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Abstract: This document deals with wireless communication links required between access points in the wagon and the transceivers of passenger's user equipment or sensors inside a wagon. 60 GHz and 300 GHz channel sounder measurement in an intra-wagon scenario are presented. The results are compared with ray tracing simulations. Then, the validated RT simulator is used to conduct extensive simulations with different transmitter and receiver deployments.

Purpose: Information of the Technical Advisory Group THz

Channel Characterization for Intra-Wagon Communication at 60 and 300 GHz Band

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Outline

- Motivation
- Validation of RT simulator through channel sounding measurement in an HST wagon
- Extensive RT simulations and Tx deployments
- Conclusion and future work

Smart rail mobility

[2]

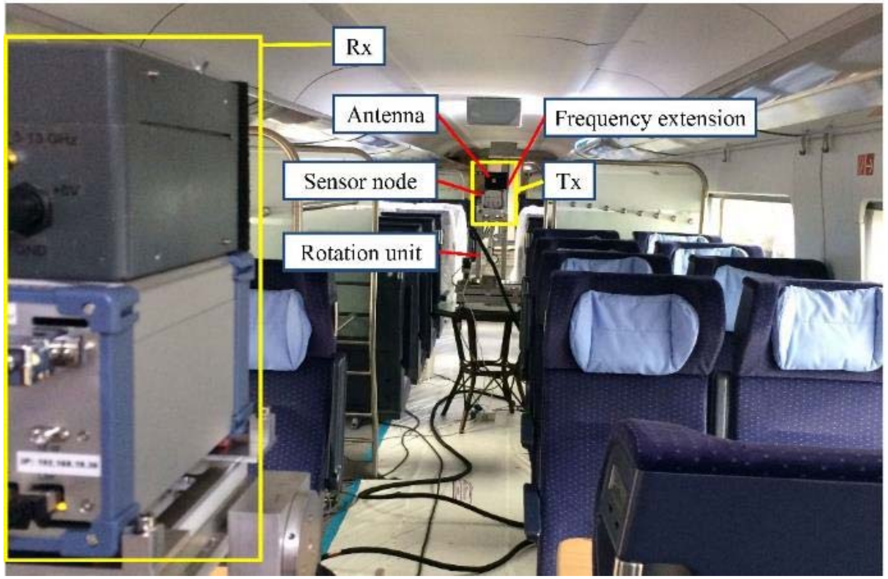
Characteristics of smart rail mobility:

- High date rate access for wireless services, hundreds of Gbps
- Increased link capacity
- Large bandwidth requirement
- Potential applications of THz?

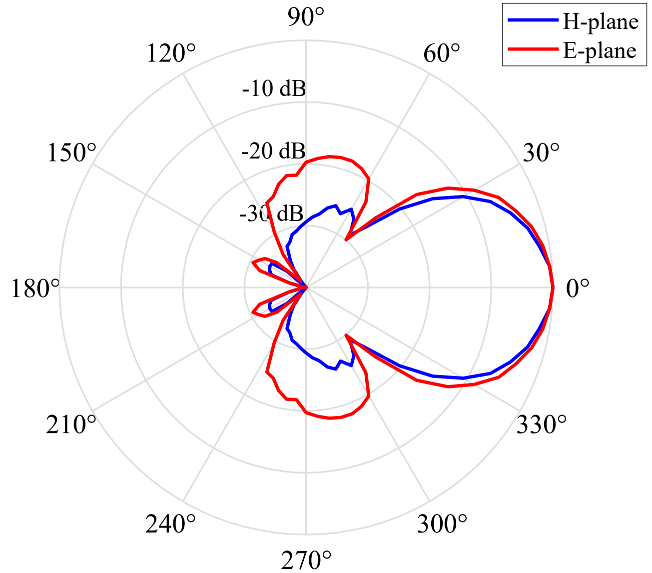
Approach

- To investigate the basic channel characteristics relevant for the wireless communication in intra-wagon scenario, we have carried out some first channel measurements in the environment of high speed trains.
- The measurements have been performed using the TUBS channel sounder [3].
- The mesurements can be used to calibrate a ray-tracing model applicable to simulate different cases for feasible Tx deployments.

