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

Submission Title: A Stochastic Indoor Radio Channel Model for THz WPANs/WLANs
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Abstract: Building upon the experimental understanding of the THz indoor radio channel and a deterministic ray tracing propagation simulator, a stochastic channel modeling approach is proposed. Such a model becomes inevitable for the system conception of THz WPANs or WLANs as soon as a system design is developed based on system simulations. Then, realistic channel conditions must be respected. For this purpose, the model features broadband channel realizations with 50 GHz bandwidth, is fully polarimetric, includes spatial channel information and allows for the fast generation of channel realizations.

Re: 15-10-0436-01-0thz_Towards_a_300_GHz_Channel_Model.pdf

Purpose: Foundation document for a THz WPAN/WLAN channel model

A Stochastic Indoor Radio Channel Model for THz WPANs/WLANs

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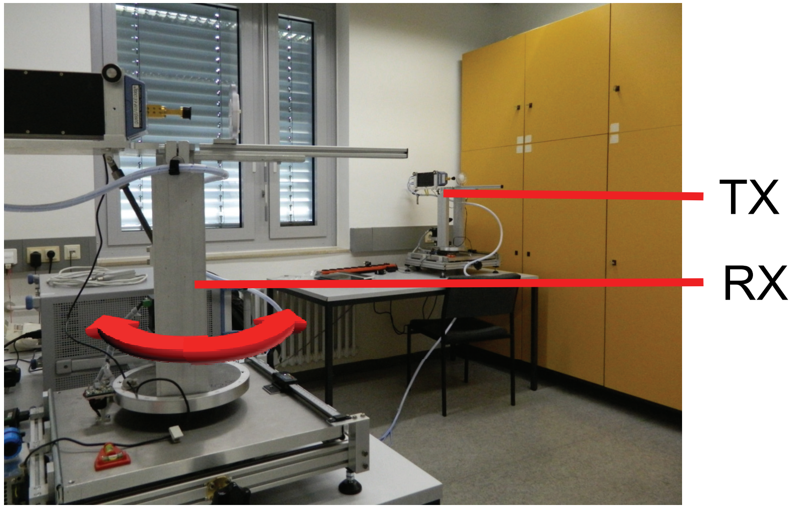
Outline

1. **Introduction**
2. Modeling Concept
3. The THz Indoor Radio Channel Model
4. Validation
5. Summary/Outlook

Introduction (1)

1. Preliminary work: indoor radio channel measurements
    - Based on a vector network analyzer
    - Rotation of TX and RX in the azimuth: 360° x 360°
    - Automatic setup

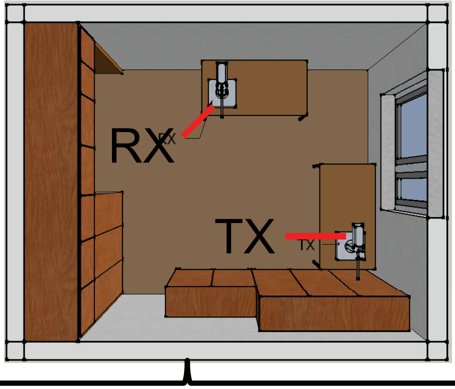


Measurement parameter	Value
Frequency	275 - 325 GHz
Angular resolution	2°
Dynamic range	145 dB
Measurement duration for one position (360° x 360°)	90 h

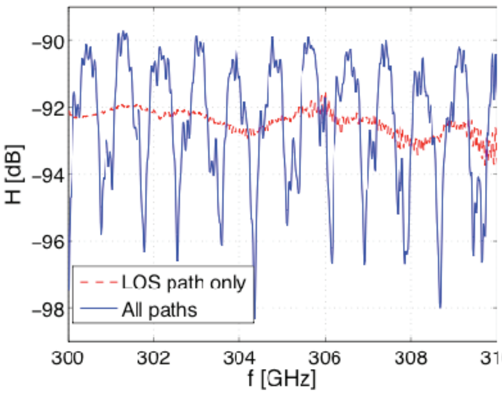
Introduction (2)

Conducted measurements:

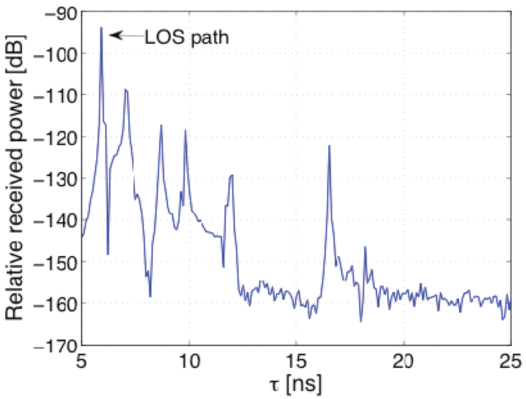
- Office environment
- 50 GHz wide channels
- Power delay profiles
- Angular power profiles



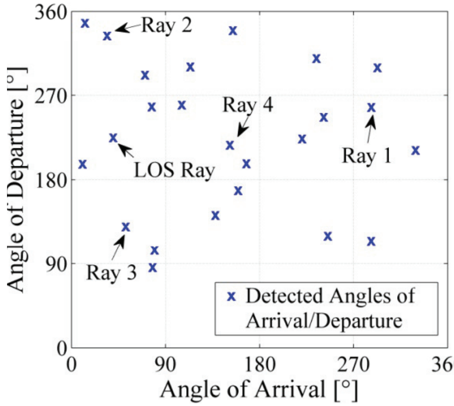
1.) Channel transfer function



2.) Power delay profile



3.) Angular power profile



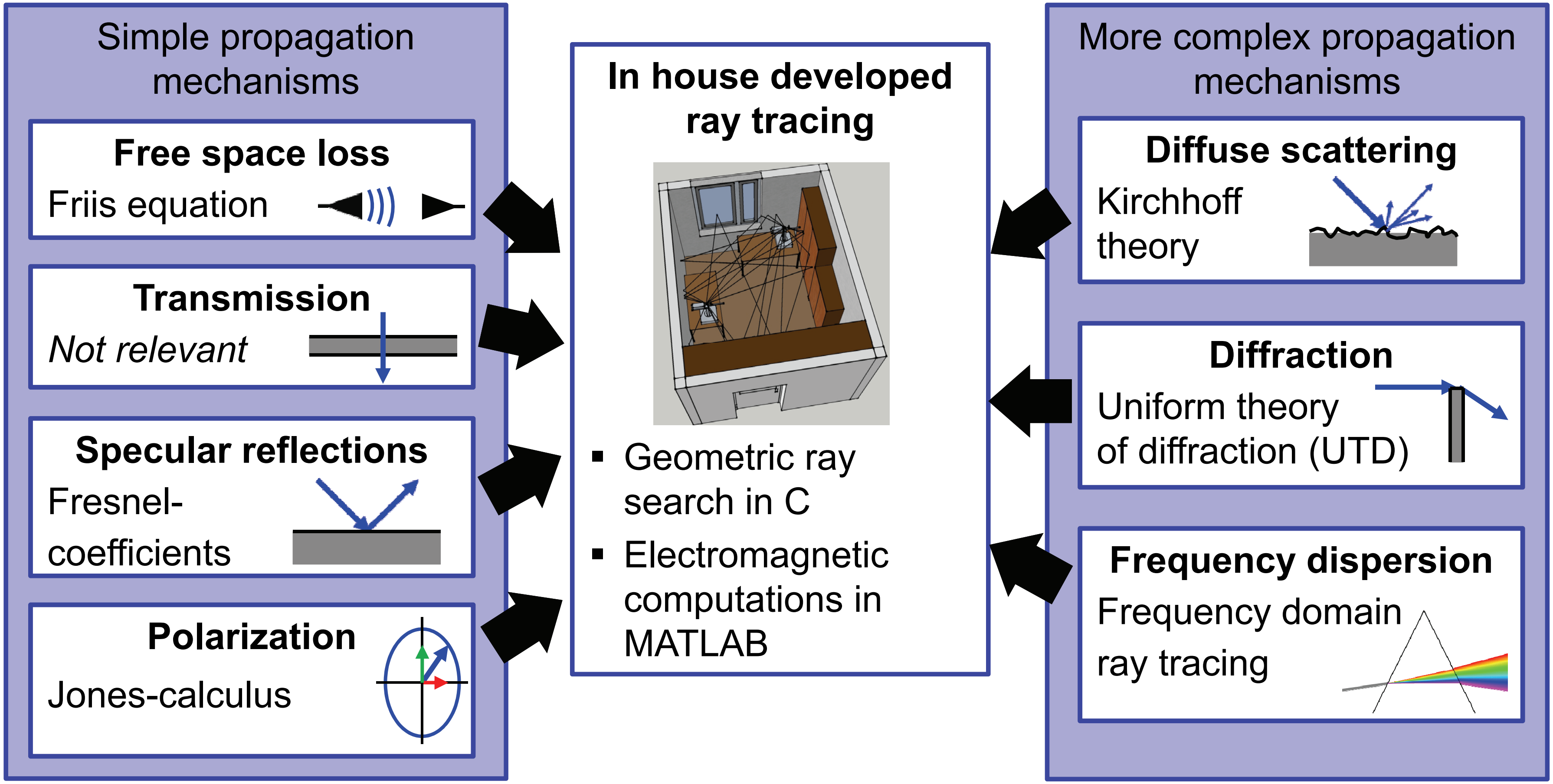
IEEE document 802.15-15-10-0436-01-0thz_Towards_a_300_GHz_Channel_Model, Reference [2]

