

March 2014 doc.: IEEE 802.15-14-0156-01-003d_Propagation_Characteristics_Intra_Device

**Project: IEEE P802.15 Working Group for Wireless Personal Area Networks
(WPANs)**

Submission Title: Propagation Characteristics for Intra-Device Communications

Date Submitted: 19 March 2014

Source: Thomas Kürner Company TU Braunschweig

Address Schleinitzstr. 22, D-38092 Braunschweig, Germany

Voice:+495313912416, FAX: +495313915192, E-Mail: t.kuerner@tu-bs.de

Re: n/a

Abstract: This contribution presents first results on measuring basic propagation characteristics for short-range intra-device communication at 60 GHz and 300 GHz

Purpose: Information of IEEE 802.15 SG 100G

Notice: This document has been prepared to assist the IEEE P802.15. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.

Release: The contributor acknowledges and accepts that this contribution becomes the property of IEEE and may be made publicly available by P802.15.

Propagation Characteristics for Intra- Device Communications at 60 GHz and 300 GHz

Thomas Kürner, Sebastian Rey, Alexander Fricke
TU Braunschweig

Scope

- Capacity to transfer data between circuits or chips suffers from limitation of using cables
- RF/Wireless connections are proposed, e. g. in [1]
- Demand for high throughput of several Gbit/s
- Carrier frequencies in the millimeter or sub millimeter domain are suitable to provide enough bandwidth
- Multipath propagation within devices may become relevant
- Measurement and modeling of basic propagation characteristics in intra- and inter-device communication is required.
- This contribution presents first results based on [2] and [3].

Reflection and Measurement Properties of Plastic Materials

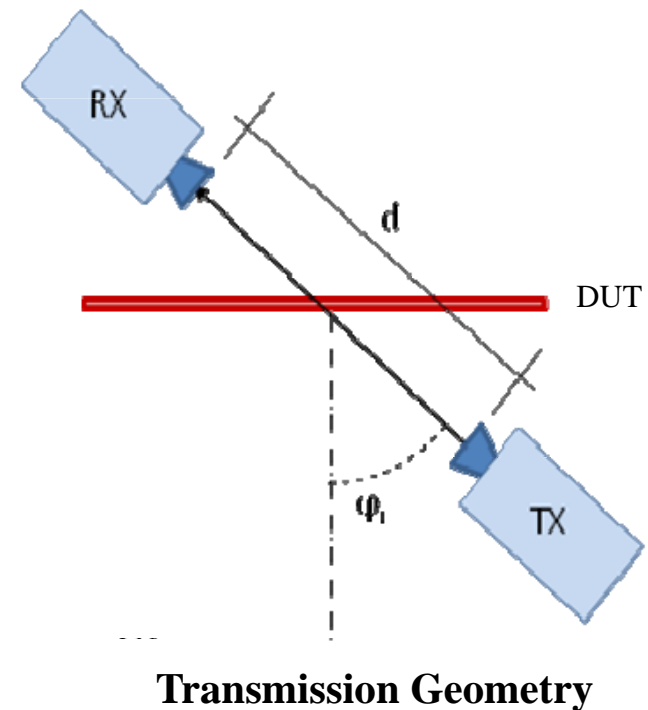
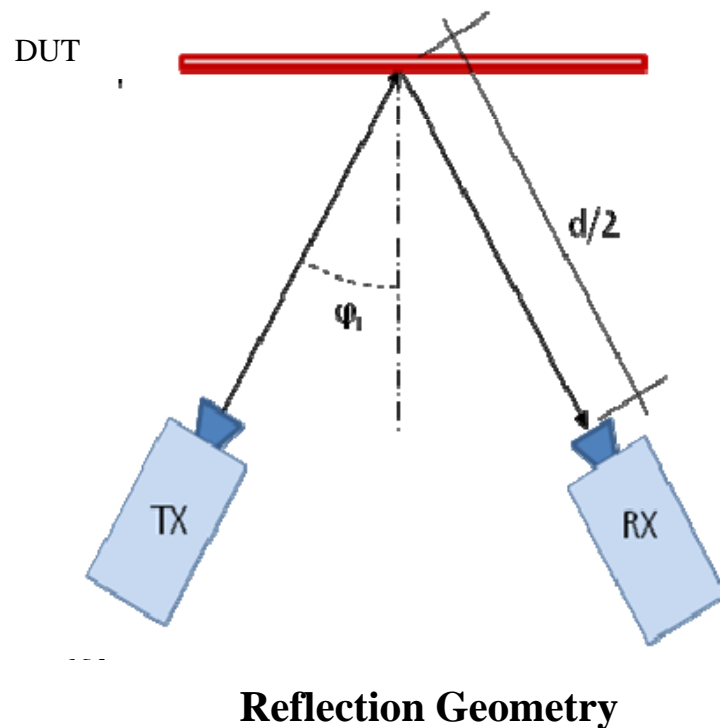
based on [2]

