ETSI GS mWT 006 V1.1.1 (2015-12)

millimetre Wave Transmission (mWT); Analysis of antennas for millimetre wave transmission

Disclaimer

This document has been produced and approved by the millimetre Wave Transmission (mWT) ETSI Industry Specification Group (ISG) and represents the views of those members who participated in this ISG.
It does not necessarily represent the views of the entire ETSI membership.

Reference

DGS/mWT-006

Keywords

antenna, application, millimetre wave, mWT, 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
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

Contents

Intellectual Property Rights

IPRs essential or potentially essential to the present document may have been declared to ETSI. The information pertaining to these essential IPRs, if any, is publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (http://ipr.etsi.org).

Pursuant to the ETSI IPR Policy, no investigation, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

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).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Executive summary

On the basis of selected applications and use cases in the millimetre wave band, especially in the V- and E-bands, and based on operators' expectations as defined in ETSI GS mWT 002 [i.1], appropriate antennas requirements have been identified. Several deployment scenarios as well as the relevance of antenna features.

A current technology review and a status review of existing standards put in perspective the challenges that the industry is facing with those new requirements.

Introduction

The number and quality of services that can be offered in a given band highly depend on the efficient use of spectrum which is closely related to the performance of the antennas. Antenna functions are key when it comes to effective spectrum management and consequent service availability.

The present document reflects a common agreement on how best to make spectrum available for the different use cases in order to avoid delays, confusion, and missed opportunities.

Antenna requirements for different mm-wave applications and use cases vary significantly.

The variety of antenna options and requirements are of great relevance for different applications and use cases. While strict licencing and tough antenna quality requirements may be the best solution in one application, another use case may call for a more self-organized deployment with antenna features that help avoid interference.

1 Scope

The purpose of the present document is to provide an analysis on antennas to be used for millimetre wave transmission covering:

- Operators' key expectations.
- Use cases (described in ETSI GS mWT 002 [i.1]) and related point to point and multipoint millimetre-wave (V-band and E-band) antenna requirements.
- Review of the current technological and regulatory status.
- Definition of terminology.

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.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

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 necessary for the application of the present document.

Not applicable.

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 reference 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 GS mWT 002: "millimetre Wave Transmission (mWT); Applications and use cases of millimetre wave transmission".

[i.2] ETSI White Paper No.9: "Overview on V-band and E-band worldwide regulations".

[i.3] Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC.

[i.4] ETSI EN 302 217-4-2 (V1.5.1) (01-2010): "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 4-2: Antennas; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.5] Federal Communications Commission (FCC) § 101.115, 47 CFR Ch. I (10-1-14 Edition).

[i.6] Industry Canada Spectrum Management and Telecommunications - SRSP-370.1 issue 1 July 2015 (draft).

NOTE: At the time of publication, this document is in draft status.

[i.7] D.M. Pozar: "Microwave Engineering", 4th edition, Wiley, 2012.

[i.8] ETSI EN 302 217-4-1: "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 4-1: System-dependent requirements for antennas".

[i.9] ETSI EN 302 217-4: "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 4: Antennas".

[i.10] Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity (R&TTE Directive).

[i.11] ETSI EN 302 217-1: "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 1: Overview, common characteristics and system-dependent requirements".

[i.12] ETSI EN 302 217-2: "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 2: Digital systems operating in frequency bands from 1,3 GHz to 86 GHz; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.13] ETSI EN 302 217-3: "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 3: Harmonized EN covering essential requirements of Article 3.2 of R&TTE Directive for equipment operating in frequency bands where no frequency co-ordination is applied".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

active antenna: antenna, where the electromagnetic signal can be amplified or processed electronically before radiation or after reception or both

NOTE: This antenna includes active components.

Adaptive Antenna System (AAS): array of antennas and associated signal processing that together is able to change its antenna radiation pattern dynamically to adjust to noise environment, interference and multipath

adaptive nulling: functionality of an antenna system, associated with signal processing, where the direction of a null (or more than one null) of its radiation pattern can be changed dynamically to adjust to noise environment, interference and multipath

NOTE: A null is the direction where local minima exist in a radiation pattern due the destructive interference of the wave fronts.

beam forming: functionality of an antenna system, where the amplitude and phase of radiating aperture of the antenna system is optimized through different techniques to achieve a desired shaped radiation pattern

beam steering: functionality of an antenna system, which allows the change in the direction of the main lobe of its radiation pattern

NOTE 1: The change in direction of the main lobe could be in more than one plane.