Problem: measurements very time-consuming

→ Propagation model necessary for extensive THz radio channel studies

Introduction (3)

2. Preliminary work: ray tracing (RT) propagation modeling



Simple propagation mechanisms

Free space loss

Friis equation

Transmission

Not relevant

Specular reflections

Fresnel-coefficients

Polarization

Jones-calculus

In house developed ray tracing

- Geometric ray search in C
- Electromagnetic computations in MATLAB

More complex propagation mechanisms

Diffuse scattering

Kirchhoff theory

Diffraction

Uniform theory of diffraction (UTD)

Frequency dispersion

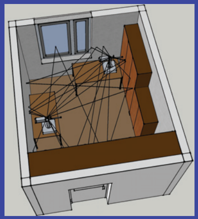
Frequency domain ray tracing

Introduction (4)

- *Idea*: optimize material parameters for RT
→ Validation and calibration of the RT tool based on measurements

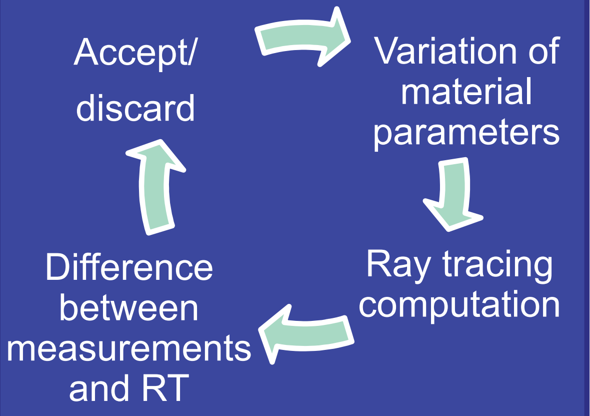
Channel measurements

Frequency domain RT



→Frequency-dependent materials

Iterative optimization of the material parameters



Accept/ discard

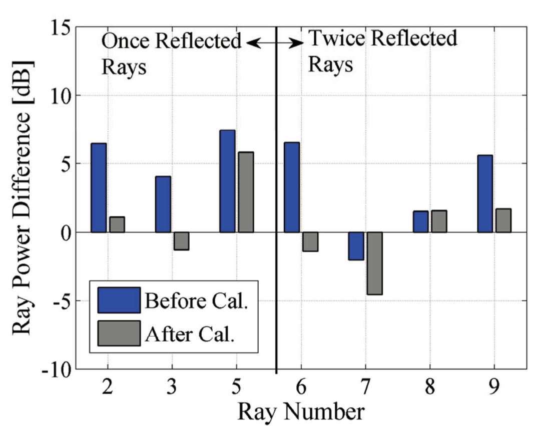
Variation of material parameters

Ray tracing computation

Difference between measurements and RT

- *Criterion*: Minimum difference between measured and simulated path losses

Difference between measured and simulated ray powers (before/after calibration)

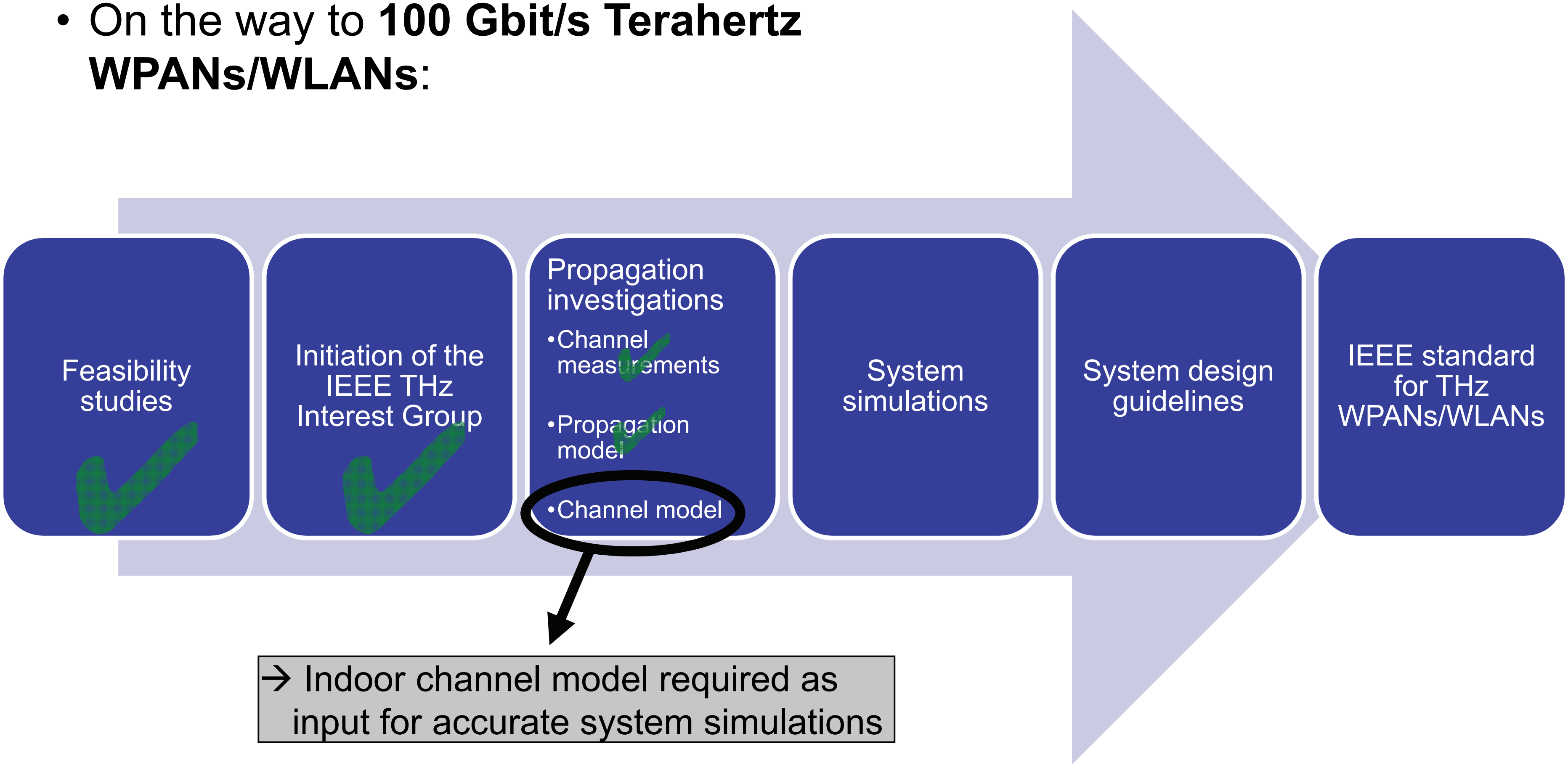


→ Significant improvement of ray tracing accuracy

Reference [3].

Introduction (5)

- On the way to **100 Gbit/s Terahertz WPANs/WLANs**:



→ Indoor channel model required as input for accurate system simulations

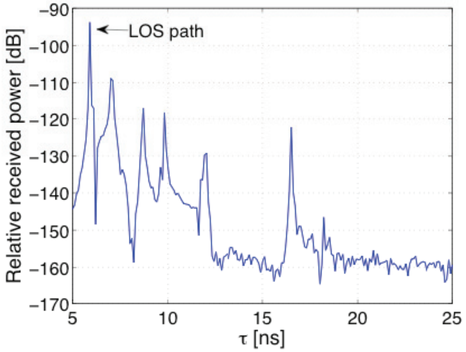
Outline

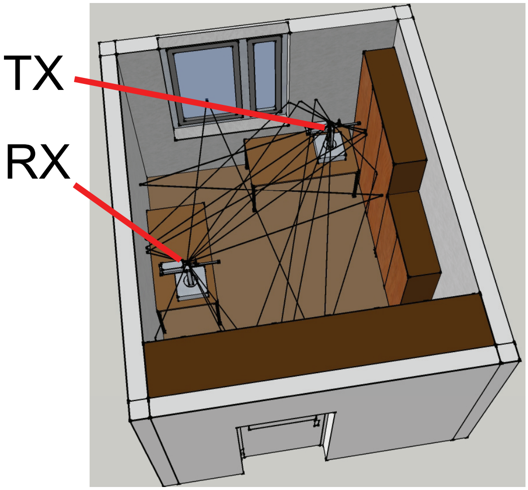
1. Introduction
2. **Modeling Concept**
    - **Requirements**
    - **Methodology**
    - **Parameter Derivation**
3. The THz Indoor Radio Channel Model
4. Validation
5. Summary/Outlook

Modeling Concept – Requirements

- *Aim*: complete channel realizations as input for system simulations
- *Requirements*:

1. Correct fading modeling, IQ-modulation schemes
   → Complex amplitude values
2. Antenna polarization
   → Fully polarimetric realizations
3. Smart antennas
   → Spatial channel properties
4. Fast generation of channels
   → Stochastic model
5. Consideration of channel frequency dispersion
   → Modeling in frequency domain
6. Significant data
   → Extensive ray tracing simulations





