Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [60 GHz Channel Measurements for ‚Video Supply in Trains, Busses and Aircraft‘ Scenario]
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Re: []
Abstract: [This document presents the results of a measurement campaign for the 60 GHz in-vehicular radio channel.]

Purpose: [Support the channel modeling sub-committee with additional information concerning the in-vehicular radio channel.]

60 GHz Channel Measurements for ‘Video Supply in Trains, Busses and Aircraft’ Scenario

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Outline

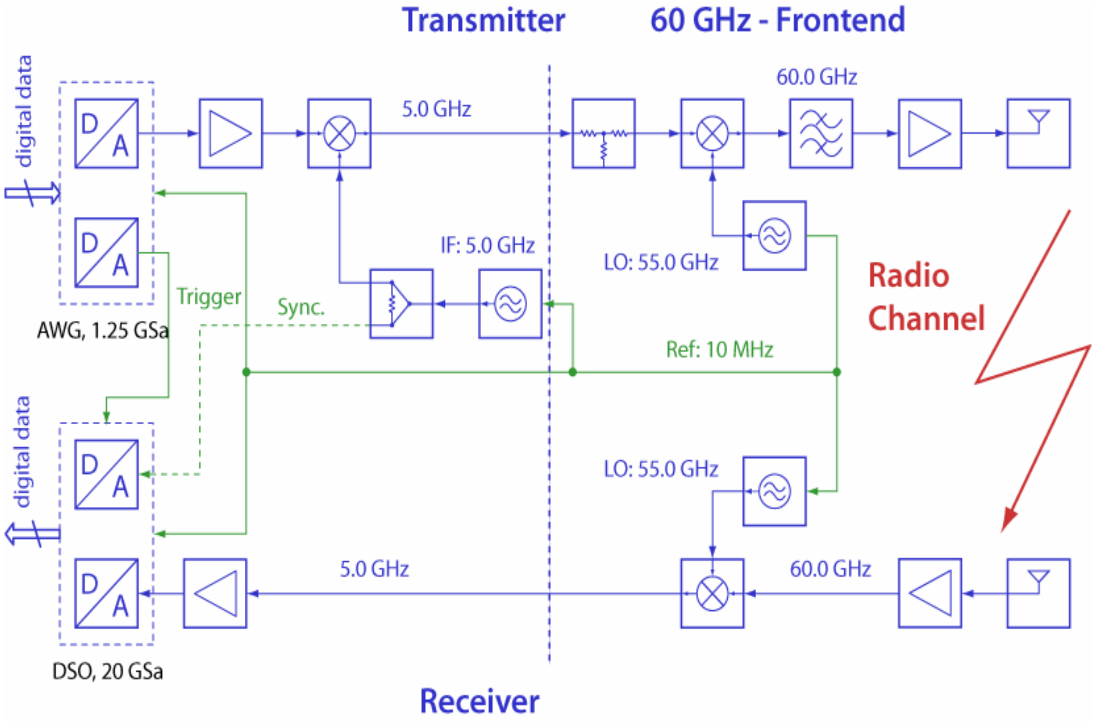
- Introduction and purpose
- Measuring method and setup
- Scenario
- Channel in time domain
- Spatial Correlation
- Channel energy and obstruction
- Conclusions

Introduction and Purpose

- Support the development of in-vehicular high-rate transmission systems: video and audio supply in trains, busses, aircrafts;
  This scenario can be considered as an extension of Usage Model UM2
- Therefore: get information about the propagation channel by measurements in application-oriented environments
- Extract basic parameters and develop a realistic channel model
- Basis for system design, synchronization and channel estimation aspects