Measurement Set-up (1/2)

- Rohde& Schwarz ZVA50 Vector Network Analyzer with frequency converters used for both 60 GHz and 300 GHz
- 60 GHz measurements:
 - ZVA-Z75 millimetre-wave converters (50-75 GHz)
 - Concial horn antennas with 20Bi gain plus PE lenses with 16 dBi gain at both ends of the link
- 300 GHz measurements
 - ZVA-Z325 millimeter-wave converters (270 to 320 GHz)
 - Pyramidal horn antennas with 20Bi gain at both ends of the link

Measurement Set-up (2/2)

- Mechanical set-up for reflection and transmission geometry consists of two arm goniometers capable of rotating the antennas around the DUT.



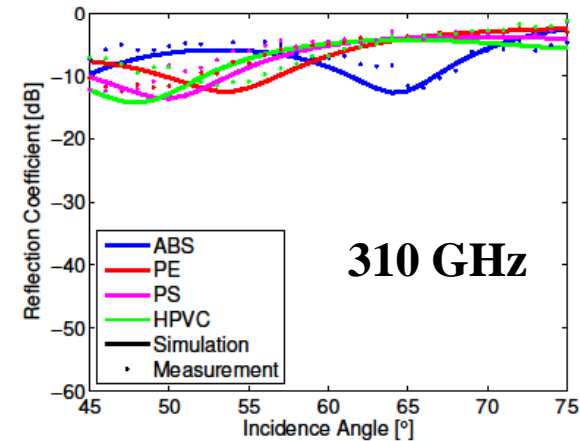
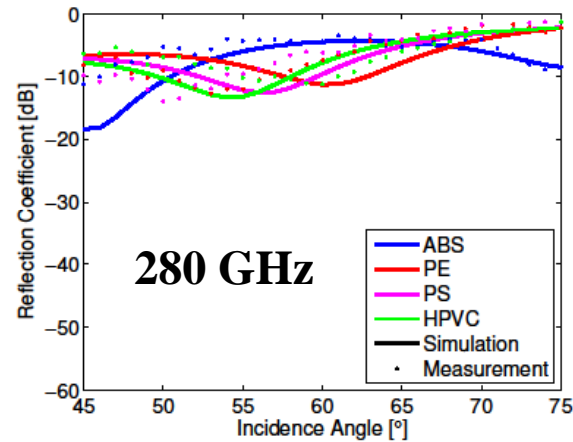
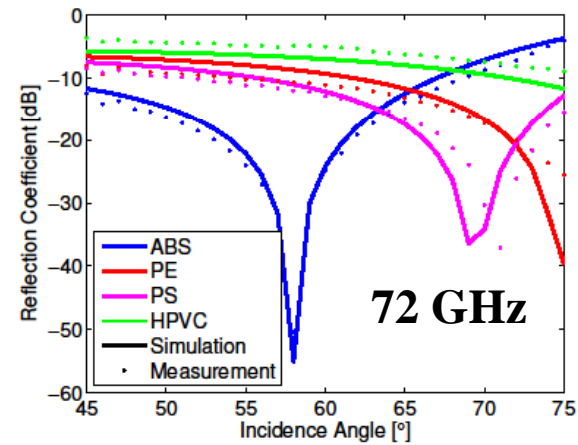
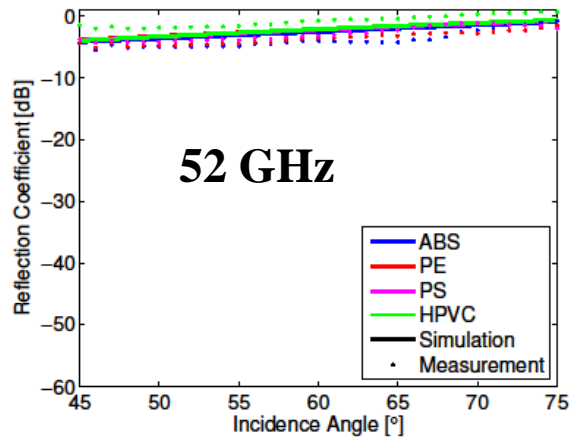
Parameter Extraction Methodology

