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

Submission Title: Ultra Broadband Indoor Channel Measurements and Calibrated Ray Tracing Propagation Modeling at THz Frequencies
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Source: Thomas Kürner Company TU Braunschweig
Address Schleinitzstr. 22, D-38092 Braunschweig, Germany
Voice:+495313912416, FAX: +495313915192, E-Mail: t.kuerner@tu-bs.de

Re: n/a

Abstract: The first part of this contribution describes a measurement campaign, where ultrabroadband channel characteristics at 300 GHz in an indoor environmen have been determined. These measurements have been used for the calibration of a ray tracing propagation model, which is described in the second part of the contribution.

Purpose: Information of IEEE 802.15 SG 100G

Ultra Broadband Indoor Channel Measurments and Calibrated Ray Tracing Propagation Modeling at THz Freqeuncies

Sebastian Priebe, Martin Jacob, Marius Kannicht, Thomas Kürner

TU Braunschweig

This contribution is based on [1]

Outline

- Introdcution
- Analysis of Measurements
- Ray Tracing Calibration
- Conclusions

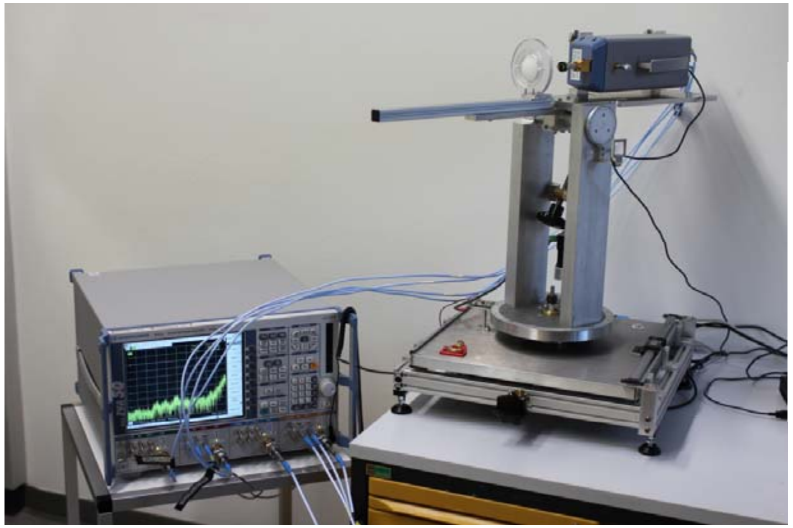
Introduction

- One possibility to derive statistical channel models, which are used for standardisation, is the application of ray tracing.
- In order to achieve highly accurate prediction results the models have to be calibrated in order to determine e. g. unkown material parameters.
- The extremely high bandwidths of up to 50 GHz have to be taken into account both in the measurements and the calibration procedure.
- Ultrabroadband measurements and calibration results are presented

Part I:
Analysis of Measurements

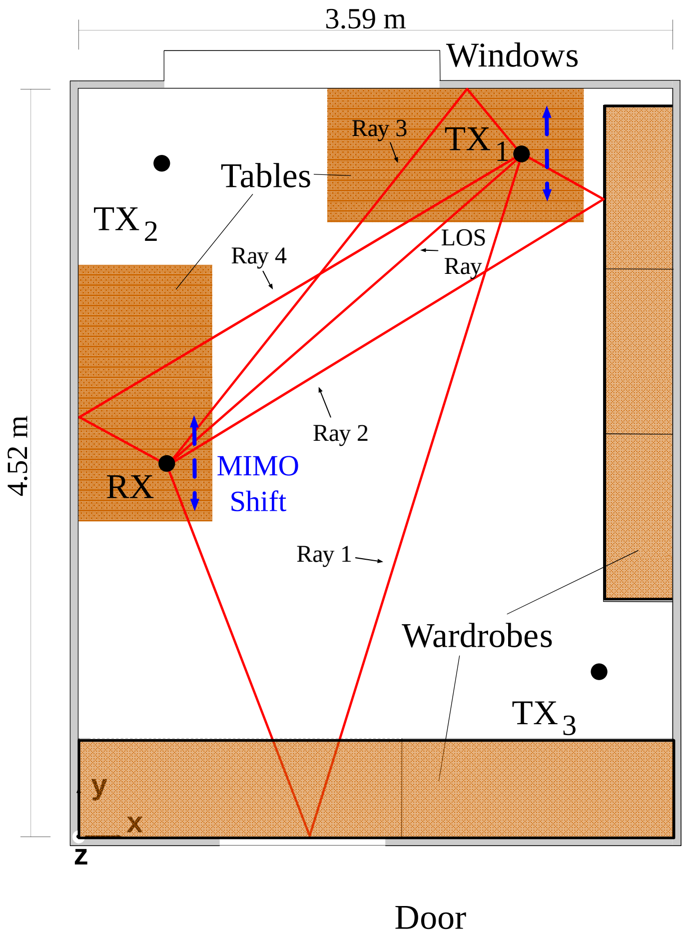
Measurement Setup (1/2)

