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

Submission Title: Indoor-to-Outdoor Path Loss Measurements in an Aircraft at 300 GHz
Date Submitted: 8 June 2020
Source: Tobias Doeker **Company:** TU Braunschweig, Institut für Nachrichtentechnik
Address: Schleinitzstr. 22, D-38092 Braunschweig, Germany
Voice: +49 531 391-2418 FAX: +49 531 391-5192, E-Mail: doeker@ifn.ing.tu-bs.de

Re: n/a
Abstract: This document presents the results of a measurement campaign done at an aircraft window at 300 GHz in order to determine the energy leaving the fuselage through the window.

Purpose: Information of the Technical Advisory Group THz

Technische Universität Braunschweig

Institut für Nachrichtentechnik

Indoor-to-Outdoor Path Loss Measurements in an Aircraft at 300 GHz

Johannes M. Eckhardt, Tobias Doeker, Thomas Kürner

IEEE 802.15 TAG THz Online, 9 June 2020

This presentation is based on:

J. Eckhardt, T. Doeker, T. Kürner, Indoor-to-Outdoor Path Loss Measurements in an Aircraft for Terahertz Communications, Proceedings IEEE Vehicular Technolgy Conference Spring, 2020 (online)

Outline

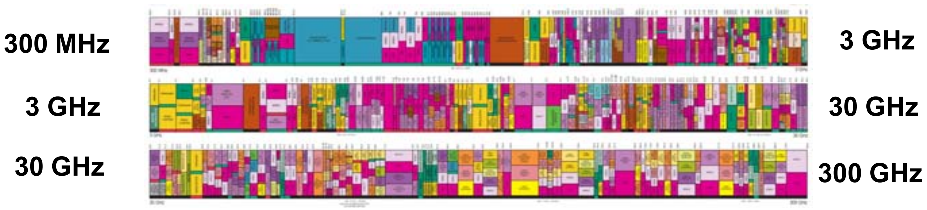
1. **Motivation**
2. **Measurement Setup**
3. **Results**
4. **Conclusion**

Outline

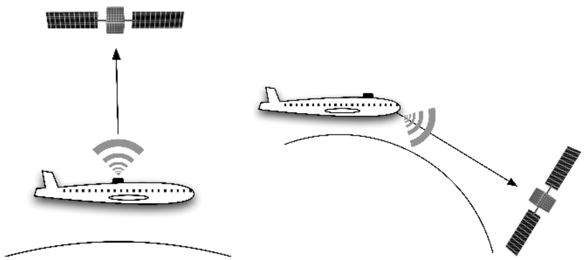
1. **Motivation**
2. Measurement Setup
3. Results
4. Conclusion

Motivation

https://www.lufthansa.com/de/en/flynet



http://discovermagazine.com/2007/jun/tireless-wireless/allochrt_lg.jpg



S. Priebe *et al.*, "Interference Investigations of Active Communications and Passive Earth Exploration Services in the THz Frequency Range," in *IEEE Transactions on Terahertz Science and Technology*, vol. 2, no. 5, pp. 525-537, 2012

- more and more connected devices within aircraft cabin
- increasing demand of high data rates
- needed bandwidth available at high frequencies
- Regulation: protection of passive services
- window = bottleneck in fuselage