Measurement Campaign



Measurement campaign in a real high-speed train wagon

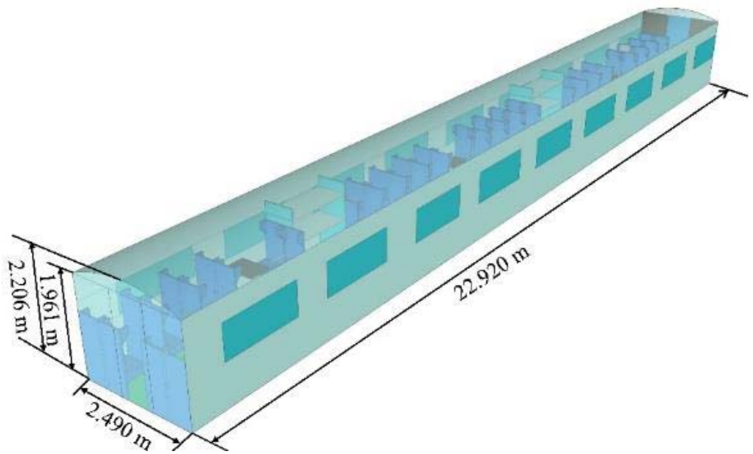


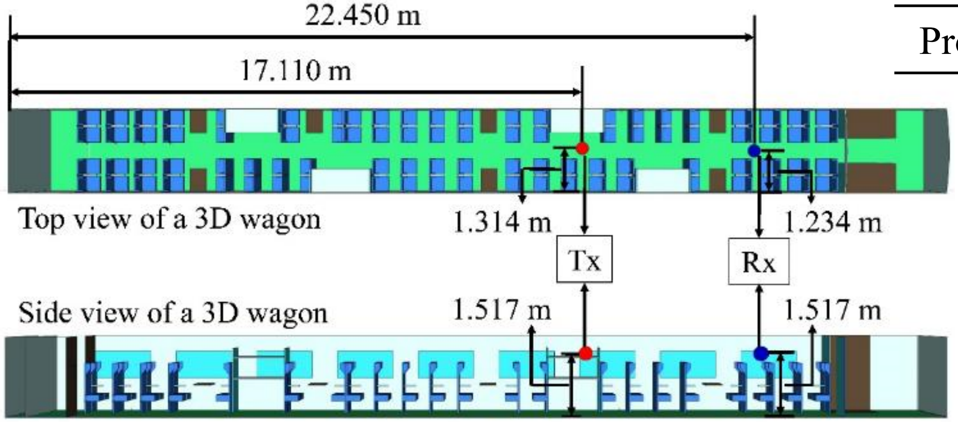
2D pattern of Tx and Rx antennas in the measurement

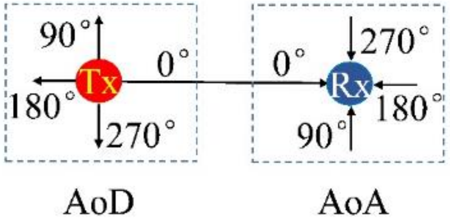
Measurement system	Bandwidth	Central frequency	Antenna type	Antenna gain	Antenna HPBW	Angular resolution
	8 GHz	304.2 GHz	Directional antenna	15 dBi	30°	10°

Validation of Geometry and Identification of Main Propagation Mechanisms

Antenna type	Omni-directive
Polarization	Vertical
Antenna gain	0 dBi
Tx power	0 dBm
Tx/Rx locations	Aisle
Tx/Rx heights	1.517 m
Frequency range	300-308 GHz
Frequency points	3200
Propagation mechanism	LOS+ 1st order of reflection