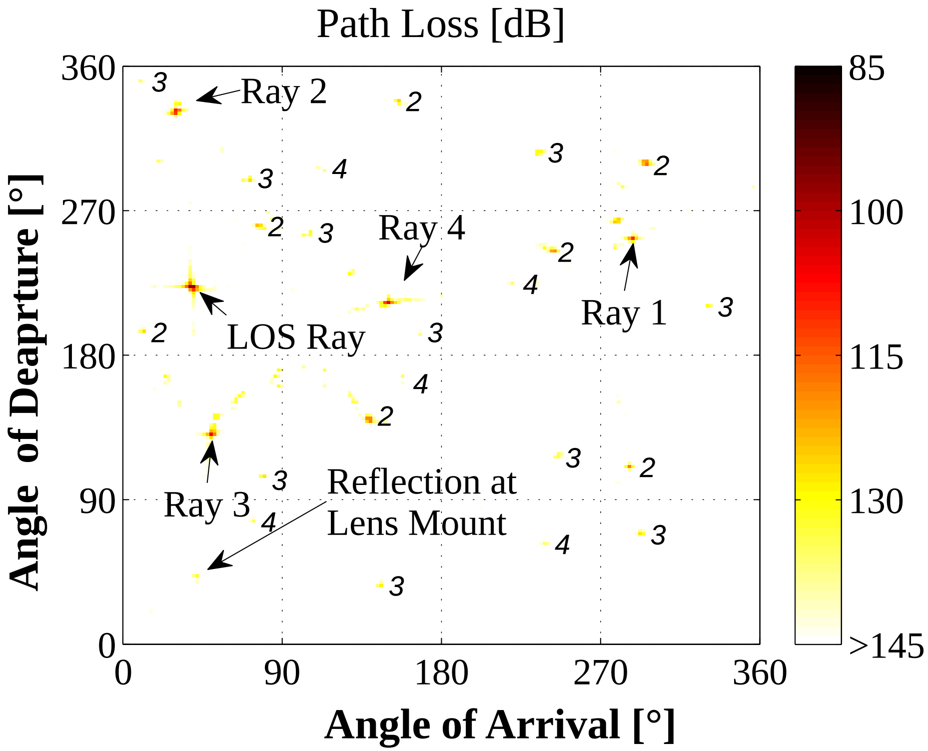
- Vector Network Analyzer Rohde & Schwarz ZVA50 with frequency extensions ZVA-Z325
- Measurements in the frequency range 275-325 GHz
- Antennas: Standard gain horn combined with focusing Polyethylen lense



- Key characteristics:
    - Temporal resolution: 0,02 ns
    - Maximum excess delay 64 ns (maximum path length 19,2 m)
    - Angular resolution: 2°

Measurement Setup (2/2)





