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Terahertz end-to-end wireless systems supporting ultra-high data Rate applications

ThoR

Deliverable D5.1

Initial results on sharing studies

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Contents

Change register

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1. Statement of independence

The work described in this document is genuinely a result of efforts pertaining to the ThoR project. Any external source is properly referenced.

Confirmation by Authors: Sebastian Rey Technische Universität Braunschweig

2. Abbreviations

FS	Fixed Service
LMS	Land mobile service
IMT	International Mobile Telecommunications
ITU-R	International Telecommunication Union - Radiocommunication Sector
EESS	Earth exploration-satellite service (passive)
EIRP	Equivalent isotropic radiated power
AI 1.15	Planned Agenda Item 1.15 of WRC-19
WRC-19	World Radiocommunication Conference 2019
MIMO	Multiple-input and Multiple-output
mmWave	millimetre-wave
PDF	Probability Distribution Function
FOV	Field-Of-View

3. Executive summary

This deliverable provides the results of simulations which show that the frequency bands 275-296 GHz, 306-313 GHz, 319-333 GHz and 354-450 GHz could be identified for fixed services (future wireless front- and backhaul) without harmful interfering with the passive Earth exploration-satellite service (EESS).

The World Radiocommunication Conference 2012 (WRC-12) revised footnote No. 5.565of the Radio Regulations [1], which identifies frequency bands for the use by passive services Though the current regulatory provisions already allow for active (communication) services in the frequency range 275-1000 GHz, each national radio administration has to decide what the “all practical steps” [1] are to protect the identified Earth exploration-satellite and the Radio-Astronomy bands. In a worst-case scenario this could lead to different decisions in different countries.

Under Agenda Item 1.15, the World Radiocommunication Conference 2019 (WRC-19) is evaluating the possibility to identify frequency bands in the range 275 to 450 GHz for the fixed service and land mobile service with a minimum of restrictions. Such an identification will enable future wireless front- and backhaul links with data rates beyond 100 Gbit/s with a bandwidth in the order of 50 GHz and will enable parts of the backbone of future International Mobile Telecommunications (IMT).

Within this document the relevant parameters of the active and passive services within the frequency range 275-450 GHz are reviewed. A simulation setup is described and the results of simulations are evaluated in regards to the possible sharing even when also land mobile systems operate in this frequency range. As a result, the bands 275-296 GHz, 306-313 GHz, 319-333 GHz and 354-450 GHz can be identified according to this study.

The comparison with other International Telecommunication Union - Radiocommunication Sector (ITU-R) studies presents slightly differences which are due to different simulation methods and different assumed distributions of the elevation angle for the fixed service. As a result, the maximum bands that can be shared, without any restrictions to the fixed service in regards to the EESS, are: 275-296 GHz, 306-313 GHz, 318-333 GHz and 356-450 GHz. The total bandwidth is 137 GHz and it is well exceeding the estimated spectrum needs of 50 GHz. With the existing allocation of 252-275 GHz for fixed services, a consecutive band of 44 GHz is available even at the lower frequency end.

4. Introduction

The ever-increasing demand for higher data transfer rates in up- and down-link for each device in a cellular network leads to huge aggregated data rates, especially in cities [2]. For the access network – the connection from a base station to a (mobile) device – several solutions are investigated like Multiple-Input and Multiple-Output (MIMO) or an increased bandwidth in the millimetre-wave (mmWave) range. These solutions all have in common that a large number of closer spaced base stations with a very limited range are required. This trend is also known as "densification".

For the backhaul of these new cells only a limited amount of solutions exists:

- Connect a new cell via a fibre
- Connect a new cell via a radio link

A fibre connection will probably not be feasible everywhere either for financial or practical reasons like timing issues or problems with the trench work. Existing radio solutions are limited to a few Gigabit-per-second and will hardly be able to cope with the increased traffic. Since almost all possible frequencies up to 100 GHz are currently under review for 5G, it is unlikely that backhaul links will get wider bandwidths in this frequency range.

