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Abstract: This presentation shows propagation measurements for beyond 5G vehicular communications at 300 GHz. The measurement setups, the general methodology and first results are presented. Side reflection measurements indicate strong multipath propagation on a multi-lane road and transmission measurements show that the vehicle transparency notably varies at different heights. Finally, it is demonstrated that under-vehicle propagation significantly contributes to the vehicular channel.

Purpose: Information of the Technical Advisory Group THz

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Low THz Band Propagation Measurements for Beyond 5G Vehicular Communications

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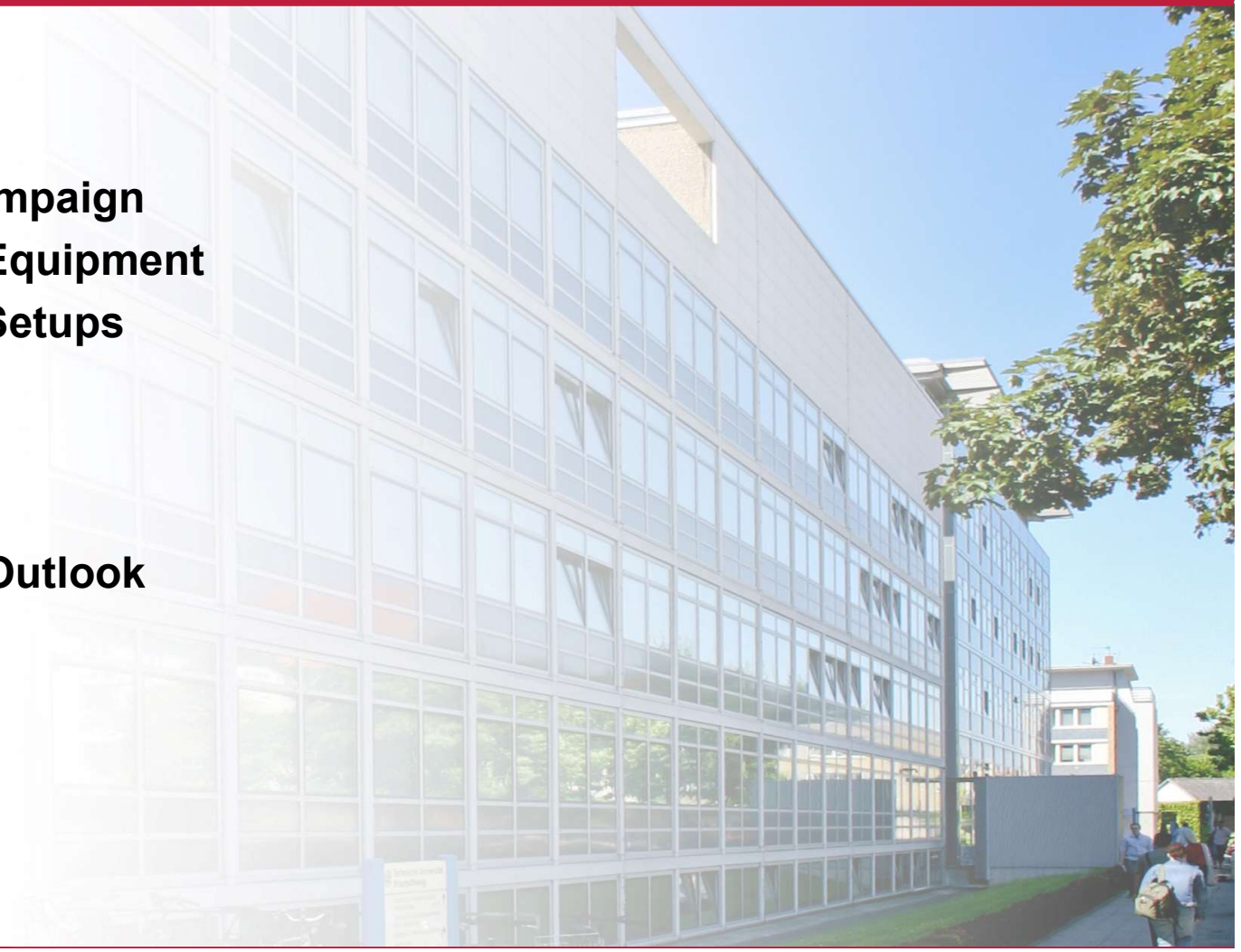
16.07.2019

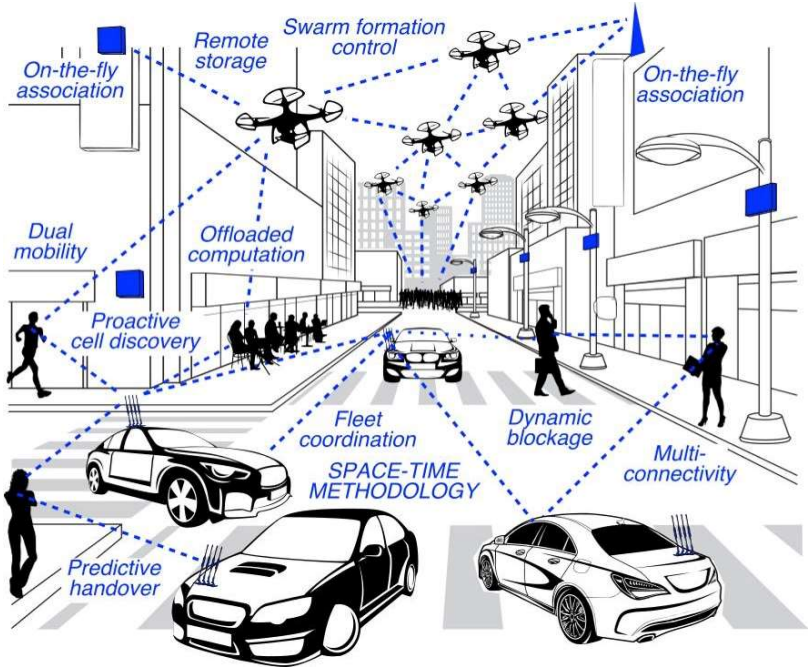
Outline



1. Motivation
2. Measurement Campaign
   - Measurement Equipment
   - Measurement Setups
3. First Results
4. Conclusion and Outlook

