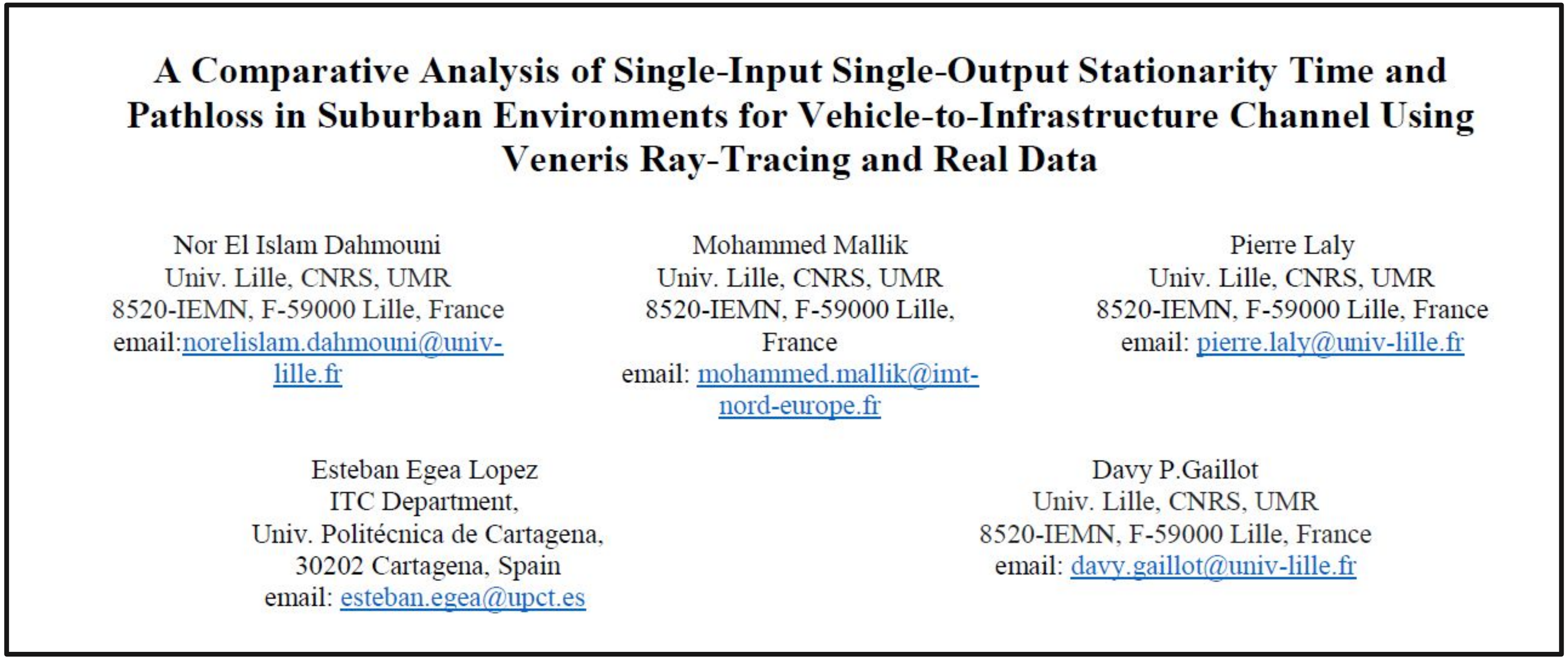

# A Comparative Analysis of Single-Input Single-Output Stationarity Time and Pathloss in Suburban Environments for Vehicle-to-Infrastructure Channel Using Veneris Ray-Tracing and Real Data

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## Presented by Nor El Islam Dahmouni

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# Presenter resume

SCAN ME

Dahmouni Nor El Islam holds **2 Master's degrees in Telecommunications**, having completed the first Master's degree in **Telecommunications Systems** at the University of Bordj Bou Arreridj, Algeria in 2019. In addition, I obtained a professional and research Master's degree in **Networks and Telecommunications** at the University of Lille in 2020.

