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Submission Title: Human Motion Sensing through Blockage and Reflection Measurements at 60 GHz and 300 GHz

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Re: n/a

Abstract: xxx.

Purpose: Information of IEEE 802.15 SC THz

IEEE 802 Wireless Plenary

Human Motion Sensing through Blockage and Reflection Measurements at 60 GHz and 300 GHz

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Acknowledgement

- The material presented here is based on the following publication:
  - T. Doeker, M. Eggers, C. E. Reinhardt, D. M. Mittleman and T. Kürner, "Human Motion Sensing through Blockage and Reflection Measurements at 60 GHz and 300 GHz," in IEEE Access, doi: 10.1109/ACCESS.2025.3573681; also presented at ETSI ISG THz as THz(25)00029 on 10 June 2025

- This project received funding from German Research Foundation (DFG) under grant number FOR 2863 “METERACOM – Metrology for THz Communications”

Overview

- First results of a measurement campaign at 60 and 300 GHz, focusing on eavesdropping with a moving human, are presented in [1]
- Beam tracking is crucial part of THz communications; therefore, movement characteristics of humans are beneficial
- In the work presented here, blockage and reflection measurements are used to determine the walking direction and velocity of a human

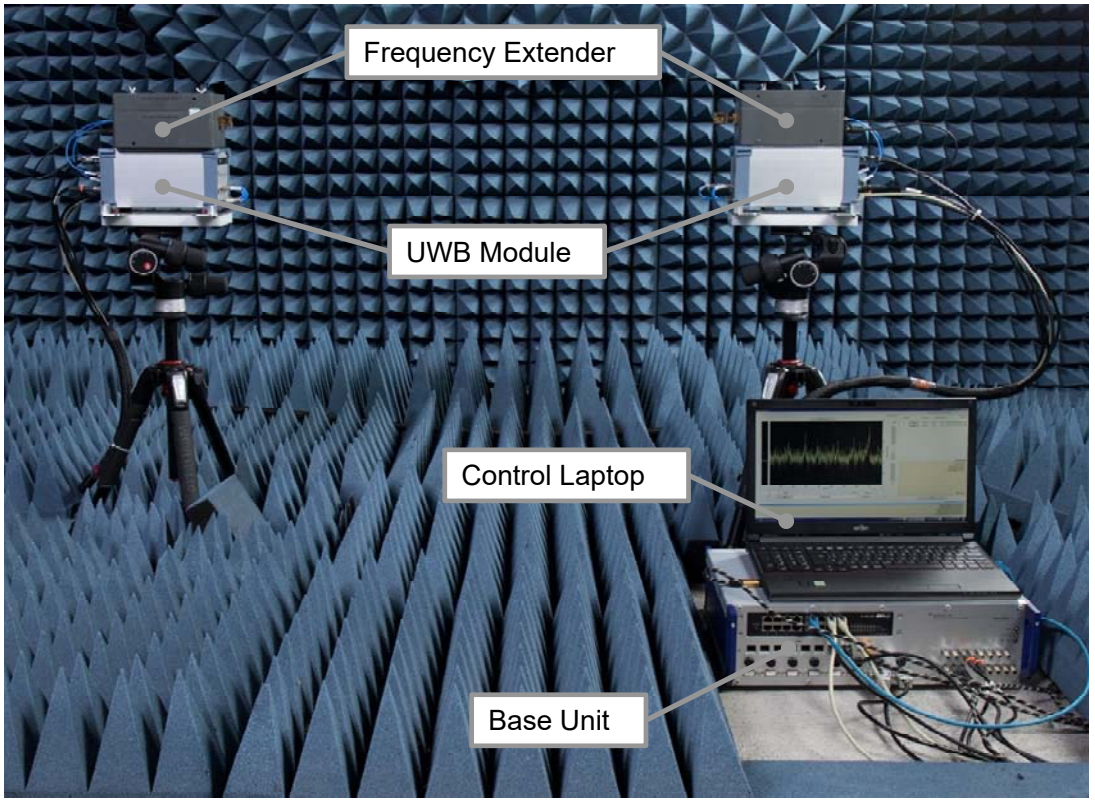
- References:

[1] T. Doeker, D. M. Mittleman and T. Kürner, "Scattering Measurements with a Moving Human at 60 and 300 GHz," *2023 48th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz)*, Montreal, QC, Canada, 2023, pp. 1-2, doi: 10.1109/IRMMW-THz57677.2023.10299385.