Outline

1. Motivation

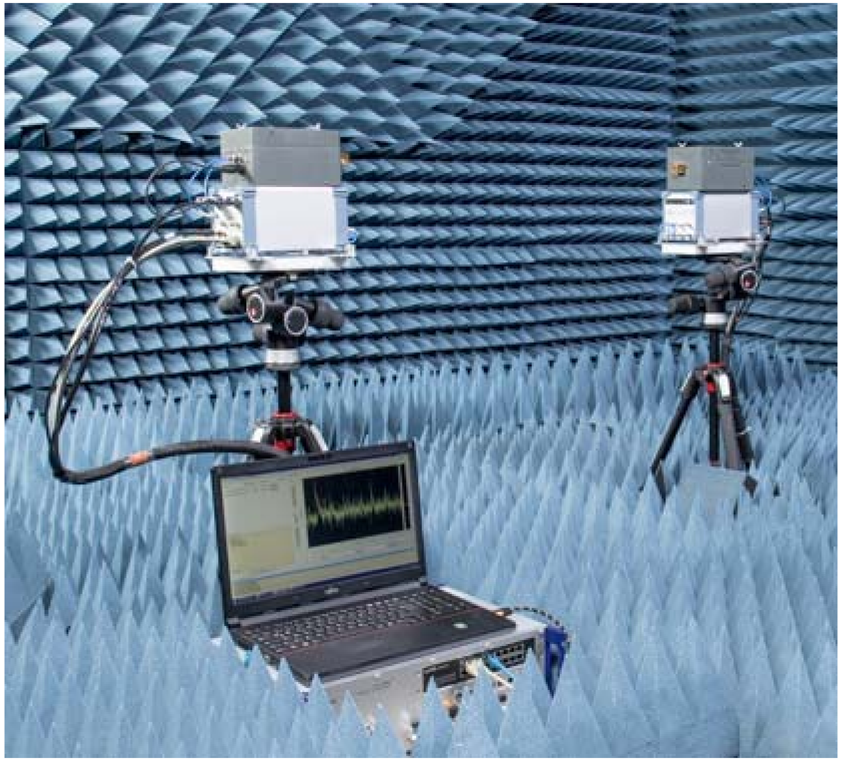
2. **Measurement Setup**

3. Results

4. Conclusion

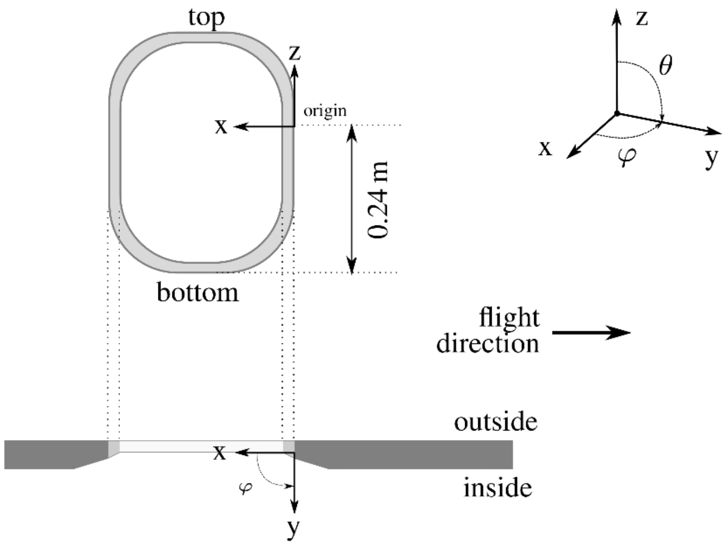
Measurement Equipment

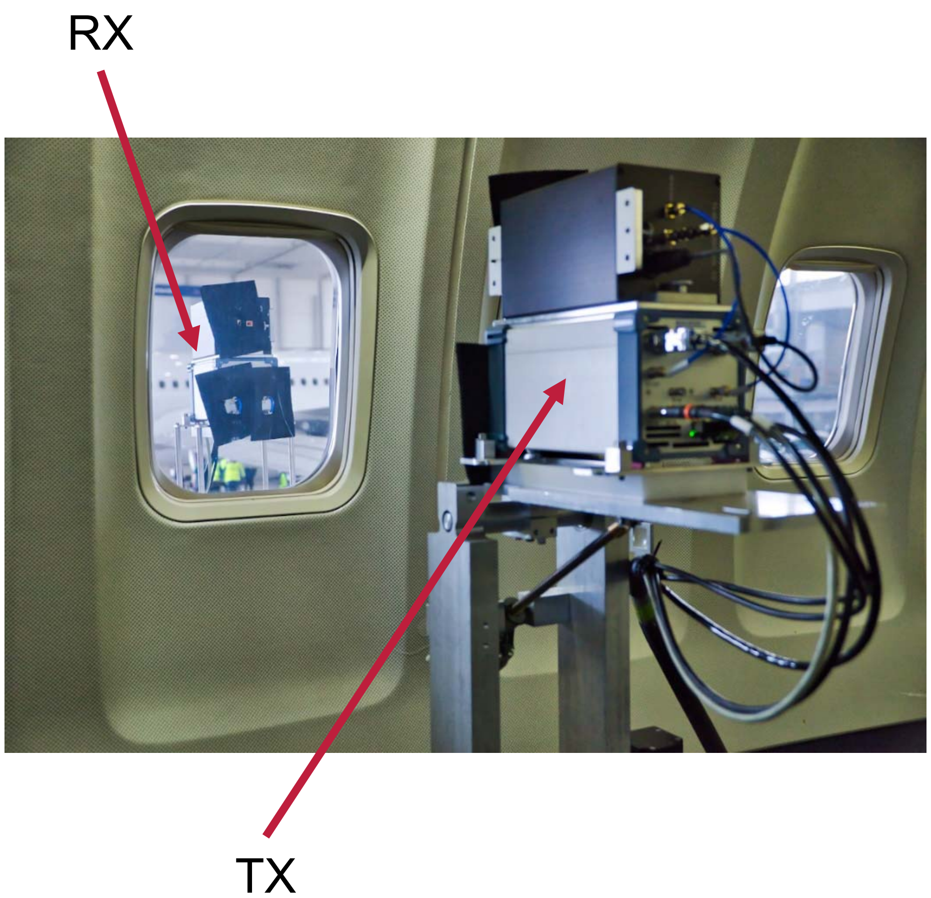
- M-sequence mmWave Channel Sounder
  - Correlation based approach to measure time-variant impulse response
  - PRSG generates M-sequence of 12^{th} order
