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Submission Title: Time-Domain Propagation Investigations for Terahertz Intra-Device Communications

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Abstract: This contribution presents some results on the assessment of ray-racing applied to scenarios typical to intra-device communications. The analysis is based on Finite Difference Time Domain (FDTD) calculations and includes a comparison of the FDTD results with results achieved by ray tracing.

Purpose: Contribution towards developing an intra-device channel model for use in TG 3d

Time-Domain Propagation Investigations for Terahertz Intra-Device Communications

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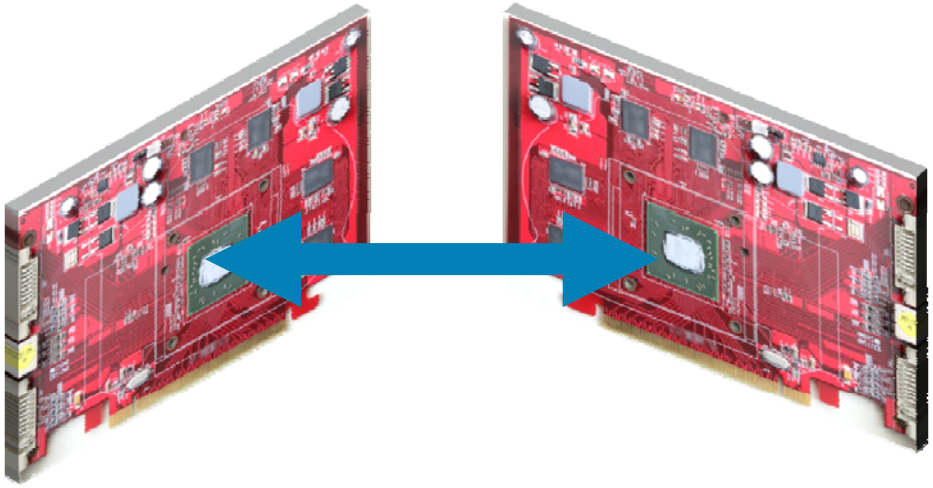
The results presented in this contribution are based on [1]

Outline

- Motivation
- Simulation Methodology
- Observations
  - Impact of the Antennas
  - Propagation along Surfaces
- Comparison with Ray Tracing
- Conclusions

Motivation (1/2) - Intra-Device Communication at THz frequencies

- Ever increasing demand **for higher wireless data rates**, 100 Gbit/s estimated for 2020.
- Hugh available bandwidths **above 300 GHz** can provide these data rates.
- Short wave lengths of several millimeters and less enable **intra device communications** from chip to chip with integrated antennas.
- Need to investigate the propagation characteristics **with typical structures and materials** for intra devices links



Motivation (2/2)- Full Wave Analysis vs. Ray Tracing

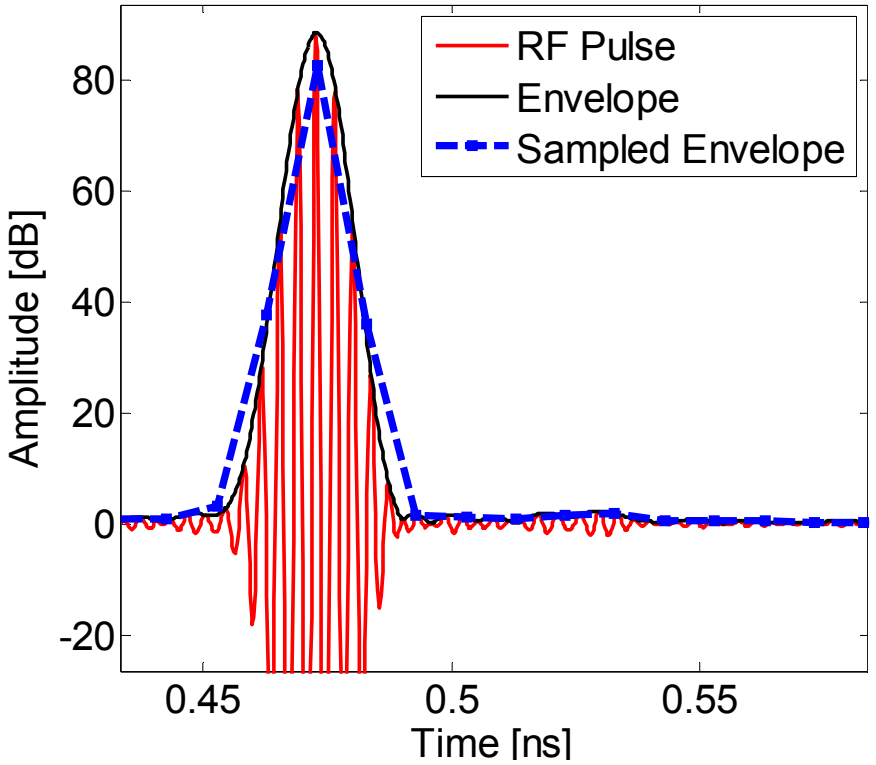
- The intra-device environment comprises many features of the order of the wavelength and the antennas are often placed in the vicinity of these objects
  - The use of widely applied high-frequency approximations such as ray tracing reaches its limits.
  - Due to the short wavelength full-wave methods reach their limits in terms of run-time and memory requirements

