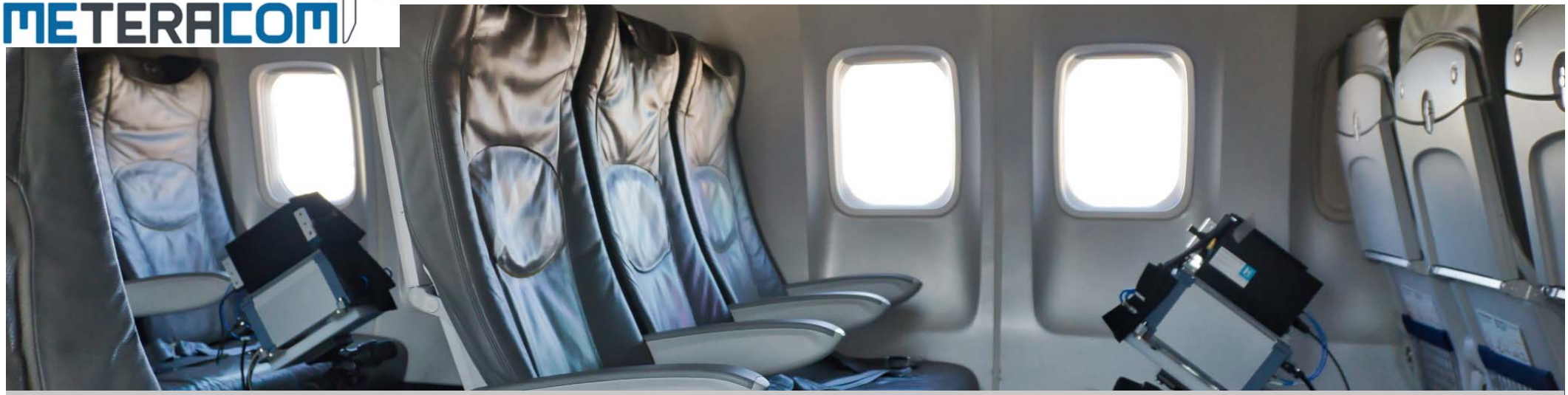
Funded by DFG Deutsche Forschungsgemeinschaft German Research Foundation

FOR 2863 Meteracom
Metrology for THz Communications

METERACOM



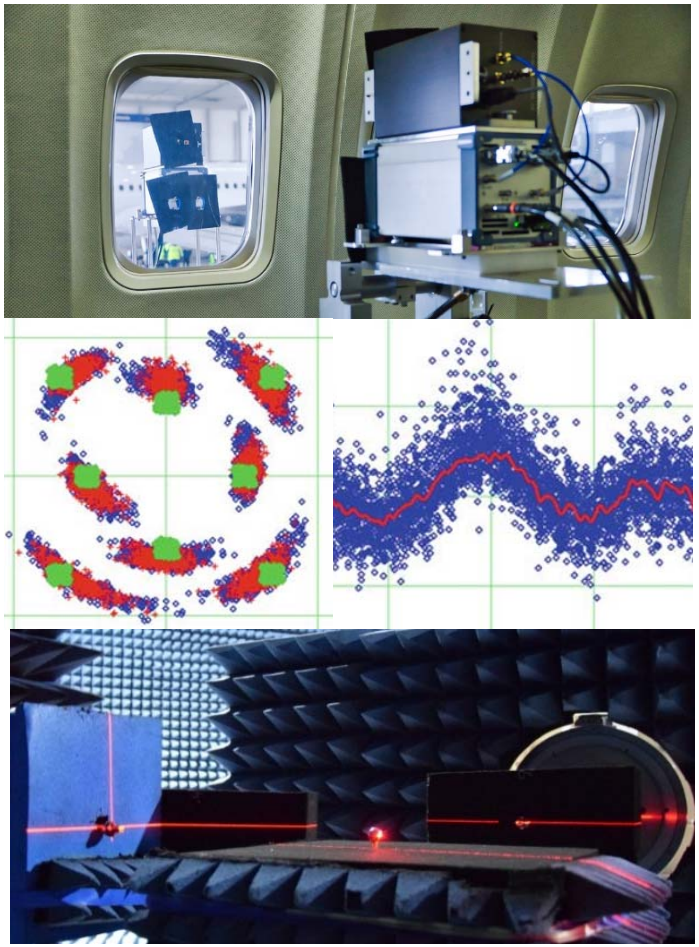
Introduction to FOR 2863 Meteracom (Metrology for THz Communications)

