LOSS PERFORMANCE OF INTRA-VEHICLE CHANNELS FOR NARROWBAND SIGNAL TRANSMISSION

Presenter: *Irfan Yusoff*

Authors: Irfan Yusoff, Xiaohong Peng, Jack Hynds

Affiliation: Aston University

Email: mohdymni@aston.ac.uk, x-h.peng@aston.ac.uk, j.hynds@aston.ac.uk

Aston University
Birmingham

IARIA

RESUME OF THE PRESENTER

- A PhD student in the Adaptative Communication Networks Research Group (ACNRG) at Aston University, Birmingham, United Kingdom
- Supervisor: Dr Xiaohong Peng
- Research: Focuses on intra-vehicle wireless communication.

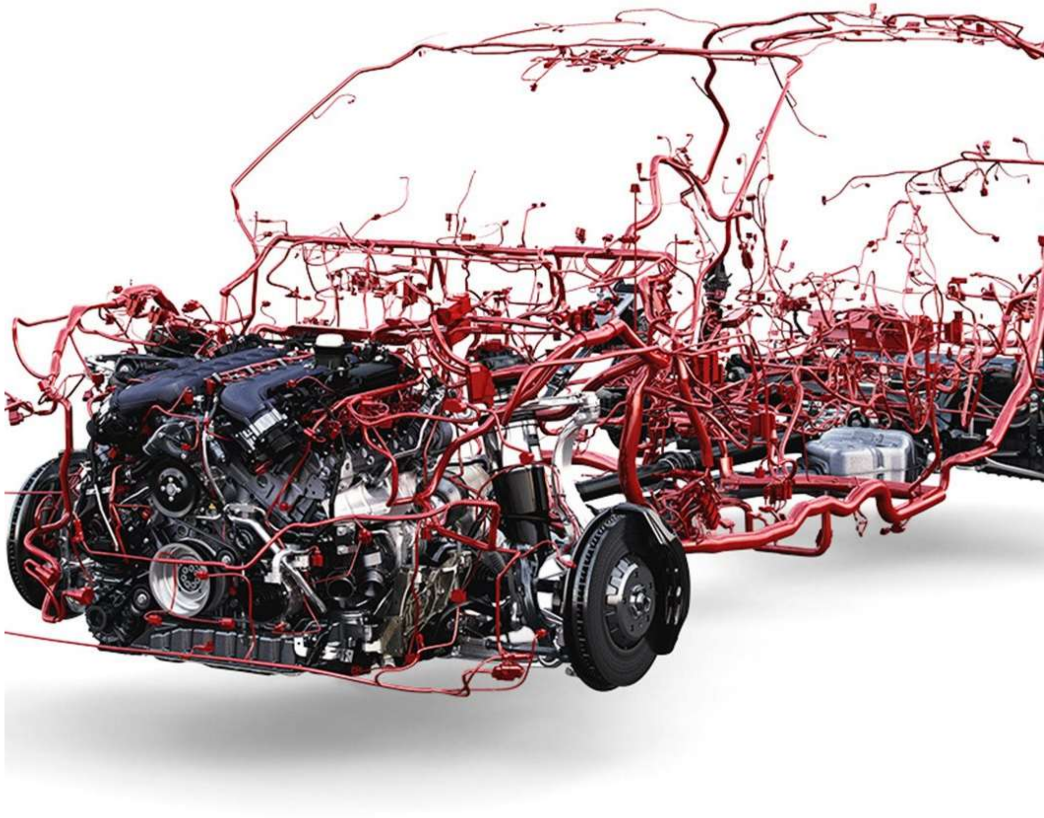
- Other research interest: Power electronics, AC-DC and DC-DC converters, Machine learning