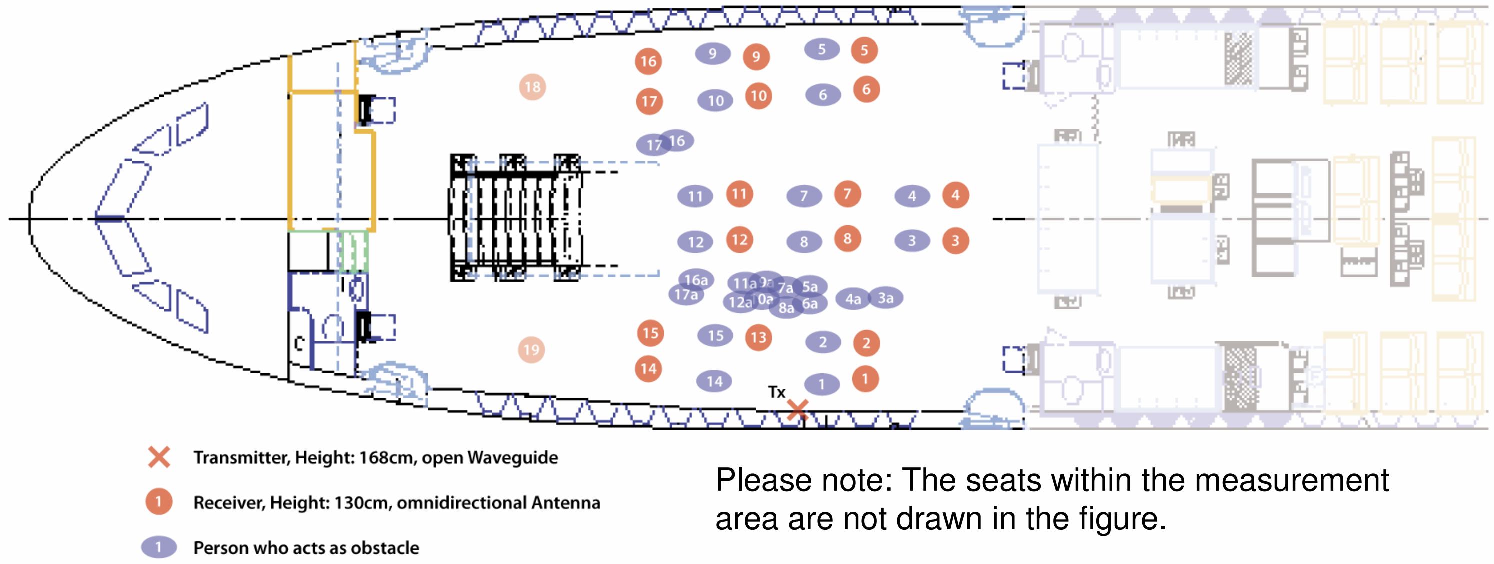
Measuring Method and Setup

- Correlation channel sounding in time domain
- In spite of high correlation gains: short measurement durations in the region of microseconds
- Measurement flat bandwidth: 1 GHz



- Small-scale-set (e.g. 100 snapshots) within some seconds
- Following examples: spatial separation of two consecutive snapshots: 1 mm

