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E-Band and V-Band - Survey on status of worldwide regulation

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Executive Summary

Microwave[1] is undergoing fast and deep transformation. Current and future mobile networks impact backhauling in several ways. The main drivers for change are the huge increase of capacity and enhanced coverage, together with new topologies where access and backhaul platforms should cope with ultra small hot-spots, strengthening the need to exploit available spectrum as much as possible and in the most appropriate way.

In particular, the first two drivers, in urban and sub-urban environments, lead to a new and revolutionary approach for microwave backhauling. Backhauling needs to satisfy apparently conflicting requirements such as increase of capacity and spectrum efficiency, very low power consumption, very low environmental impact, in short, to reduce total cost of ownership to a minimum to make the business case of operators turn positive. Capacity is increasing more and more while distances decrease and base stations get nearer to subscribers. Current traditional frequencies below 50 GHz are already very crowded and exploited, hence the need to use higher frequency bands in future-proof networks.

Due to technology evolution and availability of wide channel bandwidths, the use of frequency bands in the V-Band[2] and E-Band[2] appear to be of interest for the current and future needs for backhaul networks. The huge interest in this part of the spectrum in the last decade is also demonstrated by three European Framework Programme 7 (FP7) research projects: E3NETWORK [26] addressing mainly a backhaul solution in E-Band, MiWaves [27] addressing backhaul and access solutions in 60 GHz and 71-86 GHz Bands and IPHOBAC-NG [28] addressing integration of mm-wave radio and photonics for backhaul and other purposes.

E-Band and V-Band have different spectrum characteristics and nature:

- V-Band is characterized by a continuous block of 9 GHz of spectrum between 57 and 66 GHz, oxygen absorption that implies immunity to interference and enhanced frequency re-use, a favourable licence regime, mostly unlicensed or light licensed (country dependent).
- E-Band: since 2000, regulators have made available high frequency bands at 71-76 GHz and 81-86 GHz. E-Band enables gigabit-per-second data rates given the huge amount of available spectrum (10 GHz) without any oxygen absorption, thus allowing longer distances compared to V-Band.

Given the different nature of the two frequencies, different scenarios might be foreseen for each of them, including macro and small cell backhaul, front-haul applications, Line of Sight (LoS) today and most probably future near Line of Sight (nLoS) or No Line of Sight (NLoS).

Nonetheless, regulations for these two frequency bands aren't always already decided, opened and planned and, especially for the V-Band case, the related portions of the spectrum differ from country to country making it very fragmented.

[1] Microwave in this contest refers to the wireless technology mainly used for mobile backhauling applications using frequency bands ranging from 4 to 86 GHz.

[2] Definition of V-Band and E-Band is provided later

Introduction and Scope

The main scope of this document is to provide an updated overview on the state of regulation and spectrum allocation of both V-Band and E-Band, mainly for the case of fixed service.

In this context, the term regulation includes:

- The international standards from bodies such as ITU or ETSI and regulations from organizations, such as ECC or FCC.
- The rules at national level which, for the scope of the present analysis, can be considered as the key source of information as they reflect the national status in several countries both inside and outside the European Union.

Given the market need to effectively exploit both E-Band and V-Band frequency bands, an exhaustive investigation has been carried out among administrations and regulatory bodies to gather allocation status, licensing regime and other relevant data.

The analysis of the data collected through that investigation has been performed by the ETSI Millimetre-Wave Transmission Industry Specification Group.

The outcome of the analysis is described in two relevant deliverables:

- The present white paper
- A database included in the white paper, whose structure is discussed in Appendix [A], in which the updated country by country allocation is collected

Overview on Regulation status

General background

Sometimes there is confusion and controversy about microwave frequency band letter definitions, since there is no unique view in literature. Each letter definition is widely variable depending on the standardization body that introduced it in the past.

For the purpose of this document:

- V-Band is intended to span from 57 GHz to 66 GHz, where the oxygen absorption is significant; however, also the lower portion spanning from 48.5 GHz to 57 GHz can be generally included in the V-Band definition.
- E-Band is intended to cover 71-76 GHz and 81-86 GHz.

Terminology and definitions

Many of the concepts related to spectrum use do not have unique definitions endorsed in ITU vocabulary; general concepts are likely to be understood by experts, but slight differences in terminology and their interpretation are present among regional organizations (ECC, FCC etc.) and individual administrations.

This clause tries to propose, as far as possible, the best definition and variant of terminology for the regulatory processes to access the spectrum.

Band allocations and designations

Access to the radio spectrum is based on the Table of Frequency Allocations of the International Telecommunications Union (ITU) Radio Regulations, where defined categories of radio service are allocated frequency bands in different parts of the spectrum and for different ITU regions [C]. ITU table allocation for V-Band and E-Band are reported in Appendix [D].

The spectrum allocation can be on either exclusive, shared, primary or secondary basis. Due to scarcity of the frequency spectrum, many bands are allocated for more than one radio service and are, therefore, shared. Spectrum sharing studies aim to identify technical or operational compatibilities that will enable radio services to operate in the same (or adjacent) frequency bands without causing unacceptable interference to each other. Often, sharing becomes possible when limits are placed on certain system parameters for example, antenna radiation patterns, transmission power etc. Decisions are taken at the national level on the purpose or purposes for which particular frequencies will be used. These decisions are reflected in the International and National Tables of Frequency Allocations.

Some keywords are given here:

Allocation (to a Service): Each band has a general allocation to one or more “services”; the allocation may be worldwide or regional, but each administration can autonomously decide differently.

Radio Service: The radio services (e.g. Fixed, Mobile, Radiodetermination, etc.) are all listed in the Radio Regulations.

Radio application: Under a service there might be several “applications” (e.g. point-to-point, point-to-multipoint are different applications under fixed service). To be specifically used by a radio application the band should be “designated/dedicated” to that application.

Designation/dedication (to a radio application): The specific use of a band or portion of band for one radio application within the allocated service (e.g. some fixed service bands are "designated/dedicated" to point-to-point only, point-to-multipoint systems cannot obtain access, and vice versa).

Access to the frequency bands

There are two major methodologies for giving access to the spectrum:

- Authorization regimes
- Block assignment/auction regimes

Authorization regime

The administration decides, band by band and by radio application which type of licence is required for operating a radio; Figure 1 (reprinted from [25]) summarizes the types of licensing generally used by administrations.

Individual authorisation (Individual rights of use)		**General authorisation** (No individual rights of use)	
Individual licence[1]	**Light-licensing**		**Licence-exempt**
Individual frequency planning / coordination Traditional procedure for issuing licences	Individual frequency planning / coordination Simplified procedure compared to traditional procedure for issuing licences With limitations in the number of users	No individual frequency planning / coordination Registration and/or notification No limitations in the number of users nor need for coordination	No individual frequency planning / coordination No registration nor notification

Figure 1: Generic subdivision of authorization and licence regimes

Individual licensing [3]- this is the conventional link-by-link coordination, usually made under an administration's responsibility; sometimes, the administration delegates this task to the operators, but it keeps control of the national and cross-border interference situation. This is currently the most used method for point-to-point (P-P) link networks.

Light licensing - The most common understanding, when fixed P-P links are concerned, refers to a link-by-link coordination, under users' responsibility, reflected in the definition given by ECC Report 80 [25] as: "A 'light licensing regime' is a combination of licence-exempt use and protection of users of spectrum. This model has a 'first come first served' feature where the user notifies the regulator with the position and characteristics of the stations. The database of installed stations containing appropriate technical parameters is publicly available and should thus be consulted before installing new stations."

From the spectrum usage point of view, this method is, in principle, equivalent to individual licensing. The potential risks of errors or misuses in the coordination process might be higher because of the number of actors involved, some of them also not sufficiently technically skilled.

[3] Sometimes also referred to as "traditional licensing"

Obviously, when light licensing is intended as only requiring notification/registration (i.e. rightmost cell under light licensing in figure 1), the method is much less effective and, with respect to the licence exempt case, offers the only advantage of having the database available to help resolve claimed interference cases.

Licence exempt - This method offers the most flexible and cheapest usage, but does not guarantee any interference protection[4]. It is most popular in specific bands (e.g. 2.4 and 5 GHz) where short range devices (SRD) are allocated, but fixed service applications may also be accommodated; in addition, it is often used in bands between 57 GHz and 64 GHz but traditionally has been less attractive there due to the unfavourable propagation attenuation.

