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Horizon 2020

National Institute of Information and Communications Technology

A Perspective on Standards and Regulation on THz Communications

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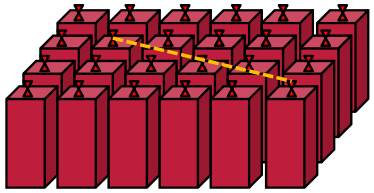
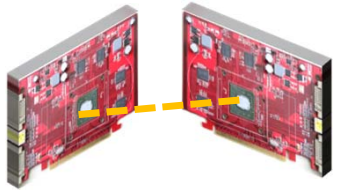
Agenda

1. Standardisation at IEEE 802
2. ThoR study „Initial results on sharing studies“ within the preparation of WRC 2019
3. Outcome and Consequences of WRC 2019
4. Next Steps in Standardsation
5. Conclusions

Standardisation Activities @ IEEE 802

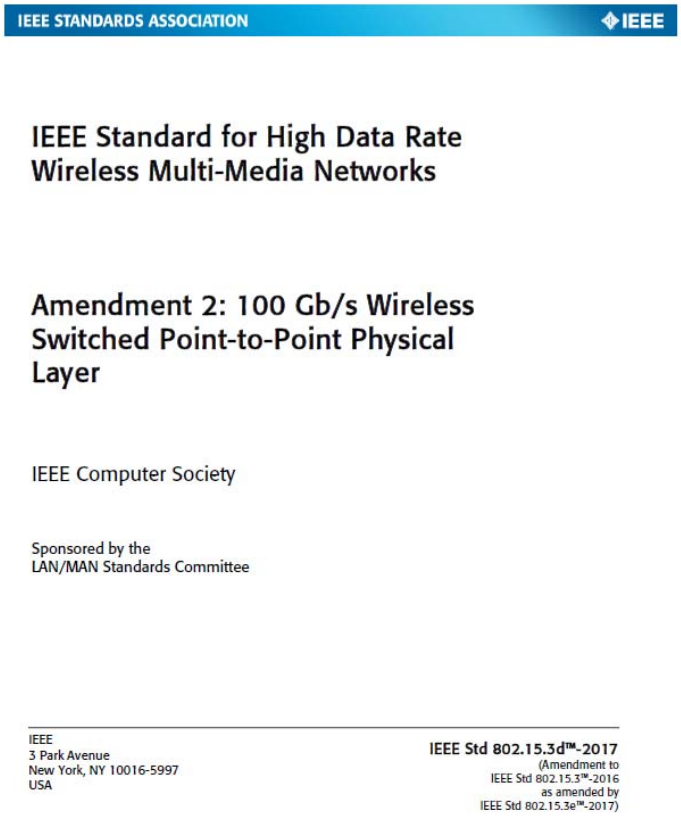
- The first project within IEEE 802 towards 100 Gbps has been approved in March 2014: Task Group IEEE 802.15.3d
- Scope of the project: *„This amendment defines a wireless switched point-to-point physical layer to IEEE Std. 802.15.3 operating at a nominal PHY data rate of 100 Gbps with fallbacks to lower 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."*
- Targeted applications:

- The standard IEEE 802.15.3d-2017 has been approved on 28th September 2017 and published on 12th October 2017 as the worldwide first wireless communications standard operating at the 300 GHz frequency range

Key facts of IEEE 802.15.3d-2017

- New PHY for Std. IEEE 802.15.3-2016
- MAC is mainly based on IEEE 802.15.3e-2017, which introduced the concept of „Pairnet“
  - Point-to-point nature with highly-directive antennas reduces the problem of interference and „fighting for access“
  - Positions of Tx and Rx antennas are known
- 8 different channel bandwidths (as multiples of 2.16 GHz)
- 2 PHY-modes (THz-SC PHY, THz-OOK-PHY) with 7 modulation schemes:
  - BPSK, QPSK, 8-PSK, 8-APSK, 16-QAM, 64 QAM, OOK
- 3 channel coding schemes:
  - 14/15-rate LDPC (1440,1344), 11/14-rate LDPC (1440,1056), 11/14-rate RS (240,224)-code.
- In the currently running revision project improvements wrt Interframe Spacing suggested by ThoR is considered


