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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

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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 dispersions
  - is roughness-dependent, especially due to scattering

- Example of temporal dispersion:

→ 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
Outline

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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: $l_{corr} = 1.3 \text{ mm}$ and $\sigma_h = 0.05 \text{ mm}$
  - plaster 2, higher roughness: $l_{corr} = 1.7 \text{ mm}$ and $\sigma_h = 0.15 \text{ mm}$
- **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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![Diagram of Office Scenario]

Plaster walls

Room height: 2.5 m
Outline

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

- Measure for the spatial dispersion provided by the **angular spread**

- 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:

  - 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)

→ 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 occurring cluster angular spreads evaluated individually for all clusters at every RX position:

- 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
Outline

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Temporal Dispersion (1)

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

\[ \tau_{\text{RMS}} = \sqrt{\frac{\sum_{i} (\tau_i - \bar{\tau})^2 P_i}{\sum_{i} P_i}} \]

- Highest RMS delay spreads under NLOS conditions
- Significant roughness dependence
Temporal Dispersion (2)

- Distance-dependent model for the RMS delay spread:

\[ \tau_{\text{RMS}} \] [ns]

\[ d \] [m]

Lower roughness

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

Higher roughness

→ Higher roughness leads to a lower RMS delay spread
Temporal Dispersion (3)

- Cluster-based modeling for directed (N)LOS communications
- Normalized histogram 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:

\[ \tau_{\text{RMS}} \text{ [ns]} \]

远更高的群延迟均方根延迟扩展对于较高的粗糙度
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
Parameters of the second order polynomials and the approximated analytical PDFs for both roughnesses can be found in:

Thank you for paying attention.

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