Block assignment/auction regimes

Block assignment - the assignment might be made through licensing (renewable, but not permanent) or through public auction (permanent). This is most common when fixed wireless access (point to multi-point, P-MP) is concerned and the user is usually free to use the block at best to deploy its network; in some cases, there might even be no limitation to the wireless communication methods used in the block (e.g. P-P and/or P-MP, terrestrial and/or satellite or any other innovative technology or architecture). In the most popular bands for this method, ECC recommendations exist suggesting intra-block protection guidelines in terms of guard bands or block-edge masks (BEM), see: [5]. For some frequency bands this method is considered the best compromise between efficient spectrum usage and flexibility for the user.

Licensing fees

The above licensing conditions do not have, in general, specific linkage to the fees paid for the use of frequency.

In most cases the right of use depends on the spectrum management department of an administration (through appropriate regulations), while the fees usually depend also on the “economic ministry” (typically regulated through higher level laws).

Therefore, in some cases, there might be little correlation between the licensing procedure and the related fee; several examples of “standard” link-by-link fees applied to unplanned/uncoordinated links exist (among which V-Band is typically considered).

One of the most popular methods to define fees for E-band usage is comprised of two main components, namely:

- The Application Fee, and
- The Frequency Management Fee.

Simplifying these two components a lot gives the following:

[4] This method, in some scenarios, can be considered as the most efficient use of the spectrum, as users are forced on the one hand to minimize generated interference and on the other hand, to maximize their immunity to interference.

- Application fee – this is a one-time charge due for the approval of frequency assignment. The application fee should cover the cost of the initial activities performed in assessing the suitability of the frequency to be used for the intended application.
- Annual Frequency Management fee – this is a recurrent fee payable annually to cover the right to use a scarce resource and the cost of the activities performed to safeguard the use of the frequencies. This part can depend on a lot of parameters, such as frequency band, channel size, capacity, congested region, hop length.

In general, a licence fee depends on channel bandwidth and frequency band. Other parameters that can affect the fee calculation are for instance the number of transmitters and geometric considerations (area). The use of incentives is frequent to promote use of higher frequencies.

Our survey confirmed that licence fees vary a lot from country to country. For the E-Band case, we have provided a high level comparison of the fees due in given cases.

In Appendix [G] a number of real methods used by administrations to determine fees are reported.

V-Band case

The following clauses summarize the CEPT, ITU-R and USA regulations as they are the most representative in the market; however, other national regulations are present and referred to in the database.

The use of frequencies around 60 GHz has a long history. The 58 GHz band was in use already in the early 1990's in a few countries [31]. Spectrum regulations have evolved since then, from the initial focus on the 57-59 GHz range [31, 32, 33, 34] that attracted some industry interest [35], the later addition of the 64-66 GHz range [2] that did not attract any industry interest [15], to the latest added possibility for a larger continuous 57-66 GHz range [1, 2, 12] that has attracted huge industry interest.

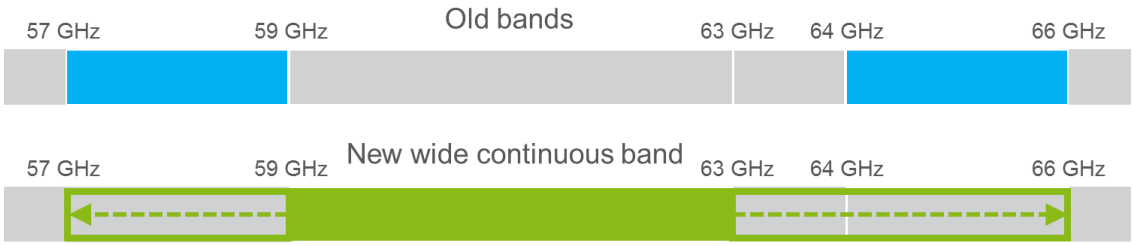

Figure 2: The older bands and the new wide continuous bands around 60 GHz

Regulation overview

International regulatory documentation for Fixed links (57-66 GHz)

The following are the European (broader CEPT area) "fixed links-specific" Recommendations for the use of the upper part (see notes) of V-Band:

- ECC Recommendation (09)01: "Use of the 57 – 64 GHz frequency band for point-to-point fixed wireless systems"[1]
- ECC Recommendation (05)02 (2009): "Use of the 64 – 66 GHz frequency band for fixed service"[2]

Within this range, the band available for fixed applications is fragmented on country basis; in particular, the range 63-64 GHz, being harmonized for "Intelligent Transport Systems" (ITS) applications (see after the chapter 'Other relevant "non-Fixed Service (FS)" international regulatory documentation') is often unavailable for fixed services.

This picture taken from EFIS system [30], provides an idea about the current implementation status of these two recommendation in Europe.

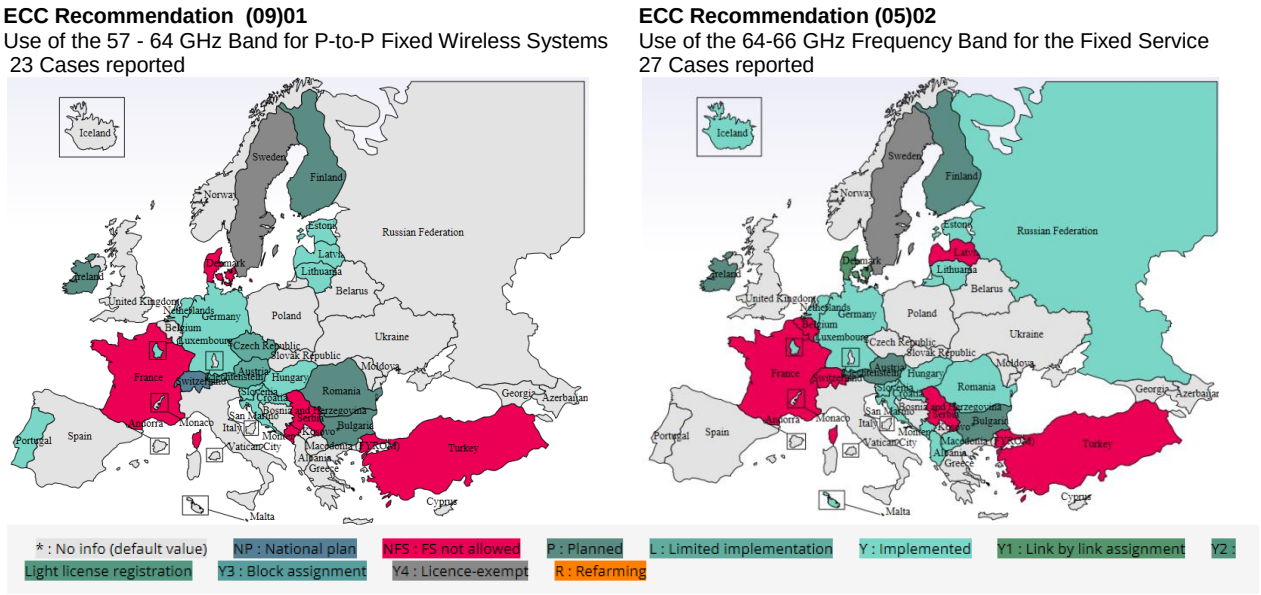

Figure 3: Implementation status of ECC(09)01 and ECC(05)02

The reason for having separate recommendations is the significantly reduced oxygen absorption impact in the upper range, which may suggest different licensing conditions. However, the two recommendations can be jointly used in a continuous 50 MHz elementary slot raster, for building up a larger aggregated channel size. The only difference lies in the different emission levels permitted.

Frequency division duplex (FDD) and time division duplex (TDD) technologies are both possible and FDD duplex separation is unspecified.

In some places, the band 59 to 61 GHz is used for NATO/military applications. Some administrations have decided to reserve the band 61-61.5 GHz for Industrial, Scientific and Medical (ISM) (SRD) use only.

Similar recommendations are available in ITU-R:

- ITU-R Recommendation F.1497-2 (2014): “Radio-frequency channel arrangements for fixed wireless systems operating in the band 55.78-66 GHz”[12]

where bands 55.78 – 57 GHz, 57 – 64 GHz and 64 – 66 GHz are treated in different annexes.