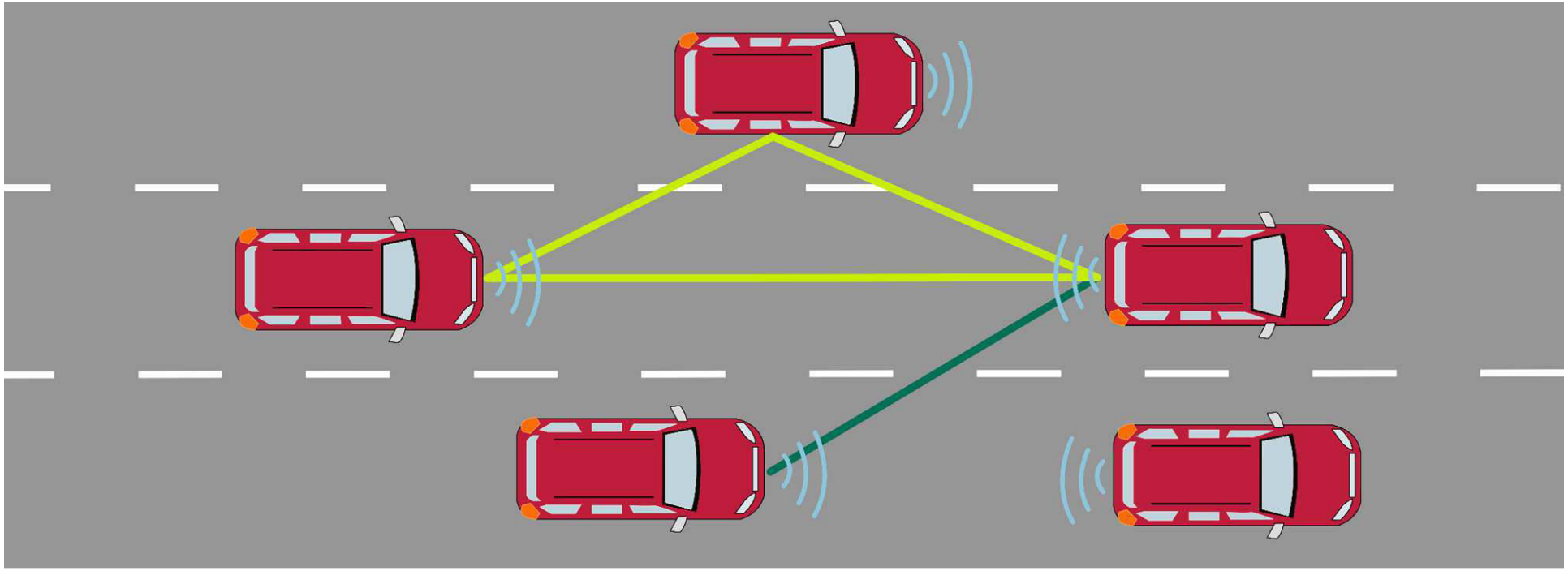
mmWave 5G/5G+ Vehicular Systems

- Traffic volume generated with Gbit/s
  - Sensed data
  - Entertainment
  - Ultra-reliable low-latency communication (URLLC)
    - Collective autonomous driving
- Radar resolution
  - cm/mm-scale resolution



[1] S. Andreev, V. Petrov, M. Dohler and H. Yanikomeroglu, "Future of Ultra-Dense Networks Beyond 5G: Harnessing Heterogeneous Moving Cells," in IEEE Communications Magazine, vol. 57, no. 6, pp. 86-92, June 2019.

Vehicular Radar and Communications over 300 GHz



- Complex propagation scenarios
- Define representative setups

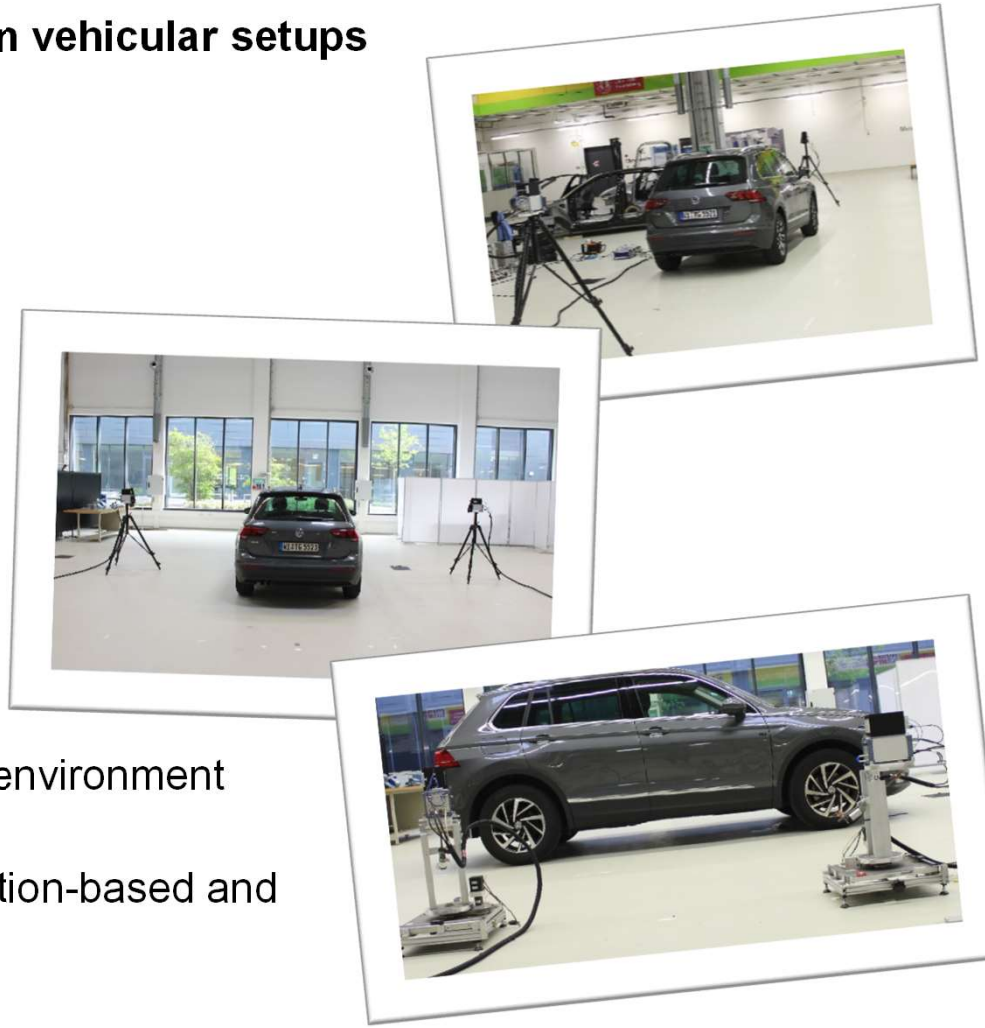
Measurement Campaign

Propagation measurements at 300 GHz in vehicular setups

- Point-to-point measurements (SISO)

