



millimetre Wave Transmission (mWT); Applications and use cases of millimetre wave transmission

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use case**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 - NAF 742 C
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Foreword

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

Modal verbs terminology

In the present document **"shall"**, **"shall not"**, **"should"**, **"should not"**, **"may"**, **"need not"**, **"will"**, **"will not"**, **"can"** and **"cannot"** are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](#) (Verbal forms for the expression of provisions).

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Executive summary

Modern consumers, individuals and corporate entities, request for advanced personalized services to perform their daily activities. Social interactions, entertainment, news, HD video streaming, distant learning, e-health, commercial transactions, e-business, cloud services, M2M applications represent a sample of a countless list of digital services that are requested from either stationary or moving end-users. Whilst different growth rates of broadband data are envisioned per region due to the existence of local idiosyncrasies, such as broadband market maturity, operators' pricing policy, consumers' psychographic characteristics and buying patterns, degree of access to the latest technological advancements, overall macro-economic climate and so forth, the demand for packet-based broadband data will continue to soar both in mobile and fixed access domains.

In order to address the increasingly diversified needs of digital natives and enterprises of the 2010s and onwards, telecommunication networks will have to be modernized at different segments. Fixed transmission networks represent a critical part of this effort and they play a pivotal role to achieve the target end-to-end KPIs per service and enhance end-users' QoE.

A variety of wireline as well as wireless technologies are available to build transmission infrastructures and usually a mixed environment of physical media is adopted. While optical fibre is perceived as the physical medium with the top performance, there are techno-economic factors that make installation or even extension of optical fibre network not always the most appropriate solution. Hence, wireless technologies represent today a significant or even a dominant percentage of various operators' transmission networks to serve efficiently the increasing upward trend for providing data-hungry applications.

While microwave solutions at traditional bands are more or less employed by all kinds of service providers (mobile, fixed), it becomes clear that moving to millimetre wave frequency bands, where underutilized massive bandwidth is available, will assist to deliver transmission services of equal to optical fibre performance avoiding the constraints that the latter might impose at particular scenarios. In this sense, millimetre wave frequency bands can be used in an immense number of current and future high-speed wireless transmission applications.

Introduction

Information society's foreseeable demand for additional broadband data consumption is further augmented by the high uptake of faster connections and the popularity of powerful data devices. In the mobile access domain, technology advances as a result of the ceaseless evolution of 3GPP standardizations that has taken mobile broadband to the next level. Similarly, at fixed access domain, increased broadband speeds become available as technologies, like fibre to the home (FTTH) or business, VDSL variants and so on are adopted. Furthermore, use of devices like smart-phones, 802.11ac routers will contribute to increase of broadband applications' usage, like video streaming, web surfing, etc.

The above dynamic situation puts more pressure on transmission networks, in order for services to be delivered tailored to consumers' expectations. While from client perspective services' data rate, response and uninterrupted availability constitute key metrics, from operators' experience additional parameters have to be carefully thought and designed to achieve the desired overall performance. In this sense, the challenges for the next generation transmission networks are multiple and are related to factors, such as:

- Network architecture, topology and density.
- Throughput.
- Range and service availability (with reference to wireless transmission networks).
- Latency and jitter.
- Interference management (with reference to wireless transmission networks).
- Network automation.
- Networking and synchronization features for advanced packet-based/mobile networks.
- Improved match between spectrum resource consumption and consumers' traffic patterns requirements.
- Equipment physical form factor.
- Power consumption.
- Security for data transport.

In the light of the expected emerging broadband communication demands and the increased challenges for the next generation transmission networks, ETSI Industry Specification Group (ISG) on millimetre Wave Transmission (mWT) aims to be a worldwide initiative with global reach that will facilitate the use of [i.1]:

- the V-band (57 - 66 GHz);
- the E-band (71 - 76 & 81 - 86 GHz); and
- - in the future - higher frequency bands from 50 GHz up to 300 GHz.

ETSI ISG mWT envisions that established and emerging broadband transmission services would benefit from high-speed wireless transmission that millimetre wave spectrum technology can accomplish.