In USA, the FCC regulates the band and 57-64 GHz is included in:

- 47 C.F.R. part 15 “Radio Frequency Devices” (15.255) [18]

Therefore, the FCC recommendation is not specific for fixed links only but it covers any generic “intentional radiator”.

International regulatory documentation for Fixed links (48,5-57 GHz)

Even if, at the date of publication of the present document, they have less importance due to lack of basic RF components on the market, the following are the European (broader CEPT area) "fixed links-specific" recommendations for the use of the lower part of V-Band:

- 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"

ITU-R Recommendations cover only two portions of the above bands:

- ITU-R Recommendation F.1497-2 (2014): "Radio-frequency channel arrangements for fixed wireless systems operating in the band 55.78-66 GHz
- F.1496-1 (2002) : "Radio-frequency channel arrangements for fixed wireless systems operating in the band 51.4 - 52.6 GHz"

In the USA those bands are currently allocated to fixed services, but not yet specifically regulated in the Part 101 or Part 15 [18, 19].

Other relevant "non-Fixed Service (FS)" international regulatory documentation

As shown above, in the USA (as in other countries following the FCC approach) the V-Band range around 60 GHz is not specifically regulated for fixed services (that have "primary" allocation in ECC), but rather for generic "Intentional radiators" (as defined in clause 15.3 [39]) systems (which may include fixed links, but all without "primary" status). The most popular application in the FCC area is WiGig based on the 802.11ad standard [38] that can be used for indoor or outdoor applications under different emissions limitations (see "Regulatory emission limitations" below).

In the CEPT area applications other than fixed services are regulated as short range devices (SRD). Multi Gigabit Wireless Systems (MGWS), similar to WiGig, are the most popular SRD. These applications are more popular among regulators than fixed ones and are more frequently found in the national allocation tables. It should be noted that SRDs do not have the same primary allocation status as fixed services, therefore they should not produce harmful interference to fixed links.

It may be worth mentioning also that Intelligent Transport Systems (ITS) are permitted on an exclusive basis in the 63GHz - 64GHz band [6].

SRDs are listed in ERC/REC 70-03 "Relating to the use of Short Range Devices (SRD)" [17], but also at higher Decision level in:

- EC Decision 2013/752/EU: "Commission Implementing Decision of 11 December 2013 amending Decision 2006/771/EC on harmonisation of the radio spectrum for use by short-range devices and repealing Decision 2005/928/EC" [6]

ITS are regulated by:

- ECC/DEC(09)01[5]: "ECC Decision on the harmonised use of the 63-64 GHz frequency band for Intelligent Transport Systems (ITS)" [7].

Regulatory emissions limitations

The upper part of V-Band (i.e. 57 to 66 GHz) is generally intended by a majority of administrations for "unplanned/uncoordinated" deployment. Therefore, for the sake of maintaining a fair and efficient use of the band, most regulations impose limitations in the emissions levels and, often, in antenna gain.

In the CEPT area the recommendation ECC/REC(09)01 indicates that the following limitations apply:

- Maximum EIRP: +55 dBm
- Minimum antenna gain: +30 dBi
- Maximum transmitter output power: +10 dBm

According to this recommendation the combination of 57-64 GHz with 64- 66 GHz channel planning according to ECC/REC(05)02) is also possible.

However, ECC/REC(05)02 does not have any emissions limit and this might imply an improper (or unfair) use of the band by high power and low antenna gain systems.

The FCC in the USA adopted a methodology (initially for E-Band) of limiting the maximum EIRP as a function of antenna gain (G) with a general formula:

$$EIRP\ (dB) = EIRPmax\ (dB) - 2*(Gmax-G)\ (dB).$$

Where EIRP and G are the values actually permitted in that station, while EIRPmax and Gmax are stated by the FCC. For V-band, Part 15 states:

- EIRPMax = +82 dBm
- Gmax = +51 dBi

In addition, FCC Rule Part 15.255 states that for indoor equipment the average power of any emissions shall not exceed 40 dBm and the peak power of any emissions shall not exceed 43 dBm. Recently, the FCC have clarified that outdoor equipment, like WiGig, can comply with both this rule or the rule above limiting the maximum EIRP as a function of antenna gain - whichever provides the higher EIRP limit. This implies that, given the EIRP limitation and the maximum transmit power, the minimum antenna gain in the FCC area becomes 13 dBi.

[5] To avoid possible misunderstanding it may be worth noting that ECC/DEC(09)01 is a different document with respect to the above mentioned ECC Recommendation (09)01. One is a Decision and the second is a Recommendation.

The following Figure 4 graphically shows the mutual limitation of EIRP, G and P out in both FCC and ECC areas.

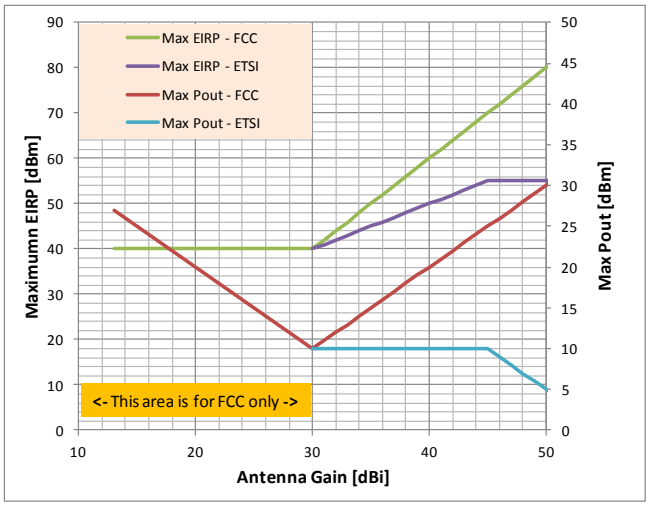

Figure 4: EIRP, Antenna Gain and Pout in both FCC and ECC + ETSI

ETSI's Technical Committee ATTM (Access, Terminals, Transmission and Multiplexing), responsible for the development of Harmonized Standards for placing fixed radio systems on the European market according to the EU Radio and Telecommunications Terminal Equipment (R&TTE) Directive and its replacement Radio Equipment Directive (RED) , analyzed the FCC approach and adopted it as a general requirement (in addition to the ECC emissions regulation) for all equipment in this part of V-Band (as well as in E-Band) in ETSI EN 302 217-3 [10].

A similar limitation for equipment working in the 64-66 GHz band can be found in ETSI EN 302 217-3.

V-Band country by country overview

This review covers 61 countries, with details reported in the attached database [Appendix A]. Although a considerable number of countries have opened the new wide continuous part of the band, covering at least the 59-63 GHz portion, the situation today is still not well harmonized with many band variations as well as fragmentation into sub-bands.

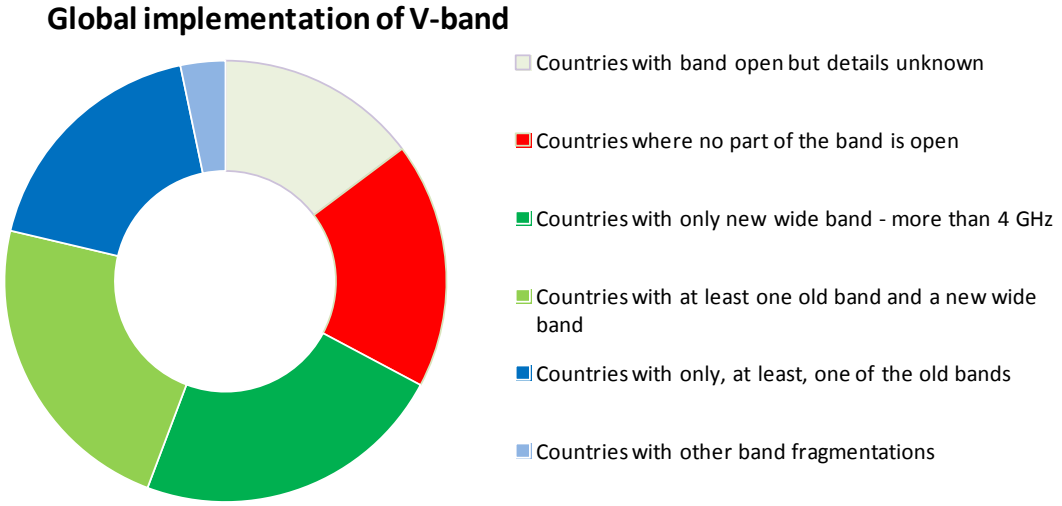

Figure 5: Global implementation of V-Band per country

More than 15 different sub-bands, covering 83 different cases in total, were found in the survey and are summarized in the database snapshot in Figure 7 and in Appendix B - Table 4.