Selected setups

- Reflexion from the vehicle body
- Vehicle transparency
  - Vehicle body attenuation
  - Front / rear window propagation
  - Side window propagation
- Under-vehicle propagation



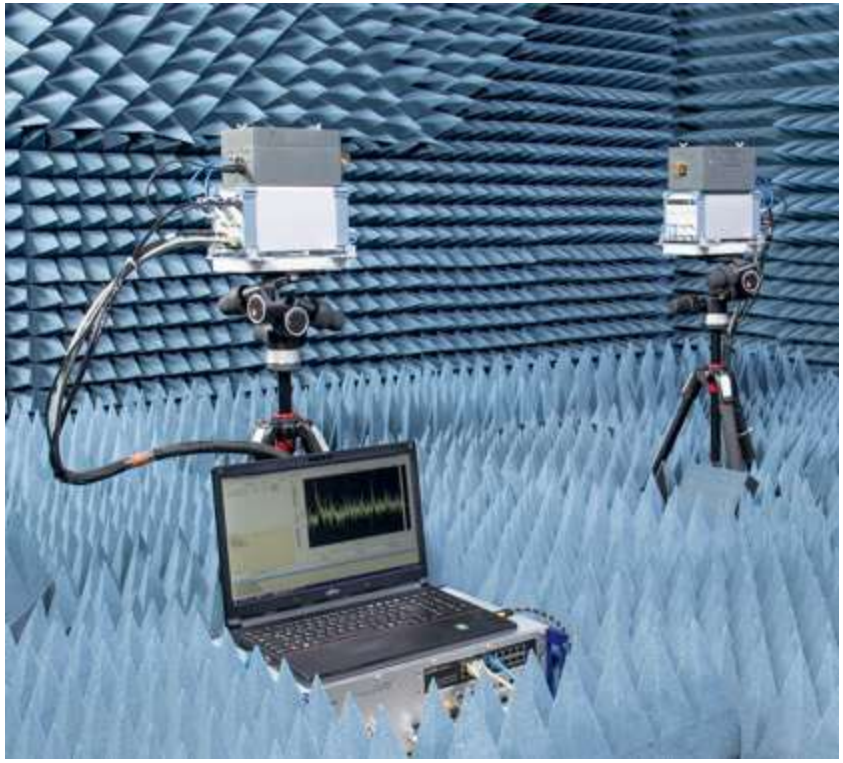
Goal

- Preliminary understanding of vehicular environment specifics at 300 GHz
- Reference data for calibration of simulation-based and analytical propagation models

Measurement Equipment (1)

M-sequence sub-mmWave Channel Sounder

- Correlation based approach to measure time-variant impulse response
- PRSG generates M-sequence of 12th order
- Clock frequency 9.22 GHz
- Carrier frequency 304.2 GHz
- Approx. Bandwidth 8 GHz
- Longest measureable delay 444.14 ns

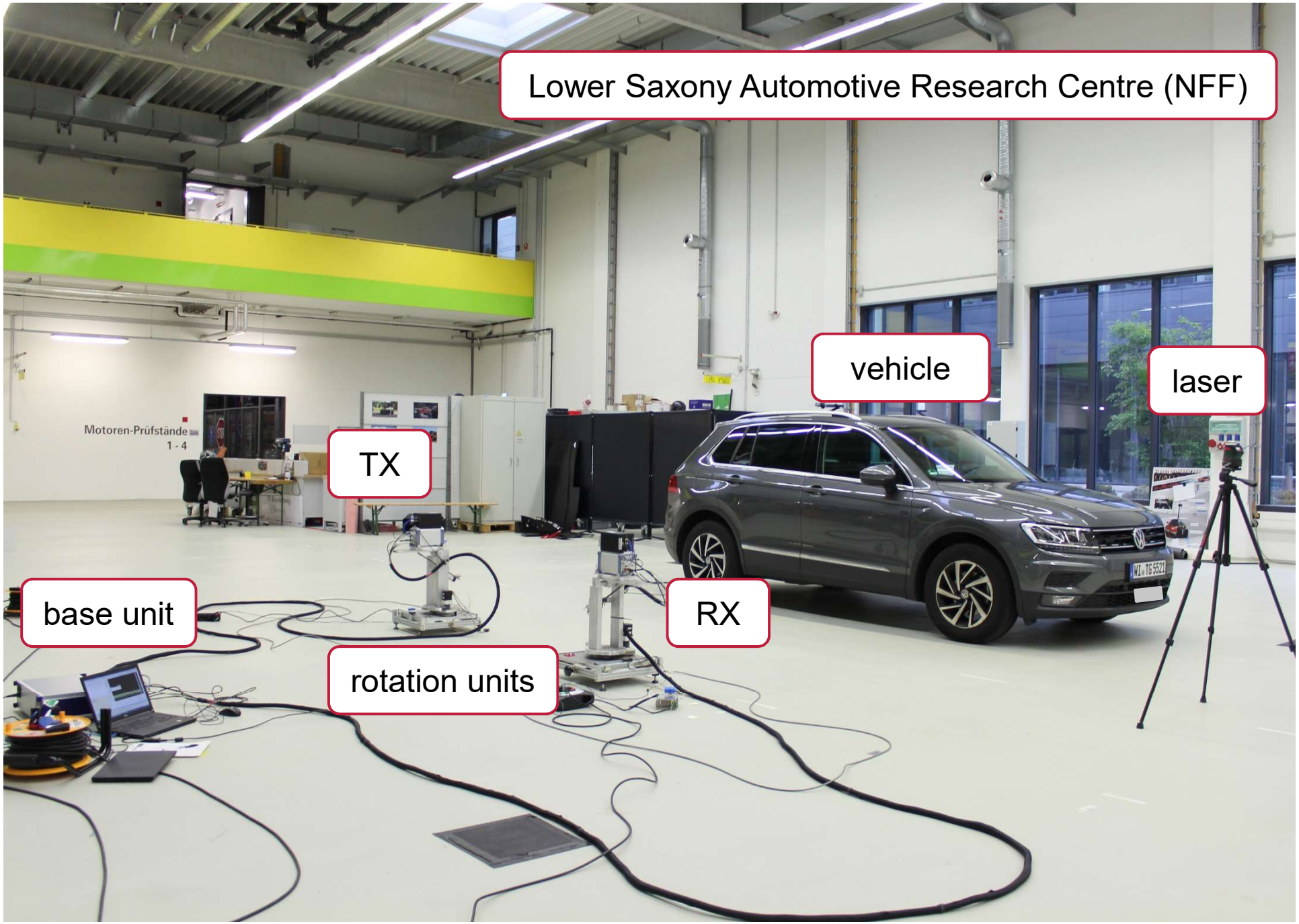


For more information see: S. Rey, J. M. Eckhardt, B. Peng, K. Guan and T. Kürner, "Channel sounding techniques for applications in THz communications: A first correlation based channel sounder for ultra-wideband dynamic channel measurements at 300 GHz," *2017 9th International Congress on Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT)*, Munich, 2017, pp. 449-453.