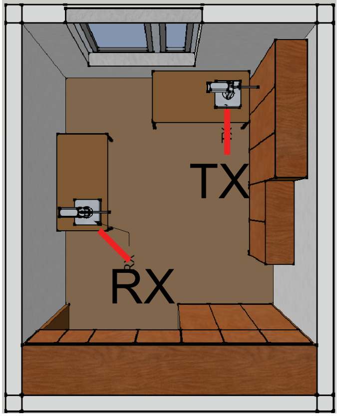
IEEE document 802.15-15-10-0436-01-0thz_Towards_a_300_GHz_Channel_Model

Modeling Concept – Methodology (1)

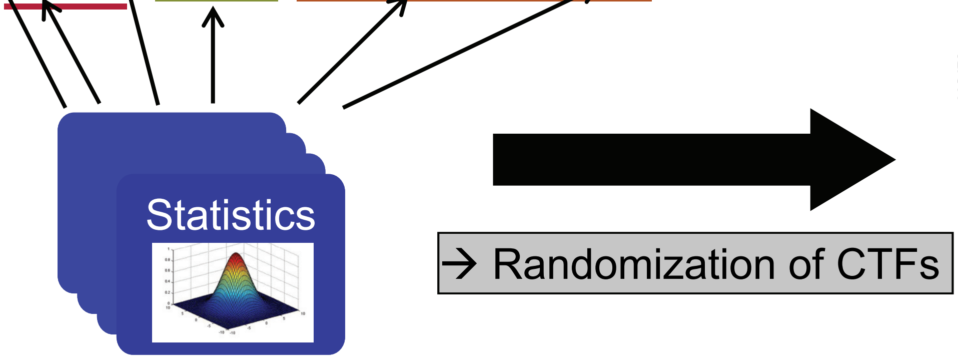
- *Idea*: modeling of the **channel transfer function (CTF)** in frequency domain

Requirements

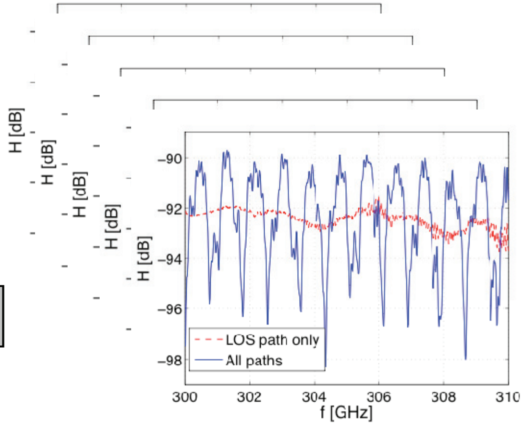
1. Complex amplitude values
2. Fully polarimetric realizations
3. Spatial channel properties
4. Stochastic model
5. Frequency dispersion
6. Extensive ray tracing simulations



$$H(f,\phi,\theta)=\sum_{i=1}^{\underline{N_{Rays}}}\underline{a_i\cdot e^{j\varphi_i}}\cdot\underline{D_i(f)}\cdot\underline{\delta(\phi-\phi_i)\cdot\delta(\theta-\theta_i)}$$

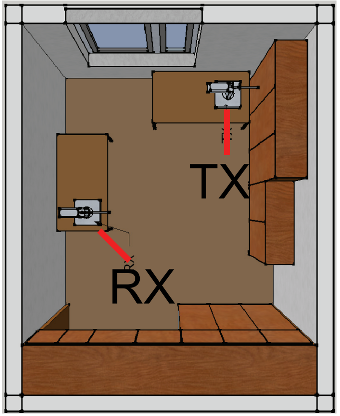


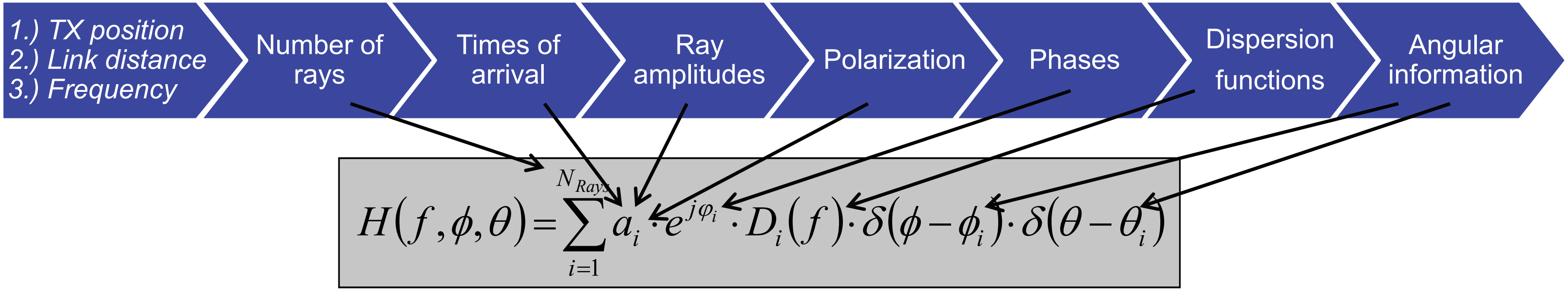
→ Randomization of CTFs



Modeling Concept – Methodology (2)

- Required input data:
  1. TX position
  2. Link distance
  3. Frequency
- Data to be randomized:
  1. Number of rays
  2. Times of arrival
  3. Amplitudes
  4. Polarization
  5. Phases
  6. Dispersion functions
  7. Angular information





1.) TX position
2.) Link distance
3.) Frequency

Number of rays → Times of arrival → Ray amplitudes → Polarization → Phases → Dispersion functions → Angular information

$$H(f,\phi,\theta)=\sum_{i=1}^{N_{Rays}} a_i \cdot e^{j\varphi_i} \cdot D_i(f) \cdot \delta(\phi-\phi_i) \cdot \delta(\theta-\theta_i)$$

Modeling Concept – Methodology (3)

- Basic form of randomized CTF:

$$\boxed{H(f,\phi,\theta)=\sum_{i=1}^{N_{Rays}}\underbrace{a_i\cdot e^{j\varphi_i}\cdot D_i(f)\cdot\delta(\phi-\phi_i)\cdot\delta(\theta-\theta_i)}}$$

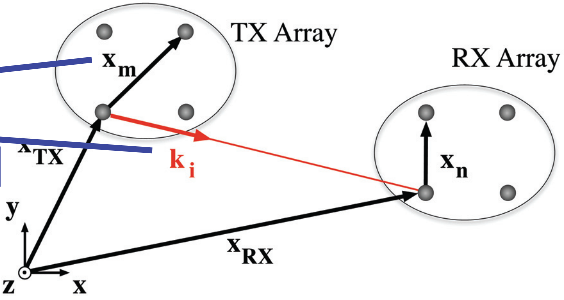
- Consideration of directive antennas:

$$H(f)=\sum_{i=1}^{N_{Rays}} H_i\cdot\underbrace{g_{TX}\left(f,\phi_{AoD,i},\theta_{AoD,i}\right)}_{\text{Angular and frequency-dependent antenna gain}}\cdot g_{RX}\left(f,\phi_{AoA,i},\theta_{AoA,i}\right)$$

- Antenna arrays: CTF between m*th* and n*th* array element

$$H_{m,n}(f)=\sum_{i=1}^{N_{Rays}} H_i\cdot g_m\left(f,\phi_{AoD,i},\theta_{AoD,i}\right)e^{j\langle\mathbf{k}_i(f)\cdot\mathbf{x}_\mathbf{m}\rangle}\cdot g_n\left(f,\phi_{AoA,i},\theta_{AoA,i}\right)e^{j\langle\mathbf{k}_i(f)\cdot\mathbf{x}_\mathbf{n}\rangle}$$

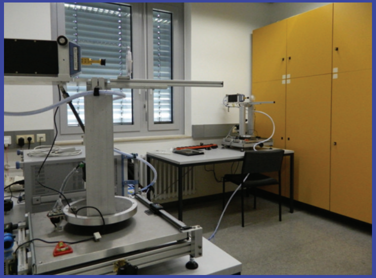
Wave vector



Modeling Concept – Parameter Derivation

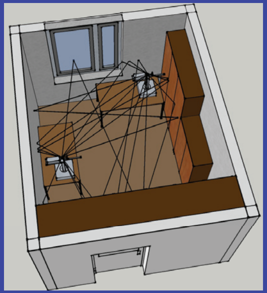
- *Aim*: realistic and extensive data basis for model

1. Channel measurements



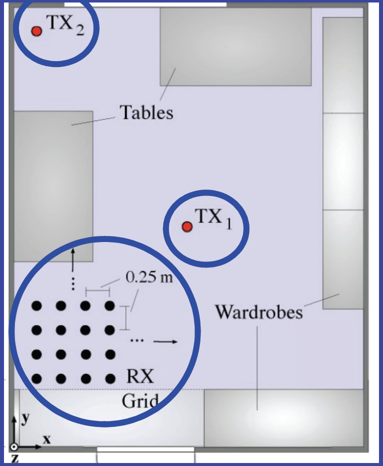
- 3 different TX/RX constellations
- f = 275 – 325 GHz

2. Ray tracing calibration



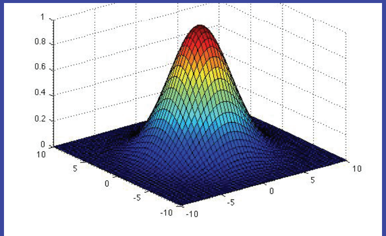
- Frequency domain ray tracing
- Accuracy improvement

