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Submission Title: Channel Sounding and Ray Tracing for Train-to-Train Communicationsat the THz Band

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Abstract: This document deals with radio links required for virtual coupling of high-speed trains. 300 GHz channel sounder measurement in a train-to-train scenario are presented. The results are compared with ray tracing simulations.

Purpose: Information of the Technical Advisory Group THz

Channel Sounding and Ray Tracing for Train-to-Train Communications at the THz Band

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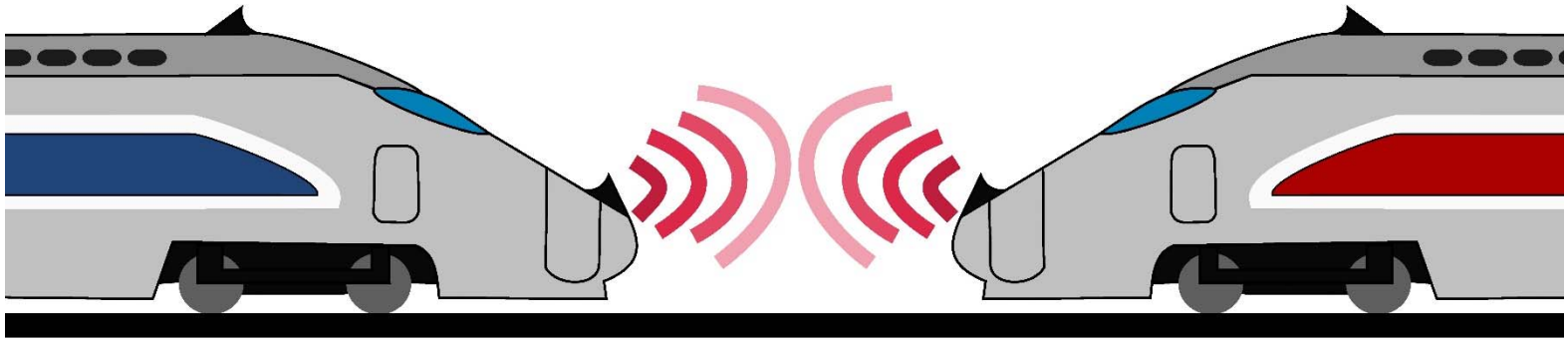
Outline

- Motivation
- Ultra-wideband (UWB) channel sounding measurements in a T2T environment
- 3D Environmental model reconstruction
- Comparison of PDP between measurement and RT
- Propagation mechanisms in train-to-train (T2T) scenario
- Conclusion and future work

Virtual coupling



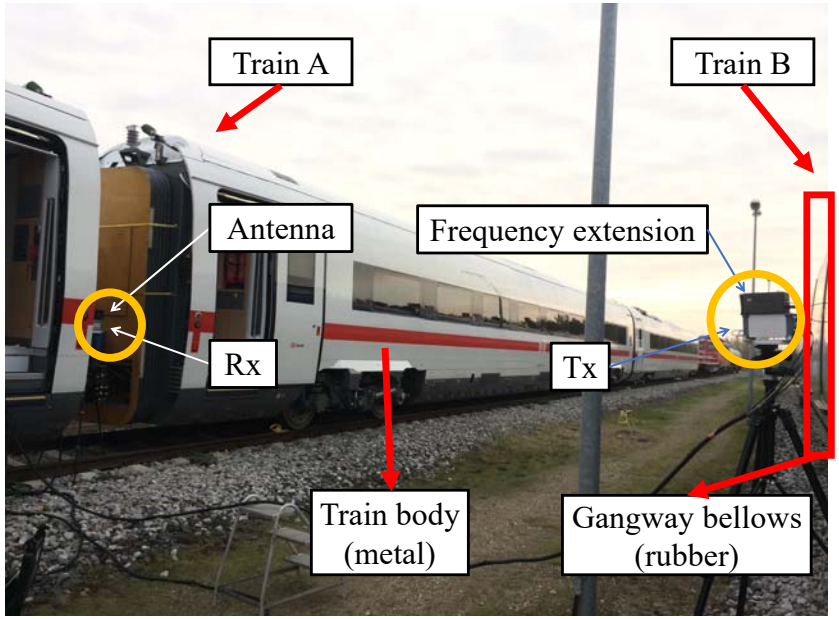
Characteristics of virtual coupling:

- Real-time coupling and decoupling
- Increased link capacity
- Large bandwidth requirement
- Potential application of THz?