It should be noted that although the addressed by ETSI ISG mWT spectrum ranges between 50 GHz and 300 GHz bands, as Figure 1 [i.1] shows, presently the 57 - 66 GHz, 71 - 76 GHz and 81 - 86 GHz bands or parts of them are open at various, but not all, countries across the world for broadband wireless fixed services. Moreover, as per Recommendation ITU-R F.2107-2 Report [i.2], frequencies up to 134 GHz band were also approved.

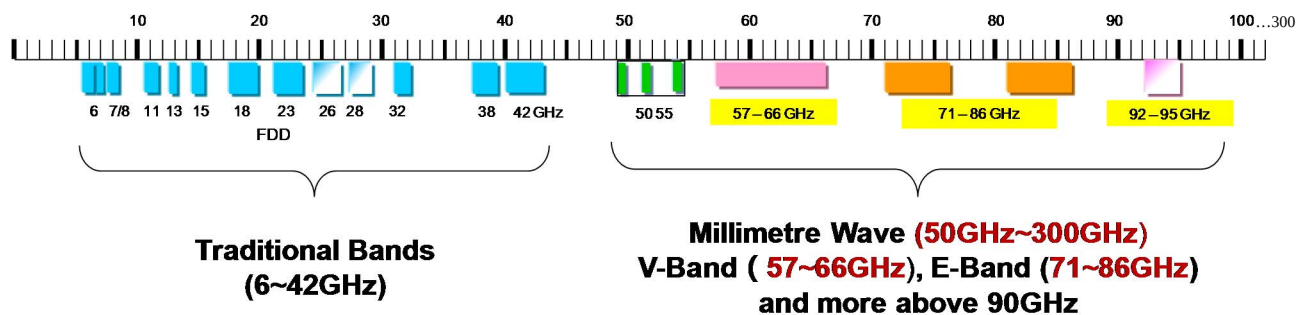


Figure 1: Millimetre wave spectrum (50 GHz to 300 GHz)

The present document, as part of ISG mWT framework, intends to propose the wireless transmission applications and use cases that can be addressed by millimetre wave spectrum, focusing on frequency bands from 50 GHz up to 300 GHz (or wavelengths from 6 mm down to 1 mm).

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1 Scope

The purpose of the present document is to provide information on the following topics:

- Millimetre wave spectrum technology overview.
- Millimetre wave spectrum technology key performance benefits.
- Potential transmission applications and use cases for millimetre wave spectrum technology.
- Key requirements per transmission application/use case of millimetre wave spectrum technology.
- Enablers of millimetre wave spectrum technology per transmission application/use case.

2 References

2.1 Normative 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 reference document (including any amendments) applies.

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2.2 Informative references

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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] An Introduction to mWTISG.

NOTE: Available at <https://portal.etsi.org/Portals/0/TBpages/mWT/Docs/Introduction%20to%20mWT%20ISG%20v1-0.pdf>.

[i.2] Report Recommendation ITU-R F.2107-2 (11/2011): "Characteristics and applications of fixed wireless systems operating in frequency ranges between 57 GHz and 134 GHz".

[i.3] ECC Recommendation (09)01: "Use of the 57 - 64 GHz frequency band for point-to-point fixed wireless systems".

[i.4] ECC Recommendation (05)07: "Radio frequency channel arrangements for fixed service systems operating in the bands 71-76 GHz and 81-86 GHz".

[i.5] ECC Recommendation (14)01: "Radio frequency channel arrangements for fixed service systems operating in the band 92-95 GHz".

[i.6] ECC Recommendation (05)02 (2009): "Use of the 64-66 GHz frequency band for fixed service".