  - Clock frequency 9.22 GHz
  - Carrier frequency 304.2 GHz
  - Approx. Bandwidth 8 GHz
  - Longest measureable delay 444.14 ns
  - Use of rotational units to measure spatially



For more information see: 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, 2017, pp. 449-453.

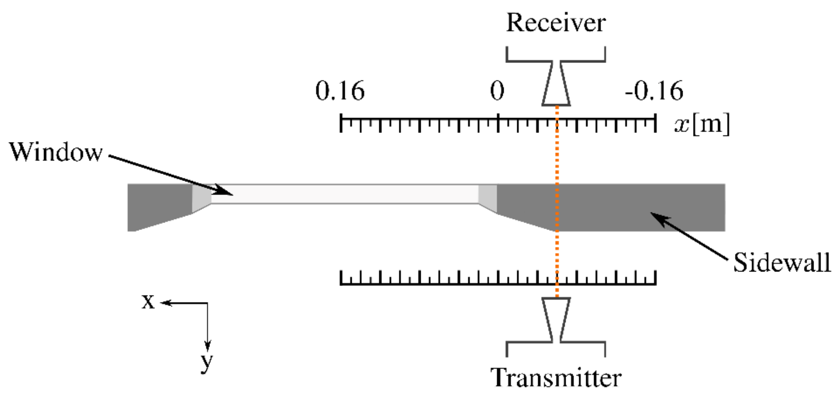
Measurement Setup (1/2)





Measurement Setup (2/2)