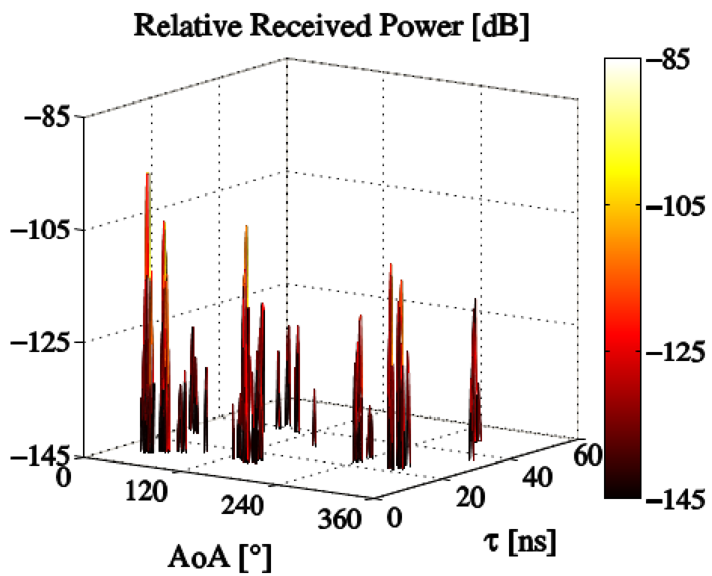
Exemplary Results for the link Tx1-Rx

Detected vs. geometrically expected number of reflected paths

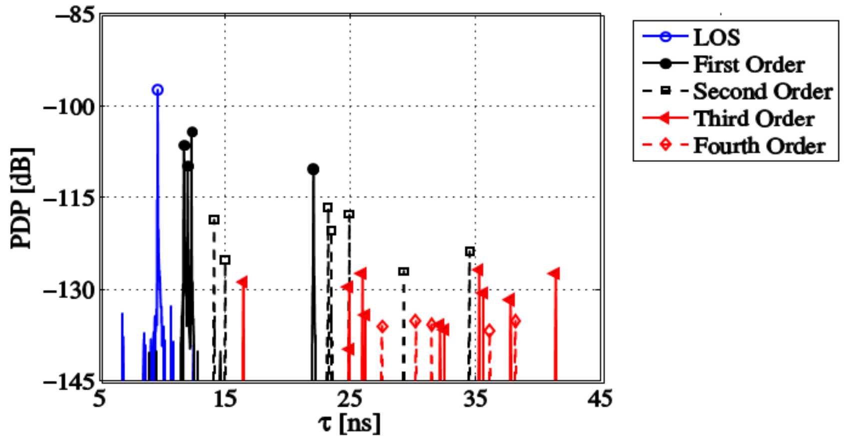
refl. order	Tx1		Tx1 ϕ Pol.		TX 2		TX3	
	Det.	Exp.	Det.	Exp.	Det.	Exp.	Det.	Exp.
1	4	4	4	4	2	4	4	4
2	7	7	7	7	4	6	7	7
3	10	10	6	10	5	8	8	8
4	5	11	1	11	1	10	3	8

- All rays of order 1, 2, and 3 are found for Tx1 and Tx3
- Higher path loss at ϕ polarisation => not all rays with 3rd order reflections are found
- At Tx2 the measurement equipment blocks some of the rays