Measurement setup (1/2)

- Correlation-based M-sequence channel sounder

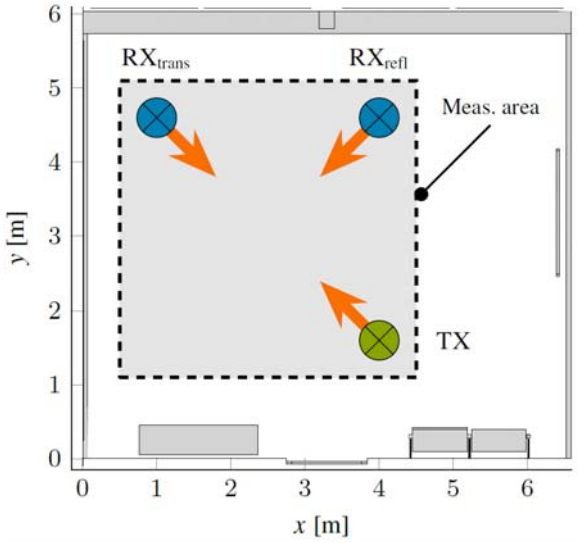
Parameter	Value
Clock frequency	9.22 GHz
Bandwidth	4 GHz
Chip duration	108.5 ps
M-sequence order	12
Sequence length	4095
Sequence duration	444.14 ns
Subsampling factor	128
Acquisition time for one CIR	56.9 µs
Measurement rate	17,590 CIR/s
Center frequency	64.5 & 304.2 GHz

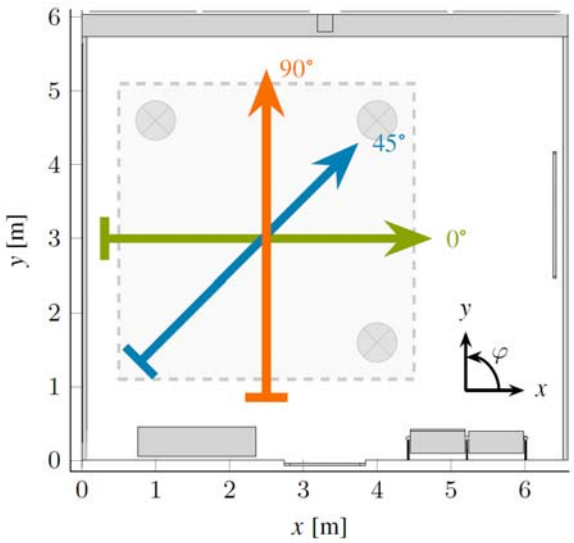


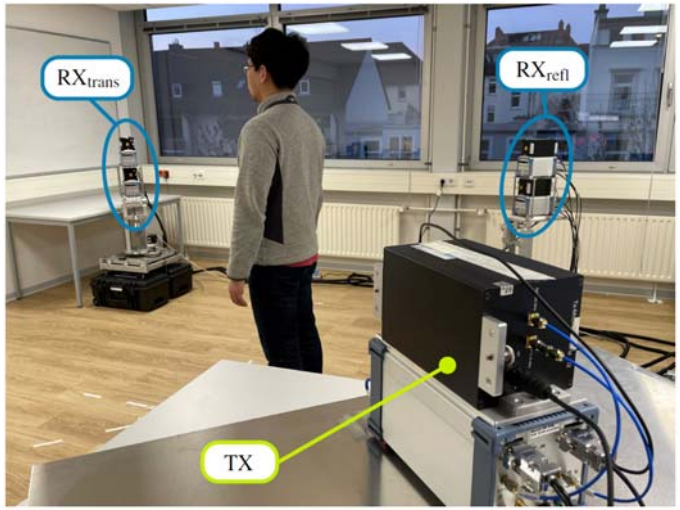
S. Rey, J. M. Eckhardt, B. Peng, K. Guan and T. Kürner, "Channel sounding techniques for applications in THz communications: A first correlation based channel sounder for ultra-wideband dynamic channel measurements at 300 GHz," *2017 9th International Congress on Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT)*, Munich, Germany, 2017, pp. 449-453, doi: 10.1109/ICUMT.2017.8255203.

