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

**Submission Title:** Spatial and Temporal Dispersion in THz Indoor Propagation Channels
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**Re:** doc.: IEEE 802.15-15-11-0146-00-0thz_diffuse-rough-surface-scattering-analysis

**Abstract:** At THz frequencies, a strong multipath propagation due to reflections and rough surface scattering is expected in indoor environments. A strong spatial as well as a strong temporal dispersion result. In order to quantify both, the angular and RMS delay spread are investigated in an office scenario employing ray tracing simulations. A distance-dependent angular as well as an RMS delay spread model are presented for two different degrees of surface roughness. Based on the results, estimates of maximum symbol rates achievable without intersymbol interference are given.

**Purpose:** Input for THz channel modeling

# Spatial and Temporal Dispersion in THz Indoor Propagation Channels

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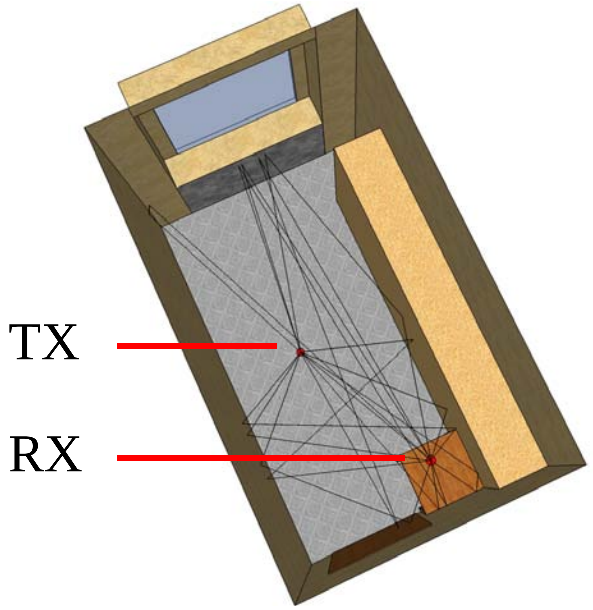
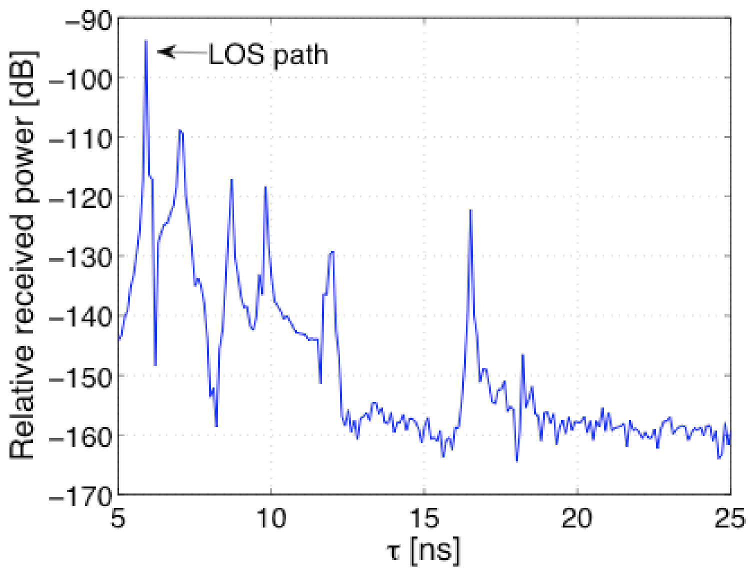
# Outline

1. **Introduction**
2. Office Scenario
3. Spatial Dispersion
4. Temporal Dispersion
5. Summary/Outlook

# Introduction (1)

- Multipath propagation:
  - has a high impact on THz indoor communication channels
  - induces high spatial and temporal channel disperions
  - is roughness-dependent, especially due to scattering
- Example of temporal dispersion:



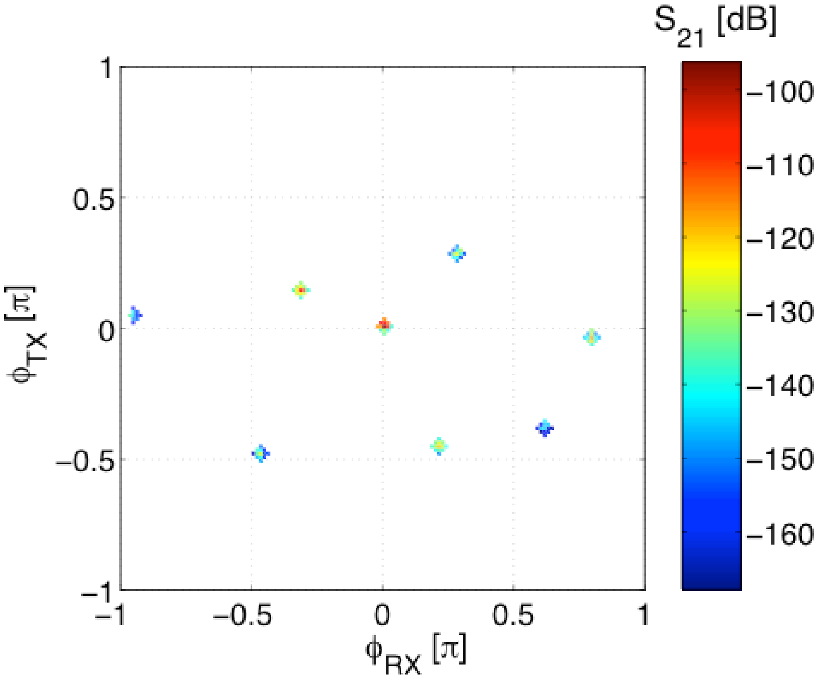



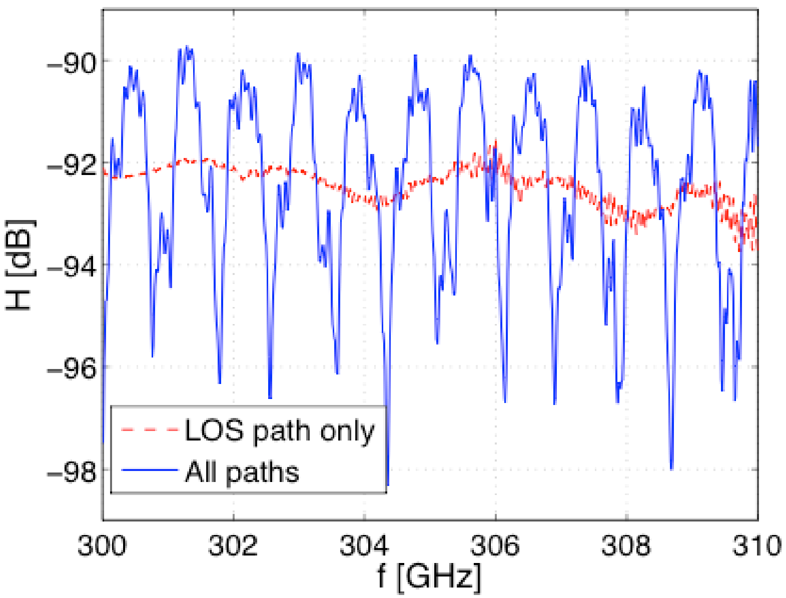

IEEE document 802.15-15-10-0436-01-0thz_Towards_a_300_GHz_Channel_Model

→ RMS delay spread relevant to estimate maximum symbol rates

# Introduction (2)

- Example of spatial dispersion:




→ Spatial information relevant for MIMO communications

→ Angular spread necessary for channel modeling

IEEE document 802.15-15-10-0436-01-0thz_Towards_a_300_GHz_Channel_Model

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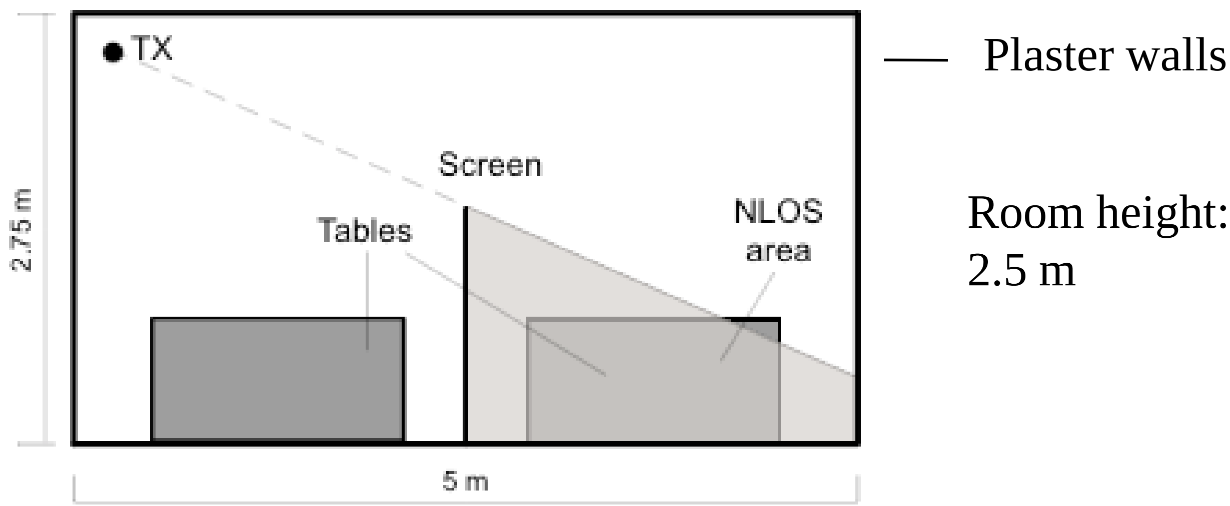
# Office Scenario

- Ray tracing simulations including scattering from rough plaster walls for two degrees of surface roughness
  - plaster 1, less rough: $l_{corr}$ = 1.3 mm and $\sigma_h$ = 0.05 mm
  - plaster 2, higher roughness: $l_{corr}$ = 1.7 mm and $\sigma_h$ = 0.15 mm
- 220 RX positions at equal distances of 25 cm and at a height of 75 cm
- LOS and NLOS conditions
- Omnidirectional antennas in vertical polarization



