



millimetre Wave Transmission (mWT); Analysis of Spectrum, License Schemes and Network Scenarios in the D-band

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<https://standards.iteh.ai/catalog/standards/sist/cd41574e-7246-4776-9c69-9c8d9d1fd21/etsi-gr-mwt-008-v1.1.1-2018-08>

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Foreword

This Group Report (GR) has been produced by ETSI Industry Specification Group (ISG) millimetre Wave Transmission (mWT).

All Companies referenced in the present document have given the consensus of all the material provided herewith.

Modal verbs terminology

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Executive summary

The evolution of Mobile Networks towards LTE-A and 5G in the next few years present significant challenges to the evolution of microwave technology, especially in terms of transmission capacity and latency.

Interest in millimetre-wave bands has risen significantly in recent years mainly due to new network topologies driving backhaul to the higher part of the spectrum and the enormous amount of under-utilized bandwidth that lies in this part of the electromagnetic spectrum.

The development of new technologies and the use of higher frequency bands allow microwave to remain a fundamental building block of mobile networks even in this framework of ever-increasing demands.

The significant advantages offered by the propagation characteristics in terms of frequency re-usability and large channel bandwidths make millimetre-wave suitable for transmitting multi-Gbps in dense urban scenarios thanks to a very compact antenna size and extreme low power.

Bands above 90 GHz are prime candidates for large volume applications in backhaul and fronthaul supporting all services requiring high speed wireless transmission.

Standardization activities are now under way of the so-called W-band (92 - 114,5 GHz) and D-band (130 - 174,8 GHz).

The present document provides an overview of the possible applications and use cases for the D-band, state of the art of the technology at such high frequencies and also possible channel schemes which can be used, including the so called "duplexer-free" scheme.

Although the present document is focused on the D-band, information and considerations on the W-band are included where appropriate and beneficial to the readers.

Introduction

Frequency bands above 100 GHz have not been commercially exploited yet and have not been regulated yet by specific recommendations.

The W-band and D-band are already considered in the table of frequency allocation issued by the ITU-R Radio Regulation 2016 [i.5].

Allocation to services		
Band [GHz]	Region 1 - Region 2 - Region 3	
92-94		FIXED
94-94.1		
94.1-95 & 95-100		FIXED
100-102		
102-105 & 105-109.5		FIXED
109.5-111.8		
111.8-114.25		FIXED
114.25-122.25		
122.25-123		FIXED
123-130		
130-134		FIXED
134-141		
141-148.5		FIXED
148.5-151.5		
151.5-155.5 & 155.5-158.5 & 158.5-164		FIXED
164-167		
167-174.5 & 174.5-174.8		FIXED
174.8-191.8		
191.8-200		FIXED

Figure 1: ITU Table of Frequency Allocation (Radio Regulation 2016) [i.5]

The table indicates fixed service (FS), and that covers all the applications of interest to ISG mWT, and which have a primary status, when considering the frequency band from 92 up to 200 GHz.

The allocation between 92 and 200 GHz is common for all three ITU regions, which facilitates the scenarios and spectrum usage solutions covering these bands.

Moreover, new spectrum and innovative ways to use the bands, new concepts related to availability to cope with the increase of capacity and hop lengths are needed. Efficient aggregation of different bands and carriers should be exploited, through BCA together with new mm-wave spectrum made available by regulation.

The proper combination of mm-wave spectrum with traditional microwave spectrum should help to incentivize spectrum efficiency and optimization of spectrum usage, driving regulators to release unused or under-utilized spectrum portions.

1 Scope

The present document describes possible scenarios and spectrum usage and proposes, aligned with CEPT ECC SE19 Working Item 37 [i.3], the channelization of the D-band (130 - 174,8 GHz) to facilitate the deployment of high capacity backhaul systems, able to decongest the network over distances shorter than usual ones for wireless transport.

Considering that the W-band and the D-band are primarily allocated to FS, part of the scope of the present document is to identify applications for future backhaul networks or similar applications.

Technical propagation characteristics of W-band and D-band are considered to analyze system behaviours and evaluate reachable distances and possible achievable throughputs.

In the absence of standardized channel plans for both the W-band and D-band, guidelines for efficient deployment in terms of spectrum, license schemes and other relevant aspects in those bands are being proposed, also considering non-operator services, in the vision of significant market share.

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.

