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

Submission Title: Path Loss Measurements and Models at 300 GHz in an Industrial Environment

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Abstract: Path loss measurements at 300 GHz were performed in an industrial environment using horn antennas. This contribution shows and aims to discuss its results and model parameters extracted for the empircial path loss models floating intercept (FI) and close-in (CI) models. Furthermore it discusses the sensitivity wrt inaccuracies in antenna alignment.

Purpose: Information of IEEE 802.15 SC THz

IEEE 802 Wireless Interim

Path Loss Measurements and Models at 300 GHz in Industrial Environments

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IEEE 802.15 SC THz
Jan 15, 2025, Held in Kobe & Hybrid via Webex

- This contribution is based on the publication:

  [1] L. Ribeiro, T. Kürner, „ Path Loss Measurements ands Models at 300 GHz in an industrial Environment", accepted for publication in EuCAP 2025, Stockholm/Sweden, April 2025

- This work has received funding from the Federal Ministry of Education and Research of Germany in the Programm of "Souverän.Digital.Vernetzt", joint Project 6G-RIC (Grant Number: 16KISK020K and 16KISK031)

Background

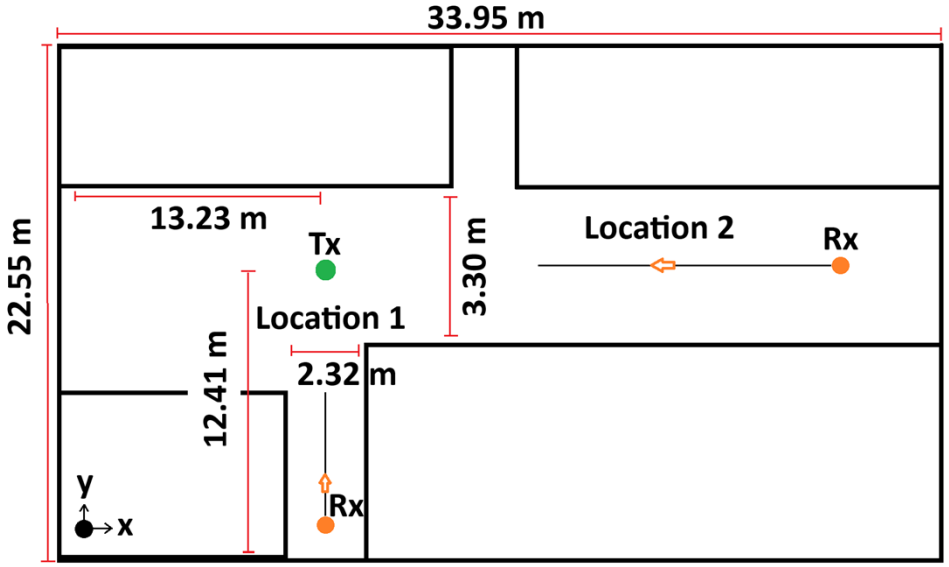
- The purpose the measurements was to provide input ETSI ISG THz GR003 [2]
- In the beginning of April 2024 channel measurements were conducted 300 GHz in the Institute of Machine Tools and Production Technology at TU Braunschweig, an alike industrial environment.

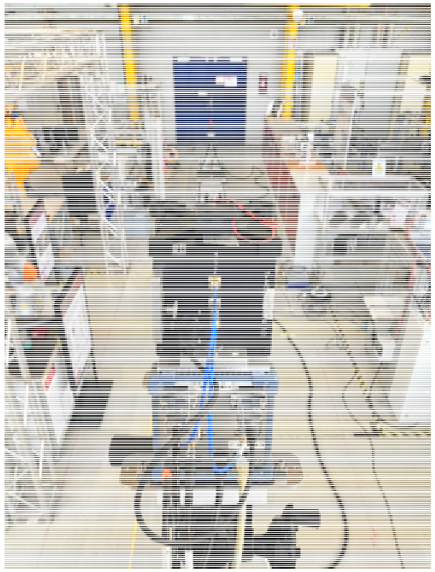
- Goal was the emulate a line-of-sight (LoS) communication between a robot and a THz access point

Measurement Equipment

Type of sounder	Correlation based channel sounder [3]
Center frequency	304 GHz
Time delay resolution	108.5 ps
Sequence length	4095
Bandwidth	8 GHz
Sampling rate	17583.5 CIRs/s
Tx/Rx antenna, gain, HPBW and polarization	26.3 dBi, 8.5°, VV
Tx antenna height	3.1 meters
Rx antenna height	1.0 meter

