Vehicular-to-Pedestrian Channel Models

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Abstract

- Protect vulnerable road users with reliable vehicle-to-pedestrian communications to reduce accidents
- Accurate vehicle-to-pedestrian channel models to design reliable vehicle-to-pedestrian communications
- Comparison of V2X channels
- Related work on vehicle-to-pedestrian channel models
- V2P path loss models

Motivation

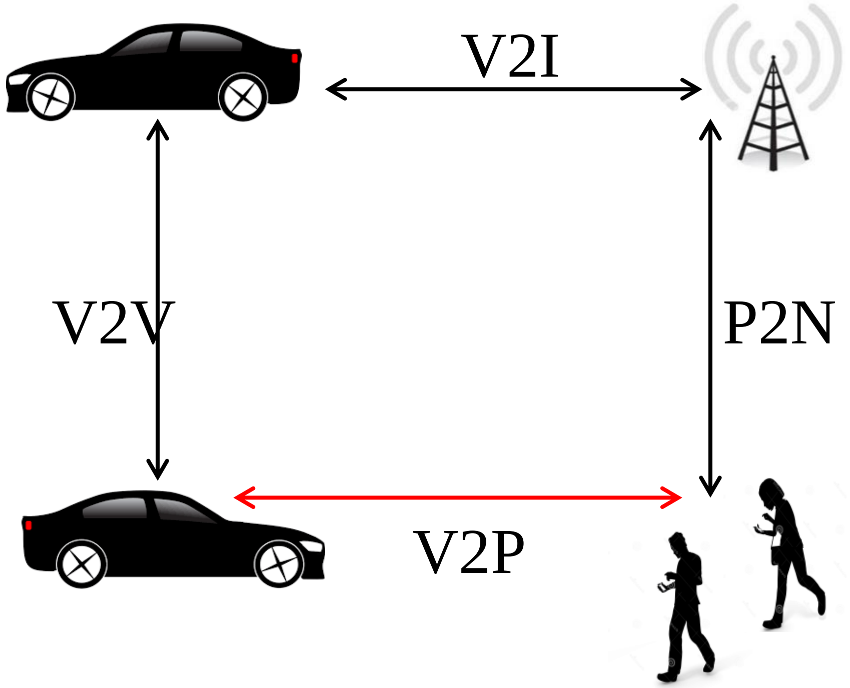
- Vulnerable road users account for 30% of road fatalities in Europe.
- Sensor-based crash avoidance systems suffer from limitations.
- 360 degree awareness by direct exchange of information between vehicles and pedestrians

Motivation

Accurate V2P channel models required for reliable communication system

Extensive work has been done for

- vehicle-to-vehicle (V2V)
- vehicle-to-infrastructure (V2I)
- person-to-network (P2N)



V2P channel models only 3 recent papers

[2] @ 1.85 GHz, [3] @ 3.8 GHz, [4] @ 5.2 GHz

Much work to be done!

Comparison of V2X Channels

- **V2V, V2I and V2P:** Different antenna height, mobility pattern, and propagation scenarios
  ➔ different propagation aspects
- **Nonstationary V2V and V2P channels:**
  Time-variant channel statistics due to moving TX, RX, and dynamic environment
- **Signal attenuation:** Strong spatio-temporal correlations

- **Stochastic channel models [2]:** Large-scale VANET simulators e.g., ns3 and OMNet++

➔ Average packet delivery ratio, but difficult to account for geometry dependent correlations

- **Geometry-based stochastic channel model (GSCM) [3], [4]:** Link level and system level simulations in particular for safety-relevant applications such as platooning, automated and remote driving

➔ Geometry dependent packet outages, but higher complexity

Related Work: 3GPP 5G V2X Channel Models & Evaluation Methodology

3GPP 5G V2X use case groups [5]:

- Vehicle platooning
- Extended sensors
- Automated driving
- Remote driving

➔ **5G V2V performance evaluation for use case groups:**
Adapted parameter sets of GSCM [6] for below and above 6 GHz

➔ **V2P and V2I models assume same parameters as V2V**
Realistic?

