Submission Title: Measurements of the Channel Characteristics at 300 GHz
Date Submitted: 17 November 2009
Source: Thomas Kürner, Technische Universität Braunschweig
Address Schleinitzstr. 22, D-38092 Braunschweig, Germany
Voice: +495313912416, FAX: +495313915192, E-Mail: t.kuerner@tu-bs.de
Re: [doc.: IEEE 802.15- 15-09-0496-00-0thzr1-channel-measurements]

Abstract: In [doc.: IEEE 802.15- 15-09-0496-00-0thzr1-channel-measurements] preliminary results on channel measurements at 300 GHz have been presented. This contribution provides additional results by presenting measurements involving reflection, scattering and diffraction in a realistic indoor scenario. Furthermore the effect of antenna misalignment is investigated. The results can be used to derive a 300 GHz channel model.

Purpose: Input to THz Channel Modeling at IEEE 802.15 IG Thz

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.
Measurements of the Channel Characteristics at 300 GHz

Thomas Kürner¹, Sebastian Priebe¹, Martin Jacob¹
Christian Jastrow², Thomas Kleine-Ostmann ², Thorsten Schrader ²

¹ Institut für Nachrichtentechnik, Technische Universität Braunschweig, Germany
² Physikalisch-Technische Bundesanstalt, Braunschweig, Germany
Content

• Measurement System
• Influence of Antenna Misalignment
• Characterising Propagation Phenomena
  – Reflection
  – Scattering
  – Diffraction
• Measurements in a complete Indoor Scenario
• Conclusions
300 GHz Transmission System


see also: doc.: IEEE 802.15-15-08-0336-01-0thz-thz-communications.pdf
300 GHz Radio Channel Measurement System - 1

- R & S ZVA40 Vector Network Analyzer
- External 300 GHz transmitter (Tx) and receiver (Rx) front ends
- Core component: subharmonic schottky diode mixer
- Same external local oscillator (DRO) (16.66 GHz x3 x3) for Tx and Rx for phase synchrony
- Three different types of antennas used
- Frequency range: 290 – 310 GHz
- Frequency Domain $\rightarrow$ Time Domain

see also: doc.: IEEE 802.15-15-09-0496-01-0thz-measuring-the-channel-characteristics-at-300GHz-preliminary-results.pdf
300 GHz Radio Channel Measurement System - 2

see also: doc.: IEEE 802.15-15-09-0496-01-0thz-measuring-the-channel-characteristics-at-300GHz-preliminary-results.pdf
# Antennas

<table>
<thead>
<tr>
<th></th>
<th>Horn Antenna</th>
<th>Wave Guide</th>
<th>Horn Antenna with Polyethylen Lens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain</td>
<td>26 dBi</td>
<td>10 dBi</td>
<td>40 dBi</td>
</tr>
<tr>
<td>3 dB- width</td>
<td>11°</td>
<td>100°</td>
<td>1°</td>
</tr>
</tbody>
</table>

![Antenna Images](image_url)
Antenna Diagram:
Horn Antenna with Polyethylen Lens
Influence of Antenna Misalignment

- Measurements for Horn Antenna at Tx and different Antennas at Rx
Example: Horn Antennas used at Tx and Rx Analysis in Frequency Domain
Example: Horn Antennas used at Tx and Rx
Analysis in Time Domain
### Summary on Antenna Misalignment

<table>
<thead>
<tr>
<th>Displacement</th>
<th>Antenna at Rx</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Horn Antenna</td>
</tr>
<tr>
<td>d = 40 cm, h = 0 cm</td>
<td>-23,3 dB</td>
</tr>
<tr>
<td>d = 40 cm, h = 2 cm</td>
<td>-27,4 dB</td>
</tr>
<tr>
<td>d = 40 cm, h = 4 cm</td>
<td>-29,3 dB</td>
</tr>
</tbody>
</table>
Reflection Measurements