OUTLINE

- Introduction
- Experimental setup
- Measurement results
- Conclusion

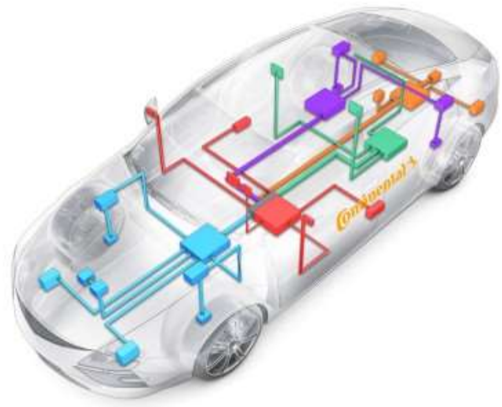
INTRODUCTION

- Why do we need wireless communication in vehicle?
- The number of electronic devices and sensors have increased significantly over the years.
  - The number of electric control units (ECU) has increased from 75 (2010) to 150 (2019).
  - Today, electronic devices is responsible for 40% of the cost of a vehicle, as compared to 18% in 2000.
- The wire harness is the third most heaviest component after the chassis and engine.
  - Can weight as much as 60 kg.



INTRODUCTION

- Research on automotive electronics is growing.
  - New features and technologies implemented in vehicle to improving driver safety and experience.
  - Which leads to increasing demand for high-bandwidth network and more cost effective solutions.
- Implementing wireless communication to reduce or replaced a wired network can bring significant benefits.
- The wireless solution offers advantages over wired based solutions.
  - Save physical space
  - Reduce weight
  - Increased fuel efficiency



INTRODUCTION

- Challenging operating environment with heavy multipath.
- No definite answer on which technology is the most suitable.
- A good understanding of the channel conditions and properties of intra-vehicle channels is required.
- Performance requirements.
  - Reliable
  - Low-latency (in certain application)
  - High bandwidth (in certain application)

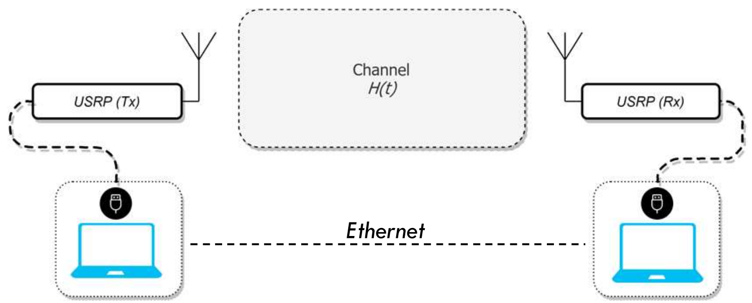
INTRODUCTION

1. Investigating the loss performance of the intra-vehicle channel
   - Mean loss
   - Large-scale fading
   - Small-scale fading
2. Compare large-scale against small-scale fading component
3. Assess different distribution function that best fit the large-scale and small-scale fading component

EXPERIMENTAL SETUP

- Channel loss measurement was performed on Jaguar land rover discovery sport.

- **Equipment and settings**
  - 2 x Ettus USRP B210
  - 2 x Laptop
  - Omnidirectional antenna
  - Frequency – 2.4 GHz & 5.9 GHz



- A frequency spectrum scan was performed before taking measurements.
- The vehicle engine and electric power turned off during the tests.

MEASUREMENT PROCEDURE

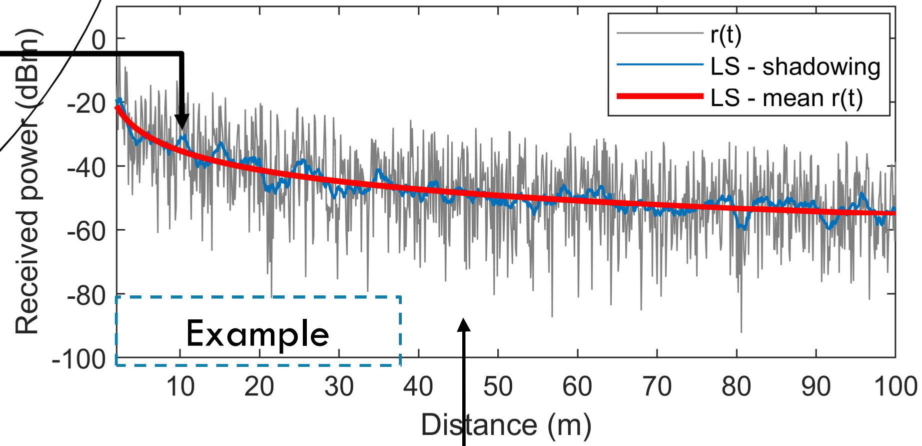
- Measuring the received signal power at 44 different locations across the passenger and boot compartments.
- The transmitter was placed at a fixed location on the dashboard of the vehicle, while the location of the receiver (USRP) was changeable.

