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

Submission Title: IEEE P802.15.3d Presentation to ETSI ISG mWT
Date Submitted: 27 September 2016
Source: Thomas Kürner (TU Braunschweig)
Address Schleinitzstr. 22, D-38092 Braunschweig, Germany
Voice:+495313912416, FAX: +495313915192, E-Mail: kuerner@ifn.ing.tu-bs.de

Re: 802.15 Liaison Letter to ETSI ISG mWT

Abstract: The document provides some information on the background and current status of IEEE P802.15.3d
Purpose: Presentation to ETSI ISG mWT

IEEE P802.15.3d Presentation to ETSI ISG mWT

Prof. Dr. Thomas Kürner (TU Braunschweig)
Chair IEEE 802.15 Task Group 3d

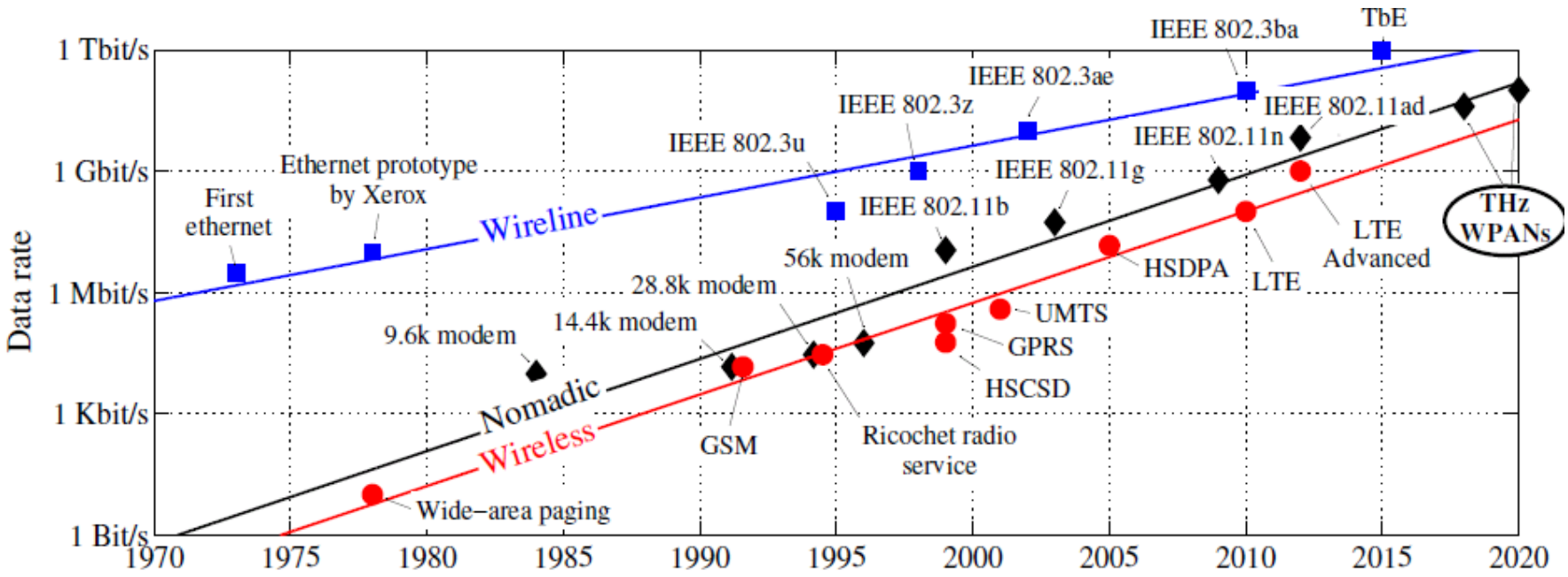
27 September 2016

Outline

- Motivation for THz Communications
- Some Results from Research Projects
- THz Communications @ IEEE 802
- Project IEEE P802.15.3d
- Activities towards WRC 2019
- Discussion

MOTIVATION FOR THZ COMMUNICATIONS

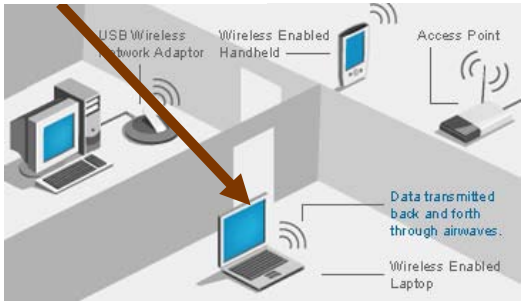
Why towards 100 Gbps?
Edholm‘s Law of data rates



Source: Kürner, T.; Priebe, S.: Towards THz Communications – Status in Research, Standardization and Regulation. Journal of Infrared, Millimeter, and Terahertz Waves, January 2014, Volume 35, Issue 1, pp 53-62

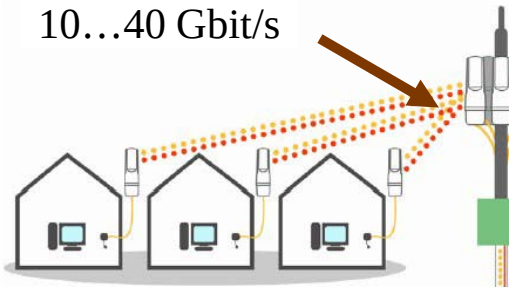
Possible Applicatons for ultra-high Data Rates of 100 Gbit/s and beyond