NOTE 2: The functionality of beam steering is achieved electrically or electro-mechanically.

dedicated antenna: antenna specifically designed for being attached to the radio equipment (i.e. with special mechanical fixing to the antenna port of the specific radio supplied), but can be separated from the equipment (typically for transport purpose) using normal tools

NOTE: For the design and testing of an accurate and precise interface between radio and antenna, intimate details of the mating parts are required. Dedicated antennas are specifically designed for specific radios and therefore ensure mechanical integrity, significantly reducing the risk for RF leakage and moisture ingress.

dynamic auto-alignment: system where there is active compensation for movement of the microwave antenna support structure such that point to point link integrity is maintained up to the rated operational specification of the antenna, typically 0,3 times the 3 dB beamwidth

installation alignment: optical or electronical system used to manually or automatically align the two antenna main beams during initial installation of the link

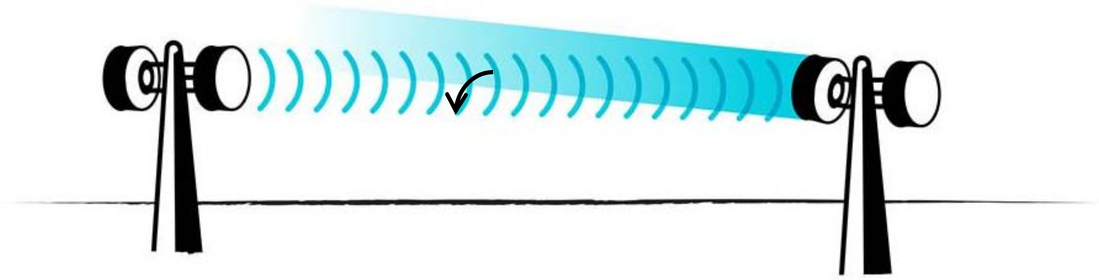

Figure 1

integral/integrated antenna: antenna which is declared as part of the radio equipment by the supplier is not physically separable from the equipment, unless it is returned to the manufacturer premises

NOTE: With integral/integrated antennas the designer owns all details of the interface between radio and antenna which allows for accurate and precise interface design. In addition the interface is enclosed by the radio housing. This drastically reduces the severe risk of moisture ingress and RF leakage.

phased array antennas: array of antennas or elements, which are simultaneously fed, and whose relative phase can be varied to change the pointing direction and beam shape of the main lobe of the array antenna radiation pattern during operation

NOTE: Main lobe or major lobe or beam is the radiation lobe containing the direction of maximum radiation. By setting the relative power levels between the phased array elements, the beamwidth of the main lobe and its sidelobe structure may be further controlled.

selectable beam antennas: antennas using time delays between arrays rather than phase shifters between arrays to steer the main beam

NOTE 1: This approach can be implemented using by either selectable line lengths or by selecting different launch configurations (e.g. different selected feeds or electronically reconfigurable reflectors) within a microwave-optic beamformer (e.g. lens/reflector systems).

NOTE 2: Selectable beam antennas may replace fixed beam antennas without the need to change the radio unit, however some extra control will be required to select the appropriate beam and possibly allow for reconfiguration. They are available with planar, cylindrical and spherical sector apertures and in their microwave optic form may allow omni or floodlight beam operation in their zero power default modes.

stand-alone antenna (ETSI definition): antenna designed independently from the fixed radio equipment, by the same or a different supplier and connected to the radio equipment in the field through standard cables or waveguides

3.2 Abbreviations

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

3GPP	Third Generation Partnership Project
5G	Fifth Generation of Mobile Networks
CFR	Code of Federal Regulations
CPD	co-Polar Discrimination
CPRI	Common Public Radio Interface
EC	European Commission
EIRP	Effective Isotropic Radiated Power
EU	European Union
FCC:	Federal Commission for Communications
IMT-Advanced	International Mobile Telecommunications-Advanced

LOS	Line Of Sight
LTE	Long Term Evolution
nLOS	near Line Of Sight
NLOS	Non Line Of Sight
OBSAI	Open Base Station Architecture Initiative
ORI	Open Radio equipment Interface
PCB	Printed Circuit Board
PtMP	Point to MultiPoint
PtP	Point to Point
QoS	Quality of Service
RE	Radio Equipment
RF	Radio Frequency
RPE:	Radiation Pattern Envelope
SRSP	Standard Radio System Plans
TCO	Total Cost of Ownership
TV	TeleVision
WI:	WorkItem
XPD	cross-Polar Discrimination

4 Operator's expectations

As detailed in the ETSI GS mWT 002 [i.1] and summarized in clause 6, multiple use cases have been identified for V- and E-band equipment. The key expectations of the operators for antennas have nevertheless some common points and some specific requirements per use case as well.

