Deterministic Channel Modeling for 60 GHz WLAN

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Abstract

- **Applications of future multi-gigabit systems using frequencies at 60 GHz and beyond will cover also operational environments with non-line-of-sight conditions. Due to the high diffraction losses at millimetre-wave frequencies and beyond establishing radio links in shadowing situations will require beam forming in order to exploit scattering and reflection processes. For the development and standardisation of these systems double directional spatial channel models for non-line-of-sight situations have to be derived. Double directional channel models contain information both about angle of arrival at the receiver and angle of departure at the transmitter. An attractive possibility currently pursued both in research projects and standardisation is to derive these channel models based on ray-tracing simulations. This presentation presents results from indoor channel measurements [1] and shows the potential of ray tracing for 60 GHz channel modeling which is a possible approach for the TGad channel model [2].**

Agenda

- Motivation and Approach
- Indoor Measurement Results
- Ray-Tracing
- Verification of Ray Tracing with Measurements
- Ray Tracing Results (5 m NLOS Analysis)

Motivation

- **Need for double-directional channel models covering, e. g.**
  - NLOS situations
  - Polarisation
  - Influence of moving people
- **In principle two ways to derive these channel models**
  - Based on extensive measurement campaigns
    - time-consuming and expensive
  - Based on ray-tracing simulations
    - quite flexible and allows to simulate large numbers of scenarios
    - BUT: ray-tracing has to be verified in a first step

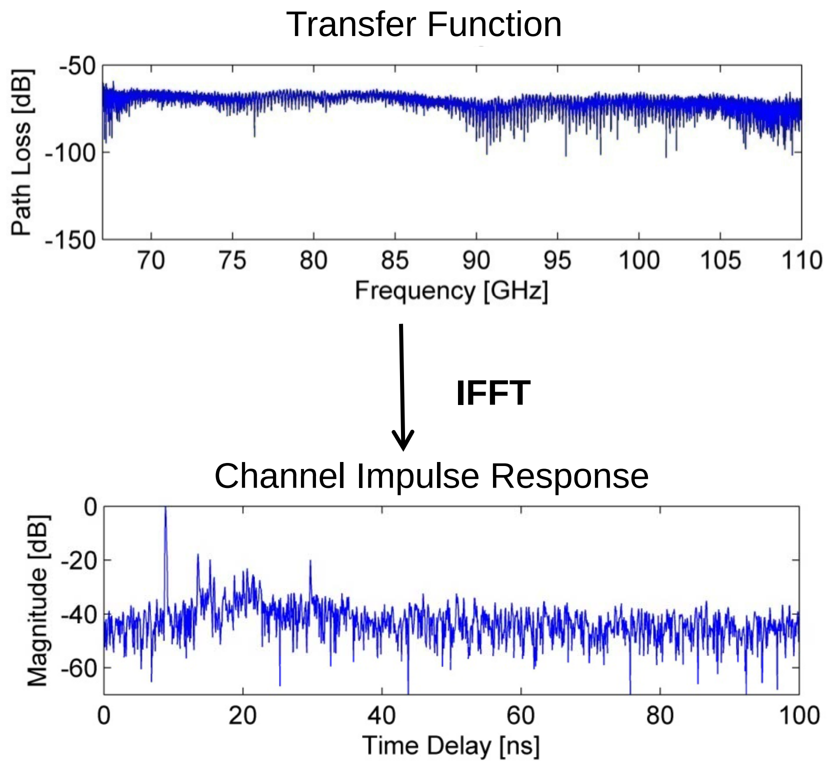
Approach

- **A three-step approach is applied:**
  - Step 1: Extensive measurement campaign in typical operational environments with the main goal to calibrate and verify the ray-tracing algorithms.
  - Step 2: Ray-tracing is applied to simulate a very large number of realistic environments.
  - Step 3: Ray-tracing results are used to derive statistical channel models

Measurement Setup

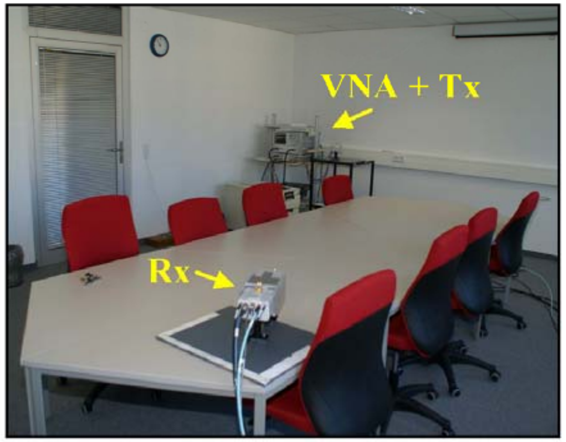
- **Vector Network Analyzer**
- External test heads
- Frequency range: 67 to 110 GHz
- Extremely wideband measurements
- Transfer functions
- PDP
    - Derived from transfer functions via IFFT