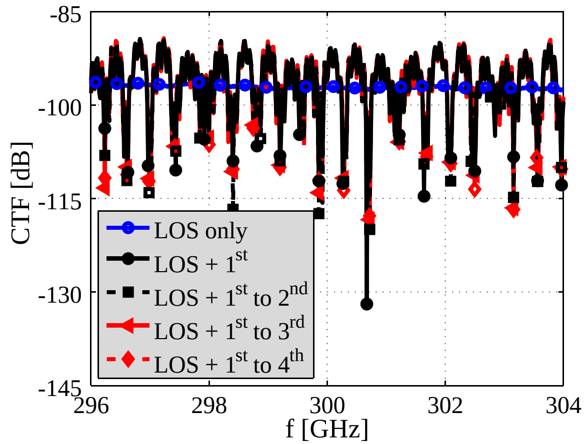
Measured Broadband Characteristics



Angular Domain

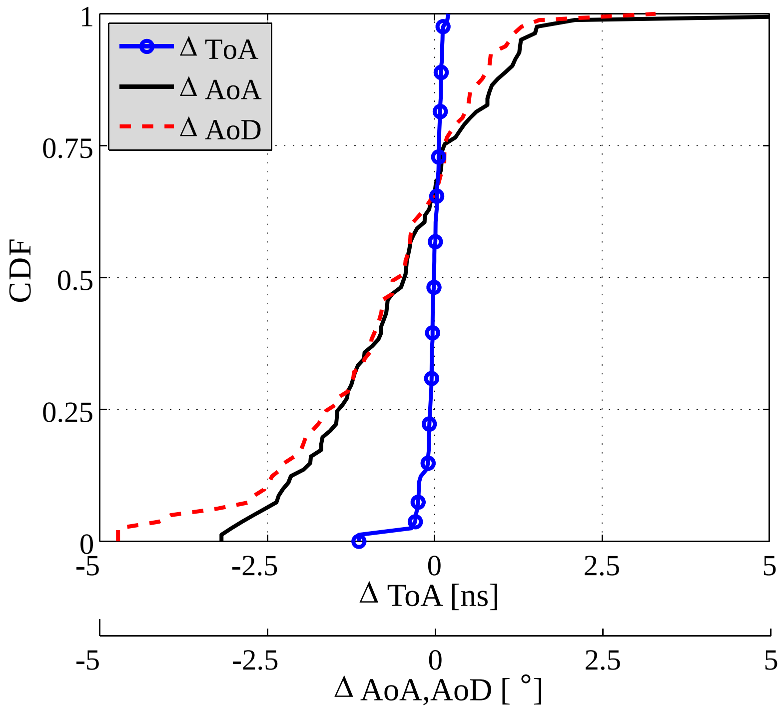


Time Domain



Frequency Domain

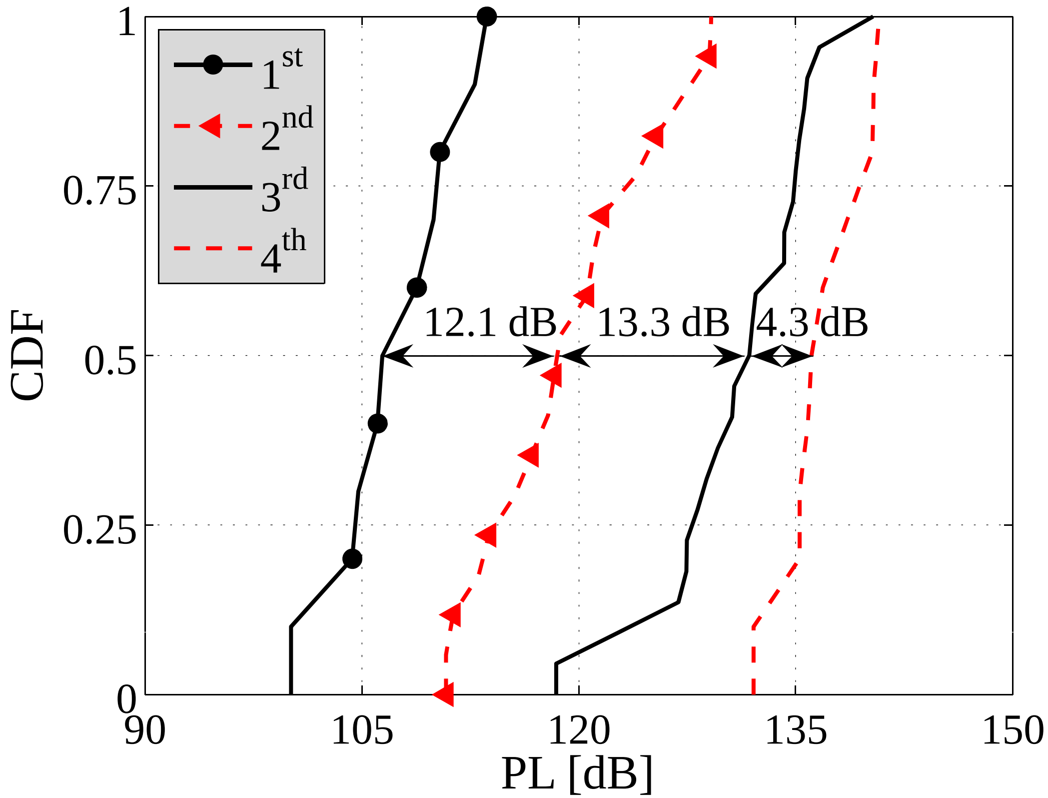
Spatial and Temporal Measurement Accuracy