Measurement setup (2/2)

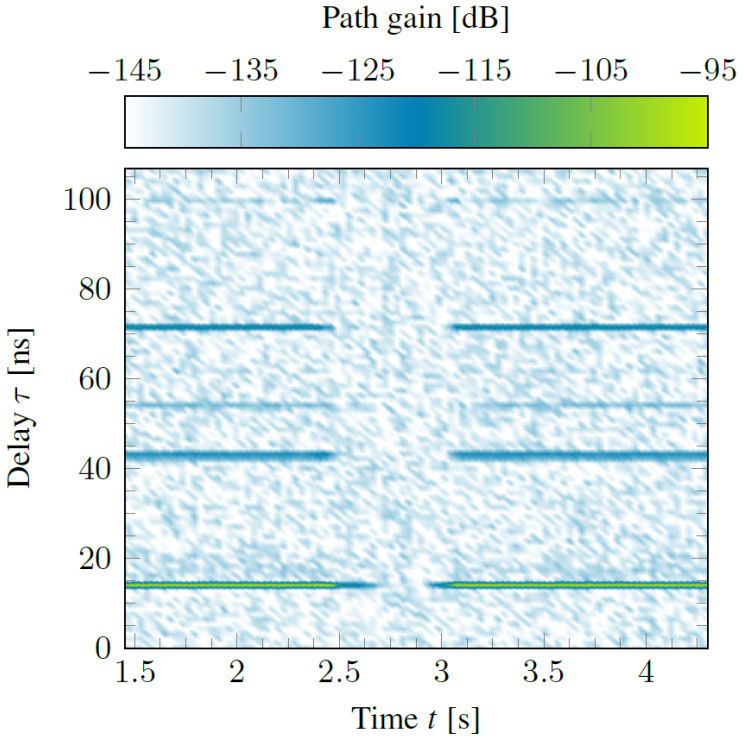
- Measurement equipment for 60 GHz and 300 GHz placed above each other
- Measurement equipment clustered: TX / RX for transmission / RX for reflection
- Human moves in three different directions; 30 repetitions per direction



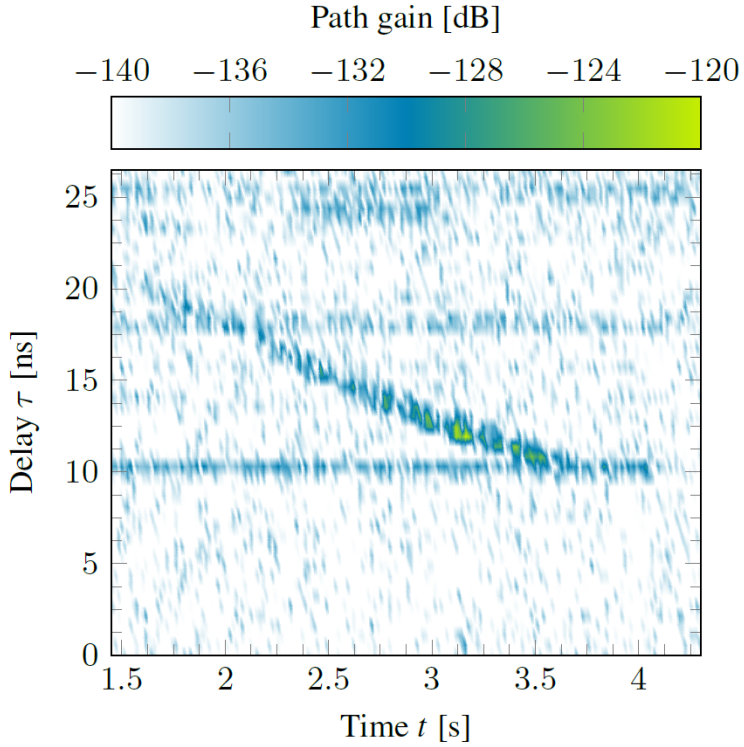




Evaluation basis – Time-variant PDP



Transmission measurement (at 300 GHz)