Thomas Kürner, Spokesman Meteracom, Technische Universität Braunschweug

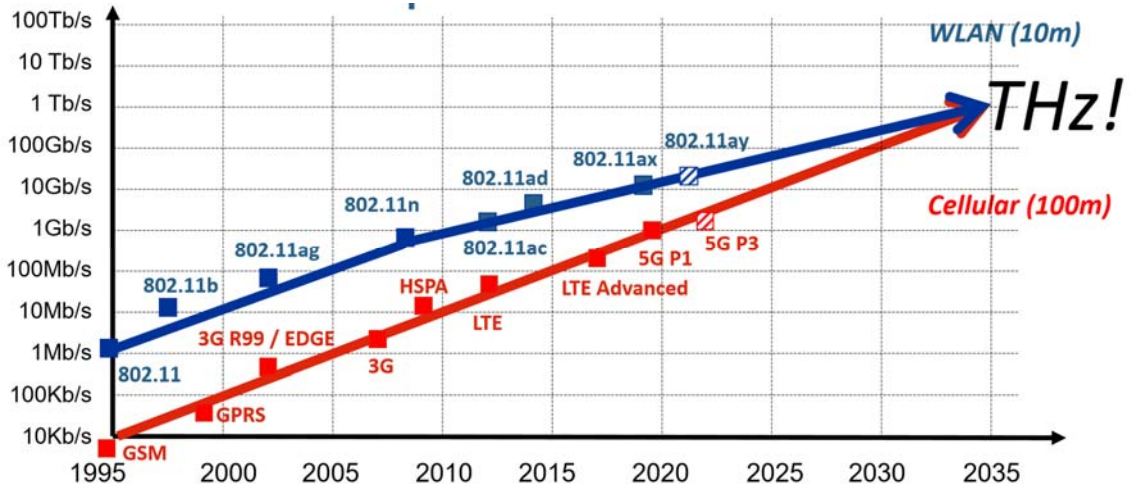
1st International Workshop on Metrology for THz Communications, Braunschweig, 28 June 2022

Agenda

- Motivation for THz Communications
- Challenges for Metrology for THz Communications
- Project Structure
- Outlook to a potential Phase II
- Consortium
- Agenda for the Workshop



Why THz Communications?

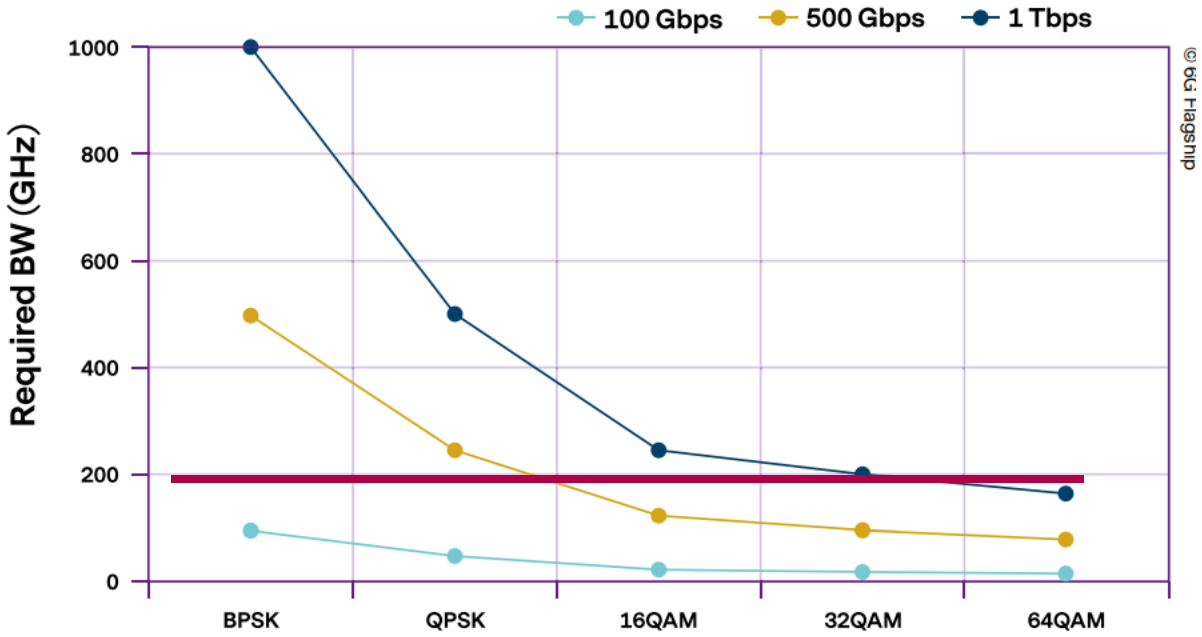


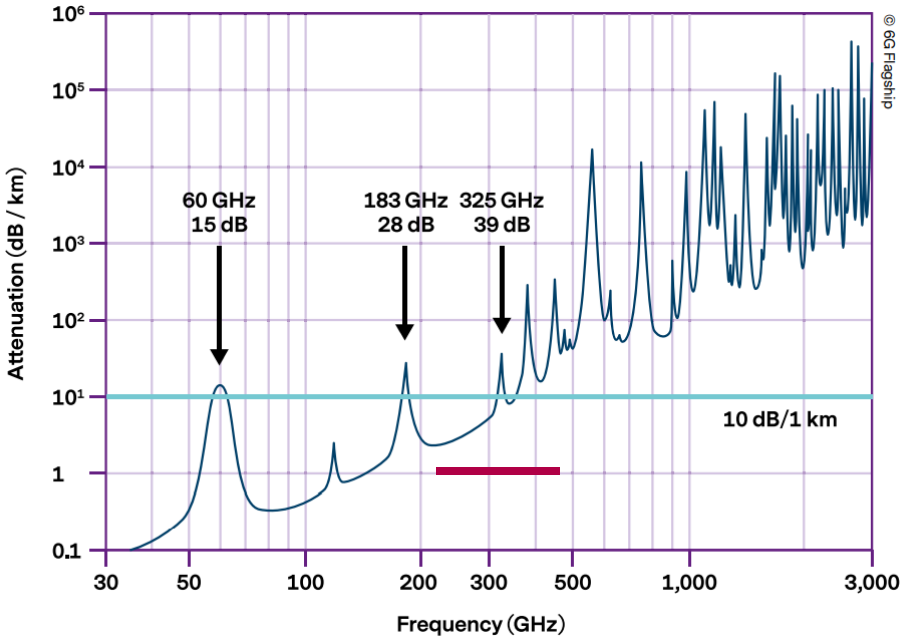
Source: G. Fettweis, 1St TERAFLAG Workshop Cassis 2018