Related Work: V2P Channel Models

V2P stochastic channel models (SCM) @ 1.85 GHz [2]

- In-vehicle to pedestrian
- LOS/NLOS and in pocket/next to face
- Path loss, shadow, small scale, and multi scale fading parameters based on measurements
- SCM with combination of Weibull and Rayleigh distributions

V2P channel models @ 3.8 GHz [3]

- Only LOS evaluated
- RX antenna fixed on long wooden stick ➔ untypical, best case pedestrian scenario
- Two-ray path loss model < 32 meters

V2P Path Loss Models

Based on [4] @ 5.2 GHz:

- **Line-of-Sight (LOS):**
  - **Static pedestrian:** Two-ray ground reflection path loss model
  - **Moving pedestrian, texting:** Log-distance path loss model + increased shadow fading
- **NLOS due to other nearby pedestrians:**
  5-10 dB additional path loss due to shadowing
- **NLOS due to parked vehicles:**
  Multiple knife edge diffraction model
- **NLOS due to buildings:**
  Log-distance path loss model (propagation through building) + knife edge diffraction (+ reflections/scattering)

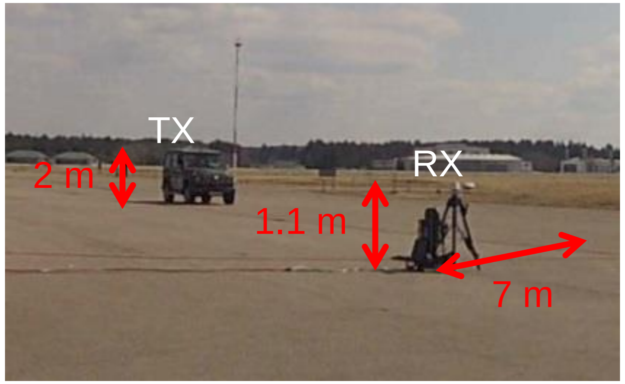
V2P Path Loss Models: LOS – Static Tripod