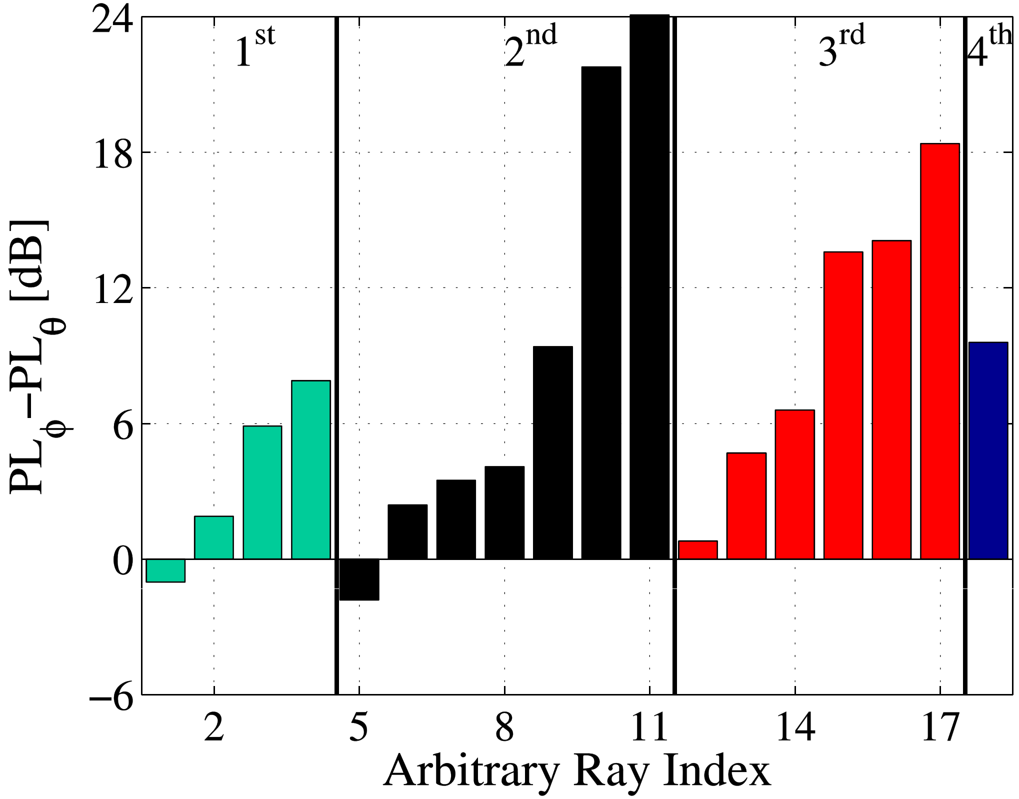
	LOS	1st	2nd	3rd	4th
AoA	0.13°	1,20°	1,11°	1,03°	1,70°
AoD	0.13°	0,95°	1,06°	1,18°	2,04°
ToA/ns	0.08	0,06	0,08	0,08	0,21

Mean absolute deviations between measured and geometrically expected path characteristics for different reflection orders

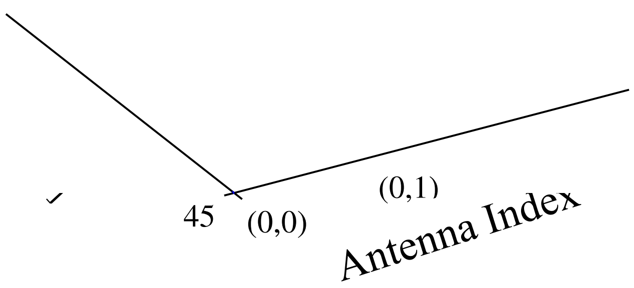
Path Loss for different reflection orders

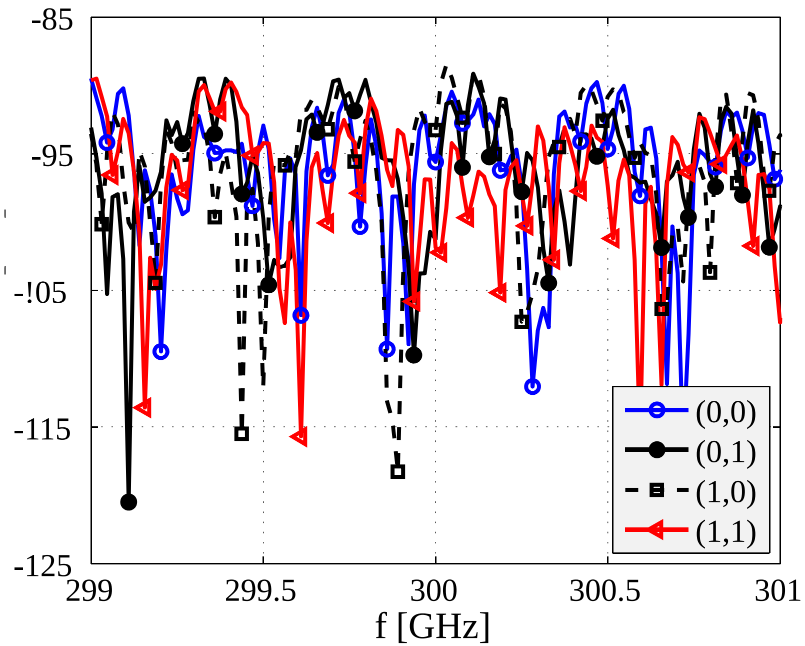


Measured Differences between ϕ and θ Polarisation



MIMO Measurement Results





Time Domain **Frequency Domain**

- High channel correlation (between 0.6 and 0.86 for CTFs)
- Ergodic capacity of 6,21 bit/s/Hz derived for 2x2 MIMO at an SNR of 10 dB compared to 3,46 bit/s/Hz at the SISO case