Measurement Equipment (2)

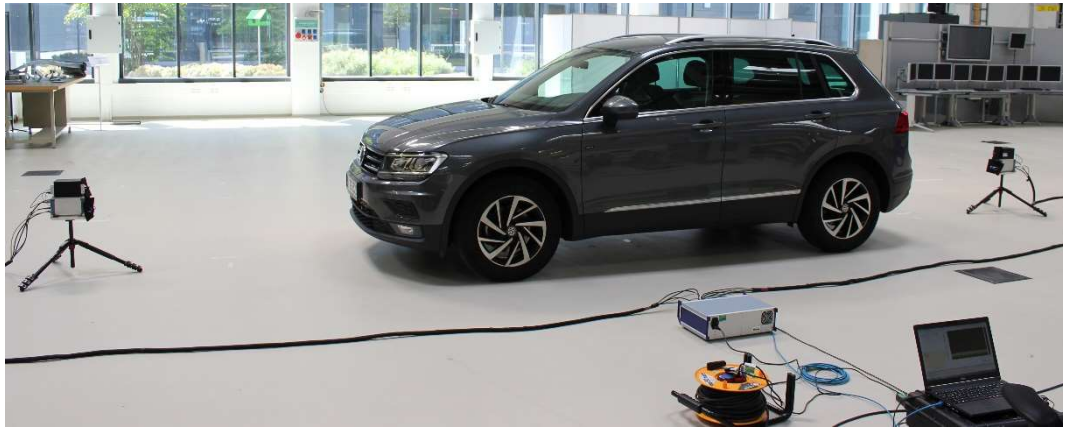
Custom-made rotation units

- Scan the whole horizontal plane
- Programmable starting and stopping angle
- Selectable step size


Lower Saxony Automotive Research Centre (NFF)
vehicle
laser
TX
RX
base unit
rotation units
Motoren-Prüfstände
1 - 4