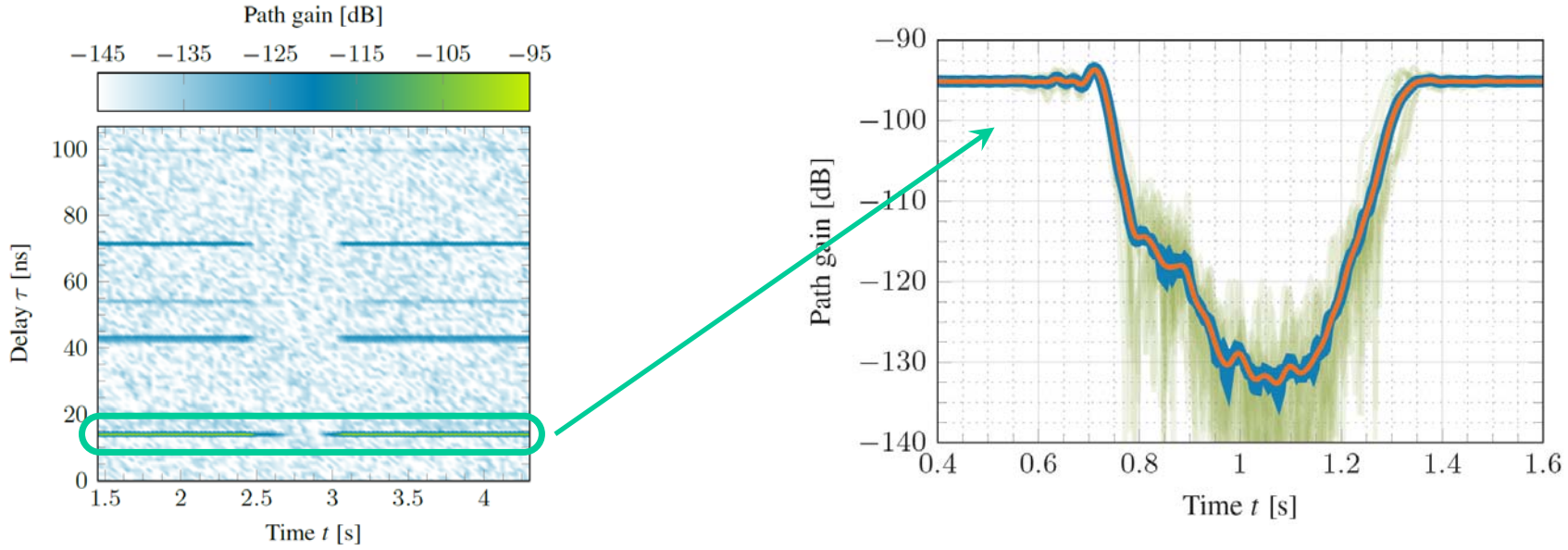


Reflection measurement (at 60 GHz)

(SNR too low at 300 GHz)

Blockage event analysis (1/2)

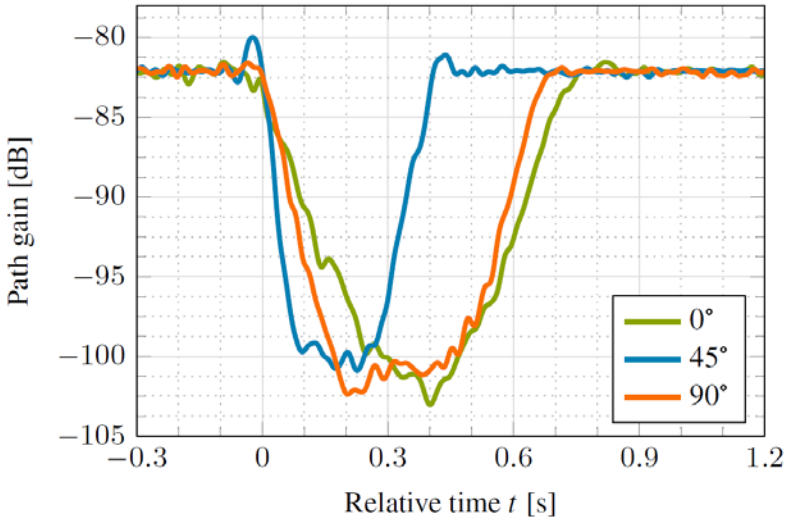
- Blockage event analysis for LOS component
- Averaging of repetitions and low-pass filtering for comparison