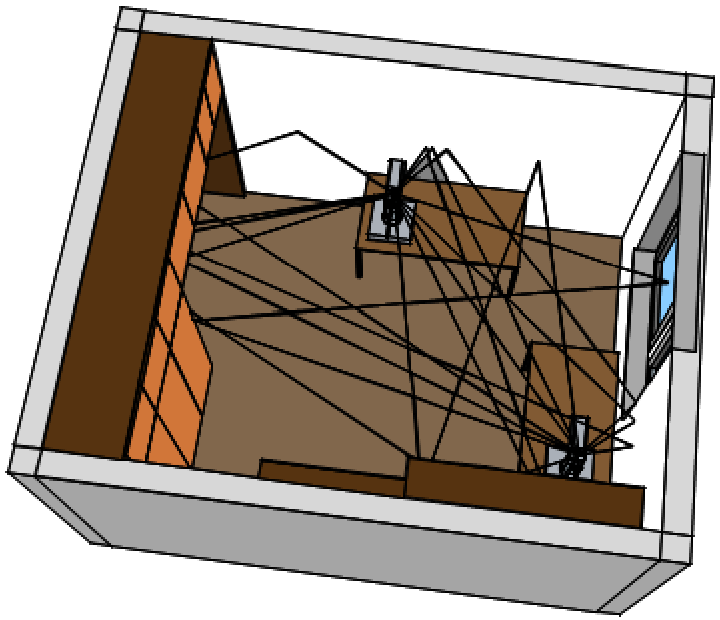
Part II:
Ray Tracing Calibration

Frequency Domain Ray Tracing and Ray-Based Concept for Calibration

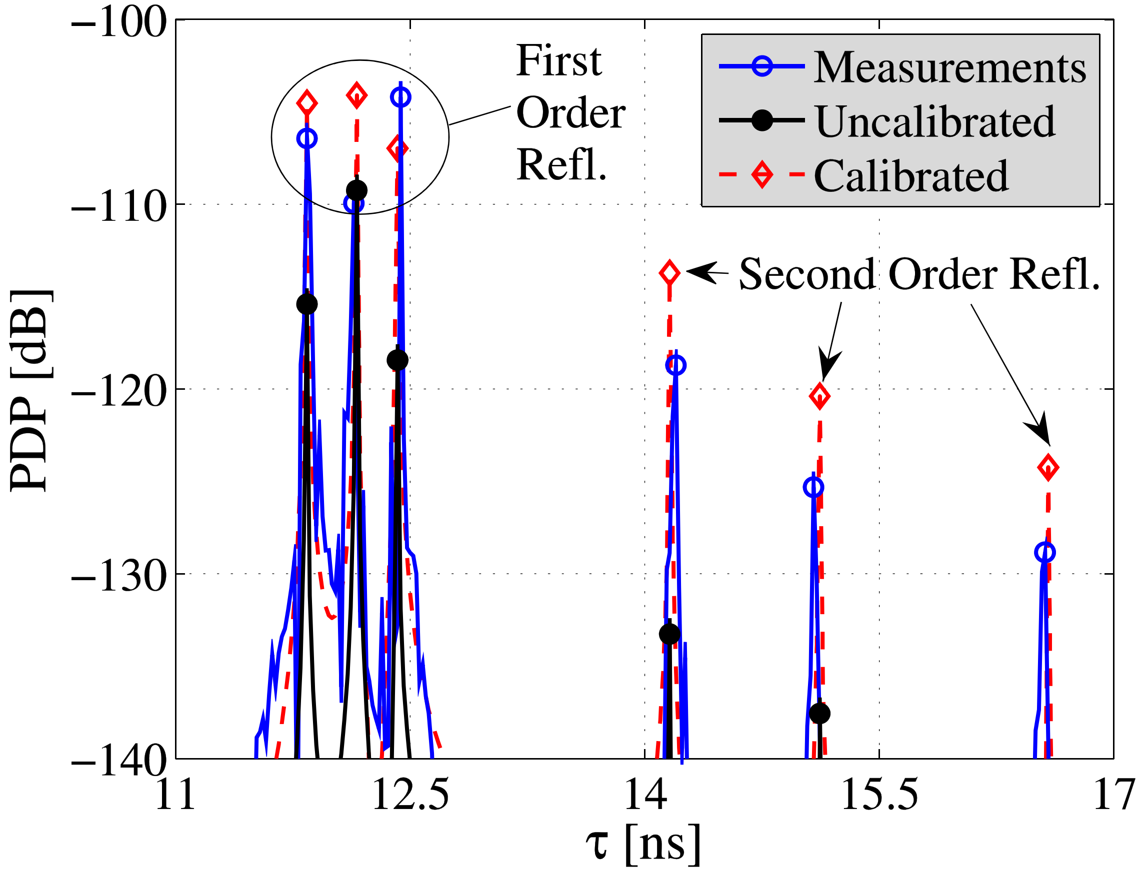
- In order to account for the effect of frequency dispersion due to the large bandwidth all rays are superimposed in frequency domain