3. Extensive RT simulations



- 2 TX placements
- 180 RX positions
- f = 275 – 325 GHz

4. Parameter derivation



- For both TX placements
- For 180 RX positions

→ Significant, measurement-based data for statistics

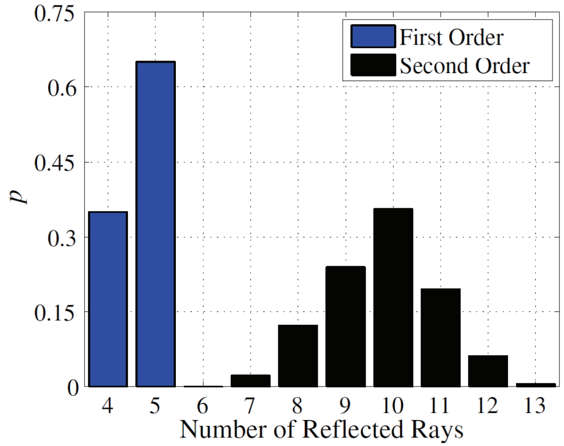
Outline

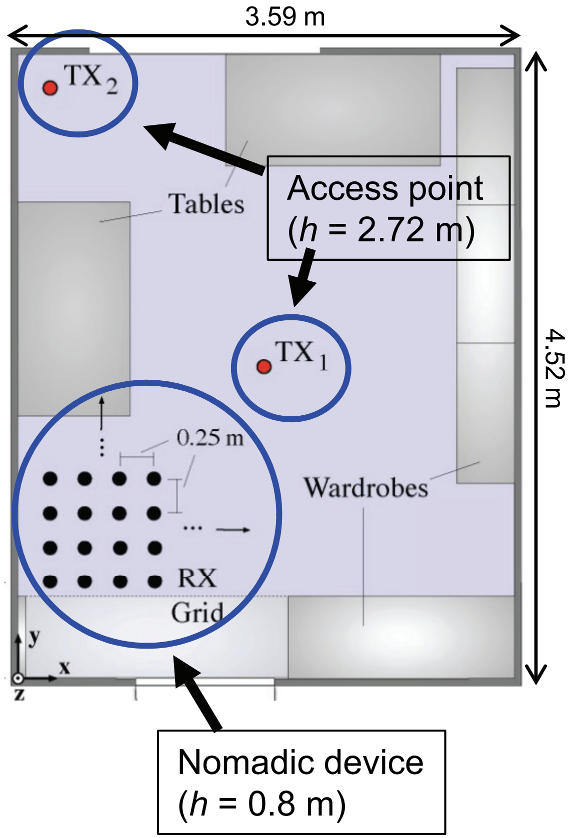
1. Introduction
2. Modeling Concept
3. **The THz Indoor Radio Channel Model**
    - **Number of Rays**
    - **Times of Arrival**
    - **Amplitudes**
    - **…**
4. Validation
5. Summary/Outlook

THz Channel Model – Number of Rays

1.) TX position
2.) Link distance
3.) Frequency
→ **Number of rays** → Times of arrival → Ray amplitudes → Polarization → Phases → Dispersion functions → Angular information

- *Setup:* nomadic device to access point connection; realistic office scenario
- 2 alternative TX positions: TX_1 and TX_2
- Ocurring number of rays:
(for TX_1; probabilities for TX_2 in [1])





Access point
(h = 2.72 m)

Nomadic device
(h = 0.8 m)

→ Number of reflections are randomized according to empiric histogram

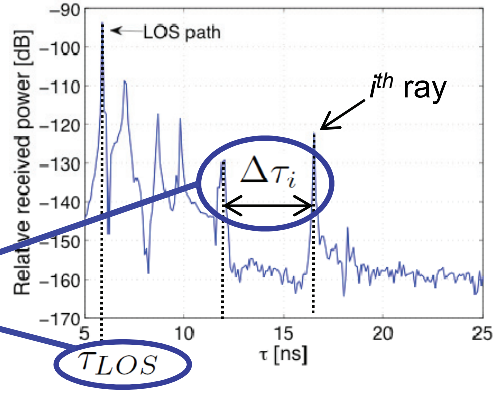
THz Channel Model – Times of Arrival

- Analytic arrival time of the line-of-sight (LOS) ray:

$$\tau_{LOS} = \frac{d}{c}$$

- Recursive time of arrival (ToA) of the i^{th} ray with respect to the previous path:

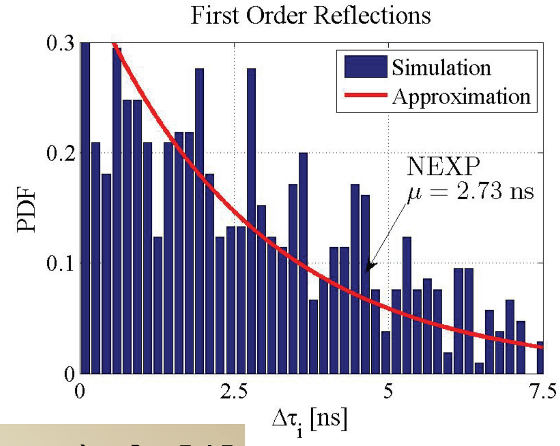
$$\tau_i = \tau_{i-1} + \Delta\tau_i$$



- Histogram of the occuring relative ToAs:

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

→ Recursive randomization of the ToAs



Different treatment of the first arriving rays (omitted here) → [1]

THz Channel Model – Amplitudes (1)

1.) TX position
2.) Link distance
3.) Frequency

Number of rays

Times of arrival

Ray amplitudes

Polarization

Phases

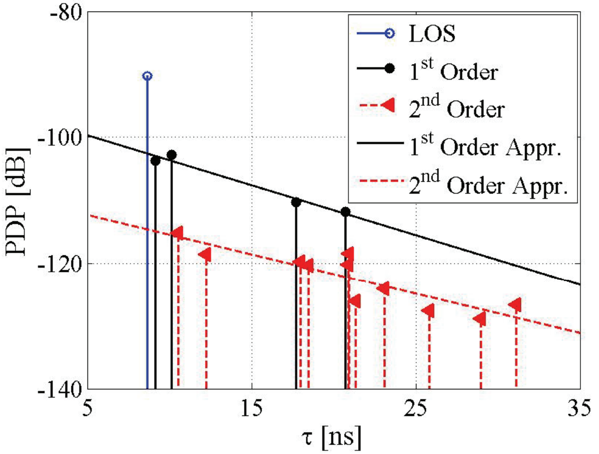
Dispersion functions

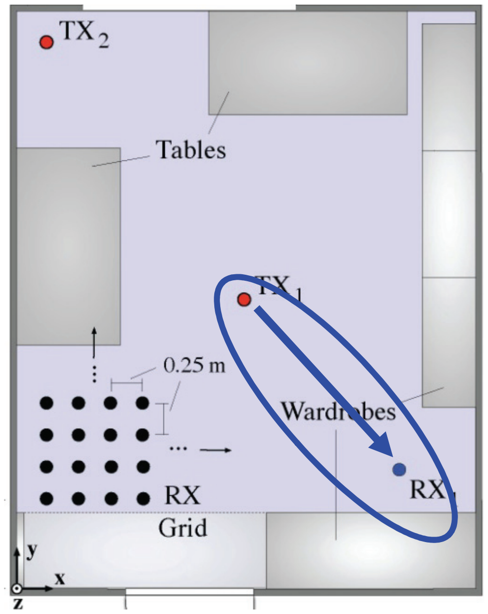
Angular information

- LOS amplitude: analytical dependent on distance ($f_0 = 300$ GHz)

$$\boxed{\begin{aligned} a_{LOS} &= 20 \cdot \log_{10}\left(\frac{c}{4\pi f_0}\right) - 20 \cdot \log_{10}(d) \\ &= -81.98\ \text{dB} - 20 \cdot \log_{10}(d[\text{m}]) \end{aligned}}$$

- *Example*: power delay profile for connection TX$_1$/RX$_1$





→ Only up to second order rays relevant because of high losses

→ Amplitude modeling with random logarithmic-linear decay over time

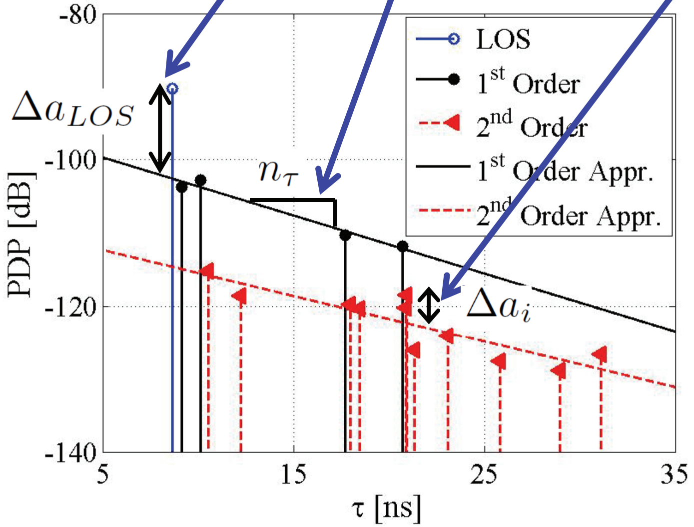
THz Channel Model – Amplitudes (2)