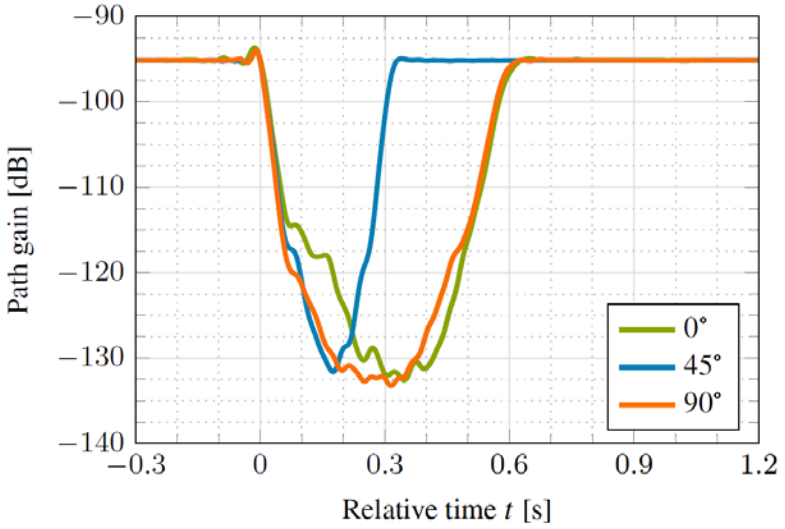
green: single measurement / blue: averaged / orange: low-pass filtered average

Blockage event analysis (2/2)