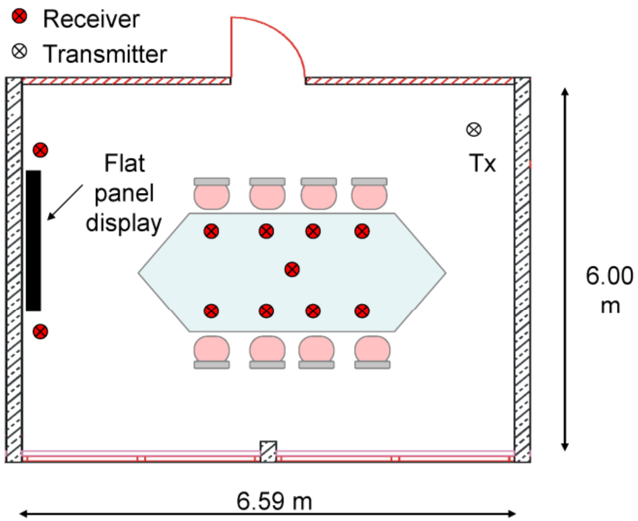
- **3 different antenna configurations**
    - Circular horn antennas
        - (20 dBi gain; 10° HPBW)
    - Open ended waveguide
        - (7 dBi gain; 80°/120° HPBW)
    - Horn-Horn, Open-Horn, Open-Open



Scenarios

- **Fully furnished conference room**
  - Transmitter at one fixed position, antenna directed to the middle of the room
  - 11 Receiver positions, Antennas pointed at TX
  - Distances between 1.70 and 5.70 m
- **Corridor as reference scenario without any furniture**
- **Goal**
  - Distance dependent path loss
  - Time Dispersion Parameters
  - Angular dispersive channel characteristics
  - Verify Ray Tracing



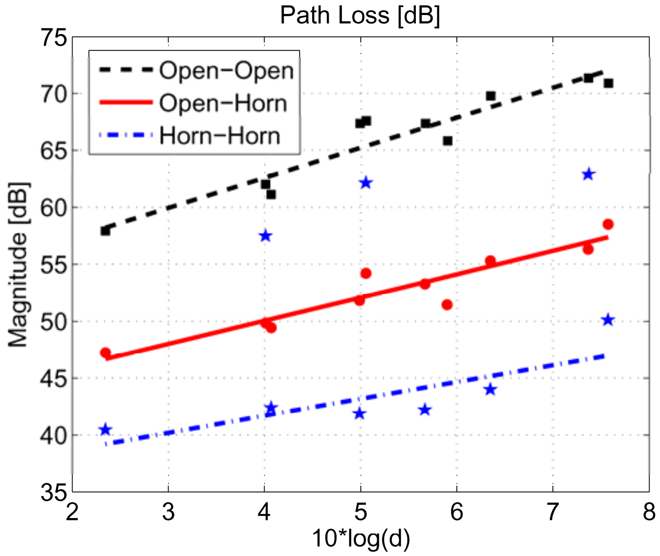


Path Loss and Shadowing - LOS

- **Large Scale parameters based on an averaging of every measured transfer function for different frequency bands**
- **Fitting:** $PL[dB] = 10 \cdot n \cdot \log_{10}(d) + PL_0$
  - Path loss exponent n
  - Reference path loss PL_0
  - Shadowing factor σ_{PL}
- **Good agreement with TG3c model (CM1) [3]**
  - n = 1.53 vs. 1.5
  - PL_0 = 75 vs. 74
  - σ_{PL} = 1.5 vs. 1.5

