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Technical and operational characteristics and applications of the point-to-point fixed service applications operating in the frequency range 275-450 GHz

# 1 Introduction

Due to progress of RF integrated devices and circuits operating in the frequency band above 275 GHz, the contiguous frequency bands become available for fixed service applications. Some applications operating in the frequency band above 275 GHz such as the point-to-point backhaul and fronthaul for mobile services are introduced and the ultra-high-speed data transmission between fixed stations become feasible.

RR No. **5.565** identifies the specific frequency bands for the radio astronomy service, the earth exploration satellite service (passive), and the space research service (passive) in the frequency range of 275-1 000 GHz. Although the use of the frequency 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

This Report intends to provide the technical and operational characteristics of the fixed service applications operating in the frequency range 275-450 GHz which will be useful for the sharing and compatibility studies between the fixed service applications and the already identified passive services.

# 2 Scope

This Report provides the fixed service applications and their technical and operational characteristics operating in the frequency range 275-450 GHz for sharing and compatibility studies between fixed service applications and passive services, as well as among active services in the frequency range 275-450 GHz.

# 3 Related Recommendation and Report

|  |  |
| --- | --- |
| Recommendation [ITU-R F.758](http://www.itu.int/rec/R-REC-F/recommendation.asp?lang=en&parent=R-REC-F.758) | System parameters and considerations in the development of criteria for sharing or compatibility between digital fixed wireless systems in the fixed service and systems in other services and other sources of interference |
| Recommendation [ITU-R M.2083](https://www.itu.int/rec/R-REC-M.2083/en) | IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond |
| Recommendation [ITU-R P.525](https://www.itu.int/rec/R-REC-P.525/en) | Calculation of free-space attenuation |
| Recommendation [ITU-R P.676](https://www.itu.int/rec/R-REC-P.676/en) | Attenuation by atmospheric gases |
| Recommendation [ITU-R P.838](https://www.itu.int/rec/R-REC-P.838/en) | Specific attenuation model for rain for use in prediction methods |
| Recommendation [ITU-R P.840](https://www.itu.int/rec/R-REC-P.840/en) | Attenuation due to clouds and fog |
| Report [ITU-R F.2323](https://www.itu.int/pub/R-REP-F.2323) | Fixed service use and future trends |
| Report [ITU-R M.2376](https://www.itu.int/pub/R-REP-M.2376) | Technical feasibility of IMT in bands above 6 GHz |
| Report [ITU-R RA.2189](https://www.itu.int/pub/R-REP-RA.2189) | Sharing between the radio astronomy service and active services in the frequency range 275-3 000 GHz |
| Report [ITU-R SM.2352](http://www.itu.int/pub/R-REP-SM/publications.aspx?lang=en&parent=R-REP-SM.2352) | Technology trends of active services in the frequency range 275-3 000 GHz |

# 4 List of acronyms and abbreviations

|  |  |
| --- | --- |
| BBU | Base band unit |
| RRH | Remote radio head |
| THF | Tremendously high frequency |

# 5 Frequency ranges of agenda item 1.15

As the unit of frequency is the hertz (Hz), frequencies shall be expressed in gigahertz (GHz), above 3 GHz, up to and including 3 000 GHz in accordance with Radio Regulations. However, the gigahertz frequency range is subdivided into three ranges as shown in Table 1. Because the frequency ranges of WRC-19 agenda item 1.15 is 275-450 GHz, two frequency bands i.e. EHF and THF must be included in the study of agenda item 1.15.

TABLE 1

Frequency bands above 3 GHz

|  |  |  |  |
| --- | --- | --- | --- |
| Band number | Symbols | Frequency range (lower limit exclusive, upper limit inclusive) | Corresponding metric subdivision |
| 10 | SHF | 3 to 30 GHz | Centimetric waves |
| 11 | EHF | 30 to 300 GHz | Millimetric waves |
| 12 | THF[[1]](#footnote-1) | 300 to 3000 GHz | Decimillimetric waves |

# 6 Overview of fixed service applications operating in the frequency range 275-450 GHz

## 6.1 Regulatory information and technology trend above 275 GHz

WRC-12 agenda item 1.6 covered the review of the Radio Regulations in order to update the spectrum use by the passive services between 275 GHz and 3 000 GHz. The revised footnote 5.565 highlights that use of the range 275-1 000 GHz by the passive services does not preclude use of this range by active services. It also states that administrations wishing to use the frequency range 275‑1 000 GHz for active services are urged to take all practicable steps to protect passive services from harmful interference. Subsequently, WRC-19 agenda item 1.15 invites ITU-R to identify candidate frequency bands for use by systems in the land-mobile and fixed services while maintaining protection of the passive services identified in No. [**5.565**](https://mail.google.com/mail/u/0/?ui=2&ik=5d305f97a4&view=fimg&th=154ba169905ff138&attid=0.1.1&disp=emb&attbid=ANGjdJ-NESaNRHlpXPARaDqV7VVmS29eXjpZ4bghaWR6su2eDcflPLG8o0qXps8Detx1WsI8_GRaNn1gemGXVMe-XQaXBuj3f-n90Uc4lWdmJ2QYP7H_6K_-e1OjzCs&sz=s0-l75-ft&ats=1463412491727&rm=154ba169905ff138&zw&atsh=0):