10...100 Gbit/s



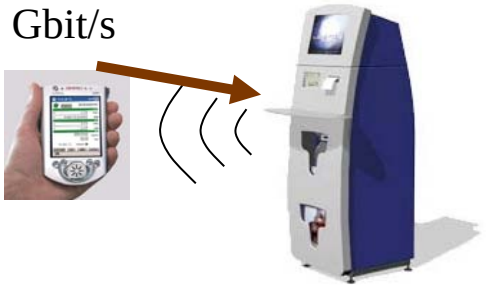
(1) THz WPANs/WLANs

10…40 Gbit/s



(2) Wireless data to home

10...20 Gbit/s

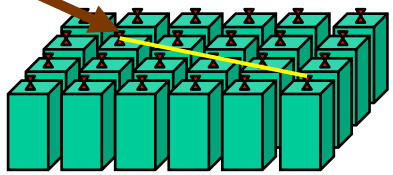


(3) Kiosk downloads

10..100 Gbit/s

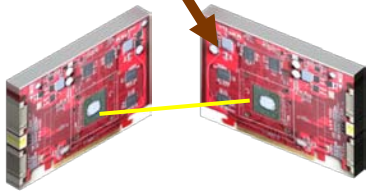
(4) Backhaul/Fronthaul links

10...100 Gbit/s



(5) Wireless Links in Data Centers

10...100 Gbit/s



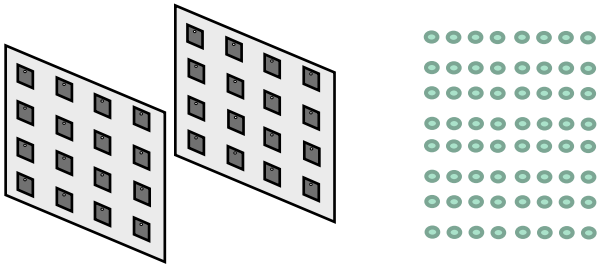
(6) Intra-Device Communication

→ Many diverse applications for ultra fast links

What are the Possibilities to achieve ultra-high Data Rates?

Using already allocated spectrum and improving spectral efficiency significantly

Extending the bandwidth using moderate spectral efficiencies



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

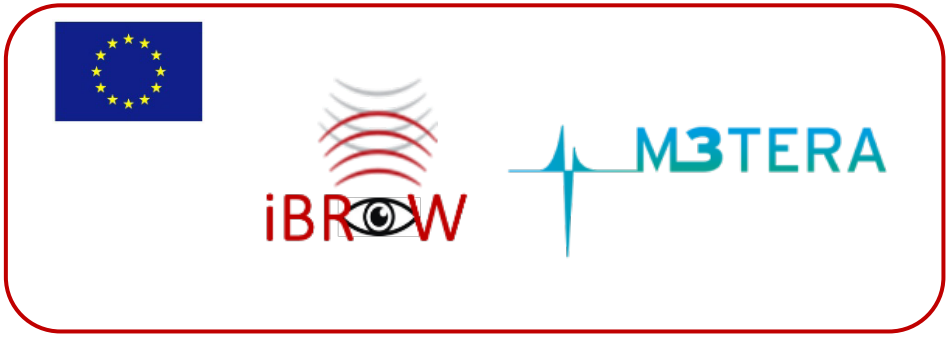
Massive MIMO
high-order modulation schemes
@60 GHz-band (6-9 GHz at allocated spectrum)

Transmission schemes of lower complexity
using 20-50 GHz bandwidth
@300 GHz and beyond (THz communication)

RESEARCH PROJECTS ON THZ COMMUNICATIONS

Research Projects/Research Programs targeting 100Gbps

- A couple of publicly funded projects are running in Europe…

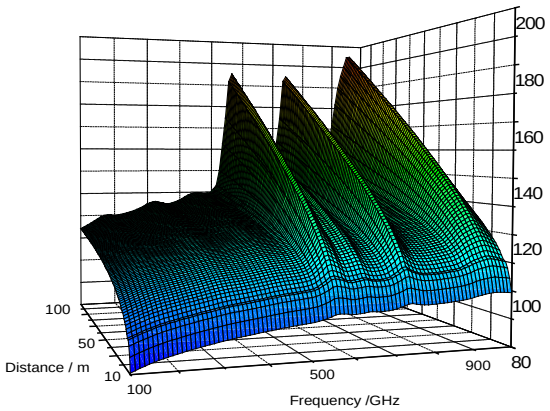


… and in other parts of the world as well. The following research groups are working on THz communications (list not complete):

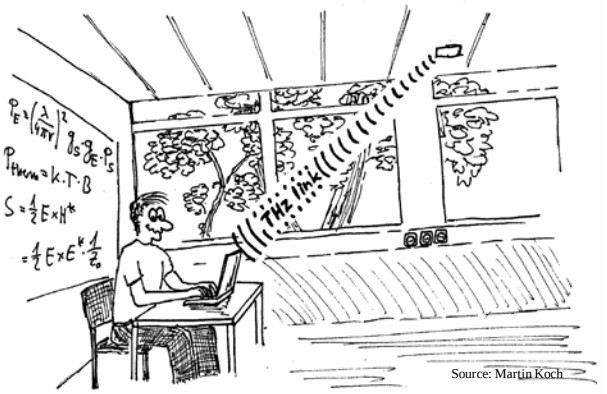
- France (Montpellier Univ., Lille University,….)
- Japan (NTT, NICT, University of Osaka, University of Hiroshima)
- USA (Bell Labs, Georgia Tech, New Jersey Institute of Technology,….)