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

> 20 GHz Bandbreite @ 300 GHz +

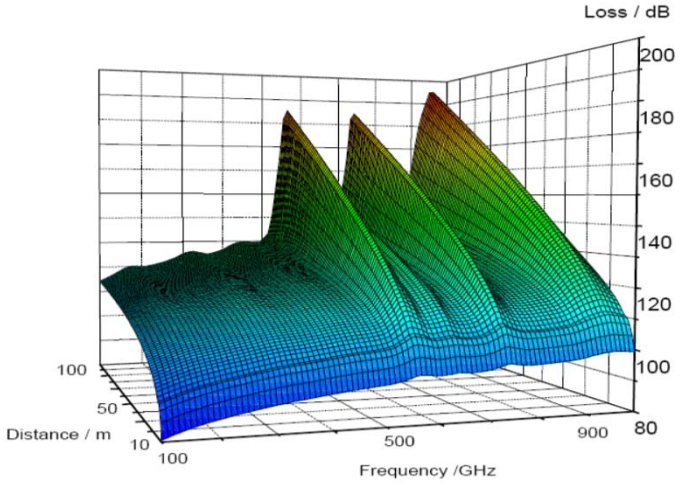
The wireless channel beyond 300 GHz bears several challenges….



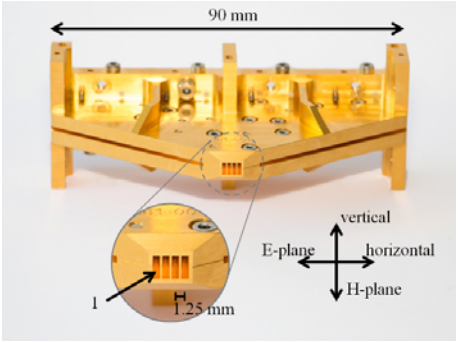


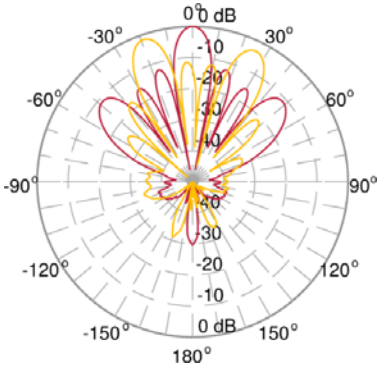
Source: Pärssinen, A., Alouini, M., Berg, M., Kürner, T., Kyösti, P., Leinonen, M. E., Matinmikko-Blue, M., McCune, E., Pfeiffer, U., & Wambacq, P. (Eds.). (2020). White Paper on RF Enabling 6G – Opportunities and Challenges from Technology to Spectrum [White paper]. (6G Research Visions, No. 13). University of Oulu. http://urn.fi/ urn:isbn:9789526228419

High gain antennas and beam forming are required



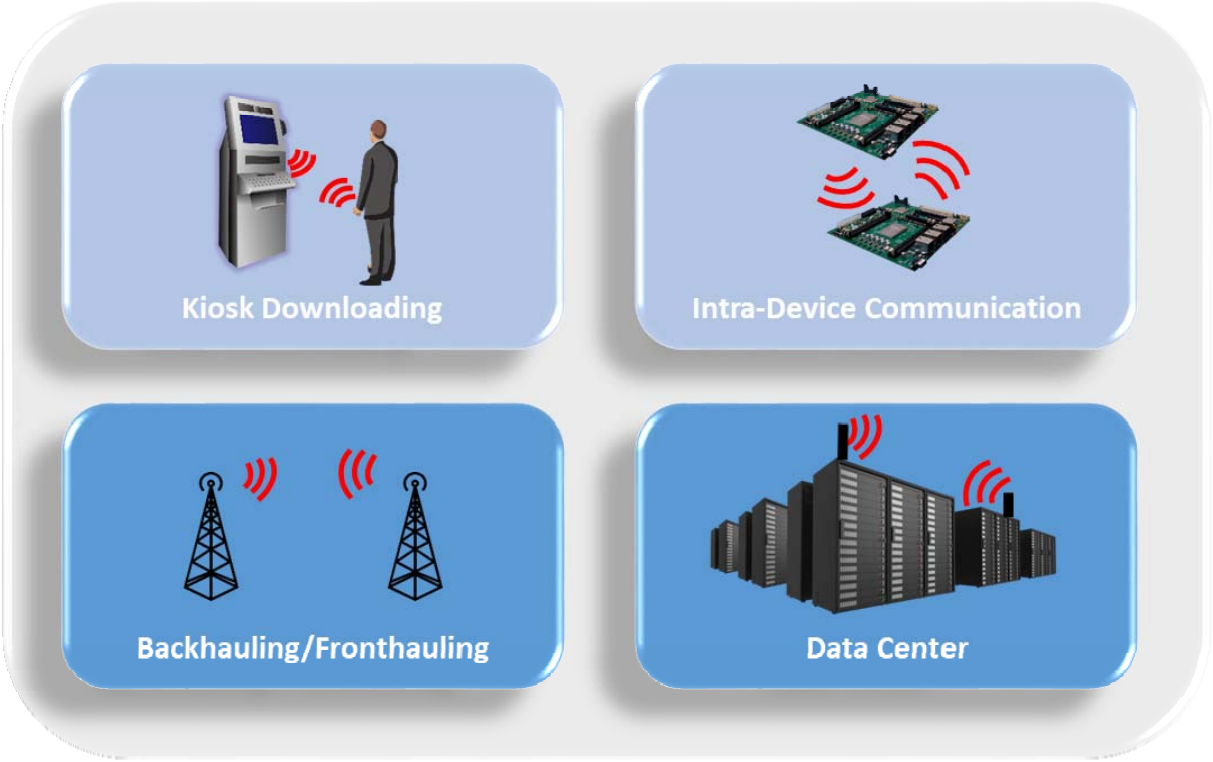
Horizon 2002 Eu-Japan Project ThoR Final Demnostrator.