1.) TX position
2.) Link distance
3.) Frequency
→ Number of rays → Times of arrival → **Ray amplitudes** → Polarization → Phases → Dispersion functions → Angular information

- Delay-amplitude function for the reflected rays:

$$\boxed{a_{i,Refl} = a_{LOS} - \Delta a_{LOS} - n_\tau \cdot (\tau_i - \tau_{LOS}) + \Delta a_i}$$

- Description with three random parameters:



Histrograms for the three parameters required

→ Amplitudes assignable based on ToAs of the rays

THz Channel Model – Amplitudes (3)

1.) TX position
2.) Link distance
3.) Frequency

Number of rays

Times of arrival

Ray amplitudes

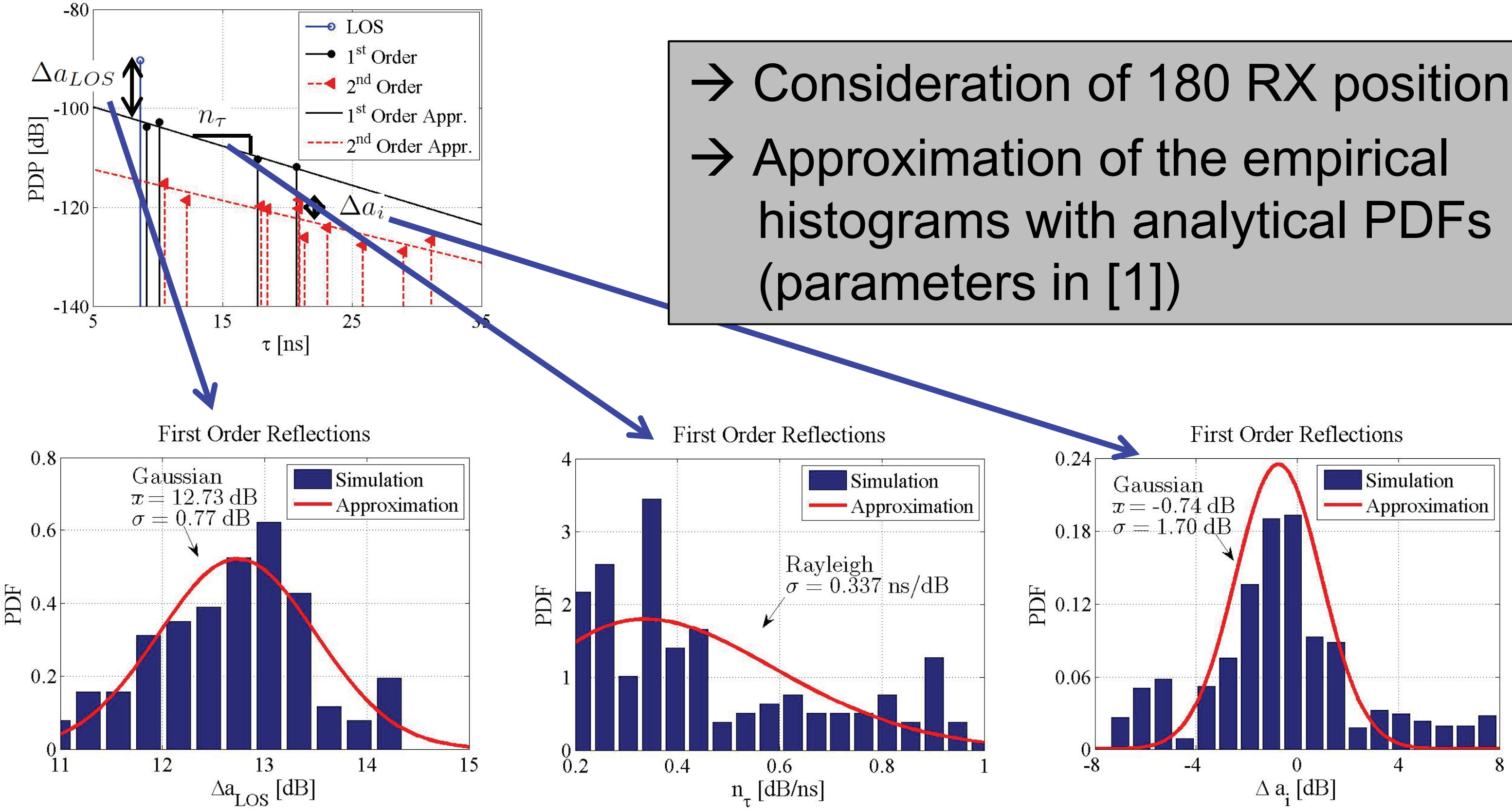
Polarization

Phases

Dispersion functions

Angular information

- Derivation of histograms for the delay-amplitude parameters:



→ Consideration of 180 RX positions

→ Approximation of the empirical histograms with analytical PDFs (parameters in [1])

THz Channel Model – Polarization

1.) TX position
2.) Link distance
3.) Frequency
Number of rays
Times of arrival
Ray amplitudes
Polarization
Phases
Dispersion functions
Angular information

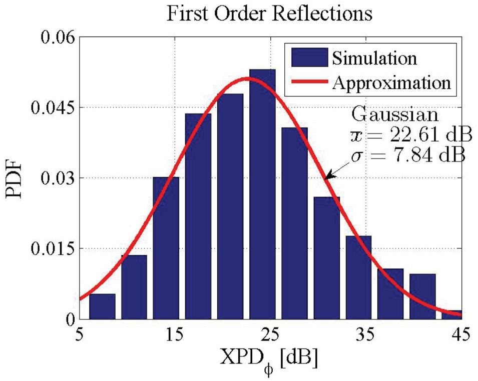
- So far: randomized amplitudes contain co and cross polarization

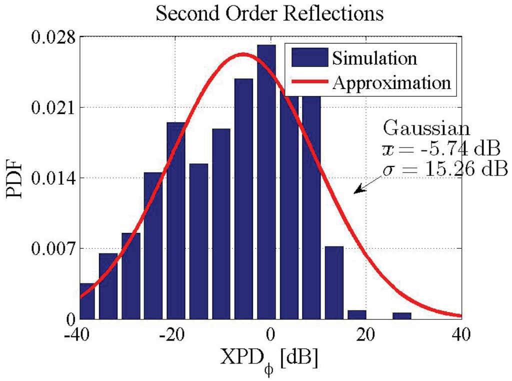
$$a_{i,Refl} = \sqrt{a^2_{i,Refl,co} + a^2_{i,Refl,cross}}$$

→ Decomposition into co and cross components via random cross polarization discrimination (XPD)

$$a_{i,Refl,co} = a_{i,Refl} - 20 \cdot \log_{10}\left(1 + \frac{1}{\boxed{10^{\frac{\mathrm{XPD}}{20}}}}\right)$$

$$a_{i,Refl,cross} = a_{i,Refl} - 20 \cdot \log_{10}\left(1 + \boxed{10^{\frac{\mathrm{XPD}}{20}}}\right)$$





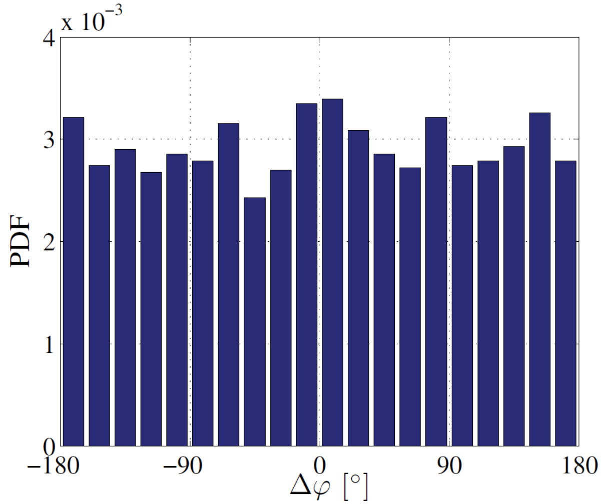
THz Channel Model – Phases

1.) TX position
2.) Link distance
3.) Frequency
Number of rays
Times of arrival
Ray amplitudes
Polarization
Phases
Dispersion functions
Angular information

- Analytic phase of the LOS ray:

$$\varphi_{LOS} = -2\pi f_0 \cdot \tau_{LOS}$$

- Phase histogram of all reflected rays:



→ Randomization of the phases according to a uniform distribution

THz Channel Model – Dispersion Functions (1)

1.) TX position
2.) Link distance
3.) Frequency
→ Number of rays → Times of arrival → Ray amplitudes → Polarization → Phases → **Dispersion functions** → Angular information