Research Challenges: Overcoming the high Path Loss through high-gain Antennas

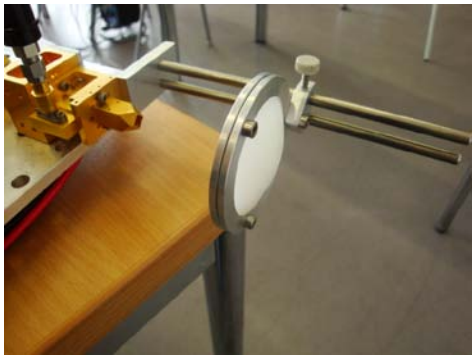
Path Loss @THz



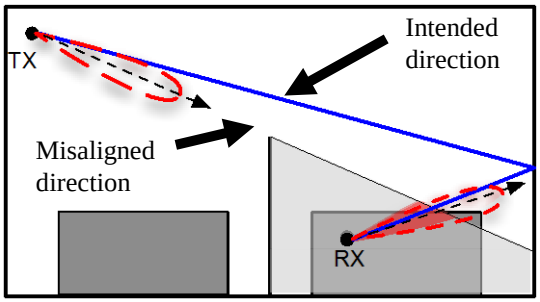
Directional Communications

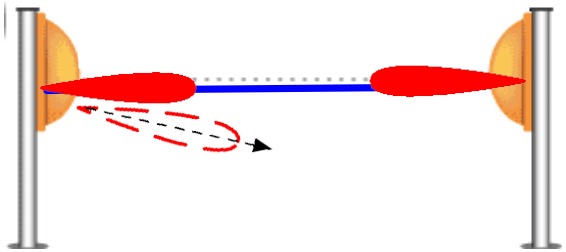


Antenna set-up used for Channel Measurements



Requirements on Antenna Alignment

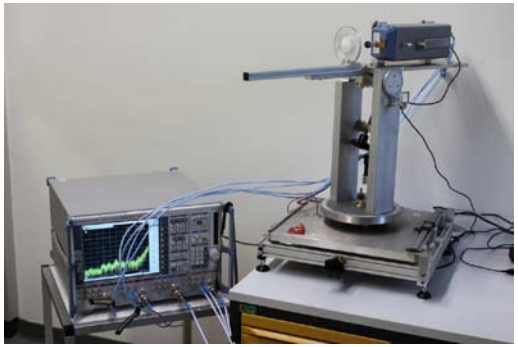


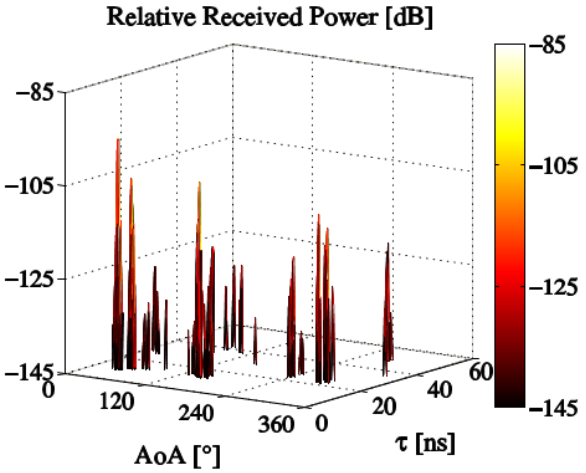


Source: S. Priebe, M. Jacob, T. Kürner: “Affection of THz Communication Links by Antenna Misalignment,” Proc. 6th European Conference on Antennas and Propagation (EuCAP), 5 pages (electronic), Prague, April 2012.

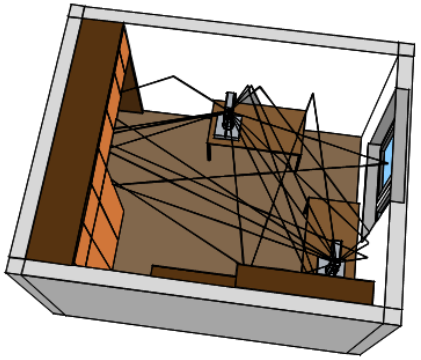
Channel Characterisation

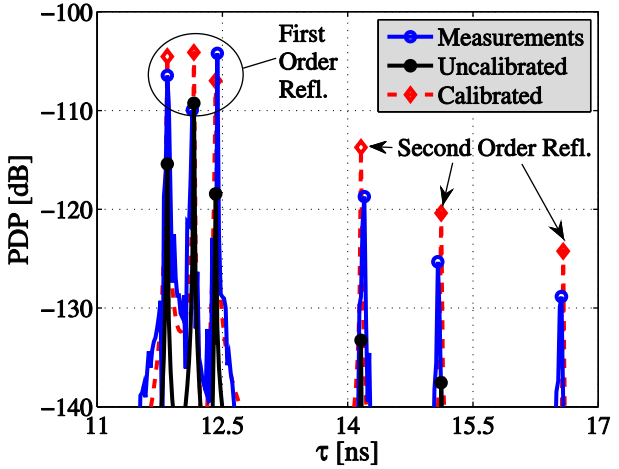
Measurements





Ray Tracing





S. Priebe, M. Kannicht, M. Jacob, T. Kürner: "Ultra Broadband Indoor Channel Measurements and Calibrated Ray Tracing Propagation Modeling at THz Frequencies ", *Journal of Communications and Networks, Vol. 15, No.6,* 11 pages, December 2013.

Achieving 100 Gbit/s

- The feasibility to achieve 100 Gbit/s has been demonstrated already within the framework of the BMBF-Millilink project
- Both photonic methods and fully integrated electronic circuits are applied

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

Wireless sub-THz communication system with high data rate

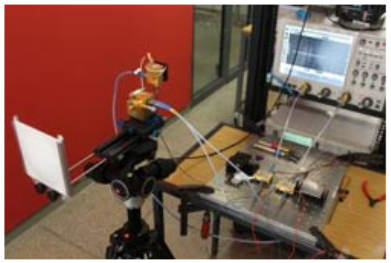
S. Koenig[1]*, D. Lopez-Diaz[2], J. Antes[1,3], F. Boes[1,3], R. Henneberger[4], A. Leuther[2], A. Tessmann[2], R. Schmogrow[1,5], D. Hillerkuss[1,5], R. Palmer[1], T. Zwick[1], C. Koos[1], W. Freude[1]*, O. Ambacher[2], J. Leuthold[1,5]* and I. Kallfass[2,3]*

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)