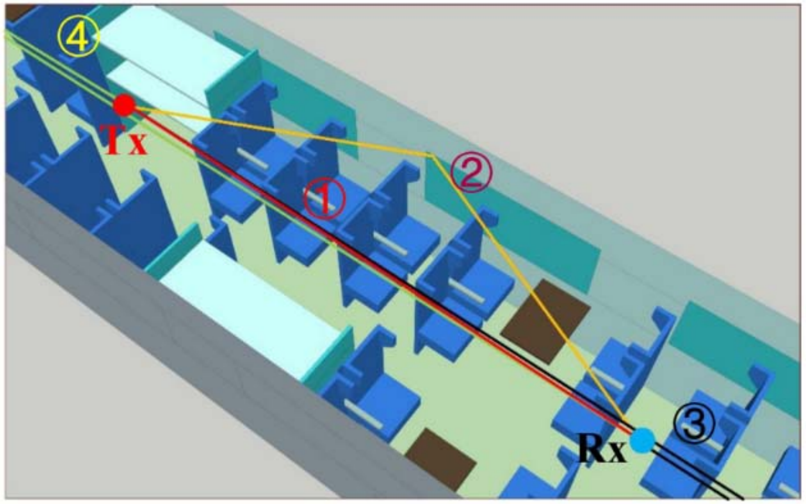






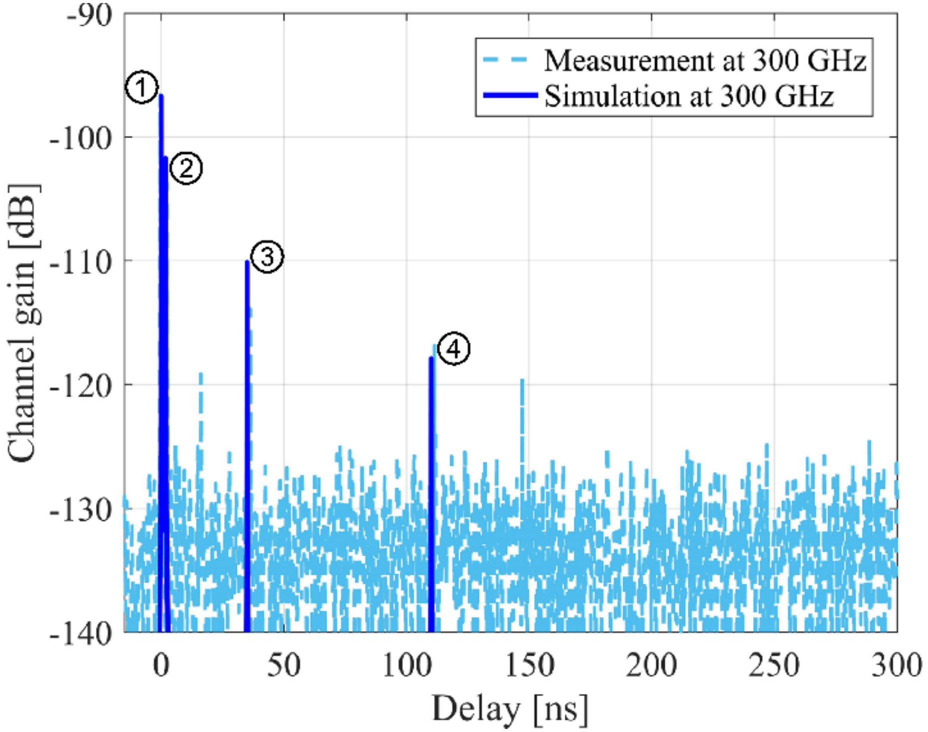
3D HST model reconstructed according to the real sizes and the coordinates of the Tx and Rx.