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)

Progress in semiconductor and photonic devices has enabled handling spectrum above 200 GHz with a simple configuration. Oscillators and amplifiers with operating frequencies from 200 GHz to 400 GHz have been developed by using compound semiconductor technologies, such as Indium Phosphide (InP) and Gallium Arsenide (GaAs) high electron mobility transistors (HEMTs) and heterojunction bipolar transistors (HBTs). According to the International Technology Roadmap for Semiconductors (ITRS), the cut‑off frequency of silicon complementary metal–oxide–semiconductors (Si CMOS) will reach 1 THz before 2021.

One of the disadvantages of THF-band signal is high levels of absorption by air. Figure 1 shows the attenuation coefficient in the frequency range 100-1 000 GHz. The attenuation coefficient in THF is generally larger than that in SHF and millimetre-wave region. However in the frequency range of 100-370 GHz, the attenuation coefficient is smaller than in the 60 GHz band. Therefore, this frequency range may be used for outdoor point-to-point fixed service applications over a distance of several hundred metres.

FIGURE 1

Attenuation coefficient in the frequency range 100-1 000 GHz

(Dashed line indicates attenuation coefficient highest peak of 60 GHz band)



## 6.2 Point-to-point fronthaul and backhaul

Figure 2 shows the network architecture of mobile systems which support high-capacity transmission between a base station and a mobile terminal. The fronthaul is defined as a link connection between the base station’s baseband unit (BBU) and the remote radio head (RRH), while the backhaul is a link between the base station and the higher level network elements. According to Recommendation ITU-R M.2083 and Report ITU-R M.2376, fronthaul and backhaul are critical challenges to accommodate the increase in data throughput of future mobile traffic. In order to meet the peak data rate 10-20 Gb/s of the mobile terminals in a small cell, the transmission capacity of fronthaul and backhaul may exceed tens of Gb/s substantially. Dense deployment scenario of small cells may cause frequency interference between base stations and mobile terminals if they operate in the similar millimetre-wave frequency bands. The frequency band above 275 GHz can meet the requirement of transmission capacity of fronthaul and backhaul, and avoid frequency interference between stations because millimetre-wave spectrum will be used for the access link.

FIGURE 2

Fronthaul and backhaul operation to be used for mobile system network



# 7 System characteristics

*[Editor’s note: At the moment there are two frequency ranges around 300 GHz, it is planned to combine them with a single set of parameters in the next meeting]*

## 7.1 Characteristics for systems planned to operate in the band 275-325 GHz

The technical and operational characteristics of fixed point-to-point systems planned to operate in the band 275-325 GHz is shown in Table 2. Annex 1 proposes radio-frequency channel arrangement for fixed service applications operating in the frequency band 275-316 GHz. Appendix 1 to Annex 1 gives information on propagation attenuation in the frequency band
275-316 GHz. In addition, Annex 1 also provides the channel arrangement for fixed service and land mobile applications operating in the frequency band 252.72 to 321.84, which is currently used in the draft of the IEEE P802.15.3d.

## 7.3 Characteristics for systems planned to operate in the band 380-445 GHz

The technical and operational characteristics of fixed point-to-point systems planned to operate in the band 275-321.84 GHz is shown in Table 2.

A proposal for transmitter spectrum mask is given in Annex 2.

TABLE 2

Technical and operational characteristics of the fixed service applications planned to operate

