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Submission Title: Channel Measurements in Workspace with Robotic Manipulators at 300 GHz and Recent Results

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Abstract: This contribution reports about time-variant channel measurements at 300 GHz in a robotic environment, which have been carried out in the framework of the European 6G-SNS-JU TIMES project.

Purpose: Information of IEEE 802.15 SC THz

Technische Universität Braunschweig

TIMES

THZ INDUSTRIAL MESH NETWORKS IN SMART SENSING & PROPAGATION ENVIRONMENTS

Institut für Nachrichtentechnik

Channel Measurements in Workspace with Robotic Manipulators at 300 GHz and Recent Results

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- This presentation is based on the following publication:

  V. Elesina, C. Reinhardt, T. Kürner, Channel Measurements in Workspace with Robotic Manipulators at 300 GHz and Recent Results, Proc. European Conference on Antennas and Propagation, Glasgow (Scotland), March 2024

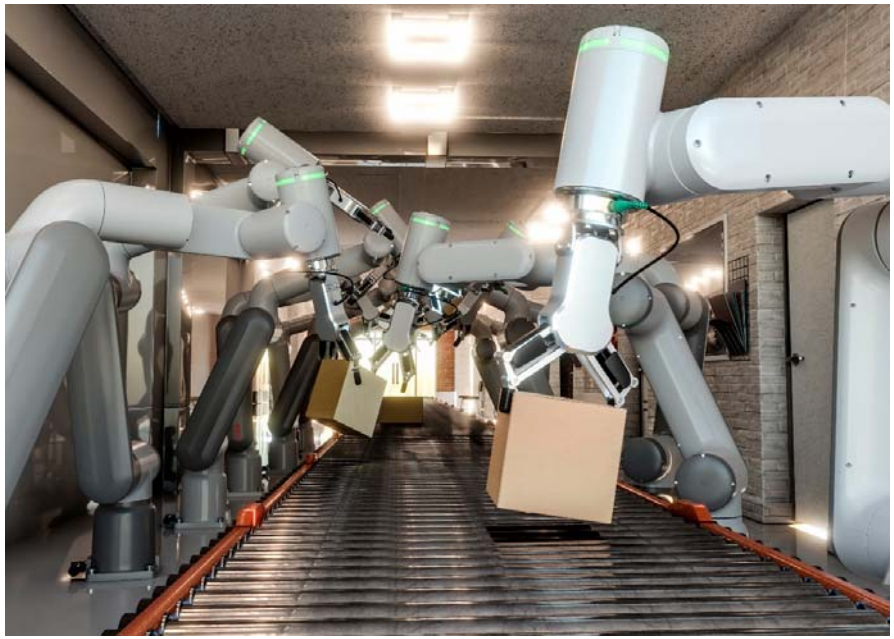
Structure

1. Motivation
2. TUBS Measurement Equipment
3. Environment and Scenario Description
4. First Results
5. Conclusion

Motivation

- Requirements for the Industry 4.0 revolution:
  - High data-rate of 1 Tbps
  - High-precision localization and imaging accuracy

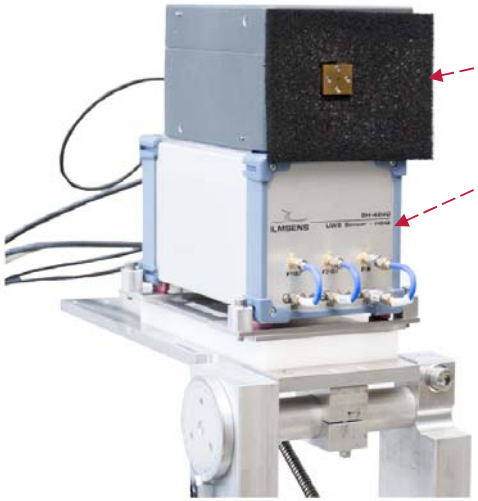
  → **Solution: Using the low THz frequency range**
- Develop channel models
  - Measurements required