IEEE STANDARDS ASSOCIATION IEEE

IEEE Standard for High Data Rate Wireless Multi-Media Networks

Amendment 2: 100 Gb/s Wireless Switched Point-to-Point Physical Layer

IEEE Computer Society

Sponsored by the LAN/MAN Standards Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 802.15.3d™-2017
(Amendment to IEEE Std 802.15.3™-2016 as amended by IEEE Std 802.15.3e™-2017)

Starting point for Radio Regulations: Outcome of WRC 2012

5.565 A number of bands in the frequency range 275-1 000 GHz are identified for use by administrations for passive service applications. The following specific frequency bands are identified for measurements by passive services:

– radio astronomy service: 275-323 GHz, 327-371 GHz, 388-424 GHz, 426-442 GHz, 453- 510 GHz, 623-711 GHz, 795-909 GHz and 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.

Administrations wishing to make frequencies in the 275-1 000 GHz range available for active service applications are urged to take all practicable steps to protect these passive services from harmful interference until the date when the Table of Frequency Allocations is established in the above-mentioned 275-1 000 GHz frequency range.

All frequencies in the range 1 000-3 000 GHz may be used by both active and passive services. (WRC-12)

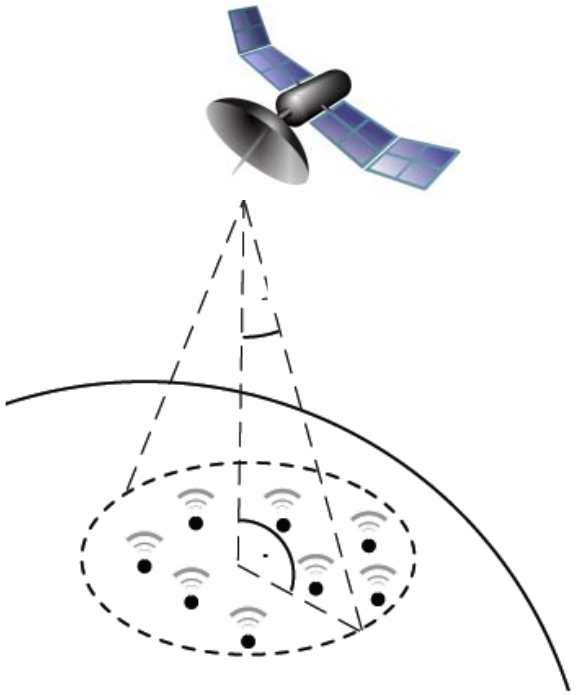
The use of the frequency band 275 to 450 GHz for mobile and fixed services was subject to WRC 2019 AI 1.15

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 in the existing footnote 5.565.

- Most importantly ITU-R has been invited to
  - study the technical and operational characteristics for the new active services and for existing passive services
  - determine the spectrum needs
  - conduct sharing studies with the passive services
  - identify candidate frequency bands

- Earth-Exploration Satellite Service (EESS) are seen as most critical
- Within the H2020-EU-Japan project ThoR sharing studies for Fixed Service and EESS have been performed (The results are available as Deliverable 5.1 at https://thorproject.eu/results/)



