International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Report ITU-R M.2417-1
(11/2022)

Technical and operational characteristics of land mobile service applications in the frequency range 275-450 GHz

M Series

Mobile, radiodetermination, amateur and related satellite services

International Telecommunication Union

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Note: *This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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REPORT ITU-R M.2417-1

Technical and operational characteristics of land mobile service applications in the frequency range 275-450 GHz

(Question ITU-R 256-1/5)

(2017-2022)

TABLE OF CONTENTS

Page

1 Introduction

Due to the progress of RF integrated devices and circuits having capability to operate above 275 GHz, contiguous frequency bands in the range 275-450 GHz can be used by land-mobile service applications. Applications operating in the frequency band above 275 GHz, such as Kiosk downloading, automatic turnstile downloading, and intra-rack and intra-chip communications, are introduced, and ultra-high-speed data transmission between terminals whose transmission distance is in the order of centimetres becomes feasible.

Radio Regulations (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 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.

Furthermore, RR No. **5.564A** identifies the frequency bands 275-296 GHz, 306-313 GHz, 318-333 GHz and 356-450 GHz 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, and indicates that 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-19)**. This Report is to be complemented by other ITU-R publications that provide the specific conditions to be applied to the land-mobile service applications, to ensure the protection of Earth exploration-satellite service (passive) applications.

The initial spectrum needs for some LMS applications above 275 GHz are shown in Annex 5 to this Report. Further studies are under way to estimate the spectrum needs for emerging LMS applications.

2 Scope

This Report provides the technical and operational characteristics of land mobile service applications in the frequency range 275-450 GHz for sharing and compatibility studies.

3 Related Recommendations and Reports

Spectrum:

Recommendation ITU-R F.699	Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to 86 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
Recommendation ITU-R P.1238	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
Recommendation ITU-R P.2109	Prediction of Building Entry Loss

Report ITU-R F.2416	Technical and operational characteristics and applications of the point-to-point fixed service applications operating in the frequency band 275-450 GHz
Report ITU-R P.2406	Studies for short-path propagation data and models for terrestrial radiocommunication systems in the frequency range 6 GHz to 450 GHz
Report ITU-R SM.2352	Technology trends of active services in the frequency range 275-3 000 GHz
Use cases:	
Recommendation ITU-R M.2003	Multiple Gigabit Wireless Systems in frequencies around 60 GHz
Report ITU-R M.2227	Use of multiple gigabit wireless systems in frequencies around 60 GHz
Report ITU-R M.2441	Emerging usage of the terrestrial component of International Mobile Telecommunication (IMT)
Report ITU-R M.2479	The use of land mobile systems, excluding IMT, for machine-type communications
Report ITU-R SM.2450	Sharing and compatibility studies between land-mobile, fixed and passive services in the frequency range 275-450 GHz

4 List of acronyms and abbreviations

BER	Bit error ratio
CPMS	Close proximity mobile system
LMS	Land mobile service
OFDM	Orthogonal frequency-division multiplexing
PCB	Printed circuit board
RR	Radio Regulations
SC	Single-carrier
VR	Virtual reality

5 Regulatory and propagation information

5.1 Frequency ranges defined in the RR

The Gigahertz frequency ranges from 3 GHz to 3 000 GHz are subdivided into three bands as shown in Table 1. The frequency range covered by this Report belongs to both millimetric and decimillimetric waves.

TABLE 1

Frequency bands above 3 GHz

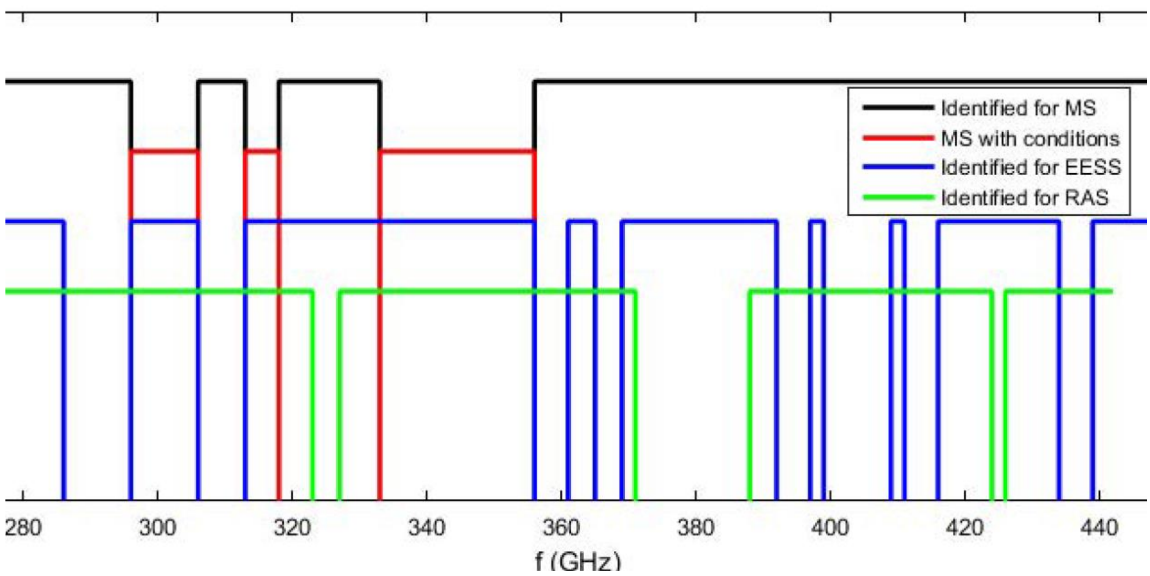
Band number	Symbol	Frequency range (lower limit exclusive, upper limit inclusive)	Corresponding metric subdivision
10	SHF	3 to 30 GHz	Centimetric waves
11	EHF	30 to 300 GHz	Millimetric waves
12	THF[1]	300 to 3 000 GHz	Decimillimetric waves

