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

Submission Title: ThoR: Initial Results on Sharing Studies
Date Submitted: 9 March 2019
Source: Thomas Kürner (Editor) **Company:** TU Braunschweig, Institut für Nachrichtentechnik
Address: Schleinitzstr. 22, D-38092 Braunschweig, Germany
Voice: +49 531 391-2416 FAX: +49 531 391-5192, E-Mail: t.kuerner@tu-bs.de
Re: n/a
Abstract: This document presents initial results on sharing studies between Fixed Service and Earth Exploration Satellite Service (EESS) wrt Agenda Item 1.15 of WRC-2019 carried out in the EU-Japan Horizon 2020 project ThoR.

Purpose: Information of the Technical Advisory Group THz

ThoR: Intial Results on Sharing Studies

Sebastian Rey, Thomas Kürner

Technische Universität Braunschweig
Institut für Nachrichtentechnik
Germany

This document is based on Deliverable D5.1 of the Horizon 2020 EU-Japan-Project ThoR ("Terahertz end-to-end wireless systems supporting ultra-high data Rate applications")
online available https://thorproject.eu/results/

Outline

- Motivation
- Operational and Technical Characteristics of the Fixed Service and Earth Exploration-Satellite Service
- Interference Scenario and Simulation Setup
- Results
- Conclusions

Motivation

- The Horizon 2020 EU-Japan Project ThoR (‚THz end-to-end wireless systems supporting ultra-high data Rate applications‘) is working towards a demonstrator based on IEEE Std. 802.15.3d-2017 (see also www.thorproject.eu and doc.: IEEE 802.15-18-00518-00-0thz_EU-Japan-Project-ThoR)

- Among others will work on interference mitigation techniques and planning rules to enable deployment of 300 GHz Point-to-Point links, which comply with the outcome of the Word Radiocommunication Conference 2019 (WRC-19)

- As part of these activities ThoR carried out sharing studies between the fixed service (FS) and the passive Earth Exploration-Satellite Service (EESS) in preparation of Agenda Item 1.15 (AI 1.15) WRC 2019

Starting point: Radio Regulations after 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)" from the Radio Regulations Ed. of 2016

Activities for the Frequency Band 275-450 GHz at 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 the active land mobile and fixed 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 the existing passive services
  - determine the spectrum needs
  - conduct sharing studies with the passive services
  - identify candidate frequency bands
- Within the H2020-EU-Japan project ThoR sharing studies have been performed [1] between the Fixed Service (FS) and
  - the Earth Exploration-Satellite Services which is regarded as most critical
  - Results are presented on the following slides

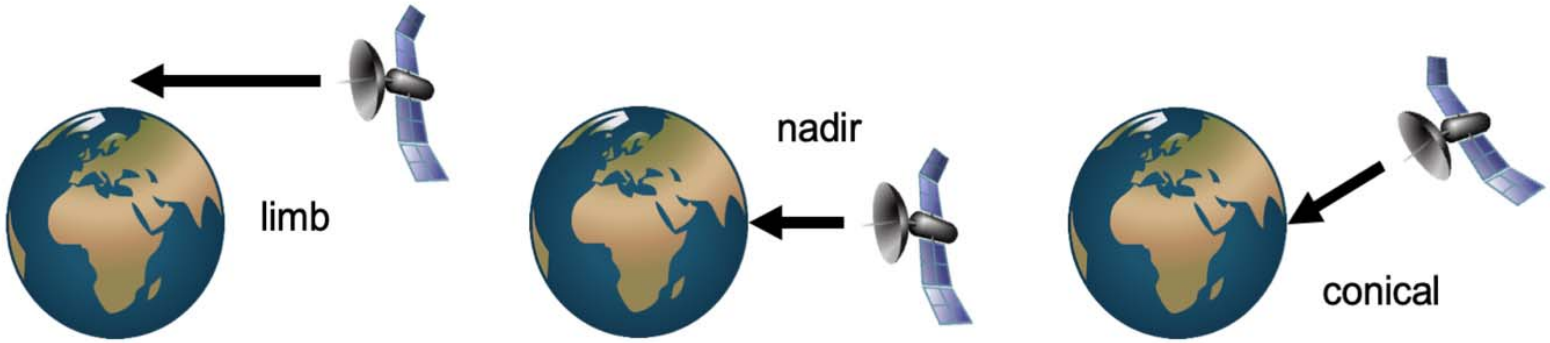
Operational and Technical Characteristics of Fixed Services