• Measurement Set-up
  – Reference measurement using a copper plate
  – Reflection Loss

\[
RL_{dB} = S_{21,MUT\ dB} - S_{21,\text{Copper}\ dB}
\]
Reflection Loss: Wood

\[ f = 300 \text{ GHz} \pm 5\text{GHz} \]

TM-Polarisation
Reflection Loss: Plaster

\[ f = 300 \text{ GHz} \pm 5\text{GHz} \]

TM-Polarisation
Scattering Loss: Wood

\[ f = 300 \text{ GHz} \pm 5\text{GHz} \]

TM-Polarisation; incidence angle \( \varphi_i = 40^\circ \)
Scattering Loss: Plaster

\[ f = 300 \text{ GHz} \pm 5\text{GHz} \]

TM-Polarisation; incidence angle \( \phi_i = 40^\circ \)
Measurement of Diffraction Loss

- Measurement Set-up

![Diagram showing measurement setup with labels Rx, Tx, and Diffraction Edge (Copper Plate) with angle symbol φ.]
Comparison of Measured Diffraction Loss with Simulations based on a Knife Edge
Measuring a complete Indoor Scenario

Measurement Set-up in a small room

Identified Rays within the room
Measurement of Multipath Signals

<table>
<thead>
<tr>
<th>Path</th>
<th>Path Length</th>
<th>Number of Reflections</th>
<th>Measured Path Loss</th>
<th>FSL</th>
<th>Other Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>1.67 m</td>
<td>0</td>
<td>90.3 dB</td>
<td>86.4 dB</td>
<td>3.9 dB</td>
</tr>
<tr>
<td>(b)</td>
<td>2.93 m</td>
<td>2</td>
<td>129.3 dB</td>
<td>91.3 dB</td>
<td>38 dB</td>
</tr>
<tr>
<td>(c)</td>
<td>2.12 m</td>
<td>1</td>
<td>109.2 dB</td>
<td>88.5 dB</td>
<td>20.7 dB</td>
</tr>
<tr>
<td>(d)</td>
<td>4.77 m</td>
<td>2</td>
<td>125.3 dB</td>
<td>95.6 dB</td>
<td>29.7 dB</td>
</tr>
<tr>
<td>(e)</td>
<td>2.78 m</td>
<td>1</td>
<td>119.6 dB</td>
<td>90.7 dB</td>
<td>28.9 dB</td>
</tr>
<tr>
<td>(f)</td>
<td>3.45 m</td>
<td>2</td>
<td>145.1 dB</td>
<td>92.4 dB</td>
<td>52.7 dB</td>
</tr>
<tr>
<td>(g)</td>
<td>2.8 m</td>
<td>1</td>
<td>120.9 dB</td>
<td>90.9 dB</td>
<td>30 dB</td>
</tr>
<tr>
<td>(h)</td>
<td>3.51 m</td>
<td>2</td>
<td>128.4 dB</td>
<td>92.9 dB</td>
<td>35.5 dB</td>
</tr>
</tbody>
</table>

Identified Rays within the room
Effect of Antenna Misalignment: Direct Ray (Path a) – Frequency Domain
Effect of Antenna Misalignment: Direct Ray (Path a) – Time Domain
Effect of Antenna Misalignment:
Reflected Ray (Path c) – Frequency Domain
Effect of Antenna Misalignment: Effect on Direct Ray (Path c) – Time Domain
Conclusions

• Comprehensive Measurement Campaign at 300 GHz
• Quantitative investigation of reflection and scattering processes from walls and diffraction effects
• Verification of ray-tracing approach in a small indoor room
• Effect of antenna misalignment has been investigated as well
Outlook

• Together with the results presented in [doc.: IEEE 802.15-15-09-0496-00-0thzr1-channel-measurements] this document is a good starting point to derive indoor channel models for THz communications.

• Potential to use ray-tracing to derive statistical channel models (comparable to channel modeling activities taking place in IEEE 802.11 TGad).