- Carrier frequency f_0 = 300 GHz
- Huge bandwidths up to 50 GHz

→ CTFs become dispersive

→ Introduction of a frequency-dependent dispersion function necessary

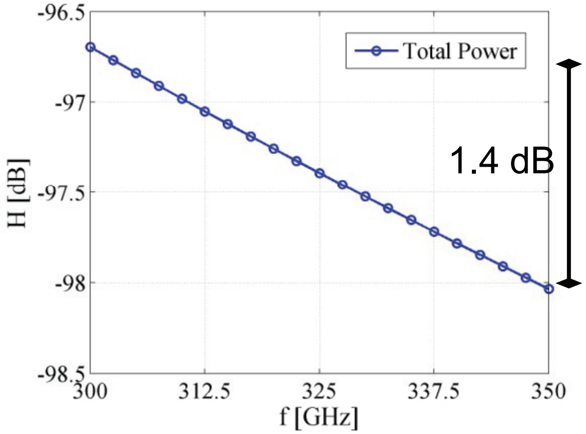
$$H\left(\underline{f},\phi,\theta\right)=\sum_{i=1}^{N_{Rays}} a_i\cdot e^{j\varphi_i}\cdot D_i\left(\underline{f}\right)\cdot\delta\left(\phi-\phi_i\right)\cdot\delta\left(\theta-\theta_i\right)$$

$$\boxed{D_i(\underline{f})=\frac{f_0}{\underline{f}^{\zeta}}}$$

300 GHz

Ray-specific dispersion coefficient

Example: CTF for a LOS link, *d* = 5.3 m

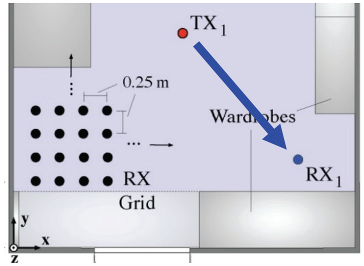


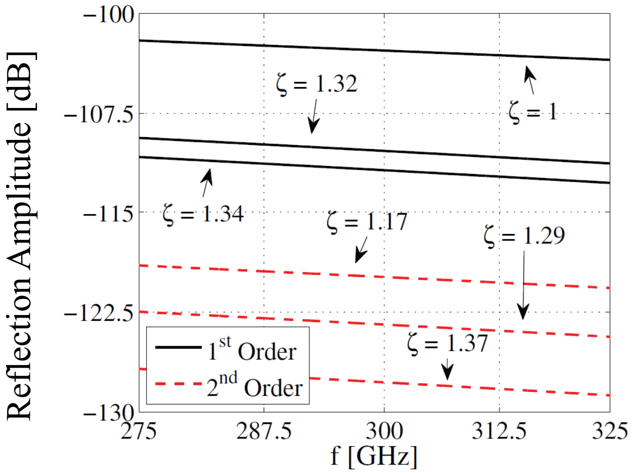
THz Channel Model – Dispersion Functions (2)

1.) TX position
2.) Link distance
3.) Frequency

Number of rays → Times of arrival → Ray amplitudes → Polarization → Phases → **Dispersion functions** → Angular information

- Ray-specific disperion coefficient ζ to be determined
- *Example*: Amplitudes of reflected rays for an exemplary TX/RX constellation





$$D_i(f) = \frac{f_0}{f^{\zeta}}$$

→ LOS ray: $\zeta = 1$

→ Reflections: randomization of ζ necessary

THz Channel Model – Dispersion Functions (3)

1.) TX position
2.) Link distance
3.) Frequency

Number of rays

Times of arrival

Ray amplitudes

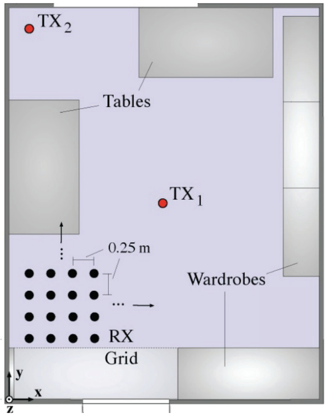
Polarization

Phases

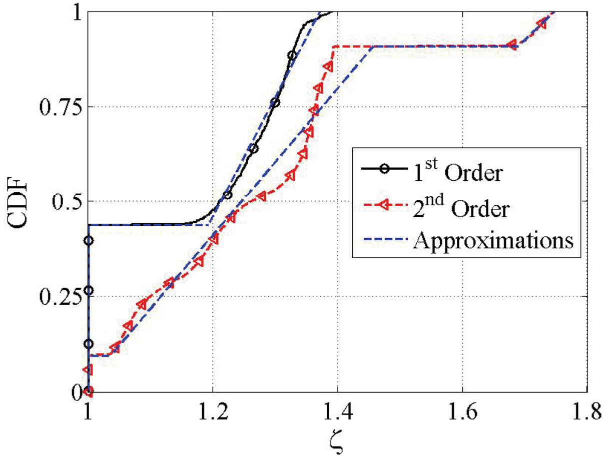
Dispersion functions

Angular information

- Empiric cumulative distribution functions (CDFs) of the occuring ζ (TX_1, 180 RX positions, f = 275 - 325 GHz)



Each reflection at the 180 RX positions



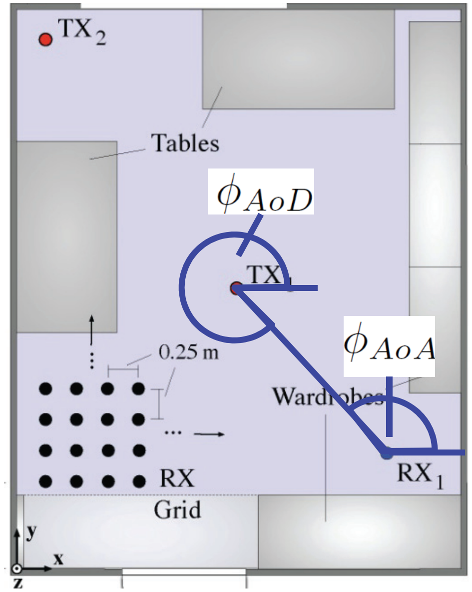
$$\mathrm{CDF}_\zeta = \begin{cases} 0 & \zeta < 1 \\ b_1 & 1 \le \zeta \le \zeta_1 \\ a_2 \cdot \zeta + b_2, & \zeta_1 \le \zeta \le \zeta_2 \\ b_3 & \zeta_2 \le \zeta \le \zeta_3 \\ a_4 \cdot \zeta + b_4, & \zeta_3 \le \zeta \le \zeta_4 \\ 1 & \zeta_4 < \zeta. \end{cases}$$

→ Approximation with linear polynomials (parameters *a* and *b* in [1])

→ Randomization of the dispersion functions possible

THz Channel Model – Angular Information (1)

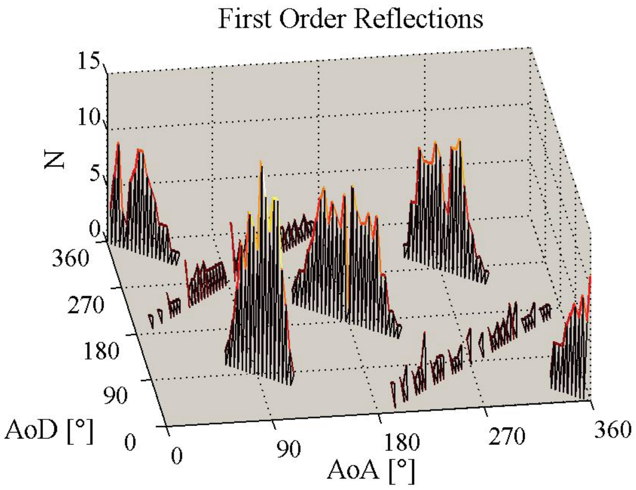
1.) TX position
2.) Link distance
3.) Frequency
Number of rays
Times of arrival
Ray amplitudes
Polarization
Phases
Dispersion functions
Angular information



- Spatial information obligatory for simulations including antennas
- Joint modeling of the AoAs/AoDs required for realistic channels
- AoAs/AoDs dependent on random RX placement

→ Randomization of angles in the AoA/AoD domain

Histogram of occurring angles in the AoA/AoD domain:



→ Rays depart/arrive only within a few limited angular ranges

THz Channel Model – Angular Information (2)

1.) TX position
2.) Link distance
3.) Frequency

Number of rays

Times of arrival

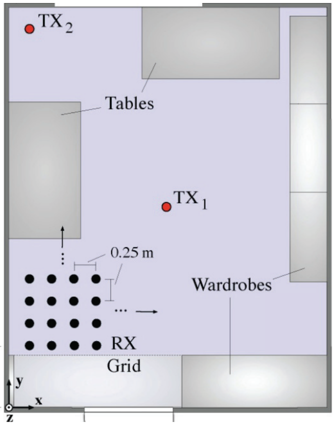
Ray amplitudes

Polarization

Phases

Dispersion functions

Angular information



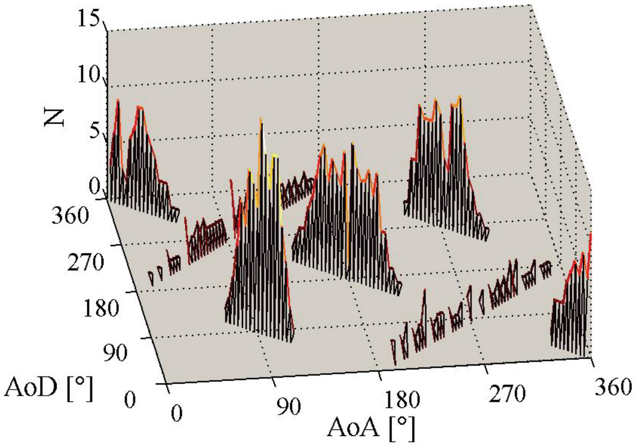
(a) Azimuth modeling

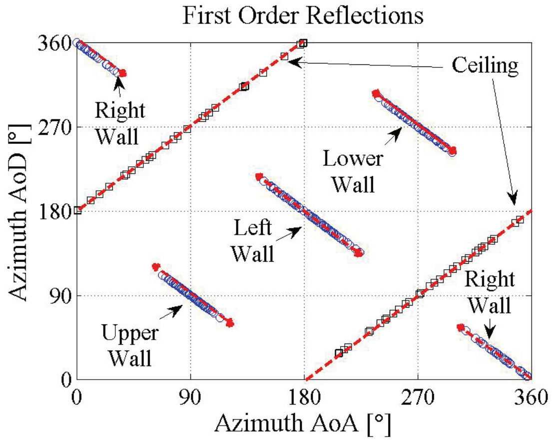
1. LOS path: random RX placement in horizontal plane