5.2 Frequency bands identified in the RR

The frequency bands identified in RR No. **5.565** that are also addressed in RR No. **5.564A** with either no specific conditions necessary to protect the Earth exploration-satellite service (EESS) (passive) applications, or which may only be used by land mobile service applications when specific conditions are applied to ensure the protection of EESS (passive) applications, are shown in Fig. 1.

FIGURE 1[2]

Identification of frequency bands in RR Nos. 5.564A and 5.565



5.3 Propagation characteristics

One of the propagation effects in this frequency range is gaseous attenuation, specific gaseous attenuation is shown in Fig. 2 on the height of the ground level (pressure 1 013 hPa, temperature 15 °C, water vapour density 7.5 g/m^3). This curve is obtained using the methodology from Recommendation ITU-R P.676-12. The Figure illustrates quite different propagation conditions for different bands identified in this frequency range.

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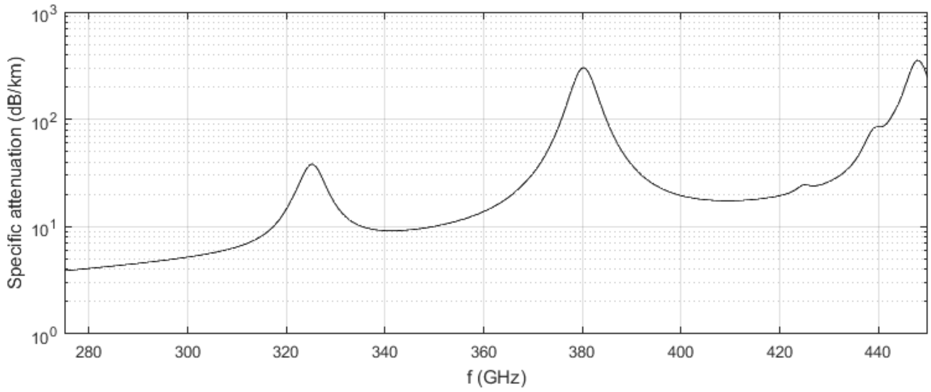
1 This symbol is introduced for this Report only. THF stands for Tremendous High Frequency.

2 This is a conceptual representation and the different services are separated for clarity.

FIGURE 2

Specific atmospheric attenuation in 275-450 GHz frequency range on the ground level



The other elements such as building entry loss and clutter loss should be considered for the system deployment of land-mobile service applications. Although prediction of those losses is provided by Recommendations ITU-R P.2108 and ITU-R P.2109, the maximum frequency band is limited below 100 GHz. Further studies on those issues are expected in the future work plans by the other groups.

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

6.1 Close proximity mobile systems in the frequency band on 275-325 GHz and 275-450 GHz

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 Fig. 3, are introduced to download 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, and shopping malls. 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 a two-hour movie whose size is about 900 MB to the user terminal, the required downloading times are 1.6 s, 1.1 s, and 0.11 s if effective throughput of devices are 4.6 Gbit/s, 6.9 Gbit/s and 66 Gbit/s, respectively. The data transfer speed in the range around 100 Gbit/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 3

Kiosk downloading mobile system

6.1.2 Automatic turnstile downloading mobile system

The automatic turnstile downloading devices have two functions, i.e. fare-paying and large-file downloading functions. Figure 4 illustrates the user terminal for paying fare and simultaneously downloading video contents, such as news, movies, etc. In order to download the contents at the automatic turnstile, high-speed data transmission capability is required for both mobile terminal and automatic turnstile station. The transmission range covered by these devices is limited to about 10 cm to avoid interference 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 by this type of application.