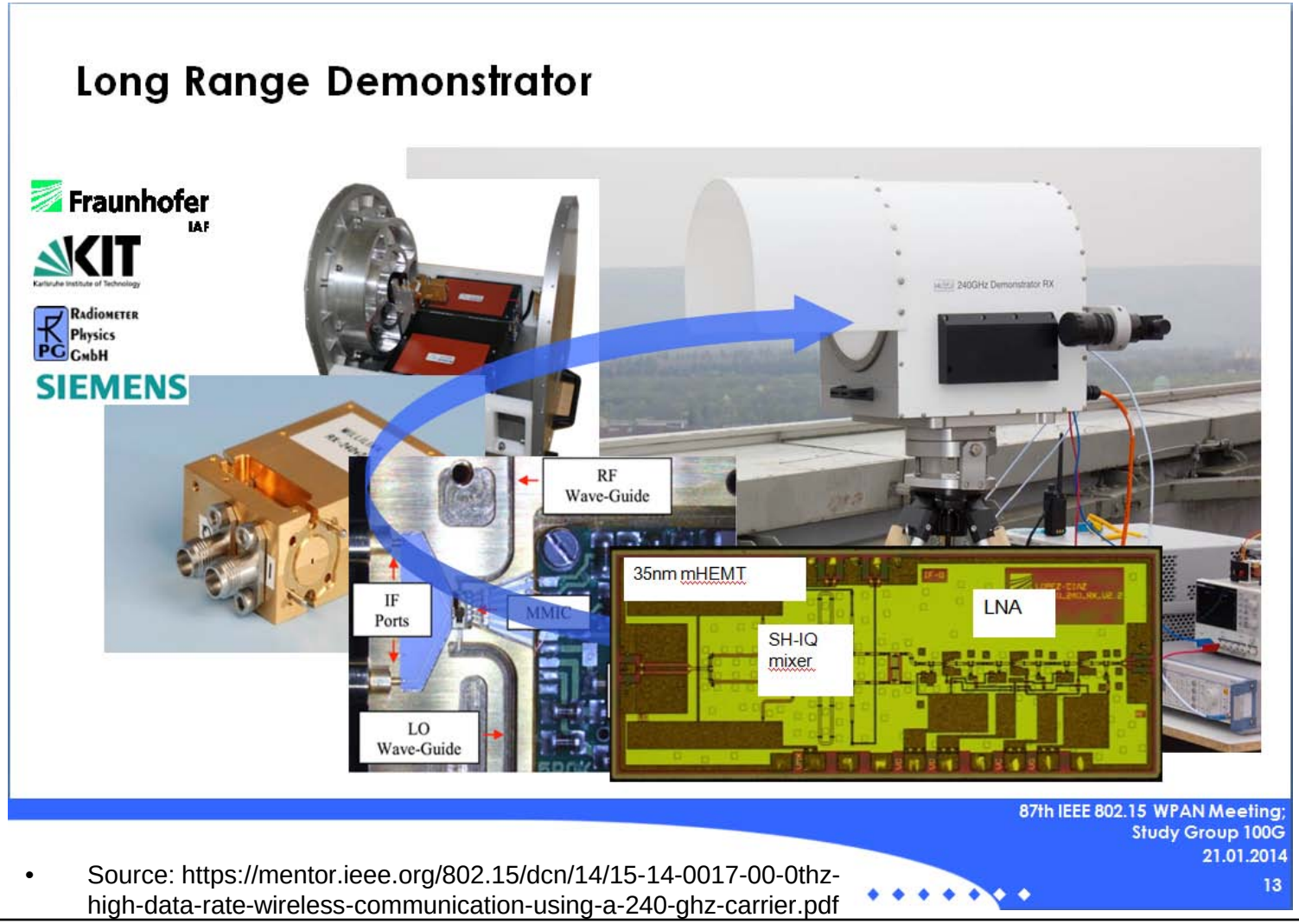


Setup for the world record of wireless data transmission at 100 gigabits per second: The receiver unit (left) receives the radio signal that is recorded by the oscilloscope (right). (Photo: KIT)

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.

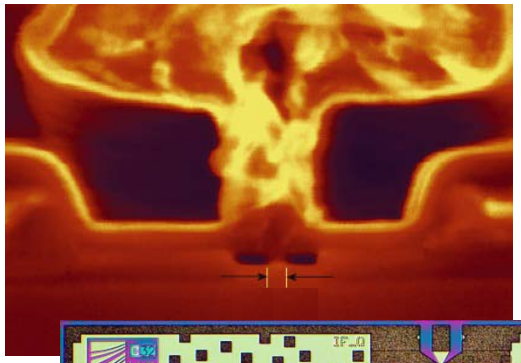
http://www.innovations-report.de/html/berichte/informationstechnologie/world-record-wireless-data-transmission-100-gbit-s-221318.html

A 240 GHz Backhaul Link

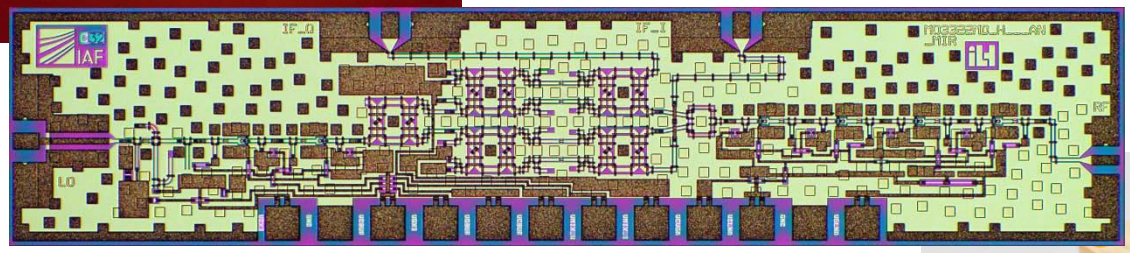


- Source: https://mentor.ieee.org/802.15/dcn/14/15-14-0017-00-0thz-high-data-rate-wireless-communication-using-a-240-ghz-carrier.pdf

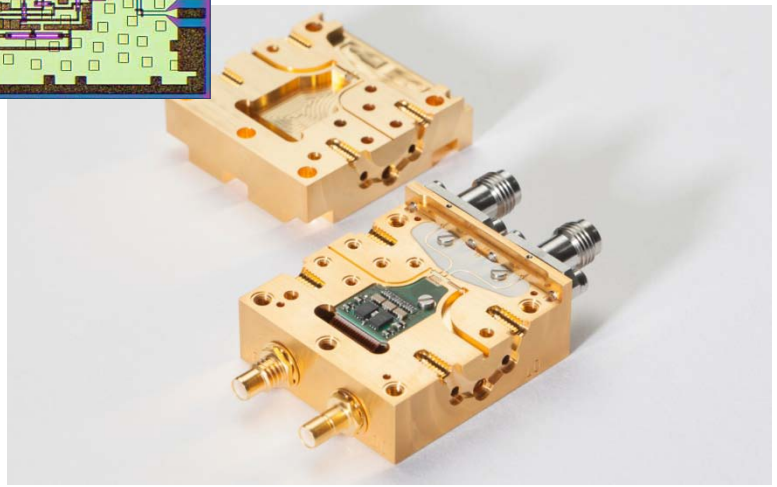
MMIC-Based Tx and Rx Modules at 300 GHz (TERAPAN project)



