This project is co-funded by

Horizon 2020

National Institute of Information and Communications Technology

Standards Aspects of THz communications

Second Towards TeraHertz Communications Workshop
Brussels, 7 March 2019
Thomas Kürner, TU Braunschweig, ThoR Project Coordinator (EU)

Outline

1. Scope of this talk
2. Standardisation Activities @IEEE 802
3. Preparation of WRC 2019
4. ThoR study „Initial results on sharing studies“
5. Conclusions

Scope of this Talk

- This presentation is intended to provide very brief information on ongoing and completed activities in standardisation and regulation for THz Communications

- Standardisation at IEEE 802:
  - A first standard for frequencies in the bands 252 to 325 GHz has been published
  - Work continues in IEEE 802.15 Techncial Advisory Group THz
  - Both activities have been lead by Thomas Kürner (TU Braunschweig) as Chair of IEEE 802.15 TG3d and IEEE 802.15 TAG THz

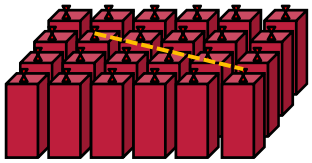
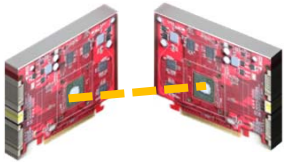
- Regulation (WRC 2019):
  - At the upcoming WRC the frequency band between 275 GHz and 450 GHz is considered by a specific agenda item AI 1.15 for land-mobile and fixed service
  - Regulators are currently in the preparatory phase
  - Coordinator for AI 1.15 in Germany and Europe (CEPT) has been Sebastian Rey (TU Braunschweig)
  - ThoR has conducted a sharing study wrt AI 1.15

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."*

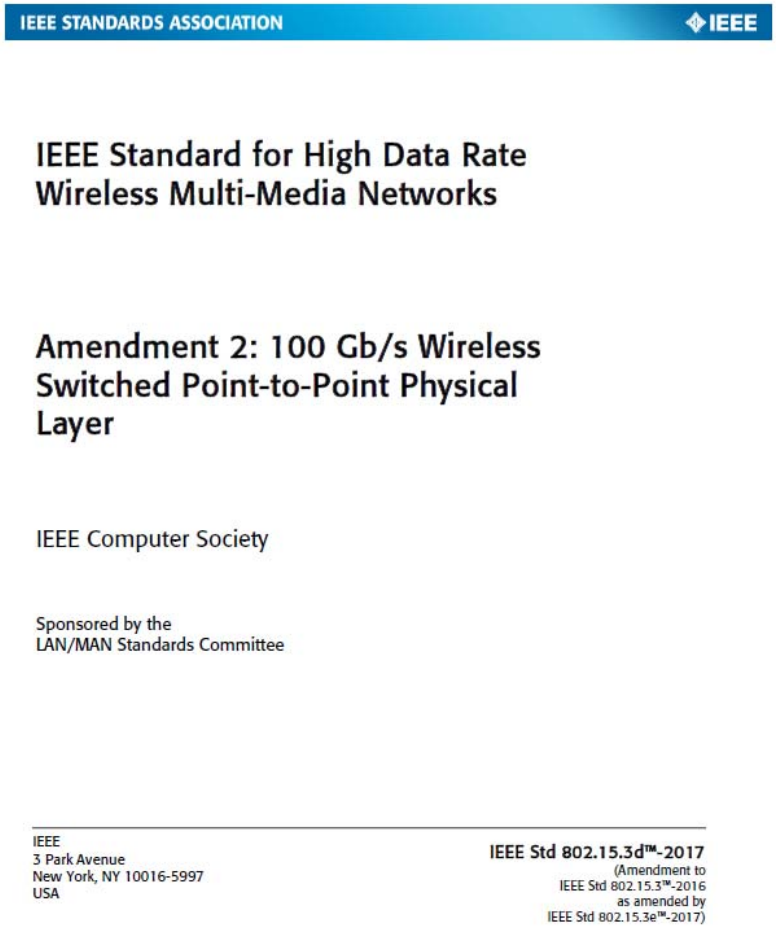
- Targeted applications:


- The standard IEEE 802.15.3d-2017 has been approved on 28th September 2017 and published on 12th October 2018 as the worldwide first wireless communications standard operating at the 300 GHz frequency range

Key facts of IEEE 802.15.3d

- 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.