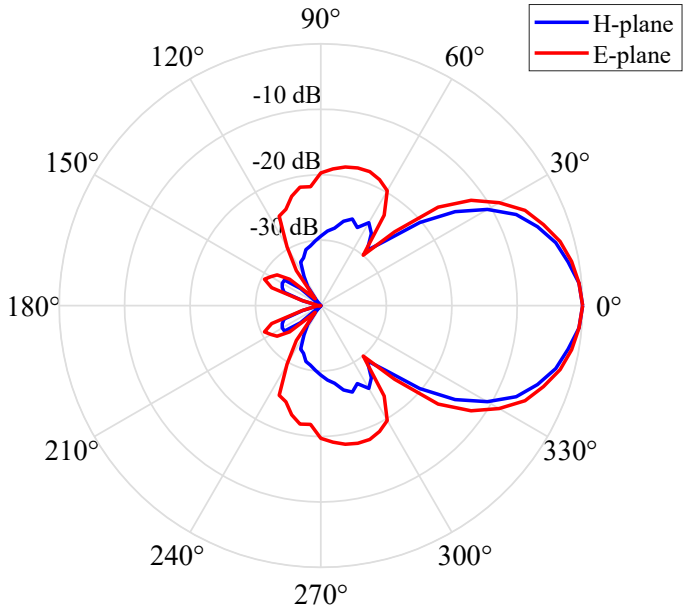
Approach

- To investigate the basic channel characteristics relevant for virtual coupling we have carried out some first channel measurements in the environment of high speed trains.
- The measurements have been performed using the TUBS channel sounder [2]
- Although the set-up does not exactly reflect the virtual coupling scenario, the mesurements can be used to calibrate a ray-tracing model applicable to simualte virtual coupling.

Measurement campaign



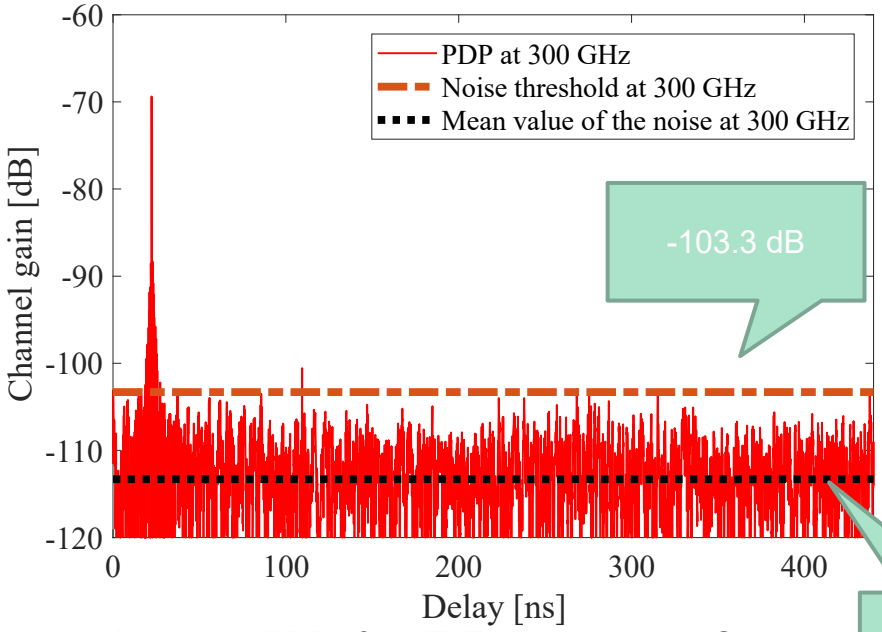
T2T measurement campaign in the train test center



