Aalto University
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Usability Benefits and Challenges in mmWave V2V Communications - A case study

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Agenda

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- Vehicle to Vehicle communications
- Potential of 39 GHz Band
- Ray Tracing Vs Ray Launchings
- Ray Tracing Tool
- Simulation Cases and environment
- Results
- Conclusion

Abstract

- The main target of this paper is to provide a comparison between explicit three-dimensional ray tracing simulations and field trial measurements on 39 GHz frequency.

- Basic practical and relevant cases for V2V communications are considered covering several important scenarios of daily life traffic.
  - LOS
  - Single car obstruction
  - Road crossing, and
  - Platooning

Vehicle to Vehicle (V2V) communications

- Intelligent Transportation System (ITS)
  - Better passenger safety
  - Efficient traffic management

- 3rd Generation Partnership Project (3GPP) standardization organization came up with Cellular V2X (C-V2X) in Release 14
  - Direction communications
  - Vehicle to Network (V2N)

- V2X applications
  - Infotainment
  - Traffic efficiency
  - Traffic safety
  - Cooperative driving

Potential of 39 GHz bands

• The ITS communication frequency bands in Europe are specified by ETSI and they occur between **5855-5925 MHz** (unlicensed) for **road safety**.

- Maximum RF power is 33 dBm
- Maximum channel bandwidth is 10 MHz
- Maximum spectral density is 23 dBm/MHz

• **High path loss**, and **high building penetration loss** are attributed to mmWave frequencies, and it makes high frequency operation suitable for short range communication.

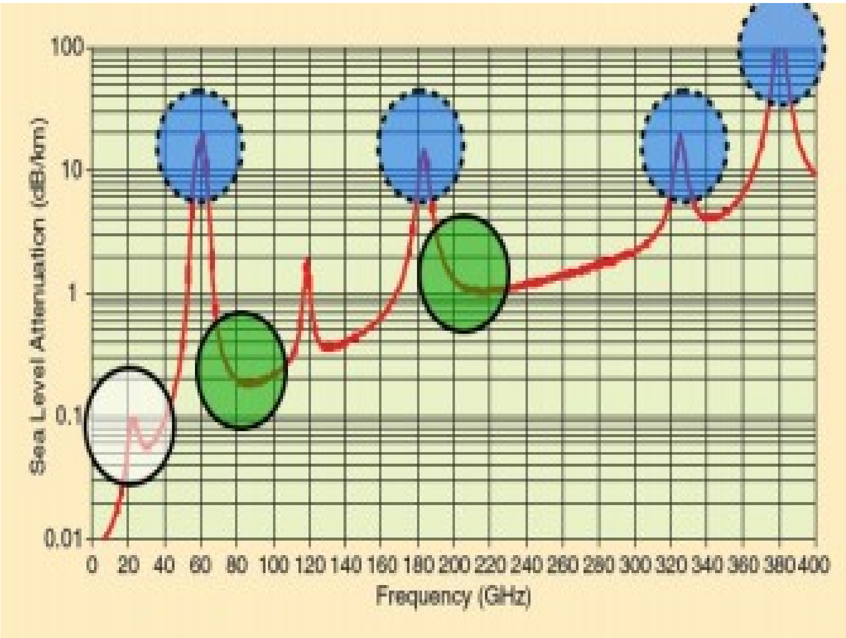
• There is additional loss at **60 GHz frequency** due to **atmospheric absorption**, however at **39 GHz** the rain attenuation and atmospheric absorption is fairly low and can be neglected.

•High **antenna gain** can be achieved at mmWave frequency by employing antenna arrays at both the transmitter and receiver side.

Potential bands

Band	BW
6 GHz	70 MHz
28 GHz (LMDS)	1.3 GHz
39 GHz	1.4 GHz
37/42 GHz	2.1 GHz
71-76 & 81-86 GHz	10 GHz

Local Multipoint Distribution Service



Ray launching Vs Ray tracing

Ray tracing techniques have been extensively employed as a "prediction tool, and for the characterization of the radio propagation environment"

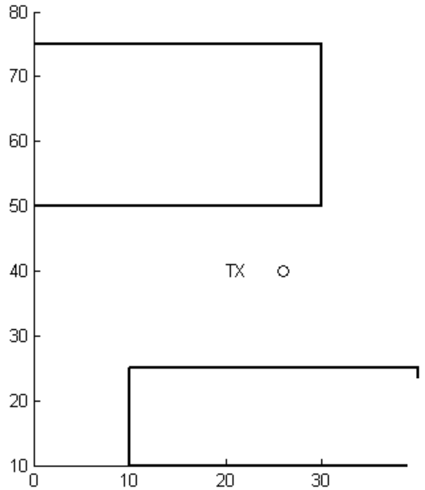
•In ray launching e.g. Shoot and Bouncing Ray (SBR), a large number of rays are launched with constant angular separation between neighboring rays from transmitter.

- Intersection and reception tests need to be performed on each ray to determine the valid rays between transmitter and receiver.

- Separation angle between the rays has major impact on the accuracy of SBR algorithm.