INTRA-VEHICLE PATH LOSS MODEL

$$L_p = L_m + X_\alpha + \beta_s$$

- The intra-vehicle path loss L_p behavior is modelled by combining the mean path loss L_m, the loss due to slow or large-scale fading X_α, and loss due to fast or small-scale fading β_s

- Large-scale fading
  - The slow-varying signal envelope
  - Shadowing + mean *r(t)*
- Small-scale fading
  - The rapid or fast changing received signal envelope



EXTRACTING THE LARGE SCALE FADING

- The large-scale fading also known as shadowing represents the local average slow fading characteristic of the received signal.
- Defined in this analysis as the local-mean received signal power within a window of 50 cm which is equivalent to 4 λ at 2.4 GHz and 10 λ at 5.9 GHz.

$$L_\gamma = \frac{1}{k} \sum_{i=1}^{k} L_i$$

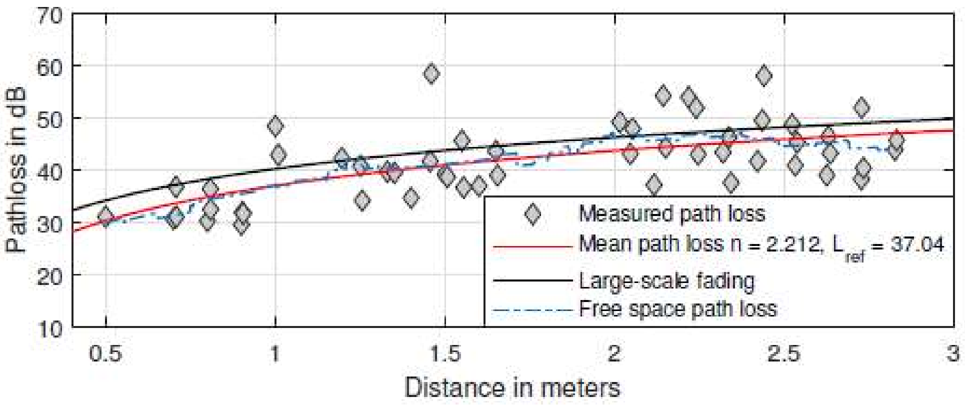
- L_γ represents the local mean, k is the window size defined by the number of samples within the window, and L_i is the path loss of the i th sample.

SMALL-SCALE FADING

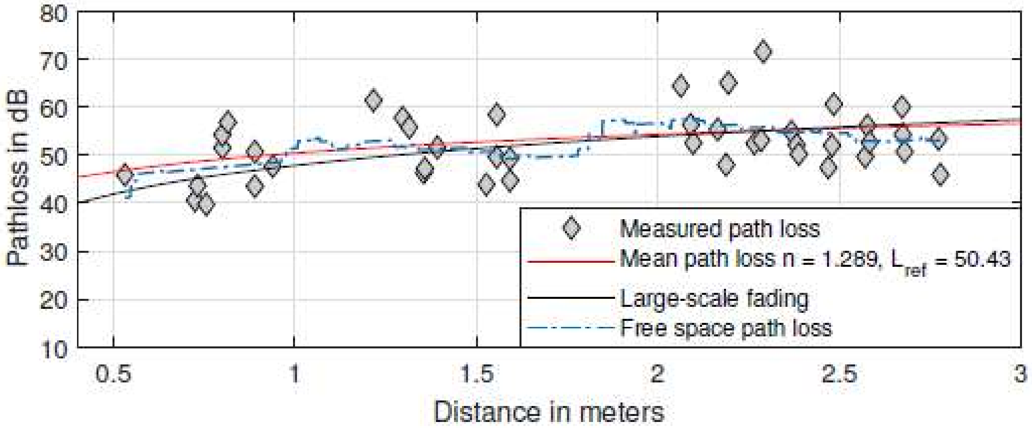
- The small-scale fading component was extracted from the measured path loss from by deducting the large-scale fading component from the actual loss measurement which represents the relative loss variation (RLV) for small-scale fading.