- [i.1] ETSI White Paper No. 15: "mmWave Semiconductor Industry Technologies: Status and Evolution".

NOTE: Available at <http://standards-iteh.ai/catalog/standards/sist/cd41574e-7246-477b-9c69-9c89d1f02102/etsi-gr-mwt-008-v1.1.1-2018-08>.

- [i.2] Abhiram Chakraborty, Saverio Trotta (Infineon Technologies AG) and Robert Weigel (Lehrstuhl für Technische Elektronik, FAU Erlangen-Nürnberg): "A Low Power Multichannel Receiver for D-Band Sensing Applications in a 0,13 μ m SiGe BiCMOS Technology (*here defined up to 132 GHz)".
- [i.3] SE19(17)16A09: "Radio frequency channel/block arrangements for fixed service systems operating in the bands 92 - 94 GHz, 94,1 - 100 GHz, 102 - 109,5 GHz and 111,8 - 114,25 GHz".
- [i.4] SE19(17)16A10: "Radio frequency channel/block arrangements for fixed service systems operating in the bands 130 - 134 GHz, 141 - 148,5 GHz, 151,5 - 164 GHz and 167 - 174,8 GHz".
- [i.5] ITU-R Radio Regulation 2016.
- [i.6] Recommendation ITU-R P.530-16 (07/2015): "Propagation data and prediction methods required for the design of terrestrial line-of-sight systems".
- [i.7] Recommendation ITU-R P.1411-1: "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.8] Recommendation ITU-R P.1238-7 (02/2012): "Propagation data and prediction methods for the planning of indoor radiocommunication systems and radio local area networks in the frequency range 900 MHz to 100 GHz".
- [i.9] Recommendation ITU-R P.838-3: "Specific attenuation model for rain for use in prediction methods".
- [i.10] Recommendation ITU-R F.1703: "Availability objectives for real digital fixed wireless links used in 27 500 km hypothetical reference paths and connections".
- [i.11] Recommendation ITU-R P.676-11: "Attenuation due to atmospheric gases".
- [i.12] IEEE 802.15™: "WPAN for 60 GHz".
- [i.13] L. Allen, M. W. Beijersbergen, R. J. C. Spreeuw, and J. P. Woerdman: "Orbital angular momentum of light and the transformation of Laguerre-Gaussian laser modes", Physical Review A, vol. 45, no. 11, 1992.
- [i.14] N. Bozinovic, et al: "Terabit-scale orbital angular momentum mode division multiplexing in fibers", Science, vol. 340 no. 6140 pp. 1545-1548, 2013.
- [i.15] F. Tamburini, et al.: "Encoding many channels on the same frequency through radio vorticity: first experimental test", New Journal of Physics 14, 2012.
- [i.16] J. Butler and R. Lowe: "Beamforming matrix simplifies design of electronically scanned antennas", Electronic Design, vol. 9, pp. 170-173, 1961.
- [i.17] EIA RS-261-B: "Rectangular Waveguides (WR3 to WR2300)".
- [i.18] IEC 60153-2:2016: "Hollow metallic waveguides - Part 2: Relevant specifications for ordinary rectangular waveguides".
- [i.19] Yuan-Hung Hsiao, Zuo-Min Tsai, Hsin-Chiang Liao, Jui-Chih Kao and Huei Wang: "Millimeter-Wave CMOS Power Amplifiers With High Output Power and Wideband Performances", IEEE Transactions on microwave theory and techniques, Vol. 61, NO. 12, December 2013.
- [i.20] Recommendation ECC REC (18)01: "Radio frequency channel/block arrangements for Fixed Service systems operating in the bands 130 - 134 GHz, 141-148,5 GHz, 151,5-164 GHz and 167 - 174,8 GHz".
- [i.21] Recommendation ITU-R F.1668: "Error performance objectives for real digital fixed wireless links used in 27 500 km hypothetical reference paths and connections".