- [i.7] Report Recommendation ITU-R F.2323: "Fixed service use and future trends".
- [i.8] ERC Recommendation 12-11 (2015): "Radio frequency channel arrangements for Fixed Service systems operating in the bands 48.5 to 50.2 GHz/50.9 to 52.6 GHz".
- [i.9] ERC Recommendation 12-12 (2015): "Radio frequency channel, arrangement for Fixed Service Systems operating in the band 55.78 to 57.0 GHz".
- [i.10] Report Recommendation ITU-R M.2134: "Requirements related to technical performance for IMT-Advanced radio interface(s)".
- [i.11] MEF 22.1.1, Mobile Backhaul Phase 2, Amendment 1 - Small Cells, July 2014.
- [i.12] CPRI Specification V6.0 (2013-08-30), Common Public Radio Interface (CPRI); Interface Specification.
- [i.13] OBSAI, Reference Point 3 Specification, Version 4.2.
- [i.14] ETSI GS ORI 002-1 (V4.1.1) (2014-10): "Open Radio equipment Interface (ORI); ORI interface Specification; Part 1: Low Layers (Release 4)".
- [i.15] ETSI GS ORI 002-2 (V4.1.1) (2014-10): "Open Radio equipment Interface (ORI); ORI Interface Specification; Part 2: Control and Management (Release 4)".
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- [i.17] "Understanding 5G: Perspectives on future technological advancements in mobile", GSMA Intelligence, December 2014.
- [i.18] Milestones: First Millimeter-wave Communication Experiments by J.C. Bose.

NOTE: Available at http://www.ieeeeghn.org/wiki/index.php/Milestones:First_Millimeter-wave_Communication_Experiments_by_J.C._Bose.

3 Abbreviations

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

2G	Second Generation of Mobile Networks
3GPP	Third Generation Partnership Project
5G	Fifth Generation of Mobile Networks
B2B	Business-to-Business
B2G	Business-to-Government
BBU	Baseband Unit
BER	Bit Error Rate
CNR	Carrier-to-Noise Ratio
CoMP	Coordinated Multipoint
CPRI	Common Public Radio Interface
CSP	Communication Service Provider
DL	Downlink
FTTH	Fibre To The Home
HD	High Definition
HD-SDI	High Definition Serial Digital Interface
HetNet	Heterogeneous Network
IMT-Advanced	International Mobile Telecommunications-Advanced
IPTV	Internet Protocol Television
IQ	In-phase and Quadrature components
ITU-R	International Telecommunication Union - Radiocommunication Sector
KPI	Key Performance Indicator
LOS	Line Of Sight
LTE	Long Term Evolution
LTE-A	LTE-Advanced
M2M	Machine-to-Machine

MIMO	Multiple Input Multiple Output
MNO	Mobile Network Operator
nLOS	near Line Of Sight
NLOS	Non Line Of Sight
OBSAI	Open Base Station Architecture Initiative
OpEx	Operational Expenditures
ORI	Open Radio equipment Interface
PoP	Point of Presence
PtMP	Point to Multipoint
PtP	Point to Point
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RF	Radio Frequency
RRU	Remote Radio Unit
SISO	Single Input Single Output
SLA	Service-Level Agreement
TCO	Total Cost of Ownership
TV	Television
UL	Uplink
VDSL	Very-high-bit-rate Digital Subscriber Line
WCDMA	Wideband Code Division Multiple Access

4 Millimetre wave spectrum technology: Overview and benefits

The high interest in millimetre wave bands has risen due to the enormous amount of bandwidth that lies in this part of the electromagnetic spectrum. With respect to the present regulatory status, typically V-band offers 7 GHz bandwidth of contiguous spectrum (57 - 64 GHz), extendable to 9 GHz whenever also the 64 - 66 GHz is open for fixed services and E-band provides two times 5 GHz bandwidth, namely 10 GHz aggregate spectrum (71 - 76 GHz and 81 - 86 GHz). Similarly, at frequency bands above 100 GHz, there are blocks of plentiful spectrum, which could be allowed for extra bandwidth for future broadband wireless transmission services. Figure 2 [i.1] illustrates the channel spacing of the fixed radio systems as function of the corresponding frequency band. The obvious advantage is that over 1 Gbps capacity figures could be provided in SISO configurations and with average physical modulations (e.g. 500 MHz and 16QAM combination), while over 2 Gbps capacity figures could be achieved by having more capable physical modulations (e.g. 64QAM).