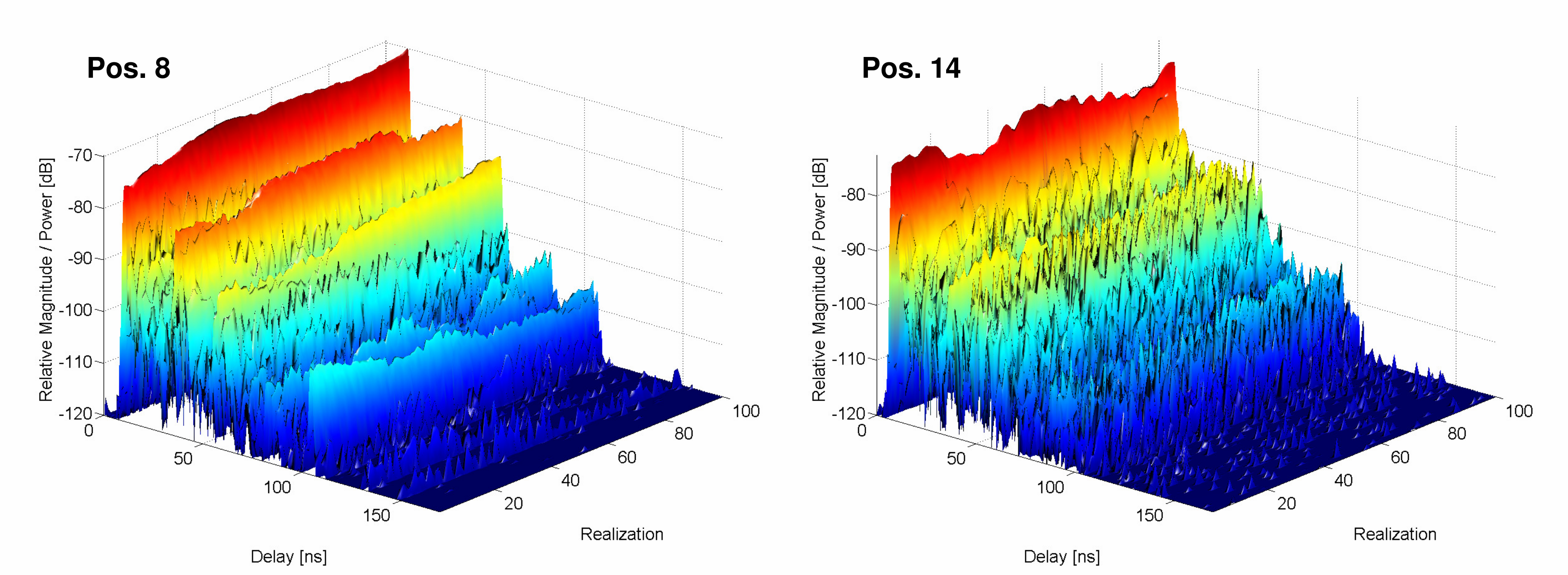
Scenario



Please note: The seats within the measurement area are not drawn in the figure.

- Characteristic for in-vehicular scenario: metallic outer skin
- Exemplary: aircraft cabin
- Antenna configuration: open waveguide at Tx, omni at Rx
- 1 Tx position, 19 realistic Rx positions at the backrests of the seats
- Rx-Tx distances between 1.4 and 7.1 m
- Realistic obstruction (person partially or totally blocking the LOS)

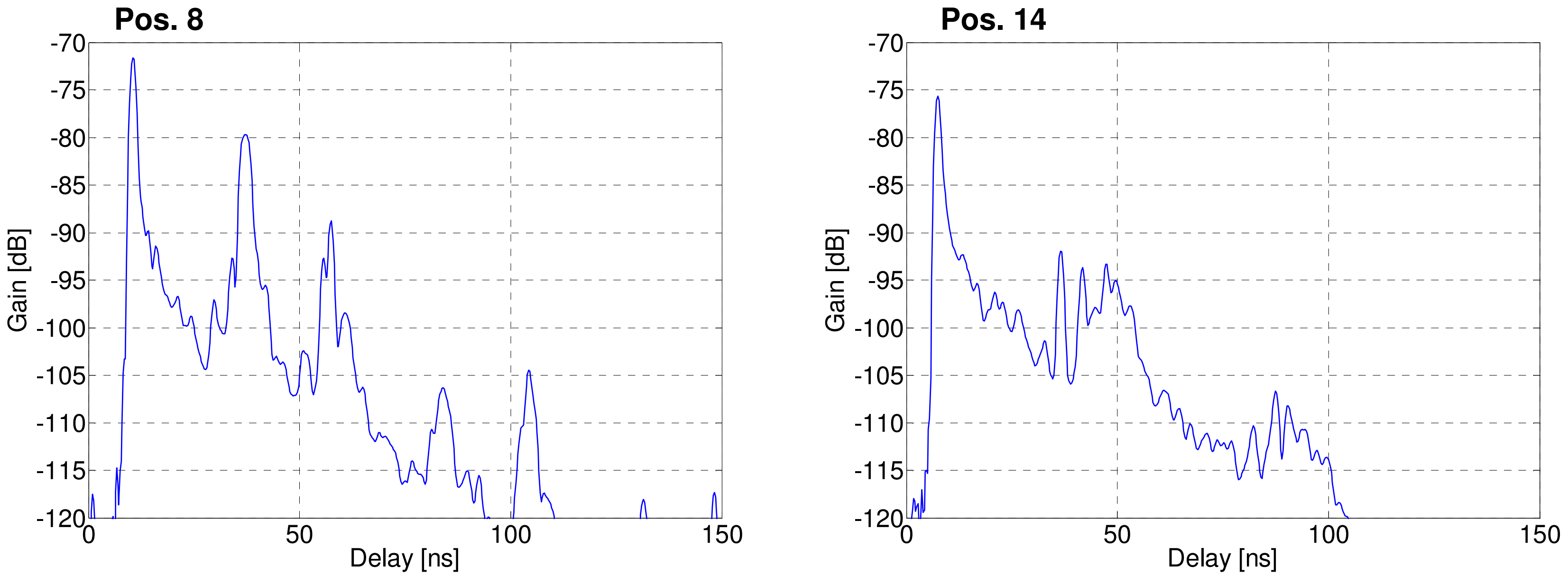
Channel in Time Domain (LOS Examples)



