ETSI GR THz 002 V1.1.1 (2024-03)

TeraHertz technology (THz); Identification of frequency bands of interest for THz communication systems

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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
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Foreword

This Group Report (GR) has been produced by ETSI Industry Specification Group (ISG) TeraHertz (THz).

Modal verbs terminology

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Executive summary

The interest for higher frequency bands increases with the increasing demand for higher bandwidths and lower latencies to serve critical applications. This is most pronounced in the research towards 6G technologies, which are expected to be ready for early deployments around 2030. Furthermore, IEEE 802 LAN/MAN Standards Committee published already in 2017, and revised in 2023 covering more frequency bands, a first wireless communication standard working in the sub-THz frequency range [i.30]. The so-called THz range is also becoming more accessible with the development towards affordable transceiver and antenna technologies.

The frequency ranges from 100 GHz and upwards is already utilized for non-communications purposes, and therefore there is a need to understand the regulatory landscape and identify the most interesting frequency bands for THz communications. The present document describes the situation 'as is' at the time of publication, while regulatory work is evolving.

The whole frequency range from 100 GHz to 3 THz is regulated by the ITU-R Radio Regulations (RR) [i.7], but on different levels. Up to 275 GHz, frequency allocations exist, which is the strictest type of global spectrum regulations. Further, the range between 275 GHz and 450 GHz is identified for fixed and mobile services. In this range, and further up to 1 THz, several bands are also identified for so-called passive services. In some of the bands in this range, specific conditions to ensure protection of the passive services exist. Above 1 THz up to 3 THz, the whole spectrum can be used freely for both active and passive services, while above 3 THz, no regulations exist.

The present document gives a comprehensive overview of the frequency ranges from 100 GHz to 1 THz, with emphasis on the regulatory status and the co-existence challenges. Between 100 GHz and 275 GHz, 8 bands with sufficient contiguous bandwidths are allocated to FIXED and MOBILE services on a co-primary basis, constituting 90,7 GHz bandwidth in total. Above 275 GHz, interesting bands have been identified for THz communications purposes based on a combination of regulatory status and favourable propagation conditions. A new concept of transmission windows is defined to help in identifying the interesting frequencies above 275 GHz. The resulting analysis have identified 12 bands of interest constituting 488 GHz of bandwidth. 91 GHz of this range is identified for fixed and mobile services.

Many frequency bands are shared with passive services. These are typically monitoring and research applications like earth exploration satellites, radio astronomy and space research. These are particularly vulnerable to interference from active usage. Sharing and protective methods are therefore needed and are indicated up to 275 GHz. Potential sharing scenarios between active and passive services have been investigated up to 450 GHz, but not for higher frequency bands.

Eventually, regulations need to exist on a regional level for the applications intended. Given that there is currently no use of mobile systems in sub-THz such a regional / national framework may not exist in most cases. The analysis is therefore focused on the availability of frequency bands allocated to the mobile and fixed service on a primary basis up to 275 GHz on the ITU level. Above 275 GHz, the analysis is focused on bands either identified for mobile and fixed services or having favourable propagation conditions based on the transmission window model. On ITU level all allocations or identifications above 100 GHz in Article 5 of the RR are on a global basis.

Introduction

The frequency range 100 GHz - 10 THz is referred to as the 'THz range', as shown in Figure 1. The corresponding wavelengths are from 0,03 mm to 3 mm. Below this range, the mm-wave and microwave frequency ranges are found, already heavily utilized for communications and non-communications applications. Above 10 THz the near- and mid-infrared spectrum starts.

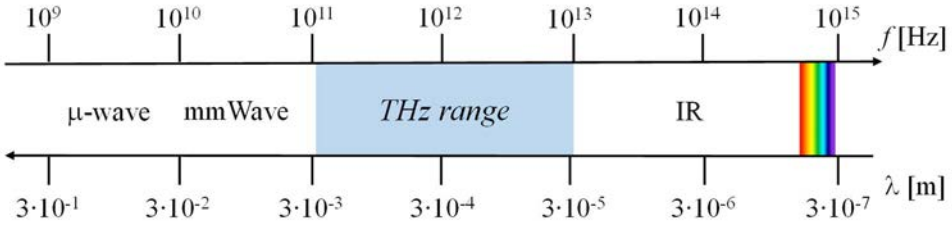

Figure 1: Position of the THz band in the radio spectrum

ITU-R has published a technology trends study of active services above 275 GHz, listing some characteristics of the band, like high permittivity, rapid attenuation in water, high spatial resolution, and good directivity [i.1]. These are all important and attractive for wireless applications.

The ETSI ISG THz concentrates on establishing the technical foundation for the development and standardization of THz communications (0,1 THz - 10 THz). However, non-communication applications cannot be overlooked. Visions and studies towards 6G communications are clear that e.g. joint sensing, imaging and communications are key components of future wireless systems [i.2]. It remains to be determined if an allocation to the Radiolocation service is needed to allow such use cases since the allocation to the land mobile service is limited to exchange of signals between stations.

Based on the regulatory status and application scenarios, the frequency band 100 GHz - 10 THz is discussed in three ranges, as shown in Figure 2.

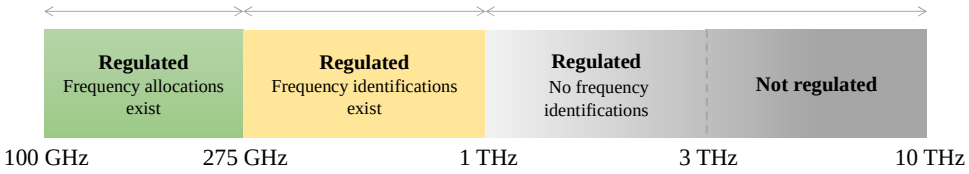

Figure 2: Frequency ranges within the THz band with different regulatory status

Frequency bands between 100 and 275 GHz are already allocated for terrestrial services on an international level through the ITU-R Radio Regulations [i.7]. Sharing and compatibility scenarios have been investigated up to 450 GHz [i.3]. Further needs for sharing studies should consequently be identified.

Parts of this frequency range has been covered by studies by the ETSI GR mWT 008 [i.4], ETSI GR mWT 018 [i.5], ETSI GR mWT 022 [i.6], where analysis of spectrum, license schemes and network scenarios for the W-band (92 - 114,5 GHz) and D-band (130 - 174,8 GHz), and further, up to 275 GHz have been done. This overlaps with the lower range, 100 - 275 GHz, studied in the present document.

An important regulation for many bands up to 252 GHz is defined in the ITU-R Radio Regulations [i.7], Footnote 5.340 (see Annex B) which explicitly protects a number of bands for passive use by Earth Exploration Satellites (EESS) and Radio Astronomy Services (RAS). Nevertheless, ITU-R Resolution 731 (WRC-23) [i.8] invites to continue studies on sharing between active and passive services above 71 GHz. Specifically, studies on the specific conditions for land-mobile and fixed service applications to ensure the protection of EESS (passive) applications in certain frequency bands are invited.

General sharing studies for frequencies above 100 GHz are published by Xing and Rappaport [i.9], where the focus is on interference from terrestrial networks towards satellites operating at 140 GHz. Further, Polese et al. [i.10] provides both policy and technological guidance on sharing above 100 GHz. Both articles conclude that technological means can make sharing possible in the bands defined by FN 5.340.

As technology evolves, the THz frequency band is becoming more feasible for exploitation, and the need to identify the most interesting parts increase. In the present document, the criteria for being of interest are based on current international regulations, available bandwidths, possible conflicts with passive services and aspects of radio wave propagation.

1 Scope

The present document will:

- identify frequency bands of interest in the sub-THz and THz range;
- describe the current regulatory situation in the frequency bands of interest; and
- identify the incumbent services to be considered for coexistence studies.

As an ETSI Group Report (GR), the present document is containing only informative elements, approved for publication by an Industry Specification Group (ISG) not mandated for regulatory actions. Thus, the present document is not intended to propose advocacy or modifications to current spectrum regulation.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long-term validity.

The following referenced documents are not necessary for the application of the present document, but they assist the user with regard to a particular subject area.

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[i.2] 5G-IA White Paper: "European Vision for the 6G Network Ecosystem". V1.0, 7 June 2021. doi: 10.5281/zenodo.5007671.

[i.3] Recommendation ITU-R SM.2450-0 (06/2019): "Sharing and compatibility studies between land-mobile, fixed and passive services in the frequency range 275-450 GHz".

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[i.5] ETSI GR mWT 018 (V1.1.1) (2019-08): "Analysis of Spectrum, License Schemes and Network Scenarios in the W-band".

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[i.96] ETSI GR THz 003: "TeraHertz modeling (THz); Channel measurements and modeling in THz bands".

[i.97] Recommendation ITU-R P.1238-12 (08/2023): "Propagation data and prediction methods for the planning of indoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 450 GHz".

[i.98] Recommendation ITU-R P.1411-12 (08/2023): "Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 100 GHz".

[i.99] Z. Xiao, Q. Yang, J. Huang, Z. Huang, W. Zhou, Y. Gao, R. Shu, and Z. He (2018): "Terahertz communication windows and their point-to-point transmission verification", Appl. Opt. 57, pp. 7673-7680 (2018). doi: 10.1364/AO.57.007673.