|  |  |  |  |
| --- | --- | --- | --- |
| Frequency band (GHz) | 275-325 |  | 380-445 |
| Duplex Method | FDD/TDD  |  | FDD/TDD  |
| Modulation  | BPSK/QPSK/8PSK/8APSK/16QAM/32QAM/64QAMBPSK-OFDM/QPSK-OFDM/ 16QAM-OFDM/32QAM-OFDM/64QAM-OFDM |  | BPSK/QPSK//8PSK/8APSK/16QAM/32QAM8PSK, 8APSKBPSK-OFDM/QPSK-OFDM/ 16QAM-OFDM/32QAM-OFDM |
| Channel bandwidth (GHz)  | Based on 200 MHz slots[2.16/4.32/8.64/12.96/17.28/25.92/51.84] |  | Based on 200 MHz slots[2.16/4.32/8.64/12.96/17.28/25.92/51.84] |
| Tx output power range (dBW)  | -30 … 0 |  | -40…-20 |
| Tx output power density range (dBW/GHz) |  -33.4 … -3.3 |  | -23.3…-57.1 |
| Feeder/multiplexer loss range (dB)  | 0 … 3 |  | 0 … 3 |
| Antenna gain range (dBi)  | 24 … 50 |  | 24 … 50 |
| Antenna pattern | Gaussian beam |  | Gaussian |
| Antenna height (m) | 10-25 |  | 10-25 |
| Antenna elevation | +/-20 deg. |  | +/-20 deg. |
| e.i.r.p. range (dBW)  | 1 … 50 |  | --33.1…26.7 |
| e.i.r.p. density range (dBW/GHz) | -26.1-46.7 |  | TBD |
| Receiver noise figure typical (dB)  | 8-15 |  | 8…15 |
| Receiver noise power density typical (=*NRX*) (dBW/GHz)  |  -106 |  | -106 |
| Normalized Rx input level for 1 × 10–6 BER (dBW/GHz)  | [SNR of 8-15dB for BPSK required, calculated according to noise power] |  | [SNR of 8-15dB for BPSK required, calculated according to noise power] |
|  |  |  |  |
| Link length (m) | 100 … 300 |  | 100 … 300 |
| Deployment Density | 1.5-3/km^2 |  | 1.5-3/km^2 |

# 8 Summary

Table 4 summarizes the candidate frequency bands for fixed service applications under WRC-19 agenda item 1.15. The first possible candidate frequency bands 275-316 GHz, 275-321.84 and 380‑445 GHz can to be used for fronthaul and backhaul

TABLE 4

Possible candidate frequency bands for fixed service applications

|  |  |
| --- | --- |
| Candidate frequency band | Applications |
| 275-25 GHz | Fronthaul and backhaul |
|  |  |
| 380-445 GHz | Fronthaul and backhaul |

*[Japan’s note: Table 3 will be updated according to the input contributions]*

# 10 References

Annex 1

Proposed RF channel arrangement examples for fronthaul
and backhaul applications

The basic channel bandwidth is 2.16 GHz, which are widely used for radio LAN, and the others are 4.32 GHz, 8.64 GHz, 12.96 GHz, 17.28 GHz, 25.92 and 51.8 GHz. The extra channels are embedded to allocate channels in the whole frequency band.

FIGURE A1

Radio-frequency channel arrangement example for fronthaul and backhaul applications



Radio-frequency channel arrangement example for fronthaul and backhaul applications discussed in standardization bodies



Appendix 1 to Annex 1

Attenuation characteristics in the frequency range 275-445 GHz

This Appendix gives information on attenuation characteristics calculated from Recommendation ITU-R P.676-10. The attenuation by rain rate and liquid water density in fog is also calculated from Recommendation ITU-R P.838-3 and P.840-6. The difference of attenuation by atmospheric gases at 275 GHz and 316 GHz is about 5 dB, but those by rain rate and liquid water density in fog are -0.1 dB and +0.6 dB, respectively. These characteristics should be used for designing point-to-point fronthaul and backhaul.

FIGURE A1-A1

Attenuation characteristics by atmospheric gases



FIGURE A1-A2

Attenuation characteristics by rain rate

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FIGURE A1-A3

Attenuation characteristics by liquid water density in fog. The calculation results above 200 GHz is extrapolated using Recommendation ITU-R 840-6.

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Annex 2

Proposal for a Transmitter Spectrum Mask

For the transmitter spectrum mask it is proposed at assume the mask currently proposed in IEEE P802.15.3d as shown in Figure A2-A1 and Table A2-A1.

FIGURE A2-A1

**Generic transmit spectral mask**

The parameters of the PSD indicated in Figure A2-A1 are defined in Table A2-A1.

Table A2-A1

**Transmit spectrum mask parameters**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Channel Bandwidth [GHz]** | $$\_{}$$ | $$\_{}$$ | $$\_{}$$ | $$\_{}$$ |
| 2.160 | **0.94** | **1.10** | **1.60** | **2.20** |
| 4.320 | **2.02** | **2.18** | **2.68** | **3.28** |
| 8.640 | **4.18** | **4.34** | **4.84** | **5.44** |
| 12.960 | **6.34** | **6.50** | **7.00** | **7.60** |
| 17.280 | **8.50** | **8.66** | **9.16** | **9.76** |
| 25.920 | **12.82** | **12.98** | **13.48** | **14.08** |
| 51.840 | **25.78** | **25.94** | **26.44** | **27.04** |
| 69.120  | **34.42** | **34.58** | **35.08** | **35.68** |

1. This terminology is used within this report. THF stands for tremendously high frequency. [↑](#footnote-ref-1)