FIGURE 4

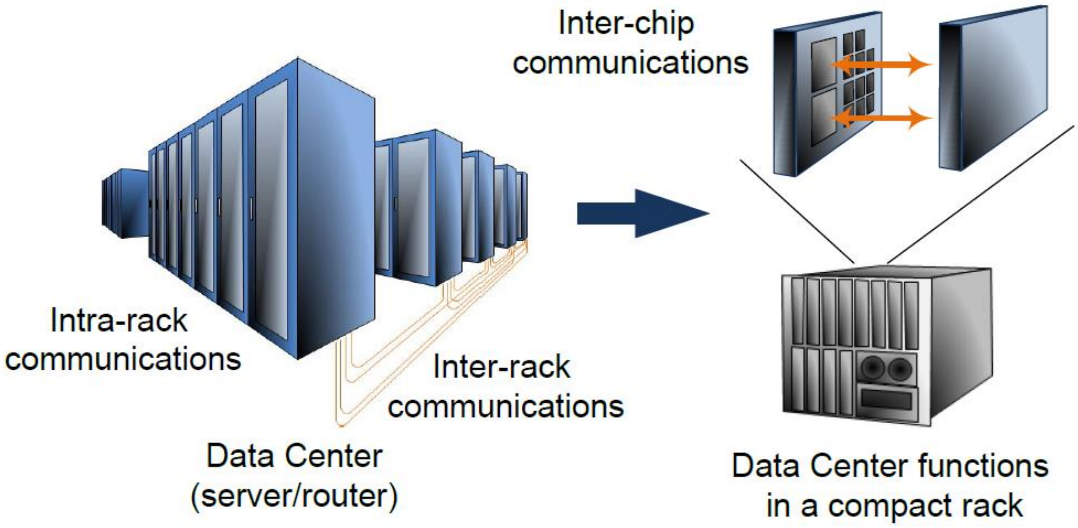
Automatic turnstile downloading mobile system

6.1.3 Inter-chip communication 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 5 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 5

Inter-chip communication system



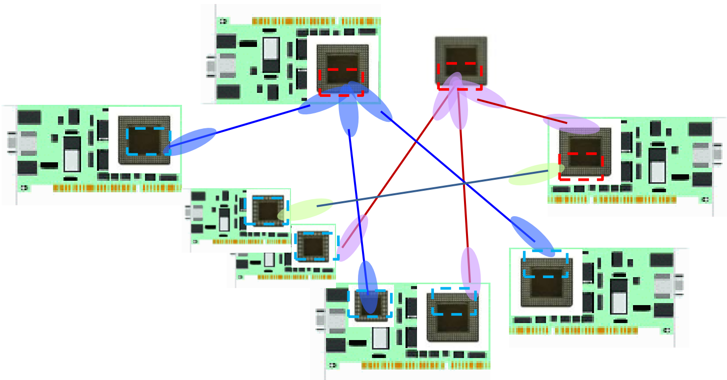
6.2 Intra-device communications

In intra-device communications, one or more communication links are operated within a device. High speed terahertz wireless links could connect two or more Printed Circuit Boards (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 large; 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.

FIGURE 6

Intra-device communication system

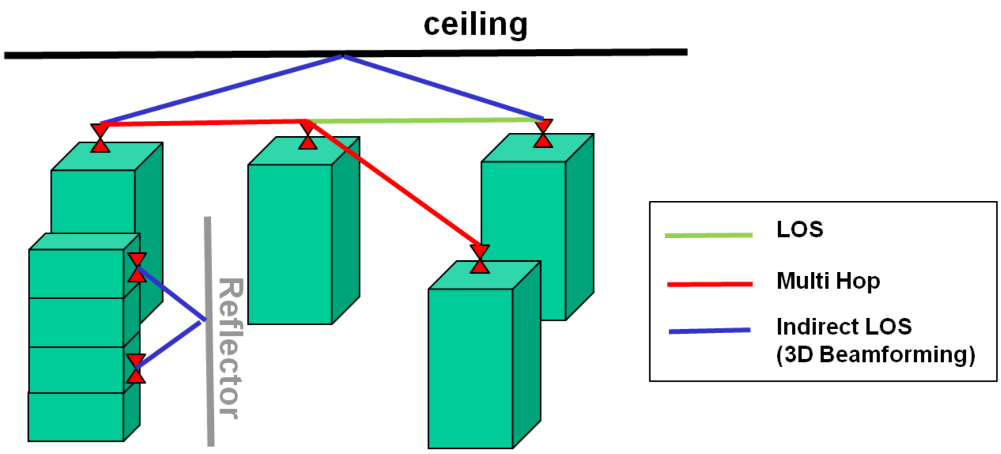


6.3 Wireless links for data centres

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 centre. In the figure some examples are illustrated between or inside the server racks (green colour boxes) for possible line-of-sight (LOS) or multi hop links.

FIGURE 7

Wireless links for data centre



6.4 Virtual reality

Virtual Reality (VR) applications require large amounts of bandwidth, often indoors over short distances. In VR applications stringent latency requirements are of utmost importance for providing a pleasant immersive VR experience[3]. This translates directly to large bandwidth requirements which may be found above 275 GHz. Immersive experience with VR streaming application requires a lot of data. If the required bandwidth is not available for specific VR applications, the quality of the content will be degraded during network transmission.

6.5 Industrial applications

Industrial applications, generally indoors in factories, are an appropriate application for frequencies above 275 GHz, and research is ongoing on future applications and requirements [5].

7 System characteristics

7.1 Close Proximity Mobile Systems (CPMSs) operating in the frequency range 275-450 GHz

Technical and operational characteristics for Close Proximity Mobile Systems planned to operate in the band 275-325 GHz and in the band 275-450 GHz are shown in Table 2.