ThoR Sharing Study: System types in the EESS

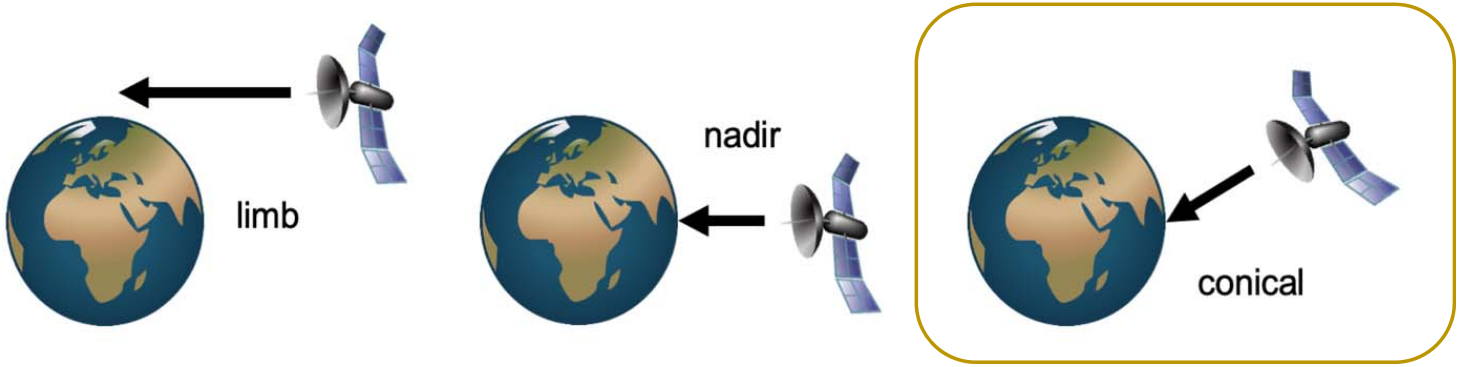


Table 3: Excerpt of the technical parameters of conical type EESS systems in the relevant bands.

EESS band no.	2	3	4	5	6	8	9
Band (GHz)	296-306	313-356	361-365	369-392	397-399	416-434	439-467
System	ICI	ICI	ICI	GOMAS	ICI	GOMAS	ICI
Altitude (km)	817	817	817	35684	817	35684	817
Nadir angle	45°	45°	45°	8.5°	45°	8.5°	45°
Elevation at the ground	25.7°	25.7°	25.7°	12.7°	25.7°	12.7°	25.7°
Max. antenna gain (dBi)	55	55	55	79	55	79	55
IFOV (km^2)	200	200	200	890	200	890	200

ThoR Sharing Study:
Technical Parameters for the Fixed Service

Table 1: Excerpt of the technical parameters of the fixed services from ITU-R F.2416 [3]

Frequency band	275-325 GHz	380-445 GHz
Antenna gain range	24 … 50 dBi	24 … 50 dBi
EIRP range	44 … 70 dBm	37 … 60 dBm
EIRP density range	30 … 67 dBm/GHz	19 … 57 dBm/GHz
Antenna pattern	Recommendation ITU-R F.699 (Single entry) Recommendation ITU-R F.1245 (Aggregate)	Recommendation ITU-R F.699 (Single entry) Recommendation ITU-R F.1245 (Aggregate)
Antenna type	Parabolic Reflector	Parabolic Reflector
Antenna height	6-25 m	10-25 m
Antenna elevation	±20° (typical)	±20° (typical)
Link length	100 … 300 m	100 … 300 m

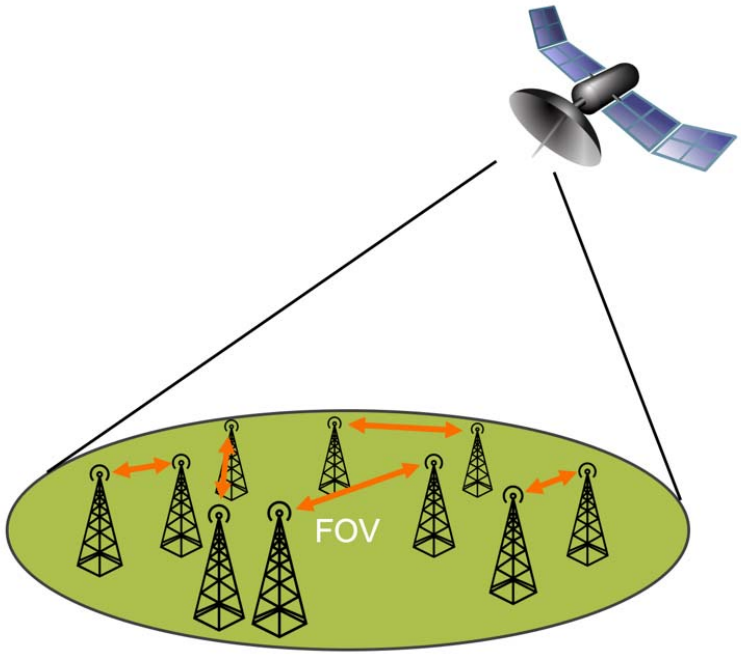
ThoR Sharing Study: Interference Criteria for EESS

Table 5: Excerpt from table "Interference criteria for satellite passive remote sensing up to 1 000 GHz" in ITU-R RS.2017 with the footnotes [7].