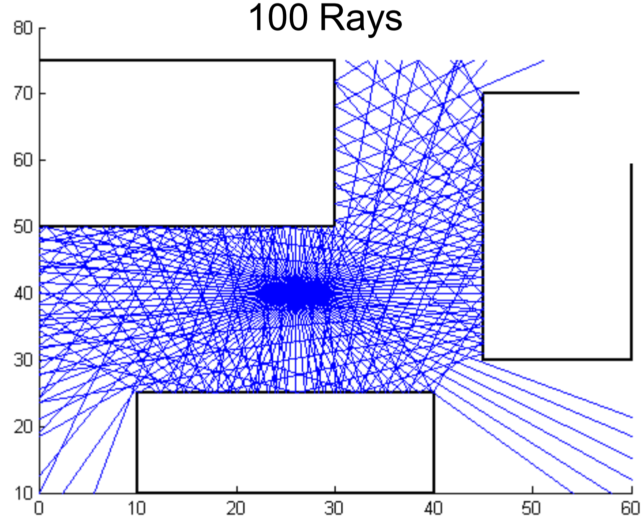
- Image Theory is more accurate, precise and rigorous compared to SBR, as it can found all ray path components with finite reflections and diffractions without redundancies, and does not require reception test

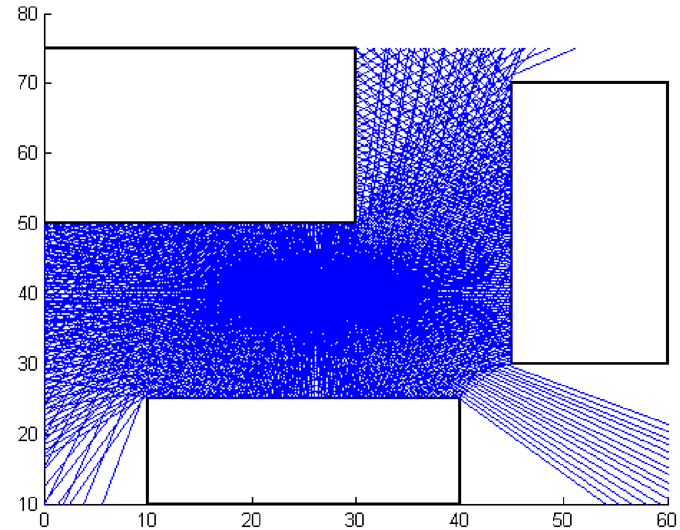
Ray launching example



Sample scenario

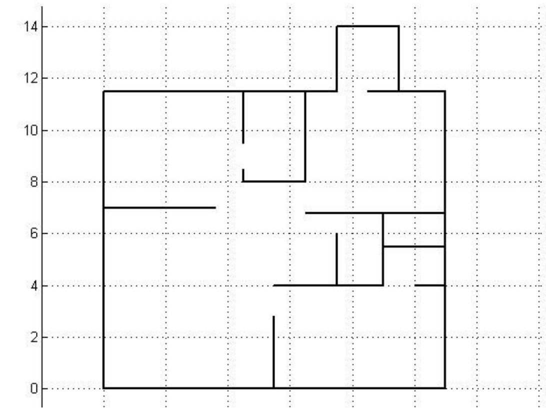
100 Rays

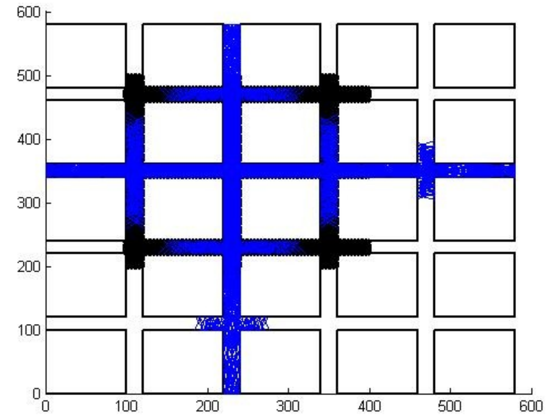


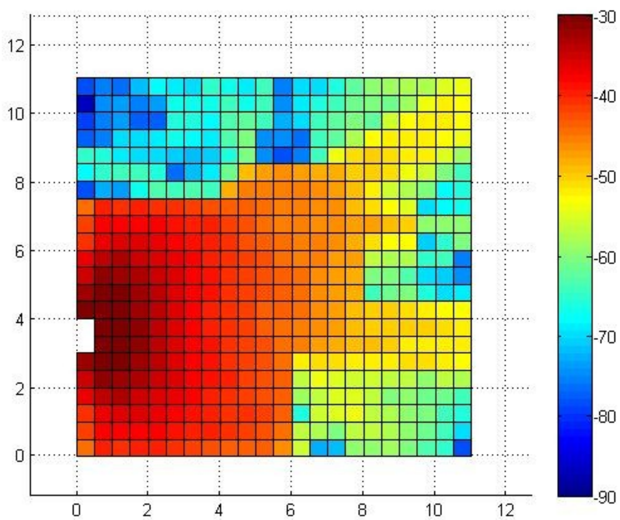


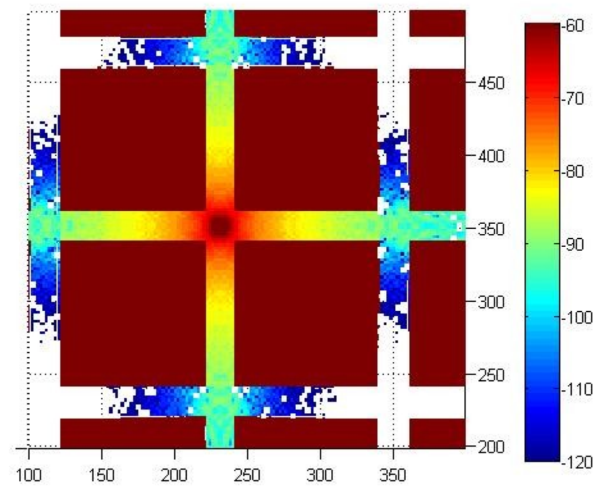
300 Rays

Ray launching examples