Ease of installation: It is expected that the installation and specifically the antenna alignment should not take more than a few minutes. This could be a real challenge with large gain parabolic antennas, for instance a 2ft E-Band antenna with a typical beamwidth of less than 0,5°. Besides, unskilled technicians could be in charge of antenna installation of street level equipment with basic link testing equipment. It can be anticipated that the initial alignment might not be precise enough.

In both cases, namely a macro-layer high gain/narrow beamwidth antenna and a street level equipment, an auto-alignment function would be preferred.

Regulatory constraints: The compatibility of the technical requirements defined by the existing standards, issued by ETSI or FCC, and the antenna characteristics with the use cases defined in the ETSI GS mWT 002 [i.1] are to be reviewed. Even if new technologies may require an evolution of the specifications, the same quality of service and a proper interference mitigation should be kept. Any proposal for a new specification should preferably start from existing standards, for instance the ETSI classes.

Functionalities: It is expected that the V- and E-Band antennas will offer new functionalities on top of already existing ones, to name a few:

- Existing functionalities: Dual-polarization, when relevant.
- Redundancy.

New functionalities:

- Installation auto-alignment as stated above.
- Beam-steering and/or beam-forming.
- Dynamic auto-alignment, for link operation resiliency.

Visual Impact: Some use cases given in ETSI GS mWT 002 [i.1] refer to applications at street level. The public acceptance of radio equipment in this case is closely linked to their visual perception. Small antennas, if possible integrated within the transceiver, are likely to be much better perceived.

Size and Windload: Even for non-street level applications, the size, weight, windload and visual perception are important features to take into account and to be minimized.

5 Antenna requirements for mm-wave applications

5.0 Introduction

In different millimetre-wave applications different antenna requirements apply. This clause examines the relationship between the millimetre-wave applications and use cases identified in ETSI GS mWT 002 [i.1] and related antenna requirements/features.

5.1 Challenges

The challenges for the next generation transmission networks are multiple and are depending on various factors. In the context of antennas, ETSI GS mWT 002 [i.1] mentions the following:

- Network architecture, topology and density.
- Throughput.
- Range and service availability (with reference to wireless transmission networks).
- Interference management (with reference to wireless transmission networks).
- Network automation.
- Improved match between spectrum resource consumption and consumers' traffic patterns requirements.
- Equipment physical form factor.
- Power consumption.

When addressing these challenges the antenna performance plays a major role.

5.2 Antenna Features

5.2.1 Antenna Appearance

The physical form factor of equipment is a key feature for site acquisition, tower rent and logistic cost. To address aesthetic concerns the antenna is ideally not recognized as such.

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 enables antenna form factors which makes antenna integration in full-outdoor and small-form factor architectures possible, thus contributing to discreet and fast installations. Besides antenna size also antenna shape and colour need to be considered.

5.2.2 Antenna Radiation Pattern Envelope

The objective of the deployment of all millimetre wave antennas is that most of the wanted energy travels to a target or targets. Usually this target is the antenna(s) at the opposite end of a wireless link. Another objective is that no or low unwanted energy travels in other directions. The wanted energy accomplishes a communication link, and the unwanted energy is an interference that can threaten adjacent communication links. Interference can induce QoS and capacity reduction. Deploying highly directive antennas with high main lobe or gain and low side-lobes is the most efficient way to prevent this situation.

It should be noted that even for the use cases defined in ETSI GS mWT 002 [i.1] and used as references for the present document, side-lobes should be kept as low as practical.

Due to the high operating frequency and resulting short wavelength even physically small antennas provide relatively high gain and directivity and low side lobe level. Nevertheless the highest gain antennas (typically 50 dBi) still correspond to a 0.6m antenna diameter with non-negligible visual impact. The directional characteristics of the antenna radiation pattern (co-polar and cross-polar) impact spatial isolation between links operating in close proximity. Highly directive antennas reduce the probability of generating interference or being subject to interference. On the other hand the higher the antenna gain, the more challenging their deployment is due to the need for precise pointing, sturdy mechanical fixing and other site provisioning. In locations that are partially isolated by surrounding trees, walls, buildings, hills, etc. interference may be limited by these obstacles. Smaller size of micro and nano cells require very short backhauling links for which high gain antennas might not be necessary. A trade-off between a tight radiation pattern and the cost/size/weight of the antennas, compatible with the interference constraints given by present and future networks is advisable. Standard bodies like ETSI and FCC define RPE masks which may be mandatory. Applicability is defined by local regulatory bodies, see WI#3 [i.2] also.