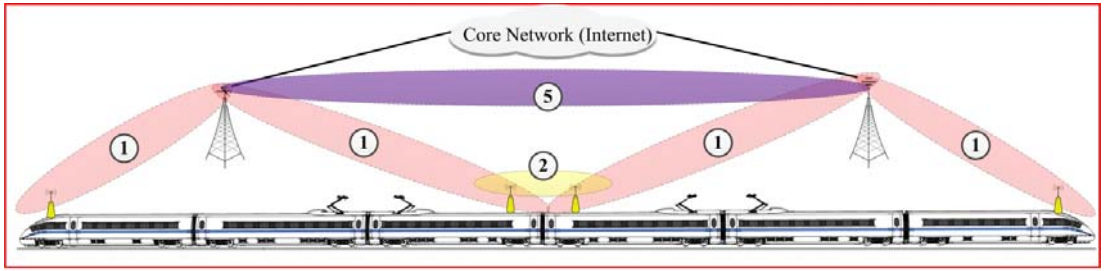
Rey, S.; Merkle, T.; Tessmann, A.; Kürner, T.: A Phased Array Antenna with Horn Elements for 300 GHz Communications. In Proc. 2016 International Symposium on Antennas and Propagation (ISAP), Ginowan, Okinawa, Japan, October 2016.

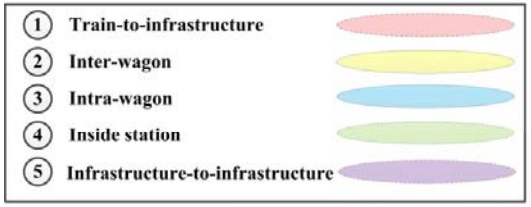
First applications for THz communications may use fixed point-to-point links….

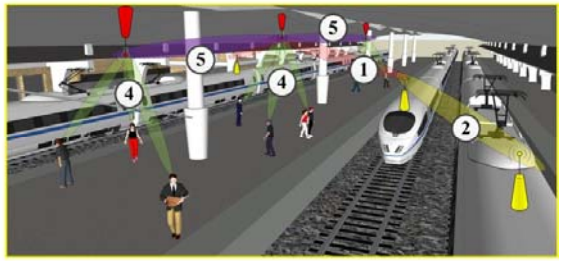


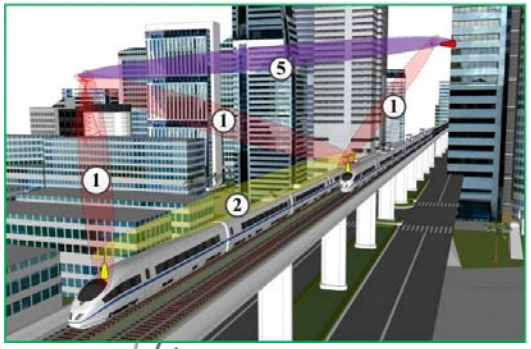
Source: T. Kürner, V. Petrov, I. Hosako, „Standards for THz Communications“ in T. Kürner, D. Mittleman, T. Nagatsuma (Eds.) *THz Communications - Paving the Way Towards Wireless Tbps*, Springer 2021

..also mobile applications may become reality









K. Guan *et al*., "On Millimeter Wave and THz Mobile Radio Channel for Smart Rail Mobility," in *IEEE Transactions on Vehicular Technology*, vol. 66, no. 7, pp. 5658-5674, July 2017.

Starting point on THz communications when Meteracom phase I was submitted (2018)

- Technological progress in semiconductor technology yielded several advanced hardware demonstrations applying both electronic and photonic approaches, for example with in the German BMBF project Millilink:

nature photonics

LETTERS

PUBLISHED ONLINE: 13 OCTOBER 2013 | DOI: 10.1038/NPHOTON.2013.275

Wireless sub-THz communication system with high data rate

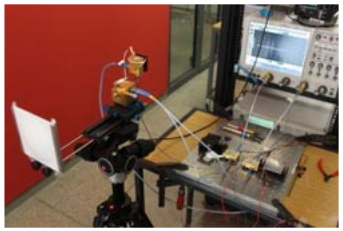
S. Koenig[1]*, D. Lopez-Diaz[2], J. Antes[1,3], F. Boes[1,3], R. Henneberger[4], A. Leuther[2], A. Tessmann[2], R. Schmogrow[1,5], D. Hillerkuss[1,5], R. Palmer[1], T. Zwick[1], C. Koos[1], W. Freude[1]*, O. Ambacher[2], J. Leuthold[1,5]* and I. Kallfass[2,3]*