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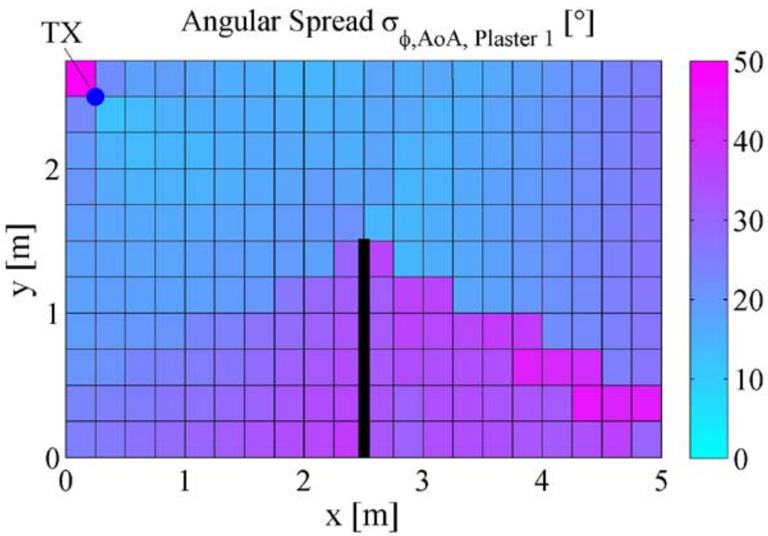
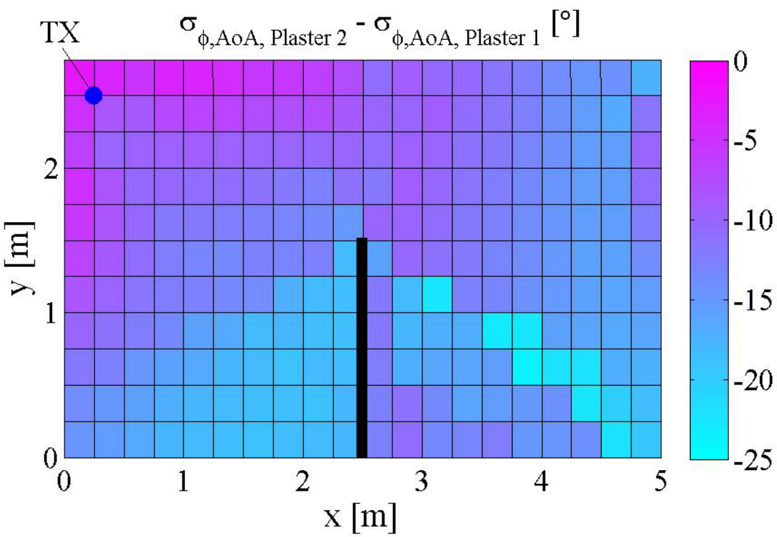
# Spatial Dispersion (1)

- Measure for the spatial dispersion provided by the angular spread
  - Second root momentum of the angular power profile; cf. B.H. Fleury, (2000), First- and second-order characterization of direction dispersion and space selectivity in the radio channel, IEEE Trans. on Information Theory, 46 (6), pp. 2027–2044.
- Only MPCs with a path loss up to 160 dB considered in the following