TABLE I: Path Loss and Shadowing Parameters

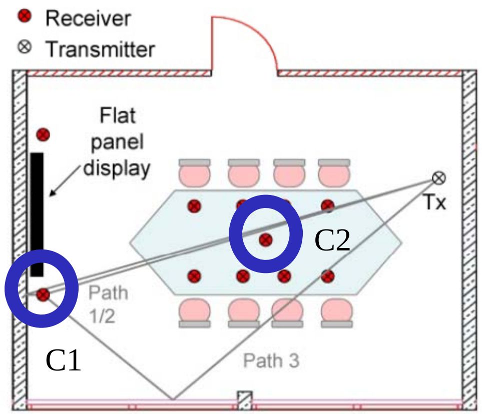
		Conference Room			Corridor
Antenna Configuration		1	2	3	3
67-72 GHz	n	1.6	1.7	1.5	2.0
	PL_0	34	46	60	57
	σ_{PL}	1.6	1.5	1.5	0.14



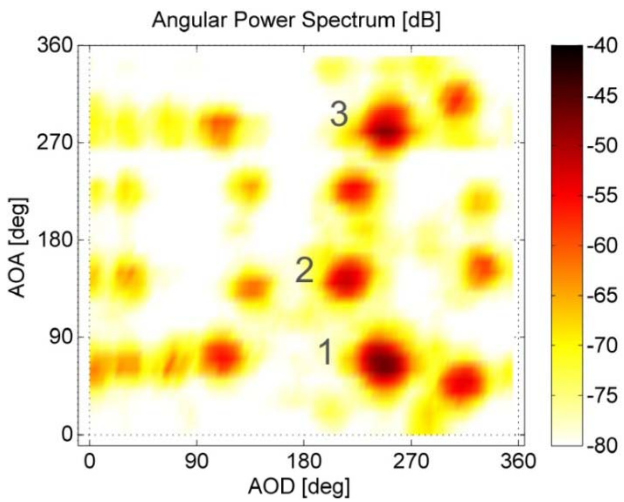
Angular dispersive channel characteristics

- **Angular Power Spectrum 67 to 72 GHz**
  - Horn-Horn configuration
  - 360 degrees in steps of 5 and 10 degrees

  - C1: 15 clusters within 25 dB
  - C2: 10 clusters within 25 dB



C1



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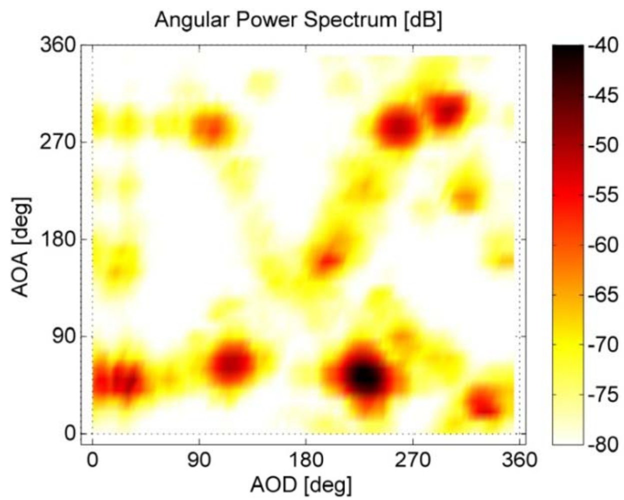
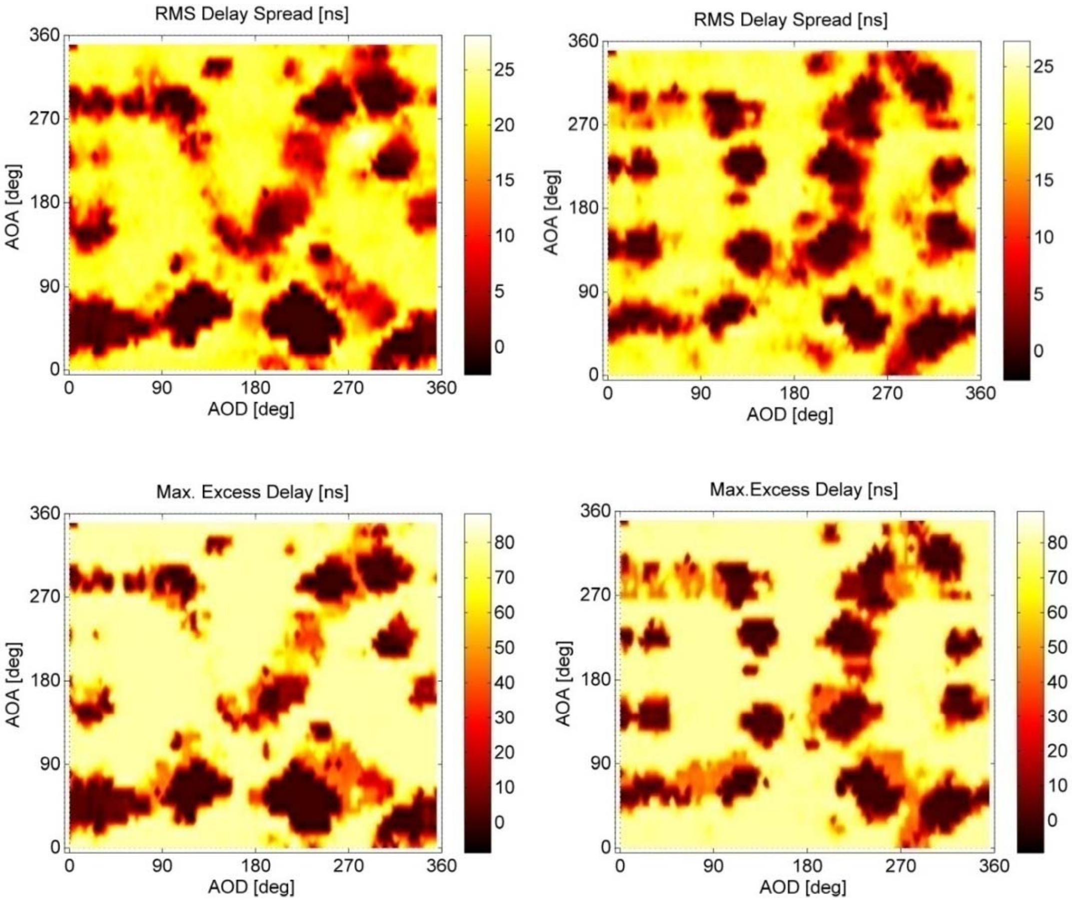