35 nm GaAs mHEMT technology
with THz cutoff frequency

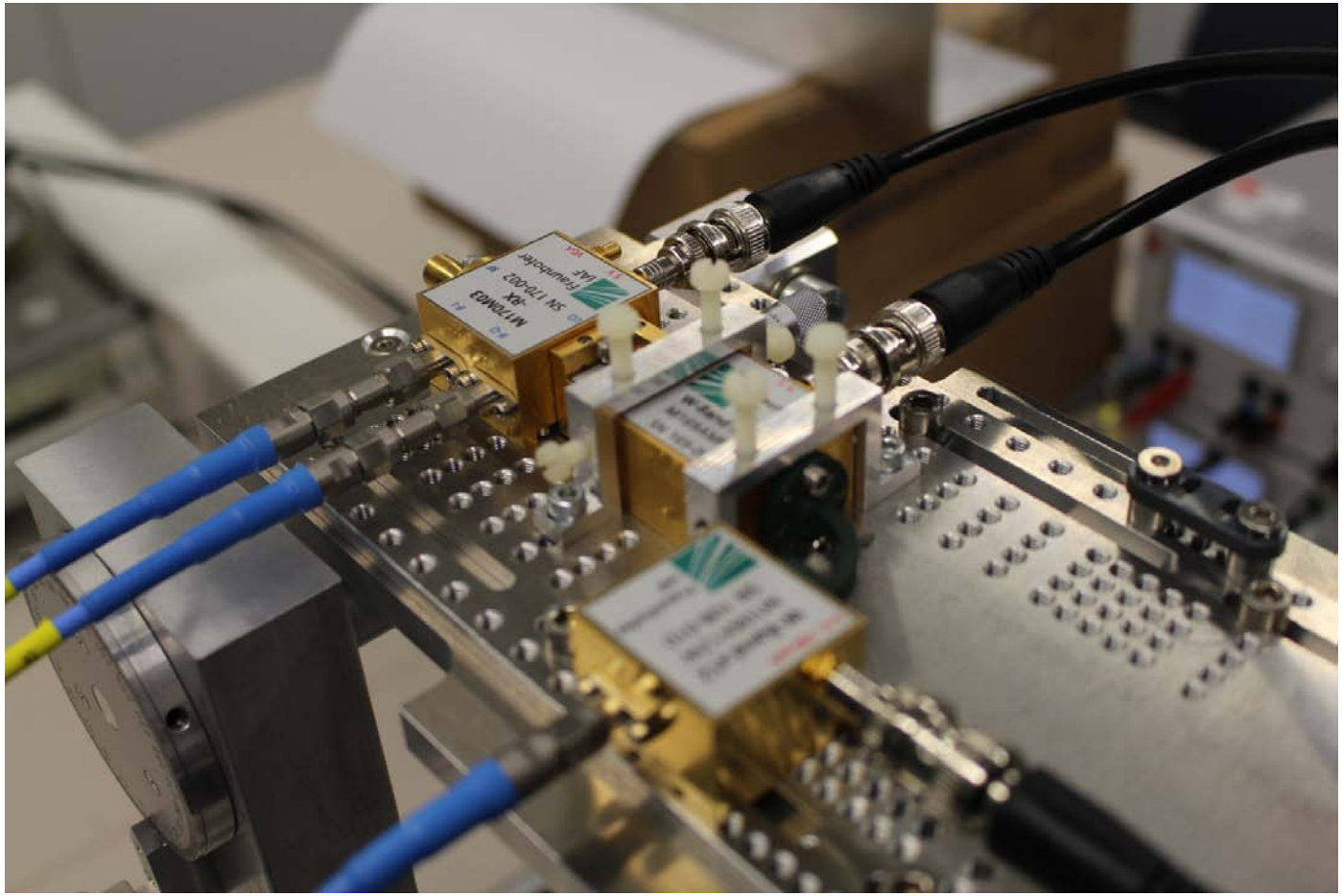


Fully integrated 300 GHz transmitter
& receiver MMICs



Compact high performance
waveguide module

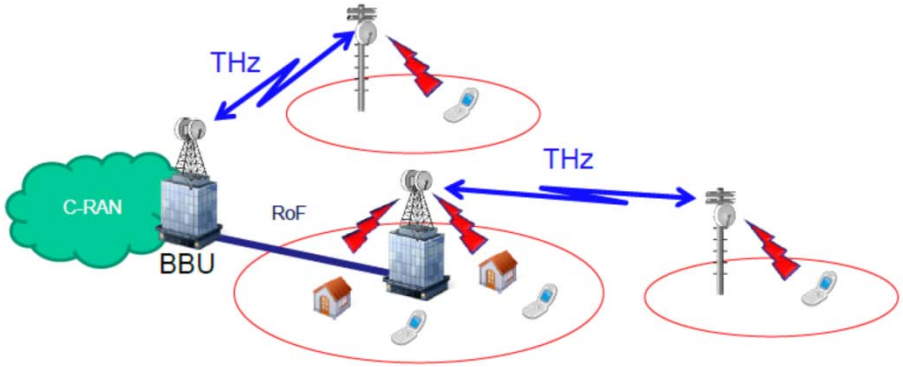
…the first generation of the TERAPAN demonstrator



Please find a link to the video at https://www.ifn.ing.tu-bs.de/en/news/ngmn/

R&D on amplifier technology in 300 GHz band (FY2014-2017)