Two possible radio-frequency channel arrangements for land-mobile service applications operating in the frequency range 275-450 GHz are shown in Annex 1. Annex 2 contains the measurement results of antenna patterns at 300 GHz.

The relationship between transmission data rate and total antenna gain of transmitter and receiver under the spectrum efficiency of 1 bit/s/Hz is shown in Annex 5 to clearly indicate that the multilevel modulation is indispensable to transmit high-speed data to CPMS devices.

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[3] Recommendation ITU-T G.1035 "Influencing factors on quality of experience for virtual reality services", 2020.

TABLE 2

Technical and operational characteristics of land-mobile CPMS applications in the frequency range 275-450 GHz for use in sharing and compatibility studies

Parameters	Values	
	CPMS application	**Enhanced CPMS application**
Frequency band (GHz)	275-325	275-450
Deployment density (1)	0.6 devices/km^2	0.6 devices/km^2
Tx output power density (dBm/GHz)	−3.8….6.9	−10.1…6.7
Max. e.i.r.p. density(dBm/GHz)	26.2…...36.9	19.9…36.7
Duplex Method	FDD/TDD	FDD/TDD
Modulation	OOK-SC/BPSK-SC/QPSK-SC/16QAM-SC/64QAM-SC BPSK-OFDM/QPSK-OFDM/ 16QAM-OFDM/32QAM-OFDM/64QAM-OFDM	OOK-SC/BPSK-SC/QPSK-SC/16QAM-SC/64QAM-SC/8PSK-SC/8APSK-SC BPSK-OFDM/QPSK-OFDM/ 16QAM-OFDM/32QAM-OFDM/64QAM-OFDM
Average distance between CPMS fixed and mobile devices (m)	0.1	0.1
Maximum distance between CPMS fixed and mobile devices (m)	1	1
Antenna height (m)	1…2	-
Antenna beamwidth (degree)	3…10	5…90
Antenna elevation (degree)	±90	±90
Frequency reuse	1	1
Antenna type	Horn	Horn
Antenna pattern	Gaussian	Gaussian
Antenna polarization	Linear	Linear
Indoor CPMS fixed device deployment (%)	100	90
Feeder loss (dB)	2	2
Maximum CPMS fixed/mobile 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	See Annex 4	See Annex 4
Maximum CPMS fixed device antenna gain (dBi)	30	30
Maximum CPMS mobile device antenna gain (dBi)	15	15
Maximum CPMS fixed device output power (e.i.r.p.) (dBm)	40	40

TABLE 2 (*end*)

Parameters	Values	
	CPMS application	**Enhanced CPMS application**
Maximum CPMS mobile device output power (e.i.r.p.) (dBm)	25	25
Average activity factor (%)	0.76	0.2
Average CPMS fixed device power (dBm (e.i.r.p))	20	20
Receiver noise figure typical (dB)	15	15

(1) Detailed information of deployment density is shown in Annex 3.

7.2 Intra-device communications

Technical and operational characteristics for wireless THz intra-device links planned to operate in the band 275-450 GHz are shown in Table 3. As an example, inside a camera the data rate between the optical sensor and the image processor is 72 Gbit/s for an 8K video with a frame rate of 60 Hz and a resolution of 12 bits for each colour [4]. Therefore, a bandwidth of 50 GHz is sufficient to provide such data rate with a simple QPSK modulation. Annex 4 proposes a Transmitter Spectrum Mask. Annex 2 contains the measurement results of antenna patterns at 300 GHz.

TABLE 3

Technical and operational characteristics of wireless THz intra-device links in the frequency band 275-450 GHz for use in sharing and compatibility studies

Parameter	Value
Frequency band (GHz)	275-450
Deployment density	0.23(1) /km^2
Maximum device output power (dBm)	10
Maximum device output power (e.i.r.p.) (dBm)	30
Maximum Tx output power density (dBm/GHz)	−10.1…6.7
Maximum e.i.r.p. density (dBm/GHz)	19.9…36.7
Indoor Deployment (%)	50
Duplex Method	TDD, FDD, SDD
Modulation	OOK-SC/BPSK-SC/QPSK-SC/16QAM-SC/64QAM-SC 8PSK-SC/8APSK-SC
Maximum distance between devices	<1 m
Antenna height (m)	1…3
Antenna beamwidth (degree)	15…180 (expected)
Frequency reuse	1
Antenna pattern	Gaussian

TABLE 3 (*end*)

Parameter	Value
Antenna polarization	Linear
Channel bandwidth (GHz)	2.16/4.32/8.64/12.96/17.28//25.92/51.84/69.12/103.68
Maximum device antenna gain (dBi)	20
Typical expected device antenna gain (dBi)	6
Maximum device activity (%)	100
Receiver noise figure typical (dB)	10(2)

(1) The deployment density is estimated as an average based on assuming that everyone thousandths citizen in Germany is using such a device. In highly populated cities the density could increase to e.g. 3.95/km^2 under the same assumptions.

