Project: IEEE P802.15 Working Group for Wireless Speciality Networks (WSN)

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

Date Submitted: 28 July 2025
Source: Thomas Kürner, TU Braunschweig
Address Schleinitzstr. 22, D-38092 Braunschweig, Germany
Voice:+495313912416, FAX: +495313915192, E-Mail: t.kuerner@tu-braunschweig.de

Re: n/a

Abstract: In this contribution, time-variant power delay profiles from measurements involving a moving human are employed to assess movement. Blockage scenario measurements are used to determine the moving direction, while reflection scenario measurements assess velocity. The results demonstrate that channel measurements can successfully be used to track human movement characteristics, specifically walking direction and velocity.

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

T. Doeker[1], M. Eggers[1], C. E. Reinhardt[1], D. M. Mittleman[2] and T. Kürner[1]

[1]TU Braunschweig, Germany

[2]Brown University, Purdue/RI, USA

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

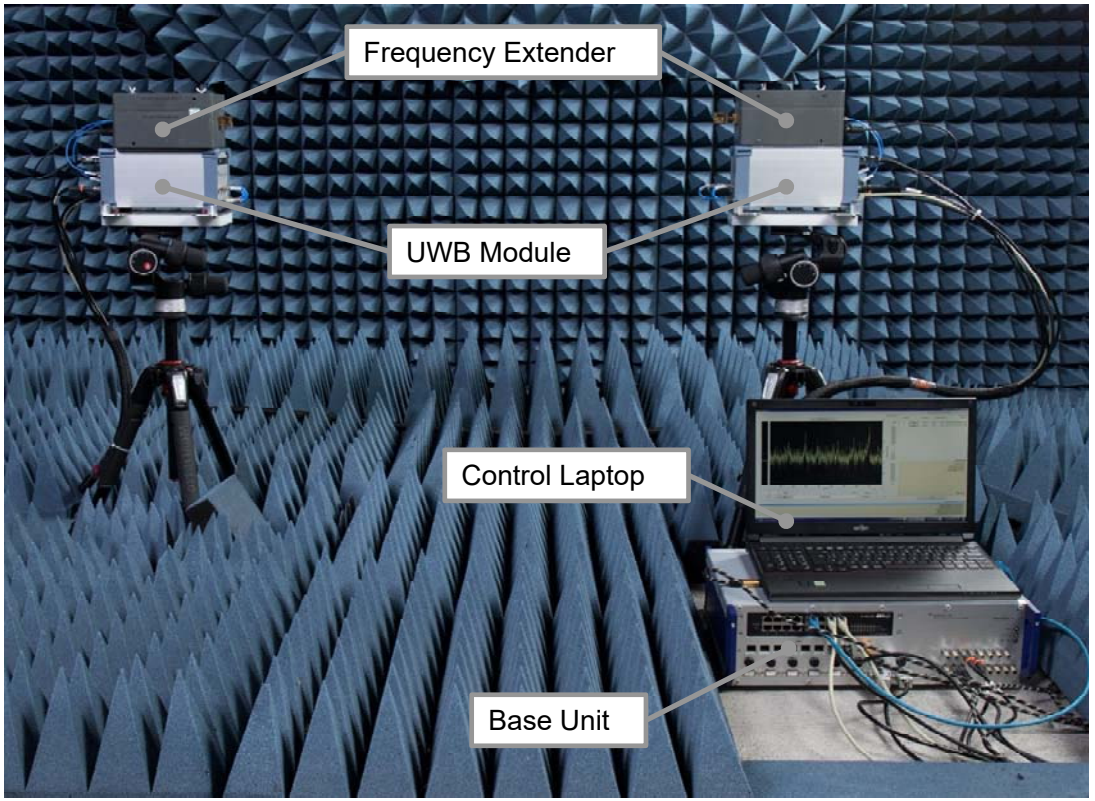
- References:

[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

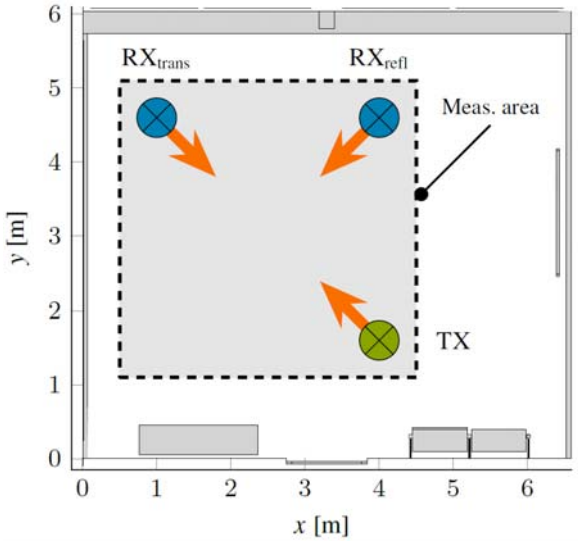
Parameter	Value
Clock frequency	9.22 GHz
Bandwidth	4 GHz
Chip duration	108.5 ps
M-sequence order	12
Sequence length	4095
Sequence duration	444.14 ns
Subsampling factor	128
Acquisition time for one CIR	56.9 µs
Measurement rate	17,590 CIR/s
Center frequency	64.5 & 304.2 GHz

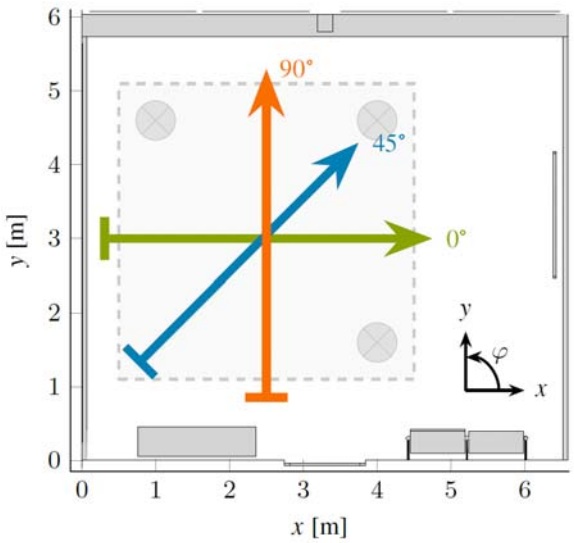


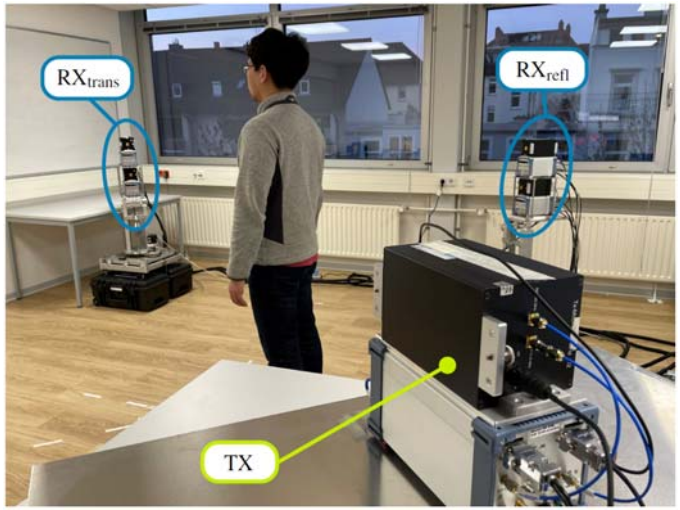
S. Rey, J. M. Eckhardt, B. Peng, K. Guan and T. Kürner, "Channel sounding techniques for applications in THz communications: A first correlation based channel sounder for ultra-wideband dynamic channel measurements at 300 GHz," *2017 9th International Congress on Ultra Modern Telecommunications and Control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

Measurement setup (2/2)