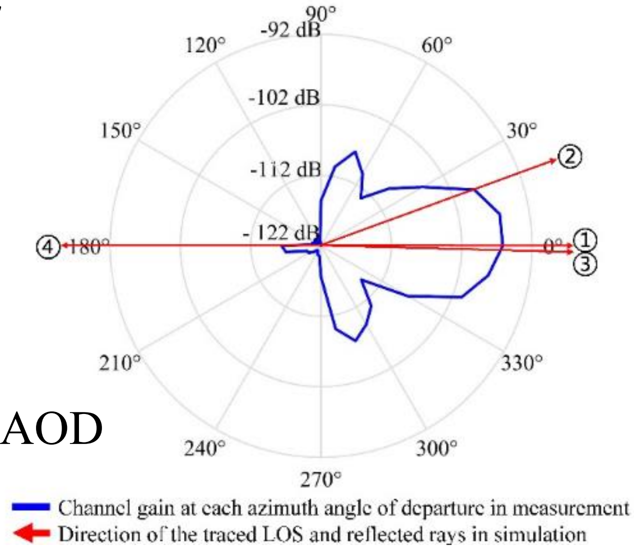
Validation of Geometry and Identification of Main Propagation Mechanisms



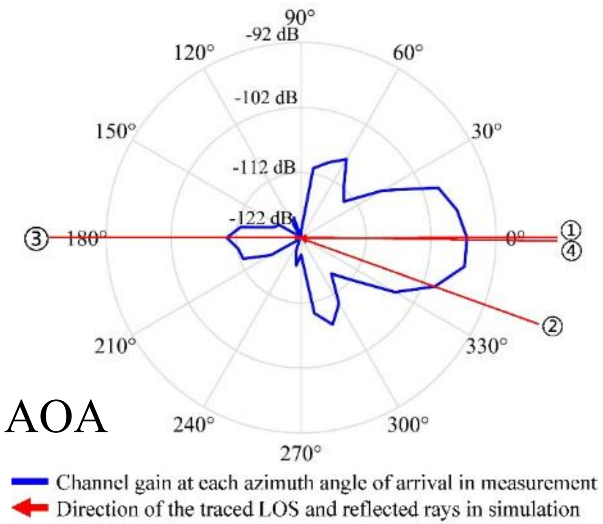
EM Property of materials in RT				
	Before calibration		After calibration	
Material	ε′	ε″	ε′	ε″
Glass [4]	6.760	0.442	4.20	0.342
Metal	1.000	1E+07	1.000	1E+07
Frequacy extension	Blocking loss:0 dB		Blocking loss: 4 dB	