One point to consider with street and low level antenna installation is that the current standards may not provide adequate guidance for the avoidance of interference as it may come from any direction and not only within the horizontal plane. A partial or full 3D pattern might be necessary.

5.2.3 Antenna XPD

Radio waves that propagate orthogonally to each other (e.g. in the vertical (V) or horizontal planes (H)) may be used to reduce interference, increase available bandwidth and combat multipath effects. Antennas can be single (one polarization per antenna, the most standard case in millimetre wave transmission), dual polarized (two polarizations per antenna) or circular polarisation (typically not used for millimetre wave transmission). ETSI and FCC give recommendations on minimum XPD values. Applicability is defined by local regulatory bodies. See also ETSI White Paper No. 9 [i.2].

5.2.4 Antenna Gain

From the frequency planning point of view, the best condition (. higher interference protection to nearby links) is when the required E.I.R.P. is obtained with the highest antenna gain and the lowest output power as defined by the general Friis equation [i.7].

$$\frac{Pr}{Pt} \propto GtGr\left(\frac{\lambda}{4\pi R}\right)^n$$

On the other hand antenna gain is related to reflector size, an aspect that has become one of the most binding requirements in urban areas for their ambient impact. Moreover small size (low gain) antennas have a wider beam than high gain antennas, which facilitates radio alignment and hence reduces installation time.

Consequently trade-off has to be taken into account between maximizing efficiency in frequency planning and ease of installation, visual benefits and cost.

ETSI and FCC give recommendations on minimum gain values. Applicability is defined by local regulatory bodies. See also ETSI White Paper No. 9 [i.2].

5.2.5 Antenna dynamic radiation

Antennas may incorporate functionalities that allow the radiation pattern to be dynamically changed.

By beam steering the direction of the main lobe can be changed. The change in direction of the main lobe could be in one plane or more than one plane. The functionality of beam steering is achieved electrically or electro-mechanically. This feature may be used to compensate for pole swing and sway. Another application is to direct the radiation where the linkpartner is located, reducing effective interference with other transmitters (refer to clause 5.2.2).

Another functionality is to change the direction of a null (or more than one null) of the radiation pattern dynamically to adjust to noise environment, interference and multipath. A null is the direction where local minima exist in a radiation pattern due the destructive interference of the wave fronts.

Sophisticated systems can take factors that traditionally hampered transmission, such as physical obstacles and motion, and use them to generate information that increases capacity.

5.2.6 Antenna Integration level

An antenna may:

1) not be physically separable from the equipment in field;

2) separable from the equipment using normal tools in field;

3) or be designed independently from the fixed radio equipment and connected to the radio equipment on the field through cable or waveguide.

Separable antennas enable configurations in the field making the system more flexible and adjustable to specific requirements. Integrated antennas mean simplified logistics, easier installation and no electrical interface that's exposed to the environment. (See also clause 3.1).

5.3 Antenna Requirements for various deployment scenarios

5.3.0 Introduction

When looking at the enablers for wireless transmission applications described in ETSI GS mWT 002 [i.1] all use cases have a need for high frequency re-use and network densification, require an optimized TCO and rapid time-to-market of broadband services, and most use cases call for "non-telecom"-shaped equipment form factor/aesthetics. Network design and implementation practices however indicate that the relevance of specific antenna features depends on application, use case and deployment scenario. This clause maps the use cases and applications described by ETSI GS mWT 002 [i.1] to the three most relevant deployment scenarios and describes with which antenna features their specific challenges can be addressed.

5.3.1 Rooftop Installations

Figure 2

Rooftop installations are well supported by conventional antennas and current regulations. When equipping macrocells with mm-wave backhaul solutions, the motivation is typically higher throughput per cell site compared to the ones of legacy networks. Point-to-Point LOS radio link and regulation schemes that ensure interference-managed operation are preferred. Aesthetic concerns apply only in some places. For most installations a split-mount radio unit form factor is acceptable.

To reach last-mile distances of up to 5 km and target availability medium gain (40 dBi to 50 dBi) antennas of ETSI class 2 to 4 are required with long known interference-managed operation. As pre-aggregation sites have to accommodate more and more backhaul links, antennas with very high frequency re-use capabilities, namely higher class antennas with better sidelobe suppression or dual polarization become more probable.

Auto-alignment of radio units might be handy, in case it expedites drastically the installation time over relatively long transmission distances. This is done one-time during installation and does not justify beamsteering functionalities.