Scenario	Size of Scenario [in cm]	Simulation run time[2]	Memory requirements [GByte]
Scenario as presented here	13x1x0.5	3 h	3.6
Medium scenario for intra-device communcation	20x20x20	108d[1]	2900[1]

[1]extrapolated data [2]Computer with 4 CPUs, 3.4 GHz clock and 32 GB RAM

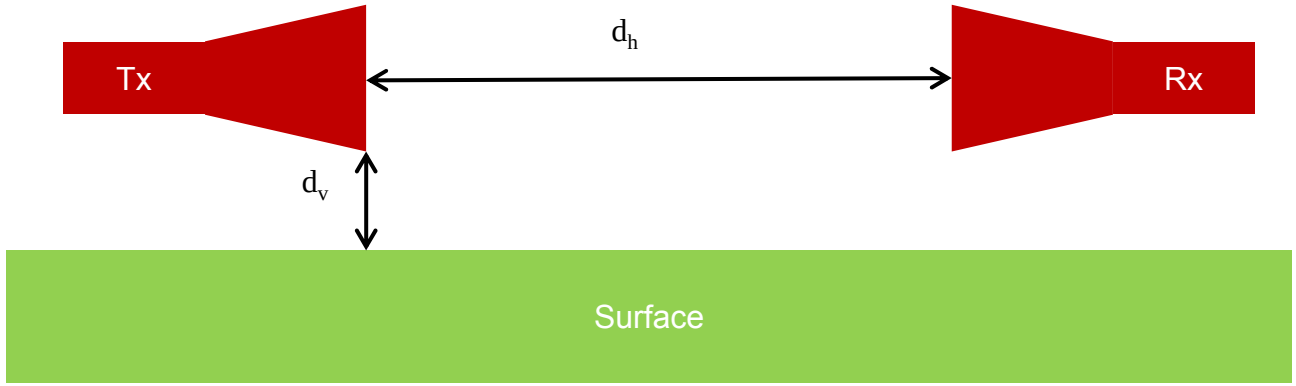
Time Domain Analysis of Ultra-Broadband Signals - Simulation Methodology

- Simulation Method: Finite Difference Time Domain (FDTD)
- Simulation Tool: CST® Microwave Studio®
- Due to the high bandwidth the transient solver is used
- 10 mesh lines per wave length in the hexahedral mesh
- Derivation of the base band time signal: sampled envelope of the RF time pulse integrated over intervals of 0.1 ns