- Using Transfer Matrix Method (TMM) as described in [4]
- Determination of material parameters in two steps:
 1. Determining reflection coefficients for incidence angles between 45° and 75°
 2. Running simulations using TMM with variation of phase and amplitude . Parameter set with lowest RMS error compared to measurements is selected
- Due to low two layer thicknesses (yielding low attenuation) only real part of the refractive index is determined at 60 GHz

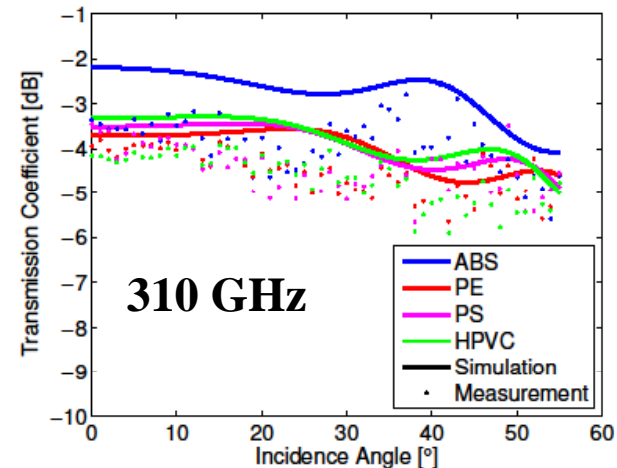
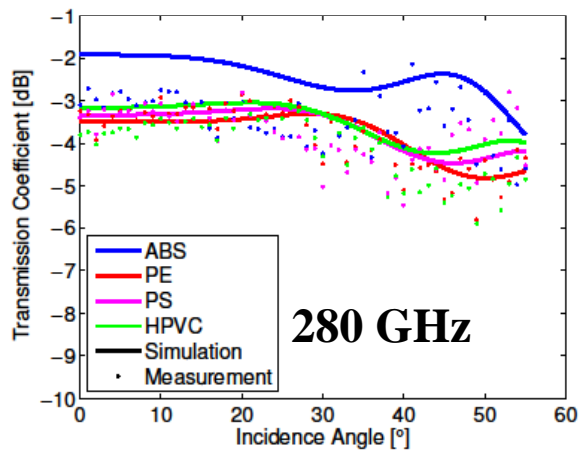
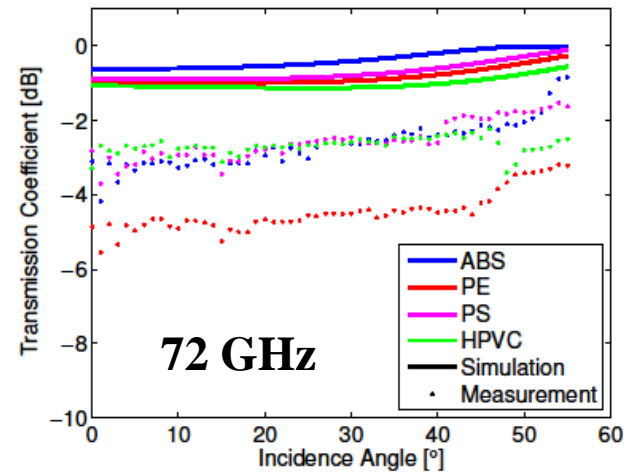
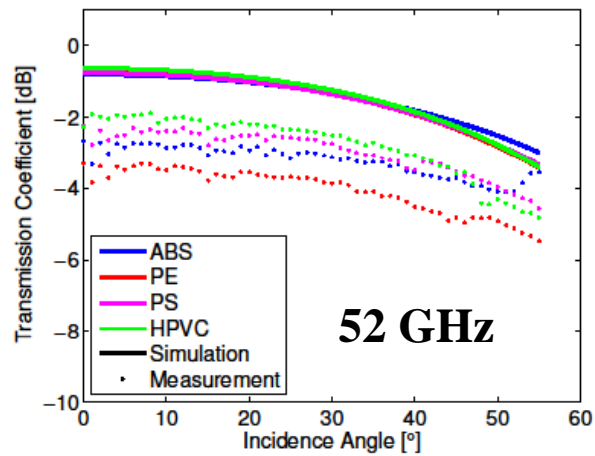
Parameters of investigated Material Samples