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

allocation (of a frequency band): According to the ITU-R Radio Regulations [i.7], No. 1.16: "Entry in the Table of Frequency Allocations of a given frequency band for the purpose of its use by one or more terrestrial or space radiocommunication services or the radio astronomy service under specified conditions. This term shall also be applied to the frequency band concerned".

fixed service: According to the ITU-R Radio Regulations [i.7], No. 1.20: "A radiocommunication service between specified fixed points".

footnote (to the Table of Frequency Allocations): part of the ITU-R Radio Regulations [i.7] providing additional explanations and restrictions on the use of the frequency bands to which they are referring to

identification (of a frequency band): definition of a frequency band for a specific use in accordance with a resolution from the ITU-R WRC, which does not preclude the use of the frequency band by any other application of the services to which they are identified and does not establish priority in the ITU-R Radio Regulations [i.7]

interference: According to the ITU-R Radio Regulations [i.7], No. 1.166: "The effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radiocommunication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy".

mobile service: According to the ITU-R Radio Regulations [i.7], No. 1.24: "A radiocommunication service between mobile and land stations, or between mobile stations".

primary service: Services whose names are printed in "capitals" in the Table of Frequency Allocations in the ITU-R Radio Regulations [i.7] (example: FIXED) are called "primary services".

radiodetermination: According to the ITU-R Radio Regulations [i.7], No. 1.9: "The determination of the position, velocity and/or other characteristics of an object, or the obtaining of information relating to these parameters, by means of the propagation properties of radio waves".

secondary service: Services whose names are printed in "normal characters" in the Table of Frequency Allocations in the ITU-R Radio Regulations [i.7] (example: Mobile) are called "secondary services".

service (Radiocommunication service): According to the ITU-R Radio Regulations [i.7], No. 1.19: "A service as defined in this Section [The ITU-R RR, ed. Note] involving the transmission, emission and/or reception of radio waves for specific telecommunication purposes".

transmission window: frequency band defined between the $1/\sqrt{2}$ values of transmittance relative to the peak value of transmittance of each frequency band

NOTE: The term transmission was adopted to refer to the use of such bands exclusively for telecommunications. More details can be found in Annex A.

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AAS	Active Antenna System
BW	BandWidth
CDR	Contour Determination and acquisition Radar
CEPT	European Conference of Postal and Telecommunications Administrations
ECC	Electronic Communications Committee
ECO	European Communications Office
EESS	Earth Exploration Satellite Service
FCC	Federal Communications Commission
FN	FootNote
FS	Fixed Service
FSS	Fixed Satellite Service
ISAC	Integrated Sensing And Communications
ISS	Inter-Satellite Services
LPR	Level Probing Radar
MSS	Mobile Satellite Service
PMP	Point-to-Multi-Point
RAS	Radio Astronomy Service
RDI	RadioDetermination systems for Industry automation
RF	Radio Frequency
RLS	RadioLocation Service
RNS	RadioNavigation Service
RNSS	RadioNavigation Satellite Service
RR	Radio Regulations (ITU-R)
SRD	Short Range Devices
SRS	Space Research Service
TLPR	Tank Level Probing Radar
TW	Transmission Window
UWB	Ultra Wide Band
WRC	World Radiocommunication Conference

4 Frequency range 100 - 275 GHz

4.1 Introduction

The frequency range 100 - 275 GHz is included in the Table of Frequency Allocations of the Radio Regulations [i.7], with allocations for both active and passive services, including footnotes. Following decisions at WRC-23 [i.11] in total 20 bands are allocated MOBILE and FIXED services, some adjacent to each other, on a co-primary basis with other services, summing up to a total of 98,4 GHz of available bandwidth for terrestrial radiocommunications applications. Based on this and limiting to available contiguous bandwidth of 6 GHz, the frequency range 100 - 275 GHz is subdivided into the following eight frequency bands of interest:

- Frequency Band 1: 102 - 109,5 GHz.
- Frequency Band 2: 141 - 148,5 GHz.
- Frequency Band 3: 151,5 - 164 GHz.
- Frequency Band 4: 167 - 174,8 GHz.
- Frequency Band 5: 191,8 - 200 GHz.
- Frequency Band 6: 209 - 226 GHz.
- Frequency Band 7: 231,5 - 239,2 GHz.
- Frequency Band 8: 252 - 275 GHz.

Further, there are three narrower bands with FIXED and MOBILE primary allocations, which are discussed in clause 4.10. The reason being that RF technology evolution may prove it feasible to cost effectively implement transceivers with narrower bandwidths than 6 GHz.

Especially Footnote No. 5.149 is worth noting, since it covers all the interesting bands in this range (as well as below):

- **FN 5.149:** "*In making assignments to stations of other services to which the bands […] are allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service (see Nos. 4.5 and 4.6 and Article 29) (WRC-07)*".

Radio astronomy primary service allocations are partly overlapping with the fixed and mobile services. ITU-R has published two recommendations on the protection of radio astronomy services (Recommendation ITU-R RA.1272-1 [i.12] and Recommendation ITU-R RA.769-2 [i.15]).

4.2 Frequency band 102 - 109,5 GHz

4.2.1 Description

The frequency band 102 - 109,5 GHz comprises two adjacent bands in the ITU-R Radio Regulations [i.7]:

- 102 - 105 GHz; and
- 105 - 109,5 GHz.

It comprises a total bandwidth of 7,5 GHz.

4.2.2 Regulatory situation

4.2.2.1 Globally

The whole frequency band 102 - 109,5 GHz contains an allocation to FIXED and MOBILE service on a co-primary basis. The number of services with whom the spectrum is shared differs in the two sub-bands (102 - 105 GHz and 105 - 109,5 GHz). All allocations in this frequency band are made on a global basis and are identical to all three ITU-R regions. Three footnotes apply:

- **FN 5.149** (102 - 109,5 GHz): "*... administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service…*".
- **FN 5.341** (102 - 109,5 GHz): "*In the bands 1 400-1 727 MHz, **101-120 GHz** and 197-220 GHz, passive research is being conducted by some countries in a programme for the search for intentional emissions of extra-terrestrial origin*".
- **FN 5.562B** (105 - 109,5 GHz): "*...the use of this allocation is limited to space-based radio astronomy only*".

4.2.2.2 Regionally

In Europe, the frequency range 92 - 114,5 GHz is designated for the use of fixed services. The European Communications Committee (ECC) of CEPT has in ECC Recommendation (18)02 [i.16] defined channel/block arrangements for FS systems in this band. A common channel raster of 250 MHz slots for multiple bands have been defined between 92 GHz and 114,25 GHz. ECC also recommends a paired block setup in the whole range with duplexing distances of 11,5 GHz to 14,2 GHz.

Further, ECC Report 282 [i.17] provides supporting information and considerations on deployment of Point-to-Point (PP) radio links in the frequency ranges 92 - 114,25 GHz (referred to as W-band) and 130 - 174,8 GHz (referred to as D-band). The frequency ranges above 100 GHz are considered attractive for 5G backhaul purposes. To investigate this, ECC Report 342 [i.18] describes a Point-to-Multipoint (PMP) system intended to operate within Fixed Service (FS) for backhaul applications which implements a star topology by leveraging on an Active Antenna (AAS).

The European Communications Office (ECO) has recently published ECO Report 04 [i.19] the implementation status for Fixed Services in Europe. For the bands above 100 GHz, only a few countries have implemented the recommended channel plan from [i.16]. Some countries are considering and studying; however, most countries has not given any information.

This clause is applicable for other bands between 100 GHz and 275 GHz.

4.2.3 Other services with allocated spectrum

4.2.3.1 Service descriptions and protective methods

Overview of co-primary frequency allocations:

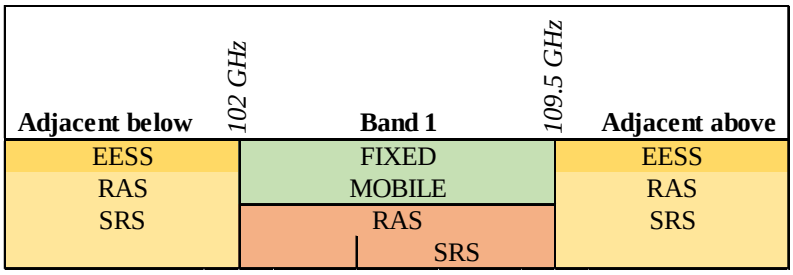

Figure 3: Co-primary service allocations in the band 102 - 109,5 GHz

Protective methods towards other co-primary service allocations:

- RADIO ASTRONOMY (RAS): Co-existence is based on the use of exclusion zones around the RAS stations [i.12], see FN 5.149 and FN 5.341.
- SPACE RESEARCH (SRS) (passive) (105 - 109,5 GHz): Limited to space-based radioastronomy. Not directed towards earth which ensures protection, ref FN 5.562B.

Interference from MOBILE and FIXED services in adjacent bands, below 102 GHz and above 109,5 GHz:

- EARTH EXPLORATION-SATELLITE (EESS) (passive): restrictions on out-of-band emissions, if Nadir or Conical Scan. See Recommendation ITU-R RS.1861-1 [i.13].

4.2.4 Conclusive remarks and recommendations

For this frequency band allocations in the RR, which are relevant for THz communications already exist. These band can be considered taking into account the regional situations and the protective methods defined for the band itself and the adjacent bands. The ITU-R WP5C is currently working on "Radio frequency arrangements for fixed wireless systems" [i.14]. The results are expected to be prepared by 2027 and will complement the European regulations, see clause 4.2.2.2.

4.3 Frequency band 141 - 148,5 GHz

4.3.1 Description

The band 141 - 148,5 GHz comprises a total bandwidth of 7,5 GHz in the ITU-R Radio Regulations [i.7].

4.3.2 Regulatory situation

4.3.2.1 Globally

The frequency band 141 - 148,5 GHz contains an allocation to FIXED and MOBILE service on a co-primary basis. All allocations in this frequency band are made on a global basis and are identical to all three ITU-R regions. One footnote applies:

- **FN 5.149** (136 - 148,5 GHz): "*… administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service…*".

4.3.2.2 Regionally

In Europe, the frequency range 130 - 174,8 GHz is designated for the use of fixed services. The European Communications Committee (ECC) of CEPT has in ECC Recommendation (18)01 [i.20] defined channel/block arrangements for FS systems in this band. A common channel raster of 250 MHz slots for multiple bands have been defined between 130 GHz and 174,8 GHz. ECC also recommends a paired block setup in the whole range with duplexing distances of 15,5 GHz or 21,5 GHz.