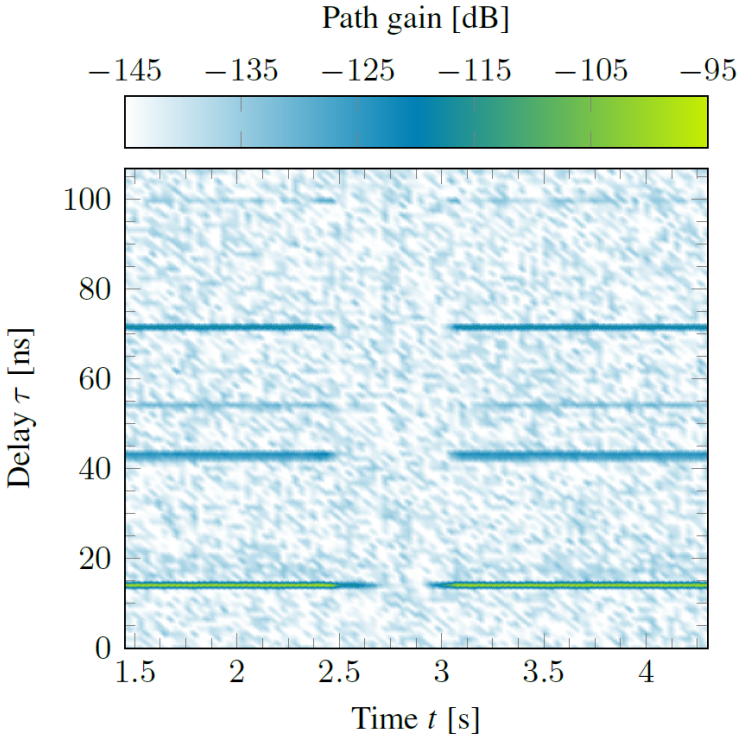
- Measurement equipment for 60 GHz and 300 GHz placed above each other
- Measurement equipment clustered: TX / RX for transmission / RX for reflection
- Human moves in three different directions; 30 repetitions per direction



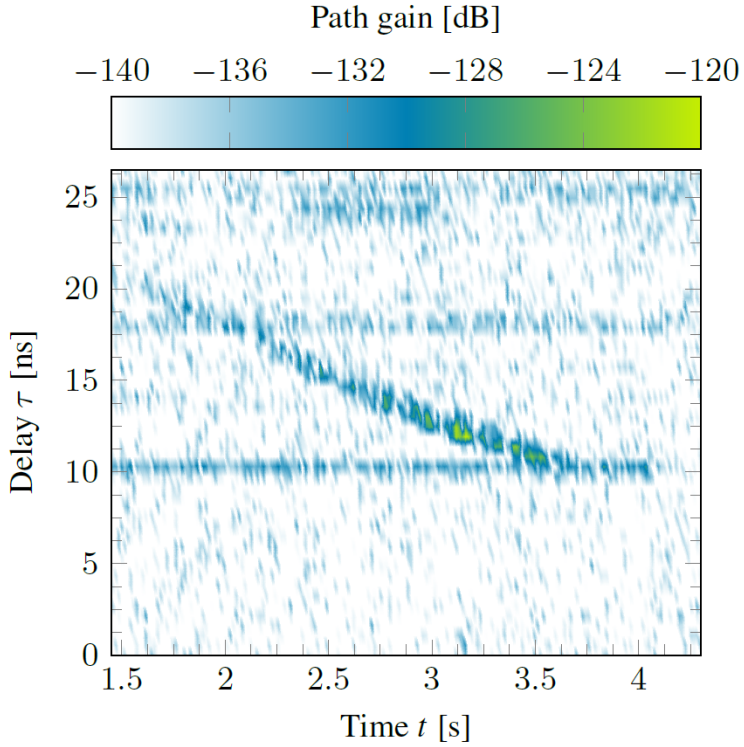




Evaluation basis – Time-variant PDP



Transmission measurement (at 300 GHz)

