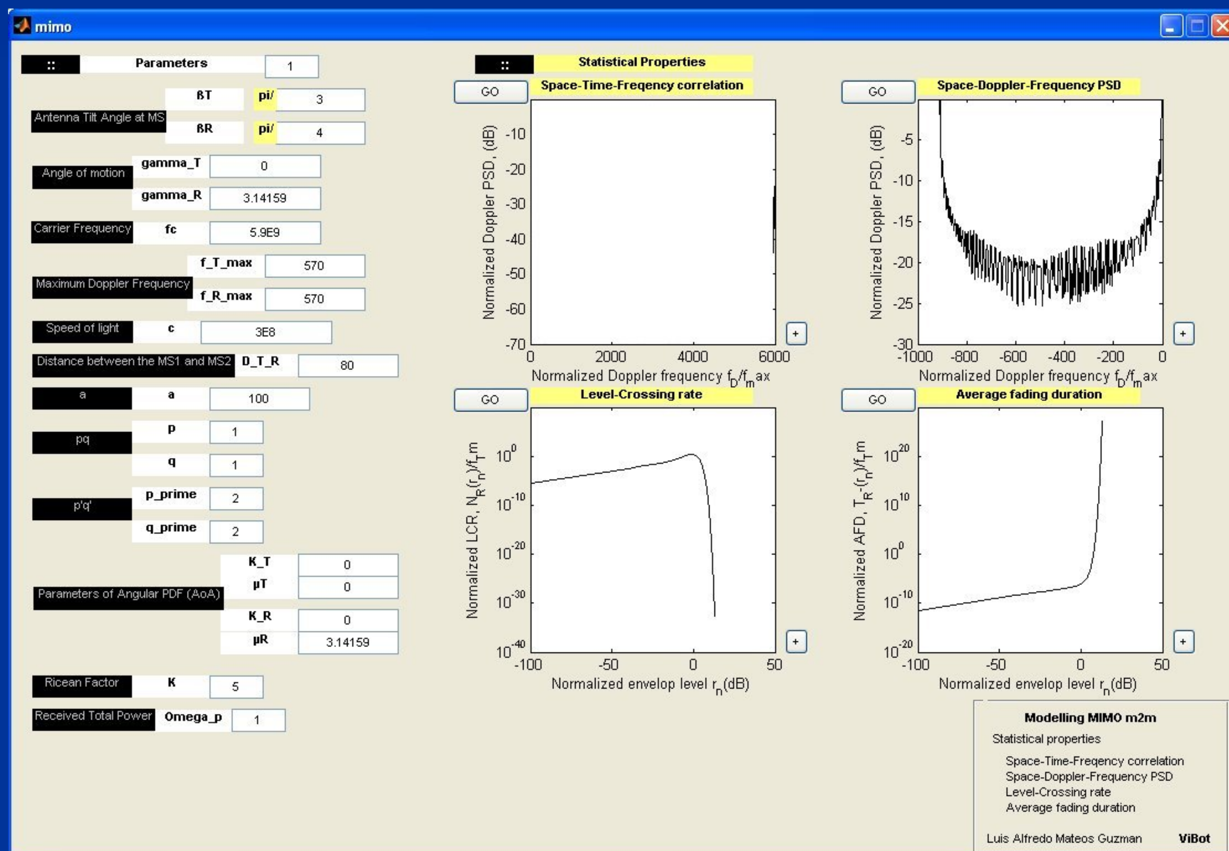
$$\sin \phi_T^{(n)} = \frac{b^2 \sin \phi_R^{(n)}}{a^2 + f^2 + 2af \cos \phi_R^{(n)}}$$

$$\cos \phi_T^{(n)} = \frac{2af + \left(a^2 + f^2\right) \cos \phi_R^{(n)}}{a^2 + f^2 + 2af \cos \phi_R^{(n)}}$$

MIMO M2M Wireless Fading Channel Model

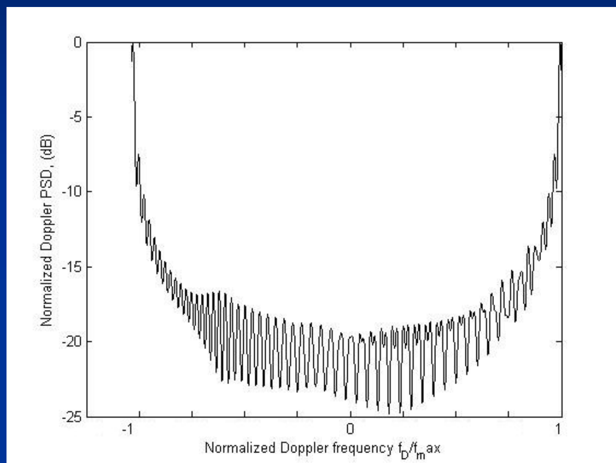
Results of the MIMO M2M Statistical Properties