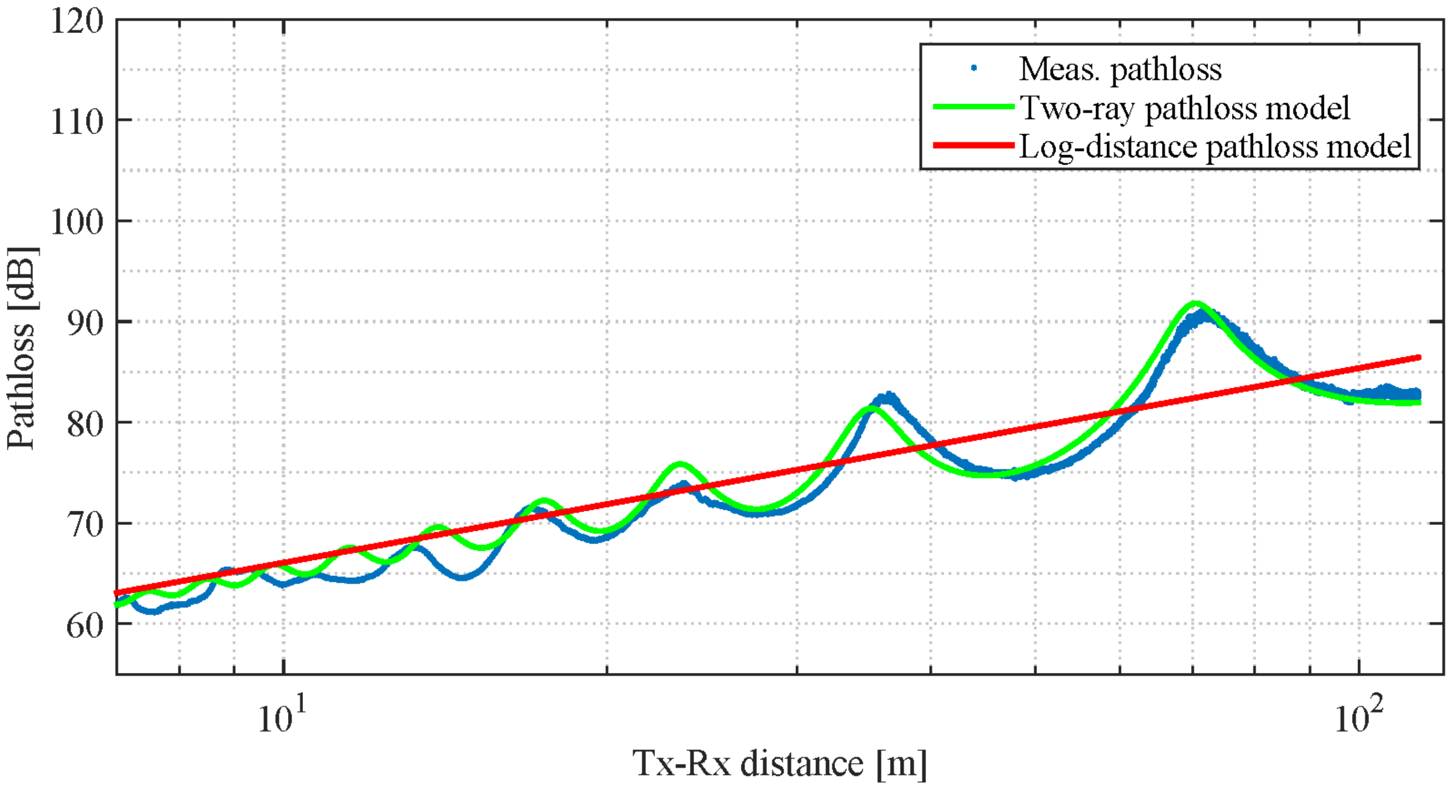
Log-distance path loss model

- Reference distance d_0 = 1 m
- Loss at d_0 $P_L(d_0)$ = 46.77 dB
- Path loss exponent n = 2.03

Log-normal shadow fading

- Standard deviation σ = 3.23 dB





V2P Path Loss Models: LOS – Moving Pedestrian, Texting

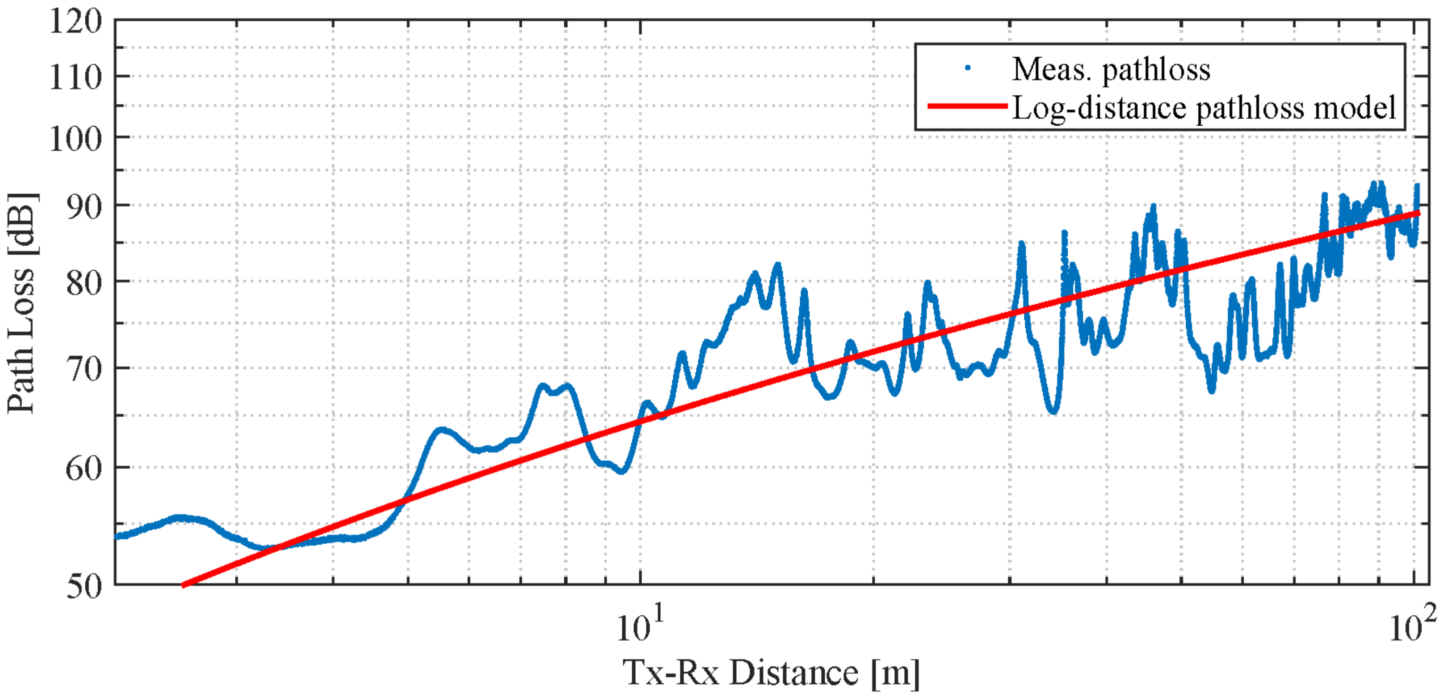
Pedestrian antenna at low elevation and close to body → self-body shadowing

Log-distance path loss model

- Reference distance d_0 = 1 m
- Loss at d_0 $P_L(d_0)$ = 40 dB
- Path loss exponent n = 2.44