$$\beta_s = L_p - X_\alpha - L_m$$

RESULT: MEASURED PATH LOSS, MEAN LOSS. LARGE SCALE FADING



2.4 GHz



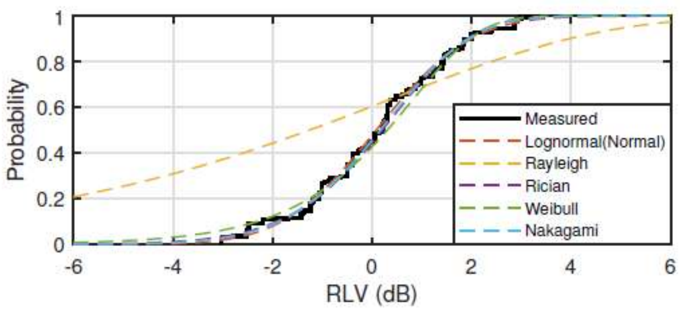
5.9 GHz

RESULT: LARGE-SCALE FADING

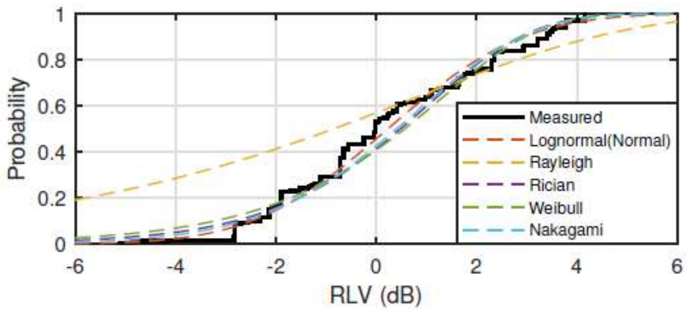
- Cumulative Density Function (CDF) of the large-scale fading.
- Represented as relative loss variation (RLV)
- The Goodness of Fit (GoT) suggest the lognormal distribution being the highest match percentage with big margins from the others.

GOODNESS OF FIT FOR LARGE-SCALE FADING (X_α)

Frequency: 2.4 GHz			
Distribution	KS	Chi	MLE
Log-normal	75.55%	23.25%	37.97%
Rayleigh	0.02%	5.44%	<0.01%
Rician	6.92%	23.85%	23.62%
Weibull	0.41%	23.67%	2.92%
Nakagami	17.10%	23.79%	35.5%
Frequency: 5.9 GHz			
Distribution	KS	Chi	MLE
Log-normal	91.17%	20.76%	65.06%
Rayleigh	0.1%	24.73%	<0.01%
Rician	1.92%	18.12%	7.92%
Weibull	<0.1%	16.98%	2.8%
Nakagami	6.72%	19.42%	24.22%