- In order to test the mathematical model A Matlab Simulator Environment GUI – was developed

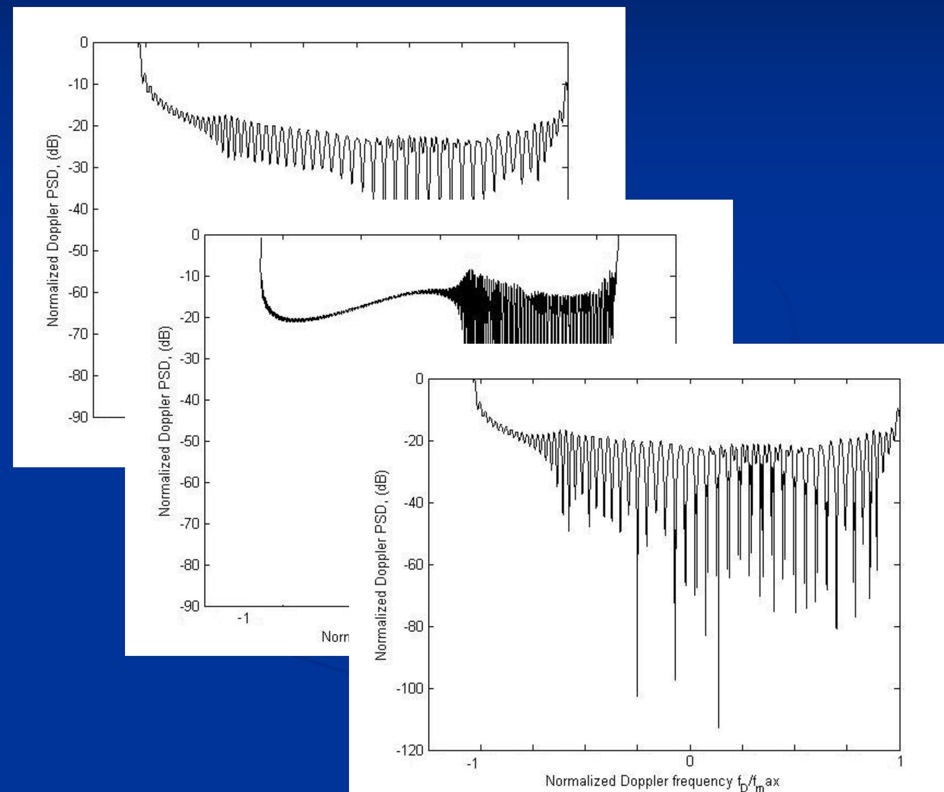


MIMO M2M Wireless Fading Channel Model

Results of the MIMO M2M Statistical Properties



- Isotropic scattering environment, opposite direction



- Non-Isotropic scattering environment, opposite and same direction

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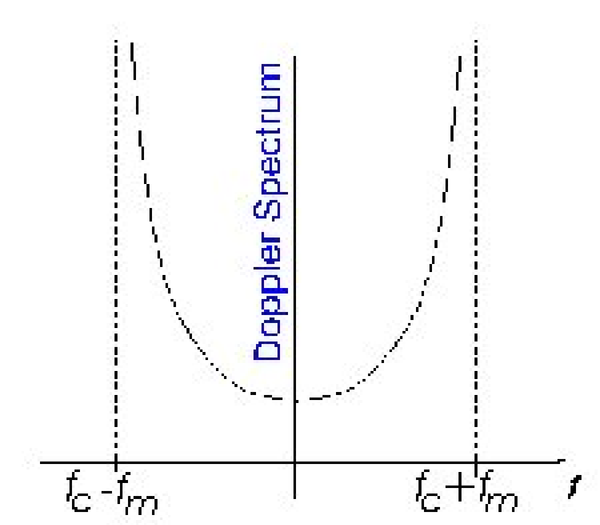
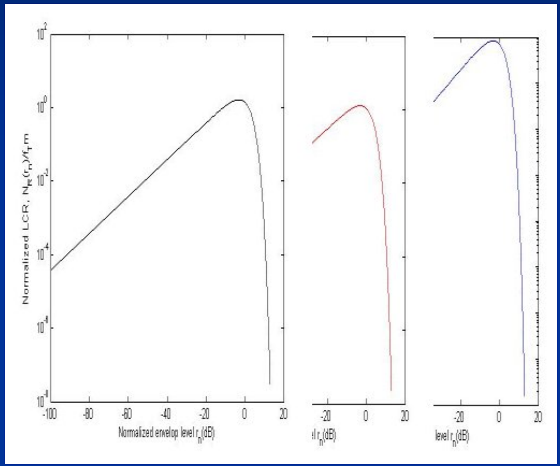
Results of the MIMO M2M Statistical Properties