Log-normal shadow fading

- Standard deviation σ = 5.47 dB



V2P Path Loss Models: NLOS, Crowd Shadowing

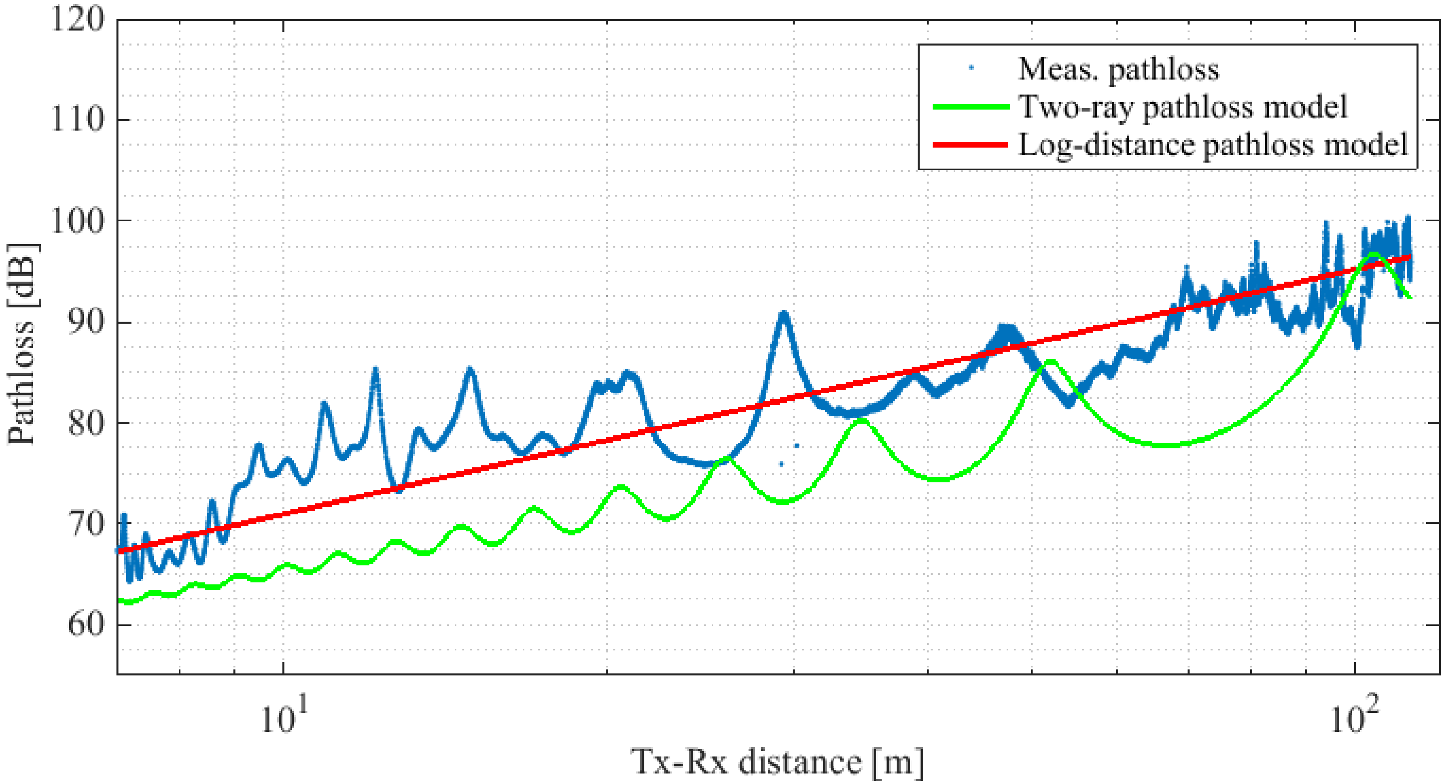
Nearby other pedestrians → 5-10 dB additional path loss due to shadowing