World Record: Wireless Data Transmission at 100 Gbit/s

15.10.2013

Nature Photonics: Combination of Photonics and Electronics for Wireless Broadband Transmission in Rural Areas or Rapid Data Exchange between Mobile Devices

Extension of cable-based telecommunication networks requires high investments in both conurbations and rural areas. Broadband data transmission via radio relay links might help to cross rivers, motorways or nature protection areas at strategic node points, and to make network extension economically feasible. In the current issue of the nature photonics magazine, researchers present a method for wireless data transmission at a world-record rate of 100 gigabits per second. (doi: 10.1038/nphoton.2013.275)

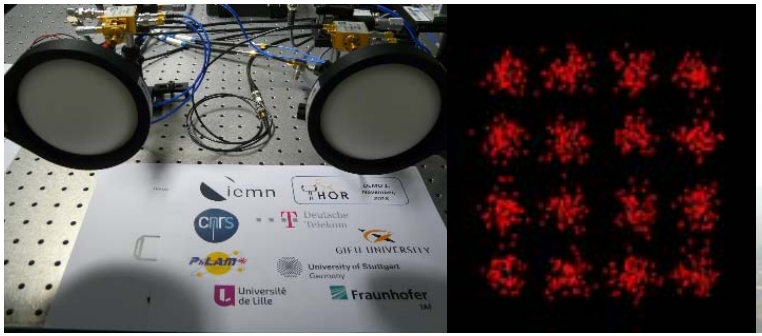


Setup for the world record of wireless data transmission at 100 gigabits per second: The receiver unit (left) receives the radio signal that is recorded by the oscilloscope (right). (Photo: KIT)

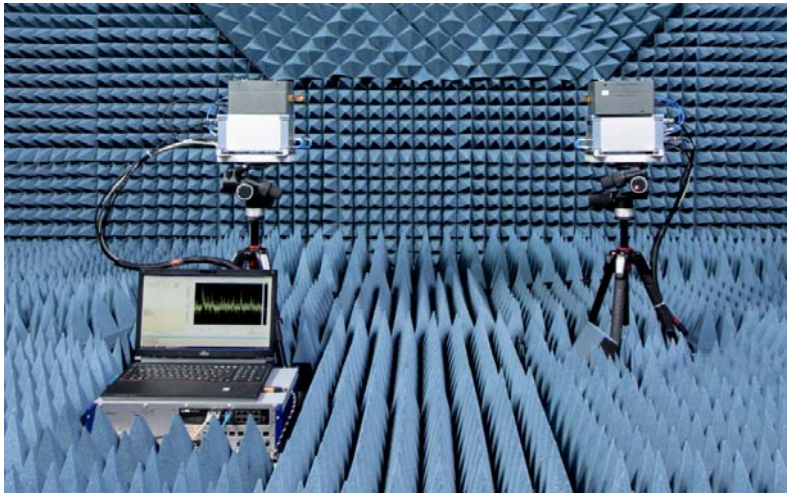
In their record experiment, 100 gigabits of data per second were transmitted at a frequency of 237.5 GHz over a distance of 20 m in the laboratory. In previous field experiments under the "Millilink" project funded by the BMBF, rates of 40 gigabits per second and transmission distances of more than 1 km were reached. For their latest world record, the scientists applied a photonic method to generate the radio signals at the transmitter. After radio transmission, fully integrated electronic circuits were used in the receiver.

The main findings from these demonstrations have been the following

- **Feasibility:** The principal feasibility of THz communications has been proven and has shown its potential for future wireless transmission.
- **Accuracy:** Non-ideal behaviour of system components and the harsh propagation conditions require adequate and sophisticated measurement equipment, procedures and algorithms to perform measurements and to calibrate the measurement equipment.
- **Real-time performance:** Measurements enabling the functionality of THz communications (e.g. Device discovery, beam-tracking and beam-switching) will be highly demanding due to factors such as the high carrier-frequency, the ultra-high bandwidth or both.