2.4 GHz



5.9 GHz

RESULT: SMALL-SCALE FADING

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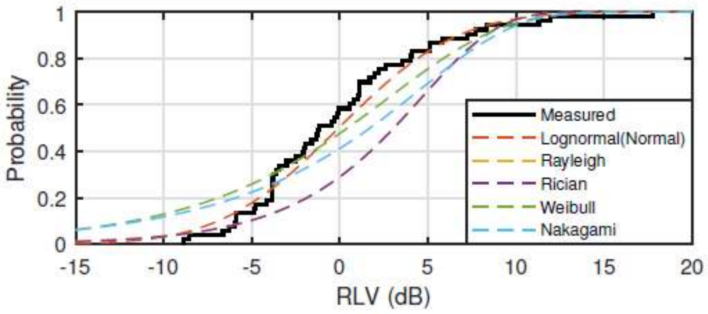
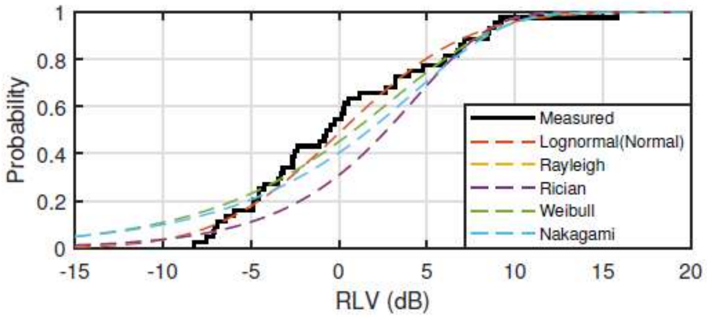
- Represented as relative loss variation (RLV)
- The Goodness of Fit (GoT) suggest the lognormal distribution being the highest match percentage with big margins from the others.

GOODNESS OF FIT FOR SMALL-SCALE FADING (β_s)

Frequency: 2.4 GHz			
Distribution	KS	Chi	MLE
Log-normal	84.41%	24.68%	92.19%
Rayleigh	0.09%	15.4%	0.29%
Rician	0.09%	15.4%	0.29%
Weibull	14.41%	23.33%	5.81%
Nakagami	1.012%	21.19%	1.42%
Frequency: 5.9 GHz			
Distribution	KS	Chi	MLE
Log-normal	70.43%	23.14%	68.81%
Rayleigh	0.01%	15.73%	3.73%
Rician	0.01%	15.73%	3.73%
Weibull	24.58%	23.39%	15.50%
Nakagami	4.96%	22.02%	8.22%