(2) Also systems with a noise figure as low as 8 dB have been reported in publications. This value is a worst case of the published parameters.

7.3 Wireless links in data centres

Technical and operational characteristics for wireless links in data centres planned to operate in the band 275-450 GHz are shown in Table 4. A bandwidth of 50 GHz is necessary to achieve a data rate of at least 100 Gbit/s with a simple QPSK modulation and enable compatibility with 100 Gbit/s Ethernet links. Annex 2 contains the measurement results of antenna patterns at 300 GHz. Annex 4 proposes a Transmitter Spectrum Mask.

TABLE 4

Technical and operational characteristics of wireless links in data centres in the frequency band 275-450 GHz for use in sharing and compatibility studies

Parameter	Values
Frequency band (GHz)	275-450
Deployment density	0.07(1) /km^2
Maximum device output power (dBm)	10
Maximum device output power (e.i.r.p.) (dBm)	40
Tx output power density (dBm/GHz)	−10.1…6.7
e.i.r.p. density (dBm/GHz)	9.9…26.7
Duplex Method	TDD, FDD, SDD
Modulation	OOK-SC/BPSK-SC/QPSK-SC/16QAM-SC/64QAM-SC 8PSK-SC/8APSK-SC
Maximum distance between devices	100 m
Antenna beamwidth (degree)	< 25 (expected)
Frequency reuse	1
Antenna pattern	Gaussian
Antenna polarization	Linear

TABLE 4 (*end*)

Parameter	Values
Indoor deployment (%)	100
Channel bandwidth (GHz)	2.16/4.32/8.64/12.96/17.28/ 25.92/51.84/69.12/103.68
Maximum device antenna gain (dBi)	30
Maximum device activity (%)	100
Receiver noise figure typical (dB)	10(2)

(1) Based on an evaluation in Germany [3] there are 2170 data centres with more than 100 servers. Assuming that in each 10 links are deployed and taking the area of Germany into account a density of approx. 0.07 links per k m^2

(2) Also systems with a noise figure as low as 8 dB have been reported in publications. This value is a worst case of the published parameters.

8 Summary

The technical and operational characteristics for several LMS applications operating in the frequency ranges 275-450 GHz are provided for use in sharing and compatibility studies with passive services and other applications. Further updates of technical and operational characteristics will be studied, if and when additional LMS applications are proposed.

9 Bibliography

[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)".

[3] Study of the existing data centres in Germany by the German Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, http://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/4037.pdf

[4] IEEE802.15-14-0304-16-003d, "TG3d Applications Requirements Document (ARD)".

[5] Marco Hoffmann *et al.*, "6G Vision, use cases and key societal values", Deliverable D1.1 of the Project 101015956 "A flagship for B5G/6G vision and intelligent fabric of technology enablers connecting human, physical, and digital worlds", 2020, *Available:* https://hexa-x.eu/wp-content/uploads/2021/02/Hexa-X_D1.1.pdf

Annexes: 5

Annex 1

Examples of radio-frequency channel arrangement

In Figs 8 and 9, two examples of channel arrangements are illustrated. The basic channel bandwidth which is widely used for Radio LAN is 2.16 GHz, and the other channels bandwidths are 4.32 GHz, 8.64 GHz, 12.96 GHz, 17.28 GHz, 25.92 and 51.8 GHz. The extra channels are embedded as additional channels in the remaining frequency band. In Fig. 9 the Radio-frequency channel arrangement described in IEEE Std 802.15.3d™-2017 is provided as an example. The frequency range considered by IEEE begins at approximately 252 GHz.