Front/Back haul for a future mobile network

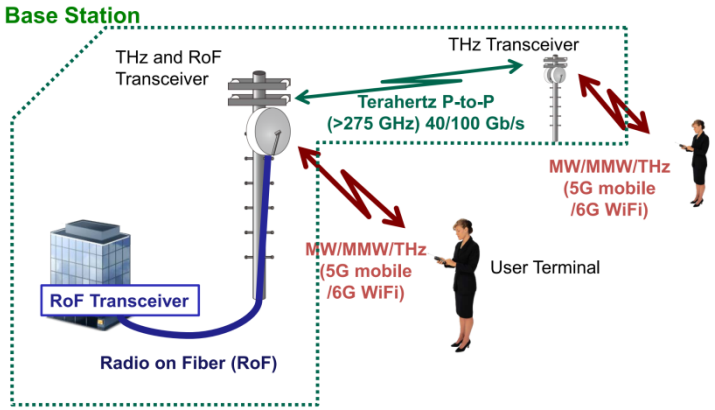


総務省
MIC Ministry of Internal Affairs and Communications

NETCOMSEC

NICT

RoF-Based Terahertz Fronthaul

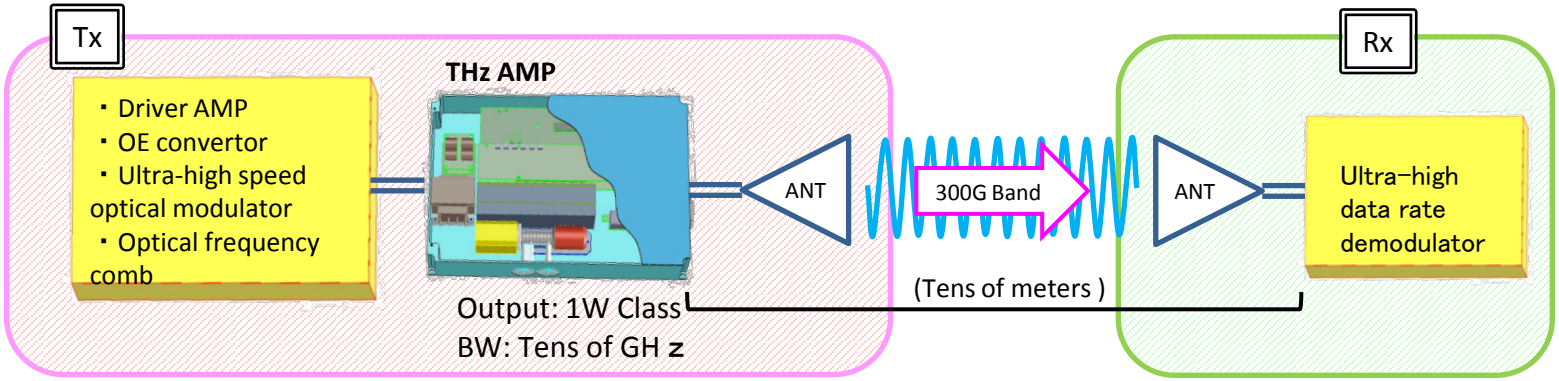


Issues:

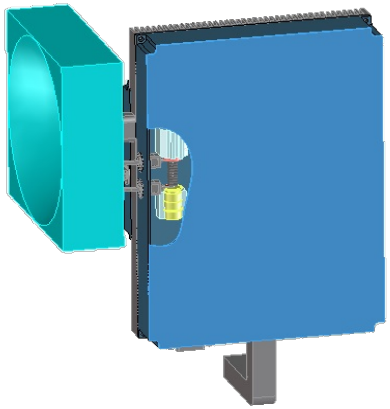
- High output PA(1W @300GHz)
- MEMS based slow wave circuit, packaging, antenna,
- 100 Gbps data Transmission experiment within few hundred meters

Purpose: Extension of Transmission Range

- Target Specifications:
  - ✔Output: 1W ✔Fractional Band Width: 10% ✔Size: A4
  - ✔Gain: > 20dB
- Demonstration: Tens of meters x 40Gbps

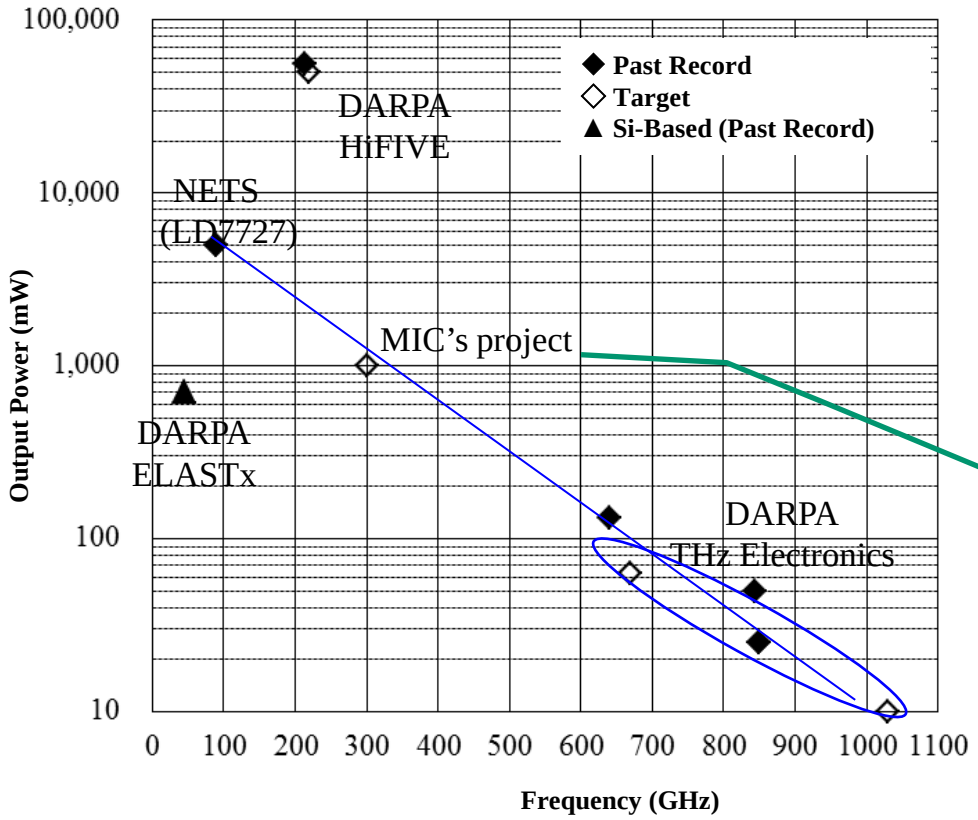


Ultra-small Radio Head
(Future success)