Scenarios of Interest

a) Side reflection

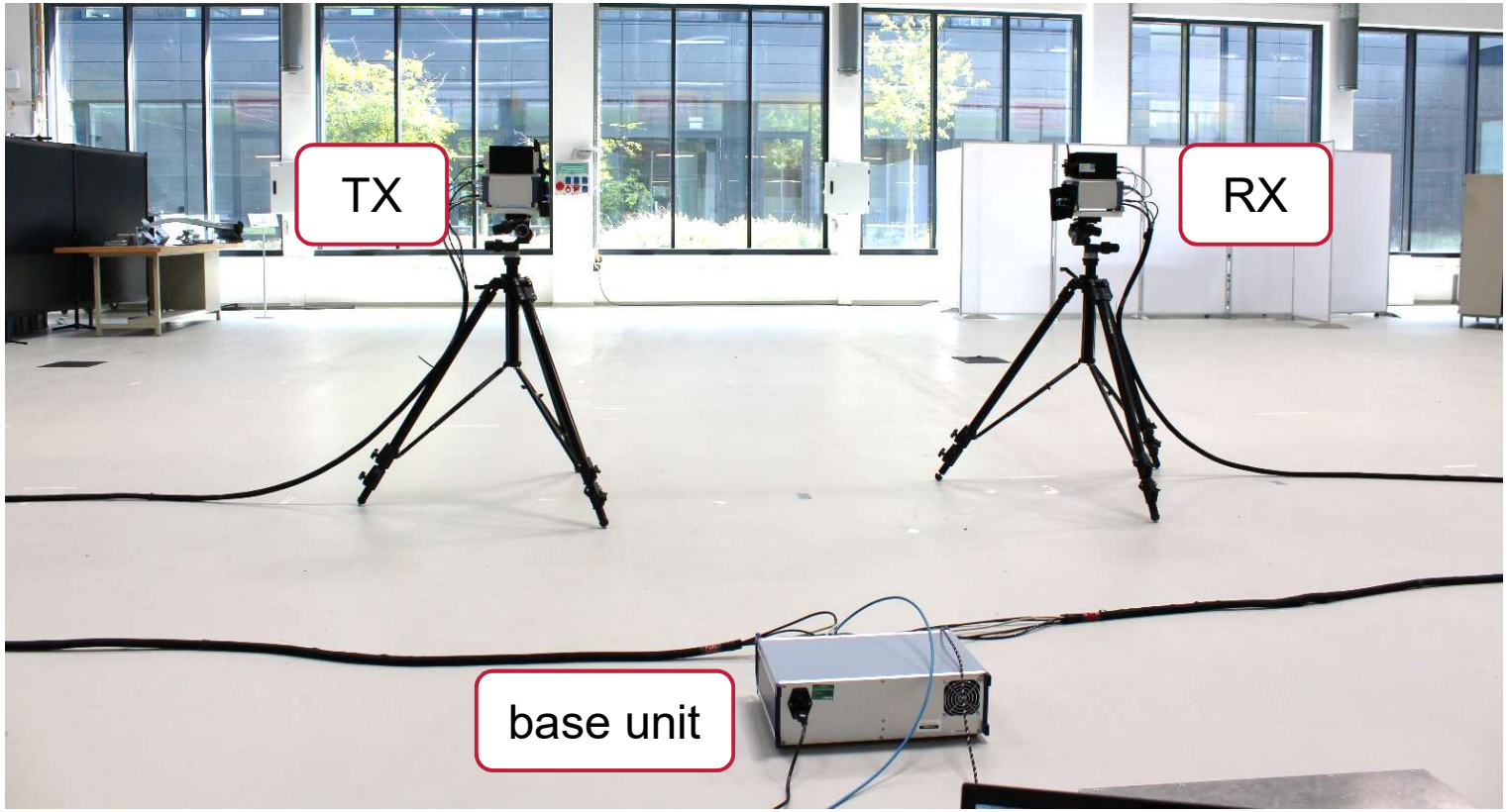


b) Under-vehicle propagation

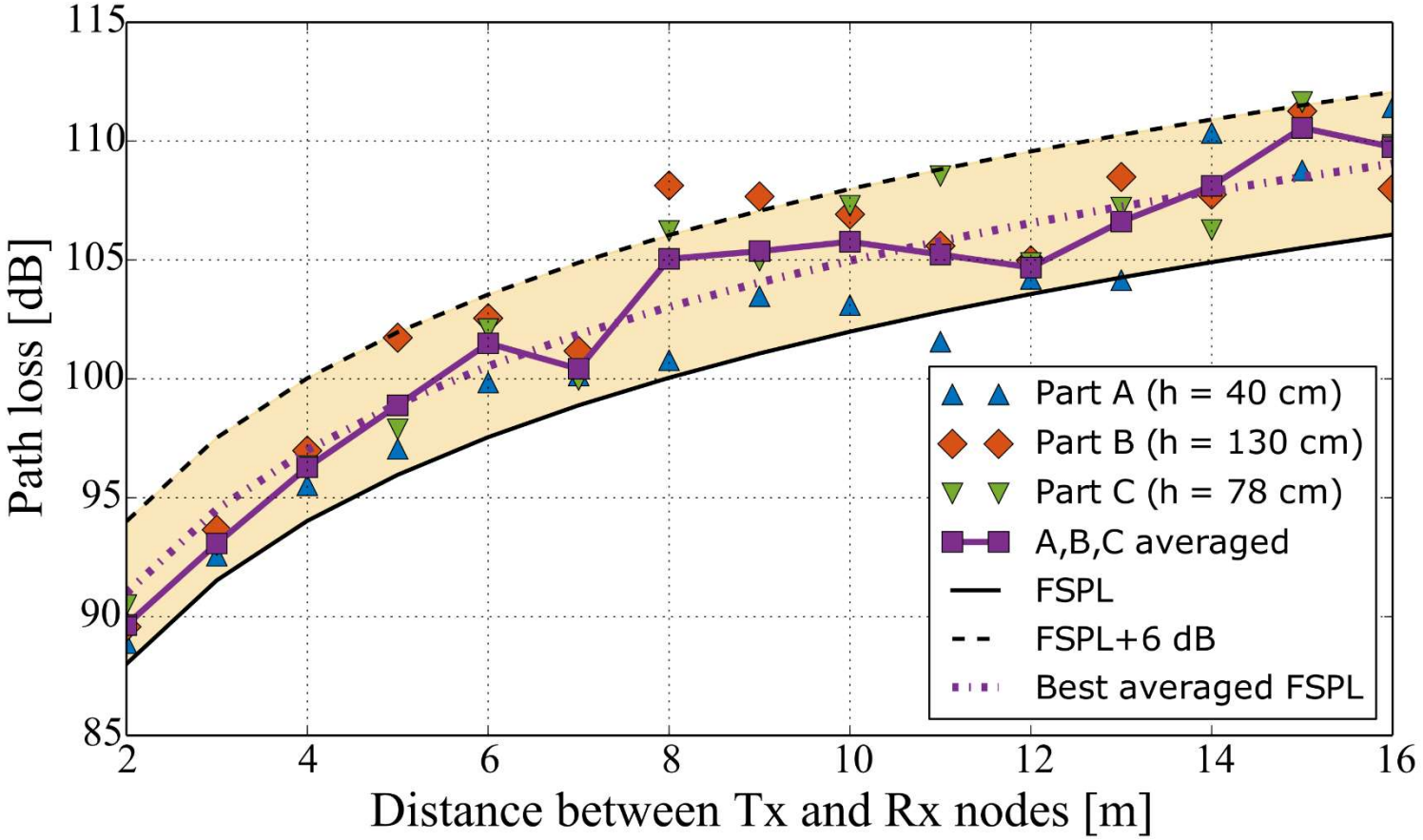
c) Transparency at different heights

d) Side window propagation

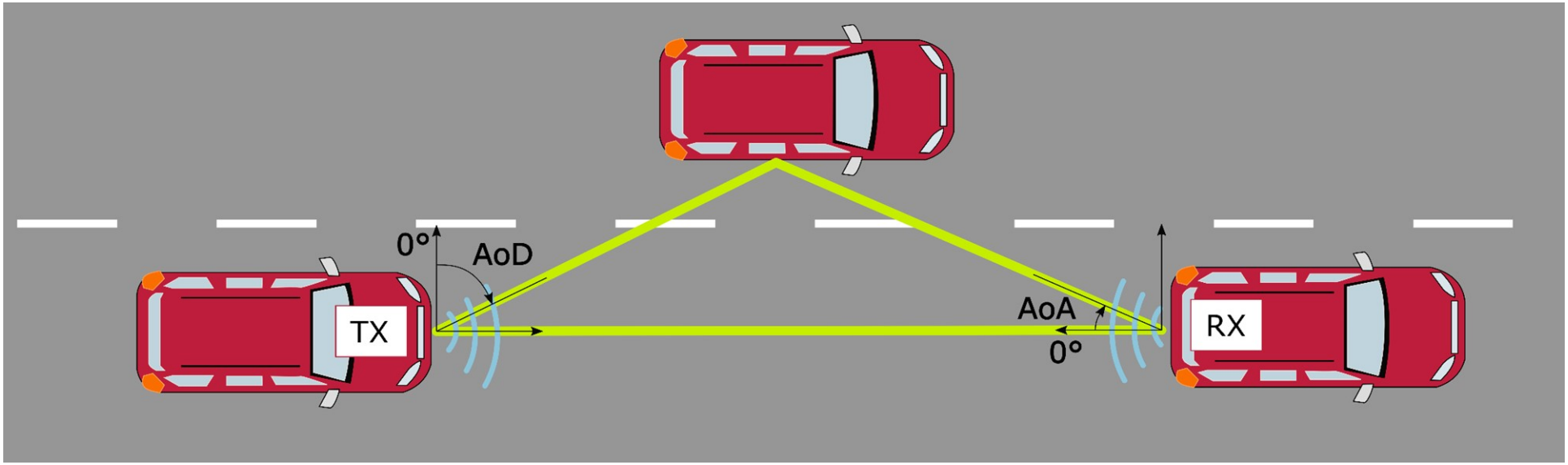
Reference measurements (1)



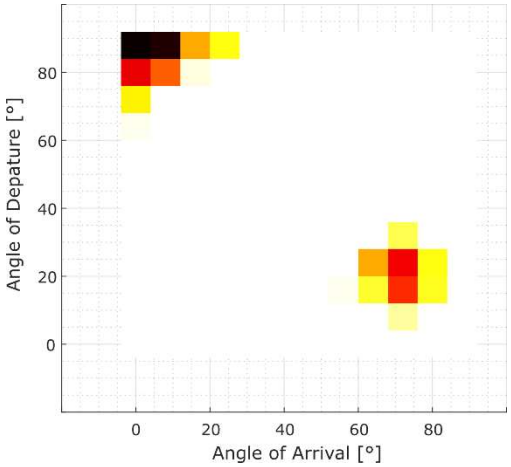
Reference measurements (2)