Currently, I'm a fourth-year Ph.D. student at **the University of Lille** and **the IEMN** (The Institute of Electronics, Microelectronics, and Nanotechnology) laboratory, on the topic "***Multidimensional characterization of a propagation channel for vehicular communication and the contribution of AI for estimating channel characteristics.***" At the same time, I am a teacher-researcher at the University of Nantes and the IUT (University Institute of Technology) of La Roche-sur-Yon.

# Presentation Plan

- Introduction
- Motivation
- Objectives
- MaMIMOSA sounder and its configuration
- Ray-tracing with Veneris
- Measurement Campagne (Video demonstration)
- Methodology
- Results and Discussion
- Conclusion and Future Work

# Introduction

**5G Transformation**

Massive MIMO, mmWave, and Beamforming have sparked significant transformation across various domains.

**Vehicular Communication**

intelligent transportation systems (ITS), which impose strict requirements on vehicular communications, providing superior security and quality of service (QoS). C-V2X and ITS-G5 were developed to meet the needs of ITS systems.

**Standardization and Innovation**

Release 16 by 3GPP introduces NR C-V2X or NR-V2X, enhancing reliability, reducing latency, and ensuring compatibility through advanced features like V2I, V2V, and V2P.

**Channel Characterization**

Thorough characterization of propagation channels is vital for designing communication systems, enabling precise modeling and fostering the development of reliable and interoperable networks.

# Introduction

**Ray tracing**, a deterministic modeling technique, is widely utilized for characterizing 5G radio channels.

**WSSUS assumption**: Is a key feature in wireless channel modeling. This assumption implies that channel statistics remain constant over time and frequency, simplifying transceiver design and enabling the use of less complex techniques.

**Non-WSSUS channels in vehicular communication**, the rapid mobility of transmitters and receivers, along dynamic scatters, challenge the assumption of WSSUS in channel modeling. Which is valid for a local region called TF stationarity region.

# Motivation

- The critical importance of establishing **robust 5G systems** that meet the **demands of Intelligent Transportation Systems** (ITS)
- The **necessity for precise channel characterization and modeling** of V2I (Vehicle-to-Infrastructure) communication channels to ensure their reliability and performance
- **Addressing the challenge posed by the non-stationary behavior** inherent in V2I channels, which arises from factors such as high mobility and dynamic scatters
- The gap in comprehensive comparisons between real measurement data and Ray-tracing models for **the stationarity time (WSS)**

# Objectives

- **Conducting a comparative analysis** of Single-Input Single-Output (SISO) suburban channels for Vehicle-to-Infrastructure (V2I) communication. This analysis involves comparing data generated by a Ray-tracing simulator with real-world data.

- **Assessing the violation of Wide-Sense Stationarity** (WSS) assumptions in terms of stationarity time (Ts) by examining the second-order statistics of the channel.

- **Performing a comprehensive large-scale analysis**, including estimating the path-loss exponent and comparing it between simulated and real data sets.

# MaMIMOSA sounder and its configuration

| | |
|---|---|
| **Carrier Frequency** | **5.89 GHz** |
| **Measurement Bandwidth** | **80 MHz** |
| **Frequency points** | **818** |
| **Delay resolution** | **12.5 ns** |
| **Doppler resolution** | **0.181 Hz** |
| **CTF duration** | **~ 1 ms** |
| **Transmit power** | **0 dBm** |
| **Tx – Rx Height** | **2 m – 3m** |