2D pattern of Tx and Rx antennas in the measurement

Measurement system	Bandwidth	Central frequency	Antenna type	Antenna gain	Antenna HPBW
	8 GHz	304.2 GHz	Directional antenna	15 dBi	30^0

Measurement results



Measured PDP of the T2T channel at 300 GHz

Rician *K*-factor

$$KF = 10 \cdot log_{10}\left(\frac{P_{strongest}}{\sum P_{remaining}}\right)$$

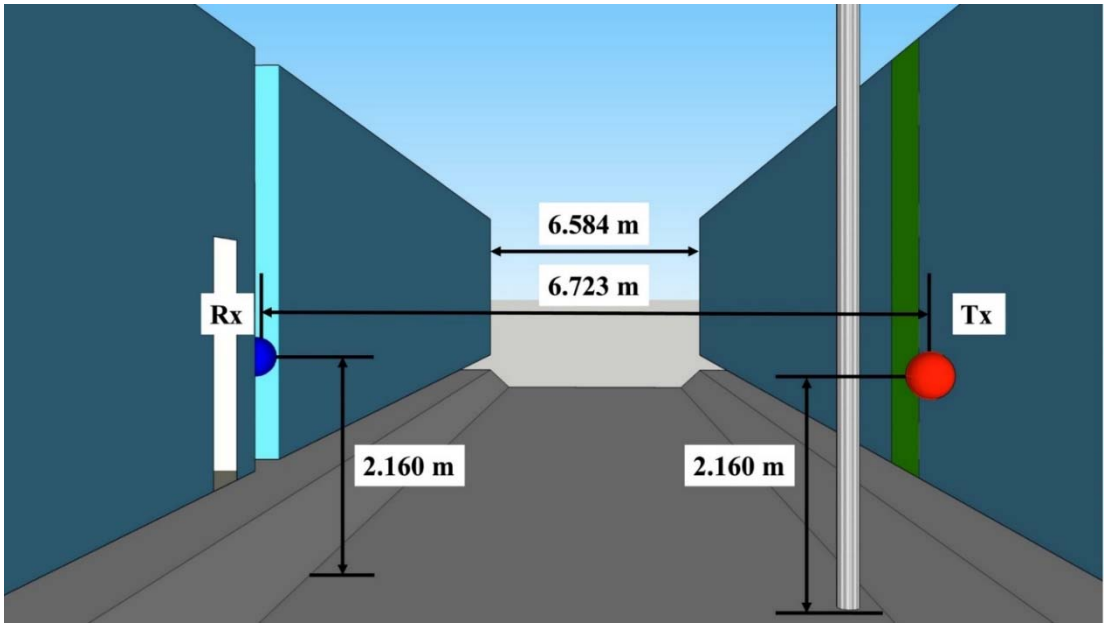
RMS delay spread

$$\sigma_\tau = \sqrt{\frac{\sum_{n=1}^{N} {\tau_n}^2 \cdot P_n}{\sum_{n=1}^{N} P_n} - \left(\frac{\sum_{n=1}^{N} \tau_n \cdot P_n}{\sum_{n=1}^{N} P_n}\right)^2}$$