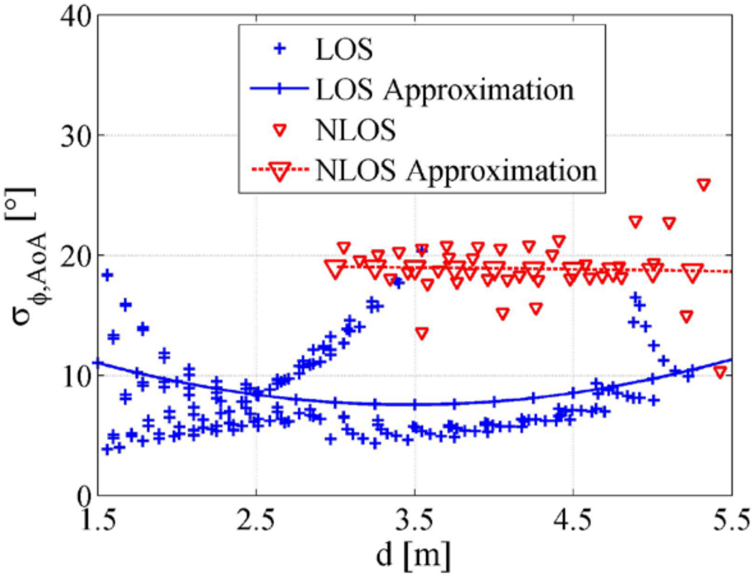


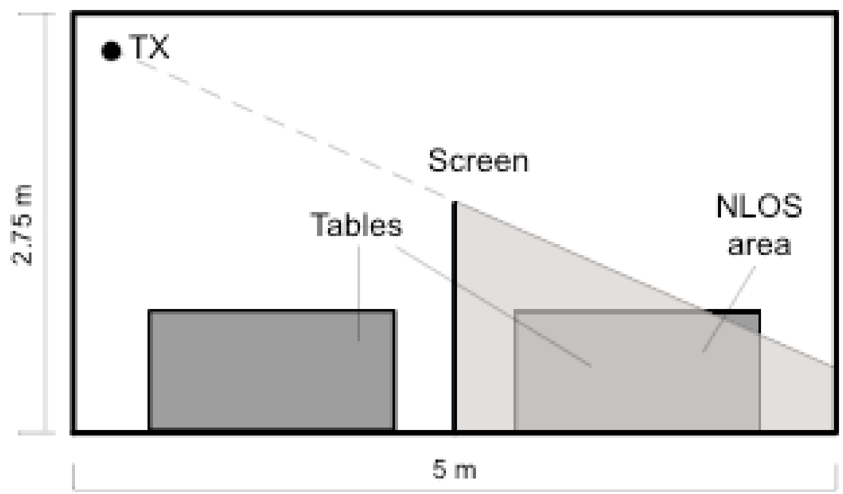

→ A certain roughness dependence of the angular spread observable especially under NLOS conditions

# Spatial Dispersion (2)

- TX/RX-distance-dependent angular spread model for plaster 2:




AoA, azimuth

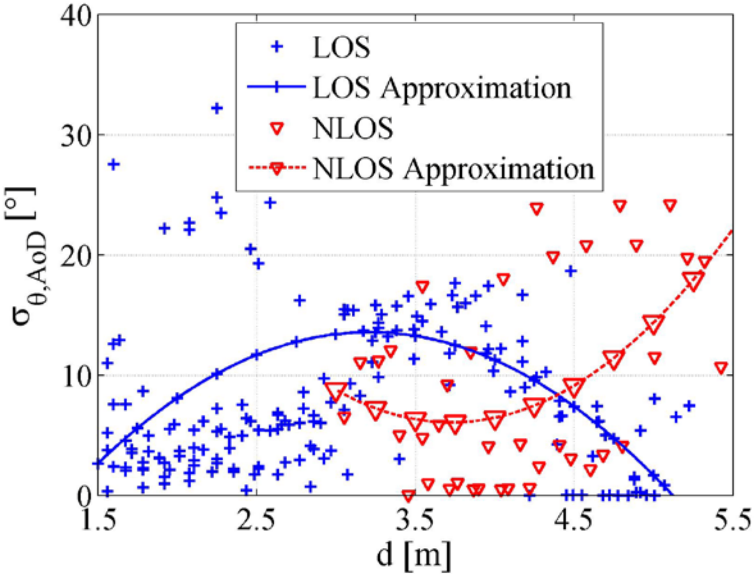



→ First values for d = 1.5 m due to height difference between TX and RX

→ Good approximation with second order polynomial

→ Prediction of spatial channel dispersion

# Spatial Dispersion (3)



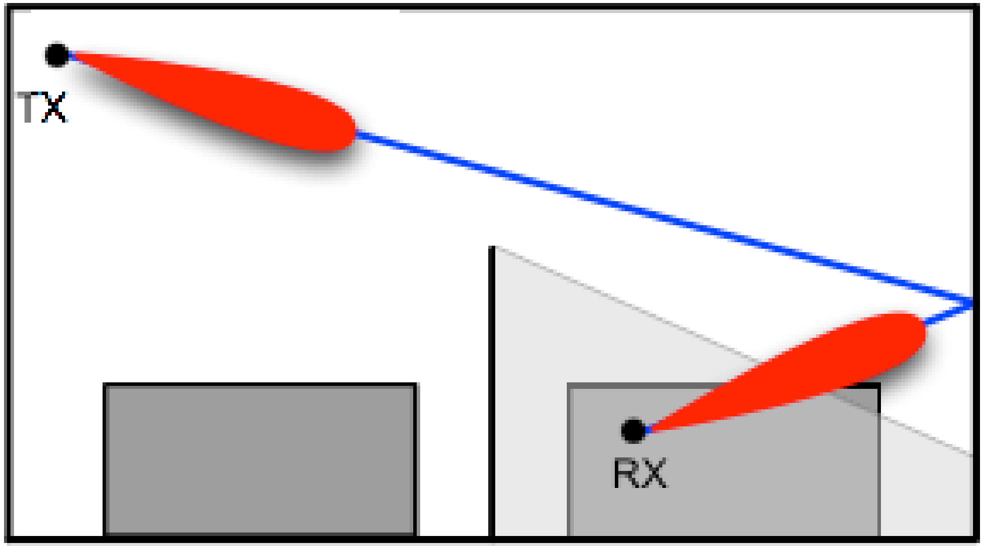

AoD, elevation

→ Highest spreads close to walls

→ Polynomial parameters including the second roughness of plaster 2 given in [1]

# Spatial Dispersion (4)

- Omnidirectional antennas assumed so far
- But: highly directive (smart) antennas required for directed (N)LOS communications