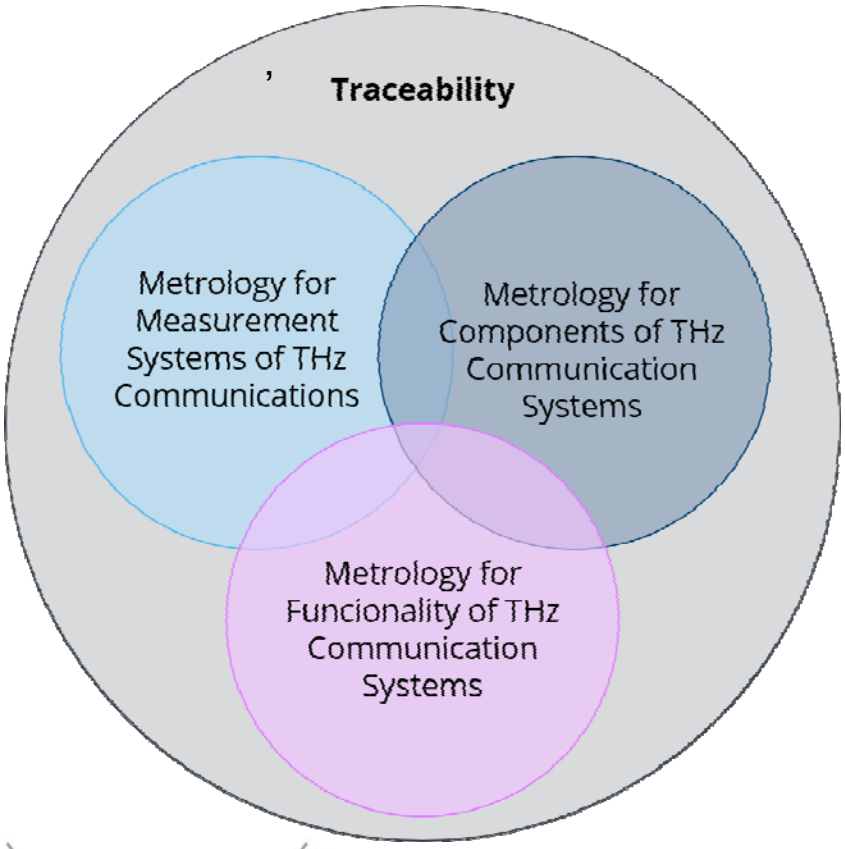


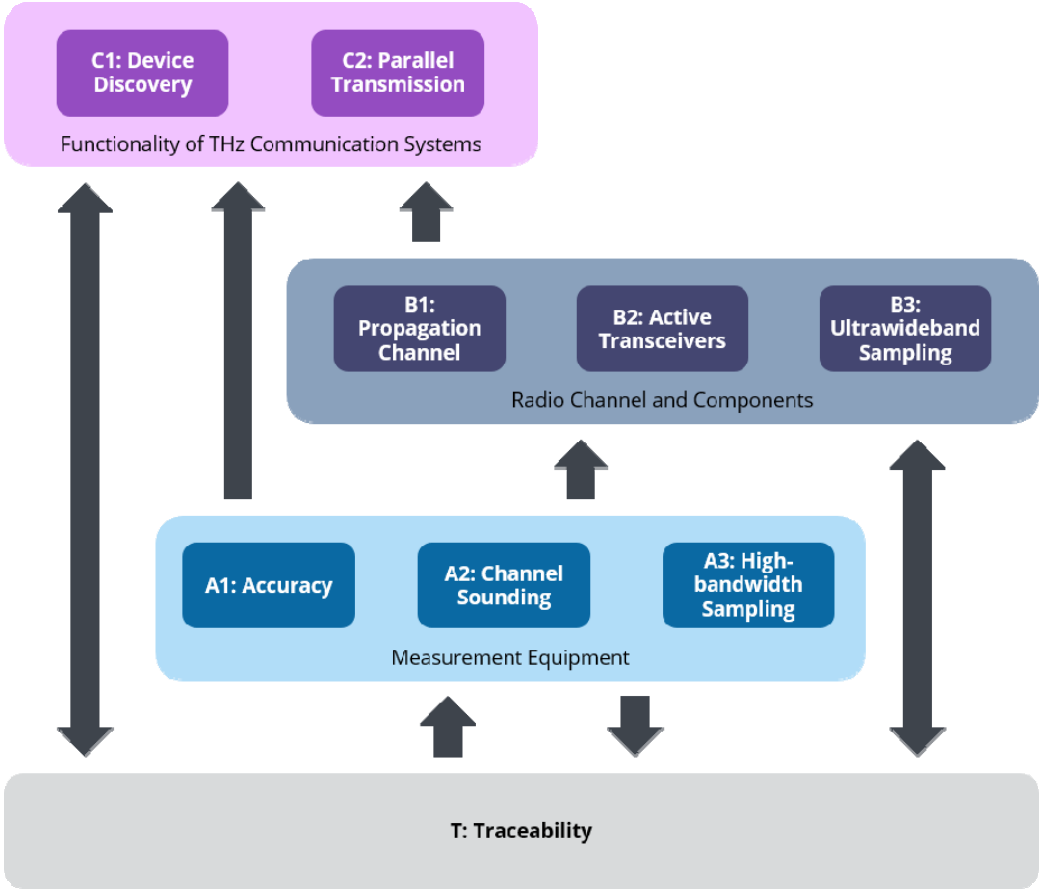
THz Metrology



- From these findings it is obvious that the capability to performing measurements and evaluating these measurements in a proper way are crucial for the advance of THz communication systems.
- Metrology at THz frequencies is still in its infancy and as of today it only covers detector calibration to characterization of ultrafast devices and to measurement uncertainty analysis of different spectrometer types available at THz frequencies.
- But how about Metrology for THz communications and the role of Meteracom?

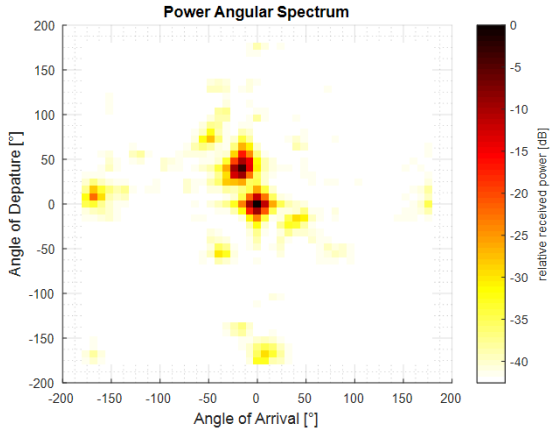
Meteracom addresses the grand challenges of metrology in THz communications systematically and in four distinct project areas