*Table 1 Configuration parameters*

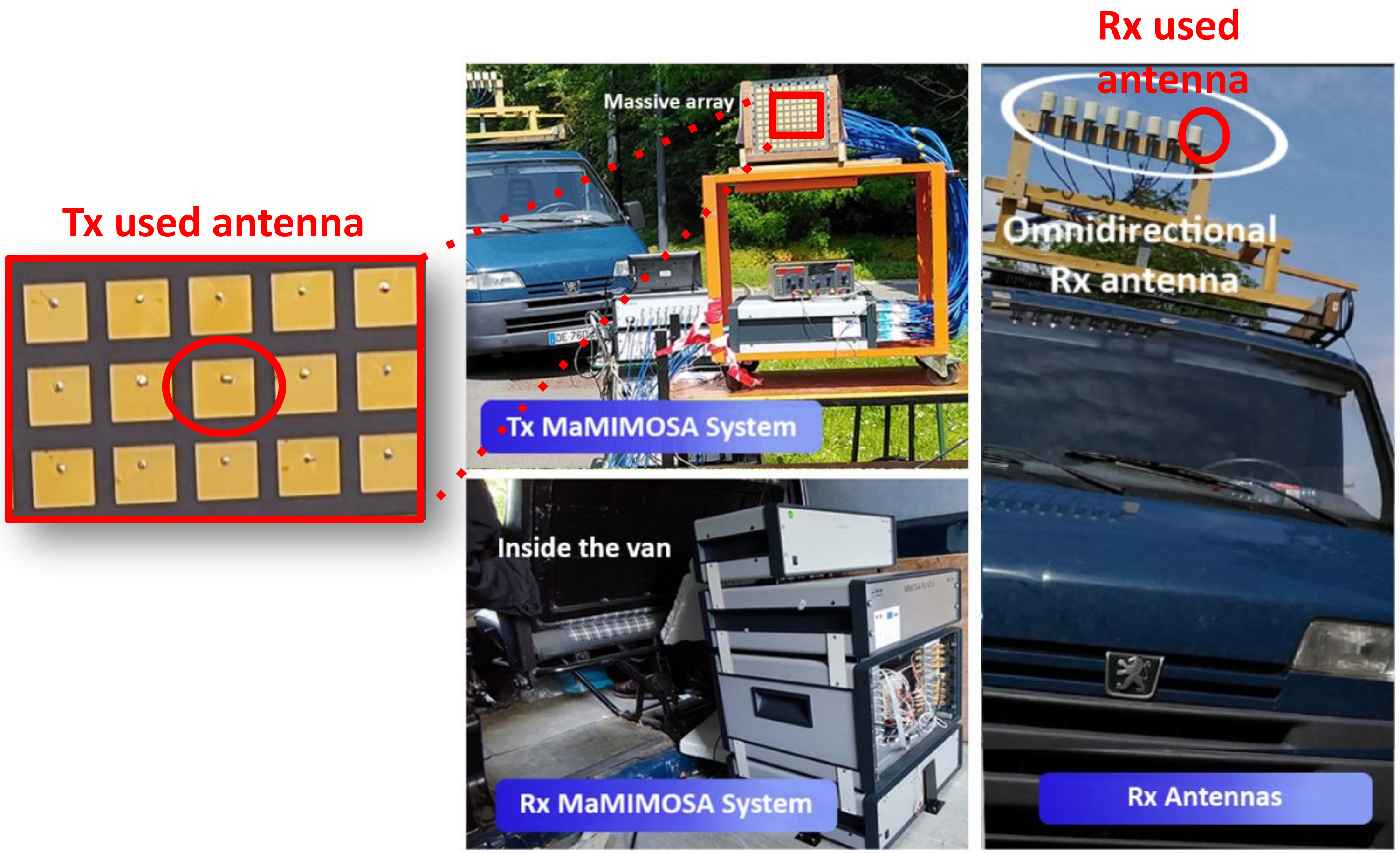


*Figure 1 MaMIMOSA Rx –Tx systems and antennas*

Additional details about MaMIMOSA conception and performance can be found in [1][2]