Terahertz (THz) communications, also called sub-mm communications, operates in the frequency range from around 300 GHz to 3 THz. Currently, this frequency range is not allocated and only used for research purposed considering active communications. With huge bandwidths and by nature very limited transmission distances (e.g. up to 300 m with directive antennas), THz links are a very promising solution for these short range backhaul links. Nevertheless, there are passive services operating in this frequency range providing valuable insights e.g. in the composition of earth's atmosphere or in the universe. These services, identified in Footnote 5.565 of the Radio Regulations, must be protected from harmful interference.

Active communications above 275 GHz are tolerated but it is up to each national radio administration if they allow for it or not. Since the technology has evolved to a level of maturity where active communication is possible, the agenda item 1.15 of the next World Radiocommunication Conference 2019 (WRC-19) seeks for a global allowance of these active services by identifying suitable bands in the range 275 to 450 GHz that can be shared with the passive services.

This deliverable provides additional sharing studies between the fixed service (FS, front-/backhaul links) and the passive Earth exploration-satellite service (EESS). In the following chapters an overview of the current regulatory situation and the upcoming agenda item (AI) 1.15 of WRC-19 is provided. Then the relevant technical and operational characteristics of the FS and the EESS are reviewed. After a description of the simulation scenario and methodology the results are presented and evaluated in reference to other existing studies.

5. Overview of the current Regulatory Situation and WRC-19 Agenda Item 1.15

5.1. Current regulator situation for THz communications

Frequencies above 275 GHz are currently identified by footnote No. 5.565 in the radio regulations:

"**5.565** 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 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)" [1]

Huge data rates in the THz range are enabled by bandwidths of several ten gigahertz. Obviously, sharing studies with the passive services are required since the bands in between the passive ones are insufficient. In addition, according to the radio regulations every single administration may allow the use of the 275-1000 GHz range while taking all practical steps to protect the passive services. This is a requirement without clear guidance how the protection should be implemented. Taking everything into account, active communication is already possible under the current regulation but may face different requirements in each country.

5.2. Scope WRC 2019 Agenda Item 1.15

The World Radiocommunication Conference 2015 decided in Resolution 767 to have Agenda Item 1.15 which is considering the identification of frequency bands in the range 275-450 GHz for the land mobile and the fixed services. The agenda item is a result of previous studies that acknowledged the technological feasibility of and interest in THz communications.

Most importantly, ITU-R has been invited to study …

- … the technical and operational characteristics of the land mobile and the fixed services, as well as, the spectrum needs.
- … sharing and compatibility between the land mobile, fixed and passive services in the 275-450 GHz range, while maintaining protection of the passive services already identified in footnote No. 5.565 in the radio regulations.

The first task has been finished and the results are briefly reviewed in Chapter 6.1. For the second task additional studies are performed within the ThoR project and initial results are presented in this deliverable. The intent is to find frequency bands for which a minimum of restrictions is required for the fixed services to be compatible with the passive services. The studies performed will provide clear guidance to administrations beyond WRC-19 what “all practical steps for the protection of the passive services” means.

6. Review of the active and passive services characteristics

6.1. Operational and technical characteristics of the active services and the fixed service in particular

Front- and backhaul links (Fixed Service, FS) and their characteristics in the frequency range 275-450 GHz have been studied by ITU-R Working Party 5C and the results are summarized in the adopted report ITU-R F.2416 [3]. An excerpt of the relevant parameters for the simulations is summarized in Table 1. The band 330-370 GHz is also considered to be suitable for fixed services with identical parameters.

The report also summarizes various other parameters like e.g. the modulation schemes but these are not relevant for the simulations. The height of the antennas will be neglected in the simulations since they are small compared to the slant paths of more than 100 km to the satellites. The spectrum need is estimated to be about 25 GHz in the near future and 50 GHz for a longer-term evolution. Based on a calculation in the report ITU-R F.2416 [3], the envisaged link density is 4.2 links-per-square meter.