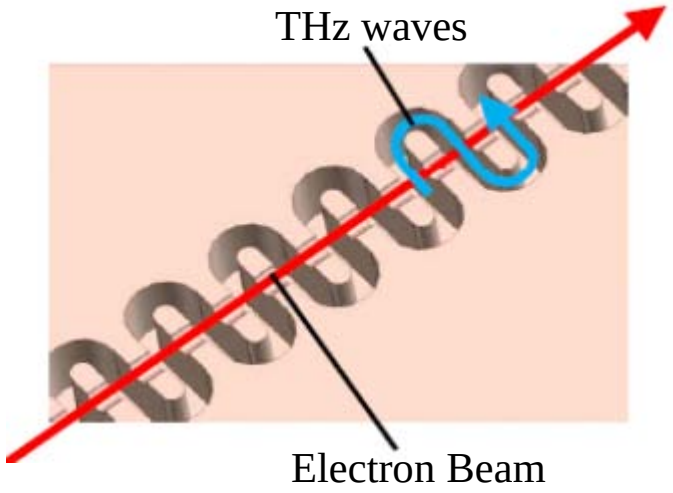
- Small Power Source
- HV Generation
- Controller (FPGA)

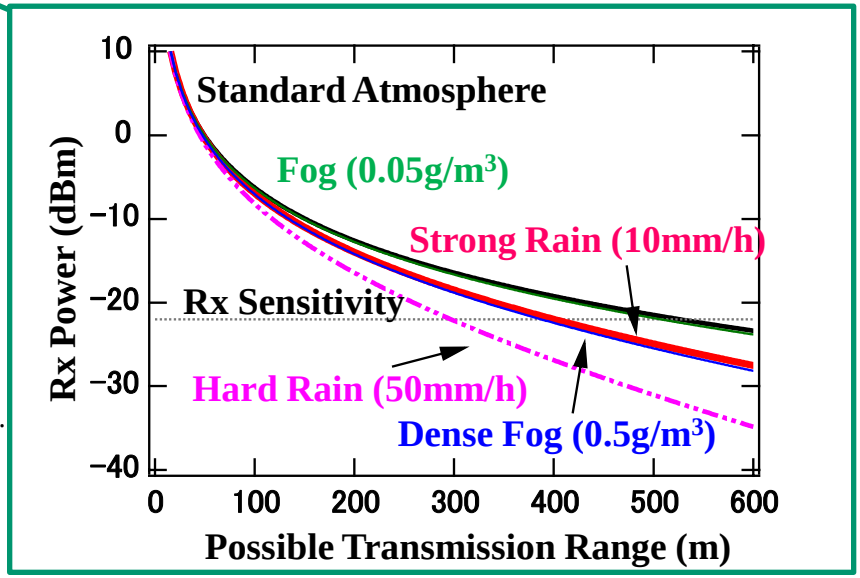
THz CW Emitters



J. D. Albrecht, CS MANTECH Conference. May 16-19, 2011.
H. B. Wallace, DMRC Millimeter-Wave Technology Workshop, Oct.30, 2014.
MIC-HP http://www.soumu.go.jp/main_content/000292205.pdf

by courtesy of Dr. Naoki Oda





THZ COMMUNICATIONS @IEEE 802

History of THz Communications @ IEEE 802.15

- January 2008: Interest Group THz
  - Monitoring of technological developments
  - Contributions to WRC 2012
- July 2013: Study Group 100G
  - Development of a PAR (Project Authorization Request) to develop a standard on wireless 100 Gbit/s based on IEEE 802.15.3c
- March 2014: Task Group 3d
  - Working towards to first standard on wireless communications at 300 GHz
  - Chair: Thomas Kürner (TU Braunschweig)
  - Vice-Chair: Iwao Hosako (NICT)

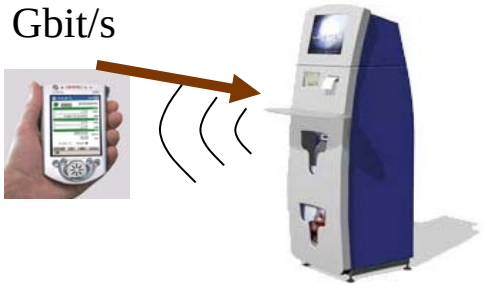
PROJECT IEEE P802.15.3D

Scope of IEEE P802.15.3d

- Scope of the project: *„This amendment defines a wireless switched point-to-point physical layer to IEEE Std. 802.15.3 operating at a nominal PHY data rate of 100 Gbps with fallbacks to lower data rates as needed. Operation is considered in bands from 252 GHz to 325 GHz at ranges as short as a few centimeters and up to several 100m. Additionally, modifications to the Medium Access Control (MAC) layer, needed to support this new physical layer, are defined..”*

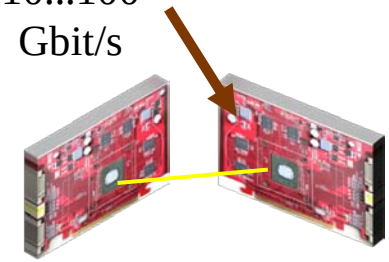
Applications for switched point-to-point links