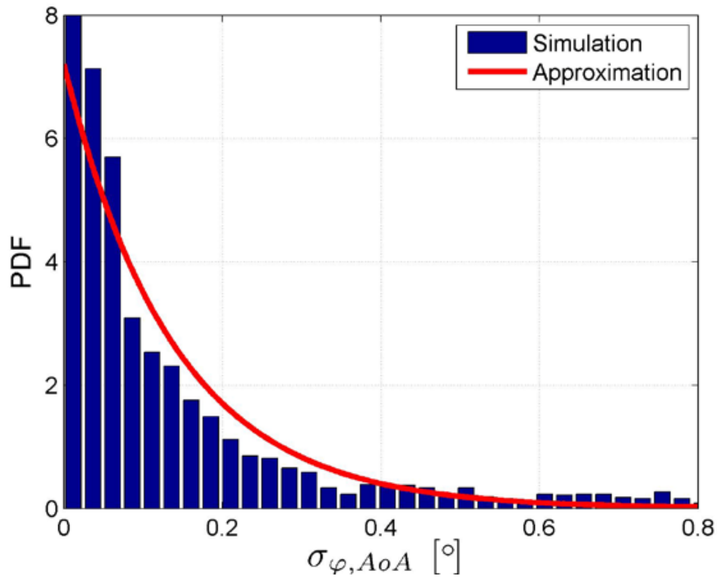



→ Selection of single multipath clusters

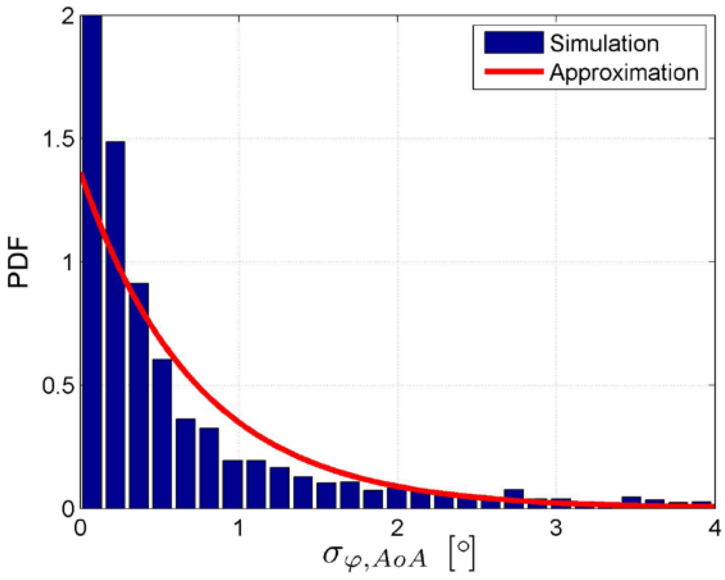
→ Cluster-based modeling of angular spread obligatory

# Spatial Dispersion (5)

- Normalized histograms of the occuring cluster angular spreads evaluated individually for all clusters at every RX position:




Lower roughness



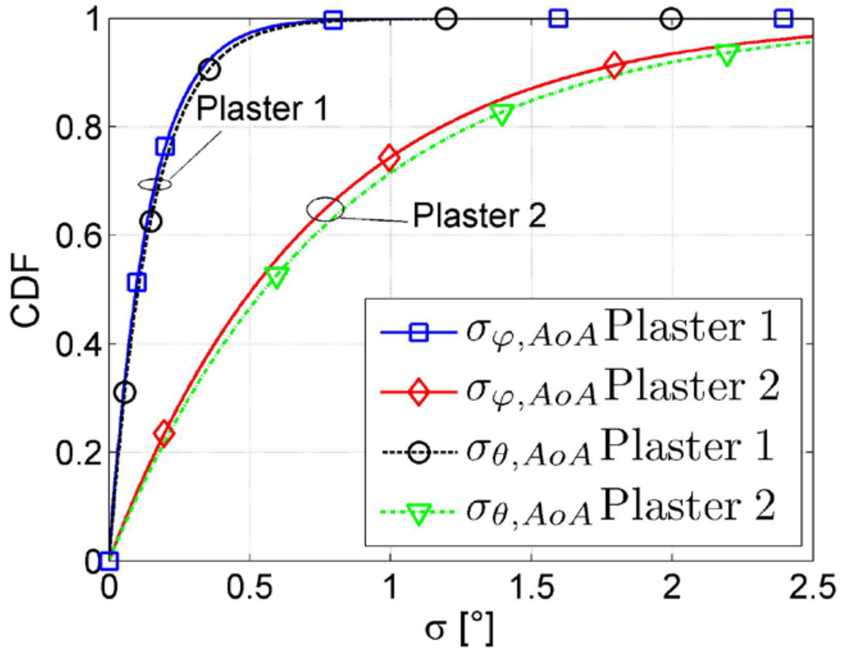

Higher roughness

→ Increasing spread for higher roughness

→ Good approximation with a negative exponential distribution [1]

# Spatial Dispersion (6)

- Comparison of approximated cumulative distribution functions:




→ Almost identical behavior in azimuth and elevation

→ AoD additionally analyzed in [1]