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

For the land mobile service, which is out of scope of the ThoR project, ITU-R Working Party 5A developed report ITU-R M.2417 [4]. Only two things are worth mentioning: The land mobile service is operating in the same frequency range as the fixed services. The spectrum need has also been evaluated as 50 GHz which can overlap with the fixed services.

6.2. Characteristics and maximum interference levels of the passive services

The already existing sharing studies for the Radio Astronomy Service (RAS) indicate that sharing will be possible though for each RAS site some minimum separation distances and avoidance angles may be necessary to avoid harmful interference, c.f. preliminary draft new report ITU-R SM.[275-450GHZ SHARING] [5]. Since this is a highly localized issue, the sharing studies within the ThoR project focus on the globally operating Earth exploration-satellite service (EESS).

For the EESS, three different kinds of operation are possible, namely limb, nadir and conical, c.f. Figure 1. For a limb system the antenna of the satellite is aligned tangential to earth's surface. For a nadir type sensor, the path from the satellite is perpendicular to earth's surface while in a conical system the satellite is receiving data from the atmosphere at a certain angle. Of course, this is a simplified overview. In reality the antenna may change its pointing angle in a regular pattern to investigate different parts of earth's atmosphere for instances.

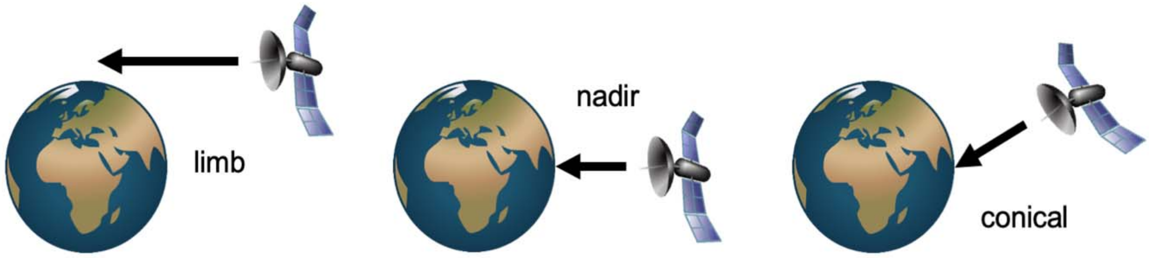

Figure 1: System types in the EESS

Plenty of systems of these three types are deployed or are scheduled for launch in the very near future. The characteristics have been compiled by ITU-R Working Party 7C (WP 7C) the new Report ITU-R RS.[275-450 GHZ CHARS] [6], which has not yet been published but WP 7C submitted the information to WP 1A for the inclusion in the preliminary draft new report ITU-R SM.[275-450GHZ SHARING] [5]. This report has been amended by further input contributions. For the simulations, parameters from both documents have been extracted and are summarized in the following.

For nadir type sensors there is only one set of parameters for the two bands in which they operate, c.f. Table 2.

Table 2: Excerpt of the technical parameters of nadir type EESS systems in the relevant bands.

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

For conical sensors there are two different sets of parameters to be taken into consideration as summarized in Table 3.

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

For limb sounders the relevant parameters are included in Table 4. In total two sets of parameters exist again for all the bands. Though the antenna is directed rather tangential to earth's surface for this type, the maximum antenna gain is used in the simulations, because the angle towards the earth is just less than one degree.

Table 4: Excerpt of the technical parameters of limb type EESS systems in the relevant bands.

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

Finally, the maximum interference levels for the passive service bands are defined in Recommendation ITU-R RS.2017 [7]and the relevant bands are cited in Table 5.

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

(1) For a 0.01% level, the measurement area is a square on the Earth of 2 000 000 km^2, unless otherwise justified; for a 0.1% level, the measurement area is a square on the Earth of 10 000 000 km^2 unless otherwise justified; for a 1% level, the measurement time is 24 h, unless otherwise justified.