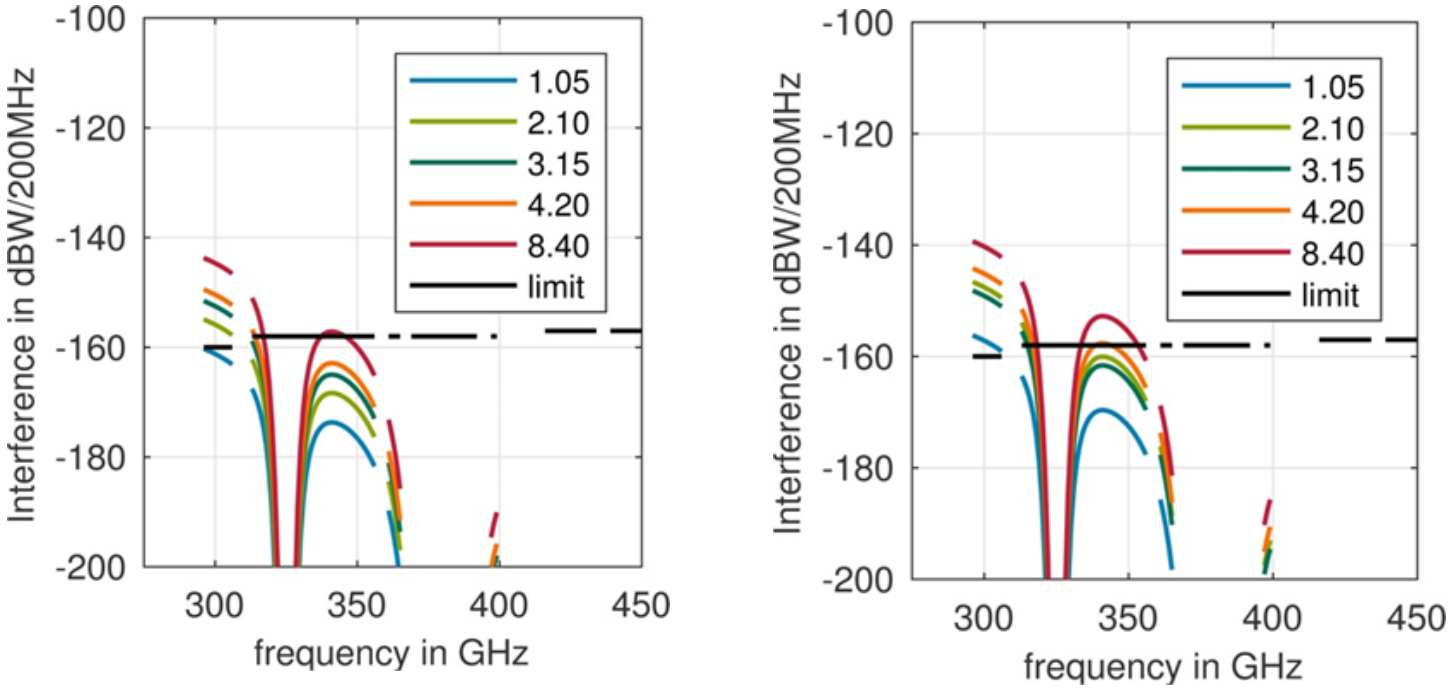
Frequency band(s) (GHz)	Reference bandwidth (MHz)	Maximum interference level (dBW)	Percentage of area or time permissible interference level may be exceeded[(1)] (%)	Scan mode (N, C, L)[(2)]
275-285.4	3	−194	1	L
296-306	200/3[(3)]	−160/−194[(3)]	0.01/1[(3)]	N, L
313.5-355.6	200/3[(3)]	−158/−194[(3)]	0.01/1[(3)]	N, C, L
361.2-365	200/3[(3)]	−158/−194[(3)]	0.01/1[(3)]	N, L
369.2-391.2	200/3[(3)]	−158/−194[(3)]	0.01/1[(3)]	N, L
397.2-399.2	200/3[(3)]	−158/−194[(3)]	0.01/1[(3)]	N, L
409-411	3	−194	1	L
416-433.46	200/3[(3)]	−157/−194[(3)]	0.01/1[(3)]	N, L
439.1-466.3	200/3[(3)]	−157/−194[(3)]	0.01/1[(3)]	N, C, L