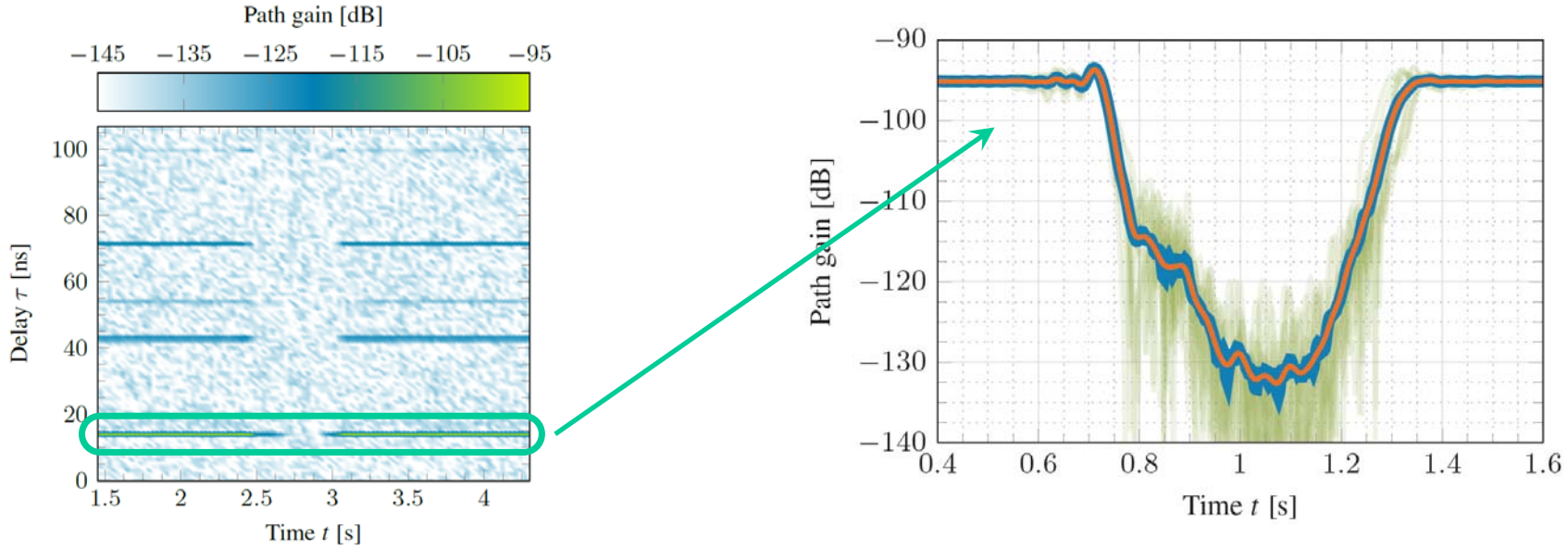


Reflection measurement (at 60 GHz)

(SNR too low at 300 GHz)

Blockage event analysis (1/2)

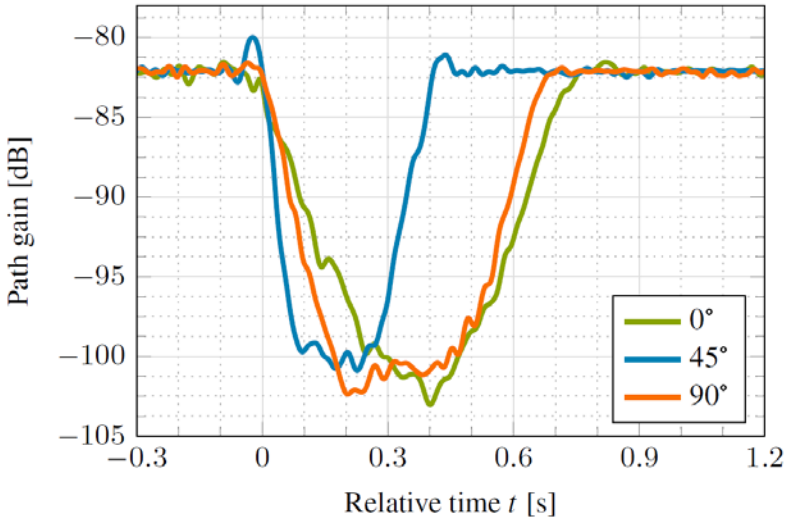
- Blockage event analysis for LOS component
- Averaging of repetitions and low-pass filtering for comparison