→ Randomization of angular cluster behavior for channel modeling

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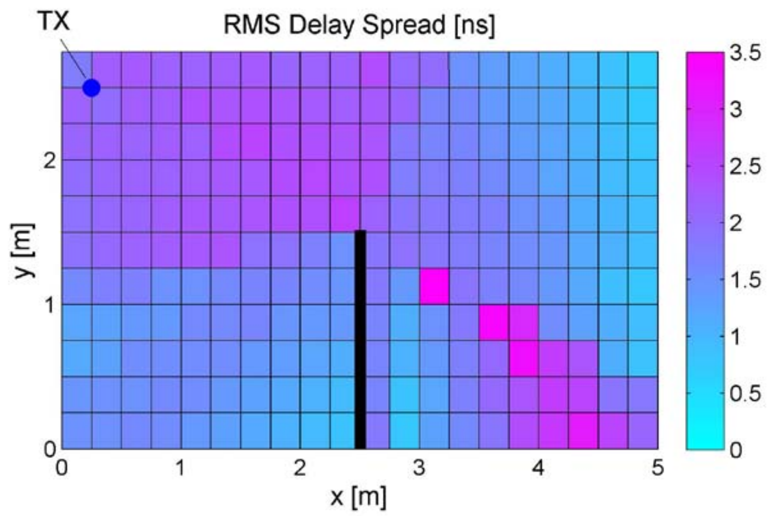
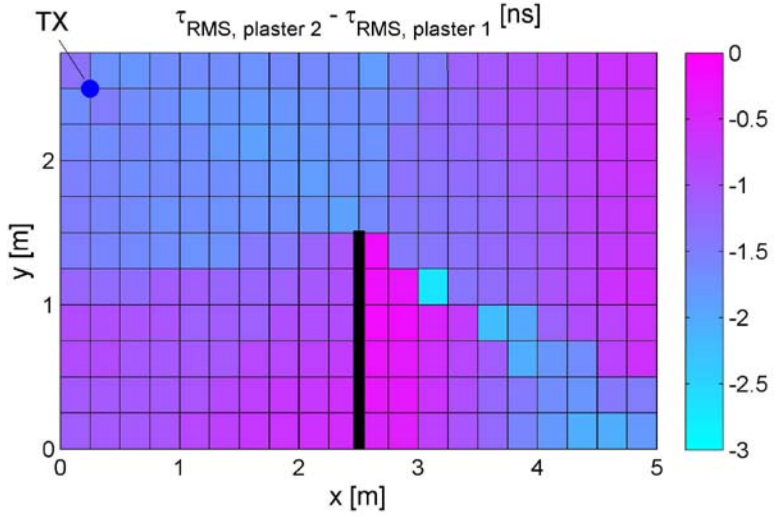
# Temporal Dispersion (1)

- Measure for the temporal dispersion given by the RMS delay spread:

$$\tau_{RMS} = \sqrt{\frac{\sum_i (\tau_i - \bar{\tau})^2 P_i}{\sum_i P_i}}$$



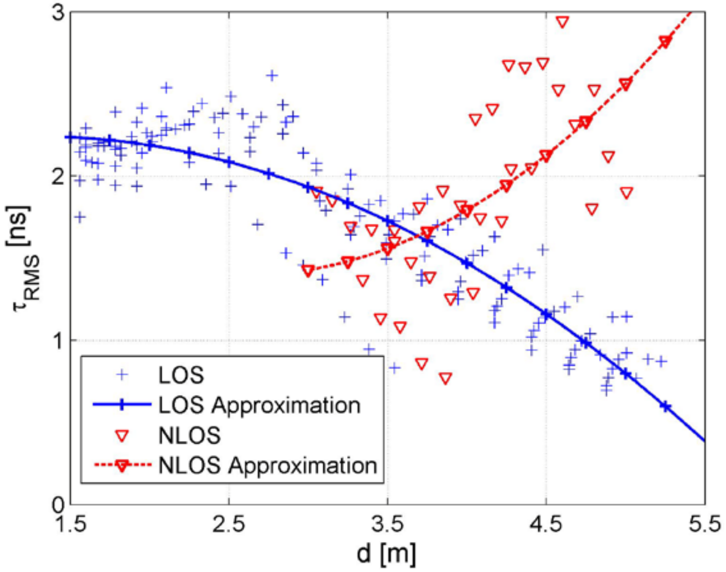




→ Highest RMS delay spreads under NLOS conditions

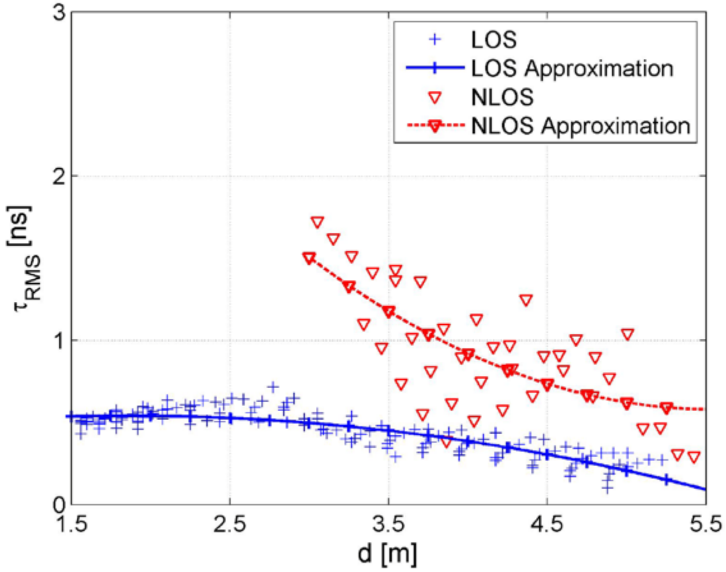
→ Significant roughness dependence

# Temporal Dispersion (2)

- Distance-dependent model for the RMS delay spread:




Lower roughness



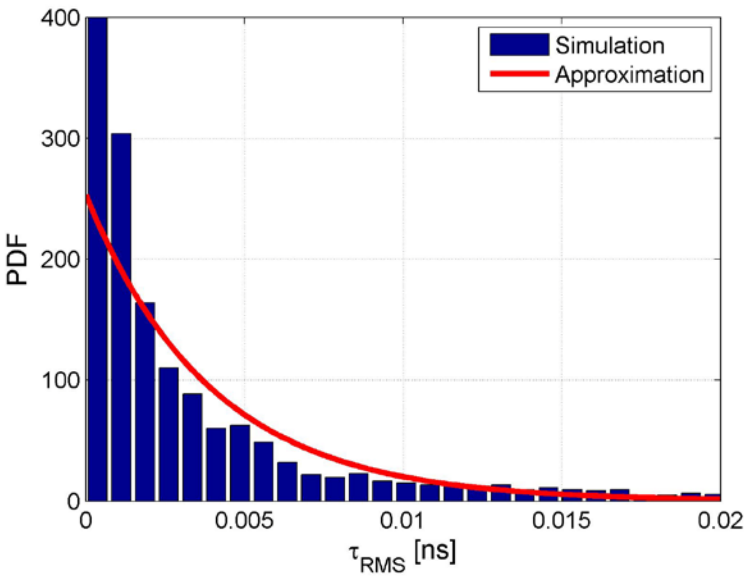

Higher roughness

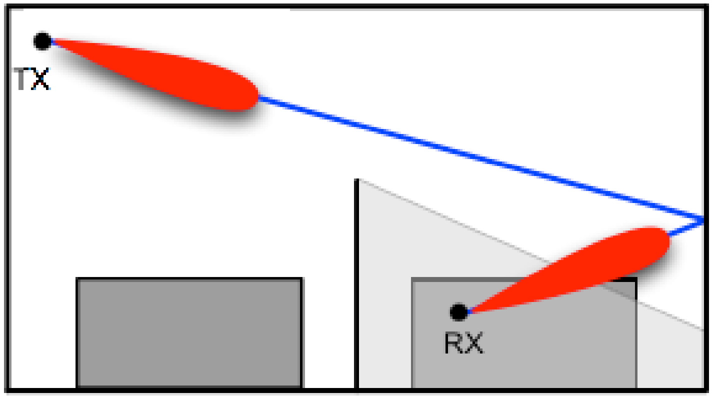
→ Several MPCs fall below the virtual noise level for the higher roughness

→ Higher roughness leads to a lower RMS delay spread

# Temporal Dispersion (3)

- Cluster-based modeling for directed (N)LOS communications
- Normalized histrogram of the cluster delay spreads for plaster 1:



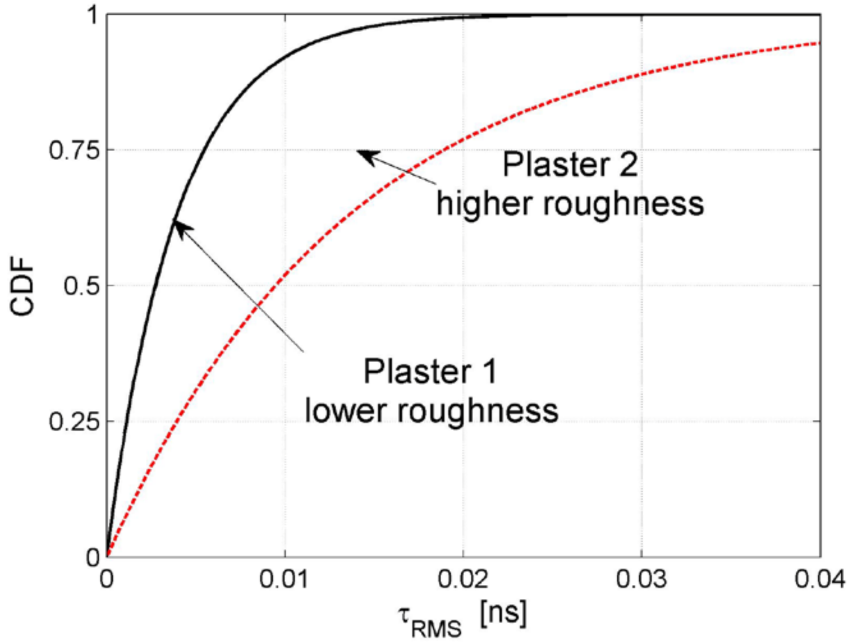




→ Good approximation with negative exponential distribution (parameters in [1])