Excerpt of the technical parameters of the fixed service from ITU-R F.2416 [2]

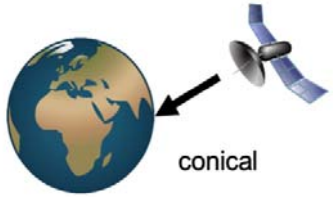
Frequency band	275-325 GHz	380-445 GHz
Antenna gain range	24 … 50 dBi	24 … 50 dBi
EIRP range	44 … 70 dBm	37 … 60 dBm
EIRP density range	30 … 67 dBm/GHz	19 … 57 dBm/GHz
Antenna pattern	Recommendation ITU-R F.699 (Single entry) Recommendation ITU-R F.1245 (Aggregate)	Recommendation ITU-R F.699 (Single 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

- Typical link density of 4.2 links-per-square kilometre
- spectrum need of 50 GHz for the FS, can also operate in between the two bands
- parameters are partly based on and in line with IEEE 802.15.3d-2017.

System Types in the passive Earth Exploration-Satellite Services (EESS)



Technical parameters of concial systems

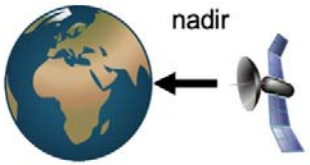


Excerpt of the technical parameters of conical type EESS systems in the relevant bands, based on the new Report ITU-R RS.[275-450 GHZ CHARS]

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

IFOV: Instantaneous Field of View

Technical parameters of nadir systems

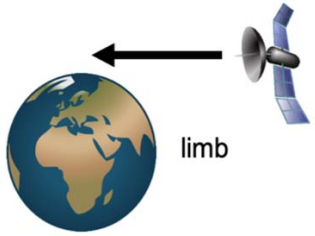


Excerpt of the technical parameters of nadir type EESS systems in the relevant bands, based on the new Report ITU-R RS.[275-450 GHZ CHARS]

EESS band no.	3	9
Band	313-356 GHz	439-467 GHz
System	Generic nadir	Generic nadir
Altitude	817 km	817km
Elevation at Ground	90°	90°
Max. Antenna Gain	55 dBi	55 dBi
IFOV	30 km^2	30 km^2

IFOV: Instantaneous Field of View

Technical parameters of limb systems



Excerpt of the technical parameters of limb type EESS systems in the relevant bands, based on the new Report ITU-R RS.[275-450 GHZ CHARS]

EESS Band No.	1	2	3	4	5	6	7	8	9
Band (GHz)	275-286	296-306	313-356	361-365	369-392	397-399	409-411	416-434	439-467
System	STEAMR	MASTER	MASTER	STEAMR	STEAMR	STEAMR	STEAMR	STEAMR	STEAMR
Altitude (km)	817	817	817	817	817	817	817	817	817
Min. Pointing Altitude (km)	6	3	3	6	6	6	6	6	6
Max. Antenna Gain (dBi)	70	80	80	70	70	70	70	70	70
IFOV (km^2)	5 x 2.5	2.3 x 4.6	2.3 x 4.6	5 x 2.5	5 x 2.5	5 x 2.5	5 x 2.5	5 x 2.5	5 x 2.5

Interference criteria of the EESS

Excerpt from the table „Interference criteria for satellite passive remote sensing up to 1000 GHz“ in ITU-R RS.2017 [3]

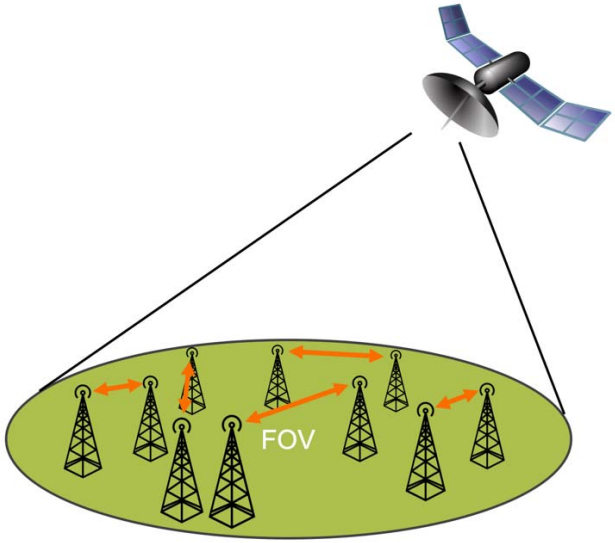
Frequency band(s) (GHz)	Reference bandwidth (MHz)	Maximum interference level (dBW)	Percentage of area or time permissible interference level may be exceeded[1] (%)	Scan mode (N, C, L)[2]
275-285.4	3	−194	1	L
296-306	200/3[3]	−160/−194[3]	0.01/1[3]	N, L
313.5-355.6	200/3[3]	−158/−194[3]	0.01/1[3]	N, C,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

