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| Annex 29 to Working Party 5A Chairman’s Report |
| working document towards a preliminary draft new report itu-r M.[300GHz\_MS\_CHAR] |
| Technical and operational characteristics of the land mobile service applications operating in the frequency range 275-450 GHz |

(WRC-19 agenda item 1.15)

# 1 Introduction

Due to the progress of RF integrated devices and circuits operating in the frequency band above 275 GHz, the contiguous frequency bands become available for land mobile service applications. Some unique applications operating in the frequency band above 275 GHz such as KIOSK downloading, ticket gate downloading and intra-rack and intra-chip communications are introduced and the ultra-high-speed data transmission between terminals whose transmission distance is in the order of centimeters 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 the 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

# 2 Scope

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

# 3 Related Recommendation and Report

|  |  |
| --- | --- |
| Report ITU-R SM.2352-0: | *Technology trends of active services in the frequency range 275‑3 000 GHz* |
| Recommendation ITU-R M.2003: | *Multiple Gigabit Wireless Systems in frequencies around 60 GHz* |
| Recommendation ITU-R P.676: | *Attenuation by atmospheric gases* |
| Recommendation ITU-R P.838: | *Specific attenuation model for rain for use in prediction methods* |
| Recommendation ITU-R P.840: | *Attenuation due to clouds and fog* |

# 4 List of acronyms and abbreviations

|  |  |
| --- | --- |
| CPMS | Close proximity mobile system |
| THF | Tremendously high frequency |

# 5 Frequency ranges of agenda item 1.15

As the unit of frequency is 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 ranges are subdivided into three ranges as shown in Table 1. Because the frequency range 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 | Frequency range (lower limit exclusive, upper limit inclusive) | Corresponding metric subdivision |
| 10 | 3 to 30 GHz | Centimetric waves |
| 11 | 30 to 300 GHz | Millimetric waves |
| 12 | 300 to 3000 GHz | Decimillimetric waves |

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

## 6.1 Close proximity mobile system operating in the frequency band 275-450 GHz

*[Editor’s note: This section will identify the specific frequency bands and land mobile service applications which will be used for sharing and compatibility studies with passive services by WP 1A.]*

### 6.1.1 KIOSK downloading mobile system

In order to enjoy movies, news, magazines and music by smart phones and tablet terminals, the terminals should have high-data-speed transmission capability and be wirelessly connected to the network to download various contents from the content providers. Several wireless devices provide wireless broadband connectivity, but the maximum speed of these devices is limited by operational and environmental conditions of the systems and the actual observed transmission rate is sometimes far from the specifications. Kiosk systems, as shown in Figure 1, are introduced to download the heavy contents to the user terminals wirelessly. Kiosk terminals are connected to the network through wired systems and located in public areas such as train stations, airports, shopping malls and etc. The distance between the user and the Kiosk terminal is typically less than 10 cm and contents are downloaded and/or uploaded to/from user terminals. In order to download two-hour movie whose size is about 900 MB to the user terminal, the required downloading times are 1.6 sec, 1.1 sec and 0.11 sec if effective throughput of devices are 4.6 Gb/s, 6.9 Gb/s and 66 Gb/s, respectively. The data transfer speed in the range 10 -100 Gb/s is achieved applying multi-modulation method and carrier frequencies above millimetre waves. If the large contiguous bandwidth is feasible in the frequency band above 275 GHz, a simple modulation scheme such as BPSK, QPSK can be applied to transmit heavy contents in a short time period.

FIGURE 1

KIOSK downloading mobile system



## 6.1.2 Ticket gate downloading mobile system

The ticket gate downloading devices have two functions, i.e. fare-paying and large-file downloading functions. Figure 2 illustrates the user terminal pays fare and simultaneously downloads video contents such as news, movies, etc. In order to download the contents at the ticket gate, high-speed data transmission capability is required for both mobile terminal and ticket gate station. The transmission range covered by these devices is limited to about 10 cm to avoid frequency interferences between mobile terminals. To meet these requirements, the spectrum above 275 GHz whose features are a broadband bandwidth and short transmission distance can be utilized to this type of application.

FIGURE 2

Ticket gate downloading mobile system



### 6.1.3 Wireless links for data centers

The goal of the introduction of wireless data links in addition to the existing fibres is to provide flexibility by providing reconfigurable routes within a data center. In the figure some examples are illustrated between or inside the server racks (green) for possible line-of-sight (LOS) or multi hop links.