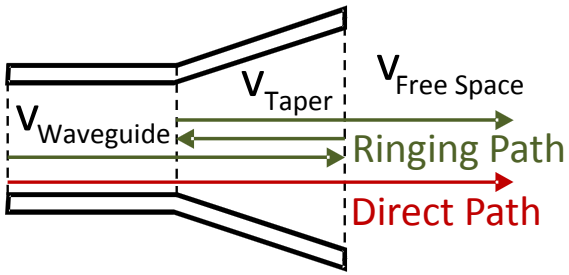
Simulation Scenario

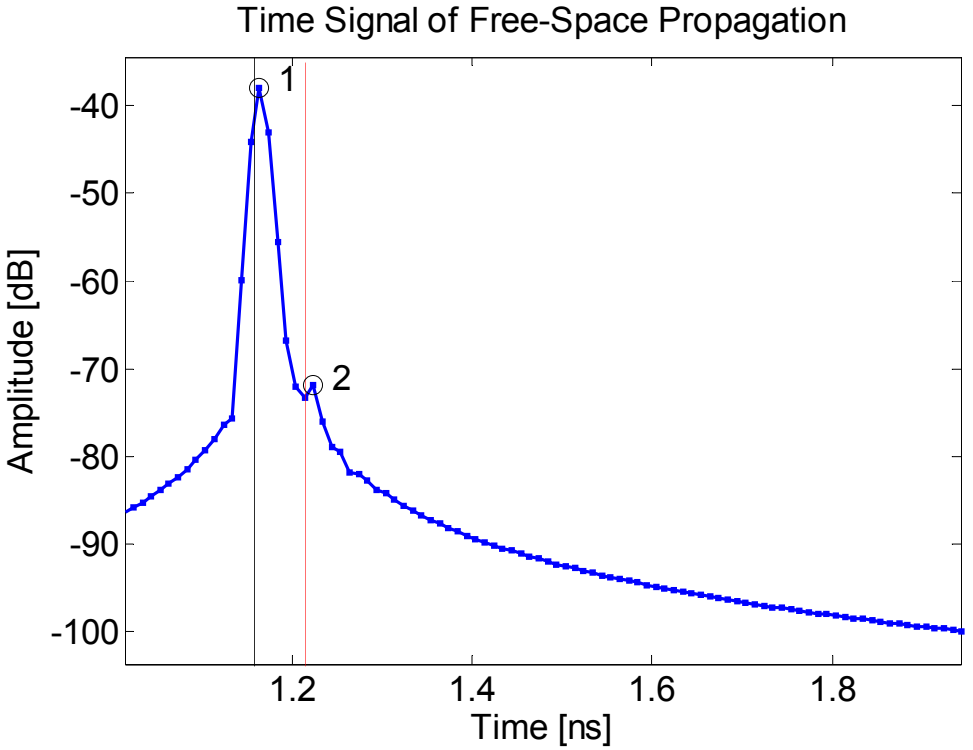
- In this investigation three effects are considered:
  - Impact of the transmitting antenna on the pulse shape
  - Propagation along metallic and plastic surfaces (ABS: acrylonitrile butadiene styrene)
  - Reflections at the transmitting and receiving antenna
- A simple scenario with two horn antennas seperated by the distance d_h above a surface is considered



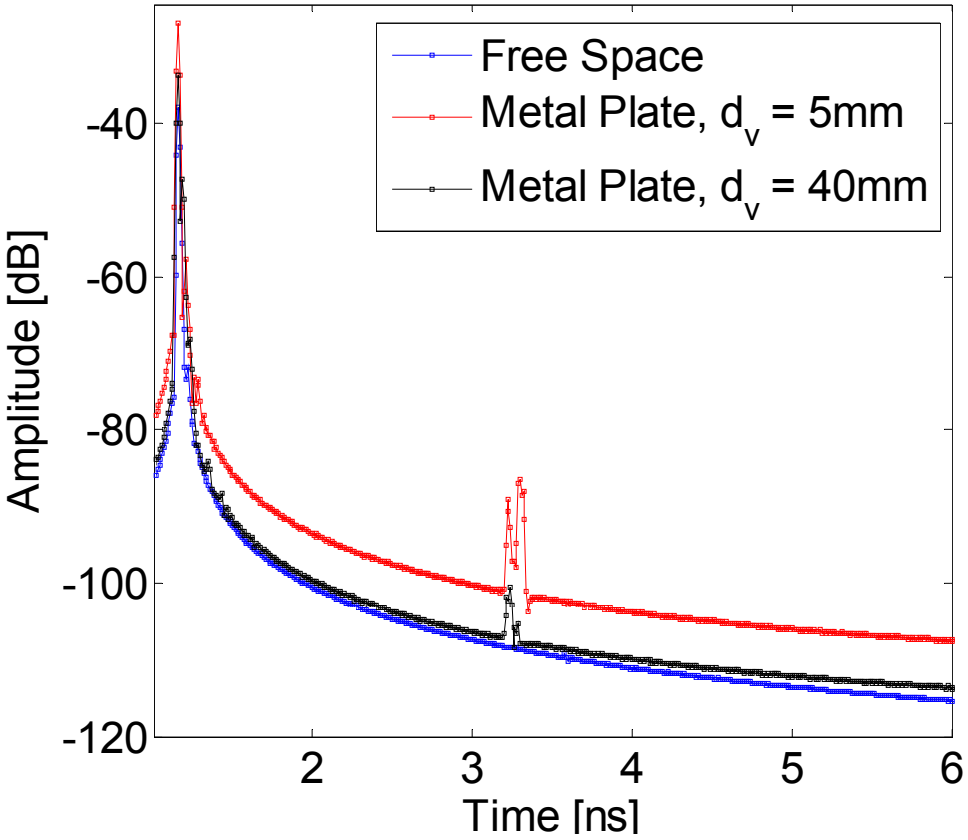
Impact of the Transmitting Antenna

- Horn Antennas separated by 300 mm
- No surface below the antennas (d_v -> ∞)
- Observation of two peaks:
  - Effect of antenna ringing (well understood from UWB)
  - Time difference can be traced back to geometrical properties of the antenna
  - 2nd peak 35 dB below the main peak.