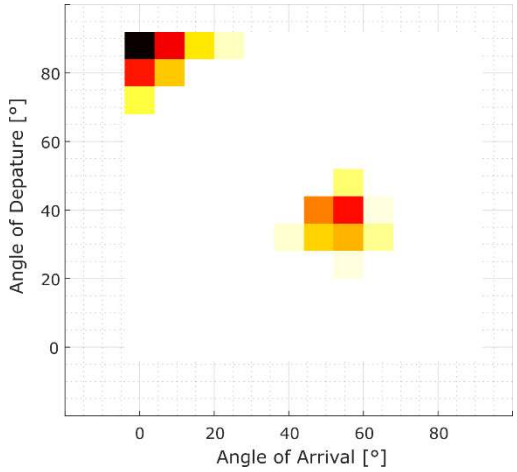
Side Reflection Measurements (1)



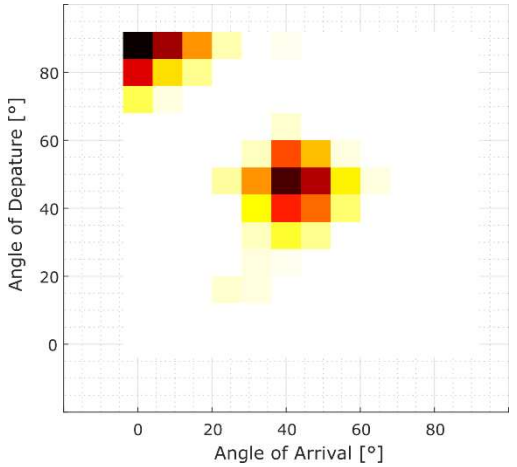
Side Reflection Measurements (2)