   → uniform $\Phi_{AoA,LOS}$ distribution between [0°; 360°]

2. Reflections:

   – Angular ranges defined through line segments in the AoA/AoD domain





THz Channel Model – Angular Information (3)

1.) TX position
2.) Link distance
3.) Frequency

Number of rays

Times of arrival

Ray amplitudes

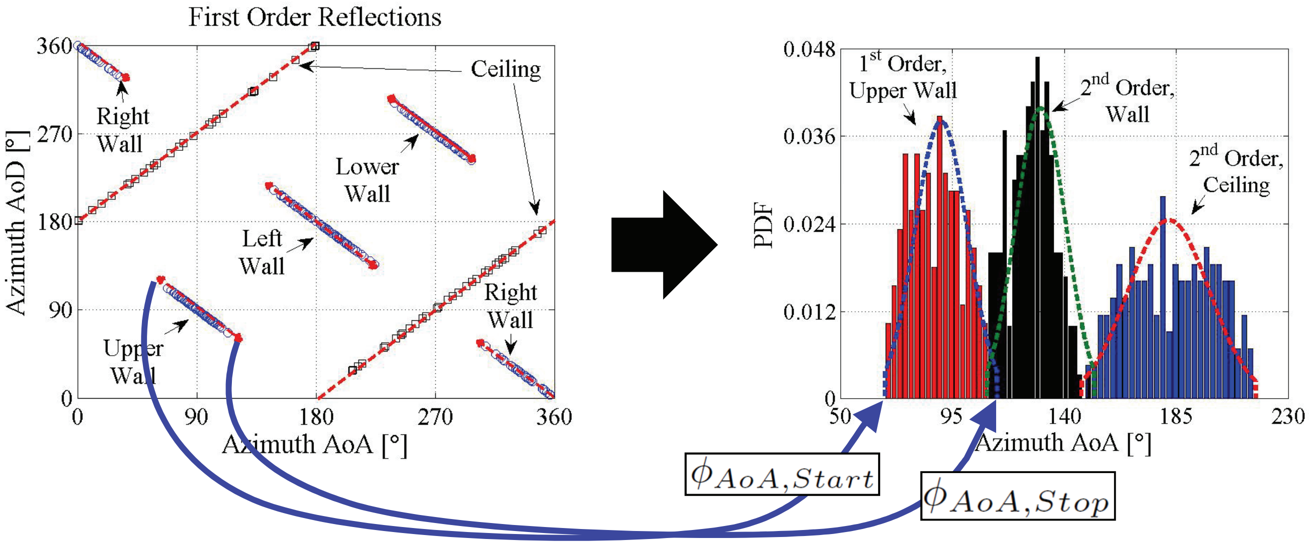
Polarization

Phases

Dispersion functions

Angular information

- Line segments in the AoA/AoD domain defined through start and stop points $\phi_{AoA,Start}$, $\phi_{AoA,Stop}$
- Gaussian distributions of occurring angles along the line segments:



→ Randomization of the azimuth AoAs from the Gaussian PDFs (parameters in [1])

- Gaussian PDF parameters:

$$\boxed{\overline{x} = \frac{\phi_{AoA,Start} + \phi_{AoA,Stop}}{2}}$$

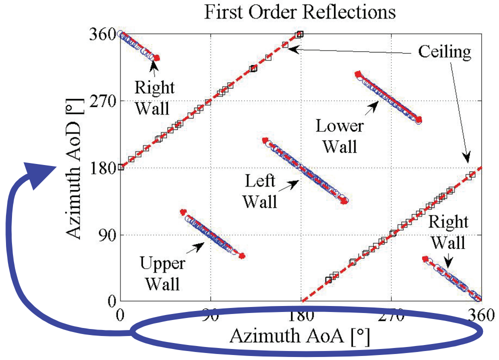
$$\boxed{\sigma = \left| \frac{\phi_{AoA,Stop} - \phi_{AoA,Start}}{\sqrt{-8 \ln C}} \right|}$$

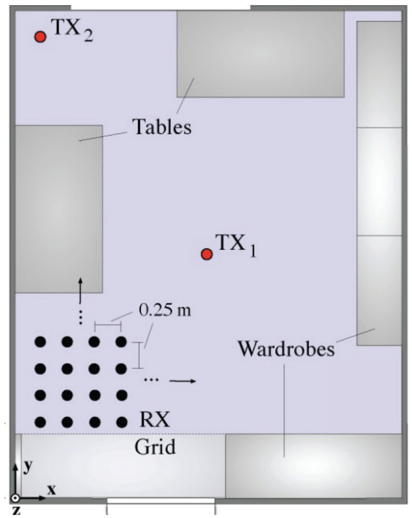
THz Channel Model – Angular Information (4)

1.) TX position
2.) Link distance
3.) Frequency
Number of rays
Times of arrival
Ray amplitudes
Polarization
Phases
Dispersion functions
Angular information

- Azimuth AoAs randomizable

→ Determination of the azimuth AoDs from the AoAs:





- Analytic expressions:

$$\phi_{AoD,i} = \begin{cases} 360^\circ - \phi_{AoA,i} & \text{, LOS} \\ \psi_\phi + \phi_{AoA,i} & \text{, } 1^{st} \text{ order, ceiling} \\ \psi_\phi - \phi_{AoA,i} & \text{, } 1^{st} \text{ order, walls} \\ \psi_\phi - \phi_{AoA,i} & \text{, } 2^{nd} \text{ order, ceiling} \\ \psi_\phi + \phi_{AoA,i} & \text{, } 2^{nd} \text{ order, walls.} \end{cases}$$

Multiples of 180° (cf. [1])

→ Azimuth AoDs from the analytic dependencies

THz Channel Model – Angular Information (5)

1.) TX position
2.) Link distance
3.) Frequency

Number of rays → Times of arrival → Ray amplitudes → Polarization → Phases → Dispersion functions → **Angular information**

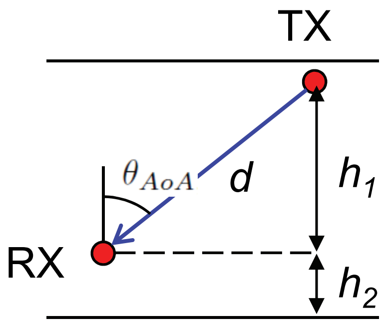
(b) Elevation modeling

1. LOS path: analytic

$$\theta_{AoA,LOS} = \arccos\left(\frac{h_1}{d}\right)$$

2. First order ceiling ray: analytic

$$\theta_{AoA,Ceil} = \arctan\left(\frac{\sqrt{d^2 - h_1^2}}{h_1 + 2h_2}\right)$$



3. All other rays: random relative to the LOS
   - Distance dependence to be respected → more realistic

$$\theta_{AoA,i} = \theta_{AoA,LOS} + \Delta\theta_{AoA,i}$$

Exponential decrease over distance (parameters in [1])

$$\Delta\theta_{AoA,i} = \underline{c_{\Delta\theta} \cdot e^{d \cdot \mu_{\Delta\theta}}} + \chi_{\Delta\theta_{AoA}}$$

Gaussian distributed random variable

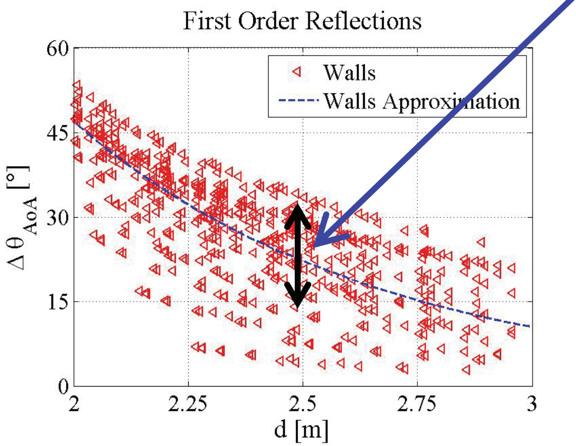
THz Channel Model – Angular Information (6)

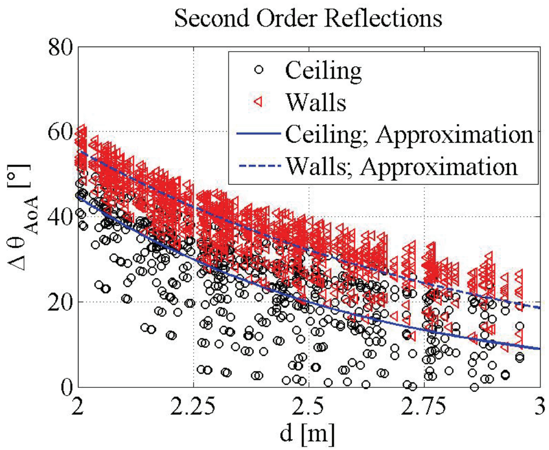
1.) TX position
2.) Link distance
3.) Frequency
Number of rays
Times of arrival
Ray amplitudes
Polarization
Phases
Dispersion functions
Angular information