ECC Report 282 [i.17], ECC Report 342 [i.18] and ECO Report 04 [i.19] is also covering this band. See clause 4.2.2.2.

4.3.3 Other services with allocated spectrum

4.3.3.1 Service descriptions and protective methods

Overview of co-primary frequency allocations:

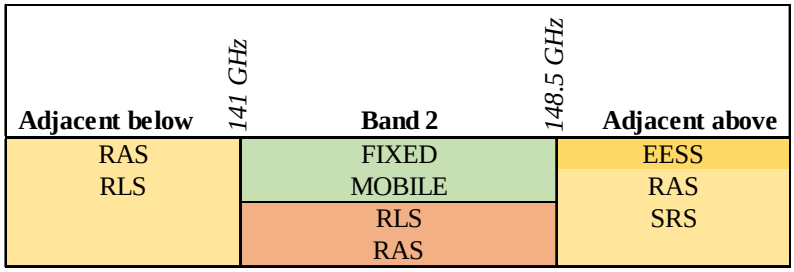

Figure 4: Co-primary service allocations in the band 141 - 148,5 GHz

In Europe, a number of bands between 116 GHz and 260 GHz has been designated for the use for UWB radiodetermination applications compliant with the RADIOLOCATION primary service allocation. ETSI TR 103 498 [i.21] is a system reference document describing UWB radiodetermination applications within the frequency range 120 GHz to 260 GHz. ECC Report 334 [i.22] further considers the co-existence of UWB applications between 116 GHz and 260 GHz to incumbent services. ECC Report 351 [i.23] explicitly focuses on UWB radiodetermination applications between 116 GHz and 148,5 GHz for vehicular use and studies interference scenarios with Radio Astronomy, Fixed Services, Earth Exploration Satellite Services (passive), and Amateur and Amateur-Satellite Services, and concludes with the conditions needed to fulfil co-existence.

Based on these reference documents and studies, the ECC Decision (22)03 [i.24] where the following bands are designated by CEPT administrations:

- 122,25 - 130 GHz and 134 - 148,5 GHz for generic indoor surveillance radar.
- 174,8 - 182 GHz, 185 - 190 GHz and 231,5 - 250 GHz for RadioDetermination systems for Industry automation (RDI).
- 116 - 148,5 GHz, 167 - 182 GHz and 231,5 - 250 GHz for Level Probing Radar (LPR), Tank Level Probing Radar (TLPR) and Contour Determination and acquisition Radar (CDR).

This clause is applicable also for other bands between 100 GHz and 275 GHz.

Protective methods towards other co-primary service allocations:

- RADIOLOCATION (RLS): The shared use with FIXED services is discussed in ECC Report 334 [i.22]. These are mainly based on e.i.r.p. limitations. Further studies are documented in ECC Report 351 [i.23], which concentrates on vehicular radar usage. These studies handle primarily how UWB Radio determination may interfere with FIXED services and not the opposite.

- RADIO ASTRONOMY (RAS): Co-existence is based on the use of exclusion zones around the RAS stations [i.12], ref FN 5.149.

Interference from MOBILE and FIXED services in adjacent band above 148,5 GHz:

- EARTH EXPLORATION-SATELLITE (EESS) (passive): Restrictions on out-of-band emissions, if Nadir or Conical Scan. See Recommendation ITU-R RS.1861-1 [i.13].

4.3.4 Conclusive remarks and recommendations

The same remarks as in clause 4.2.4 are valid, see also clause 4.3.2.2.

No co-existence studies regarding interference from FIXED services towards UWB radiodetermination has been done, see clause 4.3.3.1.

The frequency band allows Integrated Sensing And Communications (ISAC) since the band is already allocated to the MOBILE and RADIOLOCATION Service.

4.4 Frequency band 151,5 - 164 GHz

4.4.1 Description

The frequency band 151,5 - 164 GHz comprises three adjacent bands in the ITU-R Radio Regulations [i.7]:

- 151,5 - 155,5 GHz;
- 155,5 - 158,5 GHz;
- 158,5 - 165 GHz.

It comprises a total bandwidth of 12,5 GHz.

4.4.2 Regulatory situation

4.4.2.1 Globally

The whole frequency band 151,5 - 164 GHz contains an allocation to FIXED and MOBILE service on a co-primary basis. The number of services with whom the spectrum is shared differs in the three sub-bands (151,5 - 155,5 GHz, 155,5 - 158,5 GHz and 158,5 - 164 GHz). All allocations in this frequency band are made on a global basis and are identical to all three ITU-R regions. One footnote applies for the two lower sub bands:

- **FN 5.149** (151,5 - 158,5 GHz): "… *administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service…*".

4.4.2.2 Regionally

The same regulatory situation as in clause 4.2.2.2 applies in Europe.

4.4.3 Other services with allocated spectrum

4.4.3.1 Service descriptions and protective methods

Overview of co-primary frequency allocations:

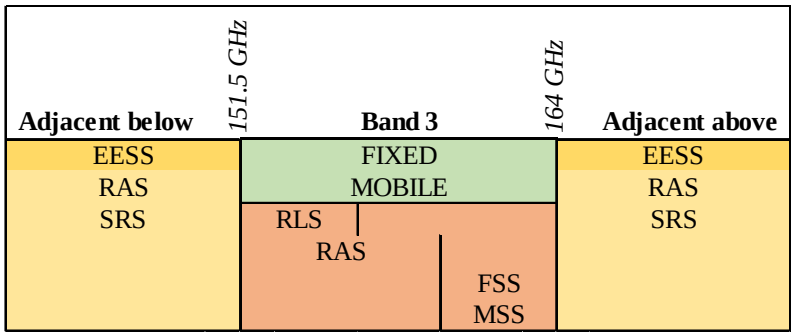

Figure 5: Co-primary service allocations in the band 151,5 - 164 GHz

Protective methods towards other co-primary service allocations:

- RADIOLOCATION (RLS) (151,5 - 155,5 GHz): The shared use with FIXED services is discussed in ECC Report 334 [i.22]. These are mainly based on e.i.r.p. limitations. These studies handle primarily how UWB Radio determination may interfere with FIXED services and not the opposite.
- RADIO ASTRONOMY (RAS): Co-existence is based on the use of exclusion zones around the RAS stations [i.12], ref FN 5.149.
- FIXED-SATELLITE (FSS) (space-to-Earth): No method specified.
- MOBILE-SATELLITE (MSS) (space-to-Earth): No method specified.

Interference from MOBILE and FIXED services in adjacent bands below 151,5 GHz and above 164 GHz:

- EARTH EXPLORATION-SATELLITE (EESS) passive: restrictions on out-of-band emissions, if Nadir or Conical Scan. See Recommendation ITU-R RS.1861-1 [i.13].

4.4.4 Conclusive remarks and recommendations

The same remarks as in clause 4.2.4 is valid, see also clause 4.4.2.2.

No co-existence studies regarding interference from FIXED services towards UWB radiodetermination has been done, see clause 4.4.3.1. Resolution COM6/5 from WRC-23 [i.11] invites studies for protecting EESS between 164 - 167 GHz, which is an adjacent band, towards agenda item 1.18 at WRC-27.

The frequency band allows Integrated Sensing And Communication (ISAC) since the band is already allocated to the MOBILE and RADIOLOCATION Service.

4.5 Frequency band 167 - 174,8 GHz

4.5.1 Description

The frequency band 167 - 174,8 GHz comprises two adjacent bands in the ITU-R Radio Regulations [i.7]:

- 167 - 174,5 GHz; and
- 174,5 - 174,8 GHz.

It comprises a total bandwidth of 7,8 GHz.

4.5.2 Regulatory situation

4.5.2.1 Globally

The whole frequency band 167 - 174,8 GHz contains an allocation to FIXED and MOBILE service on a co-primary basis. The number of services with whom the spectrum is shared differs in the two sub-bands (167 - 174,5 GHz and 174,5 - 174,8 GHz). All allocations in this frequency band are made on a global basis and are identical to all three ITU-R regions. Three footnotes apply:

- **FN 5.149** (167 - 174,5 GHz): "*… administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service…*".
- **FN 5.558** (Related to Mobile Services): "*In the bands 55.78-58.2 GHz, 59-64 GHz, 66-71 GHz, 122.25-123 GHz, 130-134 GHz,* ***167-174.8 GHz*** *and 191.8-200 GHz, stations in the aeronautical mobile service may be operated subject to not causing harmful interference to the inter-satellite service (see No. 5.43)*".
- **FN 5.562D**: "***Additional allocation: In Korea (Rep. of),*** *the frequency bands 128-130 GHz,* ***171-171.6 GHz, 172.2-172.8 GHz and 173.3-174 GHz*** *are also allocated to the radio astronomy service on a primary basis. Radio astronomy stations in Korea (Rep. of) operating in the frequency bands referred to in this footnote shall not claim protection from, or constrain the use and development of, services in other countries operating in accordance with the Radio Regulations. (WRC-15)*".

4.5.2.2 Regionally

See clause 4.2.2.2 on the use of FIXED services in Europe.

4.5.3 Other services with allocated spectrum

4.5.3.1 Service descriptions and protective methods

Overview of co-primary frequency allocations:

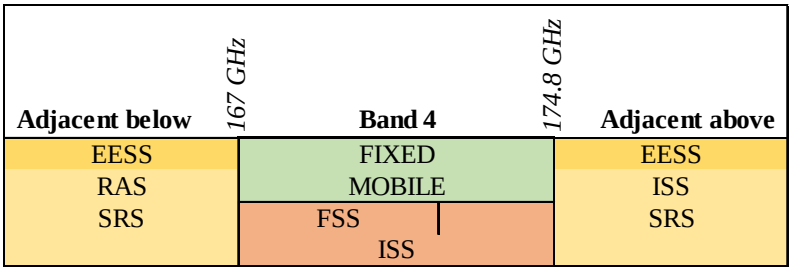

Figure 6: Co-primary service allocations in the band 167 - 174,8 GHz

Protective methods towards other co-primary service allocations:

- RADIO ASTRONOMY (RAS): Co-existence is based on the use of exclusion zones around the RAS stations [i.12], ref FN 5.149 and FN 5.562D.
- FIXED-SATELLITE (FSS) (space-to-Earth): No method specified.
- INTER-SATELLITE (ISS) In space. At significant distance, therefore not a blocker, ref FN 5.558.