Log-distance path loss model

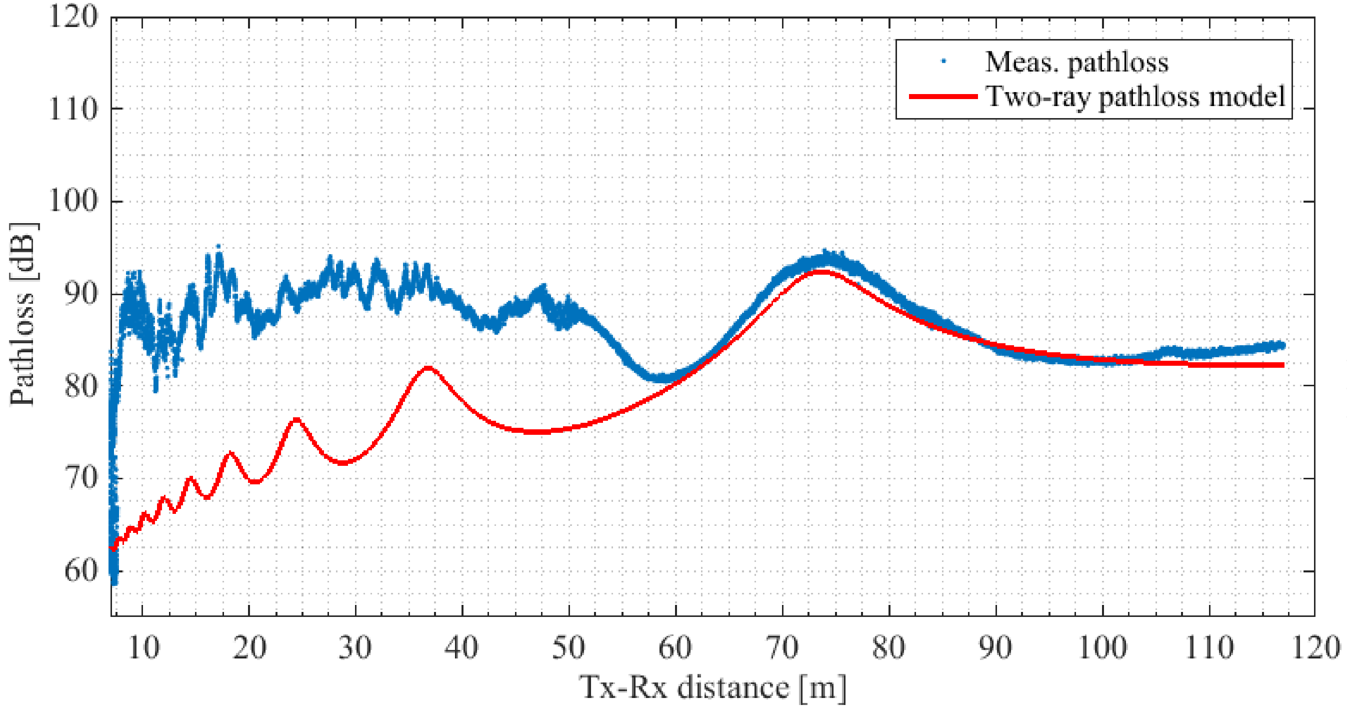
- Reference distance d_0 = 1 m
- Loss at d_0 $P_L(d_0)$ = 67 dB
- Path loss exponent n = 1.26