The fragmented situation today can be attributed to:

- Historical reasons where many countries have not yet adopted the wide band regulations that include the previously excluded 59-64 GHz portion;
- Sharing reasons where in some countries segments of the band are excluded due to concerns for other primary services. For example in some countries the 63-64 GHz portion is excluded due to ITS;
- Regulatory concerns where the band in some countries is split into segments with different regulations. For example, concerns can be due to the much lower propagation loss in the 64-66 GHz part, or due to different sharing conditions.

The following figure depicts the most popular segments for these bands, as reported in our survey.

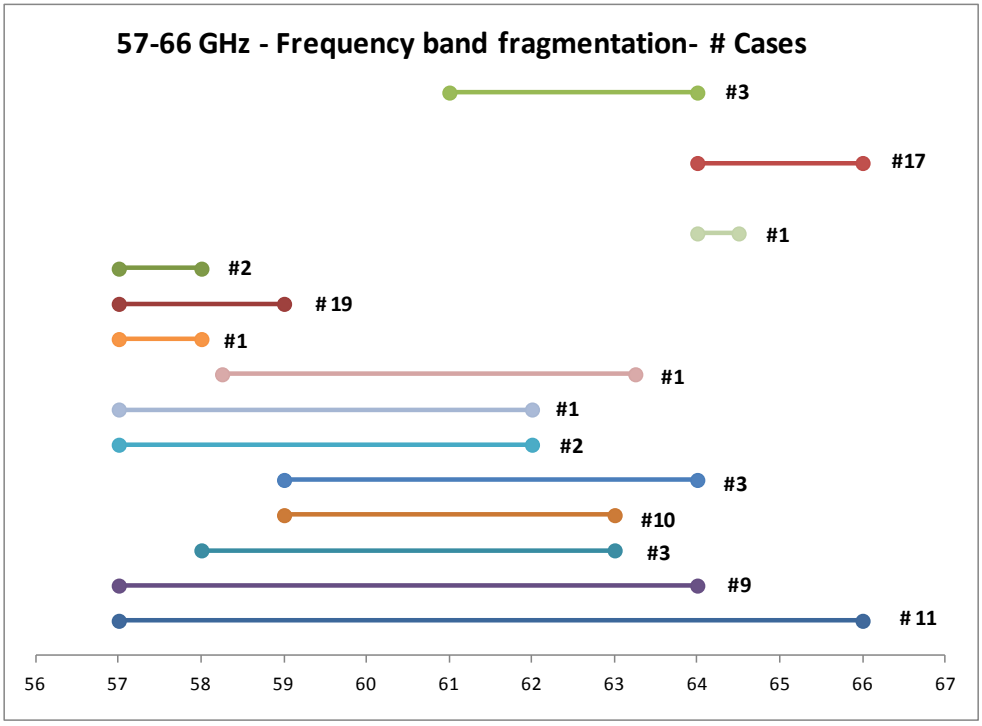

Figure 6: Band fragmentation in 57-66 GHz & numbers of cases reported

A summary of the licensing and duplex situation for the old bands and the new wide continuous bands is given in Figure 7 and Figure 8.

The dominant duplex arrangement is allowing both FDD and TDD, but in the old 57-59 GHz band there are also some cases were only TDD is allowed.

Contrary to common belief, licensing is more common than licence exempt (unlicensed). However, for the new wide continuous bands unlicensed is almost as common as licensed. Unlicensed is also quite common in the old 57-59 GHz band, while licensed dominates in the old 64-66 GHz band.

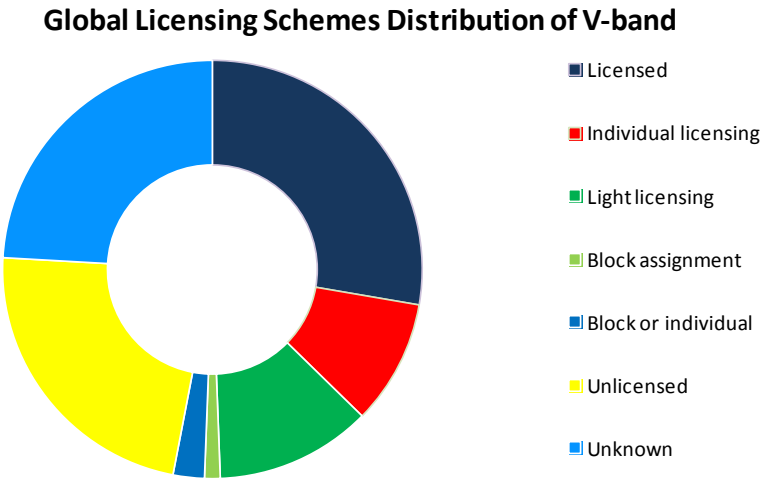

Figure 7: Global Licensing Schemes Distribution of V-Band

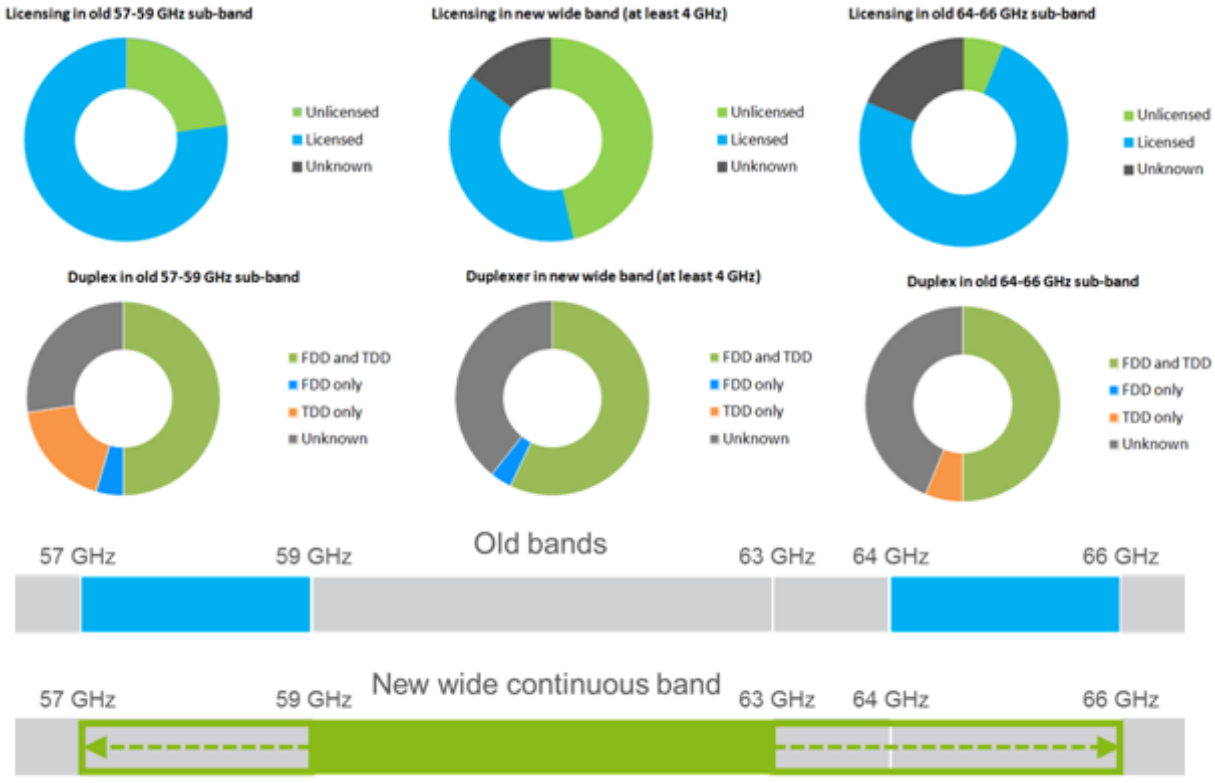

Figure 8: Global implementation of Licensing and Duplex in the old bands and the new wide band

E-Band case

The following clauses summarize the CEPT, ITU-R and USA regulations as the most representative for most of the market. However, other national regulations could be present and referred to in the database.