Although temporary transmission links for special events and emergency are not mandatorily installed on rooftop sites only, requirements for this use case are comparable to roof top installations. The main difference is that such links need to be quick to install which makes auto alignment functionalities more important.

Typical roof top applications:

- Macro-cell mobile backhaul application (mobile network upgrade (existing cells) and expansion (new cells).
- Fronthaul for macro cells application (mobile network upgrade (existing cells) and expansion (new cells).
- Temporary infrastructure application (Special events and Public safety).
- TV signal relay application.
- Next-generation mobile transmission applications.
- Business-to-business application.
- Broadband connectivity to governmental buildings.

5.3.2 Street Level Installations

Figure 3

In urban and sub-urban environments outdoor operator-managed small cells are placed at lampposts, outside buildings' walls, payphones, notice boards and similar public spots. This introduces a few new requirements for the backhaul solutions and antennas in particular. Roll-out has to be easy and fast, due to the "non-telecom" professional working environment. Therefore, automation mechanisms, such as self-alignment by beam-steering looks to be quite significant for efficient small-cell backhaul. If beemsteering is not available, low gain antennas with a wide opening angle make alignment easier. This goes along with the fact that only relatively short distances have to be covered.

In locations that are fully or partially isolated by surrounding obstacles (trees, buildings, hills, etc.) interference is limited by these obstacles and the directivity of the antenna becomes less significant. A trade-off between a highly demanding RPE and the cost/size/weight of the antennas, compatible with the constraints is advisable.

At street-level radio propagation conditions express a more dynamic behaviour compared to roof top installations due to the increased phenomenon of multipath. In addition, clear LOS conditions are not always found because of obstacles (e.g. signposts) or could be variable (e.g. seasonal trees' foliage). A wireless transmission technology that supports PtP/PtMP topologies, nLOS/NLOS radio propagation conditions and building penetration is desired.

Street level backhaul equipment's aesthetics need to blend into the urban environment, thus small form factor and integral antennas are preferred.

This is especially relevant in places classified as historic heritage sites, pedestrian areas and anywhere else where telecom equipment is subject to public objection.

Typical street level applications:

- Small-cell mobile backhaul application (rooftop-to-street / street-to-street and clutter extensions).
- Fronthaul for small cells application (Rooftop-to-street / Street-to-street connectivity and Multi-hop in-clutter extensions).
- Fixed broadband application (Wireless to the cabinet).
- Next-generation mobile transmission applications.
- Business-to-business application.
- Business-to-government application (Broadband connectivity to governmental buildings) and public Wi-Fi hotspot backhaul.
- Video surveillance backhaul application.
- Public safety applications.

5.3.3 Installations in residential and public areas

Figure 4

When connecting homes wirelessly very low cost and easy to install equipment is required. Similar to WiFi type applications the installation may be done by non-microwave-expert residents themselves. Consequently a technology that ensures easy, discreet and fast installations with auto-alignment (beam-steering) antennas is desired.

PtP/PtMP/mesh topologies with a high link availability figure and LOS/nLOS/NLOS radio propagation conditions are desired transmission properties for this application. This can be achieved by active antennas with beam steering, beam forming or adaptive nulling functionalities or low gain antennas with a wide opening angle.

Wireless technology form factor and aesthetics have to blend into the environment of deployment to an extent that only small form factor integral antennas are feasible.

Typical residential and public area applications

- Fixed broadband application (Wireless to the home).

5.3.4 Antenna feature relevance

As an overview of the above text table 1 summarizes characteristics and advantages of specific antenna features for different deployment scenarios.

Table 1: Relevance of antenna features for different deployment scenarios.

	Roof Top Installations	**Street Level Installations**	**Installations in residential and public areas**
Antenna Appearance (unobtrusive)	★☆☆☆☆	★★★★☆	★★★★★
Antenna RPE (high class)	★★★★☆	★★★☆☆	★★★☆☆
Antenna XPD (high Class)	★★★★☆	★★★☆☆	★★☆☆☆
Antenna Gain	Medium (40-50)	Low (x-38) see note	low (x-38) see note
Antenna dynamic radiation (beamforming, beamshaping)	☆☆☆☆☆	★★★☆☆	★★★★☆
Antenna Integration Level	★☆☆☆☆ Stand alone / dedicated	Integral	Integral

NOTE: Low antenna gain for the street level and residential installation and public area use cases will be decided after conducting investigation and analysis aimed to achieve adequate capacity for these use cases while maintaining relatively small antenna size suitable for installation at street furniture and structures at street level.