Interference from MOBILE and FIXED services in adjacent bands below 167 GHz and above 174,8 GHz

- EARTH EXPLORATION-SATELLITE (EESS) passive: restrictions on out-of-band emissions, if Nadir or Conical Scan. See Recommendation ITU-R RS.1861-1 [i.13].

4.5.4 Conclusive remarks and recommendations

The same remarks as in clause 4.2.4 is valid, see also clause 4.5.2.2. Resolution COM6/5 from WRC-23 [i.11] invites studies for protecting EESS between 164 - 167 GHz, which is an adjacent band, towards agenda item 1.18 at WRC-27.

4.6 Frequency band 191,8 - 200 GHz

4.6.1 Description

The band 191,8 - 200 GHz comprises a total bandwidth of 8,2 GHz in the ITU-R Radio Regulations [i.7]. A water vapour absorption line is present at 183 GHz [i.53].

4.6.2 Regulatory situation

4.6.2.1 Globally

The whole frequency band 191,8 - 200 GHz contains an allocation to FIXED and MOBILE SERVICE on a co-primary basis. All allocations in this frequency band are made on a global basis and are identical to all three ITU-R regions. Four footnotes apply:

- **FN 5.149**: "*… administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service…*".
- **FN 5.341**: "*In the bands 1 400-1 727 MHz, 101-120 GHz and **197-220 GHz**, passive research is being conducted by some countries in a programme for the search for intentional emissions of extra-terrestrial origin*".
- **FN 5.554**: "*In the bands 43.5-47 GHz, 66-71 GHz, 95-100 GHz, 123-130 GHz, **191.8-200 GHz** and 252-265 GHz, satellite links connecting land stations at specified fixed points are also authorized when used in conjunction with the mobile-satellite service or the radionavigation-satellite service*".
- **FN 5.558** (Related to Mobile Services): "*In the bands 55.78-58.2 GHz, 59-64 GHz, 66-71 GHz, 122.25-123 GHz, 130-134 GHz, 167-174.8 GHz and **191.8-200 GHz**, stations in the aeronautical mobile service may be operated subject to not causing harmful interference to the inter-satellite service (see No. 5.43)*".

4.6.2.2 Regionally

All allocations on the ITU-R level are made on a global basis.

4.6.3 Other services with allocated spectrum

4.6.3.1 Service descriptions and protective methods

Overview of co-primary frequency allocations:

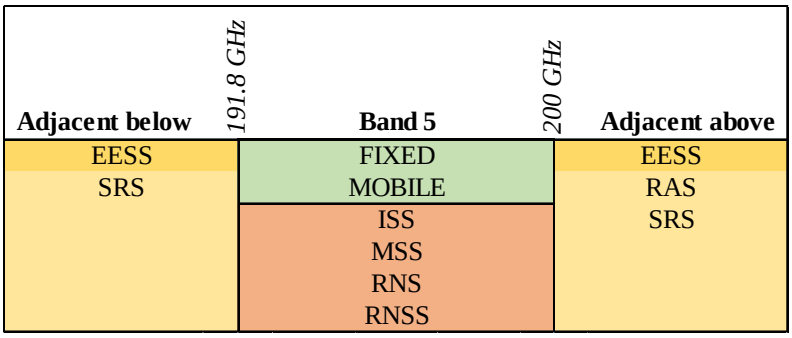

Figure 7: Co-primary service allocations in the band 191,8 - 200 GHz

Protective methods towards other co-primary service allocations:

- INTER-SATELLITE (ISS): In space. At significant distance, therefore not a blocker, ref FN 5.558.
- MOBILE-SATELLITE (MSS): No method specified.
- RADIONAVIGATION (RNS): TBD.
- RADIONAVIGATION-SATELLITE (RNSS): TBD.

Interference from MOBILE and FIXED services in adjacent bands below 191,8 GHz and above 200 GHz:

- EARTH EXPLORATION-SATELLITE (EESS) passive: restrictions on out-of-band emissions, if Nadir or Conical Scan. See Recommendation ITU-R RS.1861-1 [i.13].

4.6.4 Conclusive remarks and recommendations

For this frequency band allocations in the ITU-R RR, which are relevant for THz communications already exist. This band can be considered taking into account the regional situations and the protective methods defined for the band itself and the adjacent bands.

Resolution COM6/5 from WRC-23 [i.11] invites studies for protecting EESS between 200 - 209 GHz, which is an adjacent band, towards agenda item 1.18 at WRC-27.

4.7 Frequency band 209 - 226 GHz

4.7.1 Description

The frequency band 209 - 226 GHz comprises two adjacent bands in the ITU-R Radio Regulations [i.7]:

- 209 - 217 GHz; and
- 217 - 226 GHz.

It comprises a total bandwidth of 17 GHz.

4.7.2 Regulatory situation

4.7.2.1 Globally

The whole frequency band 209 - 226 GHz contains an allocation to FIXED and MOBILE service on a co-primary basis. The number of services with whom the spectrum is shared differs in the two sub-bands (209 - 217 GHz and 217 - 226 GHz). All allocations in this frequency band are made on a global basis and are identical to all three ITU-R regions. Three footnotes apply:

- **FN 5.149**: "*… administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service…*".
- **FN 5.341**: "*In the bands 1 400-1 727 MHz, 101-120 GHz and **197-220 GHz**, passive research is being conducted by some countries in a programme for the search for intentional emissions of extra-terrestrial origin*".
- **FN 5.562B** (217 - 226 GHz, related to Space Research): "*...the use of this allocation is limited to space-based radio astronomy only*".

4.7.2.2 Regionally

All allocations on the ITU-R level are made on a global basis.

4.7.3 Other services with allocated spectrum

4.7.3.1 Service descriptions - regional differences

Overview of co-primary frequency allocations:

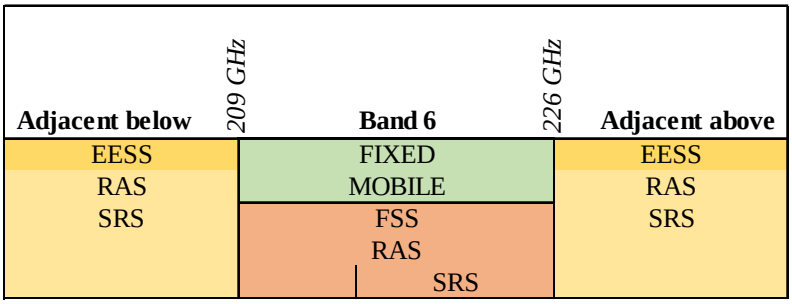

Figure 8: Co-primary service allocations in the band 209 26 GHz

Protective methods towards other co-primary service allocations:

- FIXED-SATELLITE (FSS) (space-to-Earth): No method specified.
- RADIO ASTRONOMY (RAS): Co-existence is based on the use of exclusion zones around the RAS stations [i.12], ref FN 5.149.
- SPACE RESEARCH (SRS) (passive) (217 - 226 GHz): Limited to space-based radioastronomy. Not directed towards earth which ensures protection, ref FN 5.562B.

Interference from MOBILE and FIXED services in adjacent bands below 209 GHz and above 226 GHz:

- EARTH EXPLORATION-SATELLITE (EESS) passive: restrictions on out-of-band emissions, if Nadir or Conical Scan. See Recommendation ITU-R RS.1861-1 [i.13].

4.7.4 Conclusive remarks and recommendations

For this frequency band allocations in the RR, which are relevant for THz communications already exist. These band can be considered taking into account the regional situations and the protective methods defined for the band itself and the adjacent bands.

Resolution COM6/5 from WRC-23 [i.11] invites studies for protecting EESS between 200 - 209 GHz, which is an adjacent band, towards agenda item 1.18 at WRC-27.

4.8 Frequency band 231,5 - 239,2 GHz

4.8.1 Description

The frequency band 231,5 - 239,2 GHz is located in TW2 (see Annex A) and comprises four adjacent bands defined as an outcome of the WRC-23 [i.11]:

- 231,5 - 232 GHz;
- 232 - 235 GHz;
- 235 - 238 GHz; and
- 238 - 239,2 GHz.

It comprises a total bandwidth of 7,7 GHz.

4.8.2 Regulatory situation

4.8.2.1 Globally

The whole frequency band 231,5 - 239,2 GHz contains an allocation to FIXED and MOBILE service on a co-primary basis. The number of services with whom the spectrum is shared differs between the four sub-bands. All allocations in this frequency band are made on a global basis and are identical to all three ITU-R regions. Three footnotes apply:

- **FN 5.563A:** "*In the bands 200-209 GHz, **235-238 GHz**, 250-252 GHz and 265-275 GHz, ground-based passive atmospheric sensing is carried out to monitor atmospheric constituents*".
- **FN 5.563B:** "*The band **237.9-238 GHz** is also allocated to the Earth exploration-satellite service (active) and the space research service (active) for spaceborne cloud radars only*".
- **FN 5.B114** (New after WRC-23): "*In the frequency band **235-238 GHz**, stations in the Earth exploration-satellite service (passive) **shall not claim protection** from stations in the fixed and mobile services*" [i.11].

This frequency band is subject to Agenda Item 1.8 at WRC-27 on new allocations for the radio location service (Resolution 663 [i.26] and Resolution COM6/23 in [i.11]).

4.8.2.2 Regionally

All allocations on the ITU-R level are made on a global basis.