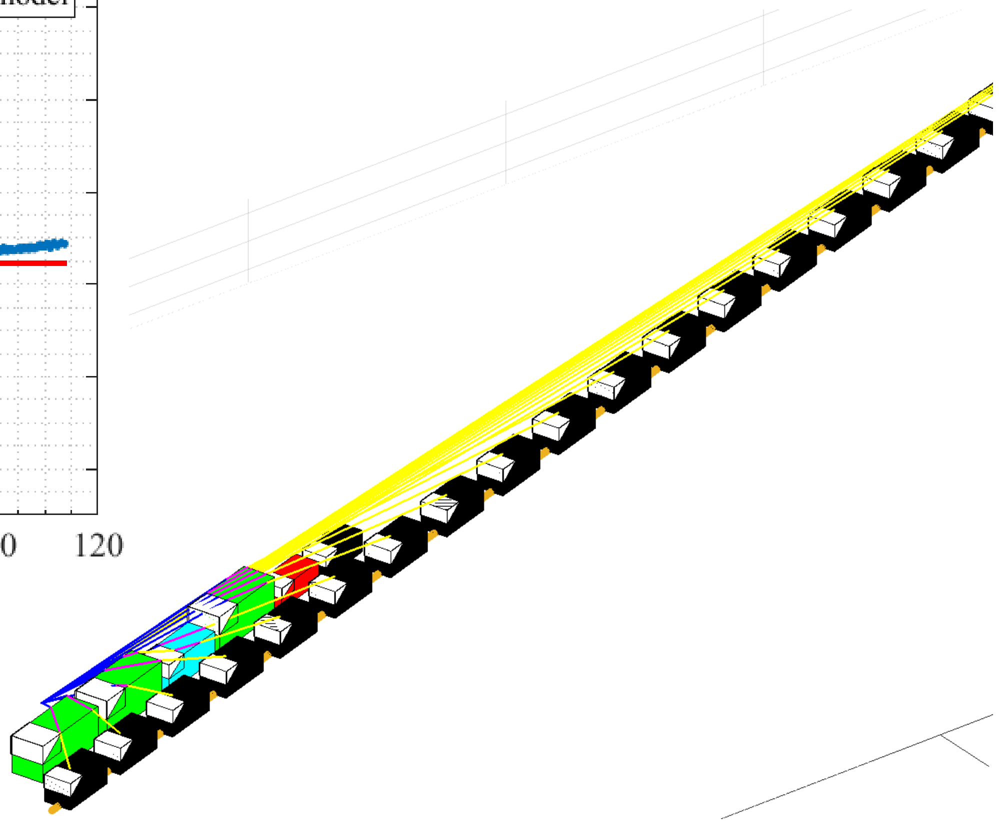
Log-normal shadow fading

- Standard deviation σ = 3.35 dB



V2P Path Loss Models: Parking Cars, NLOS, Diffraction – First Results





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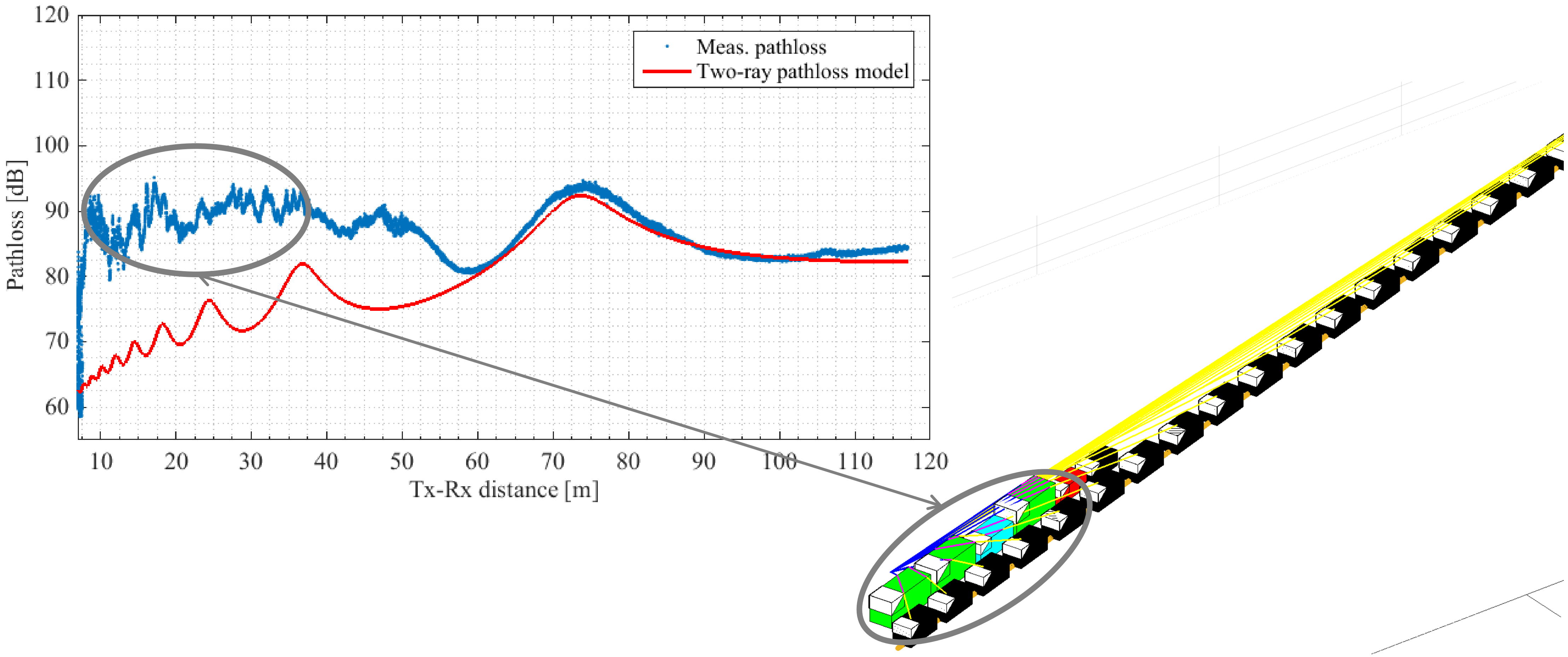