Regulation overview

FCC

During 2003, the Commission adopted a Report and Order (modified by Memorandum Opinion and Order on reconsideration [20]) establishing service rules to promote non-federal government development and use of the millimetre wave spectrum in the 71-76 GHz, 81-86 GHz and 92-95 GHz bands on a shared basis with federal government operations.

FCC had first produced regulations for E-Band use [19]. No specific channel arrangement is defined and any channel size is formally permitted (even if the N x 1250 MHz aggregation is commonly used). Both FDD and TDD are allowed. FDD applications shall use 10 GHz duplex separation. Minimum antenna gain of 43dBi is required, but in future can become 38dBi. Licensing is based on "Non-exclusive Nationwide with Link Registration" and coordination is mandatory.

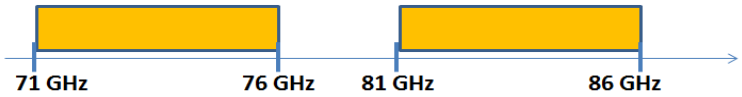

Figure 9: FCC Frequency Plane

A summary of the main FCC technical specifications for operation in the E-Band are depicted in the following table:

FCC - Technical Specifications for Operation in E-Band	
Maximum power limit	5 dBW
Maximum equivalent isotropically radiated power (EIRP)	55 dBW
Transmitter maximum power spectral density (PSD)	150 mW/100 MHz
Automatic transmit power control (ATPC)	Optional
Minimum antenna gain	43dBi (38dBi)[6]
Provision for reduced EIRP	Max EIRP reduced by 2 dB per 1 dB reduction in antenna gain respect 50dBi
Minimum spectral efficiency	0.125 bits/s/Hz

Table 1: FCC Technical Specifications

[6] See Petition for Rulemaking [36]; FWCC asks that the Commission authorize smaller antennas in the 71-76 and 81-86 GHz bands

CEPT/ECC

At the same time the ECC has also produced ECC/REC(05)07[3], which, in its first release, did not foresee any specific channel arrangement apart from a generic 250 MHz slot subdivision (max 19 slots per each band, with 125 MHz guard band on each side) and the possibility of aggregating any of them up to any size and, when FDD is concerned, duplex separation of 10 GHz (cross band duplex) or lower than 5 GHz (in band duplex).

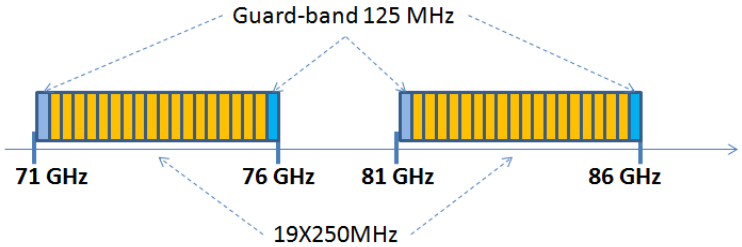

Figure 10: Frequency plan according to ECC/REC(05)07

Later on in 2009 the ECC recognized the high importance that this band was assuming for the expected high density deployment in 3G/4G mobile backhauling. Therefore, a revision of ECC/REC(05)07 was made introducing specific channel arrangements for channel sizes ranging from 250 to 4750 MHz. The arrangements remain flexible permitting TDD and FDD applications with 10 GHz as well as 2.5 GHz duplex separation. These arrangements will ease the more efficient link-by-link coordination, which was looked at by most CEPT administrations.

A summary of the main ETSI technical specifications for operation in E-Band is depicted in the following table:

ETSI - Technical Specifications for Operation in E-Band	
Maximum power limit	30 dBm
Maximum equivalent isotropically radiated power (EIRP)	85 dBm = 55dBW
Automatic transmit power control (ATPC)	Optional
Minimum antenna gain	Pout (dBm) + 15; or 38 (whichever is the greater).
Maximum antenna gain	85 - Pout (dBm)
Provision for reduced EIRP	See Figure 11 (*)
Minimum spectral efficiency	According to ETSI Radio Interface capacity [RIC]
Complete set of specifications	ETSI EN 302 217 part 2-2 and part 3

Table 2: ETSI - Technical Specifications

(*) More details can be found in ETSI EN 302 217 [9,10]

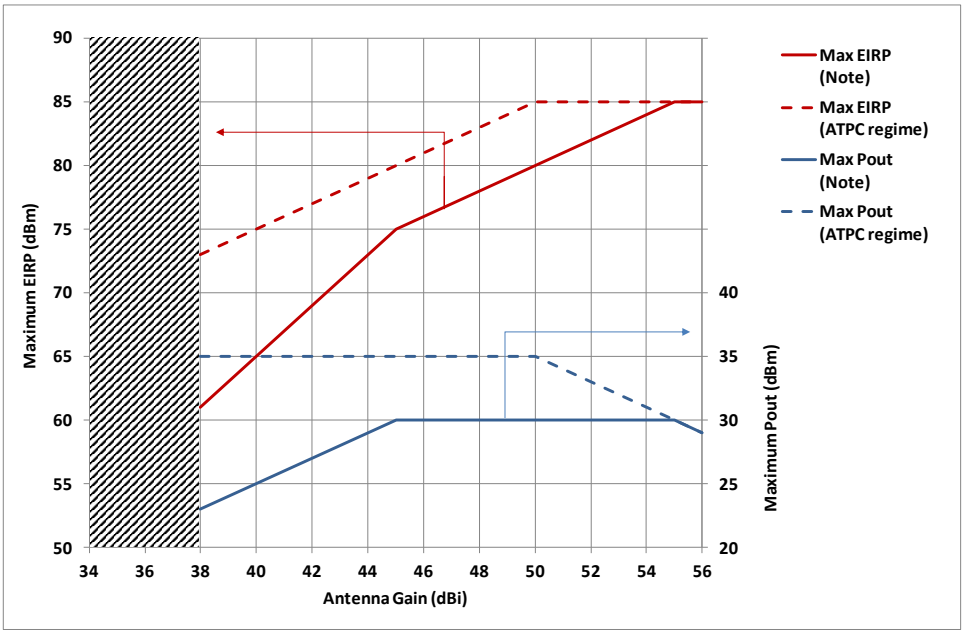

Figure 11: Emissions limitation (ETSI EN 302 217-3) for the 71-76 and 81-86 GHz band

According to our survey, in few European countries (#8), the 71-74 GHz and 81-84 GHz bands are considered as military bands for defence systems, and for this reason today not available for civil use. In others countries it has been recognized that these bands can be shared between civil and military users according to national requirements and legislation.

A lot of administrations, also outside Europe (e.g. Canada and Japan) are today adopting the frequency arrangement for E-Band as per the CEPT-recommended band plan, option 2, comprised of 250 MHz channels with 125 MHz guard-bands on either end of the bands and with the flexibility of channel aggregation within the 71-76 GHz and 81-86 GHz bands, to support higher capacities when necessary.

Disregarding some details, we can assume that emissions limits in both FCC and CEPT/ECC areas are quite similar.

It is worth mentioning that ECC has no mandate to harmonize options for licensing procedures and fees; they remain under the full responsibility of each national government.

ITU-R

In 2012 ITU-R published Recommendation F.2006 [11] that mostly reprints the options provided by ECC/REC(05)07 described above adding also the option of possible block assignment.

Here is a comparison table taken from [9].

Band (GHz)	Frequency range (GHz)	Channel separation (MHz)	Recommendations for radio frequency channel arrangements	
			ECC	ITU-R
70	71,0 to 76,0	250 to 2 250 (9 × 250)	05-07 [3]	F.2006 [11]
80	81,0 to 86,0			
70 paired with 80	71,0 to 76,0 paired with 81,0 to 86,0	250 to 4 500 (18 × 250)		
70 (upper part) paired with 80 (upper part)	74,0 to 76,0 paired with 84,0 to 86,0	250 to 1 750 (7 × 250)		
70 and 80	71,0 to 76,0 and 81,0 to 86,0	Free		
70 and 80	71,0 to 76,0 and 81,0 to 86,0	Block: 1x 5GHz 5x1GHz 4x 1,25GHz		

Table 3: E-Band- ECC and ITU comparison

The option to subdivide a 250MHz channel into 4x62,5MHz or 2x125MHz, not reported here, is foreseen in ECC/REC(05)07 only.