4.8.3 Other services with allocated spectrum

4.8.3.1 Service descriptions - regional differences

Overview of primary frequency allocations:

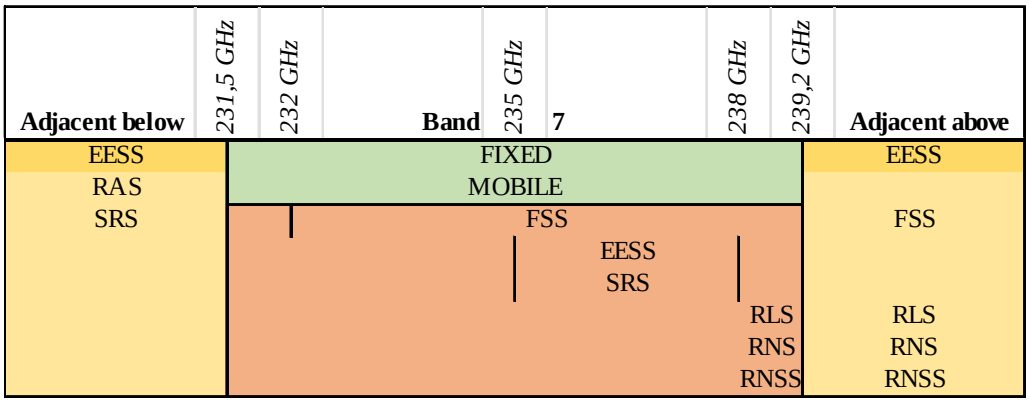

Figure 9: Co-primary service allocations in the band 231,5 - 239,2 GHz

Protective methods towards other co-primary service allocations:

- EARTH EXPLORATION-SATELLITE (EESS) (passive) (235 - 238 GHz). No protective method required (see FN 5.B114).
- FIXED-SATELLITE (FSS) (space-to-earth) (232 - 235 GHz, 235 - 238 GHz, 238 - 239,2 GHz).
- SPACE RESEARCH (SRS) (passive) (235 - 238 GHz): Limited to ground-based passive atmospheric sensing (see FN 5.563A).
- RADIOLOCATION (RLS) (238 - 239,2 GHz): The shared use with FIXED services is discussed in ECC Report 334 [i.22]. These are mainly based on e.i.r.p. limitations. These studies handle primarily how UWB Radio determination may interfere with FIXED services and not the opposite.
- RADIONAVIGATION (RNS) (238 - 239,2 GHz): TBD.
- RADIONAVIGATION-SATELLITE (RNSS) (238 - 239,2 GHz): TBD.

Interference from MOBILE and FIXED services in adjacent bands below 231,5 GHz and above 239,2 GHz:

- EESS passive: restrictions on out-of-band emissions, if Nadir or Conical Scan. See Recommendation ITU-R RS.1861-1 [i.13].

4.8.4 Conclusive remarks and recommendations

For this frequency band allocations in the ITU-R RR, which are relevant for THz communications already exist. This band can be considered taking into account the regional situations and the protective methods defined for the band itself and the adjacent bands. No further need for co-existence studies has been identified for this band.

4.9 Frequency band 252 - 275 GHz

4.9.1 Description

The frequency band 252 - 275 GHz is located in TW2 (see Annex A) and comprises two adjacent bands in the ITU-R Radio regulations [i.7]:

- 252 - 265 GHz; and
- 265 - 275 GHz.

It comprises a total bandwidth of 23 GHz.

4.9.2 Regulatory situation

4.9.2.1 Globally

The whole frequency band 252 - 275 GHz contains an allocation to FIXED and MOBILE service on a co-primary basis. The number of services with whom the spectrum is shared differs in the two sub-bands (252 - 265 GHz and 265 - 275 GHz). All allocations in this frequency band are made on a global basis and are identical to all three ITU-R regions. Three footnotes apply:

- **FN 5.149** (252 - 275 GHz): "… *administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service…*".
- **FN 5.554** (252 - 265 GHz): "*In the bands (….) 252-265 GHz, satellite links connecting land stations at specified fixed points are also authorized when used in conjunction with the mobile-satellite service or the radionavigation-satellite service*".
- **FN 5.563A** (265 - 275 GHz):"*In the bands (….) 265-275 GHz, ground-based passive atmospheric sensing is carried out to monitor atmospheric constituents*".

This frequency band is under study with respect to agenda item 1.8 at WRC-27 on new allocations for the radio location service (Resolution 663 in [i.26]).

4.9.2.2 Regionally

All allocations on the ITU-R level are made on a global basis.

4.9.3 Other services with allocated spectrum

4.9.3.1 Service descriptions - regional differences

Overview of co-primary frequency allocations:

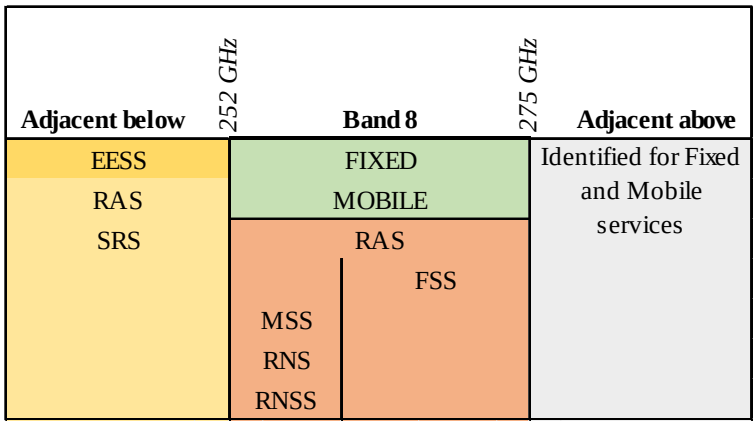

Figure 10: Co-primary service allocations in the band 252 - 275 GHz

The regional/national regulations based on these allocations described above may differ.

Protective methods towards other co-primary service allocations:

- MOBILE-SATELLITE (MSS) (Earth-to-space) (252 - 265 GHz): No method specified.
- FIXED-SATELLITE (FSS) (Earth-to-space) (265 - 275 GHz): No method specified.

- RADIO ASTRONOMY (RAS): Co-existence is based on the use of exclusion zones around the RAS stations [i.12], ref FN5.149.
- RADIONAVIGATION (RNS) (252 - 265 GHz): TBD.
- RADIONAVIGATION-SATELLITE (RNSS) (252 - 265 GHz): TBD.

Interference from MOBILE and FIXED services in adjacent bands below 252 GHz:

- EARTH EXPLORATION-SATELLITE (EESS) (passive): restrictions on out-of-band emissions, if Nadir or Conical Scan. See Recommendation ITU-R RS.1861-1 [i.13].

4.9.4 Conclusive remarks and recommendations

This frequency band is part of IEEE 802.15.3d-2023. The corresponding channel allocation is presented in [i.30] and [i.34].

4.10 Other frequency bands between 100 - 275 GHz

4.10.1 Description

There are more frequency bands in the range between 100 - 275 GHz which are allocated on a co-primary basis to FIXED and MOBILE services. Table 1 lists the frequency bands with less than 6 GHz contiguous bandwidth.

Table 1: Overview of other frequency bands between 100 - 275 GHz with FIXED and MOBILE allocations

Band #	Frequency range	Absolute bandwidth	Fractional bandwidth
1	111,8 - 114,25 GHz	2,45 GHz	2,2 %
2	122,25 - 123 GHz	0,75 GHz	0,6 %
3	130 - 134 GHz	4 GHz	3 %

Sufficient contiguous bandwidth is a limiting factor, not only regarding support for extreme bitrates, but it is also limited by the implementation feasibility. Utilizing 'narrow' bands requires sharper filters in the transceivers with higher quality factor (Q). High-Q filters are usually more expensive, but technology limits are pushed all the time. According to [i.25], it may be technologically feasible to implement RF transceivers in the THz range with filtering down to 1 % fractional bandwidth. This corresponds to absolute bandwidths between 1 and 3 GHz for the range 100 - 275 GHz. Taking into account that real filters are not infinitely sharp, the 3 dB bandwidth should be less than the available spectrum bandwidth. Based on this, Figure 11 provides an evaluation of the feasibility.

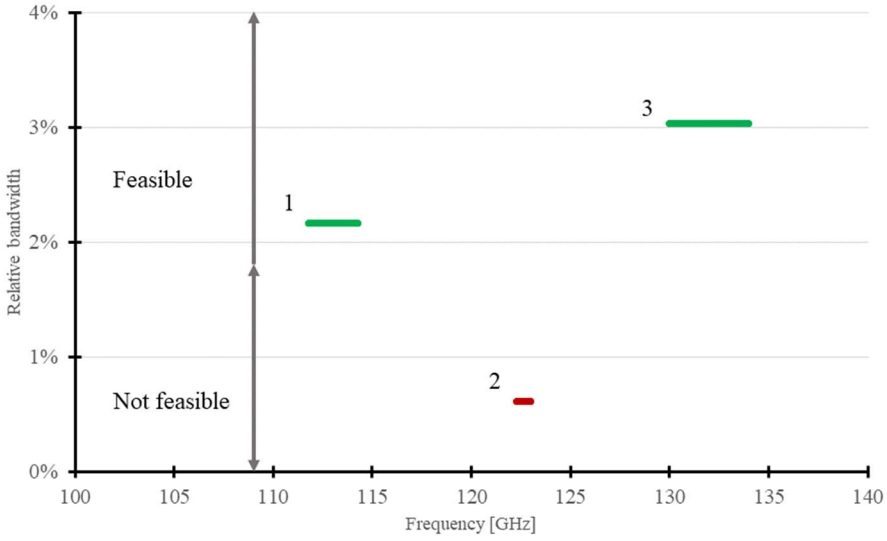

Figure 11: Feasibility of other frequency bands between 100 - 275 GHz

The evaluation shows that two out of the three bands (111,8 - 114,25 GHz and 130 - 134 GHz) might be feasible, and hence of interest for THz communications.