Reduced by 3dB for the studies related to the fixed service since the land mobile service may operate simultaneously in the same bands.

Interference Scenarios and Simulation Setup

Algorithm (Monte Carlo Simulation)

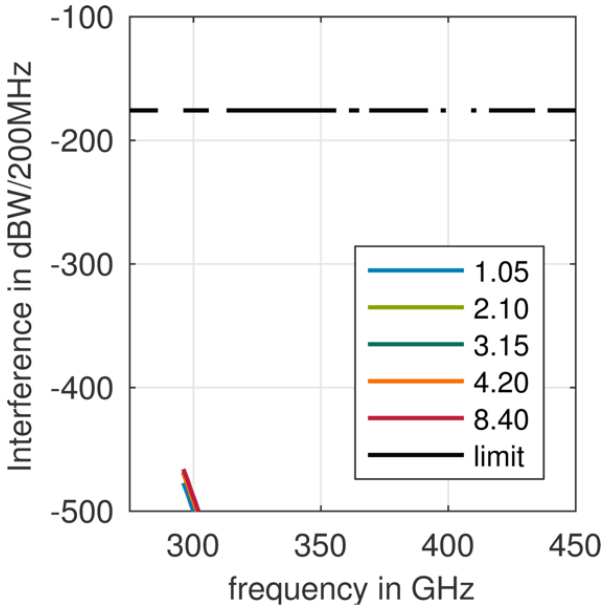
- For each passive **service type**
  - For several **link densities**
    - For different **elevation angle** distributions of the FS
      - For each of **10,000 iterations** in each band
        - The size of the instantaneous Field of View (FOV) is defined according to the passive system type
        - Links are randomly deployed (direction, power, antenna gain, …) in the FOV
        - position of the satellite is calculated according to its nadir angle and the altitude relative to the middle of the FOV
        - The total interference to the satellite is calculated according to the slant path length
      - Result: **Maximum interference power to the satellite** of all iterations



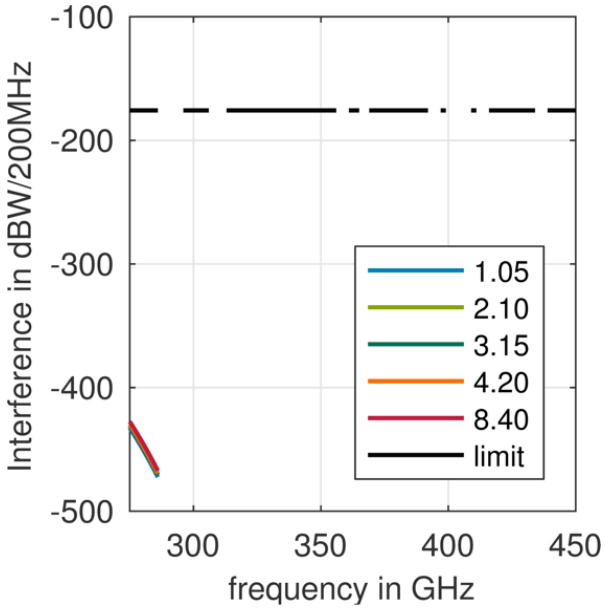
(Free space and atmospheric path loss are calculated according to ITU-R P.525 and ITU-R P.676)

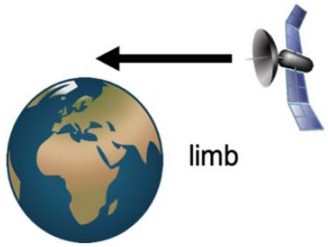
Max. interference to limb systems

MASTER, FS elevation +/-20 deg.