- Multipath propagation to a high degree → CIR consists of multitude of resolvable multipath components (RMPCs)
- Highly dispersive and frequency selective channel
- Strong reflections due to metallic outer skin:

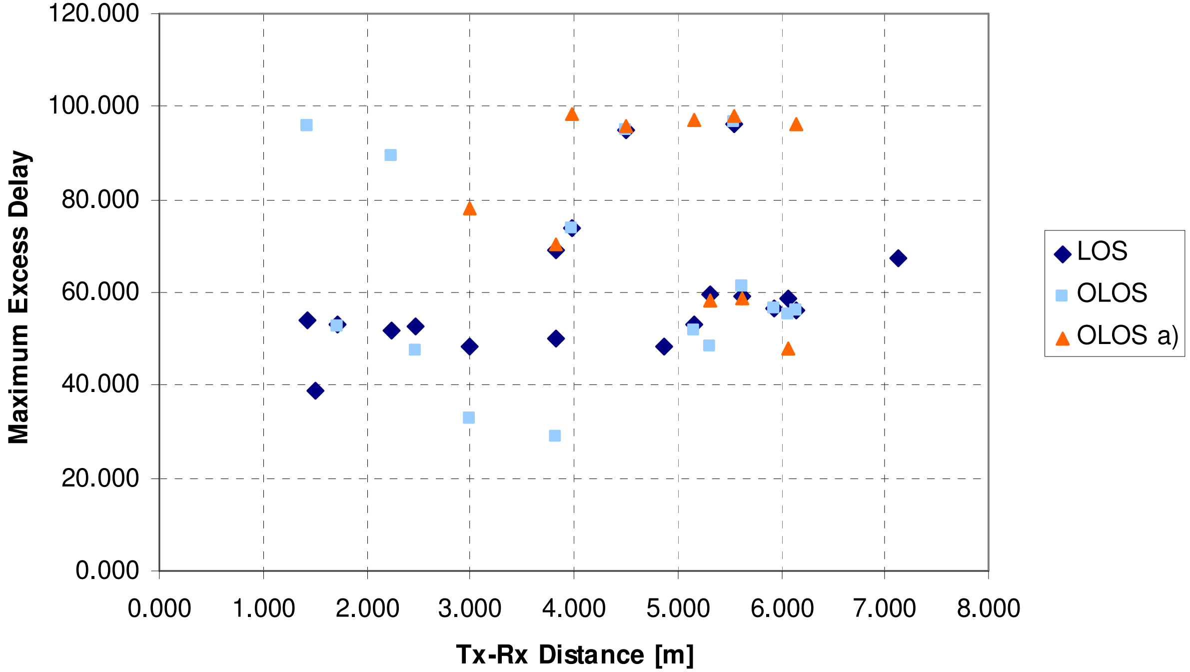
  Some RMPCs contain strong physical paths → weakly fading RMPCs with high power