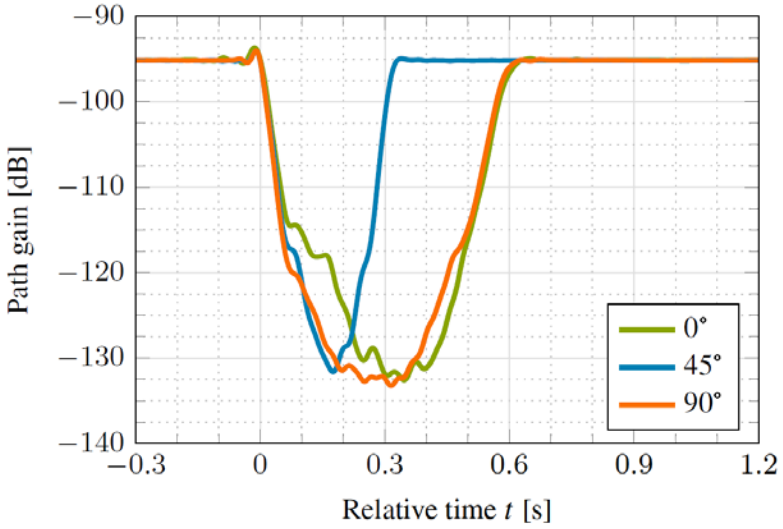
green: single measurement / blue: averaged / orange: low-pass filtered average

Blockage event analysis (2/2)