Legend: 1 star = almost not relevant
2 stars = low relevance
3 stars = relevant
4 starts = key feature
5 stars = showstopper

6 Current technological status

6.1 Parabolic antennas

Parabolic antennas are until now the preferred technical solution for point to point transmission. The main benefits are the large gain in a limited volume and ETSI- and FCC-compliant radiation patterns and a very large bandwidth. However the narrow beamwidth becomes an issue as the antenna size increases and beam alignment becomes necessary. Currently this alignment is achieved mechanically, but more complex feed structures are under development to allow faster electronic beamsteering over limited ranges to cope with high rate beam wander due to mast or mount movement due to windage, gusting or mechanical vibration due to vehicular traffic.

6.2 Waveguide-Array Antennas

The market is pushing for less visual impact and if possible flat antennas. For the V- and E-bands, waveguide-array antennas offer a convenient solution for integration in radio equipment. It has the potential of offering steerability at the cost of additional complexity and grating lobes generation that could generate interferences. However progress is being made in this area using the microwave optic selectable beam solution (see clause 3.1).

6.3 Lens antenna

Another technology that allows a beam-steering functionality is the lens antenna. Lens antennas have the feeding structure placed behind the aperture. This allows the use of complex feeders with more than one feed point, a practical way to introduce beamforming and beam-steering features. Parallel plate structures allow the size of the feed structure to radically reduce and allow cylindrical 360° azimuthal beamsteering. Elevation beam tilt can be achieved by adjusting the vertical position of the feed network behind the lens.

6.4 PCB

This flat technology is the most flexible in terms of sub-array division and therefore for beam-forming. However the high loss of the materials in the V- and E-bands limits its application to very small gain when the antenna is strictly passive. Interest in PCB antennas is likely to grow with the introduction of active antennas.

6.5 Comparative summary

Table 2: Comparative summary

Technology	PROS	CONS
Parabolic antennas	High gain ETSI and FCC compliant Large bandwidth More rotational symmetry in patterns Better return loss	Visual impact Complex electronically steerable solutions not available yet. Steering mostly electro-mechanical
Waveguide-arrays antenna	Flat - good visual perception - zoning friendly Potentially electronically steerable More degree of freedom for beam forming and adaptive nulling	Insertion loss Sophisticated manufacturing process Rotationally asymmetric in patterns Return loss
Lens antenna	Potentially electronically steerable	Size Lens loss Sidelobe performance
PCB	Flexible design Very small weight Low cost High mechanical reliability Potentially electronically steerable Active antennas made possible	Insertion loss Calibration most likely needed if electronically steerable Mainly applicable to small size antennas when strictly passive.

7 Current Antenna Standards

7.1 ETSI

7.1.0 Impact of the RE Directive

The new 2014/53/EU Directive (called RED) [i.3] is now in force. The Directive 1999/5/EC - the 'Radio & Telecommunication Terminal Equipment Directive' (called R&TTED) [i.10] will be repealed by June 2016 and R&TTED compliant equipment will be permitted on the market up to June 2017. With the cessation of the R&TTED also the legal basis for the Mutual Recognition of the Conformity for all existing Harmonized Standards under the R&TTED will no longer be valid, which implies that all existing Harmonised Standards under the R&TTED need to be revised, published and listed to comply with the RED before 13th June 2016 including point to point antenna standards ETSI EN 302 217-4-1 (01-2010) [i.8] and ETSI EN 302 217-4-2 (V1.5.1) (01-2010) [i.4]. ETSI TM4 is doing editorial changes of ETSI EN 302 217-4-1 (V1.4.1) [i.8] and ETSI EN 302 217-4-2 (V1.5.1) [i.4], which will merge into a single ETSI EN 302 217-4 standard [i.9], which will not be harmonised standard but will be referred as essential requirement, in a harmonised standard, for integral and dedicated antennas, whereas this will be guidelines for standalone antennas.

7.1.1 ETSI EN 302 217-4-1 (V1.4.1) (01-2010)

ETSI EN 302 217-4-1 (V1.4.1) [i.8] defines the system-dependent requirements for point-to-point antennas for Fixed Radio Systems. The Radiation Pattern Envelope (RPE), which defines the directional characteristic of co-polar and cross-polar signal, impacts the interference situation in the network planning. With respect to RPE, four classes have been defined, called RPE classes 1 to 4. The frequency range from 1 GHz to 86 GHz has been subdivided into seven frequency ranges. V band and E band fall in Range 6 (47 GHz to 66 GHz) and Range 7 (66 GHz to 86 GHz) respectively. ETSI EN 302 217-4-1 includes only class 1 RPE, which was removed from ETSI EN 302 217-4-2 for efficient utilization of spectrum. Part 4-1 also includes the mechanical characteristics of antennas.