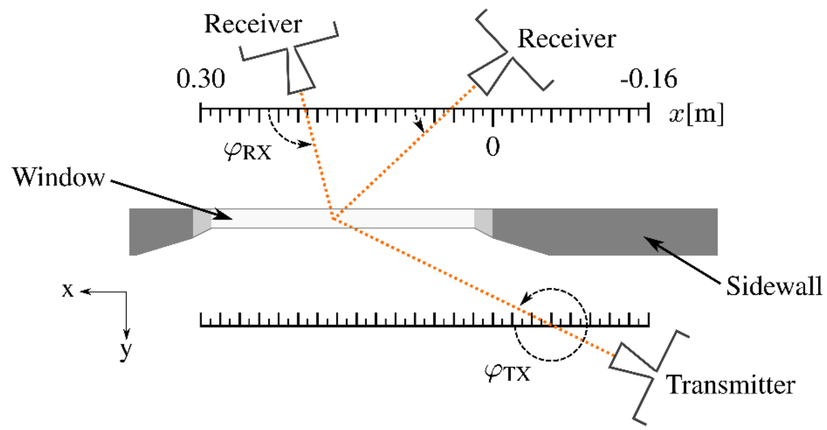
1.) Transmission @ Positions



- various positions along the window
- TX and RX always same position

→ direct path, obstructed line-of-sight

2.) Transmission @ Angles

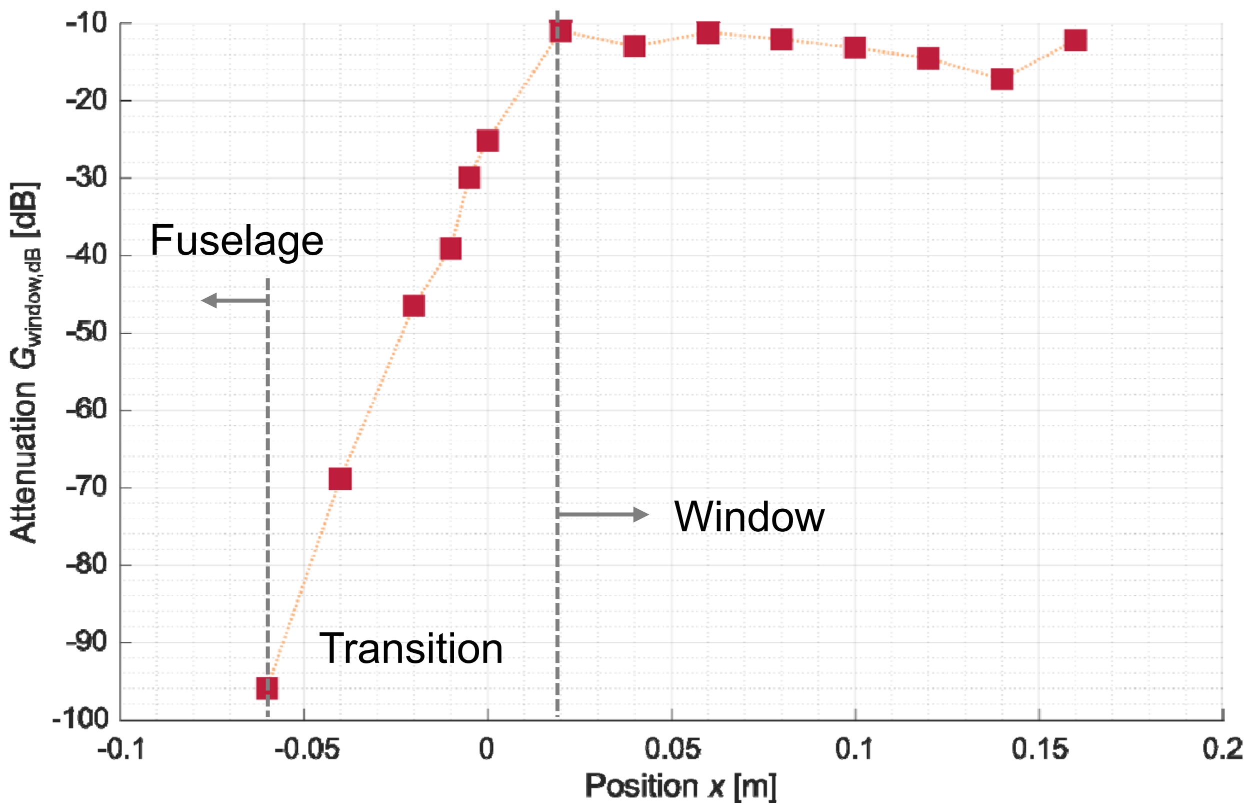


- Angle of Departure (AoD):
  φ_{TX} = 270°, 280°, 293°
- Angle of Arrival (AoA): various angle
- x-position of TX and RX: main radiation direction of antennas focused on middle of window