STEAMR, FS elevation +/-20 deg.

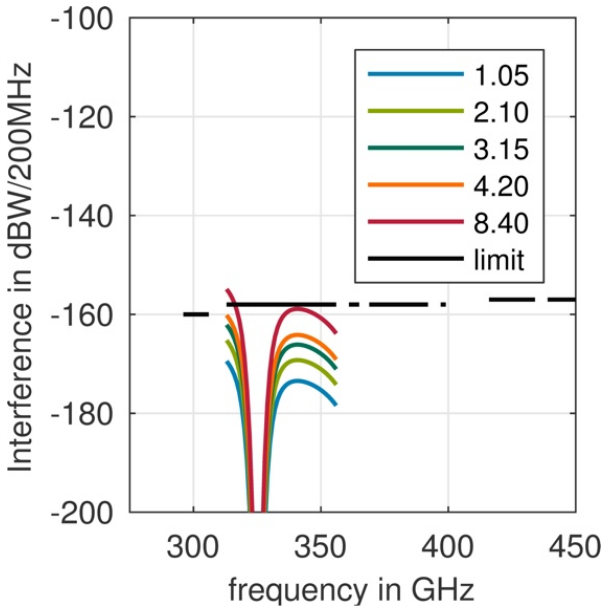




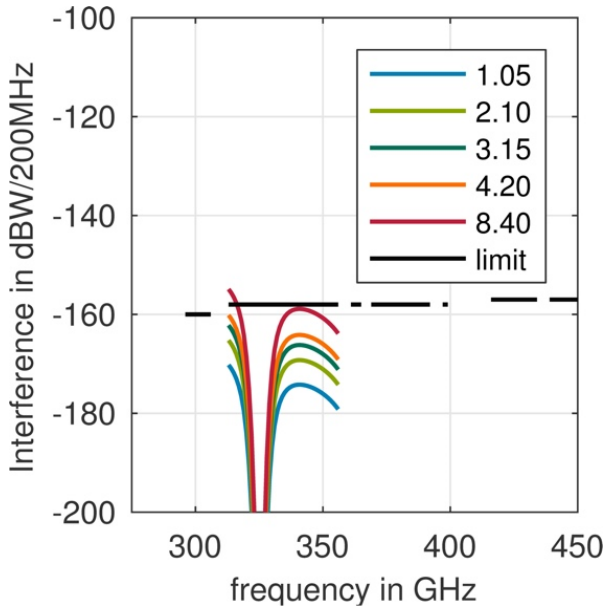
Maximum interference level for several link densities in links-per-square kilometre (different colours) and limit from ITU-R RS.2017 reduced by 3 dB taking the simultaneously operating land mobile service into account (black)

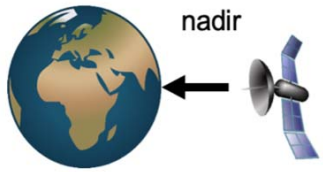
Max. interference to nadir systems

elevation +/-20 deg.



elevation +/-65* deg.



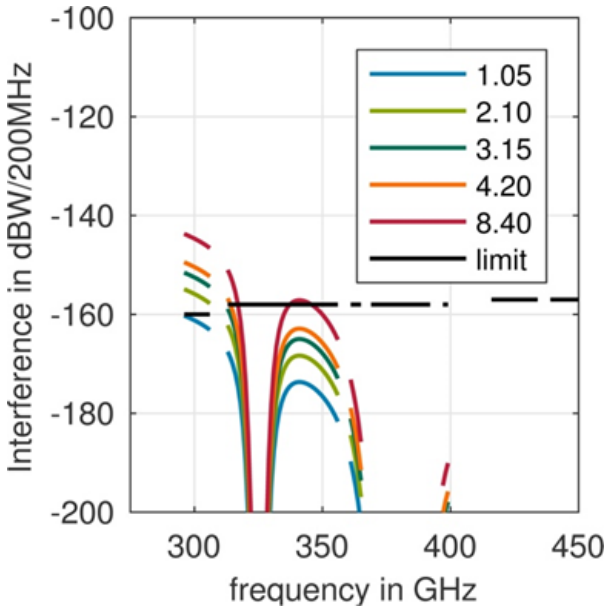


* For 98% one end of a link has an elevation equally distributed between 0-+20 deg. whereas for 2% it is between 20-65 deg. (negative value on the other end)