(2) N: Nadir, Nadir scan modes concentrate on sounding or viewing the Earth’s surface at angles of nearly perpendicular incidence. The scan terminates at the surface or at various levels in the atmosphere according to the weighting functions. L: Limb, Limb scan modes view the atmosphere “on edge” and terminate in space rather than at the surface, and accordingly are weighted zero at the surface and maximum at the tangent point height. C: Conical, Conical scan modes view the Earth’s surface by rotating the antenna at an offset angle from the nadir direction.

(3) First number for nadir or conical scanning modes and second number for microwave limb sounding applications.

7. Relevant propagation models

For sharing studies, several propagation phenomena and models have been discussed in the involved ITU-R Working Parties 1A, 3J, 3J, 5A, 5C, namely

- Free space pathloss, Recommendation ITU-R P.525 [8]
- Attenuation due to absorption by atmospheric gasses, Recommendation ITU-R P.676 [9]
- Clutter loss (Recommendation ITU-R P.2108 [10]) will not be considered for the highly directive front-/backhaul links).
- Building Entry loss (Recommendation ITU-R P.2109 [11]) will not be considered for outdoor links.

In general, the building entry loss suffers from an unknown Probability Distribution Function (PDF) of the loss in the frequency range 275 to 450 GHz. Therefore, the temporal or aerial permissible exceedance of the interference level according to Table 5 may not be used.

Scattering loss may be useful when studying the impact of one link to another but for the slant path to a satellite, scattering from buildings is not expected.

Overall the propagation models relevant for the interference studies are the ones for free space path loss (ITU-R P.525, Annex 1 for Point-to-point links) [8] and the atmospheric path loss (ITU-R P.676, Slant path (Earth-space) attenuation in Annex 1) [9]. For a global assessment the “Mean annual global reference atmosphere” defined in Recommendation ITU-R P.835 is applied.

8. Interference Scenarios and Simulation Setup

8.1. Description of the interference scenario

The simulations for all the parameter sets of the three types of sensors follow all the same methodology. The simulations are performed for a varying link density and two different elevation angle distributions. For each case, a Monte-Carlo simulation with 10,000 iterations is performed by the algorithm described in section 8.2 for the full frequency range 275-450 GHz. In general, the simulation is based on the calculation of the total interference power received by an EESS satellite from all (for the studies randomly placed) front- and backhaul-links within it's Field-Of-View (FOV), c.f. Figure 2.

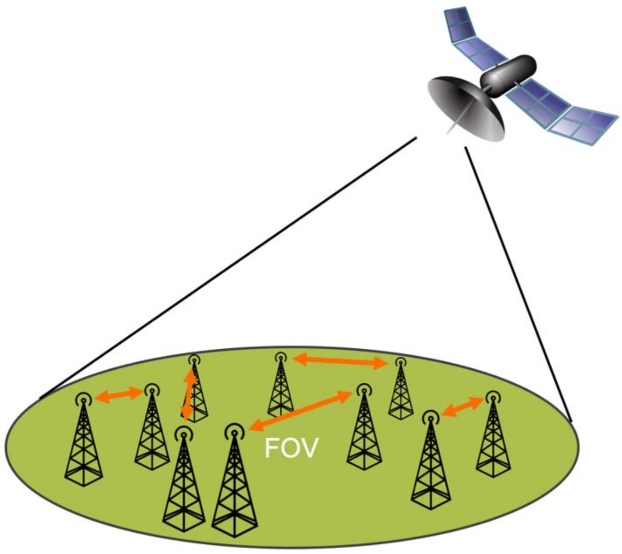

Figure 2: Illustration of an EESS satellite's Field-Of-View (FOV) with several front- and/or backhaul links in sight.

8.2. Simulation Algorithm

The following algorithm is applied to calculate the total interference power towards the EESS satellite for each of the iterations in the Monte Carlo simulation.