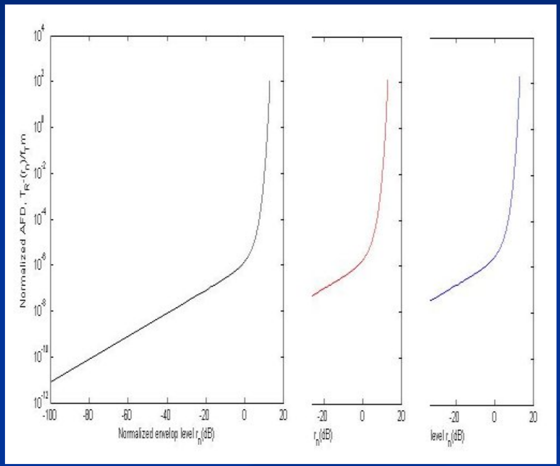
- The single bounced rays will cause a Doppler PSD similar to the U shape
- The maximum Doppler shift occurs for a wave coming from the opposite direction as the direction the antenna is moving to



MIMO M2M Wireless Fading Channel Model

Results of the MIMO M2M Statistical Properties





- LCR and AFD in Isotropic and Non-Isotropic scattering environment, opposite direction

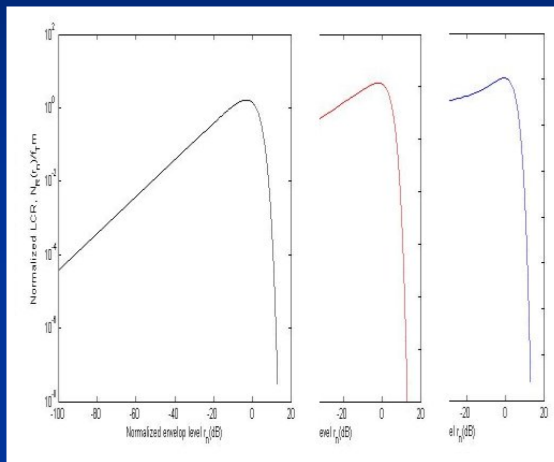
MIMO M2M Wireless Fading Channel Model

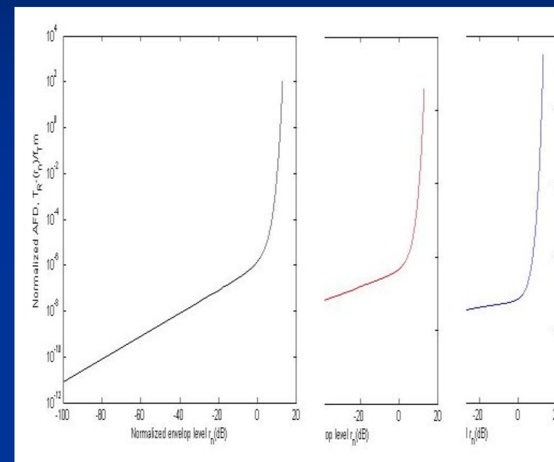
Results of the MIMO M2M Statistical Properties

- The influence of the Ricean factor (Kpq) for a non-isotropic M2M channel on the LCR and AFD
- The fades are shallower when Kpq is larger
- The AFD tends to be larger when Kpq is larger

MIMO M2M Wireless Fading Channel Model

Results of the MIMO M2M Statistical Properties





- LCR and AFD in Non-Isotropic scattering environment, opposite direction, Kpq = 0,1,5

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Conclusion

- The spectral shape of the Doppler spread determines the time domain fading waveform and dictates the temporal correlation and fade slope behaviors
- The numerical simulations have revealed that the LCR and AFD are very sensitive to the angle spreads (Kt,Kr), mean values (mt,mr) of the AoA (Ar) and AoD (Ad), and directions of motion (Vt and Tr) in non-isotropic scattering environments

MIMO M2M Wireless Fading Channel Model

Future work

- The extension of the study for the MIMO M2M into wideband channel modelling.
- These obtained interesting observations and analysis can be considered as useful guidance for further proposing more realistic MIMO M2M channel models