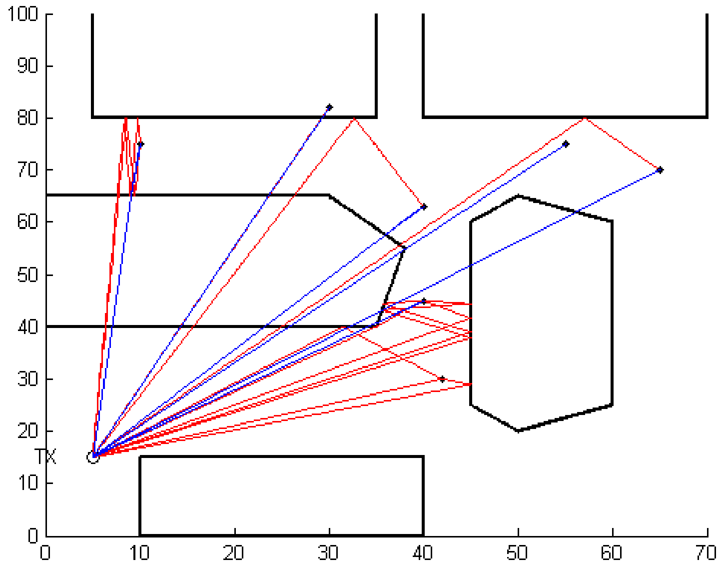


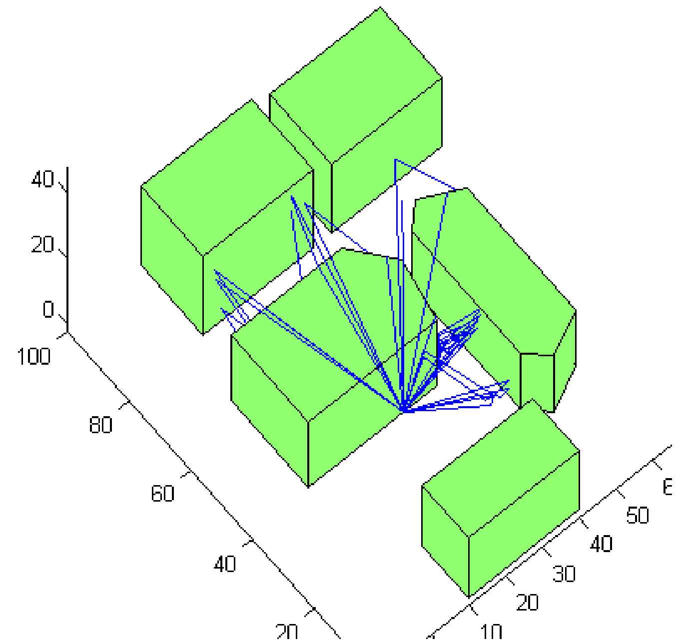


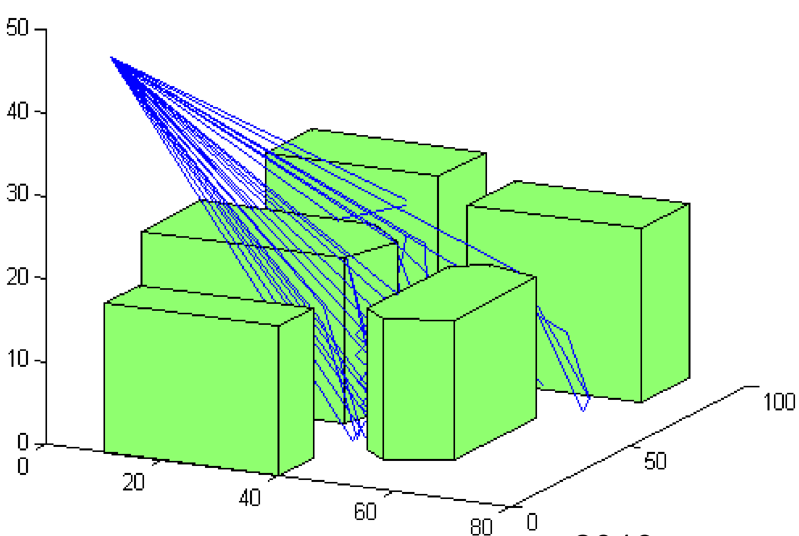


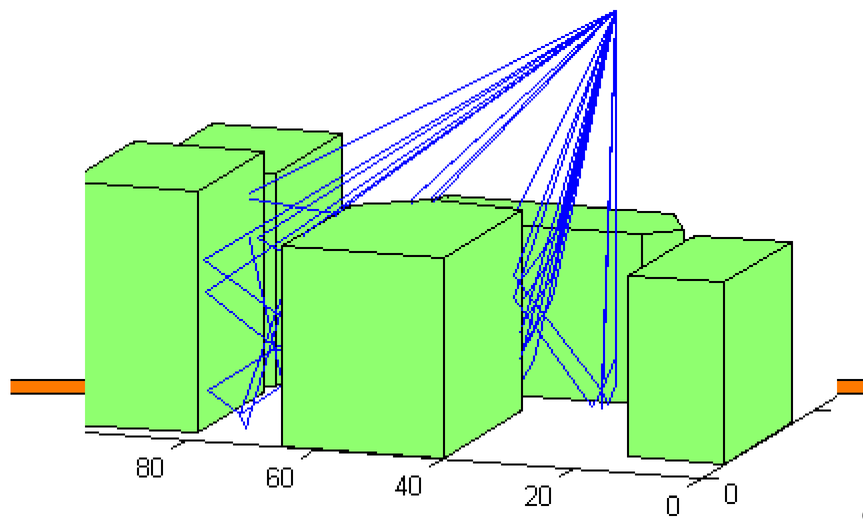


Few Examples of Ray tracing







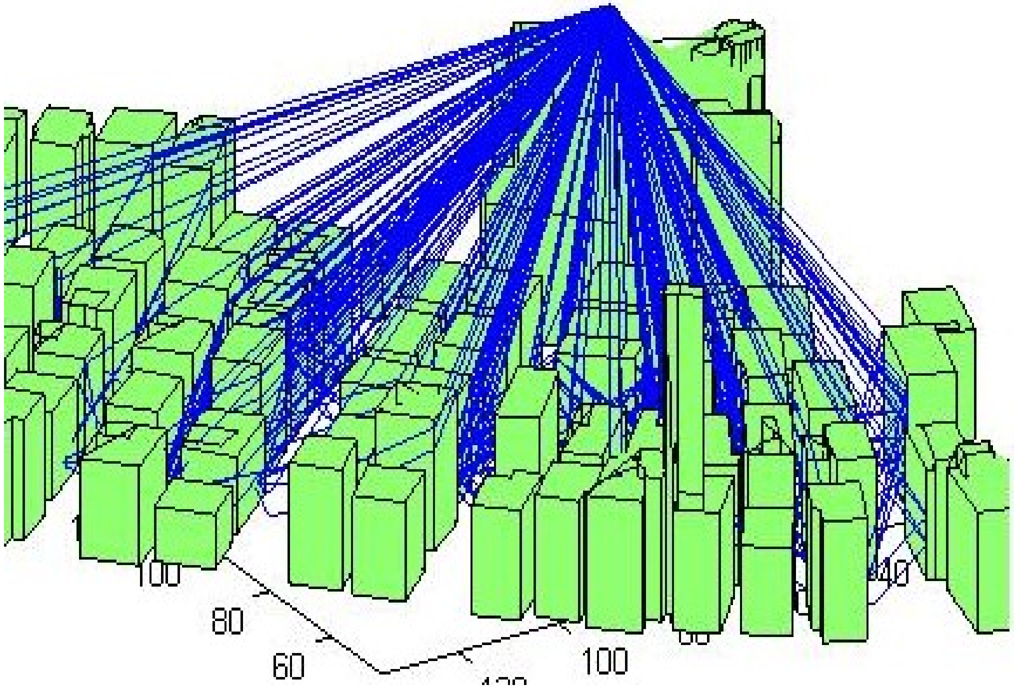


3D Ray Tracing Tool

• We have indigenously developed a full three dimensional ray tracing tool in MATLAB environment. The ray tracing technique used in this tool is based on **Image Theory (IT) algorithm**.

•Unlike a quasi three dimensional environment, it supports ray tracing in full three dimension. Transmitter