1. An Area is defined with the size of the FOV for the passive system type.
2. A number of links is randomly deployed according to the link density for this iteration run. The following parameters are randomly chosen:
    a. Centre position of the link (equal distribution in x and y)
    b. Elevation of one side of the link (distributions see below)
    c. Azimuth of this side of the link (equal distribution between (0°;360°))
    d. EIRP density (equal distribution between 30 and 67 dBm/GHz), $P_{eirp,dBW/200MHz}$
    e. Antenna gain (equal distribution between 24 and 50 dBi)
3. For the other end of each link
    a. the elevation is the negative value of the elevation which has randomly been chosen
    b. the azimuth is accordingly in the opposite direction
4. 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
5. The slant path length and the elevation on earth from the middle of the FOV to the satellite are calculated

6. The free space pathloss and the atmospheric attenuation are calculated according to the slant path length and the elevation on earth L_{fsl} (according to ITU-R P.525) and $L_{atmospheric}$ (according to ITU-R P.676), c.f. chapter 7
7. For each link the effective gain on both ends is determined by the angle between the direction of the link and the direction towards the satellite, $G_{eff,1}$ and $G_{eff,2}$
8. The total interference $P_{interference,dBW/200MHz}$ is calculated according to

$$P_{interference,dBW/200MHz} = \left(G_{eff,1} + G_{eff,2}\right) \cdot L_{fsl} \cdot L_{atmospheric} \cdot P_{eirp,dBW/200MHz}$$

In the parameters for the fixed service, the typical elevation angle is defined as the range 0 to +20° for one end of the link (negative value at the other end). Nevertheless, this does not mean, that higher (and lower) elevation angles are not permitted. Therefore, two distributions are considered in this study:

1. Equal distribution of the elevation in the interval $(0°; 20°)$
2. For 98% of the links, the distribution of the elevation is equal to case 1. For the other 2% of the links, the elevation is equally distributed in the interval $(20°; 65°)$

9. Interference Study Results

In the following, the results of the Monte Carlo simulations are presented. For each frequency, the maximum interference power density is presented to evaluate the sharing possibilities. The link density is chosen as 25%, 50%, 75%, 100% and 200% of the expected 4.2 links-per-square-kilometre.

9.1. Limb systems

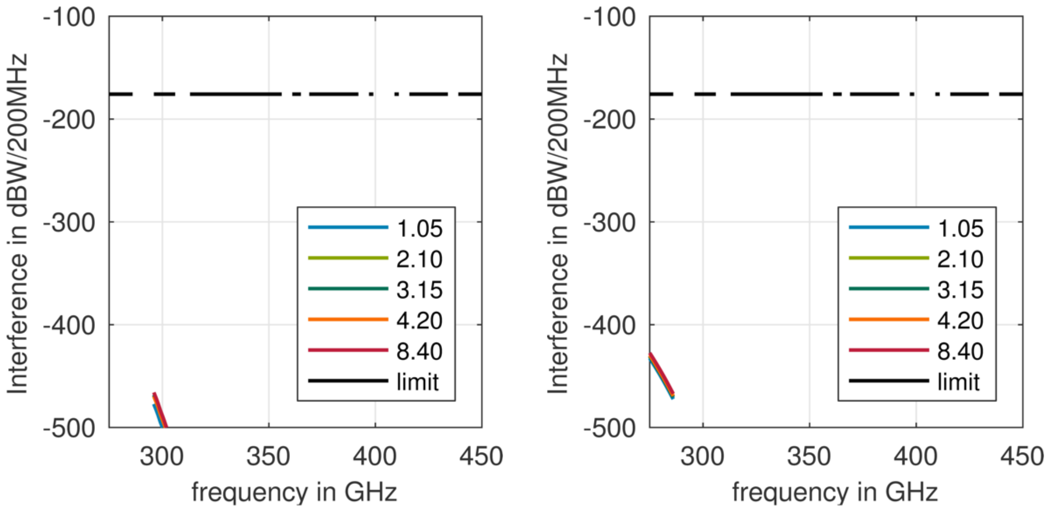

Figure 3: Maximum simulated interference power density for elevation angles between -20° and +20° for the MASTER (left) and the STEAMR (right) system for several link densities in links-per-square kilometre (colour) and the maximum interference level to the EESS.