3 Abbreviations

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

5G	Fifth Generation of Mobile Networks
BCA	Band and Carrier Aggregation
BER	Bit Error Rate
BH	BackHaul
BW	BandWidth
CMOS	Complementary Metal Oxide Semiconductor
DHBT	Double Heterojunction Bipolar Transistor
DS	Duplex Spacing
EM	ElectroMagnetic
FDD	Frequency Division Duplex
FS	Fixed Service
FWA	Fixed Wireless Access
Gbaud	Giga baud
HBT	Heterojunction Bipolar Transistor
HEMT	High Electron Mobility Transistor
LOS	Line Of Sight

LTE	Long Term Evolution
LTE-A	LTE-Advanced
MAG	Maximum Available Gain
MMIC	Microwave Monolithic Integrated Circuit
MOS	Metal Oxide Semiconductor
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
MW	MicroWave
OAM	Orbital Angular Momentum
PA	Power Amplifier
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
RFIC	Radio Frequency Integrated Circuit
RX	Receiver
SOI	Silicon On Insulator
TCE	Thermal Coefficient of Expansion
TDD	Time Division Duplex
TX	Transmitter
VBE	Base-Emitter Voltage
VCB	Collector-Base Voltage
VCO	Voltage Controlled Oscillator
XHAUL	generic (X) split within LTE/5G protocol stack between fronthaul and backhaul

4 Introduction to the W-band and the D-band

In the search for more spectrum all wireless applications are already using and will use higher frequencies than the traditional microwave bands. The frequency bands above 90 GHz are prime candidates for large volume applications supporting all services that require high speed and very large bandwidths.

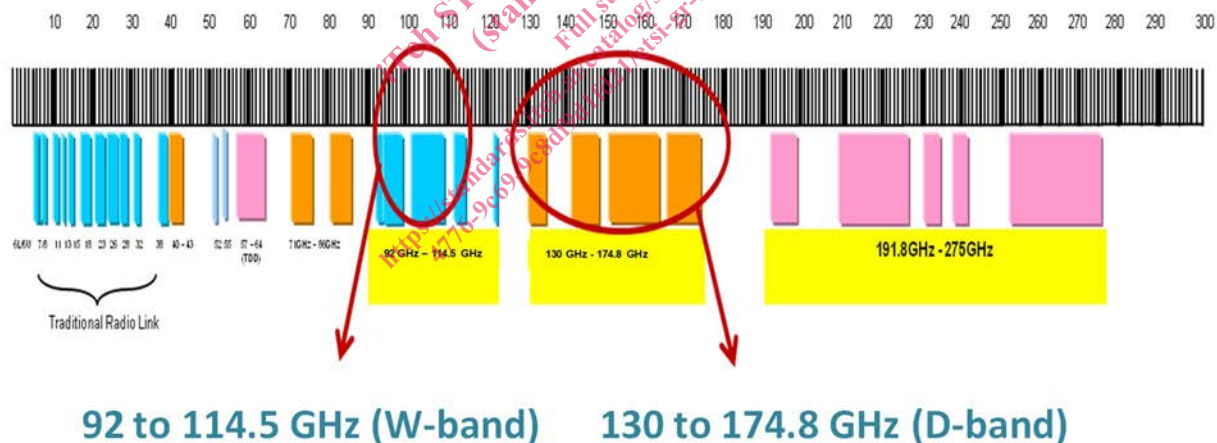


Figure 2: W and D bands spectrum

Ten different portions of spectrum are available (when some contiguous portions are considered), from 92 - 200 GHz, allocated primarily to Fixed Service, covering almost 54 % of the whole band under consideration (92 - 200 GHz).

These portions have the following bandwidth (size in GHz), ranging from 1 GHz - 12,5 GHz.