4.10.2 Regulatory situation

4.10.2.1 Globally

The frequency bands 111,8 - 114,25 GHz and 130 - 134 GHz contain allocations to FIXED and MOBILE service on a co-primary basis. The number of services with whom the spectrum is shared differs in the two bands. All allocations in this frequency band are made on a global basis and are identical to all three ITU-R regions. Six footnotes apply:

- **FN 5.149:** "*… administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service…*".
- **FN 5.341:** "*In the bands 1 400-1 727 MHz, **101-120 GHz** and 197-220 GHz, passive research is being conducted by some countries in a programme for the search for intentional emissions of extra-terrestrial origin*".
- **FN 5.562B:** "*In the frequency bands 105-109.5 GHz, **111.8-114.25 GHz** and 217-226 GHz, the use of this allocation [SPACE RESEARCH (passive)] is limited to space-based radio astronomy only*".
- **FN 5.558:** "*In the bands 55.78-58.2 GHz, 59-64 GHz, 66-71 GHz, 122.25-123 GHz, **130-134 GHz**, 167-174.8 GHz and 191.8-200 GHz, stations in the aeronautical mobile service may be operated subject to not causing harmful interference to the inter-satellite service (see No. 5.43)*".
- **FN 5.562A:** "*In the bands 94-94.1 GHz and **130-134 GHz**, transmissions from space stations of the Earth exploration satellite service (active) that are directed into the main beam of a radio astronomy antenna have the potential to damage some radio astronomy receivers. Space agencies operating the transmitters and the radio astronomy stations concerned should mutually plan their operations so as to avoid such occurrences to the maximum extent possible*".
- **FN 5.562E:** "*The allocation to the Earth exploration-satellite service (active) is limited to the band **133.5-134 GHz***".

4.10.2.2 Regionally

In Europe, the band 122 - 123 GHz has been designated for Short Range Devices (SRD). The band 122,25 GHz to 123 GHz is allocated to FIXED and MOBILE services. The lower band 122 - 122,25 GHz, however, is co-primary allocated to EESS, SRS and INTER-SATELLITE, and a separate compatibility study is done in ECC Report 190 [i.27]. For further details, see also description of European regulations for UWB radiodetermination applications in clause 4.2.3.1.

While the bands 122,25 - 123 GHz and 244 - 246 GHz are restricted by e.i.r.p. only, the band 122 - 122,25 GHz also is restricted on power spectral density (psd) and on elevation angle for radiated power, in addition to a stricter e.i.r.p. level. The requirements are updated and summarized in ERC Recommendation 70-03 [i.28], and as the European Commission Decision 2017/1483/EU [i.29].

In the US, the Federal Communications Commission (FCC) has made available some bands [i.31] with at least 5 GHz bandwidth in 116 - 123 GHz, 174,8 - 182 GHz and 185 - 190 GHz. There is also a path using experimental licenses for any band above 100 GHz, but there are additional requirements to be met which essentially acts only as a temporary way to market. While the band 116 - 123 GHz looks particularly interesting, it is shared with passive EESS which may limit its future availability outside the US.

4.10.3 Other services with allocated spectrum

4.10.3.1 Service descriptions - regional differences

Overview of co-primary frequency allocations:

- Frequency band 118,8 - 114,25 GHz:

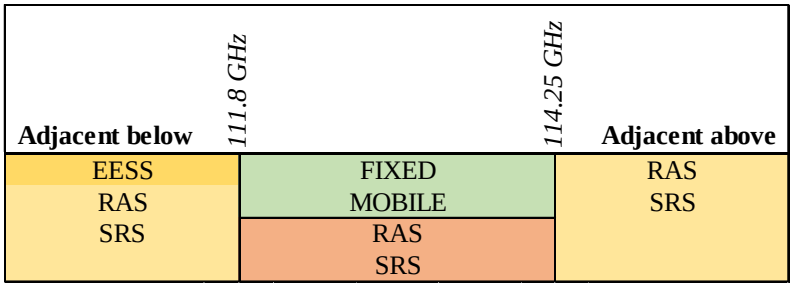

Figure 12: Co-primary service allocations in the band 111,8 - 114,25 GHz

- Frequency band 130 - 134 GHz:

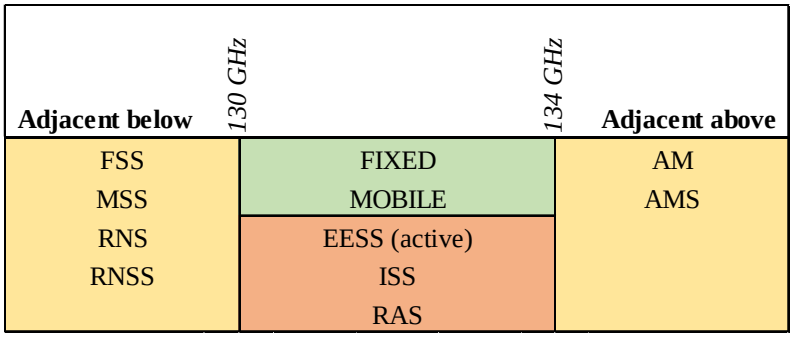

Figure 13: Co-primary service allocations in the band 130 - 134 GHz

Protective methods towards other co-primary service allocations:

- RADIO ASTRONOMY (RAS) (111,8 - 114,25 GHz): Co-existence is based on the use of exclusion zones around the RAS stations [i.12], ref FN 5.149.
- SPACE RESEARCH (SRS) (passive) (111,8 - 114,25 GHz): Limited to space-based radioastronomy. Not directed towards earth which ensures protection, ref FN 5.562B.
- INTER-SATELLITE (ISS) (130 - 134 GHz): Not directed towards earth which ensures protection.
- EARTH EXPLORATION-SATELLITE (EESS) (active) (133,5 - 134 GHz): Method TBD.

Interference from MOBILE and FIXED services in adjacent bands below 111,8 GHz and below 231,5 GHz:

- EESS passive: restrictions on out-of-band emissions, if Nadir or Conical Scan. See Recommendation ITU-R RS.1861-1 [i.13].

4.10.4 Conclusive remarks and recommendations

In addition to the bands described in the previous clauses a couple of smaller fragmented spectrum parts exist between 100 GHz and 275 GHz. Due to the small channel bandwidth available in these spectrum parts, these bands are of less interest for THz communications and might be used for specific applications only. The ITU-R WP5C is currently working on "Radio frequency arrangements for fixed wireless systems" [i.14]. The results are expected to be prepared by 2027 and will complement the European regulations, see clause 4.10.2.2.

5 Frequency range 275 - 1 000 GHz

5.1 Introduction

The frequency range between 275 and 1 000 GHz is not allocated to specific services, but identified for use by administrations for passive and active service applications as defined in FN 5.565 (see Annex C) and 5.564A (see Annex D) of the ITU-R Radio Regulations [i.7]. Based on the restrictions defined in these footnotes and the definition of Transmission Windows (TWs) (see Annex A), the frequency band 275 - 1 000 GHz is subdivided into the following 12 frequency bands:

- Frequency Band 1: 275 - 296 GHz.
- Frequency Band 2: 296 - 306 GHz.
- Frequency Band 3: 306 - 313 GHz.
- Frequency Band 4: 313 - 318 GHz.
- Frequency Band 5: 318 - 321 GHz.
- Frequency Band 6: 327 - 333 GHz.
- Frequency Band 7: 333 - 356 GHz.
- Frequency Band 8: 356 - 368 GHz.
- Frequency Band 9: 391 - 433 GHz.
- Frequency Band 10: 452 - 520 GHz.
- Frequency Band 11: 598 - 722 GHz.
- Frequency Band 12: 786 - 953 GHz.

In the following, frequency bands belonging to the same TW and having the same regulations are grouped into one section.

5.2 Frequency bands 1, 3 and 5 (275 - 296 GHz, 306 - 313 GHz, 318 - 321 GHz)

5.2.1 Description

These three frequency bands are all within TW2 (185 - 321 GHz) and have been identified for the use by mobile and fixed service at WRC-19.

5.2.2 Regulatory situation

5.2.2.1 Globally

Identification for use for the implementation of land mobile and fixed service according to FN 5.564A (see Annex D). No specific conditions are necessary to protect Earth exploration-satellite service (passive) applications. Exclusion zones are required with respect to radio astronomy. This frequency band is under study with respect to agenda item 1.8 at WRC-27 on new identifications for the radio location service (Resolution 663 [i.26]). The frequency band 275 - 325 GHz will also be under study towards WRC-31 on possible new allocations for fixed, mobile, radiolocation, amateur, amateur-satellite, radio astronomy, Earth-exploration-satellite (passive and active) and space research (Resolution COM6/13 in [i.11]).

5.2.2.2 Regionally

All identifications on the ITU-R level are made on a global basis.

5.2.3 Other services with identified spectrum

5.2.3.1 Service descriptions and possible protective methods

Spectrum has also been identified for the use of passive service applications: Radio astronomy, Earth exploration satellite service (passive), and Space research service (passive).

Possible protective methods towards other co-shared service identifications:

- Recommendation ITU-R FN 5.564A (see Annex D) applies to these bands: No specific conditions are necessary to protect Earth exploration services (passive). For radio astronomy, exclusion zones might be necessary to protect the service.

Interference from mobile and fixed services in adjacent bands:

- Below 275 GHz is only affecting RADIO ASTRONOMY, see clause 4.9.3.
- The bands 296 - 306 GHz and 313 - 318 GHz are not identified to fixed or mobile, but considered as interesting, see clause 5.3. Further studies covering the broader range might be needed.

5.2.4 Conclusive remarks and recommendations

This frequency band is part of IEEE 802.15.3d-2023. The corresponding channel allocation is presented in [i.30] and [i.34]. Under agenda item 1.8 this frequency band will be studied at WRC-27 with respect to the identification of spectrum for the radio location service. Further studies for possible new allocations will also be performed towards WRC-31, see clause 5.2.2.

Airborne applications have not been subject to sharing studies in preparation of WRC-19, where the identification has been made. Based on the results in [i.32] and [i.33] sharing studies for such applications might be necessary.