For the limb sounders, the maximum interference power density is illustrated in Figure 3 for elevation angles between -20° and +20°. Obviously, the interference is by far below the allowable limit. For elevation angles up to 65° the interference power is slightly lower and thus not depicted.

As a result, sharing between limb sounders and the proposed fixed services is possible in the whole frequency range 275 to 450 GHz.

9.2. Nadir systems

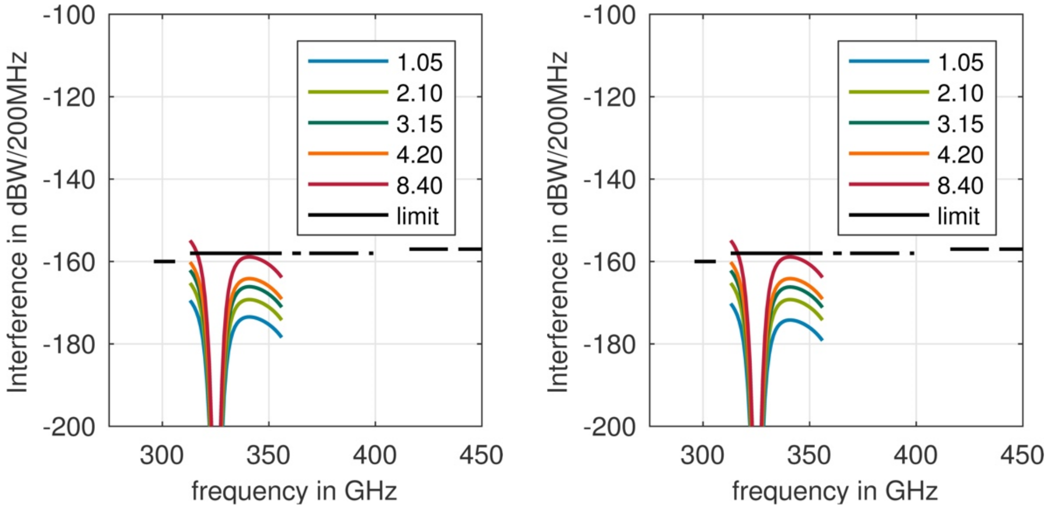

Figure 4: Maximum simulated interference power densities to a nadir type system for elevation angles between -20° and +20° (left) and -65° to 65° (right) for systems for several link densities (colour) in links-per-square kilometre (colour) and the maximum interference level to the EESS.

For Nadir type systems the maximum interference is depicted in Figure 4. Between 313 and 317 GHz, the interference exceeds the allowable limit for 200% of the expected link density. While this at a first glance would allow for sharing, it should not be used because the land mobile services can operate in the same bands at the same time. Therefore, a safety factor of two should be considered so that the 200% case is limiting the possibility for sharing here.