10...100 Gbit/s



Kiosk downloads

10...100 Gbit/s

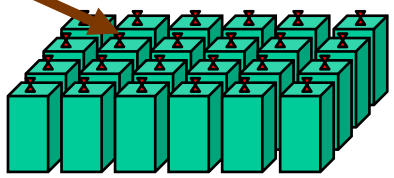


Intra-Device Communication

10..100 Gbit/s

Backhaul/Fronthaul links

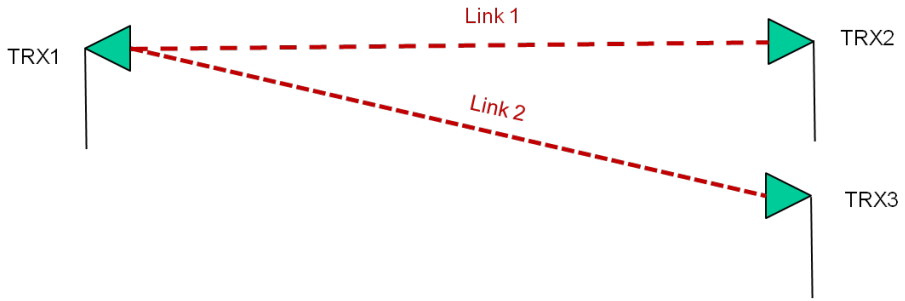
10...100 Gbit/s



Wireless Links in Data Centers

Common Characteristics of all four Applications

- It can be assumed that a-priori knowledge of the locations of Tx and Rx is available.
- As a consequence the efforts for device discovery and beam tracking may be reduced.
- Only two DEVs are involved in communications. However links may be switched between different DEVs



- The point-to-point nature with the application of highly directive antennas may yield less complex channels and less complex interference situations

Call for Proposals and Supporting Documents

- Call for Proposals:
  - https://mentor.ieee.org/802.15/dcn/15/15-15-0936-04-003d-tg3d-100g-call-for-proposals.docx
- Application Requirements Document:
  - https://mentor.ieee.org/802.15/dcn/14/15-14-0304-16-003d-applications-requirement-document-ard.docx
- Technical Requirements Document :
  - https://mentor.ieee.org/802.15/dcn/14/15-14-0309-20-003d-technical-requirements-document.docx
- Channel Modeling Document
  - https://mentor.ieee.org/802.15/dcn/14/15-14-0310-18-003d-channel-modeling-document.docx
- Evaluation Criteria Document
  - https://mentor.ieee.org/802.15/dcn/15/15-15-0412-13-003d-evaluation-criteria-document.docx

Current Status

- Proposals have been presented in July and September 2016
- Draft standard is planned for January 2017
- Target to finish the standard until beginning of 2018

Key Features of the Proposals

- Baseline:
  - Amendment is based on IEEE 802.15.3-2016
    - Amongst others: capability to carry Ethernet as payload
  - Amendment will reuse point-to-point features of the parallel running project IEEE P802.15.3e
- Variable bandwidths
  - 8 different bandwidths ranging from 2.16 GHz to 67.76 GHz are defined
- Modulation
  - SC-PHY (up to 64 QAM) and OOK-PHY

ACTIVITIES TOWARDS WRC 2019

Current Regulation beyond 275 GHz

- Footnote 5.565 in the Radio Regulations (RR):

  "The following frequency bands in the range 275-1 000 GHz are identified for use by administrations for passive service applications:

- ***Radio astronomy service**:* ***275-323 GHz, 327-371 GHz, 388-424 GHz, 426-442 GHz**, 453-510 GHz, 623-711 GHz, 795-909 GHz, 926-945 GHz;*
- ***Earth exploration-satellite service (passive) and space research service (passive)**:* ***275-286 GHz, 296-306 GHz, 313-356 GHz, 361-365 GHz, 369-392 GHz, 397-399 GHz, 409-411 GHz, 416-434 GHz, 439-467 GHz**, 477-502 GHz, 523-527 GHz, 538-581 GHz, 611-630 GHz, 634-654 GHz, 657-692 GHz, 713-718 GHz, 729-733 GHz, 750-754 GHz, 771-776 GHz, 823-846 GHz, 850-854 GHz, 857-862 GHz, 866-882 GHz, 905-928 GHz, 951-956 GHz, 968-973 GHz and 985-990 GHz.*
- *The **use** of the range 275-1 000 GHz by the passive services **does not preclude use** of this range by **active services**. […]" as long as the passive services are protected.*

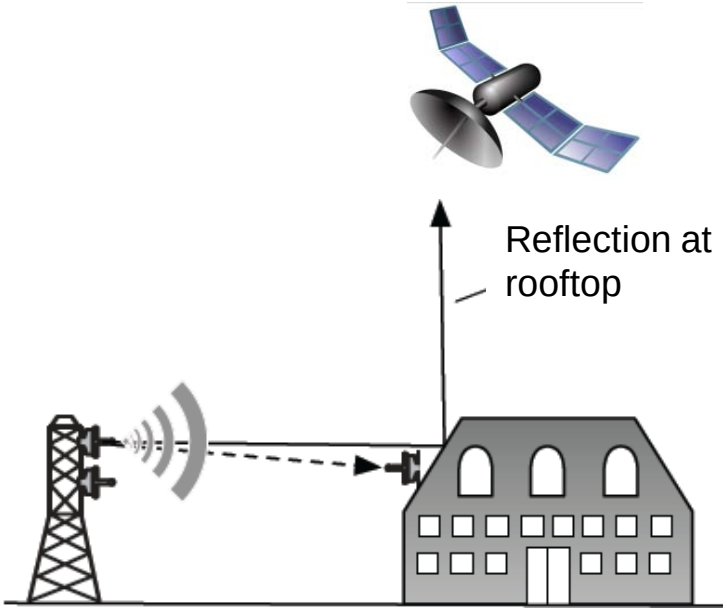
WRC AI 1.15

WRC 2015 agreed in resolution 767:

- to have an agenda item for WRC 2019 to consider identification of spectrum for land-mobile and fixed active services in the range of 275 GHz to 450 GHz while maintaining protection of the passive services identified

- ITU-R is invited to
  - identify **technical and operational characteristics**
  - study spectrum needs
  - develop propagation models
  - conduct **sharing studies with the passive services**
  - identify candidate frequency bands

Backhaul/Fronthaul Links are relevant for the Sharing Studies



More details see: Priebe, S.; Britz, D. M.; Jacob, M.; Sarkozy, S.; Leong, K. M. K.; Logan, J. E.; Gorospe, B.; Kürner, T.: Interference Investigations of Active Communications and Passive Earth Exploration Services in the THz Frequency Range. IEEE Transactions on Terahertz Science and Technology, Vol. 2, No. 5, S. 525– 537, 2012.

Relation IEEE 802 / ITU-R

– IEEE 802 and ITU-R are exchanging informations –especially on operational characteristics- via liaison statements

DISCUSSION