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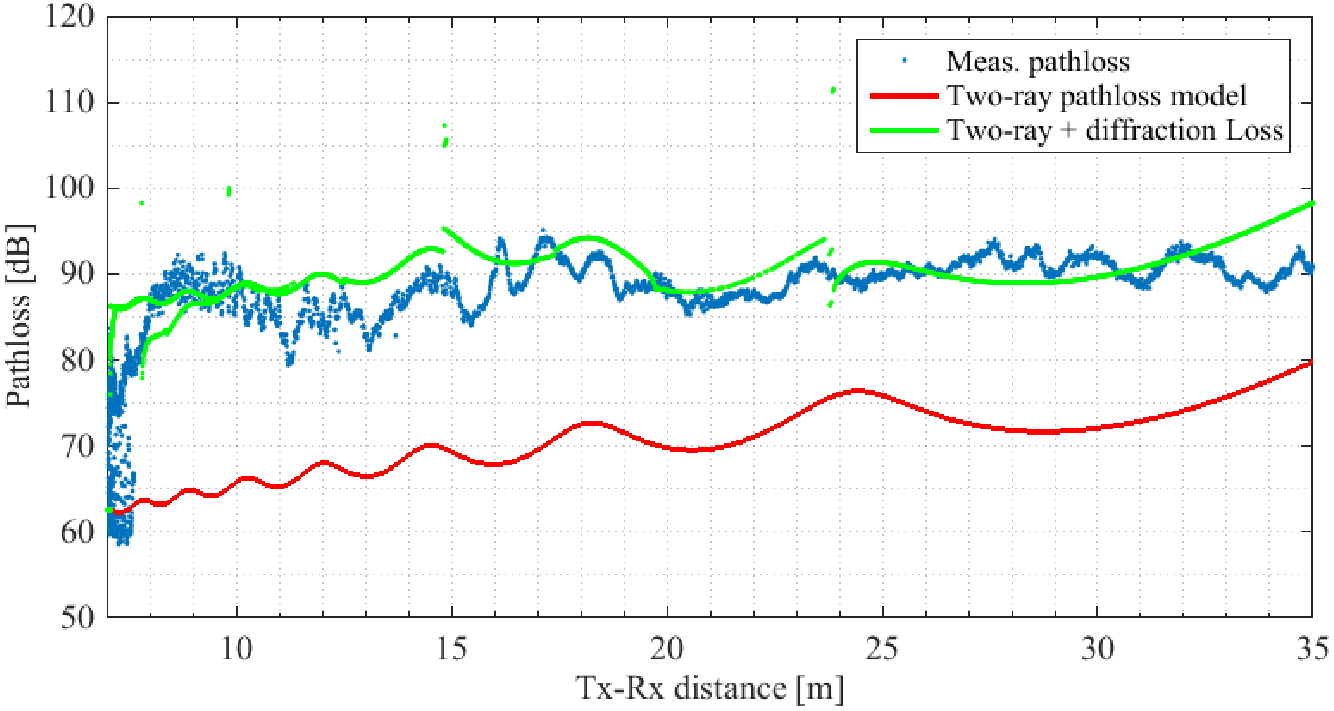
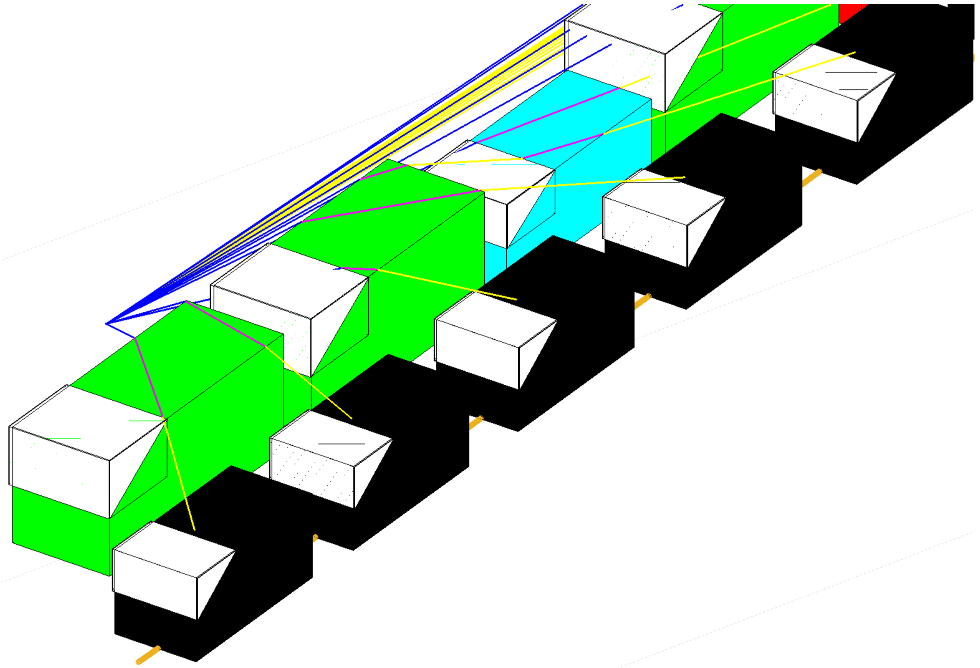