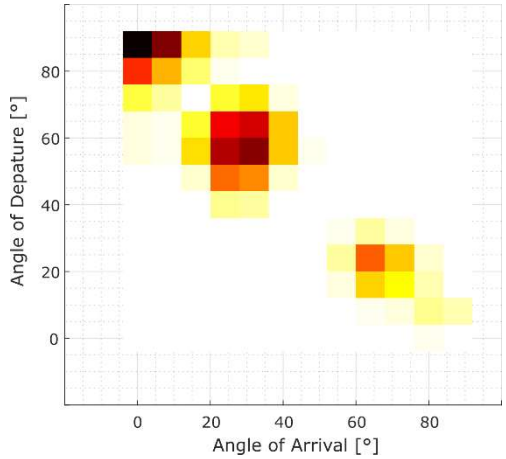
d = 2 m



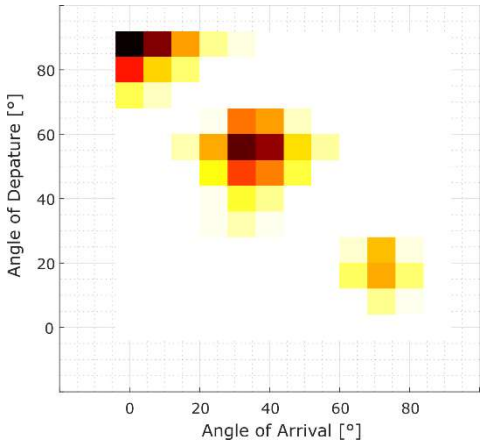
d = 4 m



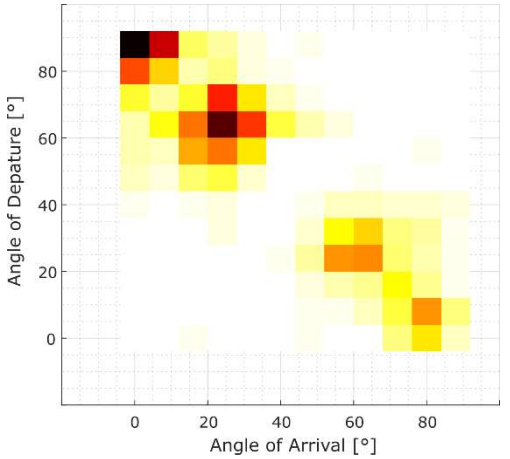
d = 6 m



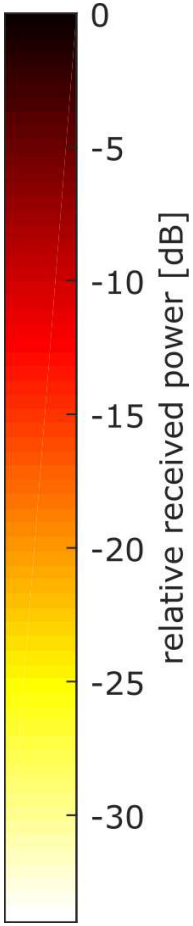
d = 8 m



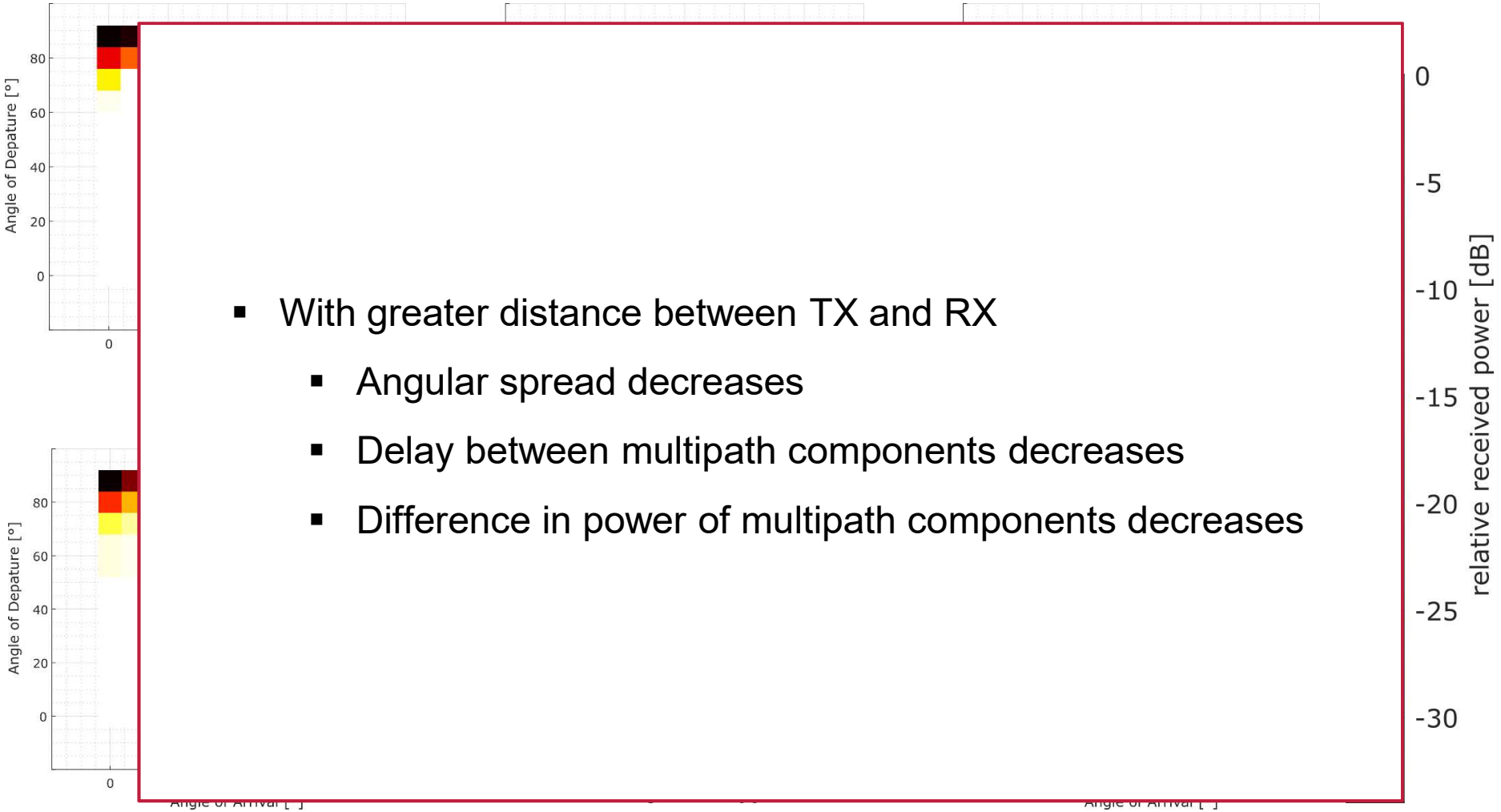
d = 10 m



d = 12 m



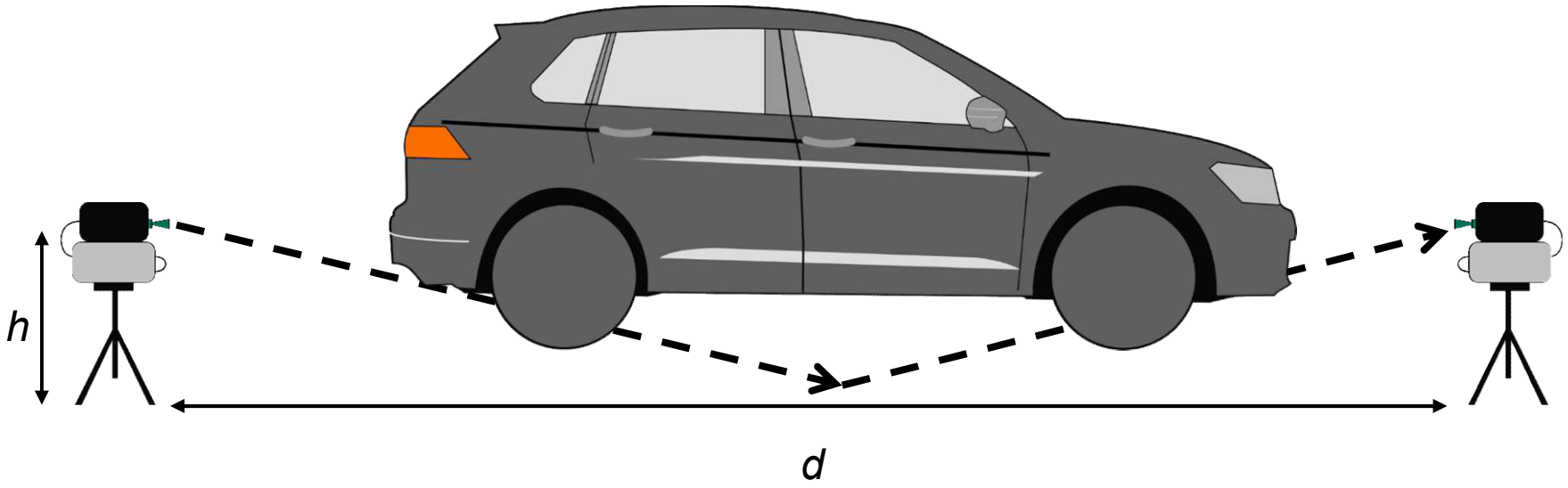
Side Reflection Measurements (2)