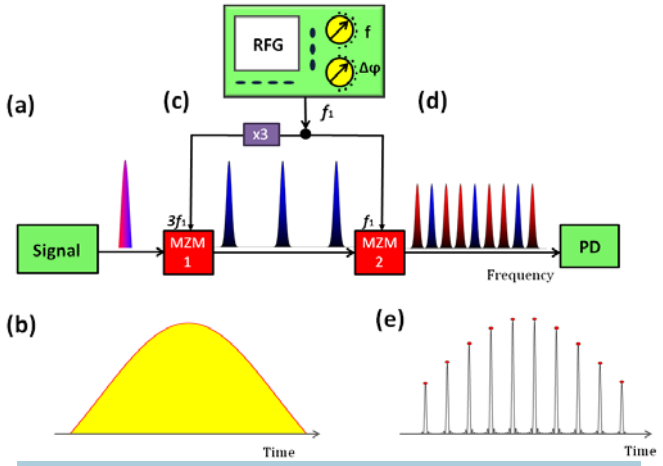


Scientific measurement equipment available in Meteracom

Measurement equipment unique to Meteracom



Time-Domain 300 GHz Channel Sounders



High Bandwidth Sampling System

Further cutting edge measurement equipment available in Meteracom

325 GHz Vector Network Analyzer

THz Time-Domain Spectroscopy

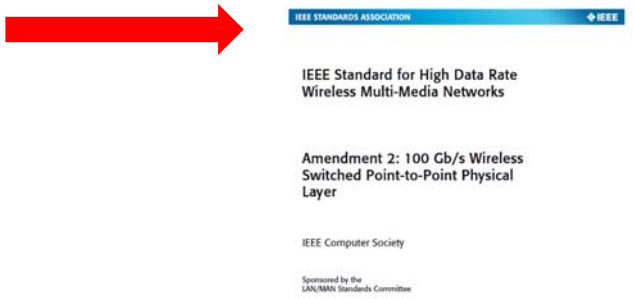
Anechoic Chamber

Arbitrary Waveform Generators

Digital Sampling Oscilloscopes

Since 2018 THz Communications made some steps towards becoming reality …

- A first 300 Ghz standard has been published (IEEE Std 802.15.3d)



- Spectrum to achieve such data rates can be found beyond 275 GHz
  - WRC 2019 has identified 137 GHz in the region 275-450 GHz for use by THz Communications

- " …6G research should look at the problem of transmitting up to 1 Tbps per user. This is possible through the efficient utilization of the spectrum in the THz regime…."

- Various 6G projects have started, where THz Communications is part of them, e.g. four 6G Hubs funded by BMBF in Germany.

6G-RIC Research and Innovation Cluster
Open6GHub
6G-life
6GEM

5 Meteracom PIs involved

- Meteracom adresses basic research questions on metrology complementing these projects

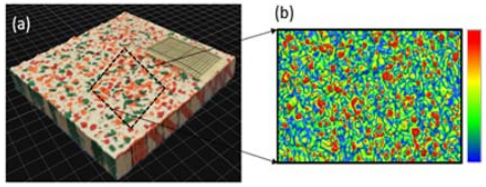
Motivation and vision for applying for Meteracom Phase II

- Meteracom is the only project specifically dedicated to metrological aspects of THz Communications.

- Although in phase I (20119-2022) we have achieved significant results in all projects, we have identified numerous research gaps, which motivate us to apply for a renewal proposal (Meteracom phase II; 2022-2025).

- With the advent of THz in 6G, the focus on metrological questions shifts from pure characterisation of components to system metrology.
  => Slight restructuring of Project Areas B and C

- New applicatons like Integrated Sensing and Communications bring new requirements on accuracy of channel meaurements
  - Different propagation physics
  - Different information about objects.
  => Consideration in Project Areas A and B



Meteracom consortium

- Interdisciplinary and distributed research unit
- 10 (9*) Principal Investigators from 6 universities and PTB
  - New in phase II: Giovanni Del Galdo (TU Ilmenau)
- 2 (1*) Mercator Fellows from NPL (UK) and Brown University Rhode Island (USA), respectively
  - New in phase II: Dan Mittleman (Brown University)
- Spokesman: Thomas Kürner (TU Braunschweig)

  * Phase I

Meteracom Workshop 28 June 2022 (Morning)

Time	Session	Speaker
09.00-09.30	Introduction to DFG FOR 2863 Meteracom	Thomas Kürner, TU Braunschweig, Germany
09.30-10.00	Invited talk: Propagation measurements and models in the mmwave band	Sana Salous, Durham University ONLINE
10.00-10.20	Metrology in wireless communication: Channel Sounder Measurement Verification Using Over-the-Air Artifact	Mohanad Al-Dabbagh, PTB, Germany ONLINE
10.20-10.40	Mitigation of thermal crosstalk for integrated THz-photonic signal processing	Souvaraj De, PTB, Germany
10.40-11.00	Calibration and verification of multidimensional channel sounder for THz applications	Giovanni Del Galdo, Technische Universität Ilmenau, Germany
11.00-11.30	Coffee break	-
11.30-12.00	Invited Talk: From 5G to 6G: Key challenges from a 6G-RIC perspective	Slawomir Stanczak, HHI
12.00-12.20	Characterization of building materials in the THz range	Fatima Taleb, Philipps-Universität Marburg, Germany
12.20-12.40	Sensitivity Analysis of a 280 – 312 GHz Superheterodyne Terahertz Link Targeting IEEE802.15.3d Applications	Dominik Wrana, Universität Stuttgart, Germany
12.40-13.00	Invited Talk: Leveraging photonics techniques for THz communications: measurements of active passive functions in the 300 GHz range	Guillaume Ducourneau, Lille University
13.00 - 14.00	Lunch break	-