- As expected, blockage event shorter at 45° walking direction

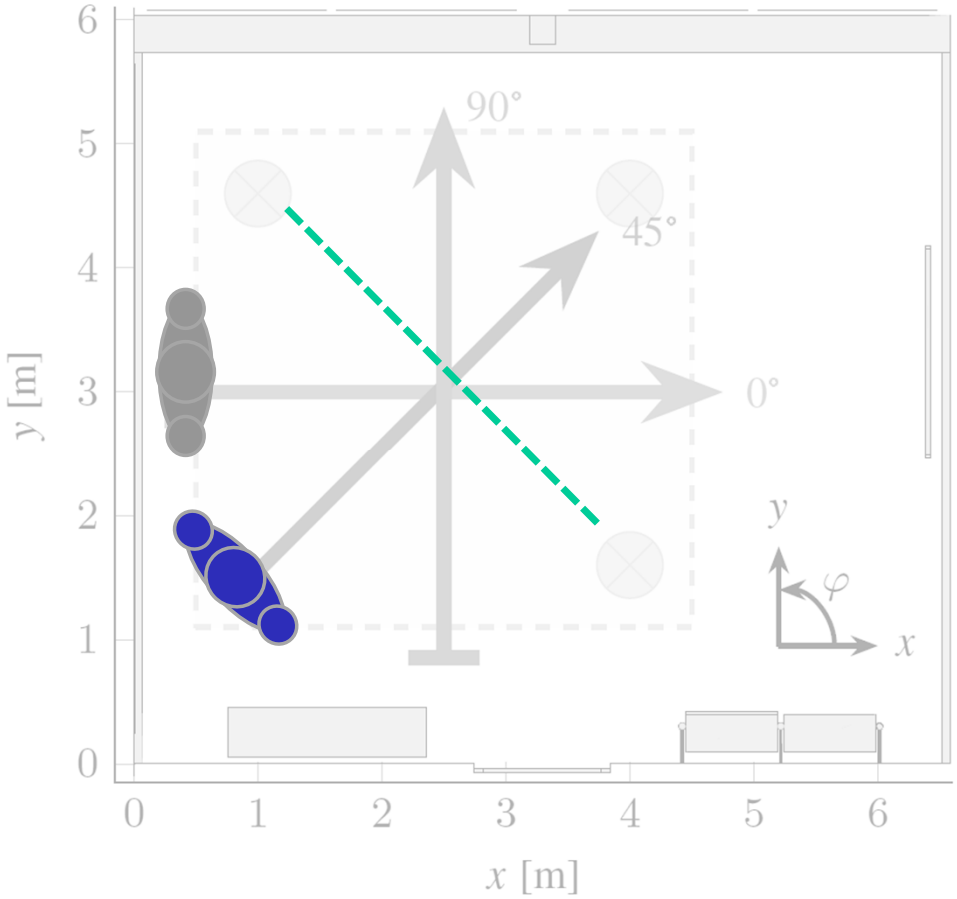


60 GHz measurement



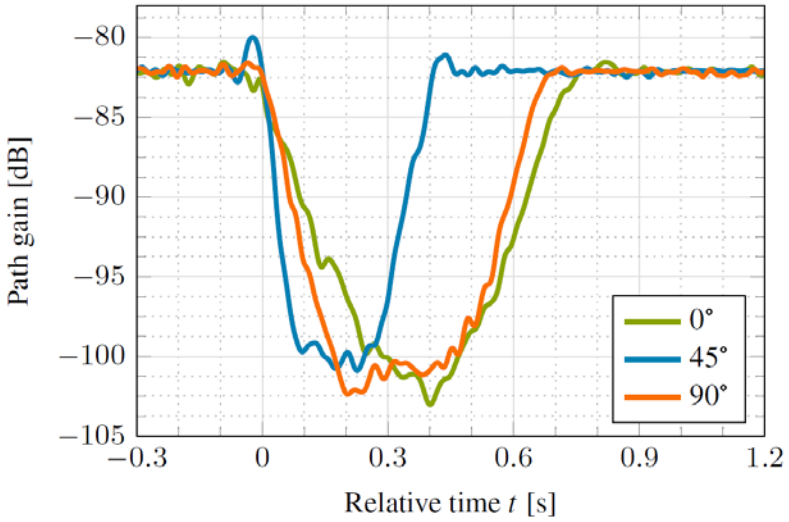
300 GHz measurement

Blockage event analysis (2/2)

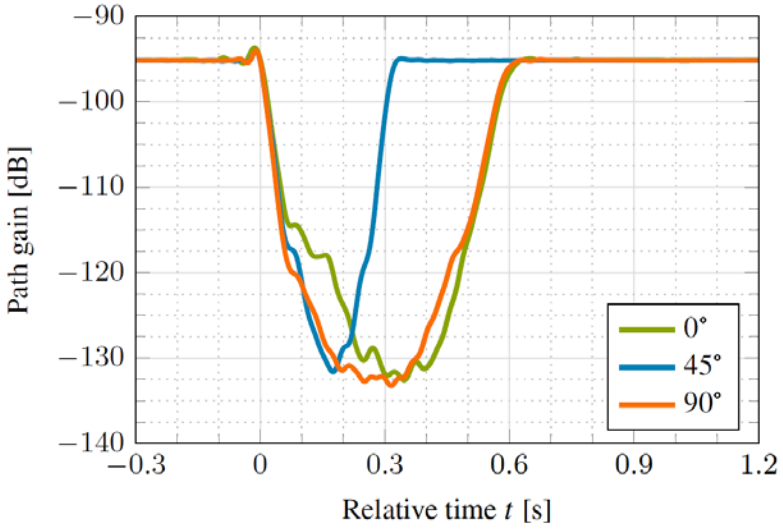


Blockage event analysis (2/2)

- As expected, blockage event shorter at 45° walking direction
- Especially, at 60 GHz different slopes of the edges recognizable



60 GHz measurement



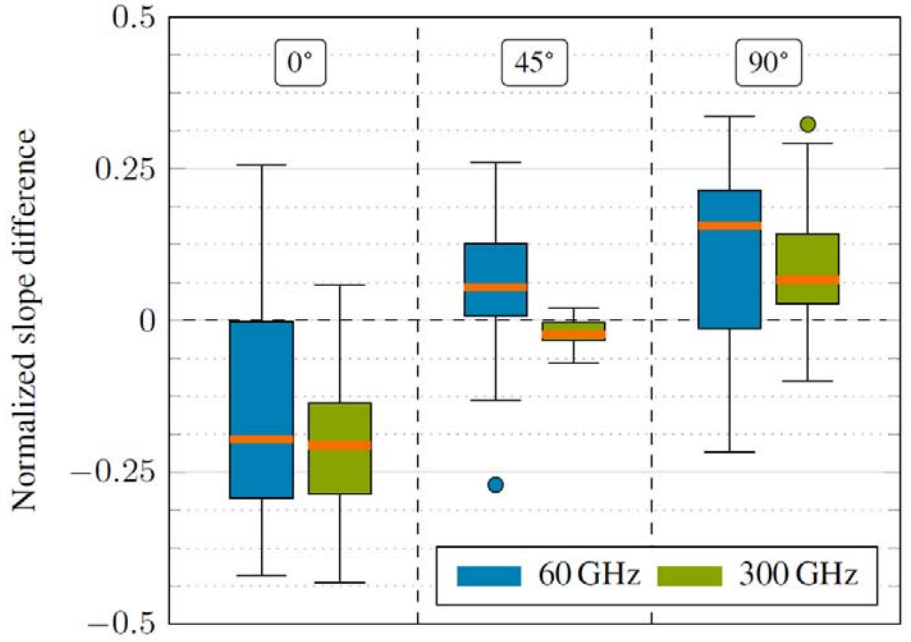
300 GHz measurement

Walking direction evaluation

- For each individual measurement calculation of normalized slope difference:

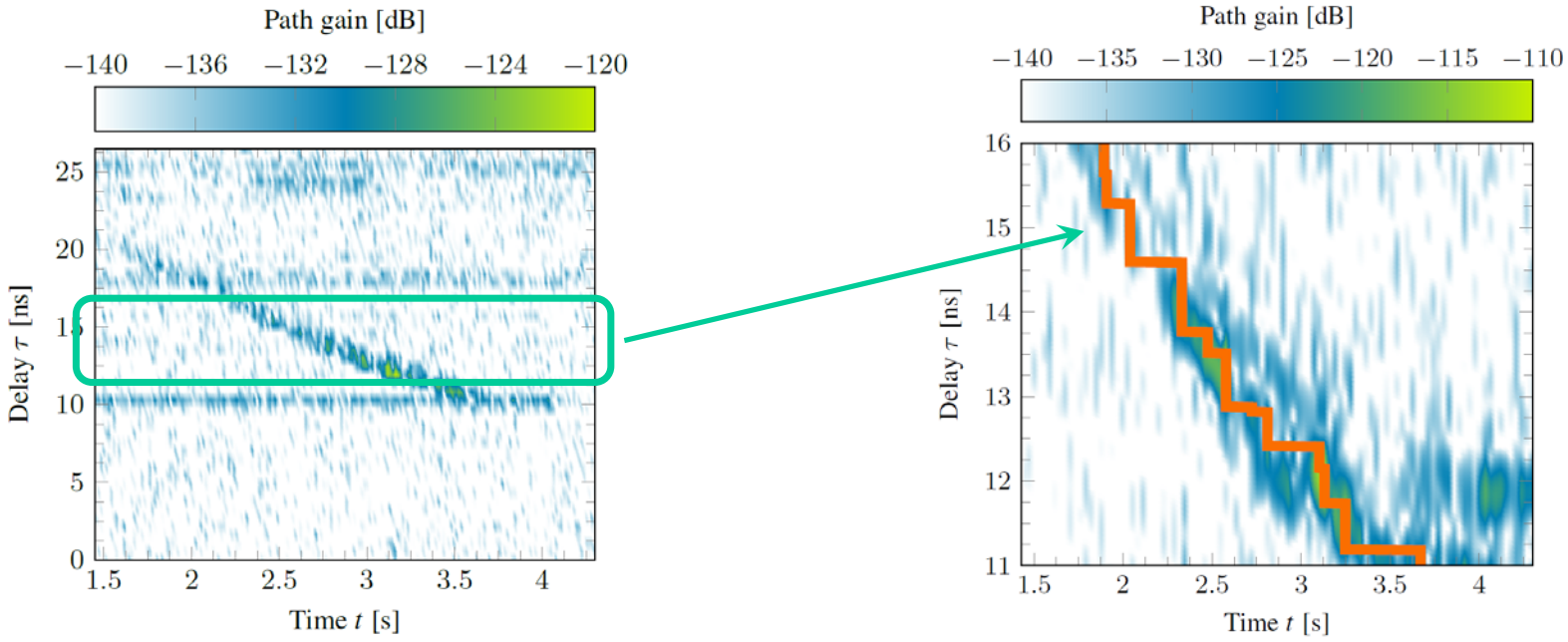
$$\overline{\Delta}_{\text{diff}} = \frac{|\Delta_{\text{min}}| - \Delta_{\text{max}}}{\max\{|\Delta_{\text{min}}|, \Delta_{\text{max}}\}}$$

- Normalized slope difference changes with walking direction:
  - Negative: 0° walking direction
  - Zero: 45° walking direction
  - Positive: 90° walking direction