can be placed at the rooftop of the building, and it also tracks the signal paths with diffraction from the rooftops.

•It takes MAP as an input in .txt or .xls file format defined in locally defined format. Information about building coordinates and building height is integrated in single file.



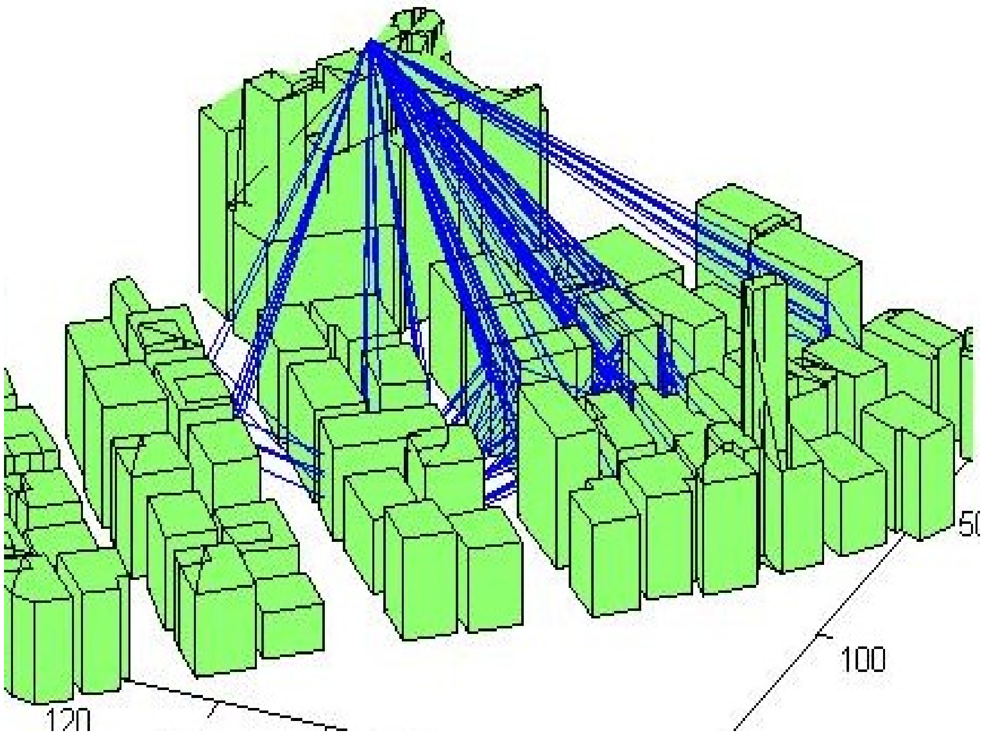
3D Ray Tracing Tool

• The ray tracing tool finds all available multipath components with predefined number of reflections and diffractions. It also provides Multipath components with reflection from Ground.