Measurement Set-Up





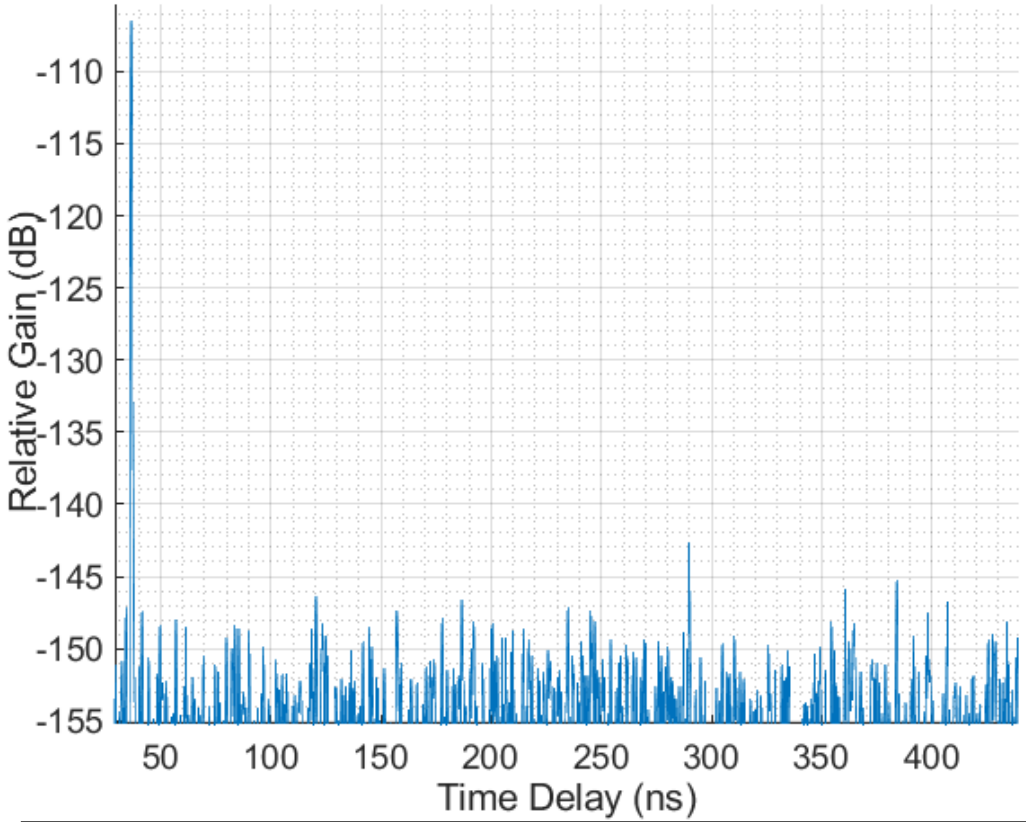
Location 1:

13 snapshots with Tx-Rx distance form 5 to 11m

Location 2:

21 snapshots with Tx-Rx distance form 5 to 15m

Typical Power Delay Profile



- In almost all measurements a clear dominant path (line-of-sight path) could be identified due to the high-gain antennas used

Path Loss Models

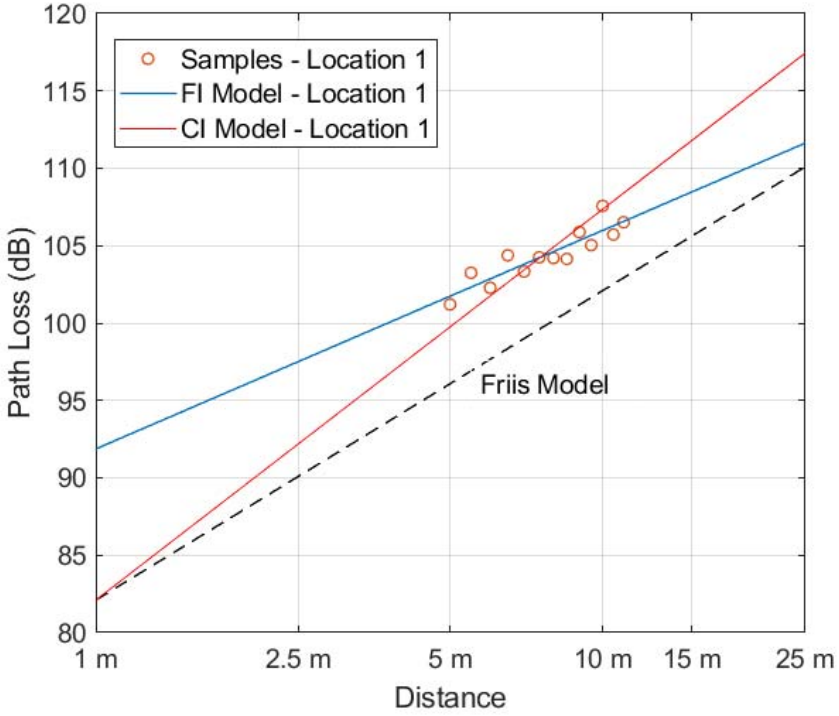
- Measurements have been used to estimate paramters of two empirical path loss models using the least-square methoid:
  - Floating Intercept (FI) Model