7.1.2 ETSI EN 302 217-4-2 (V1.5.1) (01-2010)

ETSI EN 302 217-4-2 (V1.5.1) [i.4] defines the essential requirements of point-to-point antennas. Currently this is a harmonised standard under article 3.2 of the R&TTE Directive [i.10]. The details for antenna classes in V and E bands are given below.

Table 3: Details for antennas in V and E bands as per ETSI EN 302 217-4-2 V1.5.1 (01-2010) [i.4]

ETSI Frequency Range	Frequency Range (GHz)	Antenna Radiation Pattern Envelope (RPE) class
R6	From 47 to 66 GHz	2, 3A, 3B
R7	From 66 to 86 GHz	2, 3, 4

The RPE masks of Co-polar and Cross-polar, for R6 and R7, as indicated above are given in ETSI EN 302 217-4-2 (V1.5.1) (01-2010) [i.4]. The Choice of the antenna depends on the application planned for the band, requirements of the operator and the responsible administration.

In frequency bands above 57 GHz, where single vertical polarization is predominant XPD is not considered as essential requirements for the RE Directive [i.3] conformance, even if the antenna is actually dual polarized. The value given in the present document should be considered for reference purposes only.

As per ETSI EN 302 217-3 [i.13], antenna above 57 GHz shall have a minimum gain of 30 dBi, whereas, as per ETSI EN 302 217-4 [i.9], for the bands 71 GHz to 76 GHz and 81 GHz to 86 GHz, the antennas shall have a minimum nominal gain of 38 dBi.

In the range from 57 GHz to 66 GHz, where simplified or no frequency co-ordination procedures are applied, cross-polar RPE is not considered as essential requirements for the R&TTE Directive conformance, even if the antenna is actually dual polarized.

7.1.3 ETSI EN 302 217-4

ETSI EN 302 217-4 [i.9] is being developed under the new 2014/53/EU Directive (called RED) [i.3]. In new part 4, the subpart 4-1 is merged with subpart 4-2 and there is no change in the specifications, however, new part 4 is no longer a harmonised standard.

As per ETSI EN 302 217-1 [i.11] and ETSI EN 302 217-2 [i.12], the antenna specifications given in ETSI EN 302 217-4 [i.9] are considered to be essential for integral/integrated and dedicated antennas, whereas, for standalone antennas, these will be considered as guidelines. ETSI EN 302 217-2 [i.12] is a harmonised European standard. The new ETSI EN 302 217-4 [i.9] includes class 1 RPE also, but to qualify essential requirements, the RPE class 2 or above to be met.

7.2 Federal Communications Commission (FCC) § 101.115, 47 CFR Ch. I (10–1–14 Edition)

In order to qualify for FCC antenna requirement for the 71-86 GHz band, the RPE masks are given in FCC part 101. In addition to RPE criterion i.e. the minimum radiation suppression to angle requirement, following conditions are also required to be met:

1) With either the maximum beamwidth to 3 dB points requirement given in part 101 [i.5]; or

2) with the minimum antenna gain requirement given in part 101 [i.5].

Antenna gain less than 50 dBi (but greater than or equal to 43 dBi) is permitted only with a proportional reduction in maximum authorized EIRP in a ratio of 2 dB of power per 1 dB of gain, so that the maximum allowable EIRP (in dBW) for antennas of less than 50 dBi gain becomes +55-2(50–G), where G is the antenna gain in dBi. In addition, antennas in these bands shall meet two additional standards for minimum radiation suppression:

1) At angles between 1,2 and 5 degrees from the centerline of the main beam, co-polar discrimination shall be G-28, where G is the antenna gain in dBi; and

2) At angles of less than 5 degrees from the centerline of main beam, cross-polar discrimination shall be at least 25 dB.

The initial rules had required an antenna gain of 50 dBi and set a power limit of +55 dBW EIRP. The revised rules allow antenna gains down to 43 dBi, with a proportional reduction in maximum authorized EIRP in a ratio of 2 dB reduced EIRP per 1 dB of reduced antenna gain. Currently, the minimum size of the E band antennas, which are available in market with the claim of FCC compliance, is 1 ft (30 cm).

On 5th October 2012, FWCC filed request for rulemaking to the commission to allow smaller E band antennas in USA. The new specs proposed by FWCC include category A and Category B, similar to other frequency band specs.

It was proposed to change the minimum gain requirement from 43 dBi to 38 dBi.

A supplement to the request was filed by FWCC on 4th April 2013, to make the following changes:

1) apply the co-polar discrimination (CPD) requirement to angles between 2,5 and 5 degrees; and

2) reduce the cross-polar discrimination (XPD) requirement to 21 dB.