| Material | Parameters | |
|---------------------------------------|--------------|-----------------|
| | n' 60 GHz | n' 300 GHz |
| Acrylonitrile Butadiene Styrene (ABS) | 1.627 | 1.474 - 0.0122i |
| Polyvinyl Chloride unplast. (PVC-U) | 1.691 | 1.558 - 0.0192i |
| Polyethylene (PE) | 1.691 | 1.537 - 0.0190i |
| Polystyrene (PS) | 1.675 | 1.526 - 0.0184i |

Measured and Simulated Reflection Coefficients



Measured and Simulated Transmission Coefficients

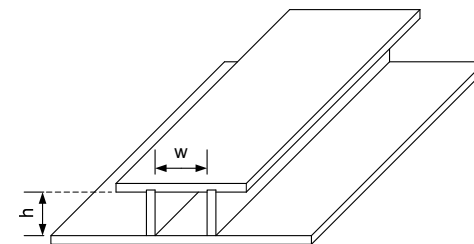
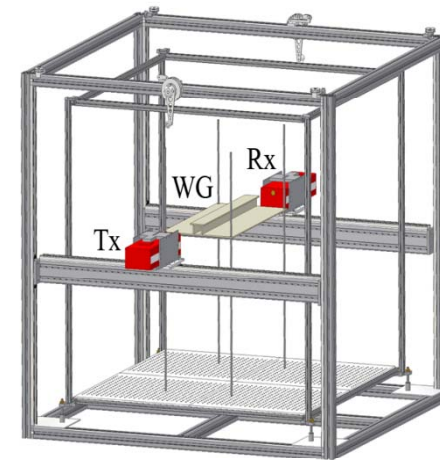


Propagation Characteristics of Waveguide-like ABS structures

based on [3]

Measurement Set-up

- Channel Transfer Function is measured as S_{12} with a Rohde & Schwarz Vector Network Analyser (ZVA 50) in combination with frequency extensions (ZVA-Z75/-Z325).
- Waveguide is mounted inside a box.
- Modular design offers possibility to alter widths and heights of the waveguide.
- Attenuators to suppress unwanted reflections (not shown).
- Distance between frequency extensions approx. 1m.
- Far field approximations are suitable.
- Polarization: E-field parallel to bottom panel.