APDPs



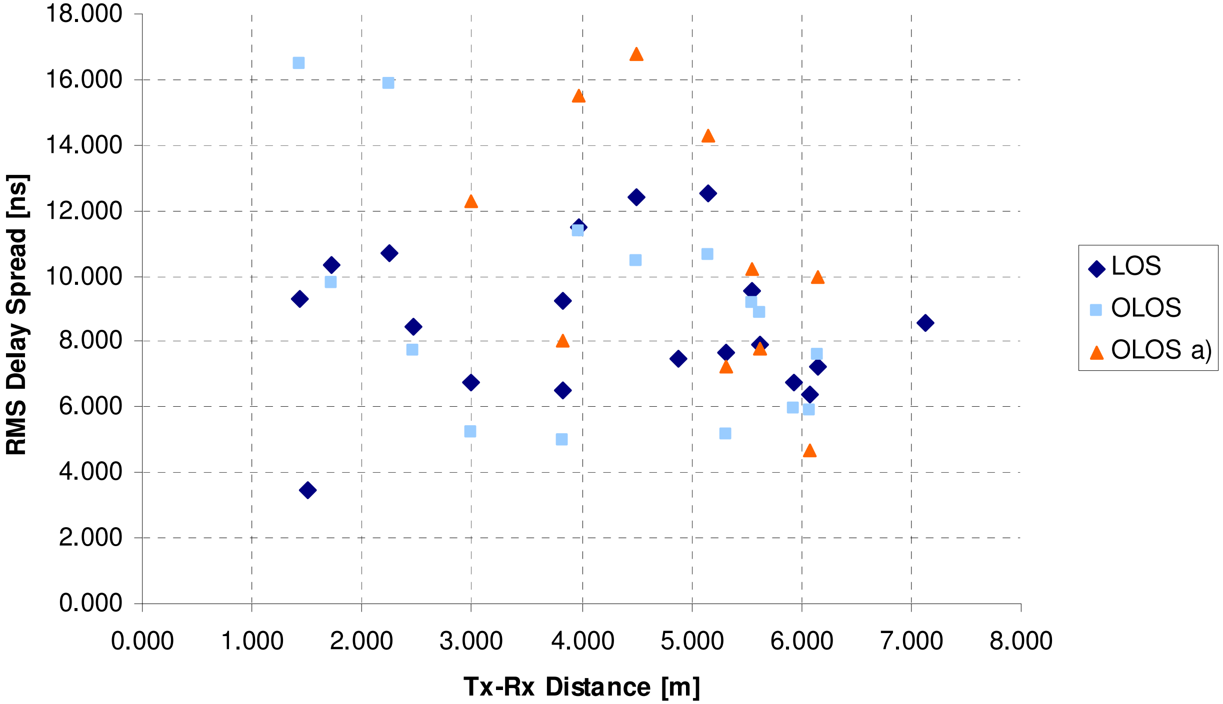
- APDP: Average of individual PDPs within one snapshot; characterizing one large-scale location
- Basis for the determination of TOA-Parameters and investigations concerning the arrival process
- APDPs also clearly show strong (weakly fading) RMPCs / clustering effects