### 6.1.4 Inter-chip communication mobile system

There has been increasing interest in applying wireless links for data centres to replace optical wired connections, because the current device technologies can make it possible to reduce the size of racks of servers/routers in data centre. Figure 3 shows how these devices can be integrated into the compact rack of servers/routers. If the same cabling connections are used in the compact rack, cabling and cooling problems in the rack cannot be avoided. The inter-chip communication between boards in the rack can eliminate cabling and cooling problems in the rack. The frequency band above 275 GHz is suitable for inter-chip communication because the antenna diameter is inversely proportional to the operational frequency

FIGURE 3

Inter-chip communication mobile system



### 6.1.5 Intra-device communications

In intra-device communications, one or more communication links are operated within a device. High speed terahertz wireless links could connect two or more PCBs or even chips on the same PCB inside a device. Typically, these devices will be shielded not only preventing emission of THz‑radiation but also blocking incoming THz signals.

The terahertz band is huge hence several channels could be used in a small area (within one device). The following figure illustrates the envisaged concept of THz point-to-point communications between boards, where the colour of the beams indicates different frequencies.


# 7 System characteristics

*[Editor’s note: Technical and operational characteristics of the land mobile radiocommunication system operating in the frequency band 275-450 GHz are invited to be addressed in this section.]*

## 7.1 Close proximity mobile system (CPMS) operating in the frequency band 275-450 GHz

*[Editor’s note: This section currently addresses 2 CPMSs. Possible merger should be discussed in the future meetings, taking into account the advance of the RF device technology and potential interference issues.]*

The expected ranges of technical and operational characteristics for close proximity mobile systems planned to operate in the band 275-320 GHz and in the band 275-450 GHz are shown in Table 2.

Annex 1 proposes two examples of a radio-frequency channel arrangement for land mobile service applications operating in the frequency band 275-450 GHz. Appendix 1 to Annex 1 gives information on propagation attenuation in the frequency band 275-320 GHz.

TABLE 2

Expected technical and operational characteristics of a land mobile CPMS applications operating
in the frequency band 275-450 GHz

| Parameters | Values |
| --- | --- |
| CPRS application operating in the frequency range 275-320 GHz | CPRS application operating in the frequency range 275-450 GHz |
| Frequency band (GHz) | 275-320 | 275-450 |
| Deployment density  | Depending on outdoor usage | Depending on outdoor usage |
| Tx output power density (dBW/MHz) |  | Range TBD |
| e.i.r.p. density(dBW/MHz) |  | Range TBD |
| Duplex Method | FDD/TDD | TDD |
| Modulation | OOK/BPSK/QPSK/16QAM/64QAMBPSK-OFDM/QPSK-OFDM/ 16QAM-OFDM/32QAM-OFDM/64QAM-OFDM | OOK/BPSK/QPSK/16QAM/64QAM8PSK/8APSK |
| Average distance between CPMS fixed and mobile devices (m) | 0.1 | 0.1 |
| Maximum between CPRS fixed and mobile devices (m) | 1 | 1 |
| Antenna height (m) | TBD | TBD |
| Antenna beamwidth (degree) | 3-10 | 15 |
| Frequency reuse  | 1 | 1 |
| Antenna pattern  | TBD | TBD |
| Antenna polarization  | Liner | Linear |
| Indoor CPRS fixed device deployment (%) | 90 | 90 |
| Indoor CPRS fixed device penetration loss (dB) | >100 | >100 |
| Feeder loss (dB) | 2 | 2 |
| Maximum CPRS fixed device output power (dBm) | 10 | 10 |
| Channel bandwidth (GHz) | 2.16/4.32/8.64/12.96/17.28/ 25.92/51.8 | 2.16/4.32/8.64/12.96/17.28/25.92/51.84/69.12/103,68 |
| Transmitter spectrum mask  | TBD | TBD |
| Maximum CPRS fixed device antenna gain (dBi) | 30 | 30 |
| Maximum CPRS mobile device antenna gain (dBi) | 15 | 30 |
| Maximum CRPS fixed device output power (e.i.r.p.) (dBm) | 40 | 40 |
| Maximum CRPS mobile device output power (e.i.r.p.) (dBm) | 25 | 40 |
| Average CPRS fixed device activity (%) | 20 | 20 |
| Average CPRS fixed device power (dBm (e.i.r.p)) | 20 | 20 |
| Receiver noise figure typical (dB) | 15 | 15 |

*[Editor's note: Table fields and contents have to be harmonized among use cases]*

## 7.2 Wireless links in data centers

The expected ranges of technical and operational characteristics for wireless links in data centers planned to operate in the band 275-450 GHz are shown in Table 3.