The decision of FCC for rule making request is still awaited.

7.3 Industry Canada Spectrum Management and Telecommunications - SRSP-370.1 issue 1 July 2015 (draft)

SRSP-370.1 [i.6] covers technical requirements or fixed Line-of-Sight radio systems operating in the bands from 71 GHz to 76 GHz and from 81 GHz to 86 GHz. At the time of publication, SRSP-370.1 issue 1 July 2015 [i.6] is in draft stage.

According to SRSP 370.1 issue 1 (draft) [i.6], the maximum EIRP from the antenna shall not, in case, exceed +55 dBW per RF Channel. The impact of antenna gain on maximum EIRP is also defined in SRSP-370.1 [i.6].

Clause 5.5 of [i.6] describes the antenna characteristics. This include RPE mask for horizontal plan and minimum Gain requirement of 38 dBi. An antenna gain less than 50 dBi, but greater than 38 dBi is permitted only with a proportional reduction in maximum authorised EIRP.

8 Conclusions

The present document provides an insight in to the development of antennas for millimetre-wave transmission. At time of writing, some design solutions have not reached maturity and so questions around future performance, features and options still exist.

Smaller unobtrusive antennas are likely to be needed and utilised at street level and less unobtrusive larger antennas at the roof top level. A rule of thumb is that the lower the antenna, the more unobtrusive it should be become.

The issue of spectrum conservation and the future proofing of geographic areas is important and strongly linked to the antenna radiation patterns. Tight radiation patterns in general will inhibit the propagation of energy in to adjacent links and systems. This in turn will allow operators to achieve optimum QoS, capacity and future system growth by maximising link density.

Annex A (informative): Authors & contributors

The following people have contributed to this specification:

Rapporteur:

André Doll, Alcatel Lucent

Contributors:

Junaid Sayed and John Cole, Commscope

Christoph Inhelder, Huber+Suhner AG

David Humphreys, National Physical Laboratory

Peter Curnow-Ford, Plasma Antennas Ltd

Dimitris Siomos, Deutsche Telekom AG

Mike Geen, Filtronic Broadband Ltd

Paolo Agabio, Vodafone UK

Lars Manholm, Ericsson LM

Roberto Macchi, SIAE Microelettronica SpA

Shaun McFall, Aviat Networks ltd

Uwe Rüddenklau, INFINEON TECHNOLOGIES

Bartlomiej Golebiowski, Nokia Solutions and Networks Gmbh & Co.

Yigal, Siklu Communication Ltd.

Neil Bullock, SiBEAM Incorporated

Annex B (informative): Bibliography

- An Introduction to mWT ISG.

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

- ECC Recommendation (09)01: "Use of the 57 - 64 GHz frequency band for point-to-point fixed wireless systems".
- ECC Recommendation (05)07: "Radio frequency channel arrangements for fixed service systems operating in the bands 71-76 GHz and 81-86 GHz".
- ECC Recommendation (14)01: "Radio frequency channel arrangements for fixed service systems operating in the band 92-95 GHz".
- ECC Recommendation (05)02 (2009): "Use of the 64-66 GHz frequency band for fixed service".
- Report Recommendation ITU-R F.2323: "Fixed service use and future trends".
- 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".
- ERC Recommendation 12-12 (2015): "Radio frequency channel, arrangement for Fixed Service Systems operating in the band 55.78 to 57.0 GHz".
- Report Recommendation ITU-R M.2134: "Requirements related to technical performance for IMT-Advanced radio interface(s)".
- MEF 22.1.1, Mobile Backhaul Phase 2, Amendment 1 - Small Cells, July 2014.
- CPRI Specification V6.0 (2013-08-30), Common Public Radio Interface (CPRI); Interface Specification.
- OBSAI, Reference Point 3 Specification, Version 4.2.
- ETSI GS ORI 002-1 (V4.1.1): "Open Radio equipment Interface (ORI); ORI interface Specification; Part 1: Low Layers (Release 4)".
- ETSI GS ORI 002-2 (V4.1.1): "Open Radio equipment Interface (ORI); ORI Interface Specification; Part 2: Control and Management (Release 4)".
- NGMN Alliance: "NGMN 5G White Paper", 17th of February 2015.
- GSMA Intelligence: "Understanding 5G: Perspectives on future technological advancements in mobile", December 2014.
- Milestones: "First Millimeter-wave Communication Experiments", by J.C. Bose.

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

History

Document history		
V1.1.1	December 2015	Publication