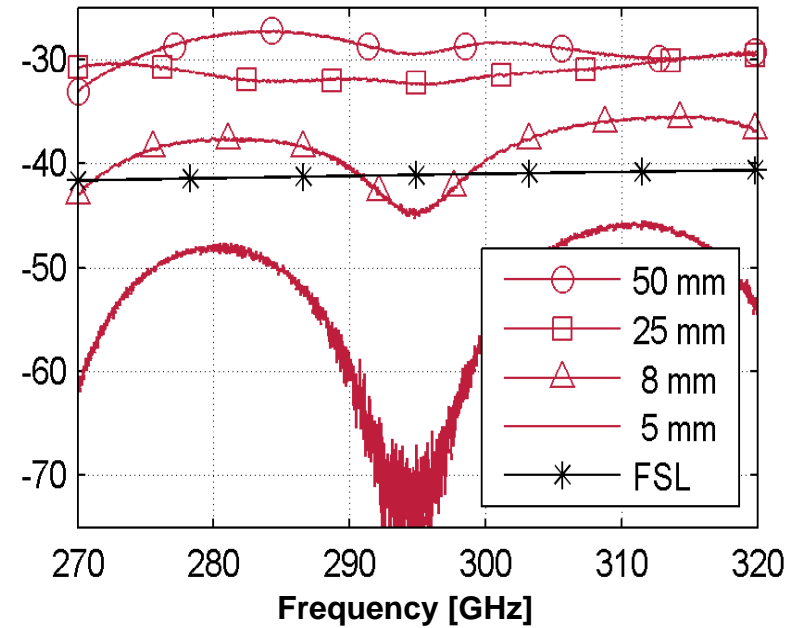
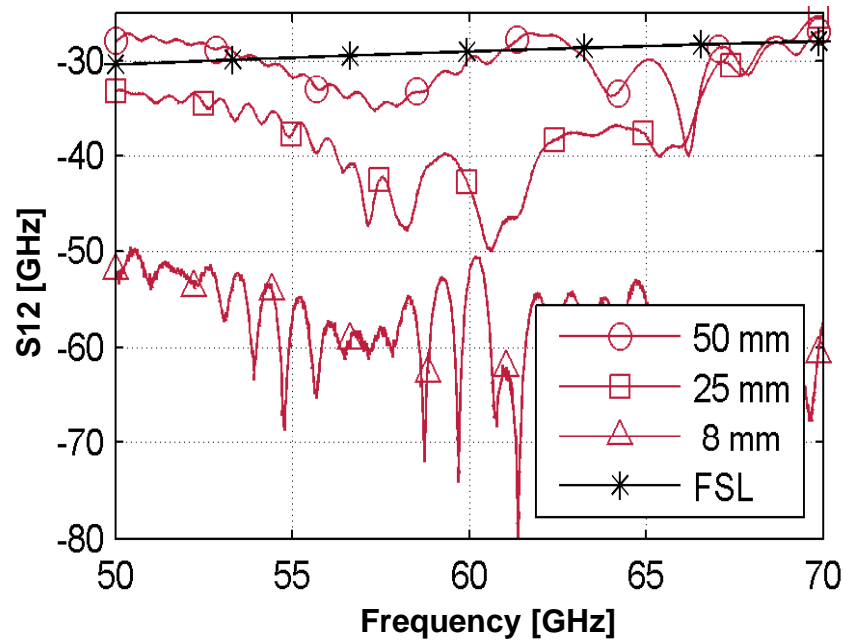


Measurement Set-up (2/2)

- Standard horn antennae (Flann microwave ltd.) are used
- Mean values of antenna characteristics (averaged over the frequency range):