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)

Current THz-related Activities in IEEE 802

- IEEE 802.15 TG THz:
  - is monitoring the progress in the area of THz communications in regard to the possibility of establishing future Study Groups with applications different from the scope of Std. IEEE 802.15.3d-2017, for example WLAN-type of applications requiring beam steering or advanced methods for device discovery.
  - is interacting in the WRC 2019 process e.g. by participation in drafting liaison statements between IEEE 802 and ITU-R.
  - may trigger a further amendment of the standard depending on the outcome of WRC 2019
  - Two meetings per year

- IEEE P802.1ACct
  - The small project IEEE P802.1Acct on proper interface definitions has been defined as a joint activity of IEEE 802 WGs 1 and 15
  - Goal of this project is to amend IEEE Std. 802.1AC wrt the definitions required to bridge the LANs with the IEEE Std. 802.15.3™-2016.
  - This will enable bridging in data centers for IEEE 802.15.3 standards

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.

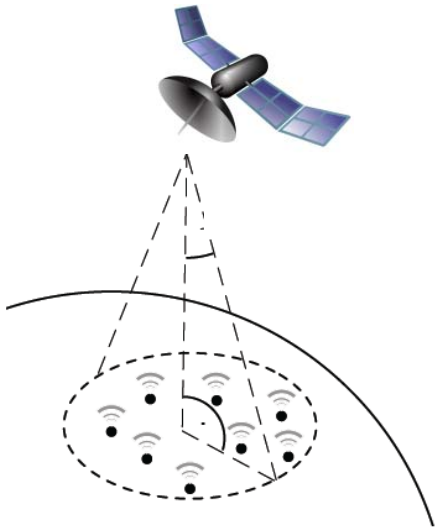
Administrations wishing to make frequencies in the 275-1 000 GHz range available for active service applications are urged to take all practicable steps to protect these passive services from harmful interference until the date when the Table of Frequency Allocations is established in the above-mentioned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

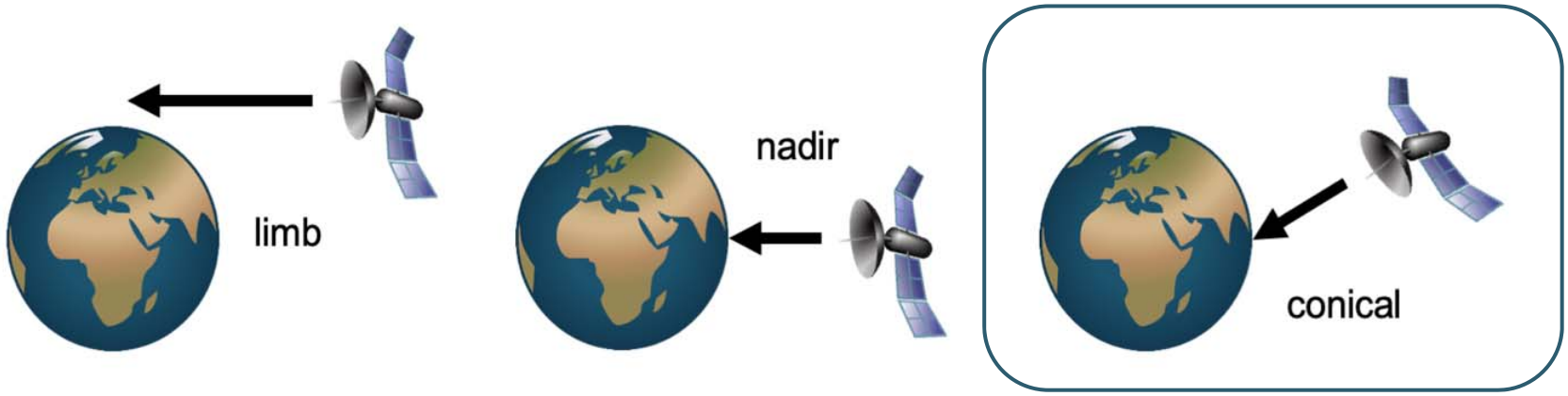


Table 3: Excerpt of the technical parameters of conical type EESS systems in the relevant bands.