Traced Rays Mapped on the Measured Results





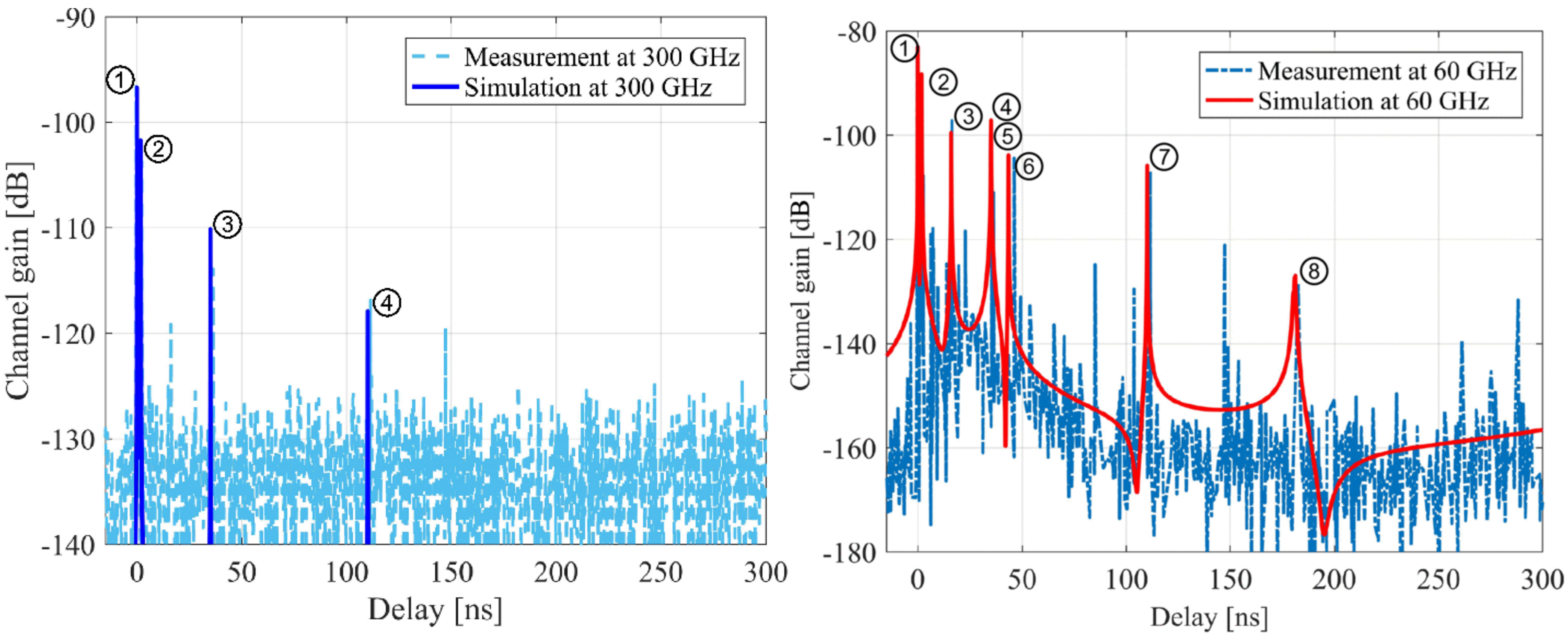
AOD



AOA

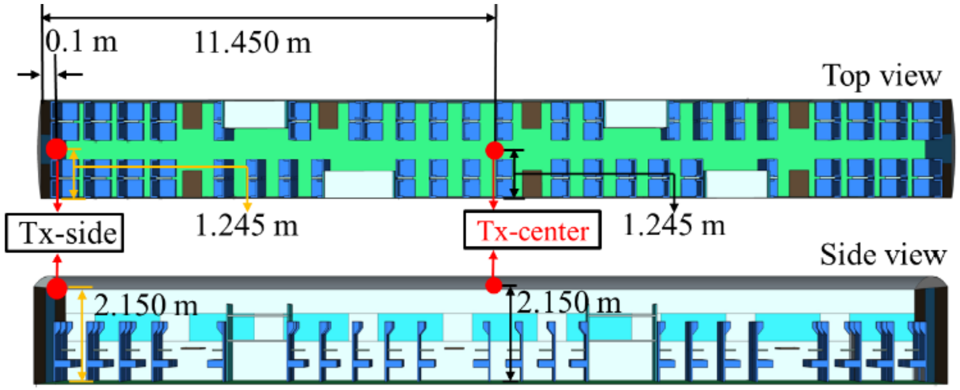
Path index	1	2	3	4
AE of gain [dB]	0.00	2.00	0.40	1.00
AE of delay [ns]	0.00	0.56	0.26	1.40

Comparison with Measuremnets and Simulation at 60 GHz



- Although more multi paths are observed at 60 GHz, still multi path propagation at 300 GHz can not be neglected