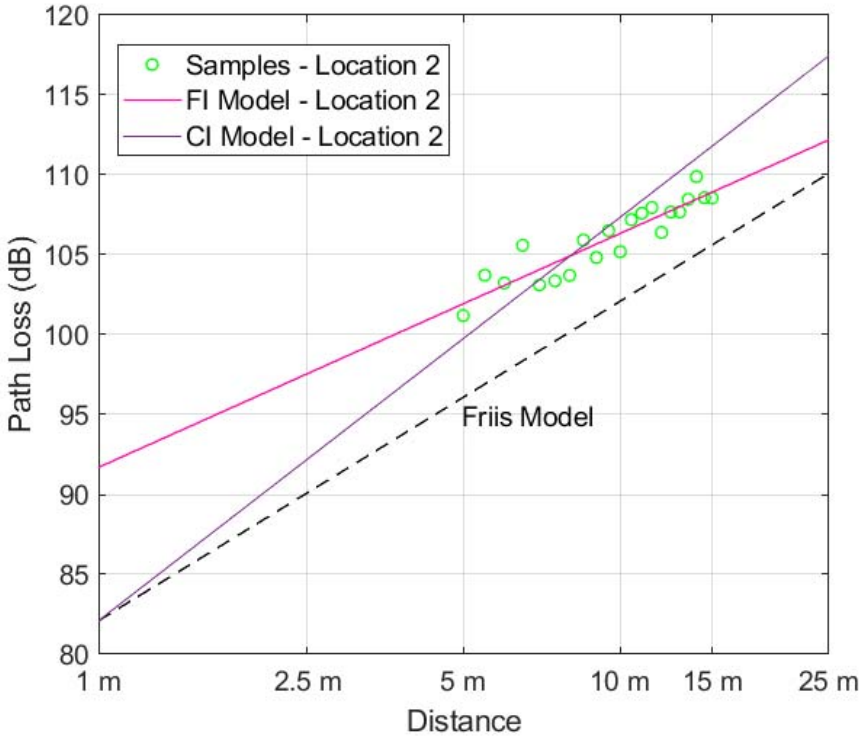
$$PL^{FI}(d) = \beta + 10 \cdot \alpha \cdot log_{10}(d) + X_{\sigma}^{FI}$$

  - Close-In (CI) Model

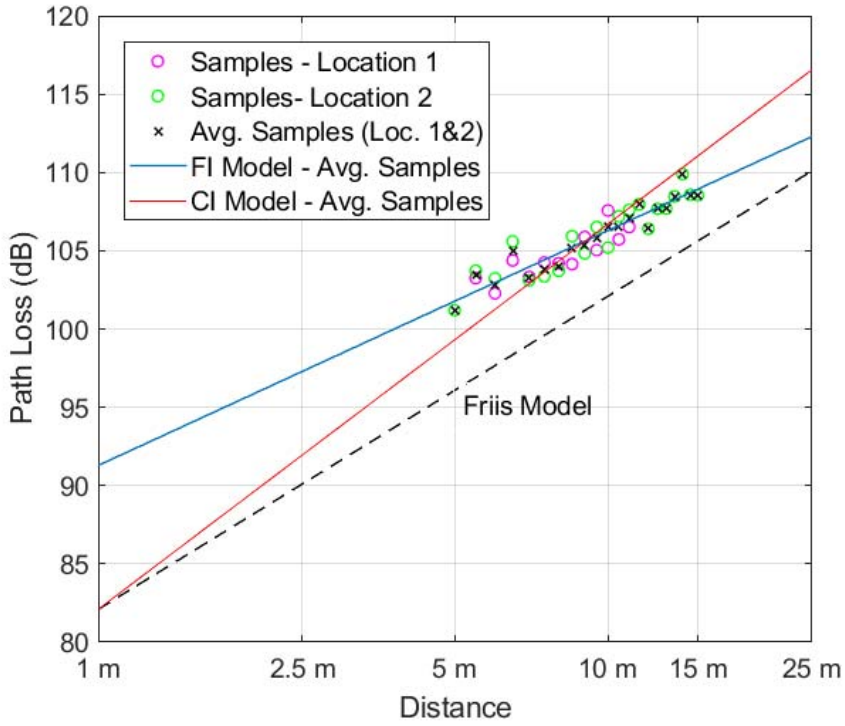
$$PL^{CI}(d) = 20 \cdot log_{10}(f_o) - 27.55 + 10 \cdot \alpha \cdot log_{10}(d) + X_{\sigma}^{CI}$$