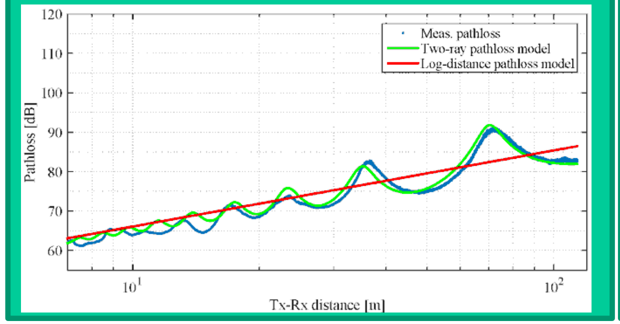


Multiple knife-edge diffraction model + two-ray path loss model

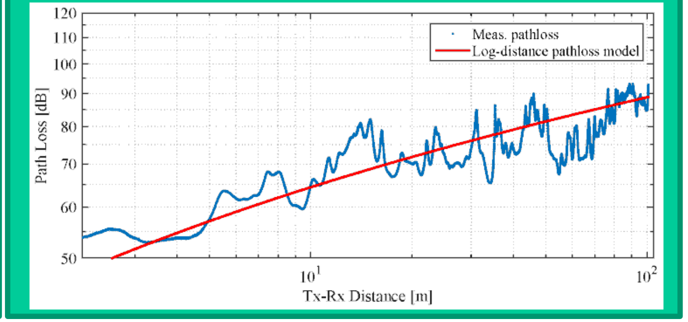
Conclusions

- **V2P channel different from V2V/V2I channel ➔ 3GPP 5G approach realistic?**
- **V2P channel models:** Recent papers [2] @ 1.85 GHz, [3] @ 3.8 GHz, [4] @ 5.2 GHz
- **V2P path loss models based on [4]:**

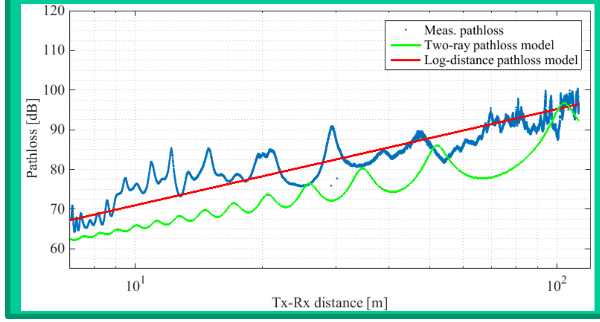
LOS static pedestrian: Two-ray pathloss model



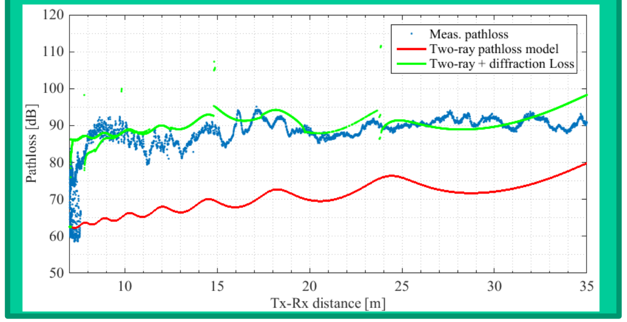
LOS moving pedestrian, texting: increased shadow fading



NLOS due to other nearby pedestrians: 5-10 dB additional path loss due to shadowing



NLOS due to parked vehicles: Multiple knife edge diffraction model



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LOS static pedestrian: Two-ray pathloss model	**LOS moving pedestrian, texting:** increased shadow fading	**NLOS due to other nearby pedestrians:** 5-10 dB additional path loss due to shadowing	**NLOS due to parked vehicles:** Multiple knife edge diffraction model

Accurate V2P channel models → Design reliable V2P communications → Protect vulnerable road users

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[5] 3GPP (2018) Study on evaluation methodology of new Vehicle-to-Everything V2X use cases for LTE and NR;(Release 15). TR 37.885, V15.0.0 (2018-06).

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[6] 3GPP (2018) Study on channel model for frequencies from 0.5 to 100 GHz (Release 15). TR 38.901, V15.0.0 (2018-06).