ThoR Sharing Study:
Interference Scenario and Monte Carlo Simulation

- An Area is defined with the size of the FOV for the passive system type.
- A number of links is randomly deployed according to the link density for this iteration run.
- The position of the satellite is calculated according to its nadir angle and the altitude with an assumed azimuth of 0° relative to the middle of the FOV (Field of View).
- The slant path length and the elevation on earth from the middle of the FOV to the satellite are calculated.
- Path loss is calcuted according to ITU-R P.525 and ITU-R P.676



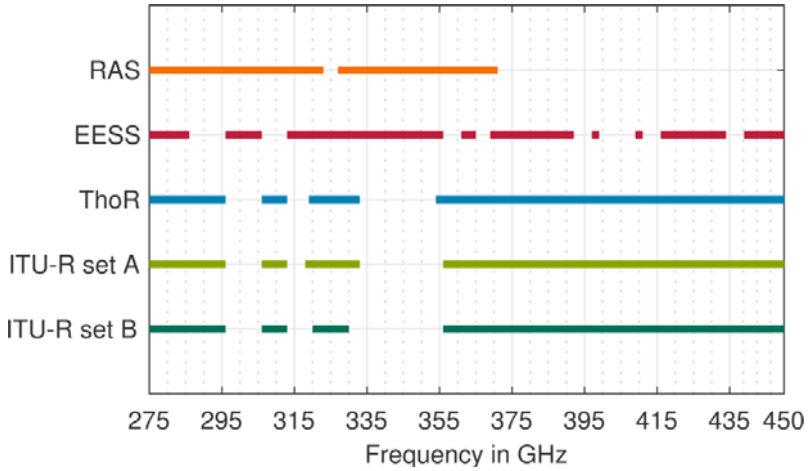
ThoR Sharing Study:
Interference Study Results for the ICI type Conical System



Maximum simulated interference power densities to an ICI type system for elevation angles between -20° and +20° (left) and -65° to 65° (right) for systems for several link densities (colour) in links-per-square kilometre (colour) and the maximum interference level to the EESS.

ThoR Sharing Study:
Brief Comparison with ITU-R Results

- Comparison of the simulation results with the EESS and RAS bands and with the summarized results discussed within ITU-R



	candidate band 1	candidate band 2	candidate band 3	candidate band 4
ThoR	275-296 GHz	306-313 GHz	319-333 GHz	354-450 GHz
ITU-R set A	275-296 GHz	306-313 GHz	318-333 GHz	356-450 GHz
ITU-R set B	275-296 GHz	306-313 GHz	320-330 GHz	356-450 GHz

Overview of the resulting candidate bands

Outcome of WRC 2019
Conditions for the Use of Spectrum for THz Communications

Frequency in GHz	Status in Radio Regulations
252-275	Allocation for land mobile and fixed service on a co-primary basis
275-296	Identification for use for the implementation of land mobile and fixed service according to FN 5.564A; no specific conditions are necessary to protect Earth exploration-satellite service (passive) applications
306-313	
318-333	
356-450	
296-306	may only be used by fixed and land mobile service applications when specific conditions to ensure the protection of Earth exploration-satellite service (passive) applications are determined in accordance with Resolution 731 (Rev.WRC-19).
313-318	
318-356	

- T. Kürner, A. Hirata, On the Impact of the Results of WRC 2019 on THz Communications, Proc. International Workshop on Mobile THz Systems, 2-3 July 2020
- World Radiocommunication Conference 2019 (WRC-19) Final Acts; [online]: https://www.itu.int/dms_pub/itu-r/opb/act/R-ACT-WRC.14-2019-PDF-E.pdf

A sound Regulatory Framework

The outcome of WRC 2019 provides a sound regulatory framework for the implementation of future THz communication systems in the frequency band 252 to 450 GHz.