Observed Effects – Propagation along a Metal Plate



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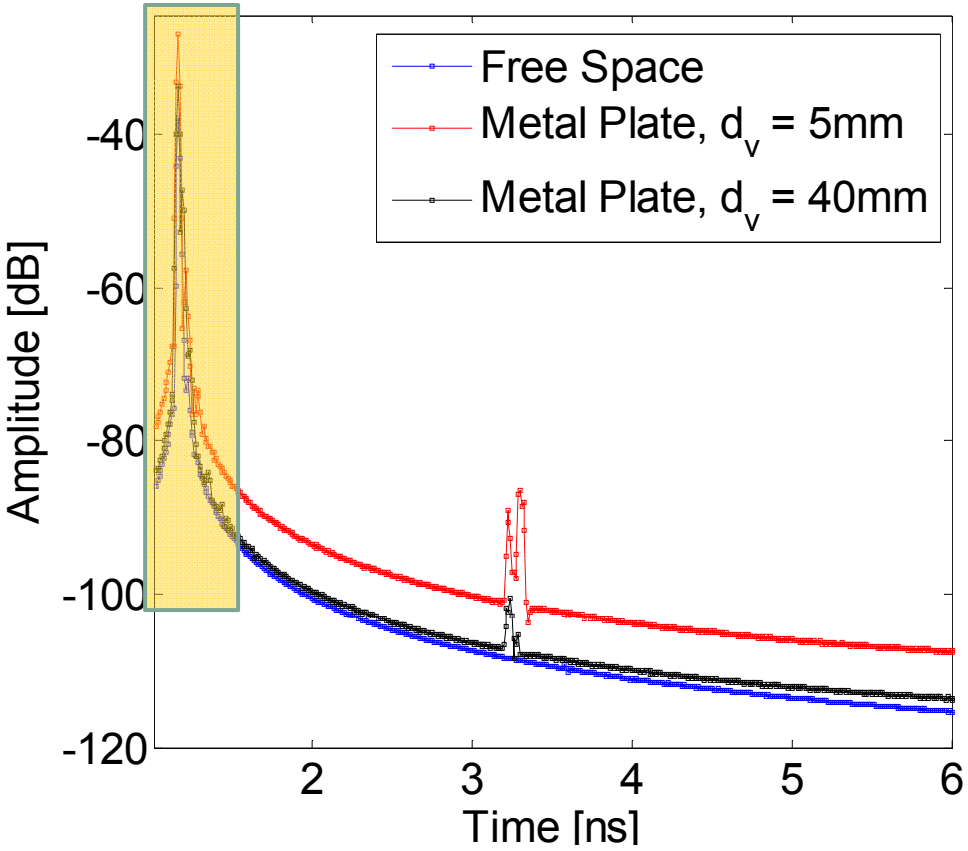