→ Extremely low temporal dispersion achievable

# Temporal Dispersion (4)

- Comparison of the approximated CDFs for the two roughnesses:




→ Far higher cluster-based RMS delay spread for higher roughness

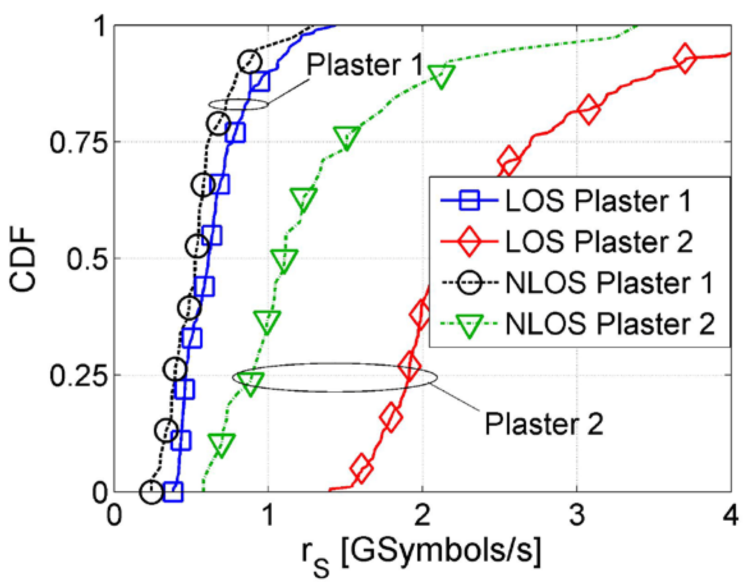
# Temporal Dispersion (5)

- Estimation of max. symbol rates based on the RMS delay spread
- In approximation, no intersymbol interference (ISI), if:

$$r_s < \frac{K}{\tau_{RMS}}$$

*K*: Constant between 0 and 1; here *K* = 1 assumed for best case estimation

- Achievable symbol rates in the scenario:




→ No consideration of link budget aspects

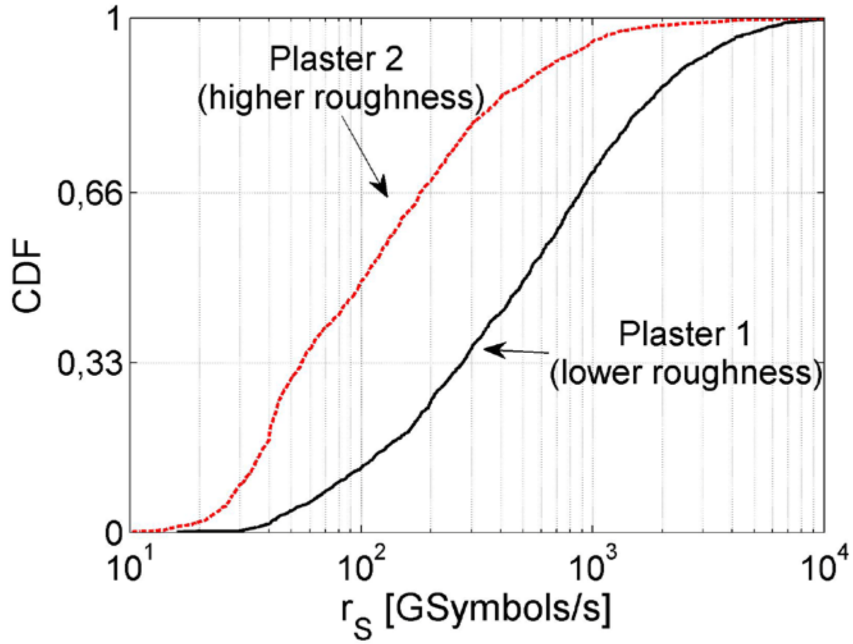
→ Better performance for higher roughness due to lower power of MPCs

→ Higher symbol rates under LOS conditions

→ Several 10 Gbit/s only feasible with spatial filtering

# Temporal Dispersion (6)

- Evaluation of maximum symbol rates for each cluster in the scenario:




→ Directed (N)LOS communications easily allow for several 10 GSymbols/s regardless of the surface roughness

→ At best, even up to 10,000 GSymbols/s can be achieved without intersymbol interference

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# Summary/Outlook

- Ray tracing simulations have been performed in an office scenario
- An angular and an RMS delay spread model have been derived to predict the spatial and temporal THz channel dispersion

→ High spatial dispersion occurs

→ No influence of the two tables can be observed

→ Single clusters allow for several 100 GSymbols/s without intersymbol interference over directed communication links

Next step:

- Development of a complete stochastic channel model including amplitude, phase and spatial as well as temporal information for system simulations

# References

Parameters of the second order polynomials and the approximated analytical PDFs for both roughnesses can be found in:

[1] Priebe, S.; Jacob, M.; Kürner, T.: *Angular and RMS Delay Spread Modeling in View of THz Indoor Communication Systems.* 12th URSI Commission F Triennial Open Symposium on Radio Wave Propagation and Remote Sensing, 8 pages, Garmisch-Partenkirchen, March 2011.

# ***Thank you for paying attention.***

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