Measured T2T Channel Parameters at THz Band

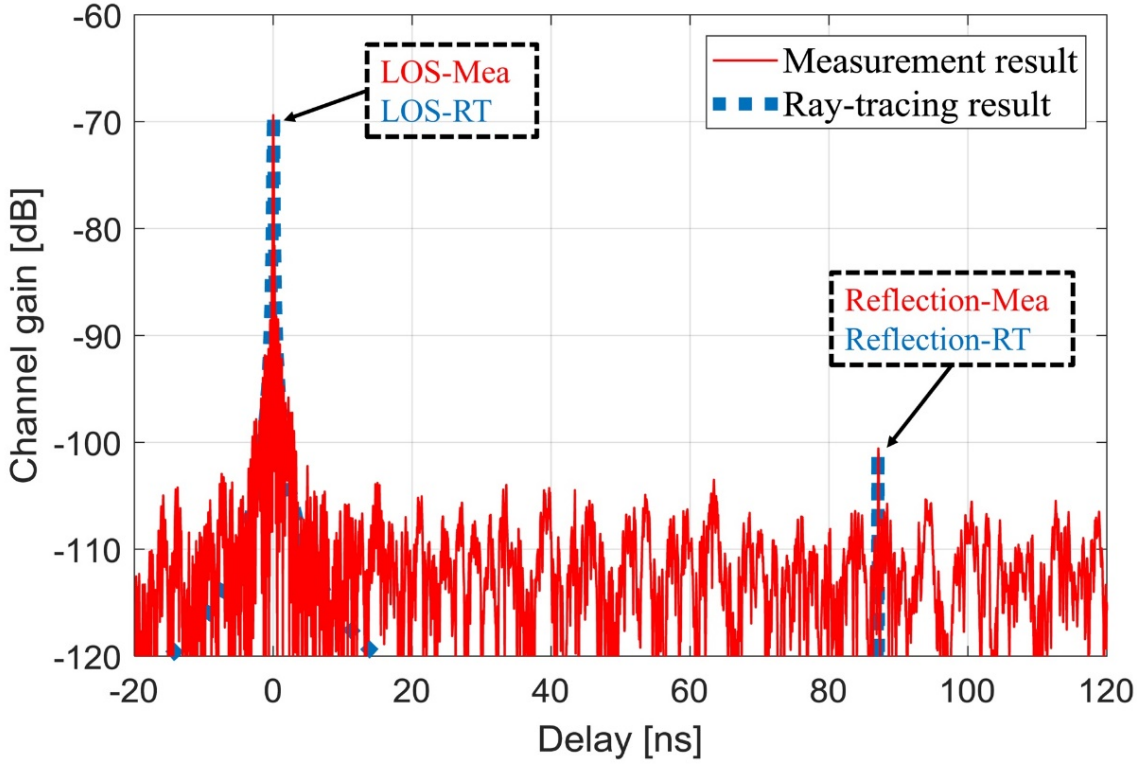
Channel	Rician *K*-factor	RMS delay spread
T2T	3.60 dB	9.23 dB

3D Environmental model reconstruction



Simulation system	Propagation mechanisms	Frequency band	Frequency points	Antenna type	Tx Power
	LOS Reflection	300 GHz ~ 308 GHz	3600	Directional antenna	0 dBm