Extensive RT Simulations and Tx Deployments



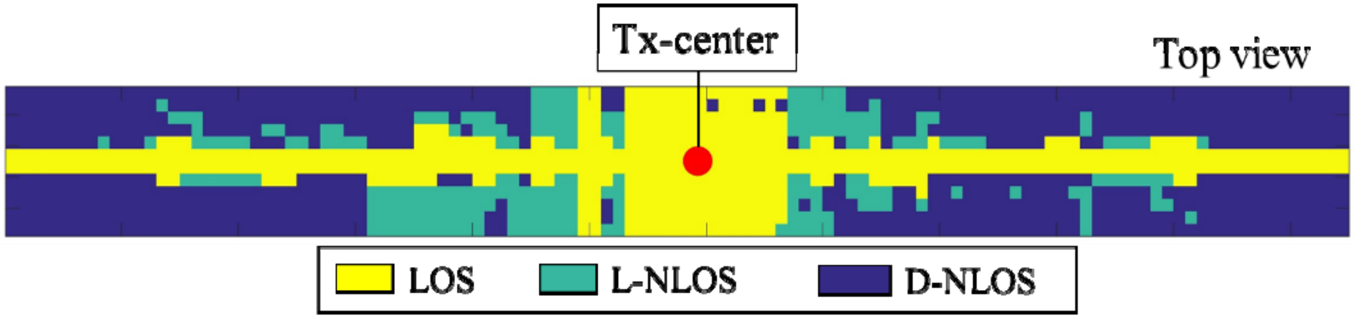
Tx position of the Tx-center deployment and the Tx-side deployment in extensive RT simulations.

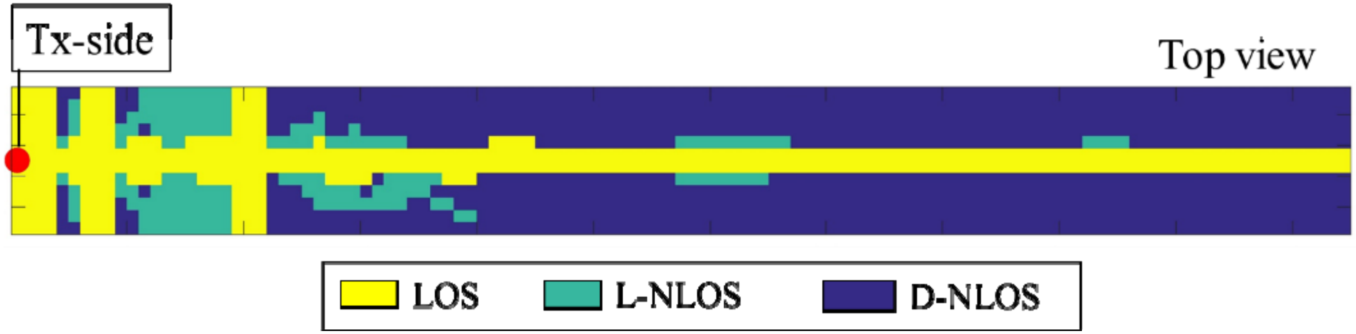
EM Property of materials in RT simulation			
Object	Material	ε'	ε''
Wagon body	Metal	1.000	10^7
Windows	Glass	4.200	0.342
Floor	PVC [5]	2.430	0.060
Tables	Wood [6]	1.689	0.070
Chair surface	Nylon [7]	2.989	0.047

Simulation setups for RT validation	
Antenna type	Omni-directive
Polarization	VV, VH, HV, and HH
Antenna gain	0 dBi
Tx power	0 dBm
Tx location	Tx-center, Tx-side
Rx height	0.8 m
Rx spatial separation	0.01 m
Frequency range	300-308 GHz
Frequency points	3200
Propagation mechanism	LOS, reflection up to 1st order, and scattering

Propagation Regions and Tx Deployments

Region classified	LOS	1st-order reflection
LOS region	✓	
L-NLOS region	✗	✓
D-NLOS region	✗	✗