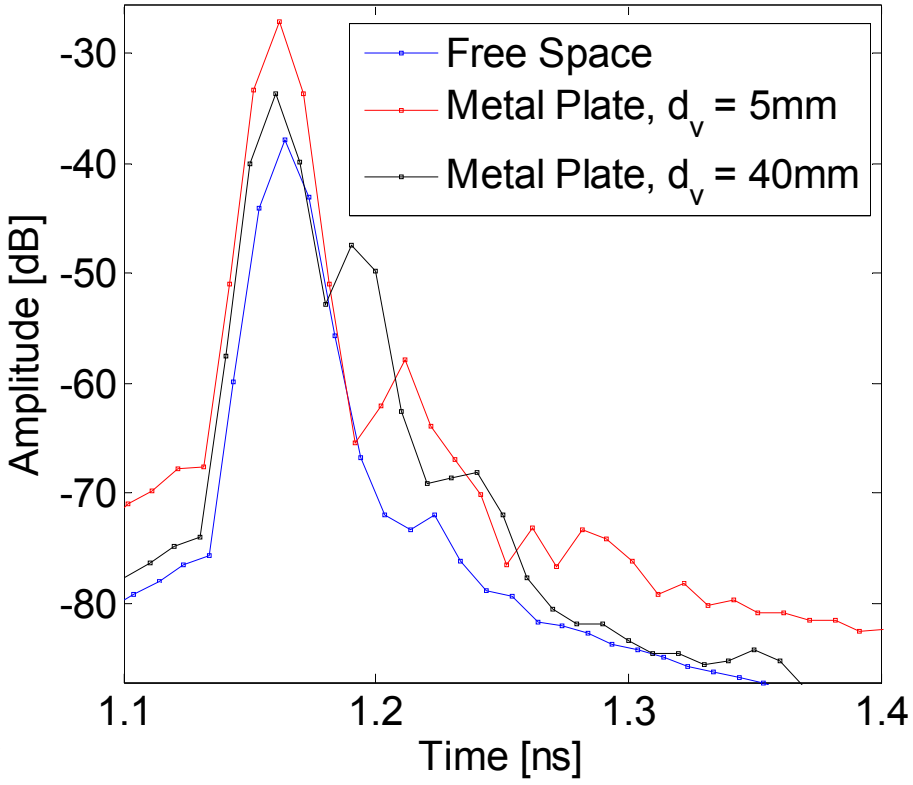

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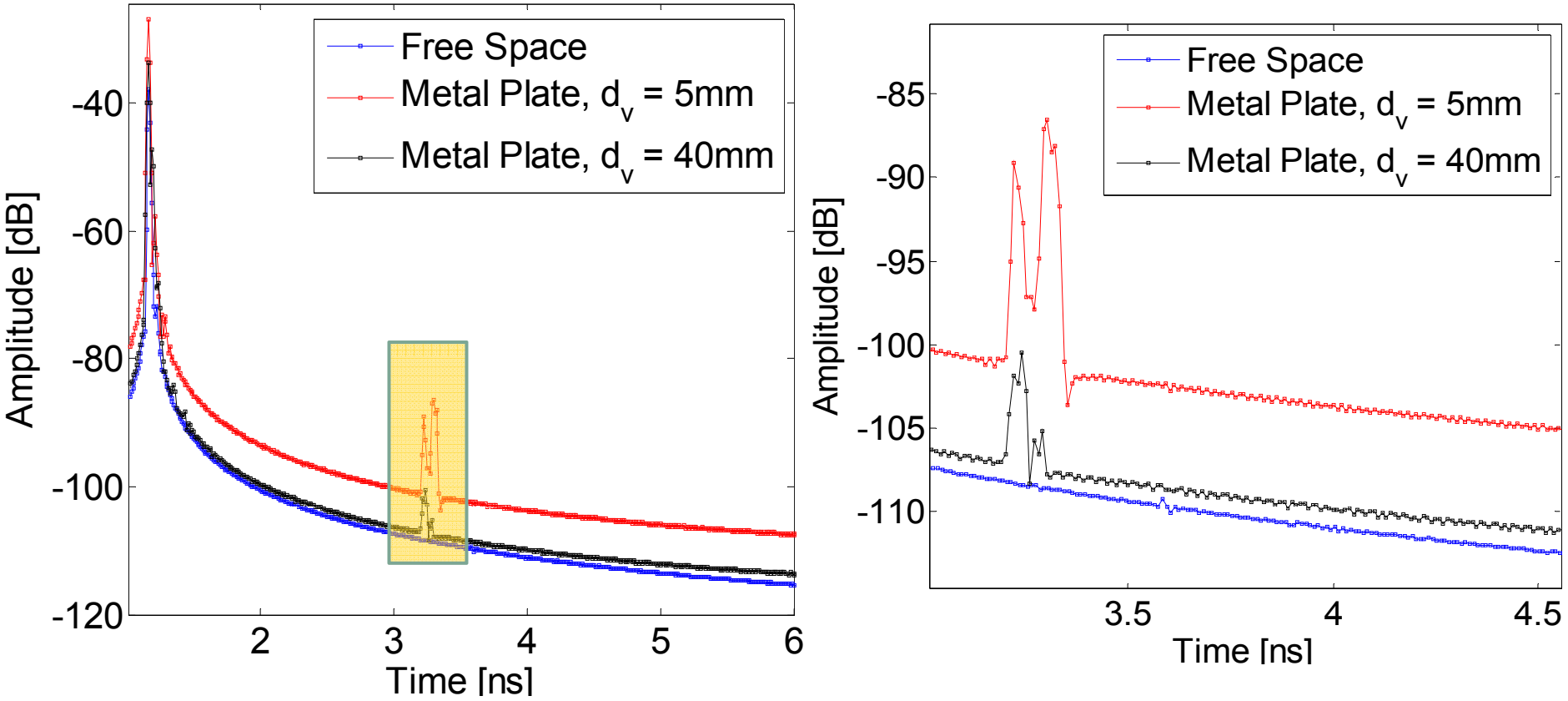