Measurements and Path Loss Modeling individually for both Locations





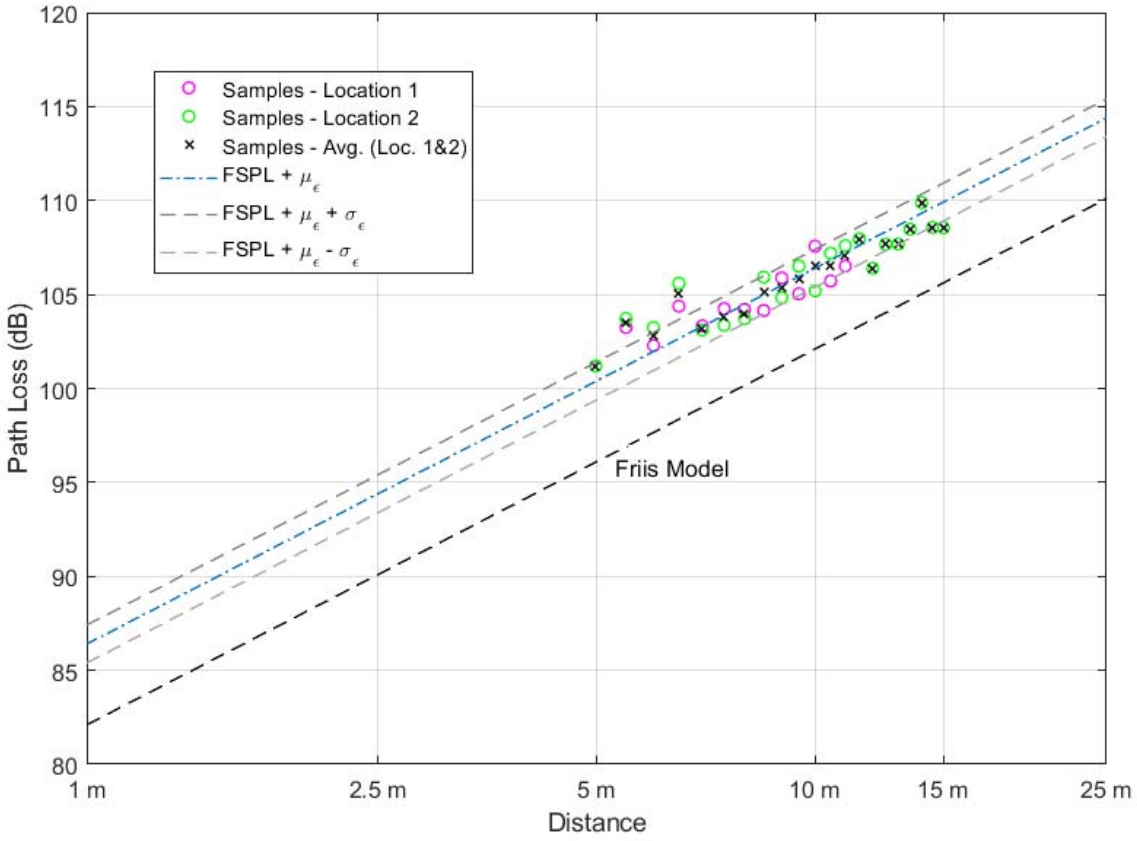
Modeling based on averaged Samples from both Locations



- Estimated Path Loss Parameters:

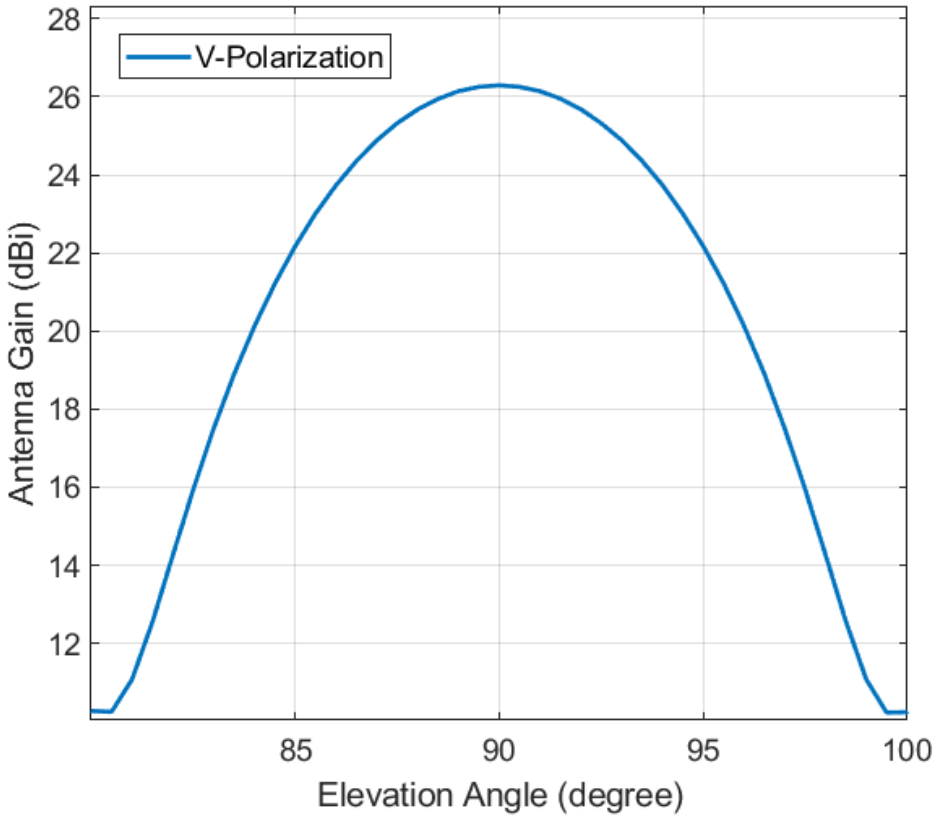
Freq. (GHz)	Location	PL estimation method	CI model (α, σ)	FI model (α, β, σ)
304	1	Strongest beam	2.52, 1.45	1.41, 89.26, 0.80
304	2	Strongest beam	2.46, 1.79	1.46, 89.09, 1.01
304	Avg. 1&2	Strongest beam	2.46, 1.64	1.50, 88.68, 0.72

Discussion of the Results



- Average distance between FSPL and averaged samples in the order of 4 dB
- Differences increases with descreasing Tx-Rx distance

Effect of Antenna Misalignment



- Antenna misalignment in the elevation of 5° (i.e. 2.5° at each end of the link) yields in 4 dB additional path loss, i.e. a misalignment of 2.5° at each link
- This does not consider misalignment in the azimuth and the measurement accuracy of the channel sounder, so that even smaller misalignments in the elevation may yiled a difference of 4dB
- Hence, the higher path loss compared to the Friis path loss is likeley due to misalignment in the horn antennas at both ends of the link.

Conclusions

- Parameters for two empirical path loss models have been derived based on measurements at 300 GHz in an industrial environment.
- The lack of multipath due to the small antenna aperture resulted in path loss models based on the strongest beam.
- The higher path loss compared to the Friis model can be justified with a misalignment of the antennas in the order of a few degrees in both ends.

References

[1] L. Ribeiro, T. Kürner, „ Path Loss Measurements ands Models at 300 GHz in an industrial Environment”, accepted for publication in EuCAP 2025, Stockholm/Sweden, April 2025

[2] ETSI GR THz 003 on “Channel measurements and modelling in THz bands”: https://www.etsi.org/deliver/etsi_gr/THz/001_099/003/

[3] S. Rey et al, “Channel sounding techniques for applications in thz communications: A first correlation based channel sounder for ultra-wideband dynamic channel measurements at 300 ghz,” in 2017 9th International Congress on Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT), pp. 449–453, 2017