Meteracom Workshop 28 June 2022 (Afternoon)

Time	Session	Speaker
14.00-14.30	Invited Talk: Key Challenges of THz Communications for 6G Era	Ho-Jin Song, Pohang University, Korea
14.30-14.50	ENOB analysis in photonic orthogonal sampling systems for Terahertz signal reception	Younus Mandalawi, Technische Universität Braunschweig, Germany
14.50-15.10	Ultra-low phase noise frequency synthesis for THz metrology using low-jitter femtosecond lasers	Christoph Scheytt, Paderborn University, Germany ONLINE
15.10-15.40	Coffee break	-
15.40-16.10	Invited Talk: THz Physical Layer Security	Edward Knightly, Rice University, Houston, USA
16.10-16.30	How image reconstruction can improve THZ communications – A compressed sensing-assisted device discovery approach	Tobias Doeker, Technische Universität Braunschweig, Germany
16.30-16.50	Challenges of Hardware Acceleration in THz Communication	Anouar Nechi, Universität zu Lübeck, Germany ONLINE
16.50-17.10	A THz Control Plane for Adaptive Coding and Modulation	Cao Vien Phung, Technische Universität Braunschweig, Germany
17.10-17.20	Closing Remarks	Thomas Kürner, TU Braunschweig, Germany

Final Workshop Project ThoR (Day 1, 29 June 2022 – Morning Session)

Time	Session	Speaker
08.15-08.30	Arrival	-
08.30-08.50	Introduction to ThoR by Coordinators	Prof. Tetsuya Kawanishi, Waseda University ONLINE
08.50-09.10	Development of the ThoR 60 GHz transceiver module	Keitarou Kondou, HRCP R+D Partnership ONLINE
09.10-09.30	Development of THz front-ends based on InGaAs mHEMT devices	Dr.-Ing. Laurenz John, Fraunhofer IAF
09.30-10.00	Sub-THz front ends for ubiquitous high data rate	Prof. Claudio Paoloni, Lancaster University
10.00-10.30	Break (+posters)	-
10.30-11.00	Industry perspective on THz communication and associated technologies	Frederic Gianesello, ST Microelectronics
11.00-11.20	10 Gbps mm-Wave link and combing scheme for utilising THz frequencies	Ran Timar, Siklu
11.20-11.40	Fixed mm-wave and THz wireless system link performance degradation due to severe weather conditions	Eisaku Sasaki, NEC Corporation ONLINE
11.40-12.10	Presentation and video of ThoR demo	Shinataro Hisatake, Gifu University ONLINE
12.10-12.15	Wrap-up	Prof. Tetsuya Kawanishi, Waseda University (ONLINE) and Prof. Thomas Kürner, TU Braunschweig
12.15-14.00	Lunch and networking	-
14.00-16.00	Poster session, Software demonstrations, Visits to demo hardware	-
18.00	Evening event Rodizio	-

Final Workshop Project ThoR (Day 1, 29 June 2022– Afternoon Session)

- Tour in smaller groups lead by TUBS team
- 2 Locations to show
  - Rooftop of Civile Engineering Building (Antennas + Room with Photonic LO)
  - Meeting room with PCs, Screen of Live Video, SW-Demo+Posters explaining SW-Demo

- Meeting Point at the entrance of „Haus der Wissenschaft“

- **Please check your time scheduled!**

Final Workshop Project ThoR (Day 2, 30 June 2022)

Time	Session	Speaker
08.15-08.30	Arrival	-
08.30-09.00	Technology trends toward Beyond 5G in Japan	Yoshiaki Amano, KDDI R&D Laboratories ONLINE
09.00-09.20	Overview of the assembly and test of front-end modules: ThoR lab demo	Prof. Guillaume Ducournau, University of Lille
09.20-09.50	THz phased-array transceivers for Beyond 5G	Prof. Kenichi Okada, Tokyo Institute of Technology ONLINE
09.50-10.15	Break (+posters)	-
10.15-10.35	Photonics-based antenna near-field measurement and far-field characterization in the 300 GHz band	Prof. Shintaro Hisatake, Gifu University ONLINE
10.35-10.55	Short-range wireless transmission using a superheterodyne THz link	Dominik Wrana, University of Stuttgart
10.55-11.15	Study of terahertz antenna and propagation for Beyond 5G mobile communication	Prof. Akihiko Hirata, Chiba Institute of Technology ONLINE
11.15-11.35	Automatic planning of 300 GHz backhaul links	Bo Kum Jung, TU Braunschweig
11.35-12.00	Break (+posters)	-
12.00-12.20	ThoR demo at Deutsche Telekom and future exploitation	Dr. Petr Jurčík, Deutsche Telekom
12.20-12.40	Wired and wireless seamless networks for beyond 5G	Prof. Tetsuya Kawanishi, Waseda University ONLINE
12.40-12.55	A perspective for standards and regulation on THz communications	Prof. Thomas Kürner, TU Braunschweig
2.55-13.00	Wrap-up	Prof. Tetsuya Kawanishi, Waseda University (ONLINE) and Prof. Thomas Kürner, TU Braunschweig

Thank you very much for your Attention

E-Mail: t.kuerner@tu-bs.de

Funded by
DFG Deutsche Forschungsgemeinschaft
German Research Foundation