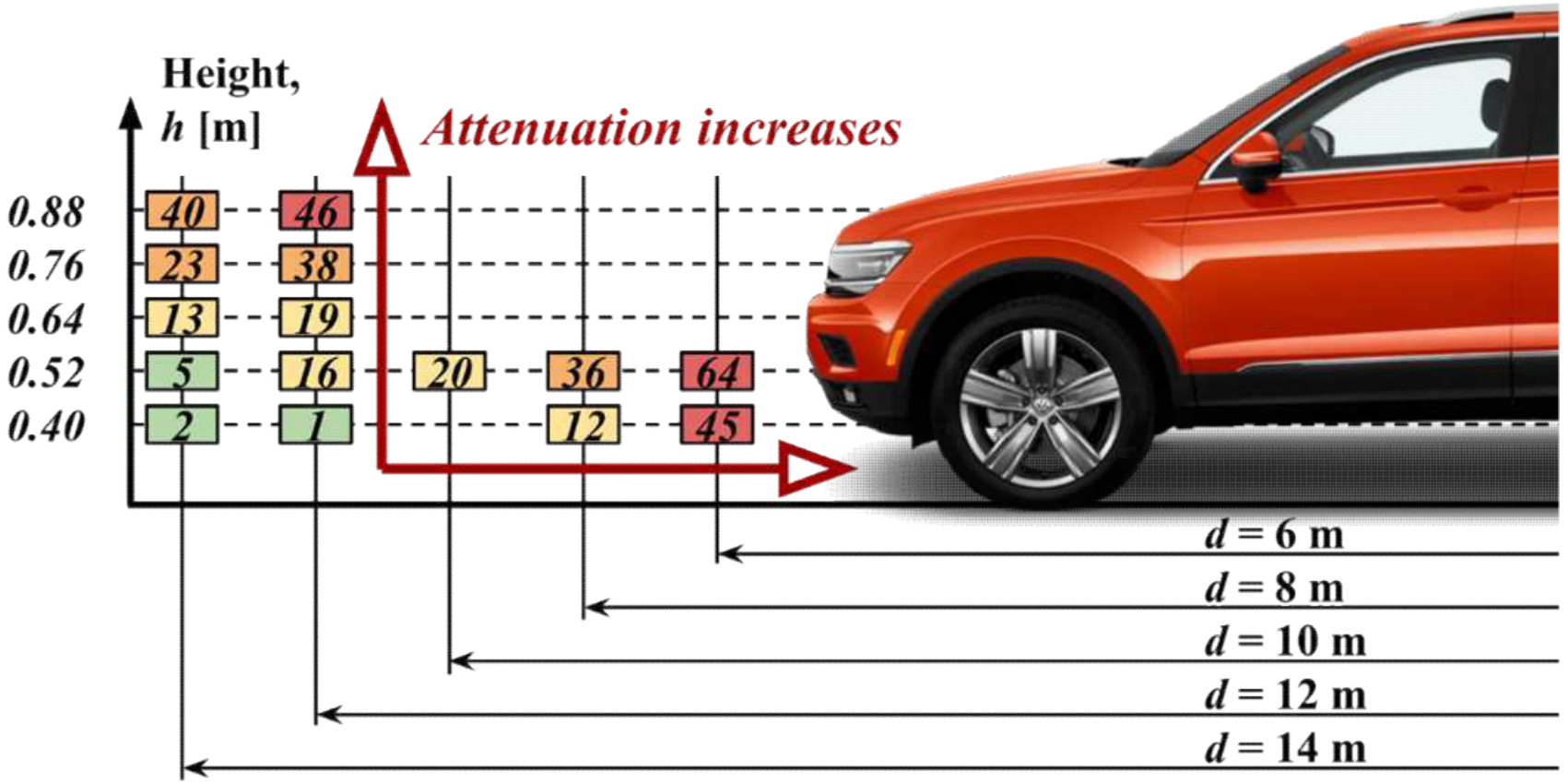
- With greater distance between TX and RX
  - Angular spread decreases
  - Delay between multipath components decreases
  - Difference in power of multipath components decreases

d = 8 m *d* = 10 m *d* = 12 m

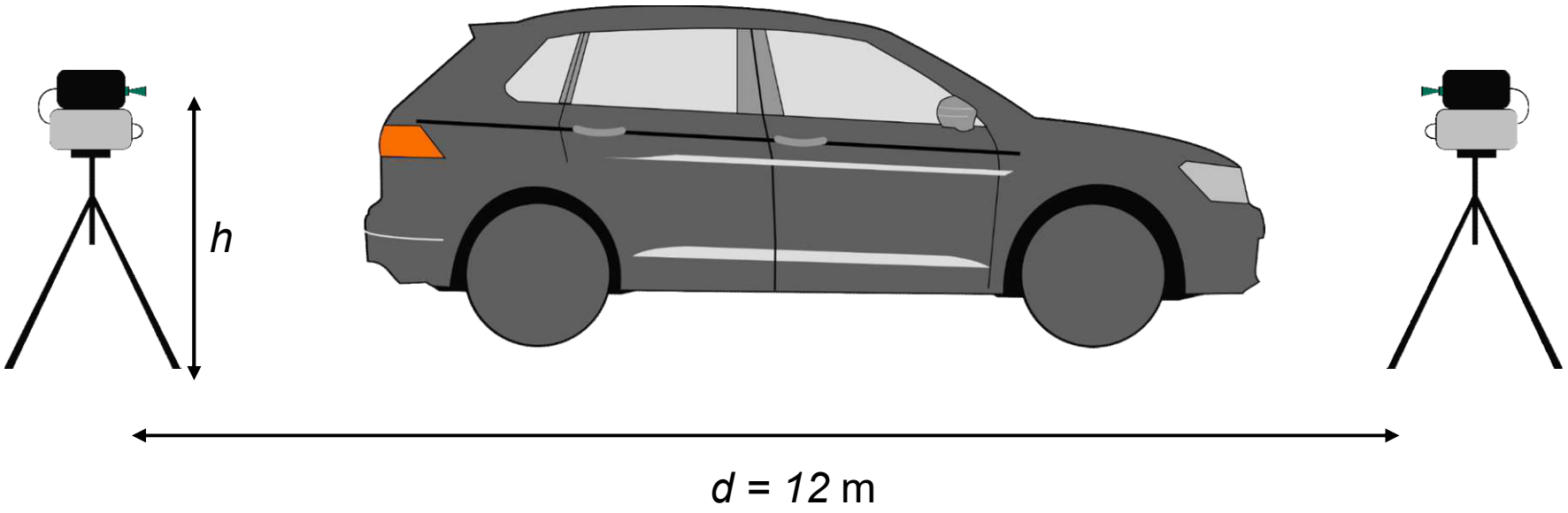
Under-Vehicle Propagation (1)



Under-Vehicle Propagation (2)



Vehicular Transparency (1)



Vehicular Transparency (2)

Measured instance (Propagation through)	Attenuation
Vehicle, bumper level (h = 0.9 ... 1.1 m)	≈ 45 dB
Vehicle penetration, engine level (h = 1.1 ... 1.2 m)	≈ 50 dB
Front + rear window (h = 1.4 ... 1.6 m)	≈ 40 dB
Near the rooftop (h = 1.6 m)	≈ 20 dB
Over the rooftop (h > 1.65 m)	≈ 0 dB
Side windows, driver + passenger, front (h = 1.25 ... 1.4 m)	≈ 33 dB
Side windows, back passengers, rear (h = 1.25 ... 1.45 m)	≈ 28 dB

- Vehicle is a significant obstacle for 300 GHz
- Losses are different for different heights
- Lower attenuation for side windows than for front/rear
- Lower attenuation for back side windows than for front side windows

Conclusion

We have presented a measurement study on 300 GHz signal propagation in representative vehicular setups

Major conclusions

- **Multipath propagation** plays an important role in vehicular communications
- Vehicle is **a significant obstacle** for low-THz band signals
- Vehicles transparency **notably varies** at different heights and from different sides
- **Under-vehicle propagation** significantly contributes to the vehicular channel

These are only selected results, more to come…

Vielen Dank für Ihre Aufmerksamkeit.

Thank you for your attention.

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