Outline

1. Motivation
2. Measurement Setup
3. **Results**
4. Conclusion

Transmission @ Positions

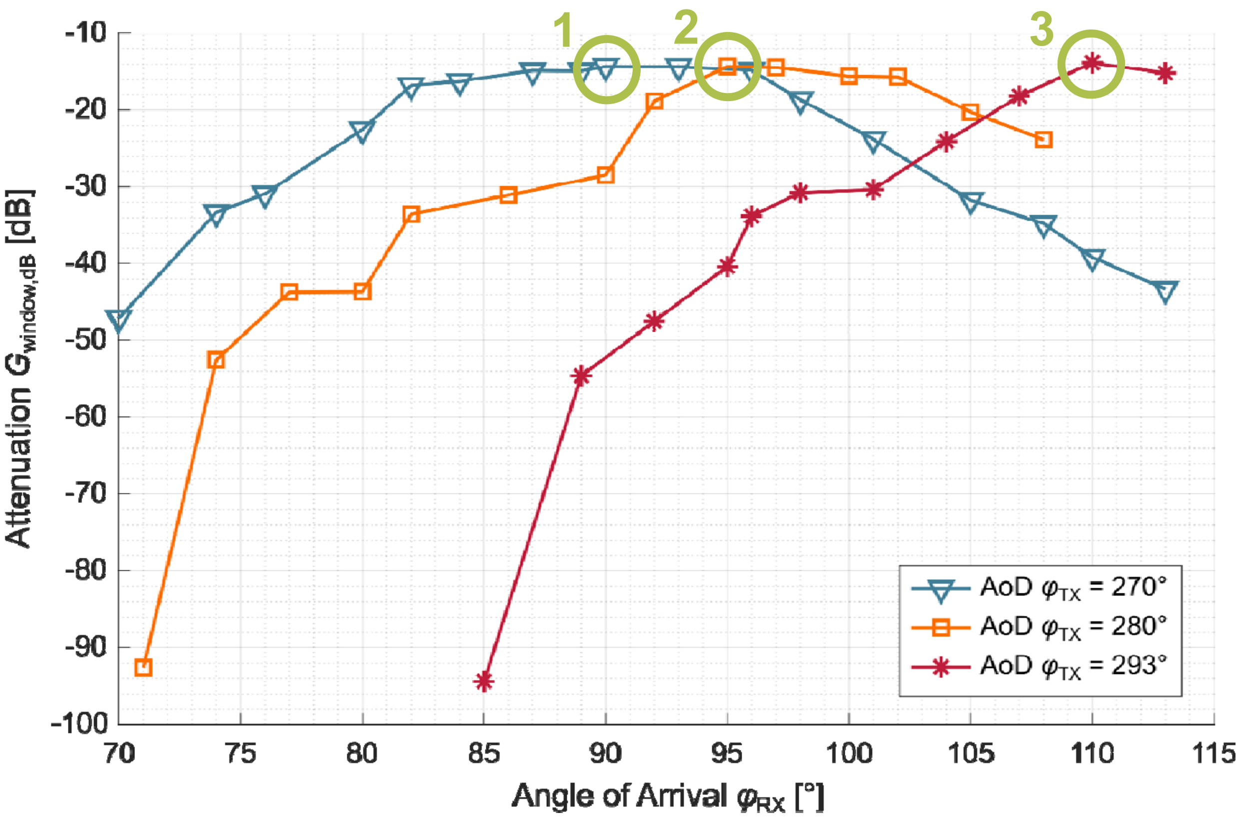


minimal attenuation $G_{window,min,dB}$ ≈ **-11.01 dB**

Technische Universität Braunschweig

Institut für Nachrichtentechnik

Transmission @ Angles



1) $\varphi_{RX} = 90°$
   $G_{window,dB} \approx -14.32$ dB

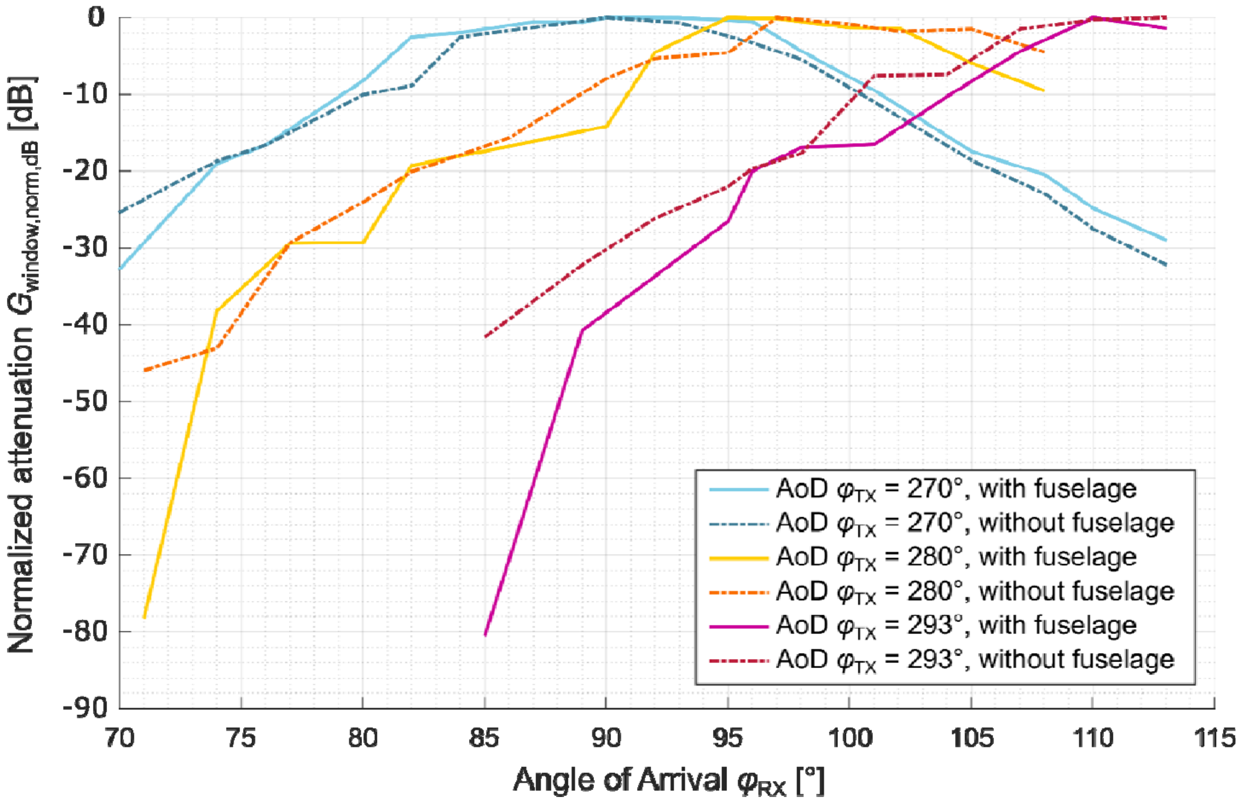
2) $\varphi_{RX} = 95°$
   $G_{window,dB} \approx -14.32$ dB

3) $\varphi_{RX} = 110°$
   $G_{window,dB} \approx -13.84$ dB

→ direct path, obstructed line-of-sight

No significant angle dependency regarding direct path. Curve shape?

Transmission @ Angles



Curve shape caused by antenna pattern!

Outline

1. Motivation
2. Measurement Setup
3. Results
4. **Conclusion**

Technische Universität Braunschweig
Institut für Nachrichtentechnik

Conclusion and Outlook

- Aircraft window transmission measurements at 300 GHz have been presented
- Minimal attenuation is given by **-11.01 dB**
- Attenuation of fuselage is given by at least -95 dB
- Angle dependency was analyzed whereby **no dependency** could be determined

- Next steps:
  - Investigations on the impact of in-cabin THz communication on passive services

Vielen Dank für Ihre Aufmerksamkeit.

Thank you for your attention.

Tobias Doeker, M.Sc.

doeker@ifn.ing.tu-bs.de