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

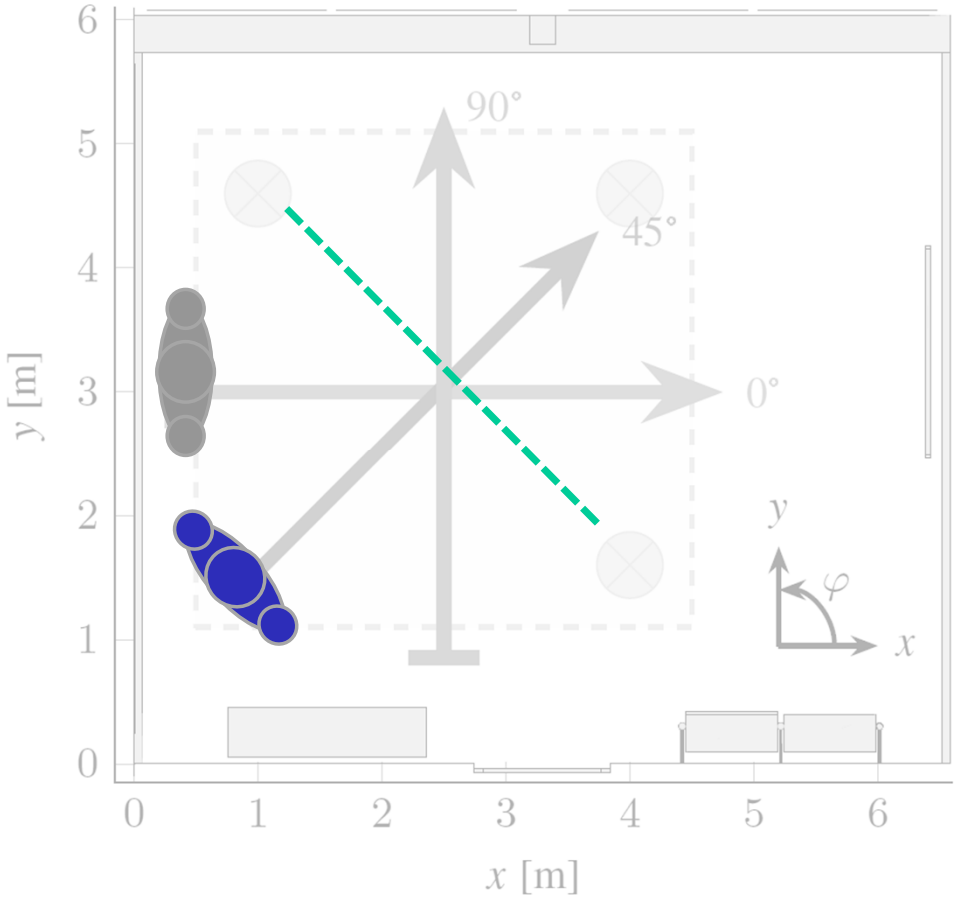


60 GHz measurement



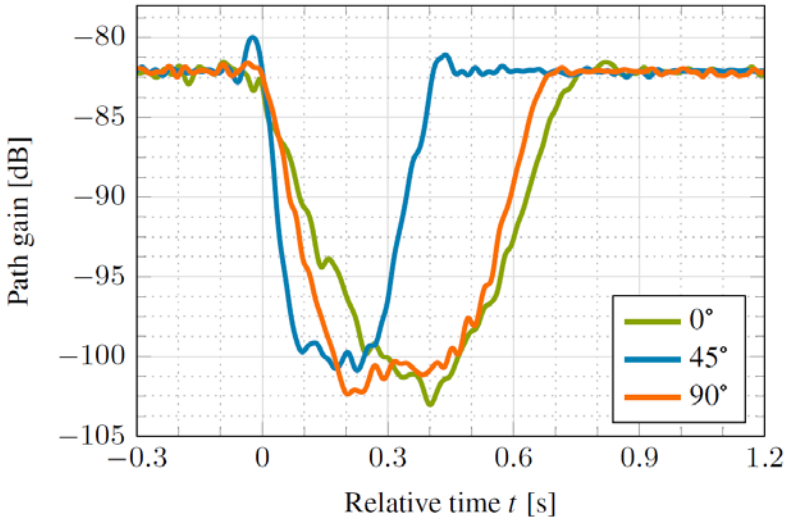
300 GHz measurement

Blockage event analysis (2/2)

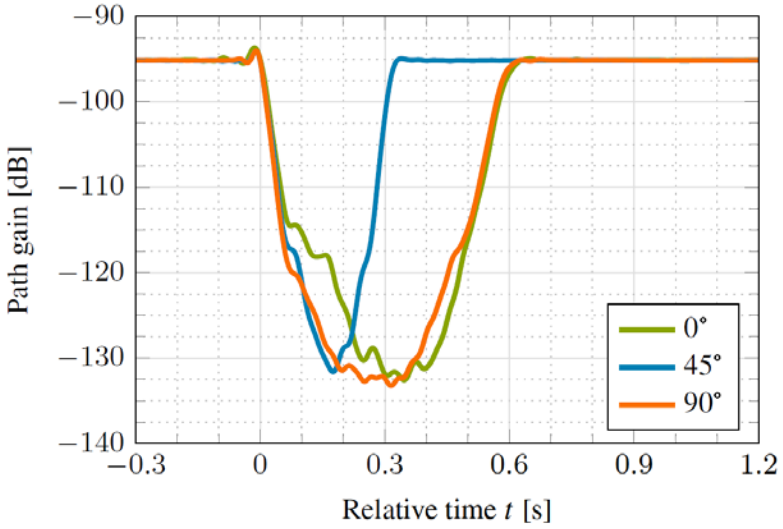


Blockage event analysis (2/2)

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



60 GHz measurement



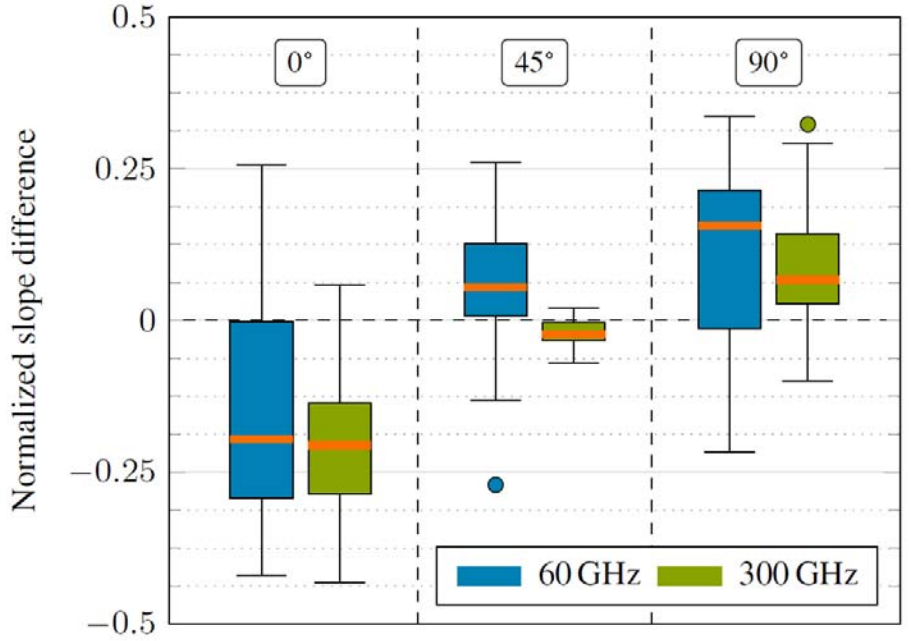
300 GHz measurement

Walking direction evaluation

- For each individual measurement calculation of normalized slope difference:

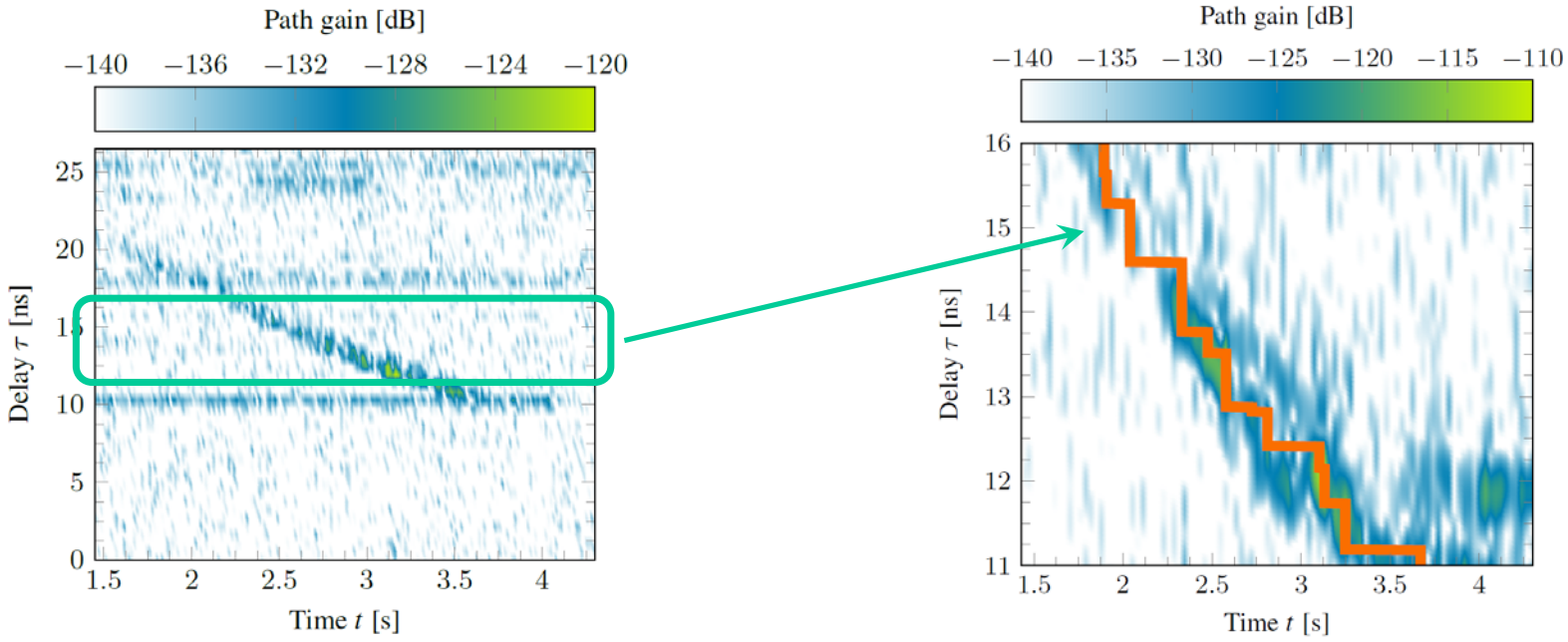
$$\overline{\Delta}_{\text{diff}} = \frac{|\Delta_{\text{min}}| - \Delta_{\text{max}}}{\max\{|\Delta_{\text{min}}|, \Delta_{\text{max}}\}}$$