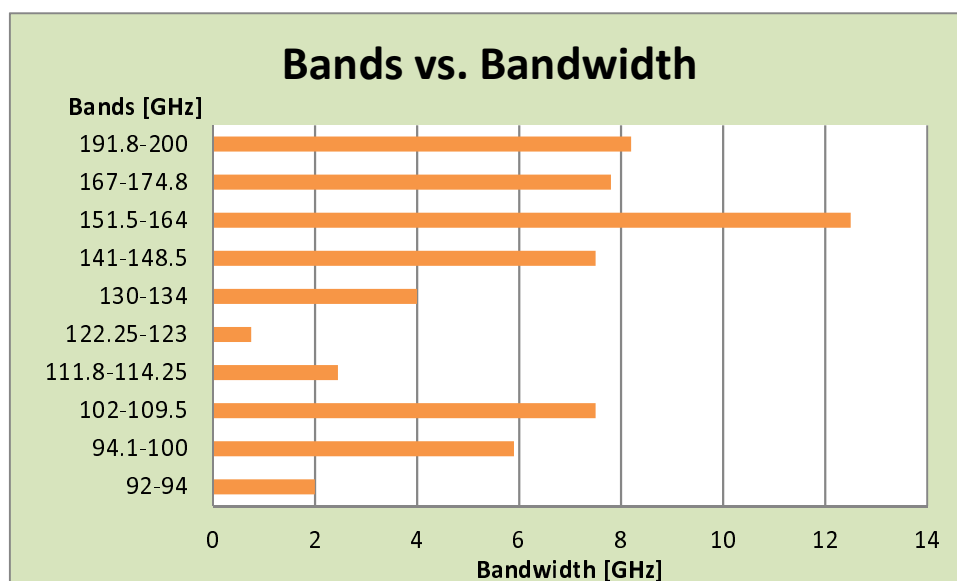


Figure 3: Portions of available spectrum in the range 92 - 200 GHz (Source: Nokia)

In principle, nothing prevents from considering more than one portion of spectrum as a single band, in line with the approach already adopted for the E-band, where 71 - 76 GHz and 81 - 86 GHz were considered together.

Since the portions of the spectrum and bandwidth have not yet been defined, the present document will identify the best way to consider such portions of the spectrum and how to arrange it into new bands and how to consider each band into channels, if any.

The existing standard of waveguides [i.17], [i.18] allows the following use:

Table 1: Designation of waveguides

Designation EIA/IEC	US commercial designation & $f_{\min}$ - $f_{\max}$ [GHz]		Cut-off Frequencies [GHz]	Band
WR8/R1200	RG138 (silver)	90,00 - 140,0	73,8	W-band
WR7/R1400	RG136 (silver)	110,0 - 170,0	90,8	D-band

Regarding the activities related to the W-band and the D-band, including possible frequency arrangements, two Work Items have been opened in CEPT ECC SE19, the Work Item on W-band (SE19_37) [i.3] and the Work Item on D-band (SE19_38) [i.4], with the scope to facilitate the deployment of fixed services in the frequency blocks already allocated to fixed services in the bands 92 - 94 GHz, 94,1 - 95 GHz, 95 - 100 GHz, 102 - 109,5 GHz and 111,8 - 114,5 GHz for the W-band and in the bands 130 - 134 GHz, 141 - 148,5 GHz, 151,5 - 164 GHz and 167 - 174,8 GHz for the D-band.

These work items aim to provide ECC Recommendation(s) guidelines on the deployment of fixed services operating in the mentioned bands.

The outcome of this analysis has been liaised to CEPT WG SE19, and may be liaised to other relevant groups for discussion.

5 ITU Regulations concerning the W-band and the D-band

5.1 ITU Regulations concerning Frequency Allocation

- Recommendation ITU-R Radio Regulation 2016 [i.5].

5.2 ITU-R Regulations concerning Propagation Aspects

- Recommendation ITU-R P.530-16 (07/2015) [i.6]: Propagation data and prediction methods required for the design of terrestrial line-of-sight systems.
- Recommendation ITU-R P.1411-1 [i.7]: 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.
- Recommendation ITU-R P.1238-7 (02/2012) [i.8]: Propagation data and prediction methods for the planning of indoor radiocommunication systems and radio local area networks in the frequency range 900 MHz to 100 GHz.
- Recommendation ITU-R P.838-3 [i.9]: Specific attenuation model for rain for use in prediction methods.

Apart from Recommendation ITU-R P.838-3 [i.9], which is valid up to 1 000 GHz, the range of validity is up to 100 GHz.

5.3 ITU-R Regulations concerning Error Performance and Availability objectives

- Recommendation ITU-R F.1668 [i.21].
- Recommendation ITU-R F.1703 [i.10].

Formulas are provided in Recommendation ITU-R F.1703 [i.10] to establish availability objectives for real links.

6 Characteristics of the W-band and the D-band

The rain attenuation in the W-band and in the D-band can be derived from figure 4. It should be noted that the rain attenuation in the D-band is around 2 dB larger than in the E-band. In addition it should be noted that the rain attenuation in the D-band is almost flat.