ETSI standards for equipment

ETSI's harmonized standards for equipment (those used for presumption of conformity and market access under 99/05/EC Directive) have followed a step-wise approach over time:

Harmonized EN 302 217-3 [10]: In 2009, EN 302 217-3 (v1.3.1) introduced minimal requirements typically suitable for uncoordinated or self-coordinated (i.e. light licence) applications. As for FCC rules, minimum antenna gain is required to ease interference control.

Harmonized EN 302 217-2-2 [9]: In 2011 ETSI, considering that some CEPT administrations were considering to adopt conventional coordination approach also in E-Band, started an overall revision also of the more popular Harmonized EN 302 217-2-2, which introduced also for the E-Band all the additional TX and RX harmonized parameters necessary for the case of fully coordinated deployment.

In conclusion, today ETSI's harmonized standards consider two kinds of equipment reflecting two different licensing systems:

- Category 1 equipment applicable when no or simplified coordination is used. Both FDD and TDD systems are covered in this annex.
- Category 2 equipment applicable only to FDD systems, when conventional link-by-link coordination based on the channel arrangements defined in ECC/Recommendation (05)07 or Recommendation ITU-R F.2006 is used.

It is worth noting that this subdivision is going to disappear, due to the forthcoming introduction of the new Radio Equipment Directive (RED) 2014/53/EU [37].

E-Band country by country overview

The following picture provides an overview of the E-Band situation worldwide as reported in the attached database [Appendix A]. The places where E-Band is today open for fixed services is indicated in green, in red the places where this band is closed today and in blue the places where the use of E-Band is open, but under review.

- Green - > Open
- Red - > Closed
- Blue - > Under Review
- Grey - > No Information

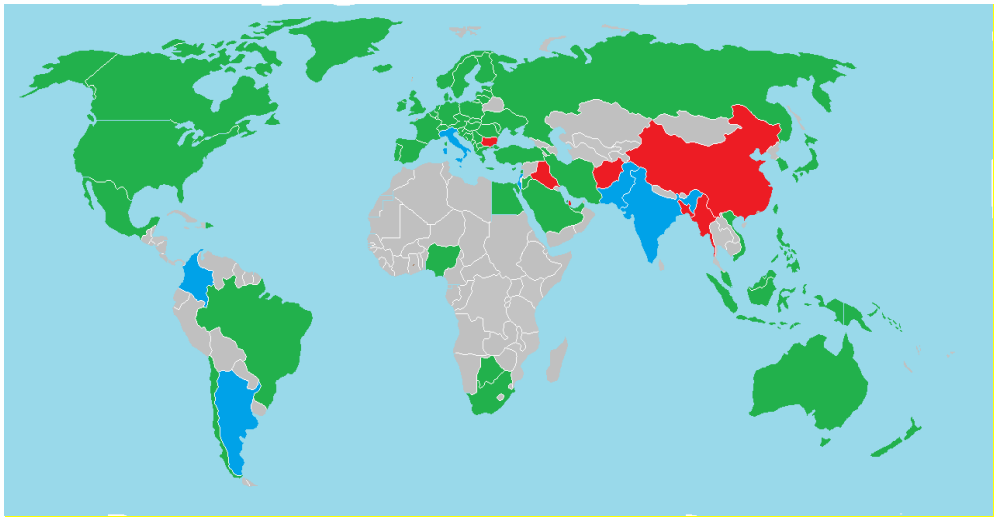

Figure 12: E-Band worldwide situation

Considering the 78 cases mapped in our survey, we have:

- 66 cases open
- 7 cases closed
- 6 cases under review

Considering 72 cases obtained aggregating the open cases (66) and the cases under discussion (6) we observed that 42 cases (58,3%) have adopted the whole band, 71-76 and 81-86 GHz, while only 8 cases (11,1%) have adopted a narrow frequency band.

Among these last 8 cases, 6 cases belong to ITU region 1 and have adopted the portion 74-76 & 84-86 GHz only, most likely because in ITU region 1 the rest of the band, 71-74 & 81-84 GHz, could be reserved for military use (NATO) and then a “Defence systems Harmonised military band” (see: ECA table [40]).

Practically, the spectrum available is never less than 2 GHz. We can likely assume that almost all the cases without a specific mention of frequency band limits are adopting the whole band.

Most of the cases are using a channel arrangement based on 250 MHz channels, with a few cases open to go below, allowing to use 62.5 and 125 MHz segmentation. Practically in all cases a certain level of

channel aggregation, nx250 MHz is allowed. In some places, n is limited to 2 and in some others limited to 8. In some cases the channel arrangement is not defined, leaving room to believe that 250MHz and nx250 MHz are allowed.

Regarding FDD and TDD, we can observe that FDD seems always permitted while TDD not allowed in at least 16 cases.

The situation, in terms of licensing methods, is very varied and not uniform at all. The most common regulation seems to be the conventional link-by-link coordination. It may be worth pointing out here that the situation should be closer to a light licensed regime since the results obtained have difficulties in discriminating between "light licensing" and "link by link" cases. Two special cases with a double regime are also reported.

In some other countries, like the US, UK, Australia and others, the E-Band is regulated with a "light-licensing" regime: self-coordinated, first-come-first-served basis with a register maintained by spectrum authority (i.e.: Appendix [E]). In this case, a low level fee is requested. In other countries, like Mexico and Columbia, the E-Band can be seen as a sort of licensing exception, so there is no coordination and usually fees are not requested.

This is the whole picture:

- 33 cases adopting link by link regime
- 1 case adopting Block assignment
- 8 cases with light licensing
- 5 cases where this band is unlicensed
- 3 cases with a sort of double regime, link by link and per Block
- 4 cases where the licensed aspect is not clearly defined and then cannot be mapped inside a specific case
- 17 cases where the licence status is unknown.

Just to provide a fair comparison among these cases, and in order to provide a first feeling regarding spectrum fees, we have collected the fees due for a specific case: a 250 MHz channel per one year and where this point impacts, for 1 Km.

For this case we have obtained the following picture:

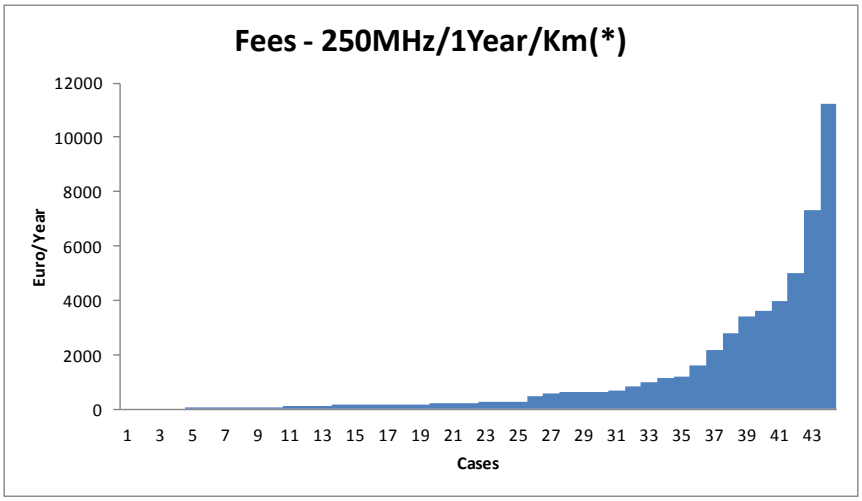

Figure 13: Fees due for 250 MHz channel/Year/Km

(*) The non-recurring fees, usually due for administrative procedure or other fixed costs are accounted for a 10 year period, usually the most popular period adopted in these cases, and then the fixed cost has been weighted divided by 10. The hop length (Km) is relevant only in very few (marginal) cases.

Analyzing the data related to the fees, taking into consideration 44 different cases, we observe that:

- 9% of the cases require no fee, likely to be in line with an unlicensed regime
- Up to 57% of the cases require less than €300 per year
- In average the fees due for this case (250MHZ/Year/Km) are €1 186, but it may be worth noticing that almost 85% of the cases require less than this average value.
- Almost 75% of the cases require less than €1 000.

Most administrations indicate maximum EIRP of 85 dBm, as expected.