TOA-Parameters: Maximum Excess Delay



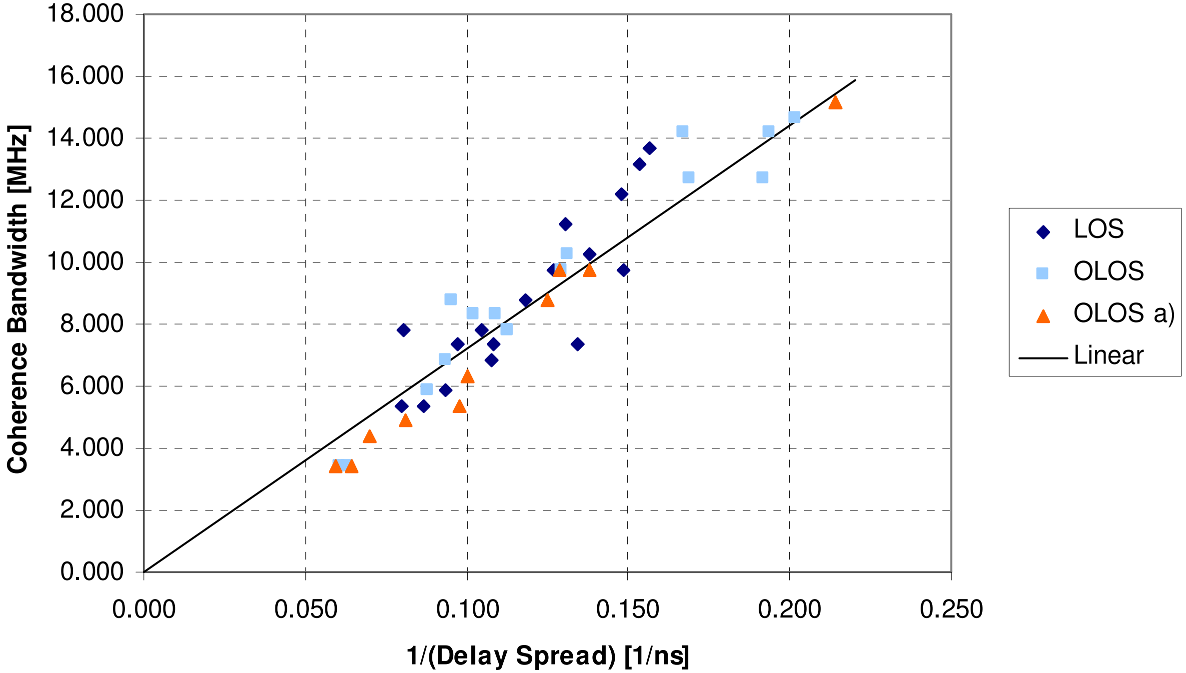
- Applied threshold: 30 dB with respect to the strongest path
- Values between 28 and 100 ns of maximum excess delay
- No identifiable dependency on the Tx-Rx distance

TOA-Parameters: RMS Delay Spread



- Delay spreads between 3 and 17 ns
- Mean Value: 9.4 ns
- Large delay spreads even for small distances; no identifiable dependency on the Tx-Rx distance

Coherence Bandwidth (0.9 Correlation)



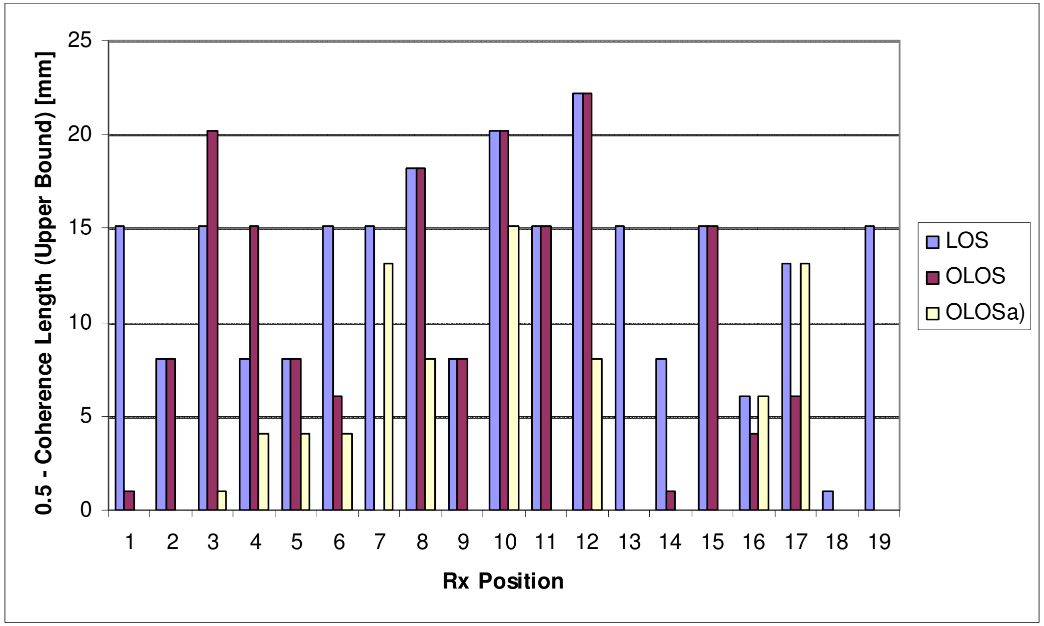
- 0.9-coherence bandwidth between 3.4 and 15.1 MHz
- Relationship between 0.9-coherence bandwidth and RMS delay spread:

$$B_{coh,0.9} = \left(\alpha_{coh} \cdot \tau_{rms}\right)^{-1}$$

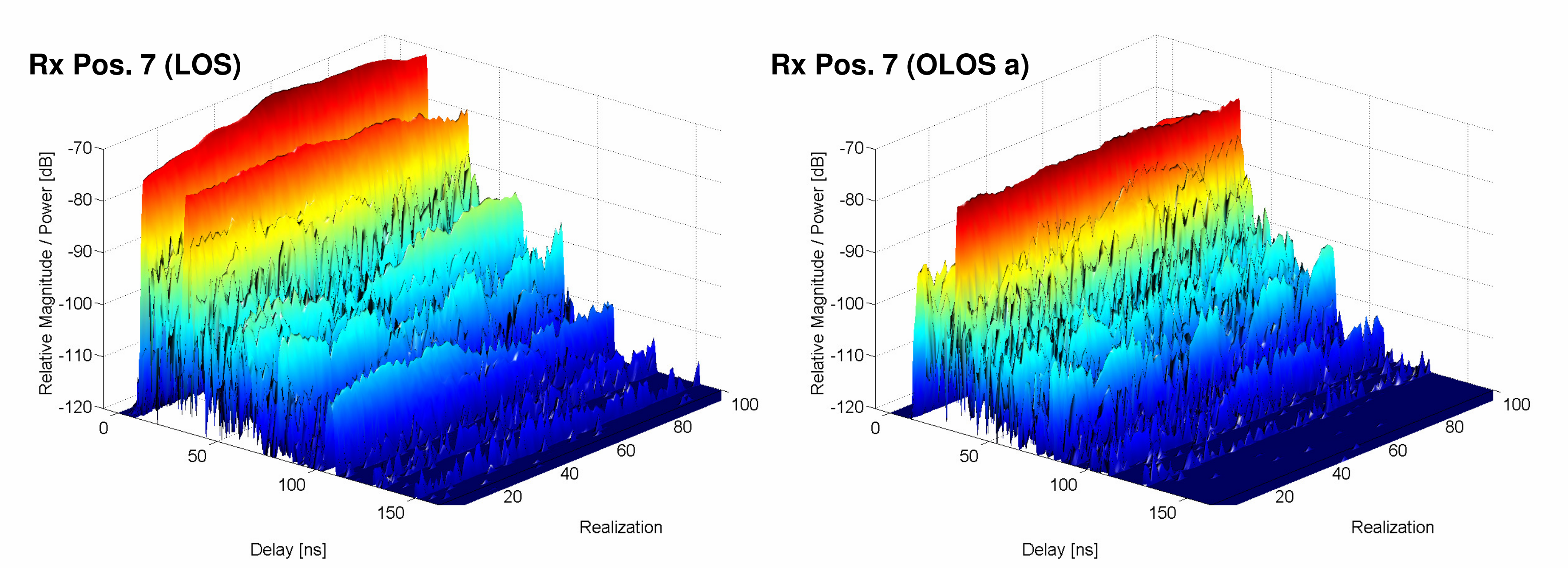
$$\alpha_{coh} \approx 13.84$$

Spatial Correlation

- Detailed investigations show a rapid decline in correlation with increasing antenna separation
- Average correlation value falls below 0.5 for separations above 10 mm
- Chart: upper bound of 0.5-correlation is between 1 and 22 mm corresponding to 0.2 and 4.4 λ
- Conclusion: Small dimension multi-antenna systems are beneficial