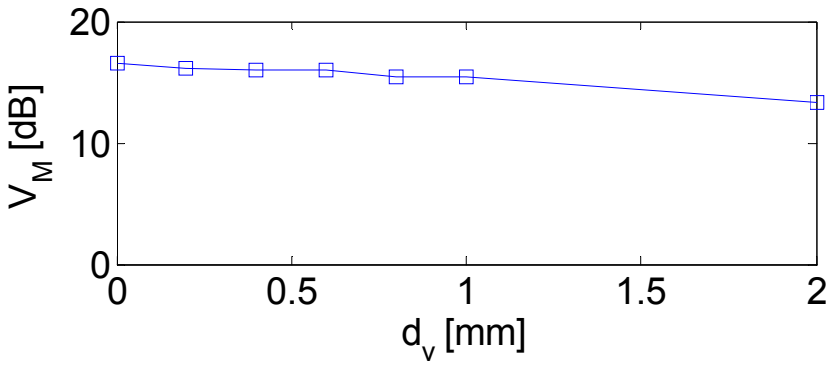
Broadband Path Loss as a Function of the Vertical Distance d_v

- Broadband Path Loss:

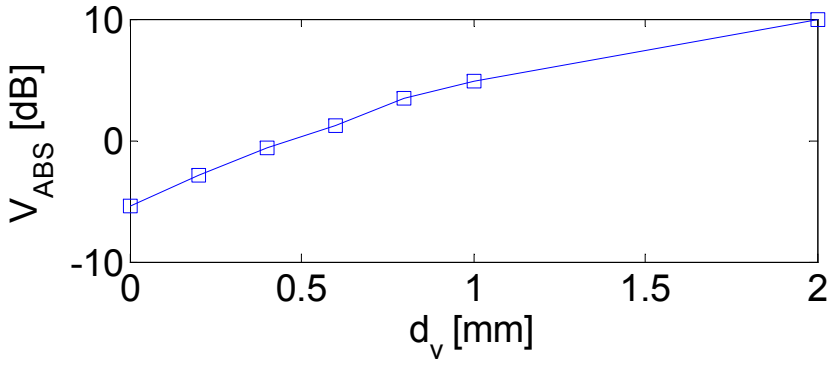
$$L_{BB} = 20 \cdot \log\left(\frac{\int_0^\infty Y_{\mathrm{Re}\,ceived}\,dt}{\int_0^\infty Y_{Transmitted}\,dt}\right)$$

- For a metal surface always lower path loss compared to free space loss due to wave guiding effects

- For a plastic surface
  - higher path loss for small values of d_v
  - lower path loss for larger values of d_v