Time Dispersion Parameters – LOS/NLOS (1)

- **Time Dispersion Parameters**
  - Horn-Horn Configuration
  - Static Threshold (20 dB)
    - RMS Delay Spread (RDS)
    - Max. Excess Delay (MED)

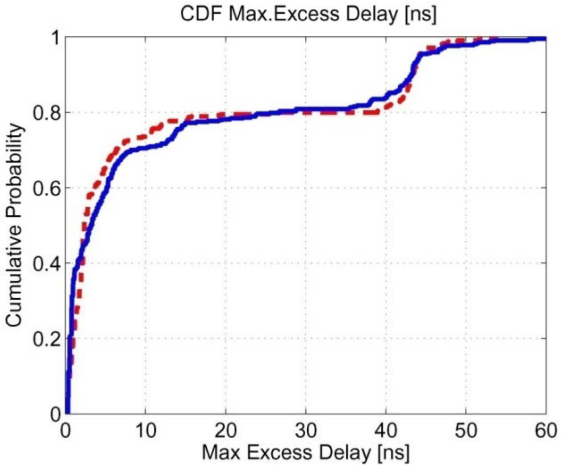
- **RDS and MED**
  - Small values at cluster centers
  - At the cluster edges values rapidly decrease

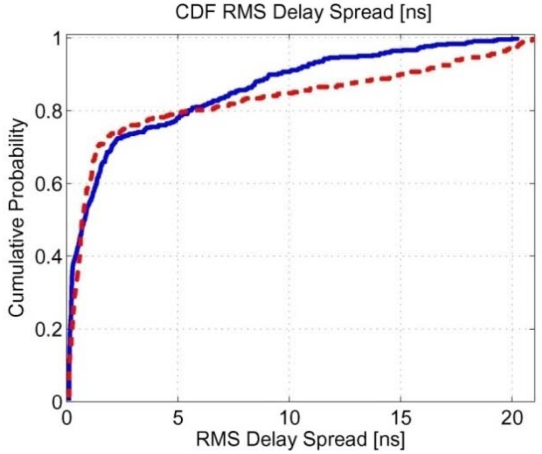
C2 C1



Time Dispersion Parameters – LOS/NLOS (2)