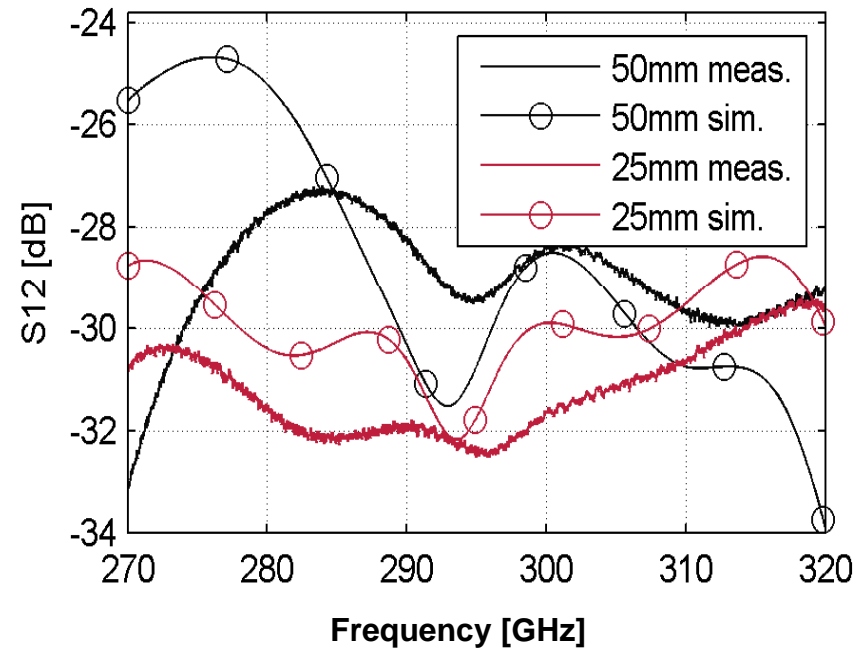
| Frequency range | Gain | HPBW _{azimuth} | HPBW _{elevation} |
|-----------------|----------|-------------------------|---------------------------|
| 50 – 70 GHz | 19.5 dBi | 20.0° | 18.6° |
| 270 – 320 GHz | 20.4 dBi | 17.3° | 16.1° |

Measured S12 for different widths and a height of 18mm



Channel Modeling

- Modeling of the propagation as free space loss with antenna gains is insufficient.
- Ray tracing propagation model is based on transfer matrix method with the following material parameters for ABS at 300 GHz: $\epsilon_r = 2.625 + j0.047$; $\tan \delta = 0.018$.
- Propagation paths with up to 5 reflections are considered.



Conclusion

- Transmission is a non-negligible effect, when it comes to plastic materials
- Reflection from plastic materials is heavily influenced by the multi-layer structure of a material
- Transfer Matrix Method is well-suited to account for both transmission and reflection in propagation simulation via ray-tracing
- Increasing attenuations through waveguide-like structures with increasing operating frequency and decreasing aperture of the waveguide.
- Ray tracing based model provides reasonable results for waveguides with a cut off frequency 50 times lower than the operational frequency.

References

- [1] M. C. Frank Chang et. al., “RF/Wireless Interconnect for Inter- and Intra-Chip Communications” Proc. of the IEEE, VOL. 89, NO. 4, APRIL 2001.
- [2] Fricke, A.; Rey, S.; Achir, M.; Le Bars, P.; Kleine- Ostmann, T.; Kürner, T.: Reflection and Transmission Properties of Plastic Materials at THz Frequencies. In Proc. 38th International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW-THz), electronic paper (2 pages), Mainz, September 2013.
- [3] Rey, S.; Fricke, A.; Achir, M.; Le Bars, P.; Kleine-Ostmann, T.; Kürner, T.: On Propagation Characteristics of Waveguide-like ABS Structures in 60 and 300 GHz Communications. In Proc. 38th International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW-THz), electronic paper (2 pages), Mainz, September 2013.
- [4] C. Jansen et. al., “The Impact of Reflections from Stratified Building Materials on the Wave Propagation in Future Indoor Terahertz Communication Systems,” IEEE Trans. on Ant. and Prop., vol. 56, no. 5, pp. 1413–1419