- From previous slide:

$$\Delta\theta_{AoA,i} = c_{\Delta\theta}\cdot e^{d\cdot\mu_{\Delta\theta}} + \chi_{\Delta\theta_{AoA}}$$

- Separate treatment of first and second order paths
- Differentiation of second order ceiling and wall reflections





→ Relative elevation AoAs randomizable

THz Channel Model – Angular Information (7)

1.) TX position
2.) Link distance
3.) Frequency

Number of rays

Times of arrival

Ray amplitudes

Polarization

Phases

Dispersion functions

Angular information

- Determination of the elevation AoD from the AoA:
  1. LOS path: $\boxed{\theta_{AoD,LOS} = 180° - \theta_{AoA,LOS}}$
  2. First order ceiling: $\boxed{\theta_{AoD,Ceil} = 90° - 3\arctan\left(\frac{h_1 + 2h_2}{\sqrt{d^2 - h_1^2}}\right)}$
  3. Others: $\boxed{\theta_{AoD} = \begin{cases} 180° - \theta_{AoA} & \text{, wall reflections} \\ \boxed{\psi_\theta} + \theta_{AoA} & \text{, ceiling reflections} \end{cases}}$

$$\boxed{\psi_\theta = \underline{a_{\psi_\theta} \cdot d + b_{\psi_\theta}} \boxed{+ \chi_{\psi_\theta}}}$$

Linear behavior over distance (parameters in [1])

Gaussian distributed random variable

→ Complete determination of all angles possible

THz Channel Model – Realization Generation

1. Define TX position, specify link distance, give frequency range
2. Randomize number of reflected rays (first and second order)
3. Determine ToAs (LOS analytic, reflections recursive)
4. Obtain parameters of ToA-amplitude funtions and determine amplitudes
5. Separate polarization components via random cross polarization discriminations
6. Assign uniformly distributed phases to the rays
7. Determine dispersion coefficients from empiric distributions
8. Randomize AoAs/AoDs in the azimuth/elevation

→ Complete channel realization

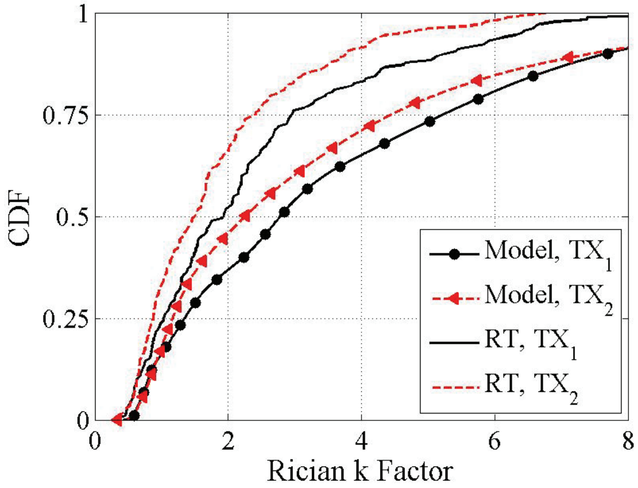
Outline

1. Introduction
2. Modeling Concept
3. The THz Indoor Radio Channel Model
4. **Validation**
    - **Broadband Channel Properties**
    - **Spatial Characteristics**
    - **MIMO Capabilities**
    - **Model Limitations/Advantages**
5. Summary/Outlook

Validation – Broadband Channel Properties

- *Idea*: validation of the stochastic model against RT simulations
- *Methodology*: RT simulations for 180 RX placements vs. 1000 stochastic realizations each, 275 – 325 GHz
- Comparison of the resulting Rician k factors (measure for the multipath richness of a channel):

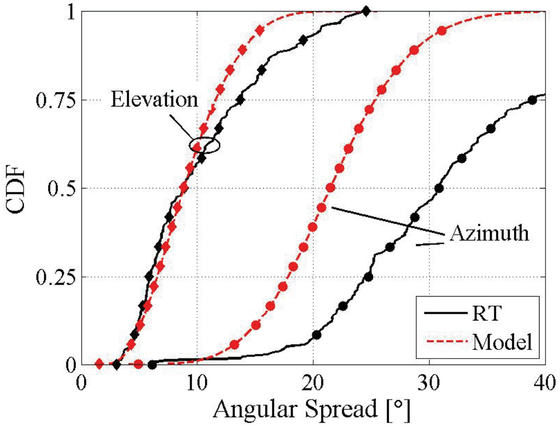
180 RX positions,
1000 realizations each



Similar curves regardless of TX position
→ Randomization of realistic multipath powers

Validation – Spatial Characteristics

- Comparison of the angular spreads for TX_1
(measure for the spatial dispersion of a channel):



→ Realistic spatial properties generated by model
→ Remaining deviations in the azimuth due to neglected parameter interdependencies

- Angular spreads averaged over all 180 positions:

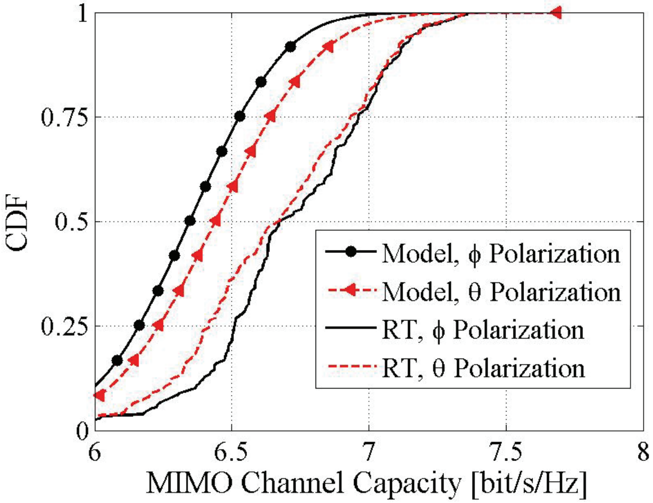
	$\overline{\sigma_{\phi,AoA}}$		$\overline{\sigma_{\theta,AoA}}$		$\overline{\sigma_{\phi,AoD}}$		$\overline{\sigma_{\theta,AoD}}$	
	TX_1	TX_2	TX_1	TX_2	TX_1	TX_2	TX_1	TX_2
RT	32.1°	27.7°	10.3°	5.9°	20.1°	24.0°	19.6°	16.2°
Model	21.7°	18.5°	9.3°	3.9°	21.7°	17.3°	18.8°	14.8°

→ Spatial channel characteristics reproduced well on average regardless of TX position

Validation – MIMO Capabilities

- Test of the model capabilities regarding multi antenna systems
- Evaluation of MIMO channel capacities (10 dB SNR, 3x3 MIMO, TX_1)

→ Simultaneous valiation of broadband *and* spatial characteristics



→ Accurate reproduction of MIMO capacities for both polarizations
→ Model suitable for the simulation of multi antenna systems

Model Limitations/Advantages

- The appproach is limited in the following ways:
  - The model is stochastic
  - It cannot be position-specific
  - Parameter sets are scenario-specific
  - No correlation properties between individual parameters are taken into account

- But:

→ The model provides a good overall accuracy
→ Simple parametrizable PDFs form the basis
→ It is much faster than RT (1000x or more)

Outline

1. Introduction
2. Modeling Concept
3. The THz Indoor Radio Channel Model
4. Validation
5. **Summary/Outlook**

Summary

A stochastic THz indoor radio channel model has been introduced that

- includes all relevant channel characteristics:
  (1) complex amplitudes
  (2) polarization
  (3) times of arrival
  (4) spatial information
  (5) dispersion
- is flexibly parametrizable
- features a significant data basis obtained from measurement-calibrated RT
- is significantly faster than RT simulations (at least 1000x)
- has been validated

Outlook

Next steps:

- The approach will have to be transfered to other setups

→ More parameter sets have to be derived

- System simulations are to be conducted

→ A THz WLAN/WPAN system concept has to be developed

References

[1] S. Priebe, T. Kürner: “Stochastic Modeling of THz Indoor Radio Channels“, accepted for publication in *IEEE Transactions on Wireless Communications,* 12 pages, 2013.

[2] S. Priebe, M. Kannicht, M. Jacob, T. Kürner: “Ultra Broadband Indoor Channel Measurements and Calibrated Ray Tracing Propagation Modeling at THz Frequencies “, submitted to the *Journal of Communications and Networks,* 11 pages, 2013.

[3] S. Priebe, M. Jacob, T. Kürner: “*Calibrated Broadband Ray Tracing for the Simulation of Wave Propagation in mm and sub-mm Wave Indoor Radio Channels*”, in Proc. 18th European Wireless Conference (EW), 10 pages (electronic), Poznan, April 2012.

Channel Realization Generator

A generator for channel realizations according to the proposed model has been implemented in C++ and can be obtained from the authors for further use.

The output format is „.mat“.

A MATLAB installation is required.

Technical Expectations Document (TED)

All information contained in this presentation is meant to be included in the technical expectations document 15-11-0745-08-0thz-thz-ig-technical-expectations-document-ted.doc.

Thank you for paying attention.

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