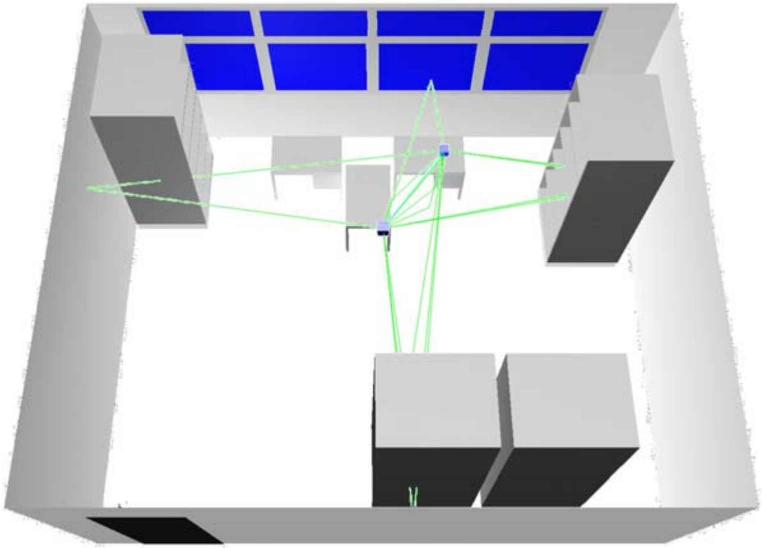
- **No significant differences between the two positions**
- **Strong increase at the beginning**
- **RMS Delay Spread**
  - 70 % < 2 ns
  - 100 % < 20 ns
- **Maximum Excess Delay**
  - 70 % < 8 ns
  - 100 % < 60 ns
- **Behaviour is traced back to the high directivity of the antennas**





Deterministic Channel Model – Ray Tracing (1)

- **3D Ray Tracing, based on the image method**
- **Implemented in C++, controled by Matlab**

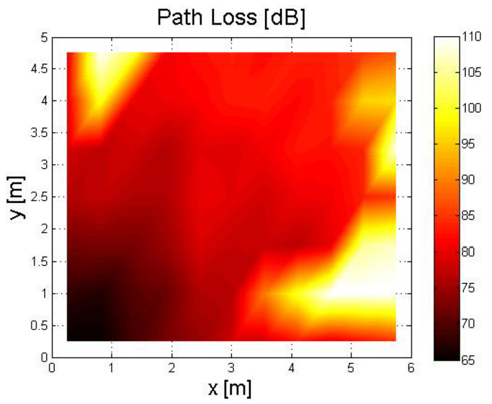


- **Input**
  - 3D Indoor Scenario
  - Material parameters @ 60 GHz
  - Carrier frequency
  - Antenna diagrams

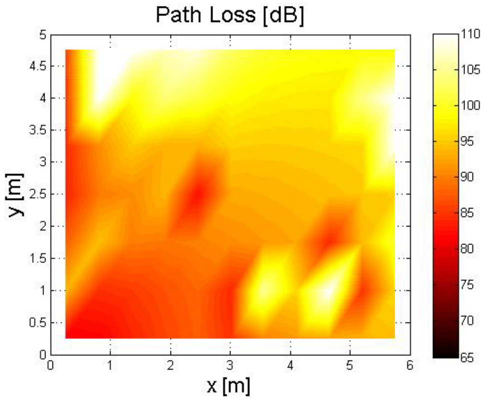
Deterministic Channel Model – Ray Tracing (2)