Within this band, four contiguous bands with bandwidths of

- 44 GHz (between 252 and 296 GHz),
- 7 GHz (between 306 and 313 GHz),
- 15 GHz (between 318 and 333 GHz) and
- 94 GHz (between 356 and 450 GHz)

are available for almost unrestricted use by THz Communications.

Longterm Activites towards WRC 2027

- The use of the identified bands for land mobile service and fixed service does not preclude the use of the bands by other application or radio service:
  - Such services are for example radar or imaging applications.
  - With its resolution, COM6/19 (WRC-19) has defined a preliminary agenda for the WRC 2027, on the identification of spectrum for radio location applications in frequency bands in the range 275-700 GHz for millimetre and sub-millimetre wave imaging systems.
  - The potential agenda item at WRC 2027 on the identification of spectrum for radio location applications in the range 275-700 GHz will require sharing studies with THz communications as the incumbent application.
- This may trigger another potential regulatory activity towards WRC 2027.

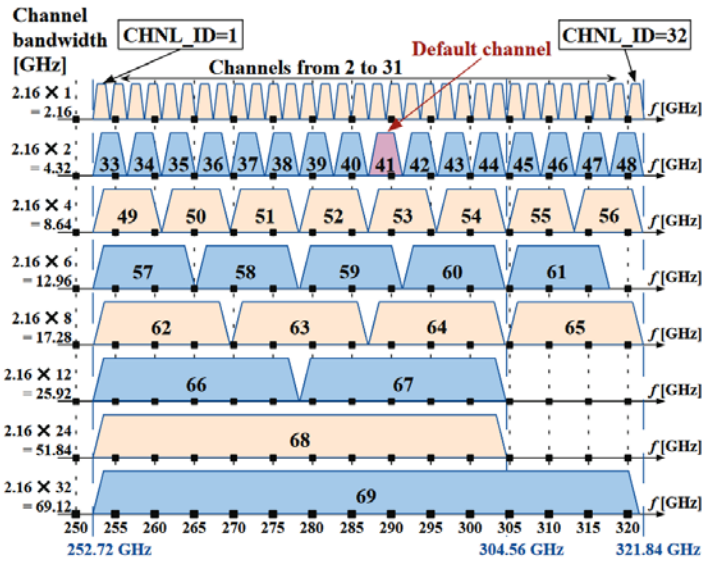
Consequences wrt IEEE 802.15.3d

- The current IEEE Std. 802.15.3d-2017 covers the frequency bands 252 to 321 GHz.

- Thereof, two potential (future) activities have been identified in the context of this standard:

  - The continuing use of the frequency bands 296-306 GHz and 313-318 GHz by this standard will be possible, if additional sharing studies in accordance with Resolution 731 (Rev.WRC-19) show that no harmful interference to EESS occurs. This may trigger a potential regulatory activity towards future WRCs.

  - In order to make use of the large chunk of spectrum between 356 GHz and 450 GHz, this will be considered in the ongoing revision project IEEE P802.15 TG3ma.



From: V. Petrov, T. Kurner and I. Hosako, "IEEE 802.15.3d: First Standardization Efforts for Sub-Terahertz Band Communications toward 6G," in IEEE Communications Magazine, vol. 58, no. 11, pp. 28-33, November 2020, doi: 10.1109/MCOM.001.2000273.

Conclusions

- The regulatory situation for THz Communication in the frequency range 275-450 GHz has been described.
- WRC 2019 has added a new footnote to the radio regulations, which describes the conditions for the use of the spectrum between 275 and 450 GHz by land mobile and fixed services.
- Totally, 160 GHz of spectrum are now available for THz communications, where no specific conditions are necessary to protect EESS.
- This includes two big contiguous spectrum bands with 44 GHz and 94 GHz bandwidth, respectively.
- IEEE 802 Std 15.3 is currently being revised allowing the inclusion of new identified frequency bands

This provides a sound basis for the future implementation of THz communications. Still, a couple of future regulatory and standardization activities have been identified.

Thank you for your attention!

ご清聴ありがとうございました

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