# Ray-tracing Veneris

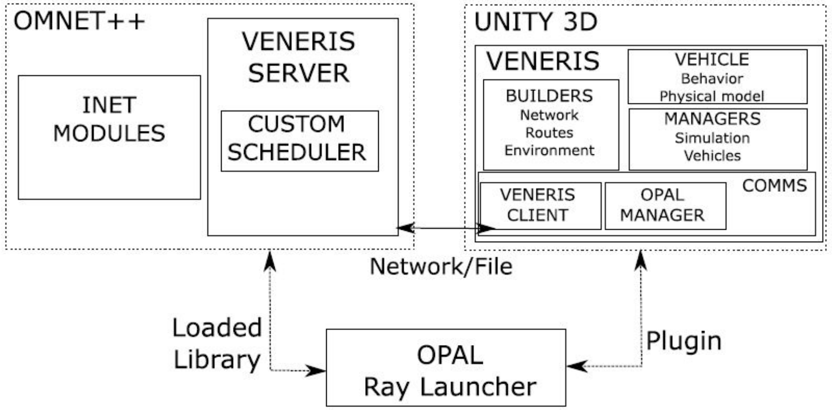


**FIGURE 1.** **Veneris main components . Opal can be used as a standalone application, as a plugin with Veneris or loaded with OMNET++. Veneris and OMNET++ communicate through the network or by files.**

- **Veneris Simulator : A** 3D traffic simulator
- **Opal:** a Ray-launching GPU-based propagation simulator
- **Veneris OMNET++ Modules:** Modules for Integration