Another significant advantage of millimetre wave spectrum apart from being massive is that it is congested-free. The requirement for non-crowded spectrum becomes more critical in urban and sub-urban environments, especially as the number of installed links begins to grow as more high-capacity sites at smaller distances are to be served. Since multiple network operators already use the long-established microwave bands in the same area, at some point in time excessive bandwidth might become more difficult to be sourced at legacy bands to cover their needs adequately. In order to avoid any potential "spectrum asphyxia", networks operators could turn to higher frequency bands. Millimetre wave bands have not been extensively used, so this part of the electromagnetic spectrum offers an alternative path to evolve wireless transmission networks effectively.

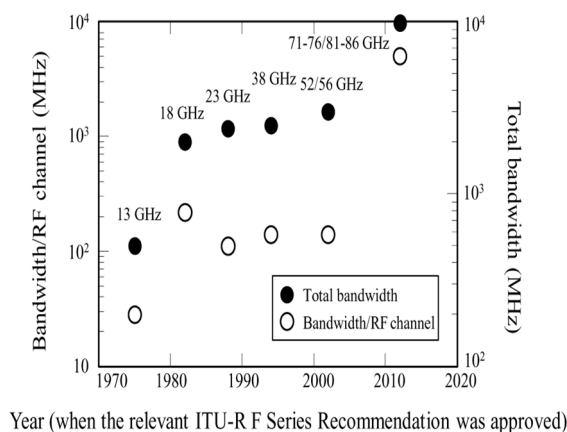


Figure 2: Channel spacing of the fixed radio systems

Additionally, it is worthwhile stating that the extraordinary amount of millimetre bandwidth facilitates the fulfilment not only of existing wireless transmission applications, but aids the development of wireless systems of future-proof performance, as well. The engineering of wide-spectrum radio systems leads to very high throughput and low packet delay figures that will be increasingly required in the next-generation transmission applications, for instance LTE-A and 5G mobile backhaul. Considering channel sizes, physical modulations and coding rates that are supported by recent implementations, it could be extrapolated that only by employing wider channels, a capacity in the range of 10 Gbps could be achieved. Also, increase of capacity, by keeping other things equal, results to further reduction of packet delay, which is observed in millimetre wave spectrum technology. At present, the one-way latency of millimetre wave radios can be lower than half a millisecond even down to 100 microseconds or less, depending on actual implementation. As specifications of certain transmission applications become increasingly stricter and require fibre-like performance even at the last-mile, millimetre wave spectrum technology could be the enabler to meet upcoming stricter demands and be conceived as a future-proof over-the-air technology.

With reference to their radio propagation properties, millimetre wave bands are defined by short-to-medium ranges (from a few hundred metres up to several kilometres), making technology at this spectrum suitable for applications in urban and sub-urban areas. It has to be stressed though that transmission distances are subject to exact frequency channel, bandwidth, target link availability at reference physical modulation and rain zone, besides system capabilities, such as transmitting power, receiver's sensitivity and antenna performance.

Furthermore, millimetre wave spectrum technology provides very high-frequency re-use capabilities. Due to the high operating frequency and resulting short wavelength even physically small antennas would provide relatively high directivity and low side lobe level. That antenna directivity ensures good spatial isolation between links operating in close proximity and reduces significantly the probability of generating interference or being subject to interference. The high operating frequency and short wavelength are further effective to reduce specular reflections from many physical surfaces (as they would appear rough at these wavelengths), in case such a surface is illuminated by the main lobe or a side lobe of a millimetre wave antenna. The reduced reflection levels would further contribute to the reduction of the chances of unintended interference. The frequent re-use gain of a single frequency channel becomes even more obvious at cases where atmospheric absorption is a significant degradation factor at some frequency bands, as shown in Figure 3 of [i.2].