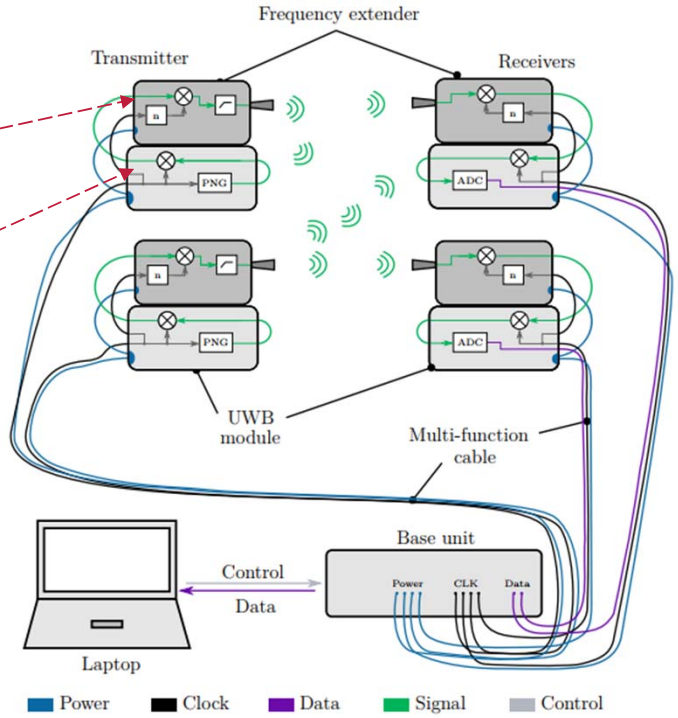


Picture: freepik.com

Measurement Equipment

- The measurements were conducted using an ultra wide band (UWB) sub-mmWave correlative channel sounder (CS)





Parameter	Value
Center Frequency	304.2 GHz
Clock Frequency	9.22 GHz
Bandwidth	approx. 8 GHz
Chip duration	108.5 ps
Order of M-Sequence	12
Sequence length	4095
Sequence duration	444.14 ns
Subsampling factor	128
Measurement Rate	17,590 CIR/s
TX/RX antenna gain	26.4 dBi
TX/RX antenna HPBW	8.5°

[1] 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

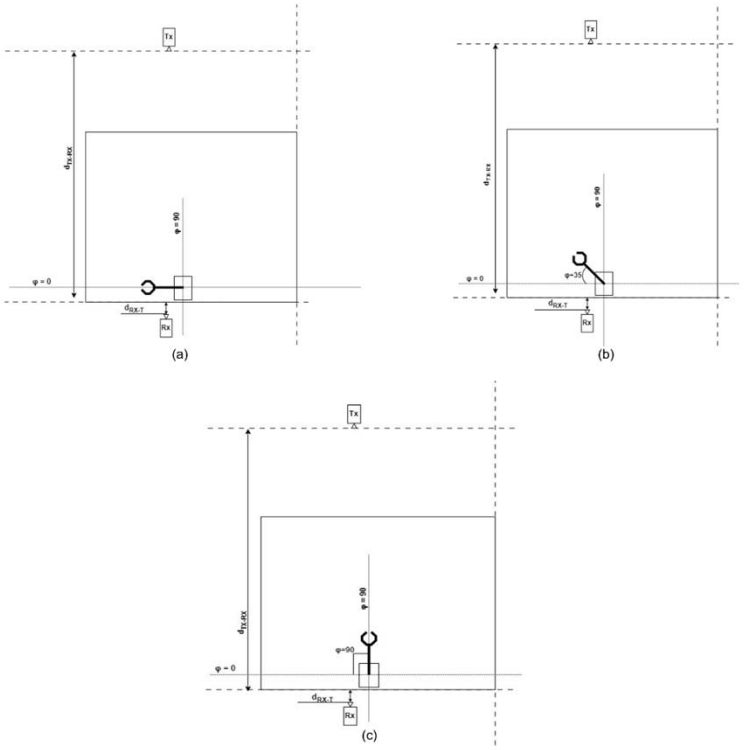
[2] J. M. Eckhardt, A. Schultze, R. Askar, T. Doeker, M. Peter, W. Keusgen, T. Kürner, “Uniform Analysis of Multipath Components From Various Scenarios With Time-Domain Channel Sounding at 300GHz,” IEEE Open Journal of Antennas and Propagation, vol. 7, pp. 446-460, March 2023

Measurement Environment

- Measurements were conducted in the Robotics Lab at TUBS
- Up to 3 robotic arms were used in different configurations
- Franka Emika robotic arms
- Setup included the movement of one arm