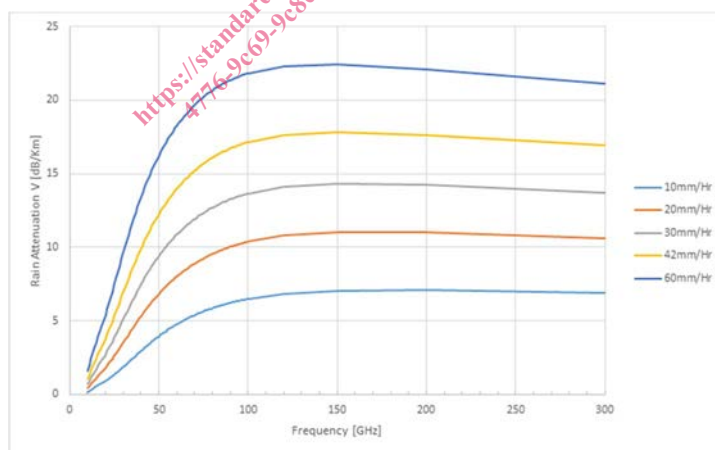


Figure 4: Specific rain attenuation up to 300 GHz (Source: Recommendation ITU-R P.838-3 [i.9])

Regarding gas attenuation, it is 1 - 2 dB/km in the D-band. This is not a dominant factor for the link distance limitation.

The gas attenuation in the D-band is almost flat. In the W-band it is lower than 1 dB/km.

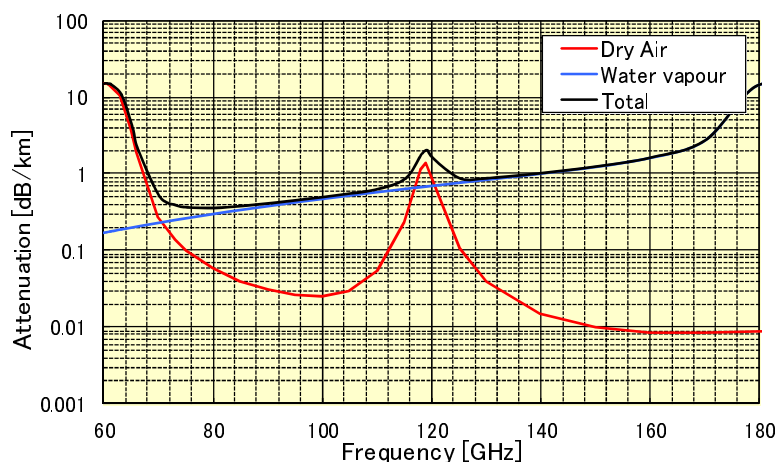


Figure 5: Specific gas attenuation up to 180 GHz (Source: Recommendation ITU-R P.676-11 [i.11])

Compared to the V-band, both the W-band and the D-band, similarly to the E-band, are in the part of spectrum which is not affected by the Oxygen absorption peaks.

7 System Behaviour

7.1 D-band system simulation

In order to evaluate covered distances and available throughputs, extensive system simulations have been carried out. As a result, estimation is given of the maximum hop length that can be reached, in the W-band and in the D-band, for different 1 Gbps solutions in different conditions and frequency bands. Moreover the estimation of the maximum hop length that can be reached for a 10 Gbps solution is provided, derived with the same approach used for the 1 Gbps cases.

The model is for pure Line of Sight (LoS) applications. The urban environmental impact has not been taken into account.

Estimation of a reasonable level of system gain to reach 1 Gbps and 10 Gbps throughputs is provided, scaling the solution that is today in place.

The maximum antenna gain considered is up to 40 dBi.

The related standards under which the calculations have been carried out are:

- Recommendation ITU-R P.530-16 [i.6].
- Recommendation ITU-R P.838-3 [i.9].
- Recommendation ITU-R P.676-11 [i.11]: specific attenuation due to atmospheric gases (dB/km) is derived from figure 5 in Annex 2 (Pressure = 1 013,25 hPa; Temperature = 15 °C; Water Vapor Density = 7,5 g/m³).

It should be mentioned that Recommendation ITU-R P.530-16 [i.6] provides models up to 100 GHz, namely "*The prediction procedure is considered to be valid in all parts of the world at least for frequencies up to 100 GHz*". This means that trials with real equipment at these extremely high frequency bands aim also to validate the ITU models for frequencies above 100 GHz.

The following conditions apply:

- Gross system gain accounts for system gain and antenna gain (estimation of gross system gain range gSyGain to reach 1 Gbps solution).
- Rain rate of 30, 60 and 90 mm/h are taken into account.
- Three cases are considered: 250 MHz, 500 MHz and 1 000 MHz channels.