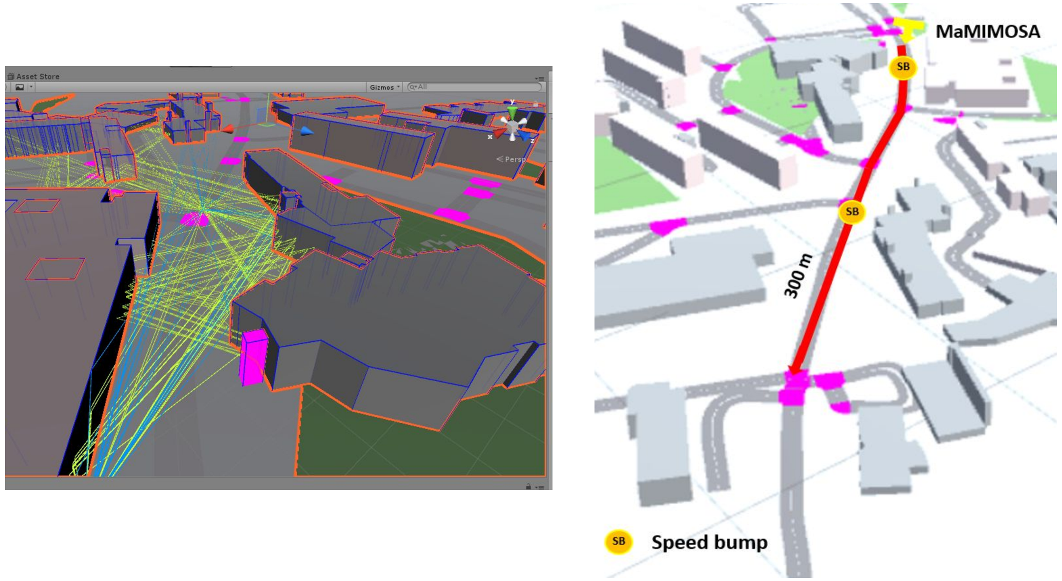


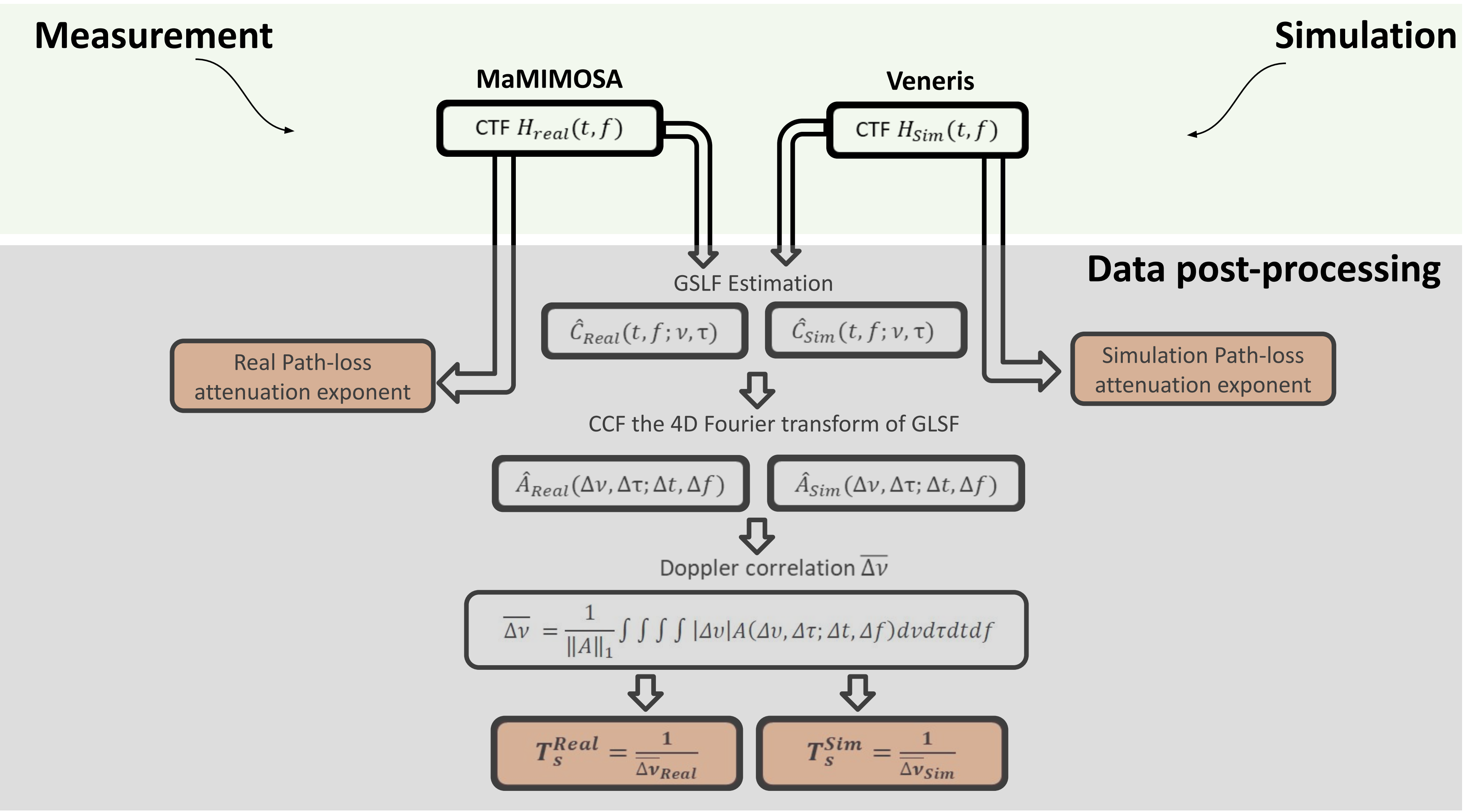
*Figure 2 Veneris interface*

Configurational details are documented in academic works [6][7].

# Measurement Campagne (Video demonstration)

CLICK HERE

# Methodology



**Measurement**

**Simulation**

**MaMIMOSA**

CTF $H_{real}(t,f)$

**Veneris**

CTF $H_{Sim}(t,f)$

**Data post-processing**

GSLF Estimation

$\hat{C}_{Real}(t,f;\nu,\tau)$ $\hat{C}_{Sim}(t,f;\nu,\tau)$

Real Path-loss attenuation exponent

Simulation Path-loss attenuation exponent

CCF the 4D Fourier transform of GLSF

$\hat{A}_{Real}(\Delta\nu,\Delta\tau;\Delta t,\Delta f)$ $\hat{A}_{Sim}(\Delta\nu,\Delta\tau;\Delta t,\Delta f)$

Doppler correlation $\overline{\Delta\nu}$

$$\overline{\Delta v} = \frac{1}{\|A\|_1}\int\int\int\int |\Delta v| A(\Delta v,\Delta\tau;\Delta t,\Delta f)\,dv\,d\tau\,dt\,df$$

$$T_s^{Real} = \frac{1}{\overline{\Delta v}_{Real}}$$

$$T_s^{Sim} = \frac{1}{\overline{\Delta v}_{Sim}}$$

Additional details regarding sampled CTF and GLSF [3] for theoretical aspects can be found in [4].