Channel Parameters of Intra-wagon Scenario with Two Tx deployments

Case	Tx-center			Tx- side		
Propagation zone	LOS	L-NLOS	D-NLOS	LOS	L-NLOS	D-NLOS
A	21.66	22.12	9.48	20.68	25.81	35.05
B	79.77	82.16	101.42	79.95	78.96	76.04
σ_{SF} [dB]	5.59	5.54	8.23	5.61	5.14	7.61
μ_{KF} [dB]	6.90	0.06	-13.60	4.27	0.22	-13.57
σ_{kF} [dB]	8.84	5.11	15.35	7.98	5.26	12.18
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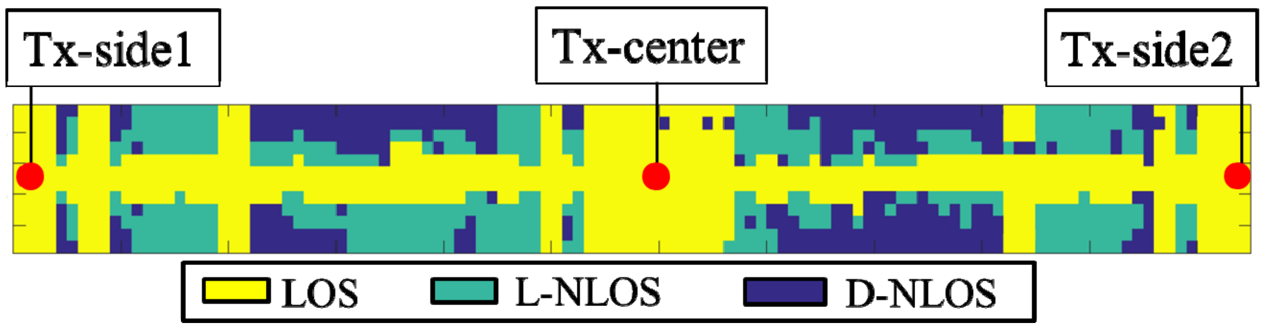
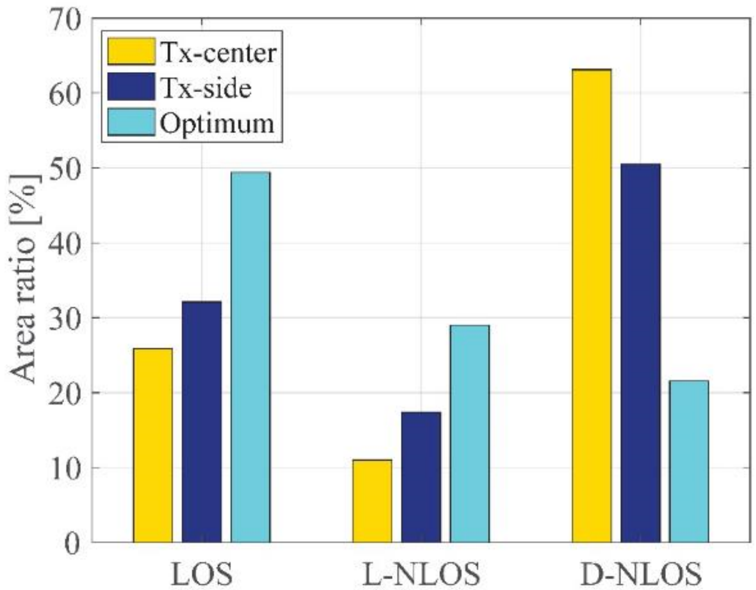
The first-order reflection becomes almost the only chance to build the link if the LOS is blocked. the RT simulation results imply that the existence of the first-order reflection indeed determines the channel characteristics.

Optimum Tx Deployment Strategy





Area ratios	Tx-center	Tx-side	Optimum
LOS	25.9%	32.1%	49.4%
L-NLOS	11.0%	17.4%	29.0%
D-NLOS	63.1%	50.5%	21.6%

Conclusion and Future Work

- **Conclusion:**
  - Measurements for Intra-wagon scenario at THz band for the first time
  - RT simulation
    - Validation through 3D model reconstruction
    - Calibration of the EM properties of the main materials
  - Extensive RT simulations with multiple Rx locations and Tx deployments
- **Future Work:**
  - To add the passengers into the wagon, and therefore, more complete evaluation and further study become possible.

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