• Receiver location can be set in an Outdoor environment or Indoor environment.

• In Indoor environment, receiver location can be at different height (floors). Height of single floor in a building can be set by the user.

• Both Vertical and Horizontal polarization are supported.

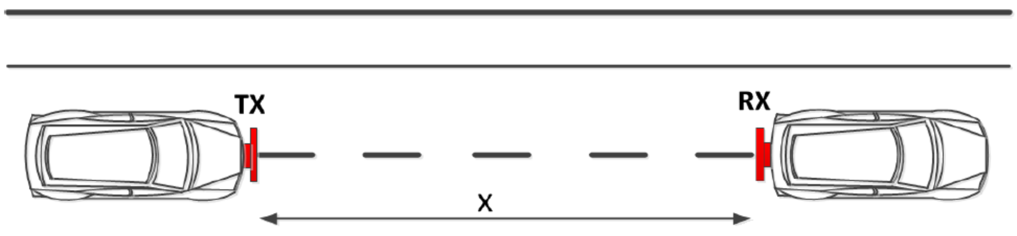


Outputs

- Serial number of Multipath component
- Path Distance (meter)
- Angle of Arrival AoA (degree)
- Angle of Departure AoD (degree)
- Direction of Arrival DoA (degree)
- Direction of Departure DoD (degree)
- E-Field (Volt/meter)
- H-Field (Ampere/meter)
- Phase shift (radians)
- Received Power (watt)
- Time delay (seconds)
- Number of reflections of path experienced
- Number of diffractions of path experienced
- Number of ground reflection of path experienced
- Receiver location (x and y coordinates)
- Receiver height (meter)
- Transmitter location (x and y coordinates)

Measurement and Simulation Cases

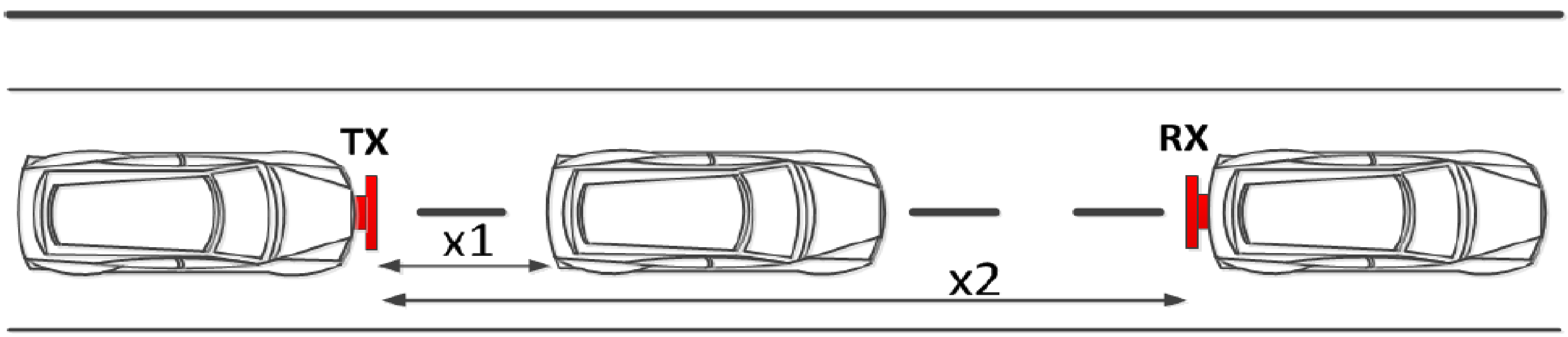
Line of Sight (LOS) case: In this case, a vehicle with the Transmitter (TX) stays static at one point while the vehicle with a Receiver (RX) moves away from the transmitter in a straight line in the direction of main lobe of TX antenna.



3GPP, "Field trial results from 39 ghz vehicle to Vehicle communication," 3rd Generation Partnership Project (3GPP), Technical Specification Group (TSG) RAN WG1 meeting RAN1-AH-1901 R1-1900446, 01 2019.