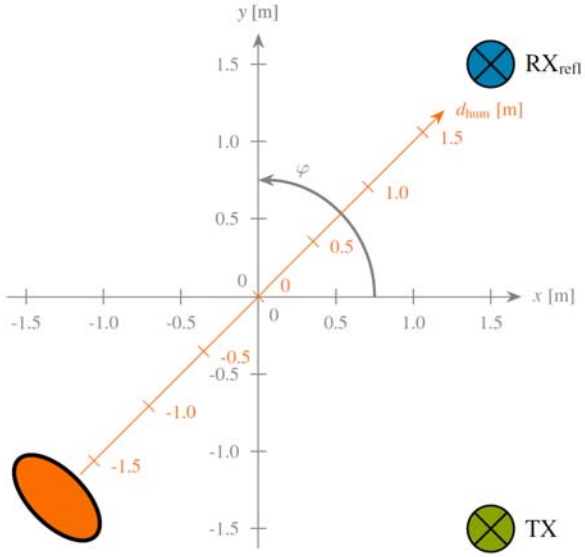
Reflection analysis

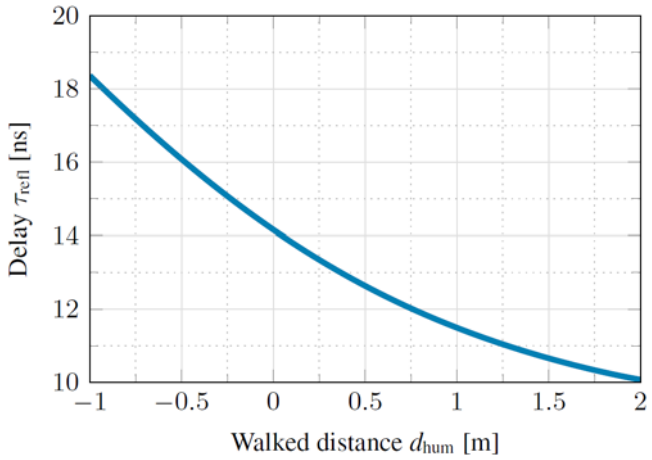
- Analysis of trajectory of reflection
- Delay range limited to time range in which only reflection is present



Trajectory evaluation

- Measured trajectory maps delay of reflection to time of measurement
- In principle, time step corresponds to certain position of (constantly) moving human
- Furthermore, certain position corresponds to certain delay due to reflection

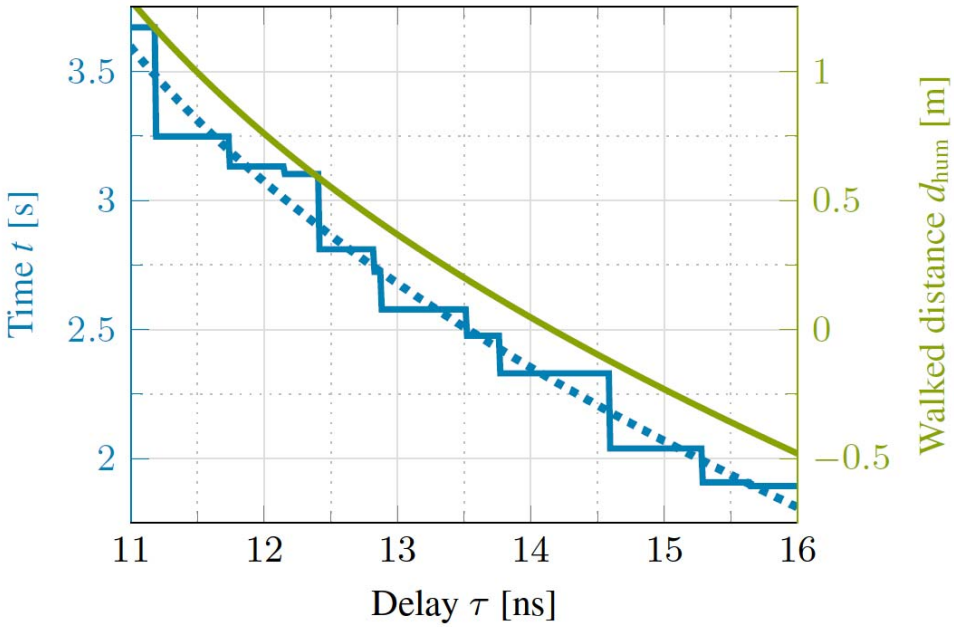




Velocity evaluation

- Time of movement and walked distance can be represented related to delay of reflection
- Time given by trajectory of measurement
- Walked distance given by geometry
- Fitting of walked distance curve
- Velocity given by (fitted) walked distance divided by elapsed time:

$$v_{\text{hum}} = \frac{D}{T}$$



Conclusion and outlook

- Channel measurement characteristics can be used for evaluation of moving human characteristics
- Blockage events can provide information about walking direction
- Reflection measurements can provide information about velocity, but geometry of setup required

- Further investigations necessary with, e.g., different people
- Determination of accuracy of walking direction evaluation