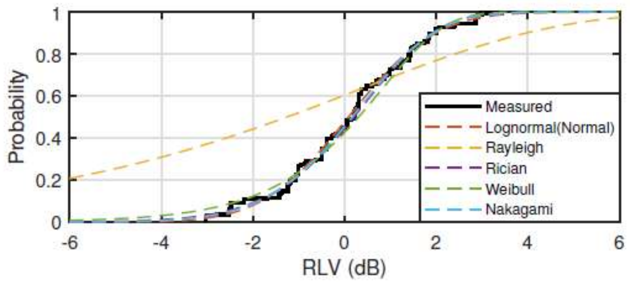


2.4 GHz

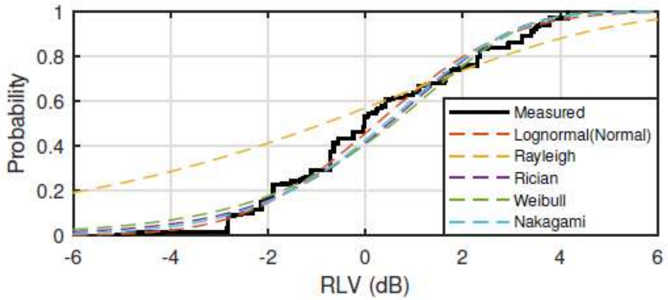


5.9 GHz

RESULT: COMPARING LARGE-SCALE AND SMALL-SCALE FADING

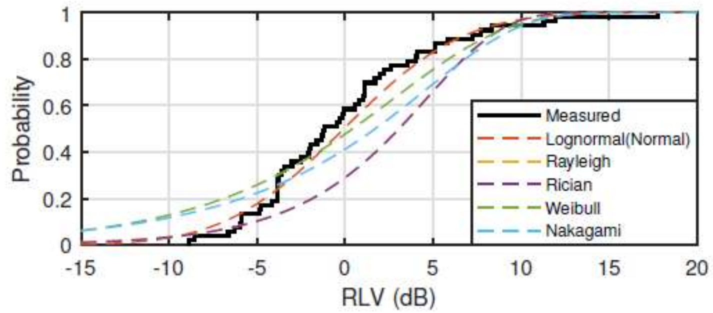


2.4 GHz

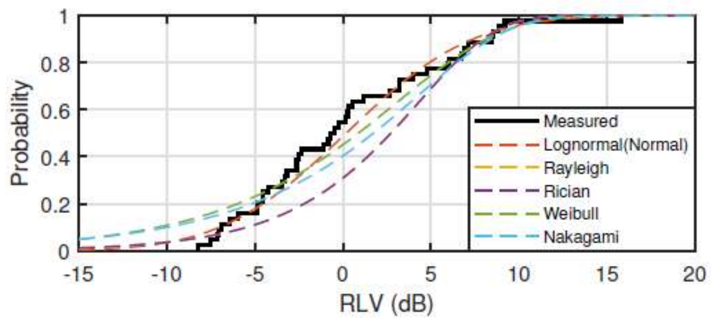


5.9 GHz

Large-scale fading



2.4 GHz

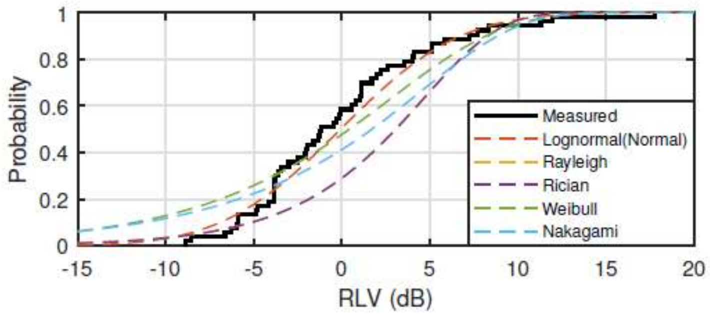


5.9 GHz

Small-scale fading

RESULT: SMALL-SCALE FADING AT 2.4 GHZ AND 5.9 GHZ

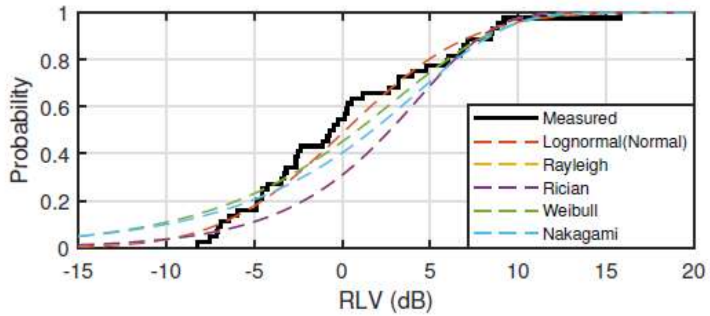
- Small-scale fading distributions for both frequencies appear to be similar to each other.
- Two-sample KS test demonstrates a close correlation between the small-scale fading components s at 2.4 GHz and 5.9 GHz



2.4 GHz

SMALL-SCALE FADING (β_s) TWO-SAMPLE-KS TEST

	KS p-value	
Frequency (GHz)	2.4(Estimated)	5.9(Estimated)
2.4(Estimated)	1	0.984
5.9(Estimated)	0.984	1



5.9 GHz

CONCLUSION

- Presented the propagation characteristic of narrowband signals at 2.4 GHz and 5.9 GHz in the intra-vehicle wireless channels.
- Various channel parameters have been extracted from the received signal power measurements.
- Our measurement has shown the similarity of small-scale fading component at 2.4 GHz and 5.9 GHz
- Multipath fading has a significant impact on the path loss performance of narrowband signals compared to the attenuation-related loss which has a varied relationship with the free-space loss depending on the operating frequency chosen.
- Small-scale fading is much more influential than large-scale fading on path loss in this environment.

Thank You