# Results and Discussion

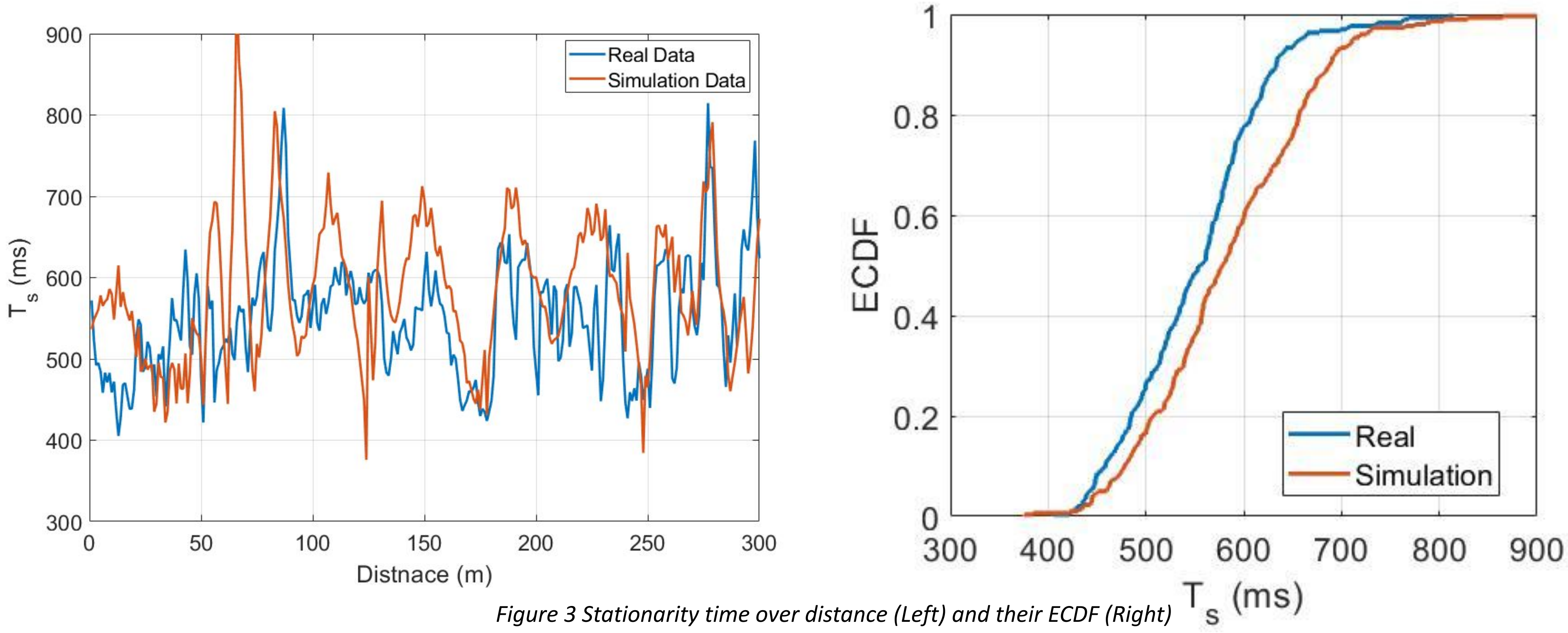


*Figure 3 Stationarity time over distance (Left) and their ECDF (Right)*

| | **Median** | **Std** | **Min** |
|---|---|---|---|
| **Ts real** | 550 ms | 74 ms | 418 ms |
| **Ts simulation** | 560 ms | 86 ms | 396 ms |