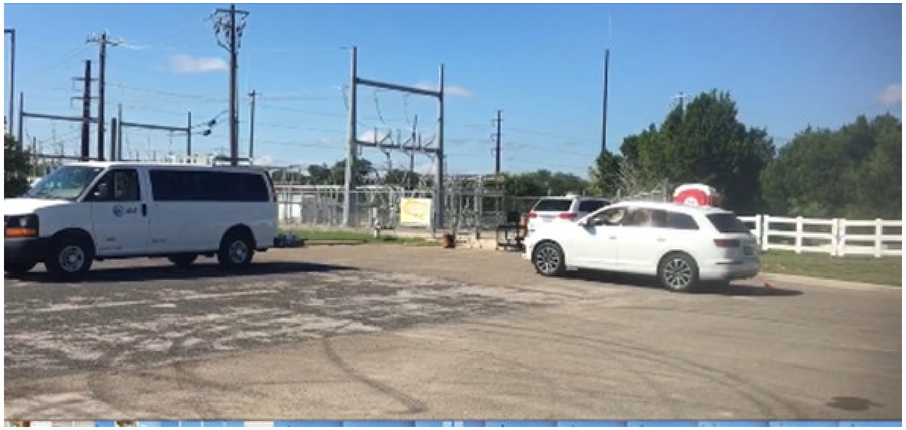
Measurement and Simulation Cases

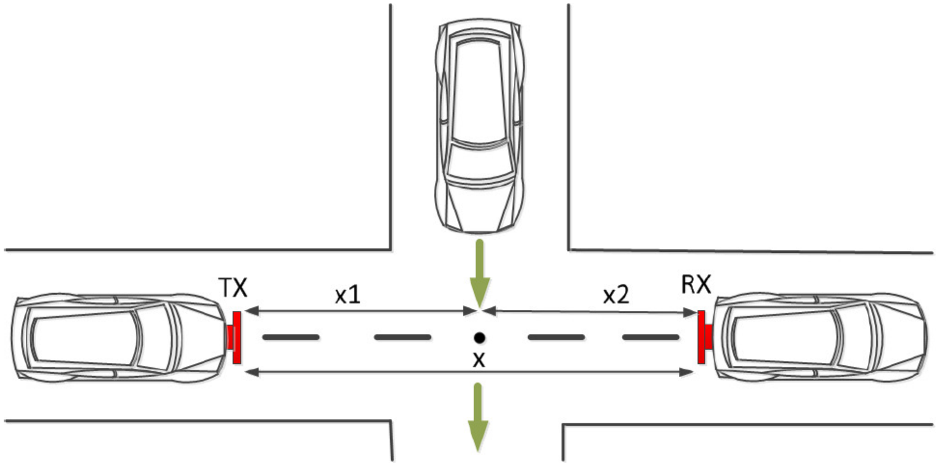
Non-LOS (NLOSv) single vehicle blockage: This case represents a NLOS scenario in which the LOS between the transmitter and receiver is obstructed by another sedan vehicle. Again the transmitter stays static while the vehicle with the receiver drives away from the transmitter.



Measurement and Simulation Cases

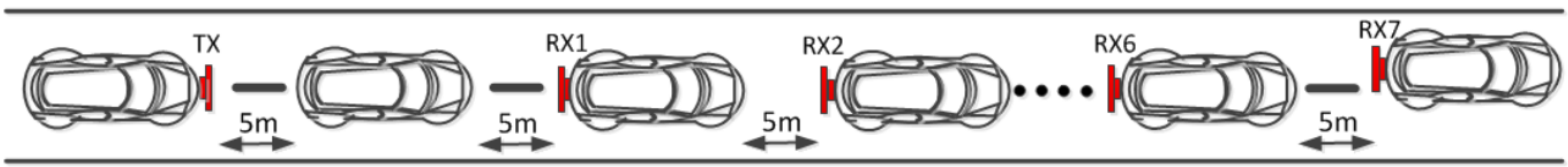
Moving vehicle obstructing LOS at road intersection: A road intersection is considered here where the TX vehicle and Rx vehicle are static and admit LOS with each other, and an another sedan vehicle drives the crossing road and obstruct the LOS.





Measurement and Simulation Cases

Platooning: This case is considered to analyze the impact of multiple blocking cars. We consider a platoon of vehicles staying static in a line. A static environment is considered, where the LOS between the TX and first vehicle mounted receiver (RX1) is obstructed by another sedan vehicle. There are seven vehicles with receiver antennas and the distance between the TX and the RX vehicle depends on the number of obstructing vehicles in between them.



Measurement and Simulation Parameters

GENERAL SIMULATION AND MEASUREMENT PARAMETERS

Parameters	Unit	Value
Frequency	GHz	39
TX power	dBm	23
TX antenna height	m	0.5
TX antenna		Directional
RX antenna height	m	0.7
RX antenna gain	dBi	Omnidirectional 2
Tx antenna model		3GPP extended model
Slow Fading Margin	dB	8