9.3. Conical systems

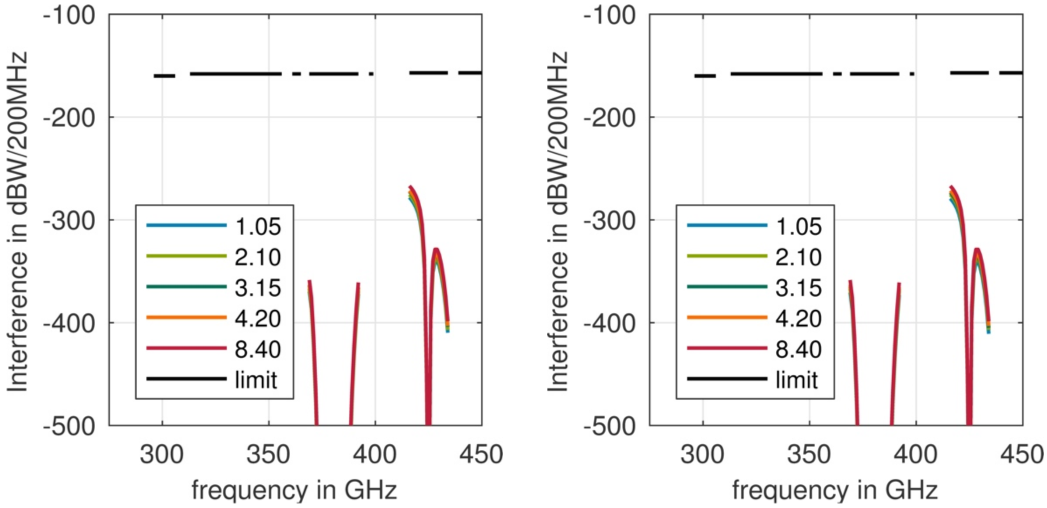

Figure 5: Maximum simulated interference power densities to a GOMAS type system for elevation angles between -20° and +20° (left) and -65° to 65° (right) for systems for several link densities (colour) in links-per-square kilometre (colour) and the maximum interference level to the EESS.

For GOMAS type systems the maximum interference power density is illustrated in Figure 5. Over the full frequency range the interference is not exceeding the maximum limit. For ICI type systems the interference power is depicted in Figure 6, and it changes noticeable for the different elevation angle distributions. Obviously, the band 296 to 306 GHz may not be made available to the fixed services since the limit is exceeded by far. Also, for the frequency range 313 to 319 GHz the interference is exceeding the limit. In the frequency range 333 to 354 GHz, the limit is exceeded for simulations with 200% of the expected link density. Anyway, since the land mobile service may be used in the same frequency range at the same time, this frequency range should also not be made available to the fixed service.

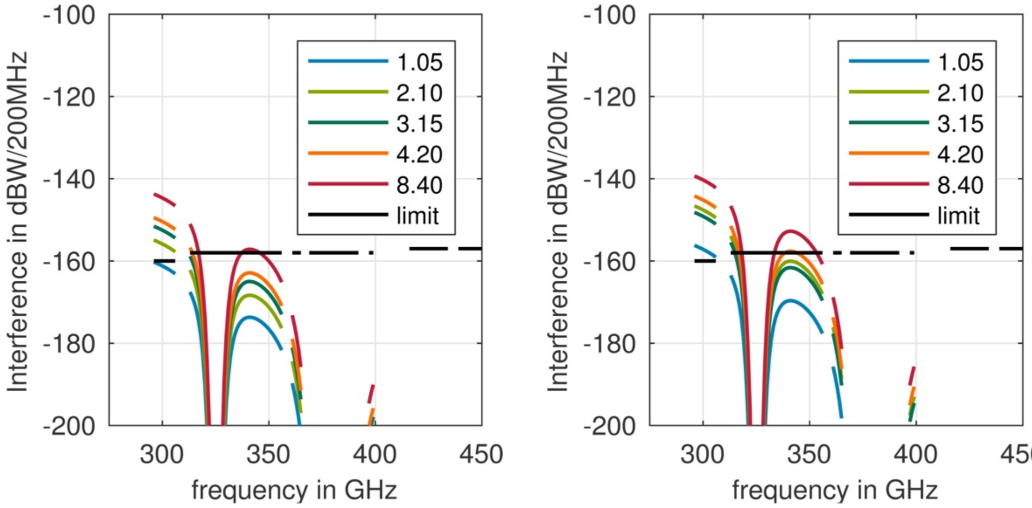

Figure 6: Maximum simulated interference power densities to an ICI type system for elevation angles between -20° and +20° (left) and -65° to 65° (right) for systems for several link densities (colour) in links-per-square kilometre (colour) and the maximum interference level to the EESS.