5.3 Frequency bands 2 and 4 (296 - 306 GHz, 313 - 318 GHz)

5.3.1 Description

These two frequency bands are all within TW2 (185 - 321 GHz) and have not been identified for the use by mobile and fixed service at WRC-19.

5.3.2 Regulatory situation

5.3.2.1 Globally

This part of the spectrum might be used by land mobile and fixed service according to FN 5.565 (see Annex C). National administrations have to take all practicable steps to prevent the passive services form harmful interference. This frequency band is under study with respect to agenda item 1.8 at WRC-27 on new identifications for the radio location service (Resolution 663 [i.26]). The frequency band 275 - 325 GHz will also be under study towards WRC-31 on possible new allocations for fixed, mobile, radiolocation, amateur, amateur-satellite, radio astronomy, Earth-exploration-satellite (passive and active) and space research (Resolution COM6/13 in [i.11]).

5.3.2.2 Regionally

All identifications on the ITU-R level are made on a global basis.

5.3.3 Other services with identified spectrum

5.3.3.1 Service descriptions and possible protective methods

Spectrum has also been identified for the use of passive service applications: Radio astronomy, Earth exploration satellite service (passive), and Space research service (passive).

Possible protective methods towards other co-shared service identifications:

- Recommendation ITU-R FN 5.564A (see Annex D) applies to these bands: These frequency bands may only be used by fixed and land mobile service applications when specific conditions to ensure the protection of Earth exploration service (passive) applications are determined in accordance with ITU-R Resolution 731 (Rev. WRC-23) [i.8]. For radio astronomy, exclusion zones might be necessary to protect the service.

5.3.4 Conclusive remarks and recommendations

This frequency band is part of IEEE 802.15.3d-2023. The corresponding channel allocation is presented in [i.30] and [i.34]. Under agenda item 1.8 this frequency band will be studied at WRC-27 with respect to the identification of spectrum for the radio location service. Further studies for possible new allocations will also be performed towards WRC-31, see clause 5.3.2.

Airborne applications have not been subject to sharing studies in preparation of WRC-19, where the identification has been made. Based on the results in [i.32] and [i.33] sharing studies for such applications might be necessary.

5.4 Frequency bands 6 and 8 (327 - 333 GHz, 356 - 368 GHz)

5.4.1 Description

These two frequency bands are all within TW3 (328 - 369 GHz) and have been identified for the use by mobile and fixed service at WRC-19.

5.4.2 Regulatory situation

The same regulatory situation as described in clause 5.2 applies.

5.4.3 Other services with identified spectrum

5.4.3.1 Service descriptions and possible protective methods

The same conditions as described in clause 5.2 apply.

5.4.4 Conclusive remarks and recommendations

This frequency band is part of IEEE 802.15.3d-2023. The corresponding channel allocation is presented in [i.30] and [i.34]. The bandwidth is significantly reduced for TW3 link distances larger than 15 m (see Annex A).

Airborne applications have not been subject to sharing studies in preparation of WRC-19, where the identification has been made. Based on the results in [i.32] and [i.33] sharing studies for such applications might be necessary.

5.5 Frequency band 7 (333 - 356 GHz)

5.5.1 Description

This frequency band is within TW3 (327,5 - 368,5 GHz) and has been not identified for the use by mobile and fixed service at WRC-19.

5.5.2 Regulatory situation

The same regulatory situation as described in clause 5.3 applies.

5.5.3 Other services with identified spectrum

5.5.3.1 Service descriptions and possible protective methods

The same conditions as described in clause 5.3 apply.

5.5.4 Conclusive remarks and recommendations

This frequency band is part of IEEE 802.15.3d-2023. The corresponding channel allocation is presented in [i.30] and [i.34]. The bandwidth is significantly reduced for TW3 link distances larger than 15 m (see Annex A).

Airborne applications have not been subject to sharing studies in preparation of WRC-19, where the identification has been made. Based on the results in [i.32] and [i.33] sharing studies for such applications might be necessary.

5.6 Frequency band 9 (391 - 433 GHz)

5.6.1 Description

This frequency band is within TW4 (391 - 433 GHz) and has been identified for the use by mobile and fixed service at WRC-19.

5.6.2 Regulatory situation

The same regulatory situation as described in clause 5.2 applies.

5.6.3 Other services with identified spectrum

5.6.3.1 Service descriptions and possible protective methods

The same conditions as described in clause 5.2 apply.

5.6.4 Conclusive remarks and recommendations

This frequency band is part of IEEE 802.15.3d-2023. The corresponding channel allocation is presented in [i.30] and [i.34]. The bandwidth of significantly reduces for TW3 link distances larger than 15 m (see Annex A).

Airborne applications have not been subject to sharing studies in preparation of WRC-19, where the identification has been made. Based on the results in [i.32] and [i.33] sharing studies for such applications might be necessary.

5.7 Frequency band 10 (452 - 520 GHz)

5.7.1 Description

This frequency band is within TW5 (457 - 488 GHz) and has not been identified for the use by mobile and fixed service at WRC-19.

5.7.2 Regulatory situation

This frequency band is under study with respect to agenda item 1.8 at WRC-27 on new identifications for the radio location service (Resolution 663 [i.26]).

5.7.3 Other services with identified spectrum

5.7.3.1 Service descriptions and possible protective methods

Spectrum has been identified for the use of passive service applications: Radio astronomy, Earth exploration satellite service (passive), and Space research service (passive).

5.7.4 Conclusive remarks and recommendations

No sharing studies have been performed in preparation of WRC-23. This band has been not yet been identified for the use by mobile and fixed service but is subject to agenda item 1.8 at WRC-27 for the identification of spectrum for the radio location service [i.11].

5.8 Frequency band 11 (598 - 722 GHz)

5.8.1 Description

This frequency band is within TW6 (635 - 696 GHz) and has not been identified for the use by mobile and fixed service at WRC-19.

5.8.2 Regulatory situation

The same regulatory situation as described in clause 5.7 applies.

5.8.3 Other services with identified spectrum

5.8.3.1 Service descriptions and possible protective methods

The same conditions as described in clause 5.7 apply.

5.8.4 Conclusive remarks and recommendations

No sharing studies have been performed in preparation of WRC-23. This band has been not yet been identified for the use by mobile and fixed service but is partly, i.e. up to 700 GHz, subject to agenda item 1.8 at WRC-27 for the identification of spectrum for radio location service [i.11].

5.9 Frequency band 12 (786 - 953 GHz)

5.9.1 Description

This frequency band is within TW7 (811 - 892 GHz) and has not been identified for the use by mobile and fixed service at WRC-19.

5.9.2 Regulatory situation

The same regulatory situation as described in clause 5.3 applies, except for agenda item 1.8 at WRC-27, which does not cover this frequency band.

5.9.3 Other services with identified spectrum

5.9.3.1 Service descriptions and possible protective methods

The same conditions as described in clause 5.3 apply.

5.9.4 Conclusive remarks and recommendations

This frequency band is not part of IEEE 802.15.3d-2023 [i.30]. The bandwidth is significantly reduced for TW3 link distances larger than 15 m (see Annex A).

No sharing studies have been performed in preparation of WRC-23.

6 Frequency range above 1 000 GHz

6.1 Frequency band 1 000 GHz - 3 000 GHz

6.1.1 Description

The high path loss in this frequency band and the very short transmission ranges makes interference unlikely and enables sharing without further mitigation measures.

6.1.2 Regulatory situation

This frequency band is ruled by FN 5.565 (see Annex C) of the Radio Regulations [i.7]. All frequencies in this band may be used by both active and passive services. No specific protections are required.

6.1.3 Conclusive remarks and recommendations

This frequency band can be used without any regulatory restrictions.

6.2 Frequency bands 3 000 GHz - 10 THz

6.2.1 Description

This frequency band is out of scope of the present document.

6.2.2 Conclusive remarks and recommendations

No further action is required.

7 Mapping the discussed frequency bands and physical environments to relevant channel measurements scenarios

To support the development of channel models for the frequency bands defined in the clauses above Table 2 below summarizes each of the physical environments, classifies them into frequency bands and indicates related THz channel measurement studies available in the existing literature for that particular environment. In order to group the available literature a less fine-granular classification is used than in the clauses above. Furthermore, within the scope of ETSI GR THz 003 [i.96] deals with channel measurements and modelling for THz bands and will aim to provide channel measurements and models for the physical environments identified in table 2. In addition, other typical indoor environments as specified in Recommendation ITU-R P.1238-12 [i.97], such as conference room, corridors, railway stations, airport terminals and commercial environments and outdoor environments as specified in Recommendation ITU-R P.1411-12 [i.98], including residential, urban and suburban will be considered for typical deployment scenarios may be considered.

Table 2: Mapping the identified frequency bands and physical environments to relevant channel measurements and modelling scenarios

Physical environment / Frequency Range in GHz	Indoor													Outdoor						
	On-body	Medical facility	Living room	Airplane cabin	Train cabin	Factory	Classroom	Data centre	Hallway	Meeting room	Office	Intra-machine/device	Inter-machine	Open space	Highway	Urban street	Urban canyon	Stadium	Square	Relevant to all Scenarios
100 - 175						[i.84]			[i.37] [i.58]	[i.36] [i.38] [i.64]	[i.48] [i.80] [i.83] [i.94]			[i.53] [i.54] [i.55] [i.66]		[i.69] [i.82]	[i.69] [i.90] [i.33]			[i.45]
175 - 250														[i.53] [i.54] [i.55]						
250 - 350				[i.33] [i.93]	[i.62] [i.65] [i.68]			[i.56] [i.57] [i.58] [i.59] [i.72]	[i.73] [i.74] [i.82] [i.83]	[i.62] [i.79] [i.88] [i.95]	[i.39] [i.41] [i.48] [i.61] [i.71] [i.81]	[i.42] [i.44] [i.46] [i.47] [i.50] [i.52] [i.56] [i.63] [i.91] [i.94]		[i.53] [i.54] [i.55] [i.89]	[i.60] [i.90]	[i.70] [i.84]	[i.70]			[i.35] [i.40] [i.43] [i.45] [i.49] [i.51] [i.92]
Beyond 350														[i.53] [i.54] [i.55]						

Annex A:
Transmission Windows

Recommendation ITU-R P.676-13 [i.53] is commonly used in order to predict the specific attenuation due to gases and related effects to frequencies up to 1 000 GHz, which can be used to predict Transmission Windows (TWs) for THz communications. [i.99] introduces the concept of transmittance to define the transmission windows. Transmittance, which is defined as the fraction of the incident electromagnetic power that is transmitted through the atmosphere. The Transmittance (T) is given as a percentage and can be derived from the atmospheric attenuation. Figure A-1 shows the transmittance and the derived transmission windows for a link distance of 100 meters at sea level, a temperature of 15° and water vapor density of 7,5 g/m^3.