- **Coverage maps**

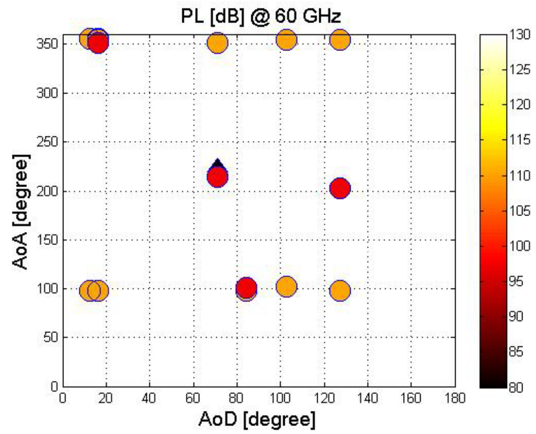
Direct



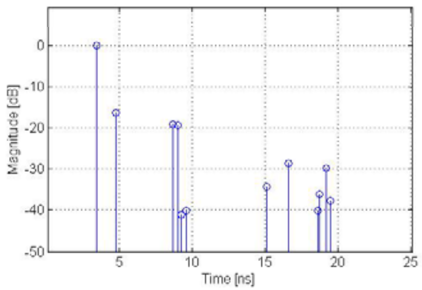
Reflected



- **AoD, AoA statistics**

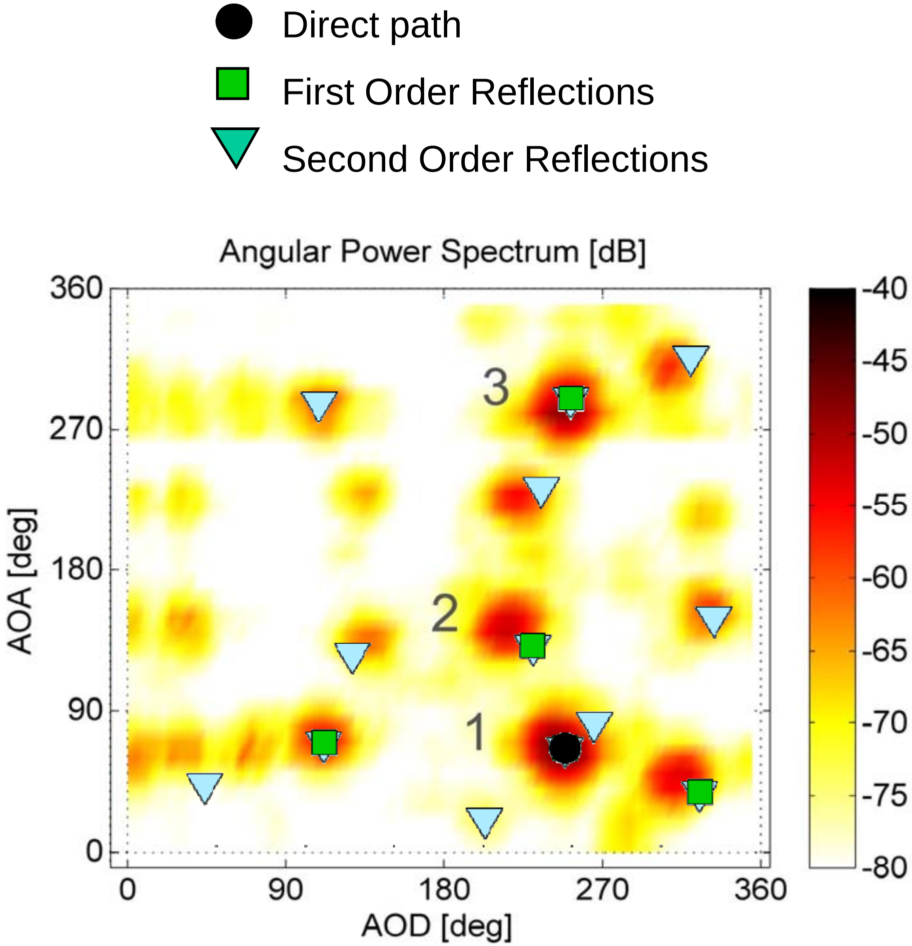


- **Impulse responses**



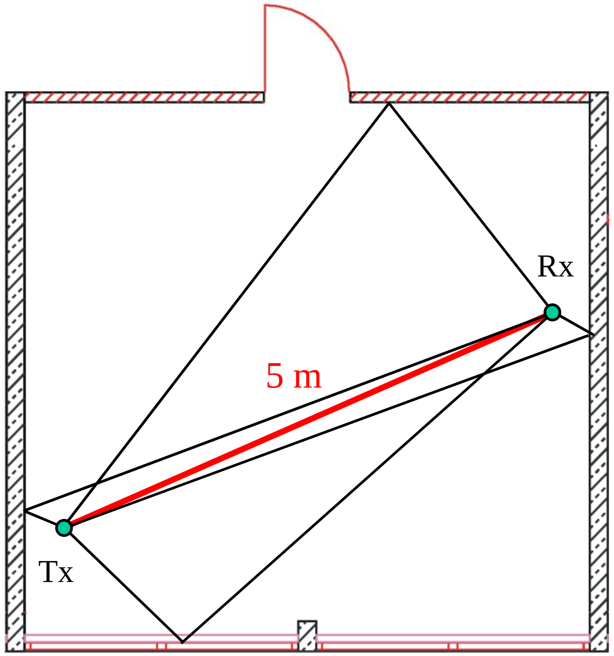
Ray Tracing vs. Measurement

- **3D Conference Room Model**
- **Comparison in Angular Domain**
  - Very good agreement of cluster positions
  - Very good agreement of path loss
    - Mean error. 0 dB
    - Standard deviation: 4 dB
- **Ray Tracing Precision Verified**