- Calibration is done for each ray individually based on the measurements presented in the first part of this contribution

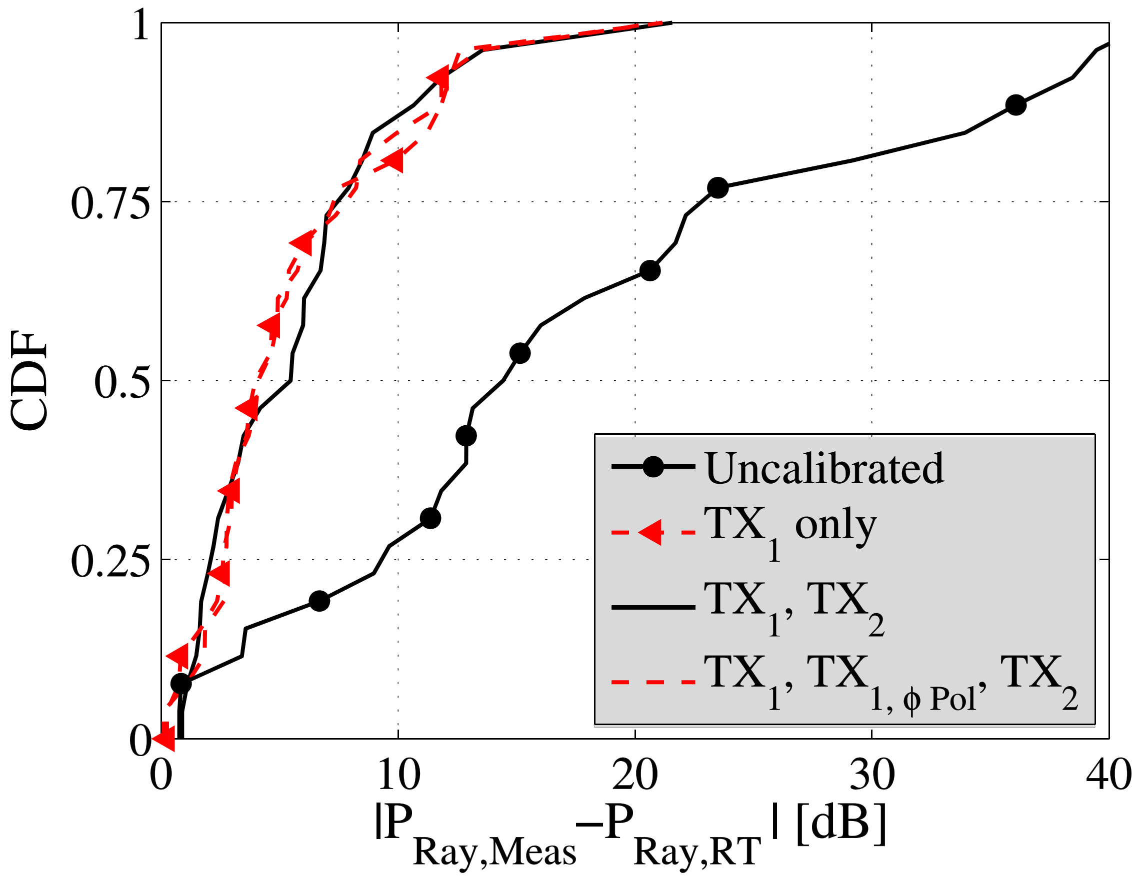
- More details can be found in [2]