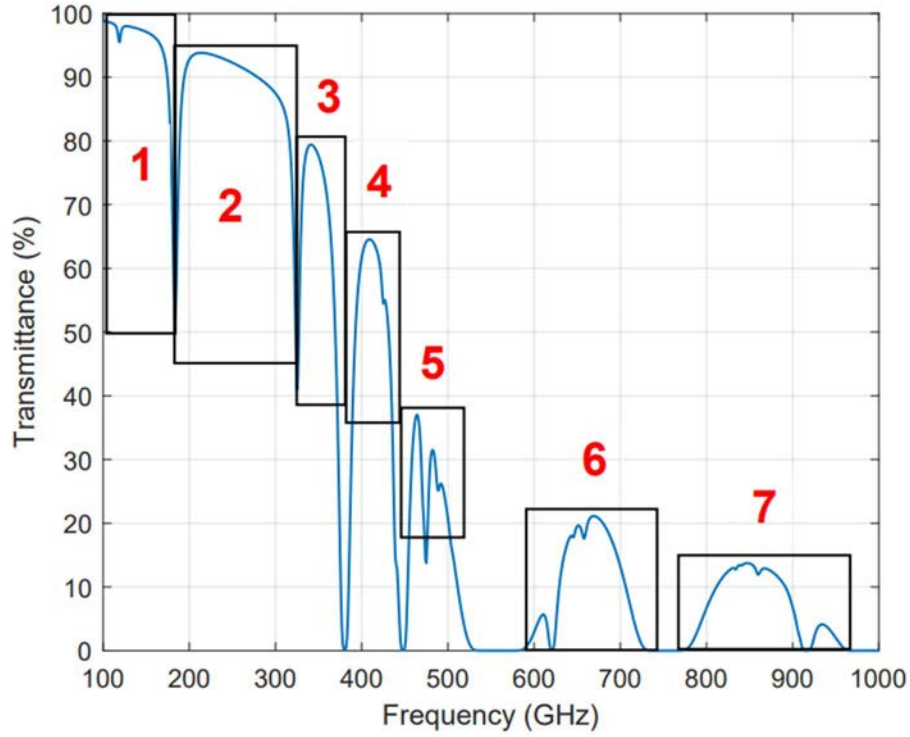

Figure A-1: Transmission windows between 100 GHz and 1 THz at sea level, a temperature of 15° and water vapor density of 7,5 g/m^3

The BandWidth (BW) of each TW is defined between the $1/\sqrt{2}$ values of transmittance relative to the peak value of transmittance of each frequency band. Since the transmittance depends on the link distance both position and BW of the TWs very with the link distance, see Figure A-2.

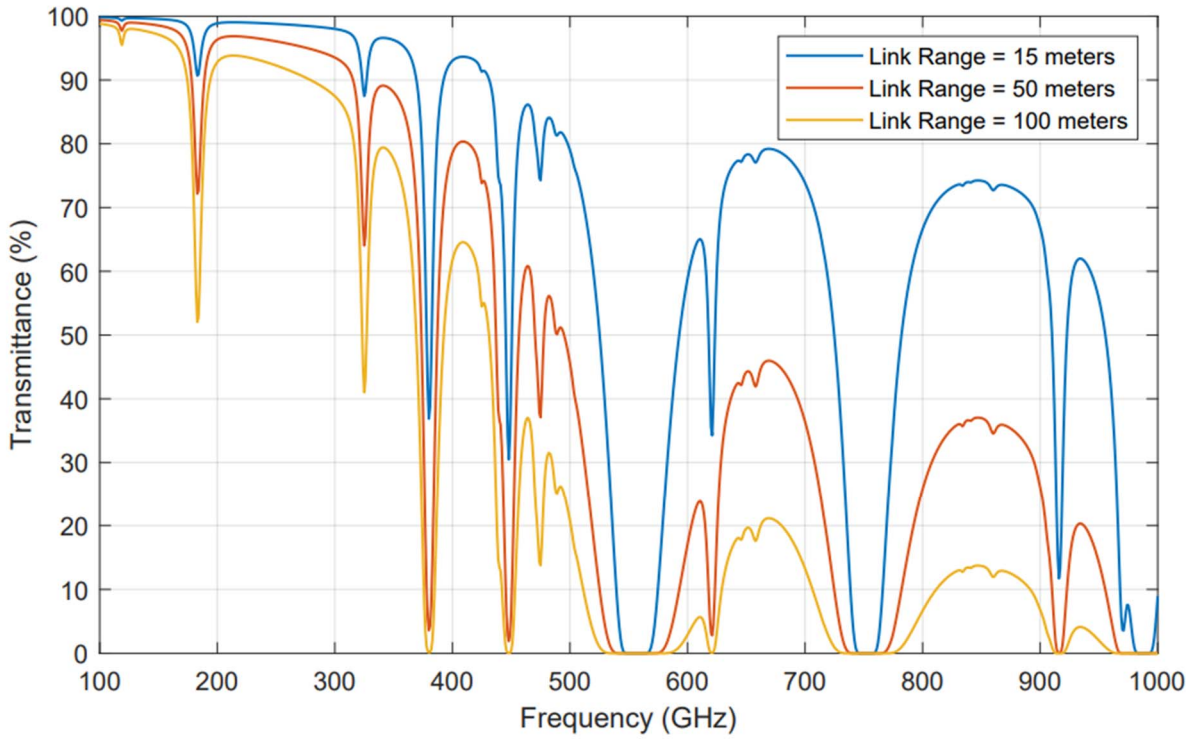

Figure A-2: Transmission windows between 100 GHz and 1 THz for various link distances at sea level, a temperature of 15° and water vapor density of 7,5 g/m^3

Table A-1 lists the TW corresponding to Figure A-2.

Table A-1: Definition of transmission windows depending on the link distance (at sea level, a temperature of 15° and water vapor density of 7,5 g/m^3)

TW	Link Distance (m)	Lower frequency (GHz)	Centre frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)
1	15	100	142	183	83
1	50	100	142	183	83
1	100	100	140	180	80
2	15	183	254	325	142
2	50	183	254	325	142
2	100	185	253	321	136
3	15	325	351	376	51
3	50	325	348	371	46
3	100	328	348	369	41
4	15	384	414	443	59
4	50	388	412	436	48
4	100	391	412	433	42
5	15	452	486	520	68
5	50	455	479	502	47
5	100	457	473	488	31
6	15	598	660	722	124
6	50	630	668	705	75
6	100	635	667	696	62
7	15	786	870	953	167
7	50	800	850	900	100
7	100	811	851	892	81

Annex B:
FN 5.340 of the Radio Regulations

"**5.340** All emissions are prohibited in the following bands:

1 400-1 427 MHz,	
2 690-2 700 MHz,	except those provided for by No. 5.422,
10,68-10,7 GHz,	except those provided for by No. 5.483,
15,35-15,4 GHz,	except those provided for by No. 5.511,
23,6-24 GHz,	
31,3-31,5 GHz,	
31,5-31,8 GHz,	in Region 2,
48,94-49,04 GHz,	from airborne stations
50,2-50,4 GHz,	
52,6-54,25 GHz,	
86-92 GHz,	
100-102 GHz,	
109,5-111,8 GHz,	
114,25-116 GHz,	
148,5-151,5 GHz,	
164-167 GHz,	
182-185 GHz,	
190-191,8 GHz,	
200-209 GHz,	
226-231,5 GHz,	
250-252 GHz (WRC-03)".	

Annex C:
FN 5.565 of 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)".

Annex D:
FN 5.564A of the Radio Regulations

"5.564A For the operation of fixed and land mobile service applications in frequency bands in the range 275-450 GHz:

The frequency bands 275-296 GHz, 306-313 GHz, 318-333 GHz and 356-450 GHz are identified for use by administrations for the implementation of land mobile and fixed service applications, where no specific conditions are necessary to protect Earth exploration-satellite service (passive) applications.

The frequency bands 296-306 GHz, 313-318 GHz, and 333-356 GHz 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-23).

In those portions of the frequency range 275-450 GHz where radio astronomy applications are used, specific conditions (e.g. minimum separation distances and/or avoidance angles) may be necessary to ensure protection of radio astronomy sites from land mobile and/or fixed service applications, on a case-by-case basis in accordance with Resolution 731 (Rev.WRC-23).

The use of the above-mentioned frequency bands by land mobile and fixed service applications does not preclude use by, and does not establish priority over, any other applications of radio services in the range of 275-450 GHz (WRC-23)".

Annex E:
Change history

Date	Version	Information about changes
2023-03	0.0.1	Initial table of contents
2023-06	0.0.2	Included approved contributions from the ISG
2023-10	0.0.3	Included approved contributions from the ISG
2023-10	0.0.4	Included approved contributions from the ISG
2023-10	0.0.5	Included approved contributions from the ISG
2023-11	0.0.6	Cleaned after editHelp
2013-11	0.0.7	Included approved contributions from the ISG addressing missing content
2024-02	0.0.8	Included approved contributions from the ISG addressing changes after ITU-R WRC-23

History

Document history		
V1.1.1	March 2024	Publication