5m NLOS Analysis based on Ray-Tracing

- **Motivation**
  - Angular domain important for Beamforming applications
  - Little information about NLOS channels
  - Ray Tracing yields deeper understanding of the channel characteristics than measurement

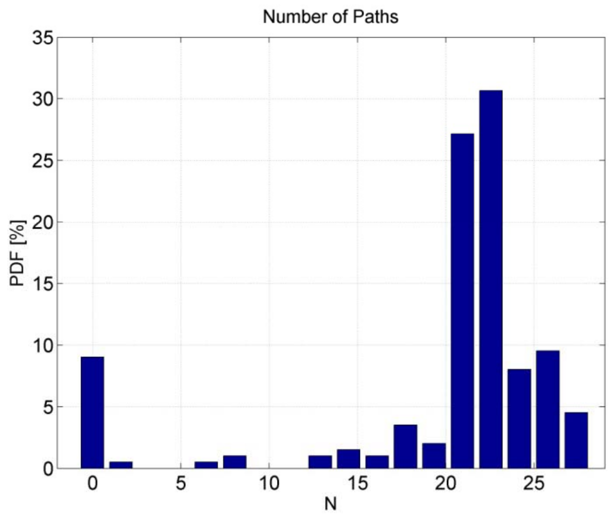


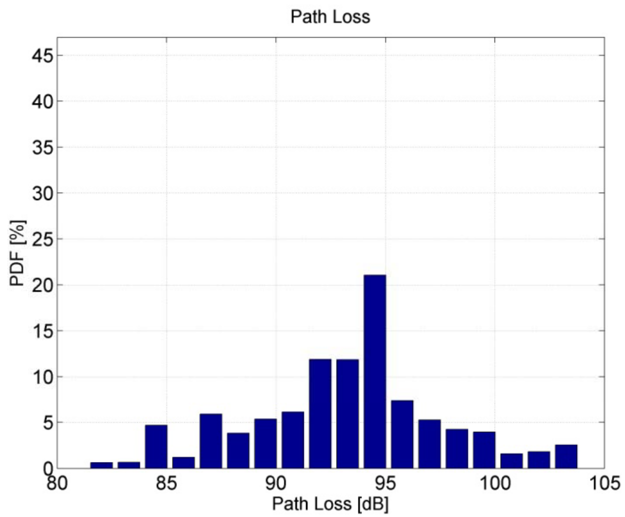
- **Scenario**
  - 200 Tx-Rx pairs inside the Conference Room
  - Tx and Rx at the same height (1 meter)
  - 5 m distance
  - Empty Room

- **Results**
  - NLOS Statistics of
    - Path Loss (without antenna gain)
    - Angular dispersion at Tx and Rx

Path Loss Statistics

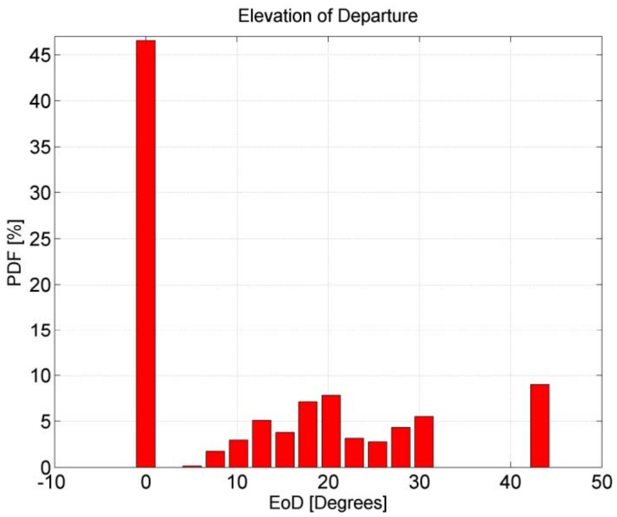
- **NLOS availability**
  - Number of Paths > 105 dB (95 dB)
    - Mean value: 20 (12) paths
    - Standard deviation: 7 (4) paths
- **Path Loss**
  - Statistics of single paths
    - Mean value: 93.8 dB
    - Standard deviation: 4.4 dB