Special case - OFCOM UK

From 2006 to 2009, when in Europe, in practice, only the UK had opened the band to fixed services, ETSI developed TS 102 524 “Fixed Radio Systems; Point-to-Point equipment; Radio equipment and antennas for use in Point-to-Point Millimetre wave applications in the Fixed Services (mmwFS) frequency bands 71 GHz to 76 GHz and 81 GHz to 86 GHz” as an aid to the market for equipment assessment.

After a public consultation, OFCOM [23] decided to change the former regime, moving from a light licence regime, based on a public database, to a double regime where the band is subdivided into two parts, a part regulated as fully coordinated (link-by-link) and the upper parts as self-coordinated (light licensing). The next figure shows how the frequency arrangement is now implemented.

Figure 14: UK E-Band frequency arrangement

Conclusions

The current status of V-Band and E-Band is captured using a set of heterogeneous sources, allowing us a good level of cross checking. Considering the standpoint of fixed service applications, mainly wireless mobile backhauling and small cell backhauling needs, we have identified some critical points which should be mitigated, according to us, for a fruitful exploitation of these two bands.

These points are:

- Huge fragmentation level of V-Band not only worldwide, but also inside homogeneous regions like the EU. Some reasons for that have been identified.
- Regulations not homogeneous both in terms of emissions limitations and licence/coordination methods, adopted country by country.
- Different approaches for the V-Band between FCC and ETSI. This fact may generate confusion for applications like WiGig in the EU area
- Mainly in the E-Band, we reported an enormous difference of fees for a link licence, mainly due to different models adopted for fee calculation, with fees sometimes too expensive and discouraging deployments.

It is foreseen to update and maintain this document.

If there is information, corrections and/or suggestions to improve the document, please provide them to the authors.

Appendix

A. Database

The database reporting the information country by country is available at http://www.etsi.org/images/files/ETSIWhitePapers/etsi_wp9_e_band_and_v_band_survey_database.zip.

The database is composed of two sheets, one for the V-Band and one for the E-Band.

The first eight columns are common for both bands:

- The ITU region (see Appendix C)
- The name of the Telecommunications Regulatory Authority
- The website
- The name of the country
- The frequency band/s
  - For the E-Band case a single band is foreseen
  - For the V-Band case a multi-band (fragmentation) option is foreseen
- The status of the band
  - Three possible cases : Open; Closed; Under Discussion
- The Channel spacing [MHz]
  - The channel spacing foreseen for each band or sub-band
- The “Max n” (for E-Band only)
  - Reports the maximum number of channels that can be aggregated to obtain a wider channel
- FDD - TDD
  - Three possible cases : FDD&TDD; FDD only; TDD only
- The Licence Regime
  - The cases foreseen are: Link by link; Block assignment; Light licensing; Unlicensed; Link by Link and Block; Licensed; Double regime.
- The Licence cost Estimation for 250MHz/Year [Euro] (E-Band only)
  - This column reports an estimation of the licence cost for the case of 250MHz channel for one year and for a hop length of 1 Km.
- Note
  - This column reports additional useful info, usually link to specific documents

Even if all efforts have been used to fill this database with validated information, it is likely that errors remain, in particular due to misinterpretation of the input data.

The sources of data have been varied, ranging from single contributors, websites of administrations and regulators and others sources, such as the Questionnaire - Revision of the ECC Report 173 related to frequencies higher than 50 GHz [15] and the ECO Frequency Information System [29].

B. Database- Snapshot

V-Band

#	Bands	# Cases	Open	Closed	Under Review/Study	FDD/TDD	FDD	TDD	Unlicensed	General Licensed	Unknown
1	57-59	19	18	0	1	10	1	3	5	14	0
2	64-66	17	14	1	2	8	0	0	1	11	5
3	57-66	11	6	4	1	1	0	0	2	2	7
4	59-63	10	8	1	1	6	0	0	4	2	4
5	57-64	9	7	0	2	6	0	0	4	3	2
6	58-63	3	2	1	0	2	0	0	1	1	1
7	59-64	3	3	0	0	0	1	0	1	2	0
8	61-64	3	2	0	1	1	0	0	0	2	1
9	57-58	2	2	0	0	0	0	2	0	2	0
10	57.25 - 58.05	1	1	0	0	1	0	0	0	1	0
11	57-58.2	1	1	0	0	0	0	0	0	1	0
12	57-62	1	1	0	0	1	0	0	1	0	0
13	58.25-63.25	1	1	0	0	0	0	0	0	1	0
14	64.5-65	1	1	0	0	0	0	1	0	1	0
15	64-64.5	1	1	0	0	0	0	0	0	1	0
	Sum	83	68	7	8	36	2	6	19	44	20

Table 4: V-Band Database summary

E-Band

E-Band - Status			
Open	**Closed**	**Under Review/Study**	**Total**
66	7	6	79

E-Band - Duplexer Method				
FDD/TDD	**FDD**	**TDD**		**Total**
38	16	0	25	79

E-Band - Regime								
Link by link	**Block assignment**	**Light licensing**	**Unlicensed**	**Link by link and Block**	**Licensed**	**Double regime**		**Total**
33	1	8	5	2	4	1	17	71

E-Band - Band -					
71-76;81-86	**74-76;84-86**	**71-74;81-84**	**71-75.5;81-86**		**Total**
42	6	1	1	27	77

License Cost Estimation for 250MHz/Year [Euro]		
No fees	4	
Average	1185,9	
Median	237,5	
# case below average and %	34	85%
# case below Median and %	22	55%
# case with Fee at no zero	40	
# case	44	

Table 5: E-Band Database summary

C. ITU Regions

According to the ITU, the world has been divided into three Regions for the allocation of frequencies as shown on the following map.

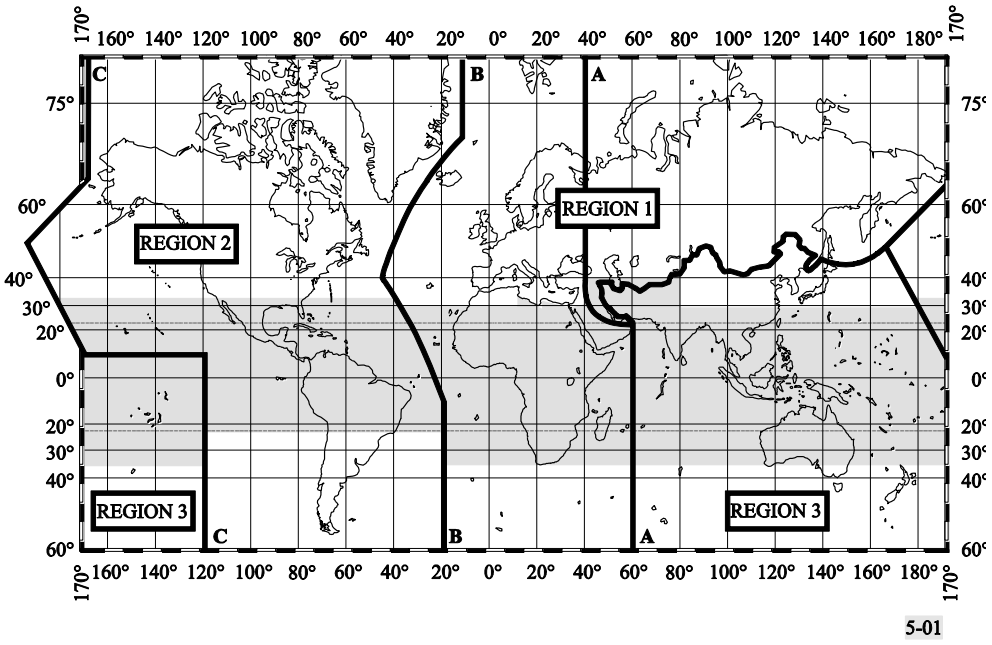

Figure 15: ITU region

D. Table of Frequency Allocation for V-Band and E-Band

These tables are from ITU Radio Regulations [13]