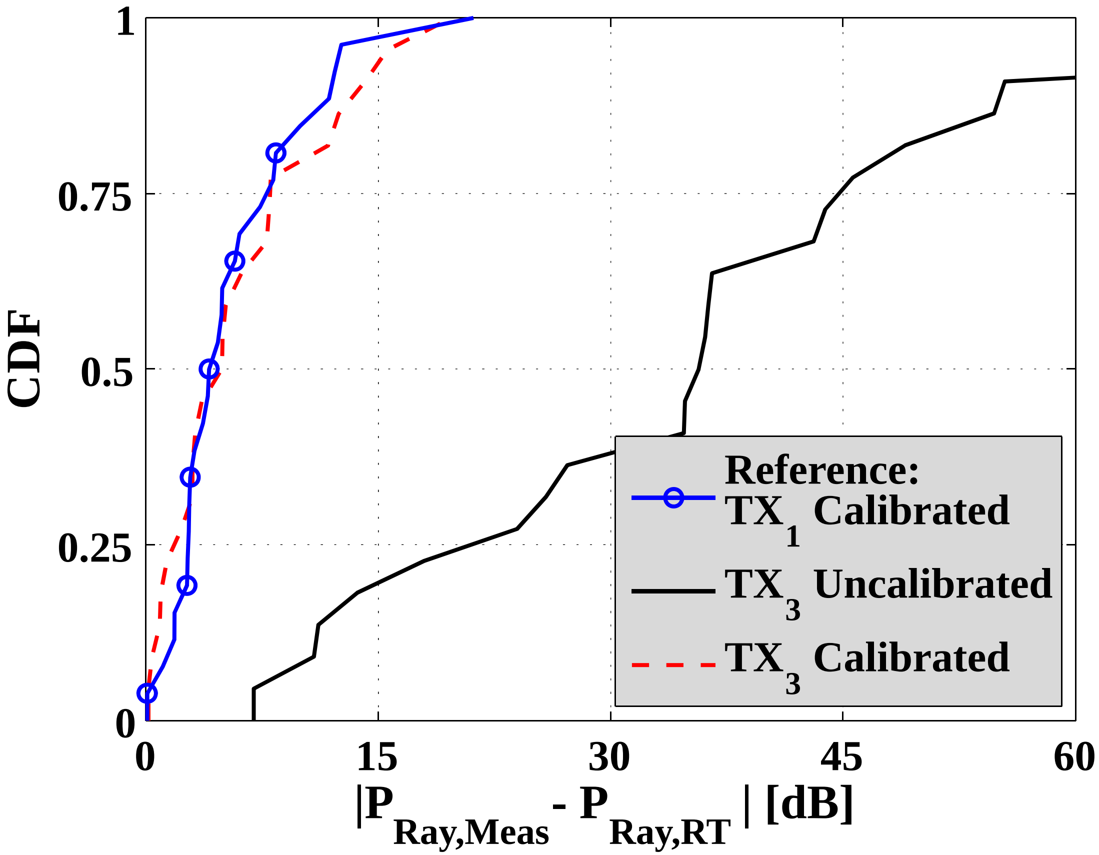
Calibration Results in Time Domain



Calibration Results – Influence of the Measurement Set used for Calibration



Calibration Results – Robustness w. r.t. Measurements not used for Calibration



Summary

- Ultrabroadband channel measurements in an indoor environment at 300 GHz have been presented
- These measurements can be used to calibrate a ray tracing propagation model based on the evaluation of single rays.
- Calibration increases accuracy of prediction significantly even for those measurments not used for the calibration
- The model is a good basis to derive statistical channel models, see e. g. [3,4]

References

[1] S. Priebe, M. Kannicht, M. Jacob, T. Kürner: “Ultra Broadband Indoor Channel Measurements and Calibrated Ray Tracing Propagation Modeling at THz Frequencies “, accepted for publication in *Journal of Communications and Networks,* 11 pages, December 2013.

[2] 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.

[3] S. Priebe, T. Kürner: “Stochastic Modeling of THz Indoor Radio Channels“, *IEEE Transactions on Wireless Communications,* vol.12, no.9, pp.4445,4455, September 2013.

[4] https://mentor.ieee.org/802.15/dcn/13/15-13-0358-00-0thz-a-stochastic-indoor-radio-channel-model-for-thz-wpans-wlans.pdf

Technical Expectations Document (TED)

All information contained in this presentation is meant to be included in the technical expectations document 15-11-0745-10-0thz-thz-ig-technical-expectations-document-ted.doc.