FIGURE 8

Radio-frequency channel arrangement for CPMS application

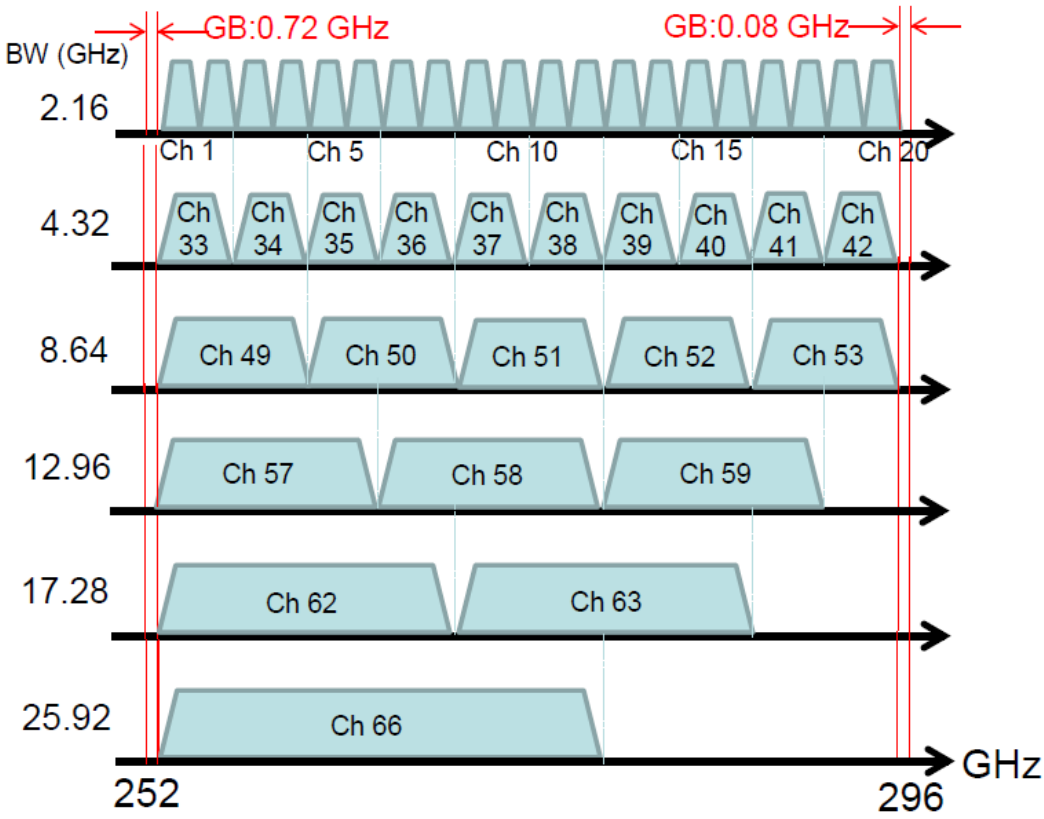
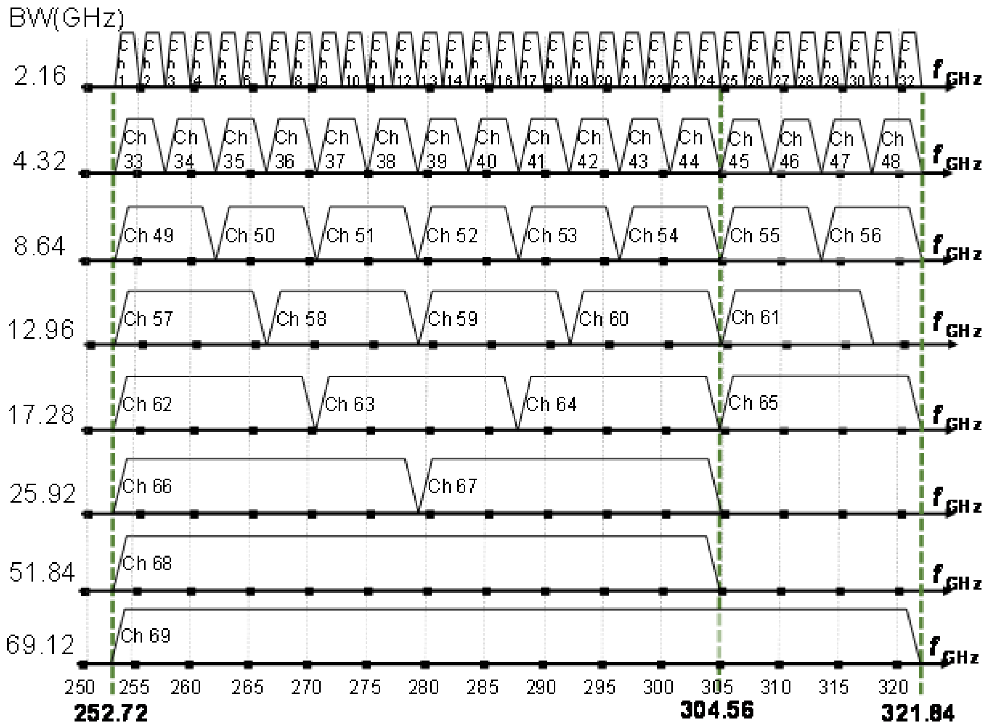


FIGURE 9

Radio-frequency channel arrangement example for CPMS, intra device communications and wireless links in data centres, which is currently described in IEEE Std 802.15.3d™-2017