Static Scenario: Access Point Communication

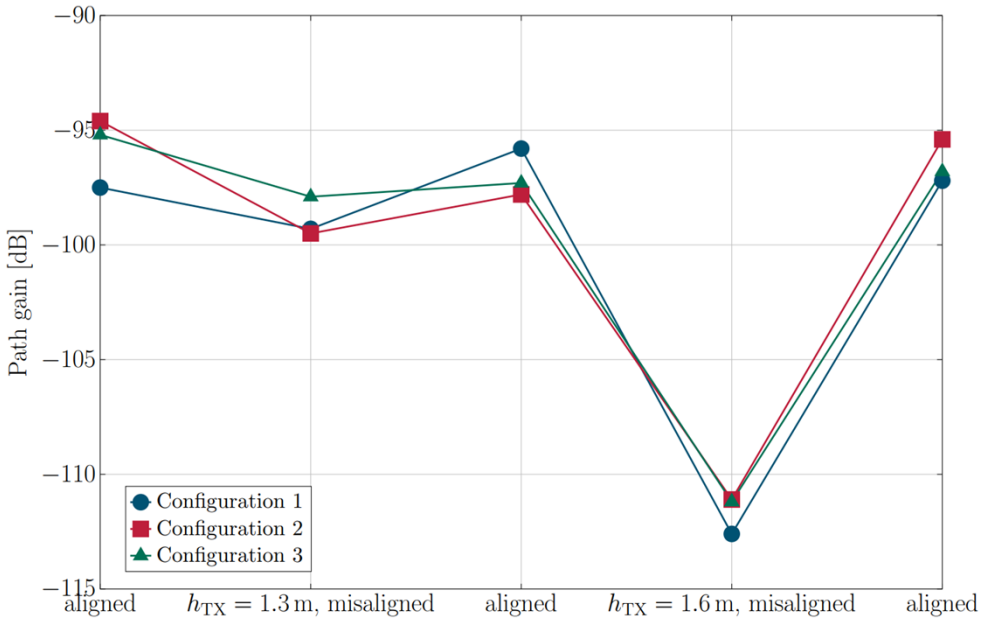
- Access Point 4m away from the RX close to the robotic arm
- Three different arm configurations
- Three different heights
- TX and RX aligned and misaligned
- In total 15 different configurations



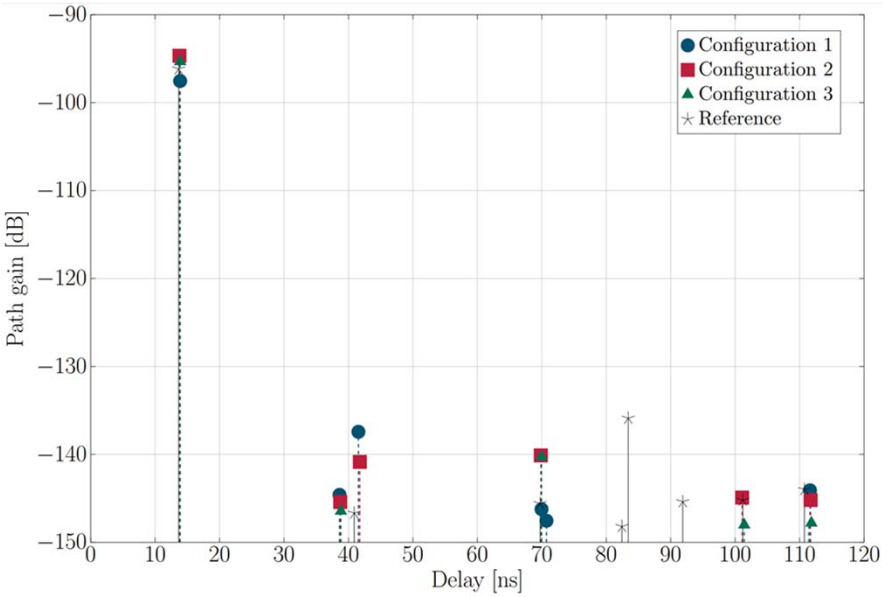
Static Scenario: Access Point Communication