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



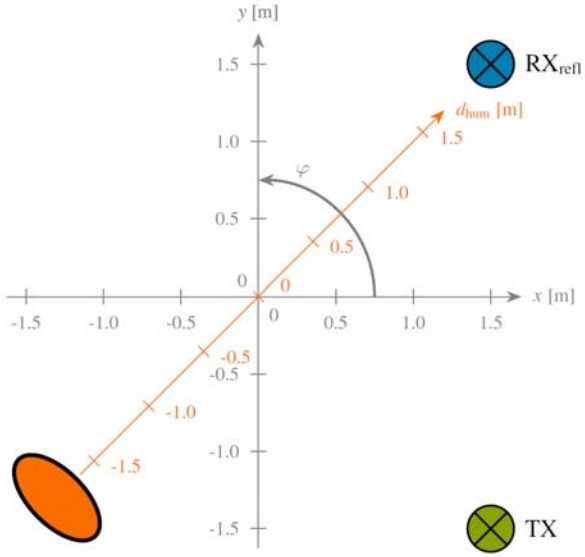
Reflection analysis

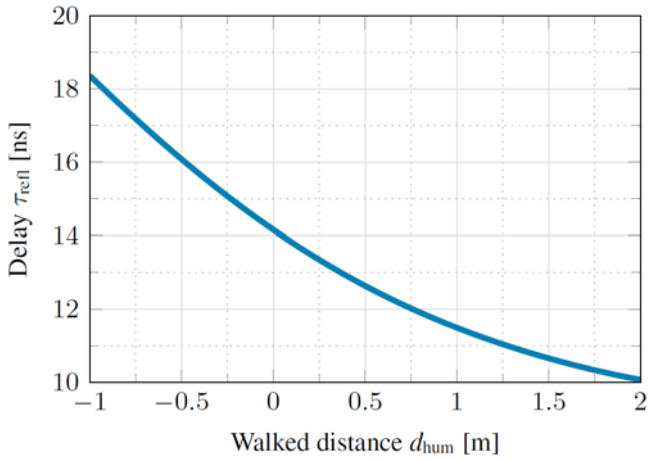
- Analysis of trajectory of reflection
- Delay range limited to time range in which only reflection is present



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

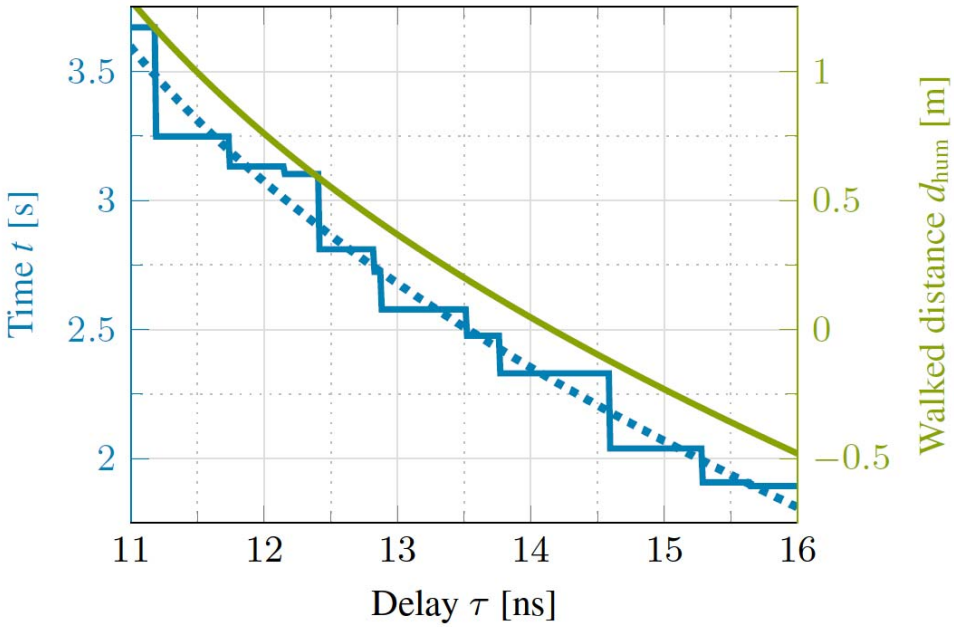




Velocity evaluation

- 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