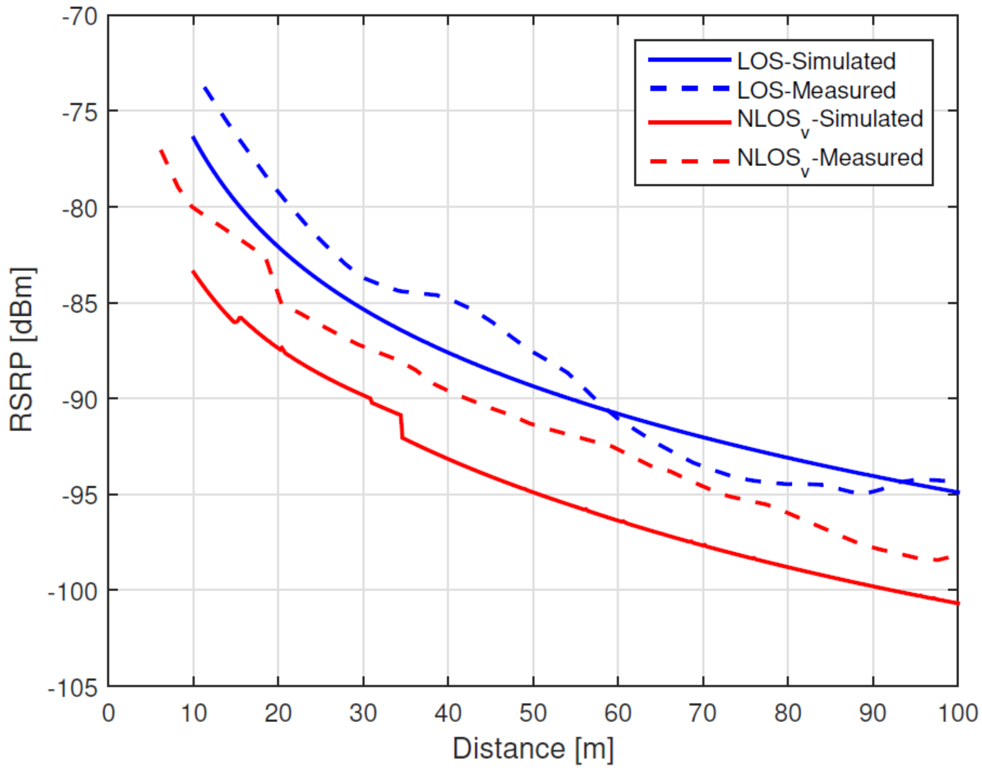
3GPP ANTENNA MODEL PARAMETERS

θ_H [°]	θ_V [°]	FBR_H $[dB]$	SLL_V $[dB]$	A_M $[dBi]$
115	60	26	-18	6

Results: LOS and NLOSv case

The measured RSRP being around **-95 dBm** and **-98.2 dBm** at a distance of nearly 100 m in LOS and NLOSv, respectively.

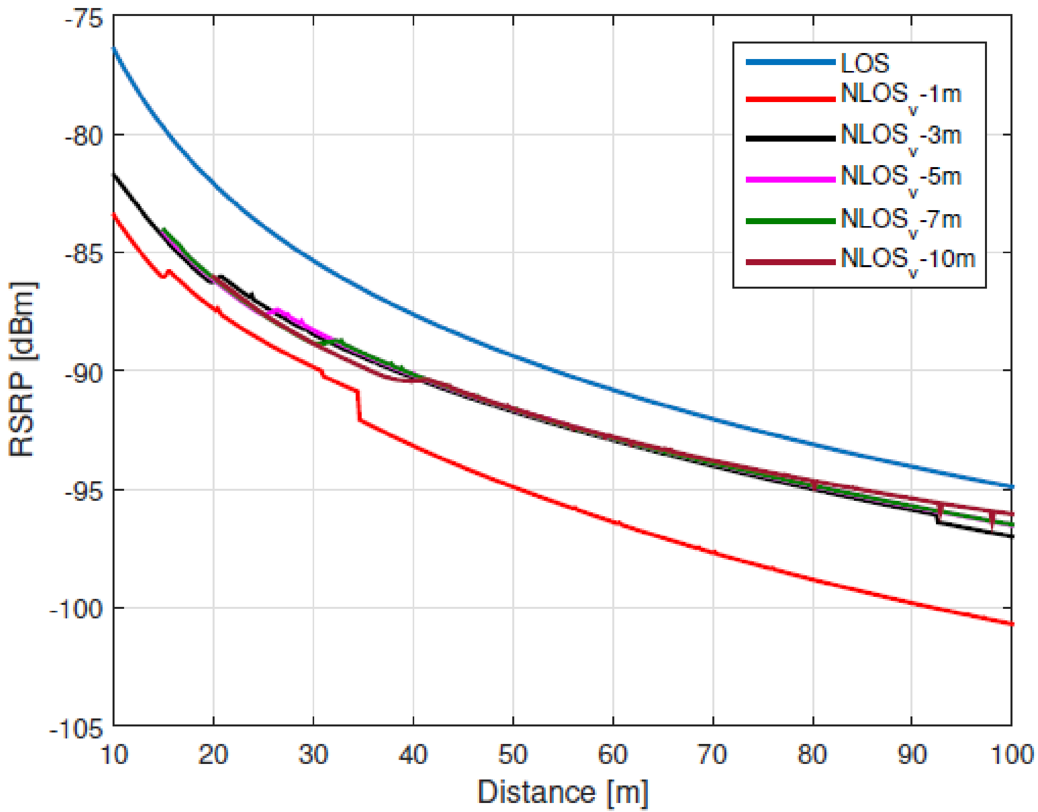
Both the simulation and measurement results reveal that the blocking effect due to obstructing vehicle at a distance of 1 m has caused a loss of around **5-7 dB** with respect to the LOS case.



Results: LOS and NLOSv case

The blockage effect is significant with 1 m TX-OB separation, while the blockage becomes less significant when TX-OB vehicle distances are larger.

Second, it is observed that for the large TX-OB separation i.e. for 3 m and more, the RSRP at RX starts to converge with the RSRP level of LOS case at large TX-RX separation. However, for small TX-OB separation i.e. for 1 m the blockage effect stays even at large TX-RX separation.