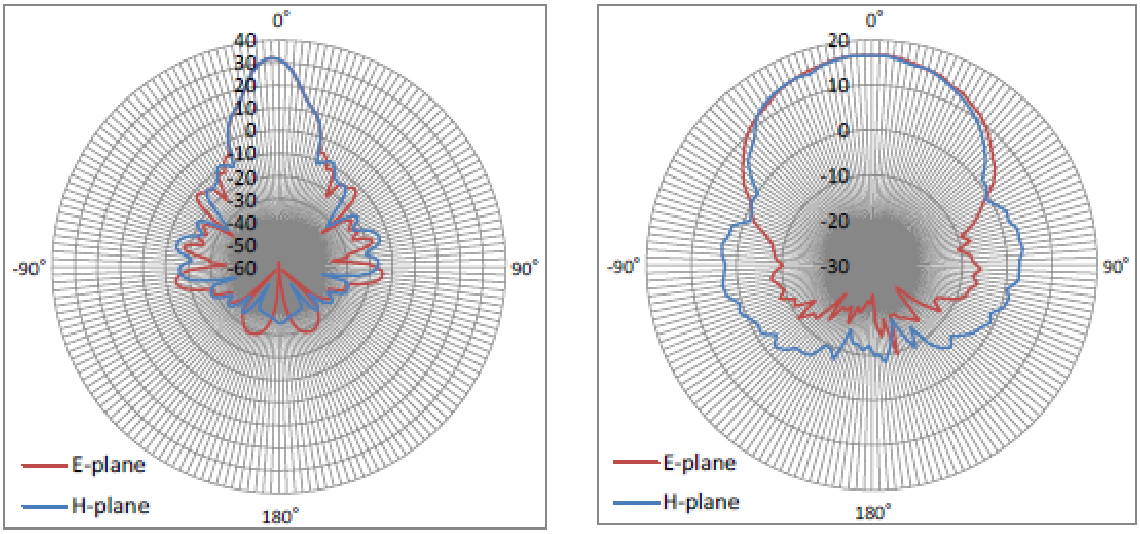
Annex 2

Measurement results of antenna patterns at 300 GHz

FIGURE 10

Measured characteristics of 30-dBi and 15-dBi antennas

(a) 30-dBi horn antenna **(b) 15-dBi horn antenna**



Reference antenna pattern provided by Recommendation ITU-R F.699 may be used for sharing and compatibility studies.

Annex 3

Deployment density and activity factor of Kiosk downloading systems

Kiosk downloading system will be used in stations, airport terminals, convenience stores. It will mainly be deployed in an indoor environment. Since the number of stations and airports is much smaller than that of convenience stores, this report summarizes deployment densities of Kiosk terminals equipped at convenience stores. The total number of convenience stores in Japan is 55 129, but 19 571 convenience stores, i.e. 35% of all stores, are distributed in the Kanto area whose size is 32 420 km^2. This concludes that deployment density in Kanto is 0.6 stores/km^2 and that in Tokyo is 3.28 stores/km^2, which is the maximum density in Japan.

The average number of customers of major convenience stores in Japan is about 1,000, but the busiest store, which is located nearby stations in Tokyo, has a peak number of customers of nearly 2 000. The following assumption is introduced for estimation of the activity factor/store:

1 Average number of customers of convenience store 1 000

2 Percentage of customers bringing CPMS devices 20%

3 Downloaded 2-hour movies by one customer 2

4	CPMS device throughput	6.9 Gb/s (see Table 6)
5	Intrinsic time of downloading by one customer	2.2 s
6	Total time of downloading	440 s
7	Typical opening hour of convenience store	7 am-11 pm (57 600 s)
8	Estimated activity factor/store	0.76%

TABLE 5

Numbers of convenience stores and stations in Kanto area

Metropolitan and Prefecture	Number of convenience store	Size (km^2)
Tokyo	7 183	2 190
Kanagawa	3 765	2 415
Saitama	2 833	3 797
Chiba	2 637	5 157
Ibaraki	1 315	6 096
Gunma	950	6 362
Tochigi	888	6 408
Kanto area(1)	19 571	32 425

(1) Kanto is the regional name of Tokyo metropolitan plus the above six prefectures.

TABLE 6

Estimated downloading time of magazine and movie

Content type	File size (MB)	Download time (s)		
		Throughput 4.6 Gb/s	Throughput 6.9 Gb/s	Throughput 66 Gb/s
Magazine	300	0.5	0.3	0.03
Movie (2 hour) H.265 (Hi-definition)	900	1.6	1.1	0.11