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

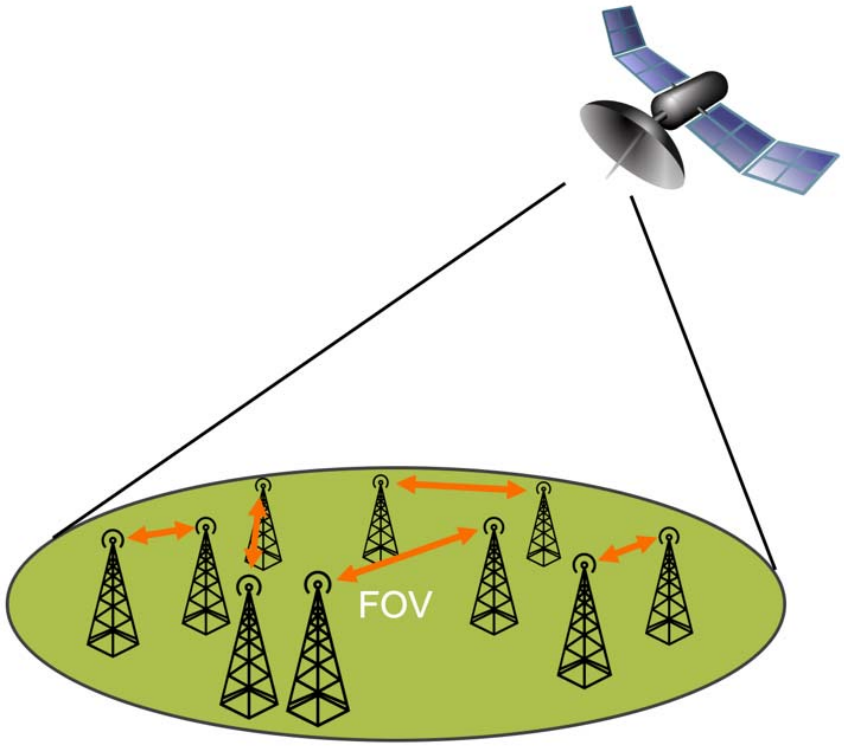
ThoR Sharing Study: Interference Criteria for EESS

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].

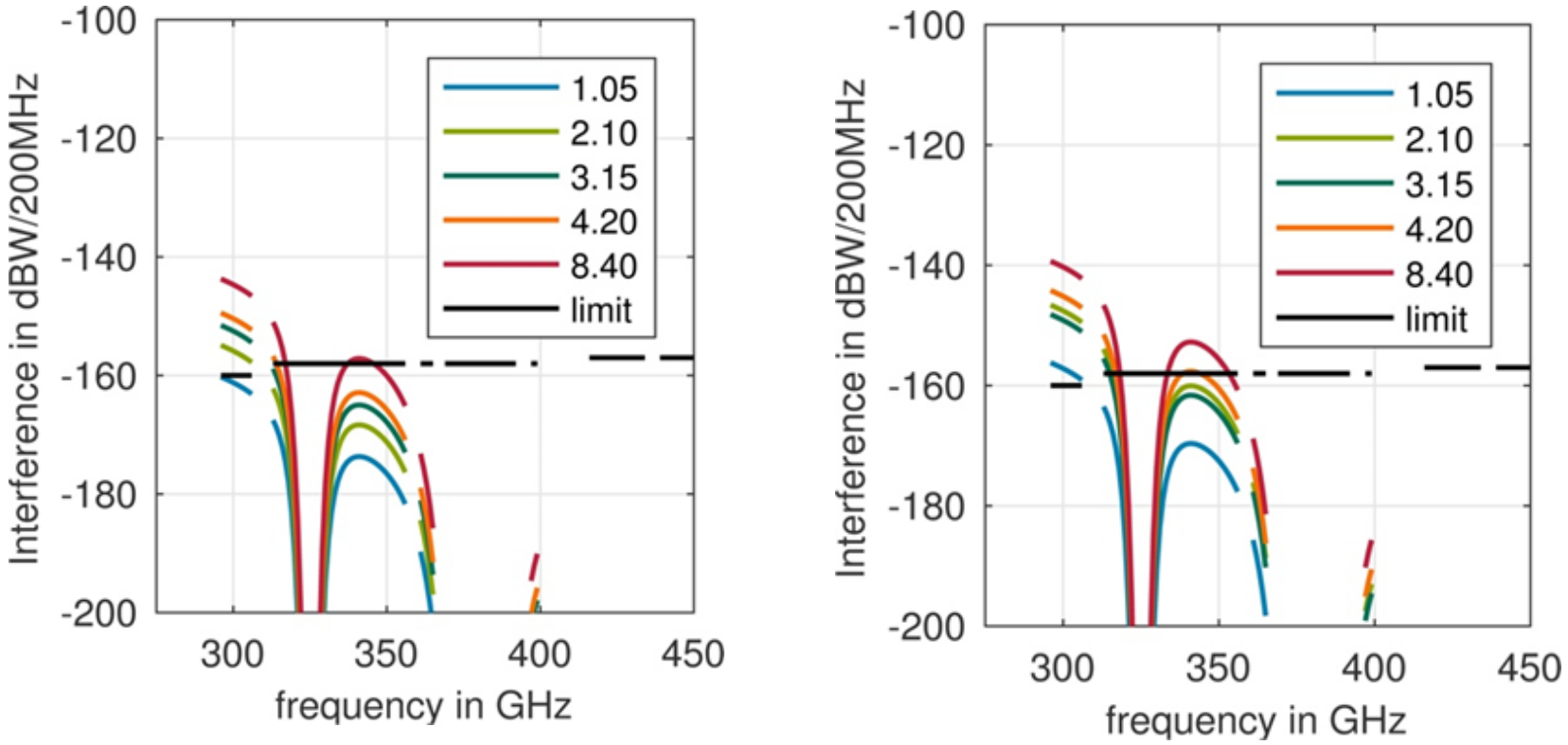
Frequency band(s) (GHz)	Reference bandwidth (MHz)	Maximum interference level (dBW)	Percentage of area or time permissible interference level may be exceeded[1] (%)	Scan mode (N, C, L)[2]
275-285.4	3	−194	1	L
296-306	200/3[3]	−160/−194[3]	0.01/1[3]	N, L
313.5-355.6	200/3[3]	−158/−194[3]	0.01/1[3]	N, C, 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