*Table 2 Comparison of stationarity time between real data and simulation*

Jensen–Shannon divergence value of **0.05** was found

# Results and discussion

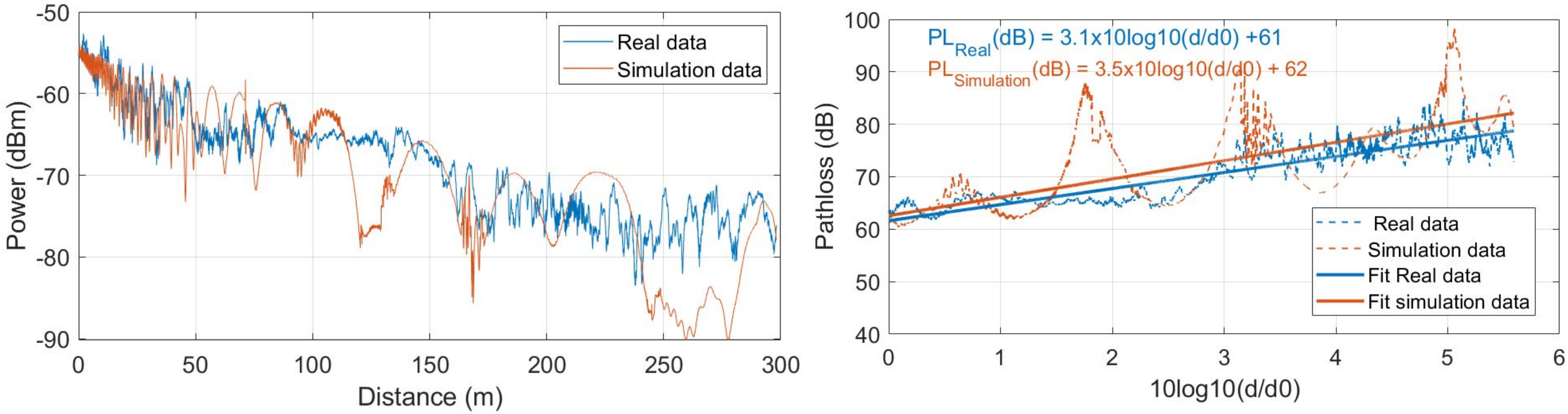
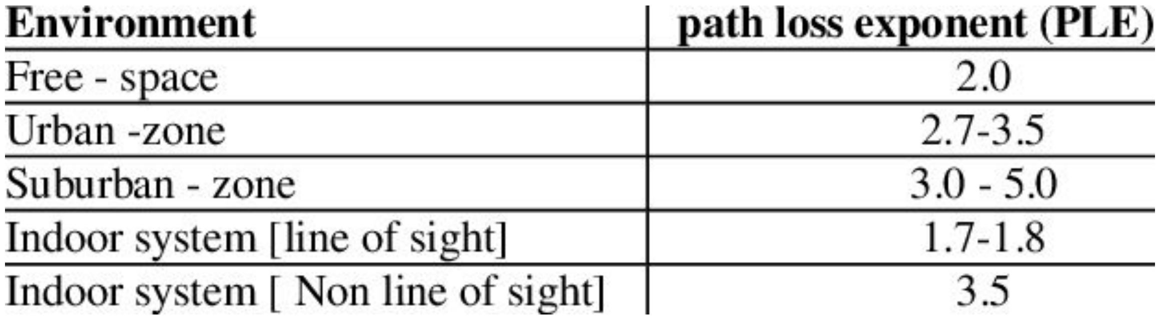


*Figure 4 Received power (Left) Path-loss fit (Right)*



| Environment | path loss exponent (PLE) |
|---|---|
| Free - space | 2.0 |
| Urban -zone | 2.7-3.5 |
| Suburban - zone | 3.0 - 5.0 |
| Indoor system [line of sight] | 1.7-1.8 |
| Indoor system [ Non line of sight] | 3.5 |

*Table 3 Path-loss  exponent values for differents environments [5]*

# Conclusion

- The stationarity time **Ts** and path-loss estimation of Veneris are relatively similar to real data measurements
- The Veneris simulator can accurately reflect the stochastic physical properties of the channel
- Based on the results obtained, Veneris appears to be a reliable tool for evaluating V2I performance

# Future Work

- Extend this paper by comparing the simulator in **massive MIMO** array configurations
- Analyze Ts spatial behavior across the array and MPC angular properties (AoA and AoD values and spreads)
- Estimate Radio Channel Characteristics and Large-Scale Parameters

# Thank you for your attention!

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