Network design and implementation benefit from millimetre wave spectrum technology. Sizeable number of available frequency channels and very high frequency re-use ease frequency planning. Also, seeing that millimetre wave spectrum technology is capable of employing wider channels, for example in the order of 200 MHz or more, by transmitting fewer bits per symbol, target data rates could be attained for certain cases. Thus, respective CNR thresholds (at a BER of 10^{-6} or better) could be low and robustness of millimetre wave rises. Moreover, lower probability of undesired interference and availability of antennas of high directivity allow the installation of more millimetre wave links per area unit by supporting any type of interconnectivity options, e.g. chain, star, tree, ring, mesh. Consequently, millimetre wave spectrum technology facilitates increased deployment density, before exhausting the expandability cap in a given area. Another benefit of millimetre wave related to network implementation appears in cases where demand for high-capacity data-centric connectivity is in locations that are fully or partially isolated by surrounding obstacles (trees, buildings, hills, rivers, etc.). In such cases, when the path length permits, use of millimetre wave offers the advantage, as compared to use of lower frequencies, that its short wavelength results in narrow Fresnel zone radius, so enabling reliable transmission over the obstacle without requiring tall masts or towers.

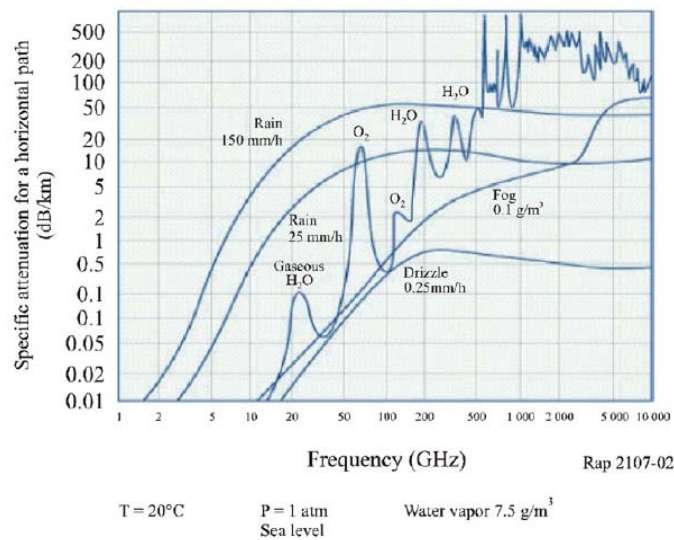


Figure 3: Specific attenuation due to rain attenuation and atmospheric gases

In addition, millimetre wave spectrum technology facilitates the manufacturing of compact products. Antenna size depends on wavelength of electromagnetic signal, so in principle millimetre wave antennas of very small dimensions can be designed. In fact, millimetre technology allows entire digital and analogue circuitry, such as network interfaces and processor, modem, radio transceiver and antenna to be accommodated at full-outdoor and small-form factor architecture, thus contributing to discreet and fast installations.

Last, but not least, another important trait of millimetre wave spectrum is that it can significantly contribute to an optimized TCO and an accelerated roll-out of a wireless transmission network. Based on the individual radio propagation characteristics of each millimetre wave frequency band, license-exempt or light licensing regimes are feasible (see [i.3], [i.4], [i.5], [i.6], [i.7], [i.8] and [i.9]). Whilst licensed regime could be of course wanted for ensuring more certainty in the expected QoS performance, the capability of adopting unlicensed and light licensing schemes can really benefit transmission network applications as a consequence of:

- Reduced OpEx due to zero or low annual spectrum fees.
- Rapid deployment, because of none or simplified (no time-consuming) registration processes.

5 Applications and use cases: Overview

The attributes of the millimetre wave spectrum technology facilitate its usage in a sizeable number of wireless transmission applications. The applications and use cases (latter are shown within brackets) that are discussed in this paper are:

- Macro-cell mobile backhaul application (mobile network upgrade, expansion)
- Small-cell mobile backhaul application (rooftop-to-street/street-to-street connectivity, multi-hop)
- Fronthaul for small cells application (rooftop-to-street/street-to-street connectivity, multi-hop)
- Fronthaul for macro cells application (mobile network upgrade, expansion)
- Next-generation mobile transmission application
- Fixed broadband application (wireless to the home, wireless to the cabinet)
- Temporary infrastructure application (special events, public safety)
- Business-to-business application
- Business-to-government application (broadband connectivity, public Wi-Fi hotspot backhaul)