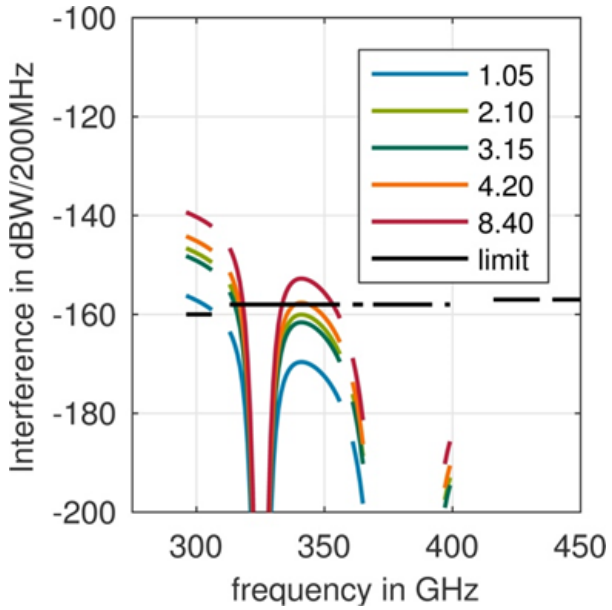
Maximum interference level for several link densities in links-per-square kilometre (different colours) and limit from ITU-R RS.2017 reduced by 3 dB taking the simultaneously operating land mobile service into account (black)

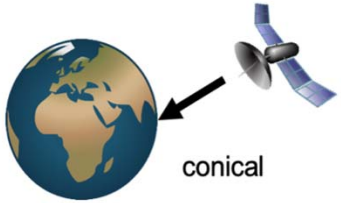
Max. interference to ICI systems

elevation +/-20 deg.



elevation +/-65* deg.



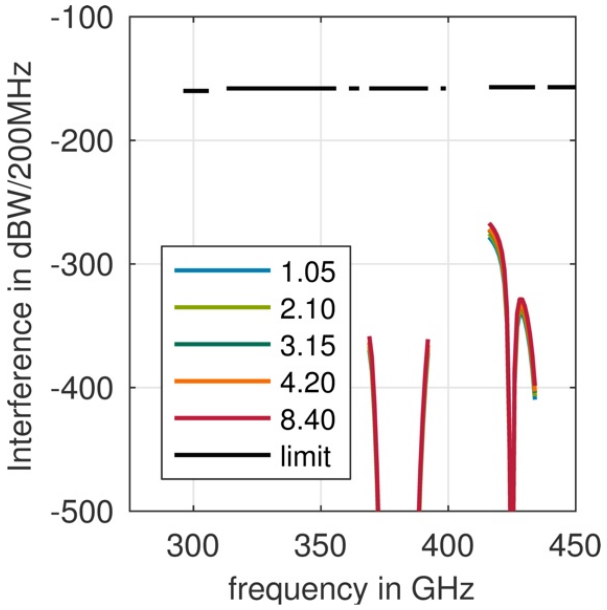


* For 98% one end of a link has an elevation equally distributed between 0-+20 deg. whereas for 2% it is between 20-65 deg. (negative value on the other end)

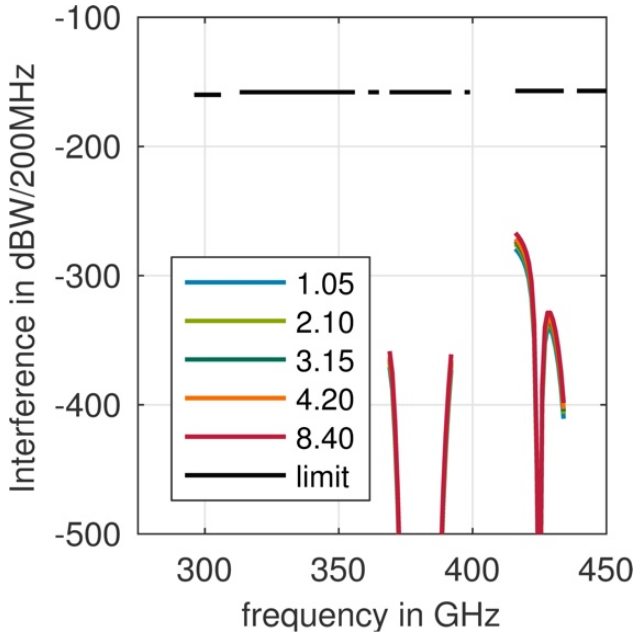
Maximum interference level for several link densities in links-per-square kilometre (different colours) and limit from ITU-R RS.2017 reduced by 3 dB taking the simultaneously operating land mobile service into account (black)