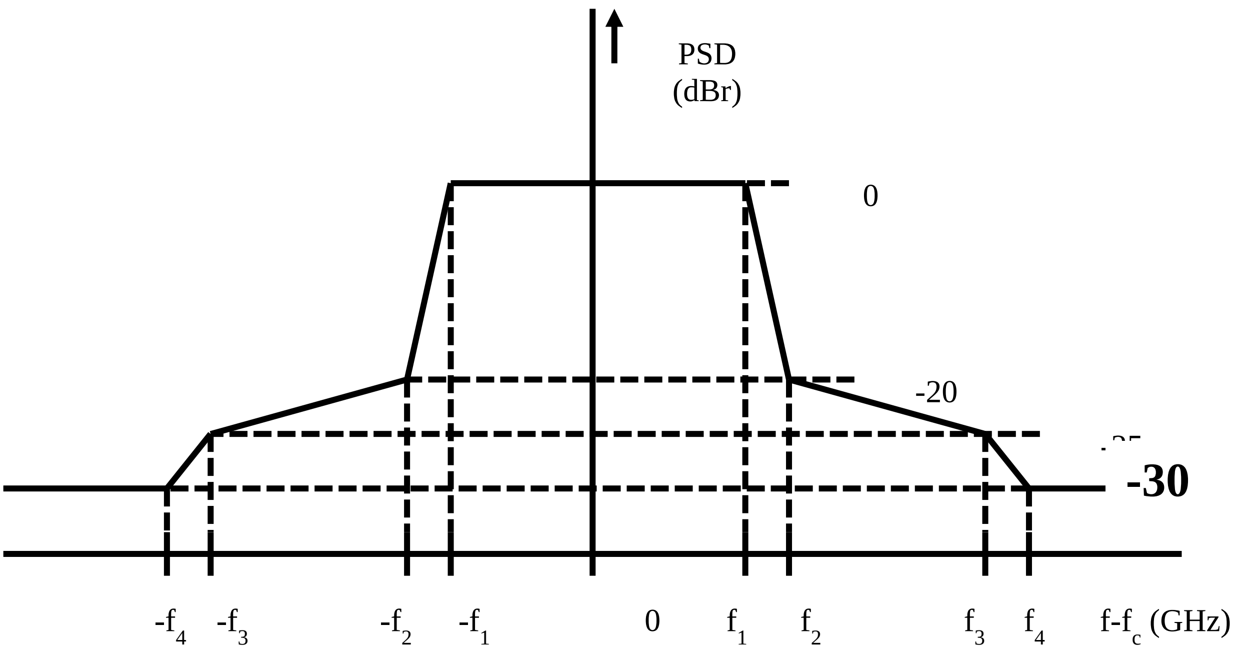
Annex 4

Example of a transmitter spectrum mask

The transmitter spectrum mask described in IEEE Std 802.15.3d^{TM}-2017 is shown as an example in Fig. 11 and Table 7.

FIGURE 11

Generic transmit spectral mask



The parameters of the mask expressed in Power Spectral Density (PSD) indicated in Fig. 11 are defined in Table 7.

TABLE 7

Transmit spectrum mask parameters

Channel bandwidth (GHz)	f_1(GHz)	f_2(GHz)	f_3(GHz)	f_4(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

Annex 5

Information on link budget of Kiosk downloading system

One example of the link budget is shown in Fig. 12. The transmitting power, carrier frequency, and transmission distance are 10 dBm, 300 GHz and 1 m, respectively, as indicated in Table 2. The total antenna gain of transmitter and receiver over 45 dBi is required to attain a data rate of 50 Gbit/s by ASK with FEC if BER is less 10^{-9}. Since the spectrum efficiency is 1 b/s/Hz in this case, a bandwidth of 50 GHz is needed to attain 50 Gbit/s. If the maximum bandwidth of 50 GHz is identified for such applications as discussed in § 7.1, the multilevel modulation scheme such as QPSK and 16 QAM whose spectrum efficiency over 2 bit/s/Hz is preferable to increase the transmission data rate. Table 8 summarizes spectrum needs for some LMS applications, taking into account the current status of technologies and applications, to support 50 Gbit/s under spectrum efficiency of 1 bit/s/Hz.

FIGURE 12

Relationship between data rate and total antenna gain under the condition of spectrum efficiency of 1 bit/s/Hz

Quantity	Symbol	Value
Transmitting power	P_t	**10 dBm**
Carrier frequency	f_c	300 GHz
Wavelength	λ_c	1 mm
Distance	d	**1 meter**
Atmospheric attenuation	α_a	0.1 dB/m @ f_c
Noise spectral density	N_0	-178 dBm/Hz
Spectral efficiency		1 bps/Hz
Noise bandwidth	B	Data rate × spectral efficiency
Total noise figure	**NF**	**15 dB**
System margin	M	10 dB

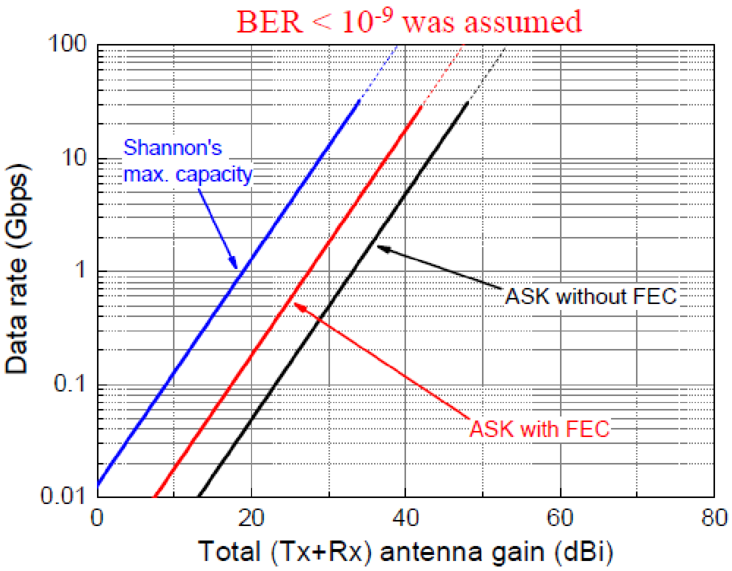


TABLE 8

Spectrum needs for land-mobile service applications in the 275-450 GHz frequency range

Applications	Spectrum needs
CPMS application	50 GHz
Intra-device communication	50 GHz (see *Note*)
Wireless links for data centres	50 GHz (see *Note*)

Note: For intra-device communication and data centre wireless link centre applications operating simultaneously in close proximity, different channels should be used.