9.4. Summary

For limb sounders, sharing with the fixed service is possible in the whole frequency range 275 to 450 GHz. The range 313 and 317 GHz should be excluded for nadir type systems, because the interference level is too high. In addition, the interference level is also exceeded for conical systems in the ranges 296 to 306 and 313 to 319 GHz, 333 to 354 GHz in the presence of land mobile systems.

Taking everything into account, the following bands can be shared between the passive EESS and the fixed service according to the simulation results presented:

275-296 GHz, 306-313 GHz, 319-333 GHz and 354-450 GHz.

10. Brief comparison with ITU-R results

In Figure 7 the simulation results and the bands of the passive EESS and RAS are illustrated. From the sharing studies included in the preliminary draft new report ITU-R SM.[275-450GHZ SHARING] [5], two possible sets of candidate bands can be deduced. These two are named ITU-R set A and ITU-R set B in the following. The exact frequencies of the bands are also summarized in Table 6.

In general, there is a great overlap in the results. Three differences can be observed. For the third candidate band, the lower frequency varies between 318, 319 and 320 GHz while the upper frequency is 333 or 330 GHz. In the studies resulting in 320 and 330 GHz the passive bands have been considered as whole, while in the other studies a closer look inside the band was taken. Finally, the start of the last band between 354 and 356 GHz is likely a difference because of different simulation methodologies and other assumed elevation angle distributions.

In total a minimum of 132 GHz and a maximum of 137 GHz can be made available to the fixed service according to the ITU-R studies. The simulations presented here closely match the results with 138 GHz. The difference to this study is likely linked to different assumptions in the unknown elevation distribution of the fixed service.

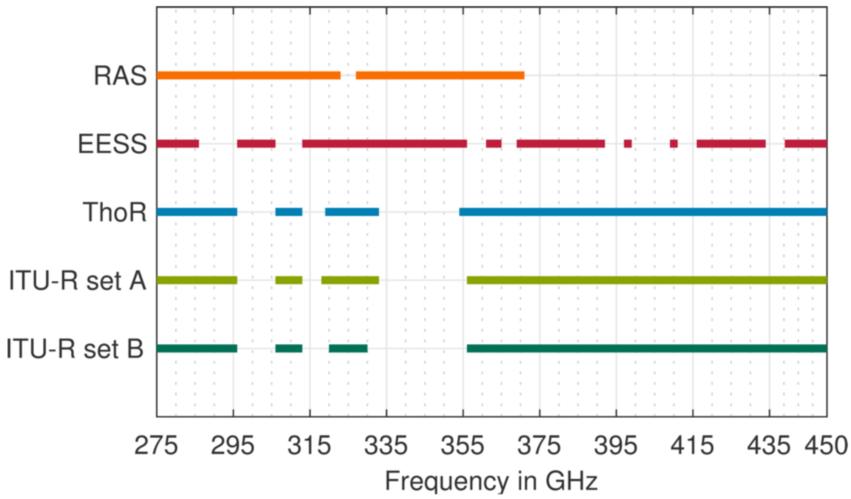

Figure 7: Comparison of the simulation results with the EESS and RAS bands and with the summarized results discussed within ITU-R

Table 6: 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

11. Conclusion

In this document, 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 according to this study without restrictions and without harmful interference to the EESS.

The comparison with other ITU-R studies presents small differences which are due to different simulation methods and different assumed distributions of the elevation angle for the fixed service. As a result, the maximum bands that can be shared, without any restrictions to the fixed service in regards to the EESS, are: 275-296 GHz, 306-313 GHz, 318-333 GHz and 356-450 GHz. This is a total of 137 GHz and well exceeding the estimated spectrum needs of 50 GHz. With the existing allocation of 252-275 GHz for fixed services, a consecutive band of 44 GHz is available even at the lower frequency end.

12. References

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