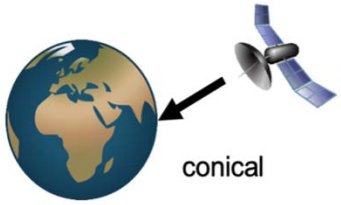
Max. interference to GOMAS systems

elevation +/-20 deg.



elevation +/-65* deg.





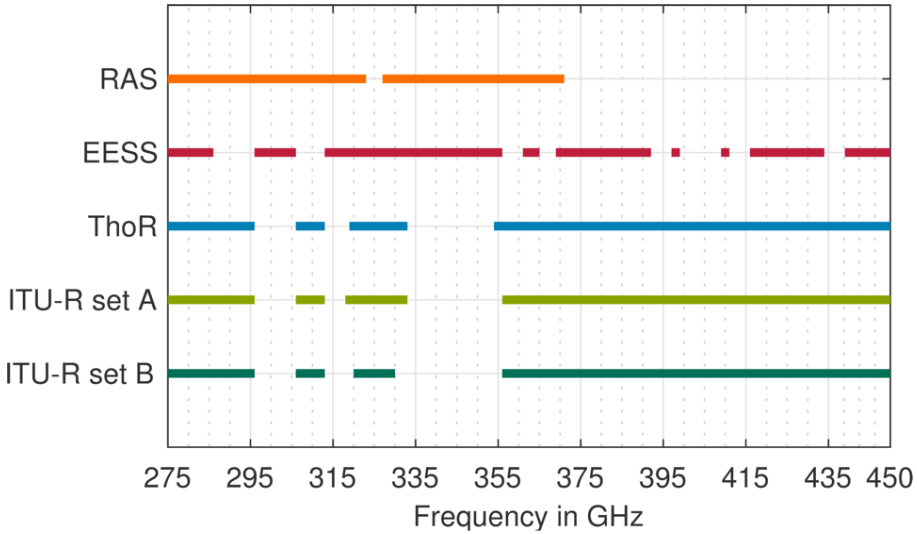
* For 98% one end of a link has an elevation equally distributed between 0-+20 deg. whereas for 2% it is between 20-65 deg. (negative value on the other end)

Maximum interference level for several link densities in links-per-square kilometre (different colours) and limit from ITU-R RS.2017 reduced by 3 dB taking the simultaneously operating land mobile service into account (black)

Brief comparison with ITU-R results

Comparison of

- simulation results
- EESS bands
- Radio Astronomy Service (RAS) bands
- summarized results discussed within ITU-R (before the CPM-2 meeting in March 2019)



Overview of the resulting candidate bands

	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

Conclusions

- The relevant parameters of the active and passive services within the frequency range 275-450 GHz have been reviewed.
- A simulation setup is described and the results of simulations are evaluated in regards to the possible sharing between the fixed service and the EESS.
- Even when land mobile systems operate in this frequency range at the same time, the bands 275-296 GHz, 306-313 GHz, 319-333 GHz and 354-450 GHz can be identified to the fixed service according to this study without any restrictions and without harmful interference to the EESS.
- The spectrum need of 50 GHz for the fixed service is overachieved by these bands. Even with the spectrum need of 50 GHz for the land mobile service (which may overlap the fixed service) the spectrum needs of a maximum of 100 GHz are met.

References

[1] S. Rey, „Initial results on sharing studies, ThoR Deliverable D5.1,“ [Online]. Available at https://thorproject.eu/results/

[2] ITU-R, „Report ITU-R F.2416: Technical and operational characteristics and applications of the point-to-point fixed service applications operating in the frequency band 275-450 GHz,“ [Online]. Available: https://www.itu.int/pub/R-REP-F.2416.

[3] ITU-R, „Recommendation ITU-R RS.2017: Performance and interference criteria for satellite passive remote sensing,“ [Online]. Available: https://www.itu.int/rec/R-REC-RS.2017/en.

The ThoR 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).