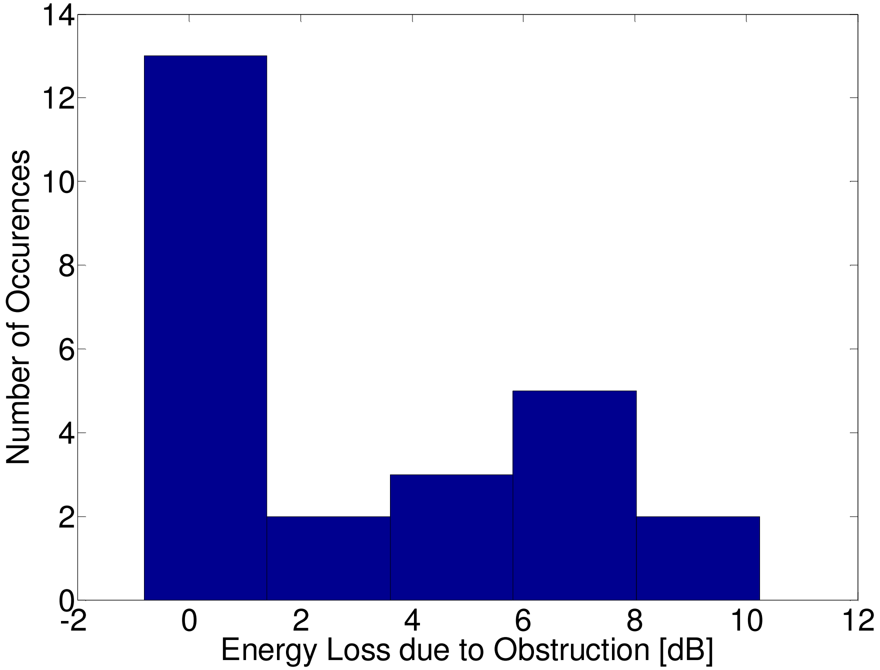
Obstruction Example



- Person blocking the LOS close to the Tx antenna
- Power of first RMPC decreases about 20 dB
- Obstruction also affects delayed RMPCs that are related to the direct path
- Total channel energy drops about 7 dB

Total Channel Energy and Influence of Obstruction

- Considering total channel energy on the basis of APDP
- Relative channel energy varies between -83 and -59 dB
- Energy loss due to obstruction strongly depends on individual Rx position
- Chart illustrates:
At worst, obstruction causes 10 dB degradation in total channel energy



Conclusions

- 60 GHz systems are very attractive for in-vehicular high-rate transmission
- Coverage
  - Full coverage may be achieved under the following conditions:
    - Make use of multipath propagation rather than avoiding it by applying directional high-gain antennas
    - Appropriate system design (multi-antenna, spatial diversity, frequency diversity, cellular approach with cooperating APs)
- Modeling
  - Clustering effects are to be included, since they are characteristic for the strongly reflective nature of the environment
  - Modeling of spatial / temporal correlations could be helpful to investigate multi-antenna configurations and effects of a time-varying channel
- Roadmap
  - Set of parameters reflecting this scenario can be generated for existing channel model within 8 weeks

Acknowledgements

- Thanks to Airbus Deutschland GmbH/Germany for the provision of the cabin test environment

Abbreviations

APDP	Averaged Power Delay Profile
AWG	Arbitrary Waveform Generator
CIR	Channel Impulse Response
DSO	Digital Sampling Oscilloscope
LOS	Line-of-Sight
MPC	Multipath Component
OLOS	Obstructed Line-of-Sight
PDP	Power Delay Profile
RMPC	Resolvable Multipath Component
RMS	Root Mean Square
TOA	Time-of-Arrival