Setup	*h*TX, m	*h*RX, m	*d*TX-RX, m	Arm's Config.	Alignment
1	1.09	1.08	4.08	1	aligned
2	1.09	1.08	4.08	2	aligned
3	1.09	1.08	4.08	3	aligned
4	1.3	1.08	4.08	1	misaligned
5	1.3	1.08	4.08	1	aligned, ±3°
6	1.3	1.08	4.08	2	misaligned
7	1.3	1.08	4.08	2	aligned, ±3°
8	1.3	1.08	4.08	3	misaligned
9	1.3	1.08	4.08	3	aligned, ±3°
10	1.6	1.08	4.08	1	misaligned
11	1.6	1.08	4.08	1	aligned, ±7°
12	1.6	1.08	4.08	2	misaligned
13	1.6	1.08	4.08	2	aligned, ±7°
14	1.6	1.08	4.08	3	misaligned
15	1.6	1.08	4.08	3	aligned, ±7°

Results: Static Scenario – Access Point Communication

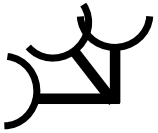


Path gain



Power Delay Profile

- Alignment has a strong influence on the path gain
- We can observe blockage of MPCs
- Constructive interference and diffraction at the arm are probable



Dynamic Scenario: Two Arm Communication

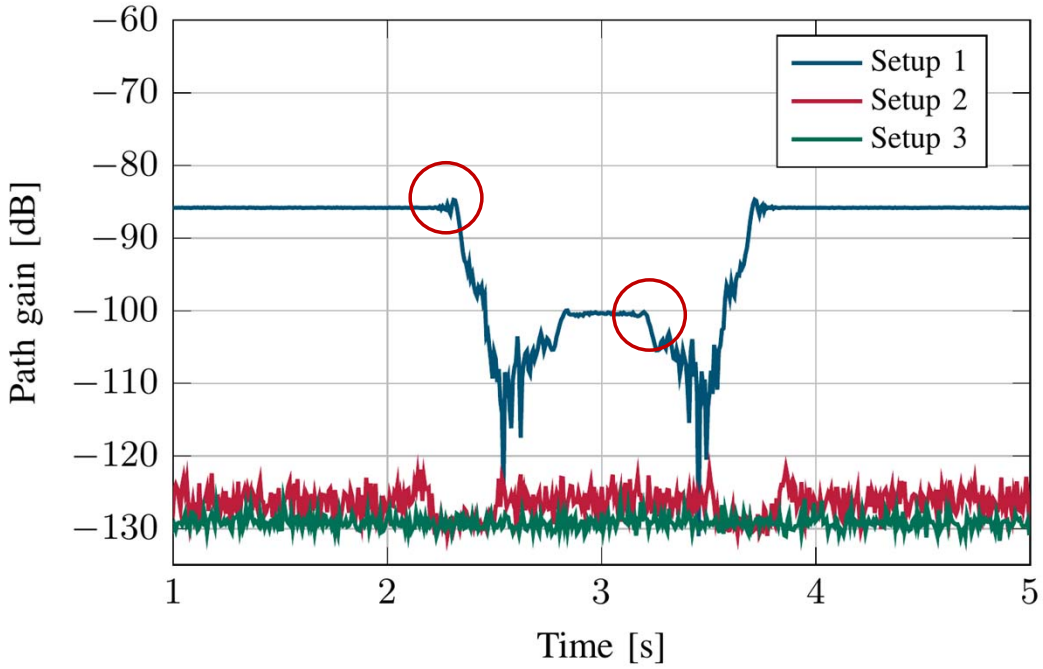
- Two different movements
  - Vertical movement
  - Rotational movement
  - Three different heigths

Setup	h_{TX}, m	h_{RX}, m	$d_{TX\text{-}RX}$, m	Movement direction
1	0.98	0.98	1.4	vertical
2	1.39	0.98	1.4	vertical
3	1.65	0.98	1.4	vertical
4	0.98	0.98	1.4	rotational
5	1.39	0.98	1.4	rotational
6	1.65	0.98	1.4	rotational

Setup 1

Results: Dynamic Scenario – Two Arm Communication

- Three different configurations
- Diffraction effect at the intersection between LOS/OLOS/NLOS
- OLOS attenuation of ~15dB
- Alignment has a strong influence on the communication



Maximum path gain

Conclusion

- These result of the Access Point scenario shows that a high number of MPCs are formed by the environment.
- The different positions of the robotic arm lead to blockage, diffraction and interference.
- Future Work will include a more in-depth analysis of these results.
- For the time-variant scenario an important task will be to investigate the influence of the speed of the movement.
- This will give a better understanding of the channel behaviour in environments with robotic manipulators.

Thank you for attention!

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