TABLE 3

Expected technical and operational characteristics of wireless links in data centers operating
in the frequency band 275-450 GHz

| Parameter | Values |
| --- | --- |
| Frequency band (GHz) | 275-450 |
| Deployment density  | TBD |
| Tx output power density (dBW/MHz) | Range TBD |
| e.i.r.p. density (dBW/MHz) | Range TBD |
| Duplex Method | TDD, FDD, SDD |
| Modulation | OOK/BPSK/QPSK/16QAM/64QAM8PSK/8APSK |
| Maximum distance between devices | 100 m |
| Antenna height (m) | TBD |
| Antenna beamwidth (degree) | < 25 (expected) |
| Frequency reuse  | 1  |
| Antenna pattern  | TBD |
| Antenna polarization  | Linear |
| Indoor deployment (%) | 100 |
| Indoor penetration loss (dB) | TBD |
| Maximum device output power (dBm) | 10 |
| Channel bandwidth (GHz) | 2.16/4.32/8.64/12.96/17.28/ 25.92/51.84/69.12/103,68 |
| Transmitter spectrum mask  | TBD |
| Maximum device antenna gain (dBi) | 30 |
| Maximum device output power (e.i.r.p.) (dBm) | 40 |
| Maximum device activity (%) | 100 |
| Receiver noise figure typical (dB) | 10 |

*[Editor's Note: Table fields and contents have to be harmonized among use cases]*

## 7.3 Intra-device communications

The expected ranges of technical and operational characteristics for wireless THz intra-device links planned to operate in the band 275-450 GHz are shown in Table 4.

TABLE 4

Expected technical and operational characteristics of wireless THz intra-device links operating
in the frequency band 275-450 GHz

| Parameter | Value |
| --- | --- |
| Frequency band (GHz) | 275-450 |
| Deployment density  | TBD |
| Tx output power density (dBW/MHz) | Range TBD |
| e.i.r.p. density (dBW/MHz) | Range TBD |
| Indoor Deployment (%) | TBD |
| Duplex Method | TDD, FDD, SDD |
| Modulation | OOK/BPSK/QPSK/16QAM/64QAM8PSK/8APSK |
| Maximum distance between devices | <1 m |
| Antenna height (m) | TBD |
| Antenna beamwidth (degree) | ~180 (expected) |
| Frequency reuse  | 1  |
| Antenna pattern  | TBD |
| Antenna polarization  | Linear |
| Maximum device output power (dBm) | 10 |
| Channel bandwidth (GHz) | 2.16/4.32/8.64/12.96/17.28//25.92/51.84/69.12/103,68 |
| Transmitter spectrum mask  | TBD |
| Maximum device antenna gain (dBi) | 20 |
| Typical expected device antenna gain (dBi) | 6 |
| Maximum device output power (e.i.r.p.) (dBm) | 30 |
| Maximum device activity (%) | 100 |
| Receiver noise figure typical (dB) | 10 |

*[Editor's Note: Table fields and contents have to be harmonized among use cases]*

# 8 Summary of possible candidate frequency bands for land mobile service applications under WRC-19 agenda item 1.15

Table 5 summarizes the candidate frequency bands for land mobile service applications under WRC-19 agenda item 1.15.

TABLE 5

Possible candidate frequency bands for land mobile service applications

|  |  |
| --- | --- |
| Candidate frequency band | Applications |
| 1) 275-320 GHz | Close proximity mobile service |
| 2) 275-450 GHz | Close proximity mobile service, intra-device communication, wireless links for data centres |
| 3)  |  |

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

# 9 Bibliographies

[1] APT/AWG/REP-66, APT Report on "Short Range Radiocommunication Systems and Application Scenarios Operating in the Frequency Range 275-1 000 GHz".

[2] IEEE802.15-15-0109-06-003e, “TG3e Technical Guidance Document (TGD)”.

**Annex:** 1

Annex 1

Examples of radio-frequency channel arrangement

In Figures A1 and A2 two examples of channel arrangements are illustrated. The basic channel bandwidth which are widely used for radio LAN is 2.16 GHz, and the other channels 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 for close proximity application



FIGURE A2

Radio-frequency channel arrangement example for close proximity, intra device communications and wireless links in data centers, which is discussed in standardization bodies



Appendix 1
to Annex 1

Attenuation characteristics in the frequency range 275-[320] GHz

*[Editor’s note: This appendix needs further review in accordance with technical and operational characteristics described in Section 7.1 at the next meetings, particularly Figures A1-A1 and A1-A3 should be extended up to 450 GHz according to the change of the frequency range due to the new proposal of the mobile system which supports up to 450 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 Recommendations ITU-R P.838-3 and ITU-R P.840-6. The difference of attenuation by atmospheric gases at 275 GHz and 320 GHz is about 11 dB, but those by rain rate and liquid water density in fog are -0.1 dB and +0.66 dB, respectively. These characteristics should be used for designing close proximity systems.

FIGURE A1-A1

Attenuation characteristics by atmospheric gases



FIGURE A1-A2

Attenuation characteristics by rain rate



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