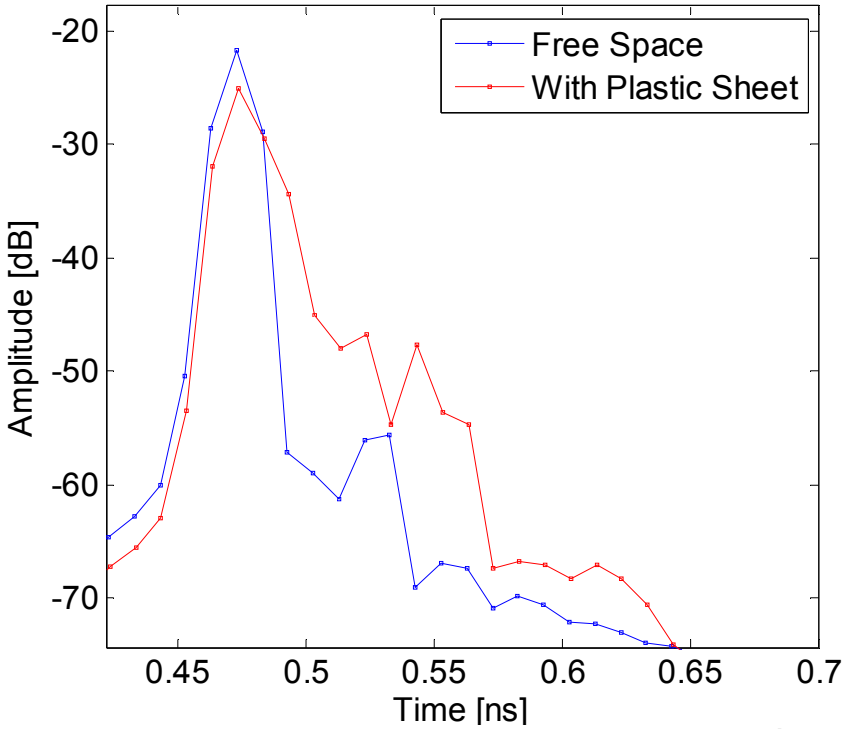
Metal Surface



Plastic (ABS)Surface

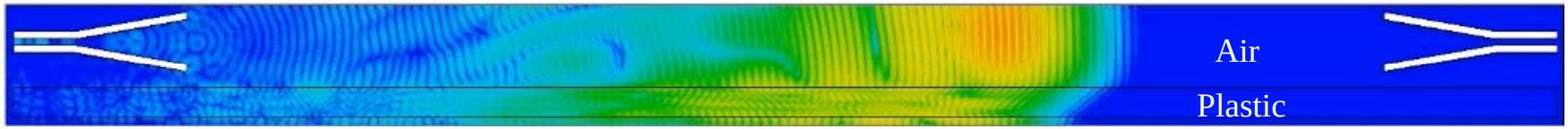
Observed Effects – Propagation along a Plastic Surface

- Thickness of plastic surface 2mm
- Similar behaviour as a dielectric slab wave guide
- A significant part of the energy couples into the lossy medium before coupling into the receiving antenna
- Lower propagation speed in the plastic layer yields larger pulse broadening