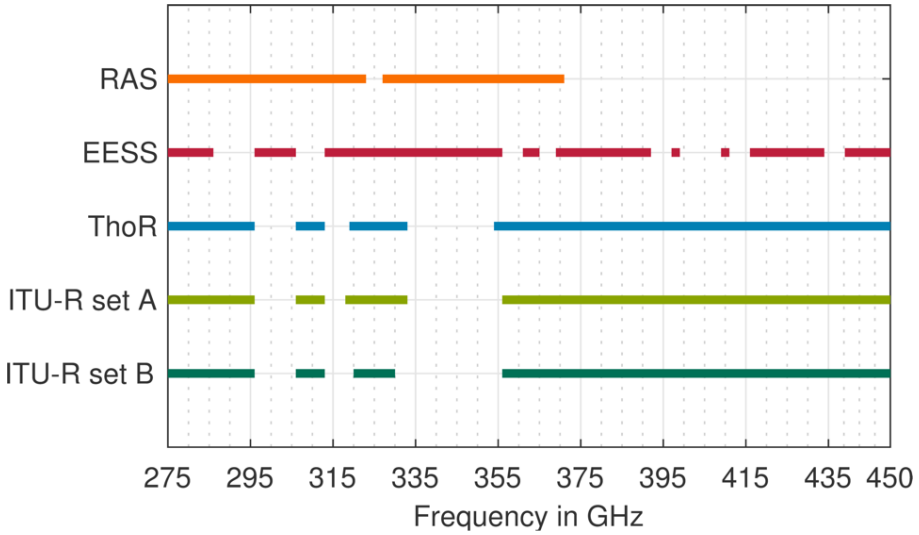
ThoR Sharing Study:
Interference Study Results for the ICI type Conical System



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

Conclusions

- With IEEE Std. 802.15.3d a first wireless communications standard at 300 GHz for a limited number of applications is available
- Further amendements for other applications and/or enhancements for transmission systems may be developed
- At WRC 2019 the identification of spectrum in the range 275 GHz to 450 GHz under AI 1.15 will provide a reliable basis for the availabilty of spectrum for future THz communication sytems
- ThoR has performed a sharing study investigating sharing of spectrum between Fixed Service and Earth Exploartion Satellite Service.
- Most likely the outcome of WRC 2019 will require an amendment of IEEE Std. 802.15.3d to handle the potentially changed availability of currently standardised frequency bands below 320 GHz and potentially new frequency bands between 320 GHz and 450 GHz

Thank you for your attention!

ご清聴ありがとうございました

For any enquiries please contact:

Bruce Napier; Vivid Components

bruce@vividcomponents.co.uk

This project has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation, under grant agreement No. 814523. ThoR has also received funding from the National Institute of Information and Communications Technology in Japan (NICT).

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