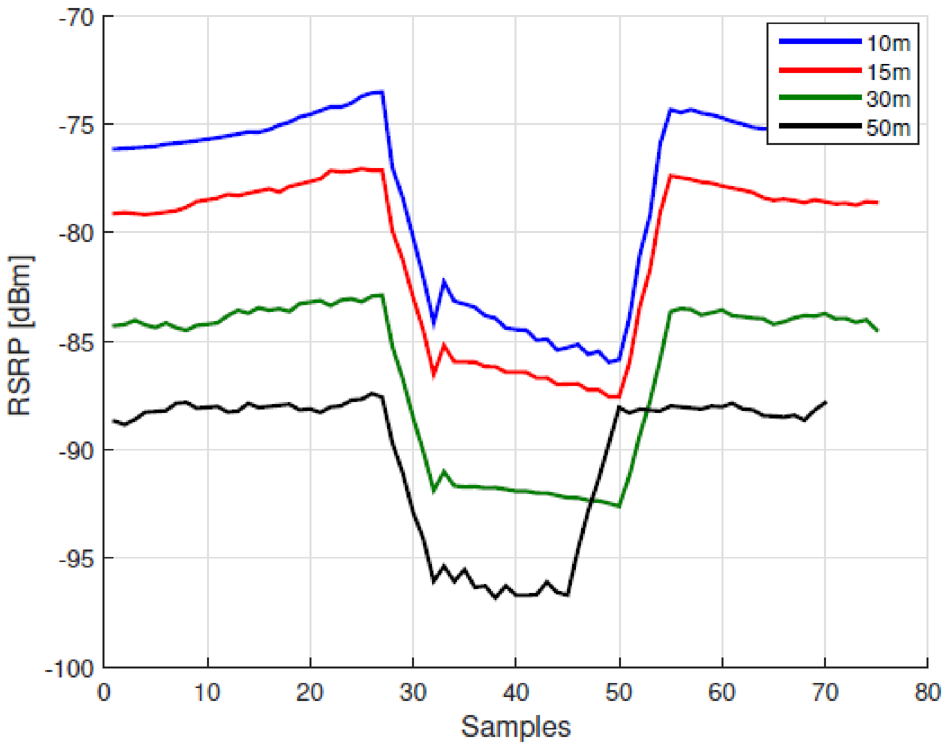


Results: Road crossing

There is a knife edge effect when the moving vehicle obstruct the LOS.

The knife edge effect is dominant and the dip in the RSRP level due to blockage is more deep in case of small TX-RX separation.

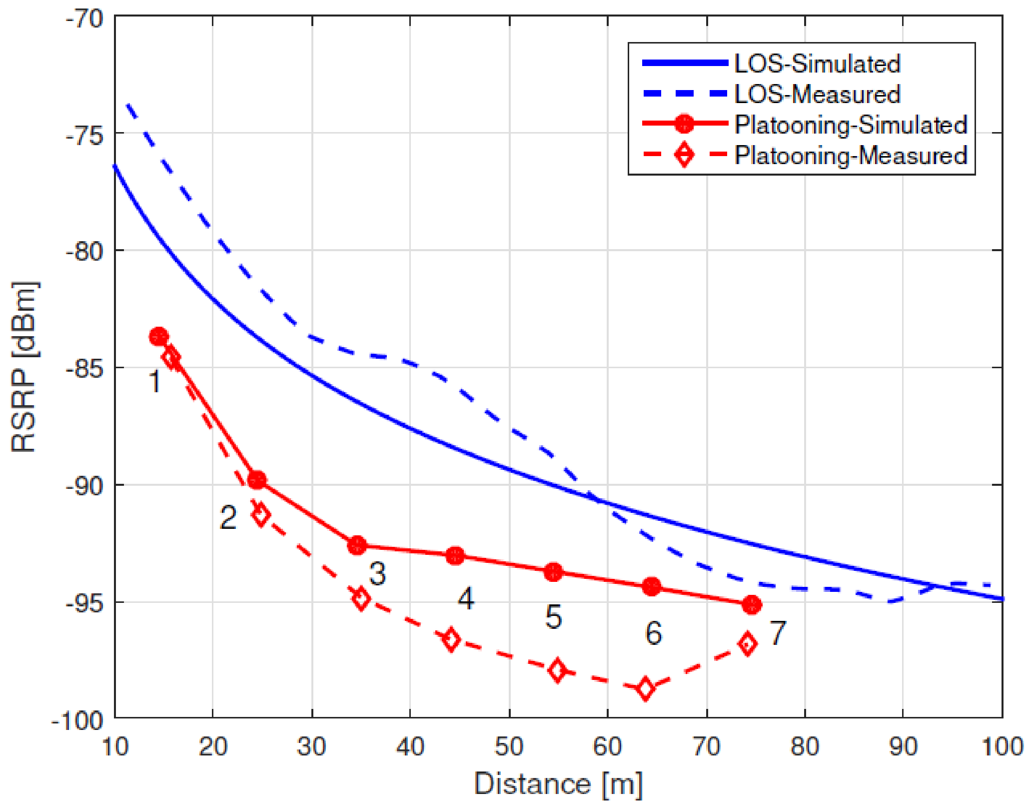
The RSRP level difference between the maxima and minima is **12.3, 10.4, 9.7, and 9 dB** for 10, 15, 30 and 50 m TX-RX separation, respectively.



Results: Platooning

The first blocking vehicle mainly adds the blockage effect whereas the rest of the vehicles contribute only marginally to the blockage loss.

The measured RSRP level differences are **6.7 dB, 3.5 dB, and nearly 1.8** dB and the simulated RSRP level differences **are 6.2 dB, 2.8 dB, and nearly 0.5 dB** between 1st and 2nd, 2^{nd} and 3rd, and 3rd and 4th vehicle, respectively.



Conclusion

- It was found that in the case of a single vehicle obstruction, the location of the obstructing vehicle relative to the TX is essential.
- Results indicate that the RSRP level better than -100 dBm can be obtained even with the 100 meters distance between the TX and RX while there is a single obstructing vehicle located at a distance of at least one meter from the TX.
- While moving away from the TX the blockage attenuation due to the obstructing vehicle becomes flat after a certain break point distance.
- While a moving vehicle intersects the LOS connection between vehicles at the road crossing the RSRP level difference between the maxima and minima is 12, 11, 10, and 8 dB for 10, 15, 30 and 50 m TX-RX separation, respectively.
- In case of platooning, the major impact of blocking is due to the first blocking vehicle. The impact of additional vehicles in the platoon less significant and it marginally increases the blockage loss.
- Results suggest that 39 GHz frequency has great potential for V2V communications.

Thanks