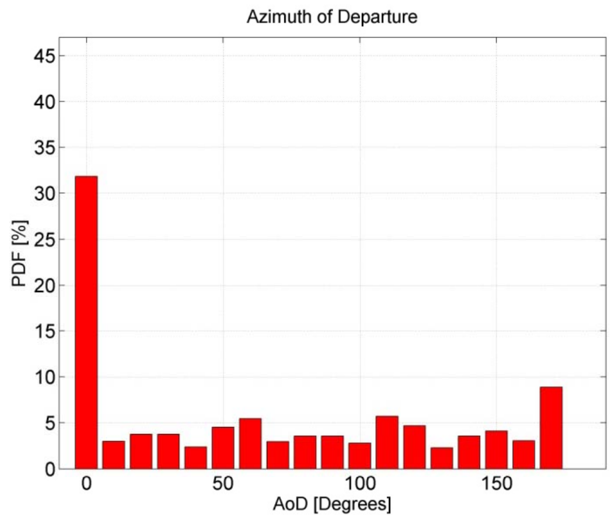




- **Both depending on indoor environment and properties of walls, ceiling…**

Angular Dispersion



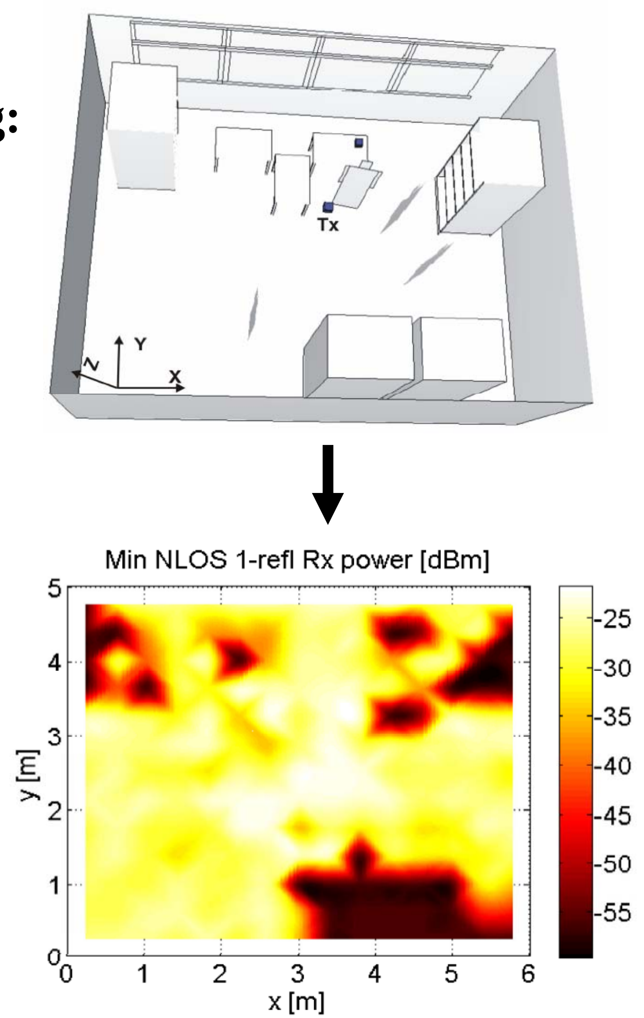


- **0° → LOS direction**
- **Elevation**
  - Peak at 0°: Reflections in the horizontal plane, because Tx and Rx are at the same height
  - Maximum Elevation Angle of 45°
- **Azimuth**
  - Peak at 0°: Reflections from floor and ceiling
  - AoD > 0°: Uniformly distributed

Next Steps

- **Ray Tracing based channel models including:**
  - Time domain (GRF) and
  - Angular Domain

- **Dynamic Channel Simulations**
  - Ray Tracing + Random-Walk-Mobility Model
  - Statistical analysis
  - Coverage probability
  - Test Beamforming Capabilities



Discussion

- **Which scenarios are the most relevant for the development of TGad channel models?**
  - Polarisation?
  - Moving people?
  - Large rooms/small rooms?

- **How can IEEE 802.11ad benefit from our results?**
  - What are the properties of channel models TGad is looking for?
  - What are the priorities?

References

- **[1] M. Jacob, T. Kürner, „Radio Channel Characteristics for Broadband WLAN/WPAN Applications Between 67 and 110 GHz“, 3rd European Conference on Antennas and Propagation 23-27 March 2009 in Berlin, Germany**
- **[2] A. Maltsev et al. „Channel Modeling for 60 GHz WLAN Systems“IEEE 802.11. document 11-08/0811r1**
- **[3] 15-07-0584-01-003c-tg3c-channel-modeling-sub-committee-final-report**