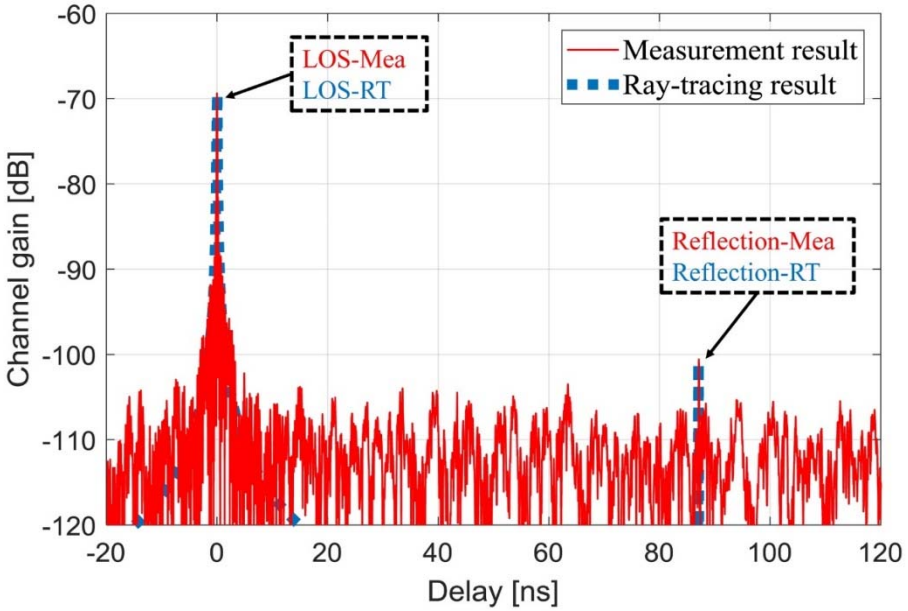
Comparison between measurement and RT



Highest order of reflection
4

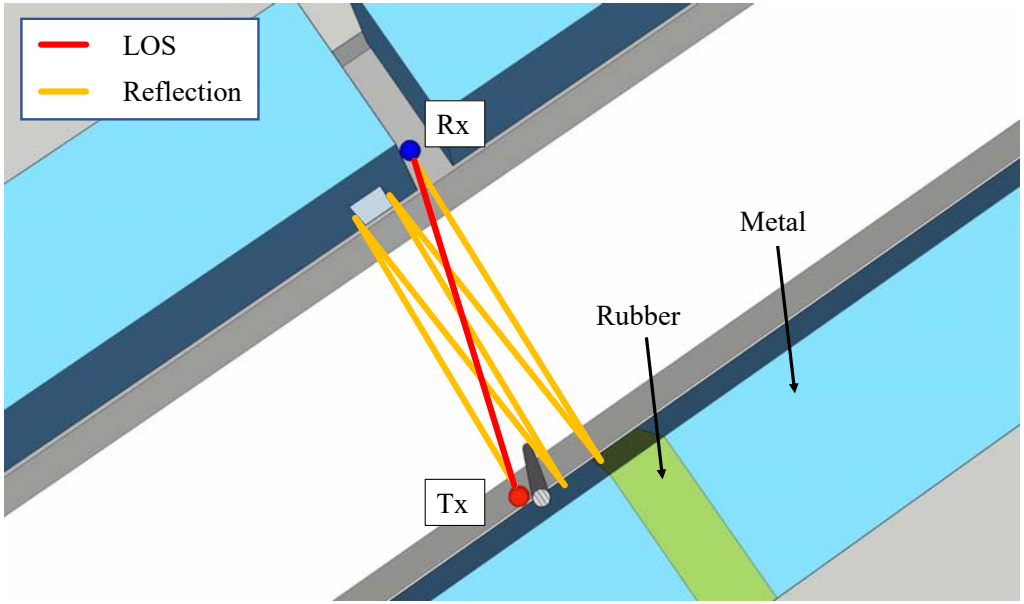
EM Property of materials in RT simulation			
Material	Metal	Brick	Rubber
ε'	1.000	3.026 [3,4]	1.021
ε''	10^7	0.159 [3,4]	1.491

Comparisons between measurement and Ray Tracing



	Measurement power [dBm]	Simulated power [dBm]	Error in power [dB]	Measurement delay [ns]	Simulated delay [ns]	Error in delay [ns]
LOS	-69.39	-69.39	0.00	0.00	0.00	0.00
Reflection	-100.60	-101.00	0.40	87.10	87.05	0.05

Propagation mechanisms in T2T scenario



Scenario	Propagation mechanisms	Material
T2T	LOS The 4th order reflection	Metal Rubber

Conclusion and Future Work

- **Conclusion:**
  - Characterization of the T2T channel at 300 GHz
    - T2T channel sounding measurements
    - The measured Rician K-factor and RMS delay spread
  - Validation of ray-tracing simulator
  - Importance of the metallic objects with smooth surface for T2T scenario at the THz band

- **Future Work:**
  - More realistic T2T scenarios simulations

References

[1] K. Guan, B. Peng, D. He, D. Yan, B. Ai, Z. Zhong, T. Kürner, Channel Sounding and Ray Tracing for Train-to-Train Communications at the THz Band, accepted for presentation at 13th European Conference on Antennas and Propagation, Krakow/Poland, April 2019

[2]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," in 9th International Congress on Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT), Munich, 2017.

[3]: R. Piesiewicz, C. Jansen, S. Wietzke, D. Mittleman, M. Koch, and T. Kürner, “Properties of building and plastic materials in the thz range,” International Journal of Infrared and Millimeter Waves, vol. 28, no. 5, pp. 363–371, 2007.

[4]: R. Piesiewicz, C. Jansen, D. Mittleman, T. Kleine-Ostmann, M. Koch, and T. Kürner, “Scattering analysis for the modeling of THz communication systems,” IEEE Transactions on Antennas and Propagation, vol. 55, no. 11, pp. 3002–3009, November 2007.