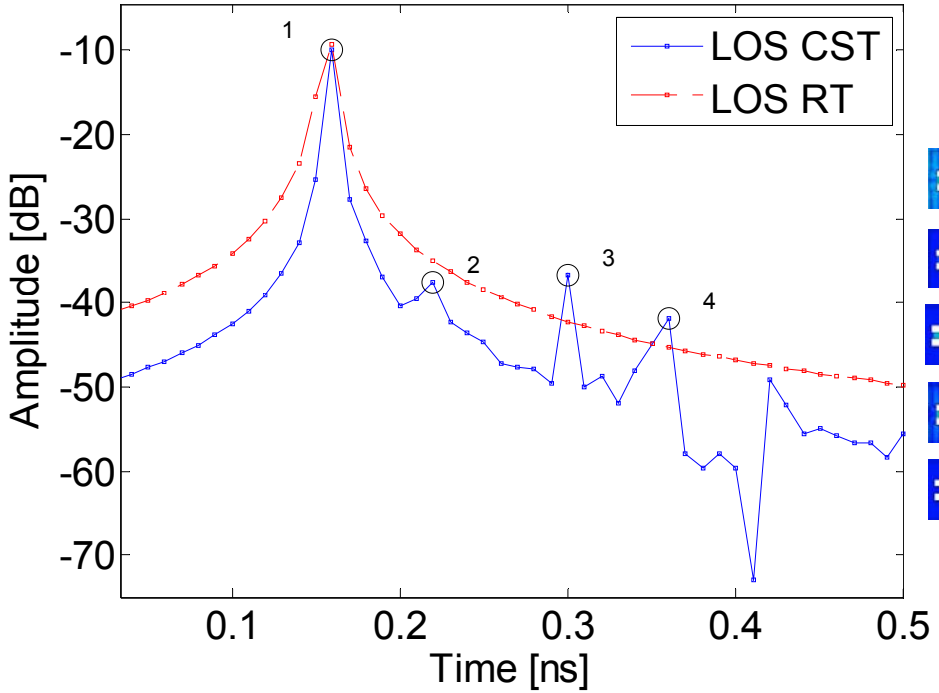


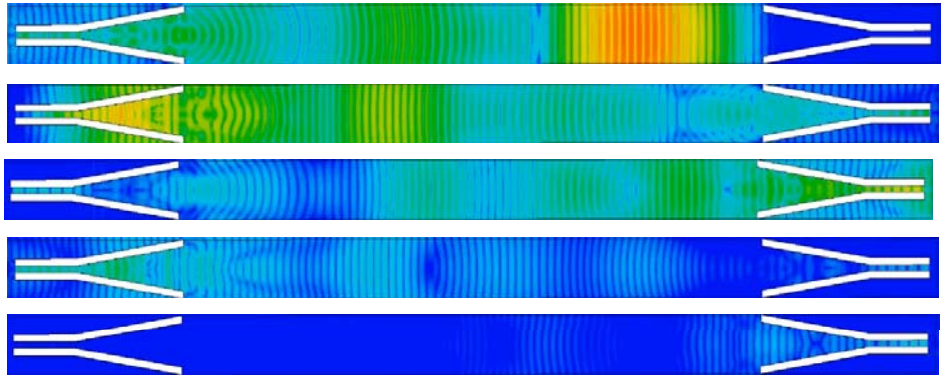
Tx Antenna

Rx Antenna



Comparison with Ray Tracing (No surface, d_h = 40 mm)

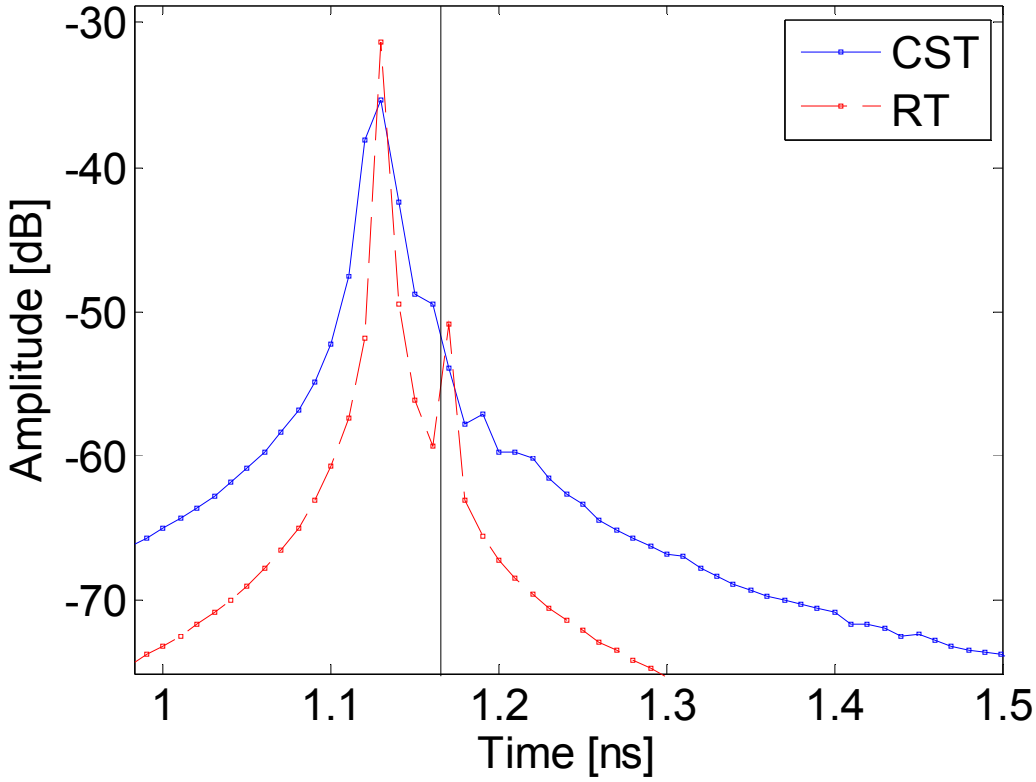




– In addition to the effect of antenna ringing also bouncing of the signal between the two antennas can be observed

Comparison with Ray Tracing (Metal surface, d_v = 40 mm)

- Second peak from reflection at metal surface clearly visible with ray tracing
- First peak with full wave simulation is much broader compared to ray tracing -> overlap with the second peak.



Conclusions

- Some of the core peculiarities of intra-device propagation modeling are introduced by means of a conceptual study using CST® Microwave Studio®.
- Analysis of the effects arising from wave propagation at close distances and along surfaces of different materials
- Analysis of broadband antenna behavior
- A key result of the paper is an initial discussion of the limits of ray tracing for intra-device communications at THz frequencies based on first simulated scenarios.
- The studies performed in this paper can be used to serve as a basis for the development of an advanced ray tracing method incorporating elements from full-wave analysis applicable to future intra-device channel modeling.

References

[1] A. Fricke, Th. Kürner, C. Homann, Time-Domain Propagation Investigations for Terahertz Intra-Device Communications, Proc. Of the 8th European Conferecne on Antennas and Propagation, EUCAP 2014, The Hague/The Netherlands, April 7-11 2014