Allocation to services		
Region 1	**Region 2**	**Region 3**
57-58.2	EARTH EXPLORATION-SATELLITE (passive) FIXED INTER-SATELLITE 5.556A MOBILE 5.558 SPACE RESEARCH (passive) 5.547 5.557	
58.2-59	EARTH EXPLORATION-SATELLITE (passive) FIXED MOBILE SPACE RESEARCH (passive) 5.547 5.556	
59-59.3	EARTH EXPLORATION-SATELLITE (passive) FIXED INTER-SATELLITE 5.556A MOBILE 5.558 RADIOLOCATION 5.559 SPACE RESEARCH (passive)	
59.3-64	FIXED INTER-SATELLITE MOBILE 5.558 RADIOLOCATION 5.559 5.138	
64-65	FIXED INTER-SATELLITE MOBILE except aeronautical mobile 5.547 5.556	
65-66	EARTH EXPLORATION-SATELLITE FIXED INTER-SATELLITE MOBILE except aeronautical mobile SPACE RESEARCH 5.547	

Table 6: Portion: 57-66 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
71-74	FIXED FIXED-SATELLITE (space-to-Earth) MOBILE MOBILE-SATELLITE (space-to-Earth)	
74-76	FIXED FIXED-SATELLITE (space-to-Earth) MOBILE BROADCASTING BROADCASTING-SATELLITE Space research (space-to-Earth) 5.561	
81-84	FIXED 5.338A FIXED-SATELLITE (Earth-to-space) MOBILE MOBILE-SATELLITE (Earth-to-space) RADIO ASTRONOMY Space research (space-to-Earth) 5.149 5.561A	
84-86	FIXED 5.338A FIXED-SATELLITE (Earth-to-space) 5.561B MOBILE RADIO ASTRONOMY 5.149	

Table 7: Portion: 71-76 & 81-86 GHz

E. US - FCC Regulation For E-Band

Extract of US Title 47, Part 101, subpart Q of the Code of Federal Regulations, available here:

http://www.ecfr.gov/cgi-bin/text-idx?node=sp47.5.101.q&rgn=div6#se47.5.101_11523

101.1523 Sharing and coordination among non-government licensees and between non-government and government services.

(a) Registration of each link in the 71-76 GHz, 81-86 GHz, and 92-95 GHz bands will be in the Universal Licensing System until the Wireless Telecommunications Bureau announces by public notice the implementation of a third-party database.

(b) The licensee or applicant shall:

(1) Complete coordination with Federal Government links according to the coordination standards and procedures adopted in Report and Order, FCC 03-248, and as further detailed in subsequent implementation public notices issued consistent with that order;

(2) Provide an electronic copy of an interference analysis to the third-party database manager which demonstrates that the potential for harmful interference to or from all previously registered non-government links has been analysed according to the standards of section 101.105 and generally accepted good engineering practice, and that the proposed non-government link will neither cause harmful interference to, nor receive harmful interference from, any previously registered non-government link; and

(3) Provide upon request any information related to the interference analysis and the corresponding link. The third-party database managers shall receive and retain the interference analyses electronically and make them available to the public. Protection of individual links against harmful interference from other links shall be granted to first-in-time registered links. Successful completion of coordination via the NTIA automated mechanism shall constitute successful non-Federal Government to Federal Government coordination for that individual link.

(c) In addition, the following types of non-Federal Government links require the filing with the Commission an FCC Form 601 for each link for the purpose of coordination and registration, in addition to registering each link in the third-party database:

(1) Facilities requiring the submission of an Environmental Assessment,

(2) Facilities requiring international coordination, and

(3) Operation in quiet zones.

(d) The Commission believes the licensee is in the best position to determine the nature of its operations and whether those operations impact these settings, and is required to submit to a database manager, as part of the registration package, documentation that an FCC Form 601 has been filed.

F. CEPT: Technical Background For Self-Coordination

Extract from Annex 3 of ECC Recommendation (09)01, available here:

http://www.erodocdb.dk/Docs/doc98/official/pdf/Rec0901.pdf

To assist the planning of PP fixed links, self-coordination approach, similar to the “light licensing”, described in ECC Report 80 [25], can be considered. Such regimes do not mean “license exempt” use, but rather using a simplified set of conventional licensing mechanisms and attributes within the scope decided by administration. This planning is delegated to the licensee.

Administrations intervene for protecting a limited number of sensitive sites while giving greater flexibility elsewhere than it could be allowed without the geographical limitation.

This process requires to record for instance the following set of simple criteria for each authorized link and makes the data available publicly to assist in the identification of operational parameters and to conduct interference analyses:

- Date of application (in order to assign priority);
- Transmit, receive centre frequencies and occupied bandwidth;
- Equipment type, specifying relevant transmitter/receiver parameters;
- Link location (geographic coordinates, height/direction of antenna, etc.);
- The antenna gain and radiation pattern.

Subject to the conditions set by the administration, it is left to the operator to conduct any compatibility studies or coordinate as necessary to ensure that harmful interference is not caused to existing links registered in the database. For example, an operator wishing to install a new link could calculate the interference that the new link will create to the existing links in the database. Then it will be possible to determine whether this new link will interfere with existing links. If so, the new link could be re-planned to meet the interference requirements of existing links in the database. Otherwise, the new link may be also co-ordinated with existing operators, who might suffer from the interference.

To assist with the resolution of disputes, licenses are issued with a “date of priority”: interference complaints between licensees may therefore be resolved on the basis of these dates of priority (as with international assignments).

G. Examples of E-Band Fees

Some cases, in anonymous form, are reported here to show how administrations determine the fee in case of E-Band exploitation. In most cases, the methods are not so different to those applied in lower and traditional frequency bands.

Case#1

The administration website proposed an online calculator. After frequency band selection we obtain the fees due according to three parts:

- Application Processing /one-time payment, for each link/radio route
- Licence / annually, for every link/radio route
- Use of RF Spectrum /annually, for each 1 MHz assigned

In this model, we have:

- One-time fees
- Annual fees composed of two parts, one fixed and a second one depending on channel bandwidth.

Case#2

Also in this case, the fee is subdivided into parts:

- Nationwide authorization non-recurring contribution for using the band and for maintaining the national database of the links.
- Registration fee per link, lasting 10 years before renewal. To this the user should add the cost of the detailed link planning for building up the interference analysis documentation to be submitted with the registration.

In this model, the total fees are totally independent of frequency, bandwidth, area.

Case#3

Also in this case we have two different parts:

- Non-recurring cost per link, for covering the planning cost. This cost is for 250MHz channel. 500 MHz channel will pay x2.
- Annual fee / link for the management of the database and surveillance independent of channel bandwidth.

This is similar to Case #1, but there is the non-recurring cost that depends on bandwidth.

Case #4

The frequency fee is calculated with the following formula:

Fee = C1 * C2 * B0 * P

Frequency band	C_1
0 – 28 MHz	0.2
28.001 – 87.5 MHz	0.9
87.501 – 108 MHz	1.5
108.001 – 146 MHz	1.7
146.001 – 174 MHz	1.9
174.001 – 380 MHz	2.0
380.001 – 470 MHz	2.0
470.001 – 862 MHz	2.0
862.001 – 960 MHz	1.4
960.001 – 2200 MHz	1.0
2200.001 – 3100 MHz	0.6
3100.001 – 5000 MHz	0.4
5000.001 – 10700 MHz	0.3
10700.001 – 19700 MHz	0.25
19700.001 – 39500 MHz	0.2
39500.001 - 55000 MHz	0.1
Above 55000 MHz	0.03

where:

- C1 = frequency band coefficient
- C2 = population coefficient
- B0 = relative band width
- P = basic fee

The relative bandwidth is calculated according to the formula:

B0 = B / 14 MHz

C2, Population coefficient, tries to take account if a specific area is congested or not. The higher the frequency band, the lower the fees are. In this case E-Band is charged ten times less compared to 10 GHz. This is a common approach among a lot of administrations.

Case #5

The administration provides a spreadsheet calculator: it is required to fill in the following data:

- Bandwidth
- Frequency
- High Demand Spectrum
- High Density Geographic Area
- Hop Length

The formula is:

Annual Fee= Unit*BW*Freq*CG*Geo*Hop_length

- In this case, to determine the Annual Fee, the administration tries to take into account a lot of different parameters, not only the frequency bands and the channel bandwidth as they usually do, but also the region (High Density Geographic Area) and if the frequency band has or not a high demand. The last item that should be pointed out is the fact that the Hop Length is considered, and the fees are directly proportional to it.

Our database (Appendix [A]) provides a lot of links to administration websites where this information is available.

References

1. CEPT/ECC/Recommendation (09)01 (02-2009): "Use of the 57 - 64 GHz frequency band for point-to-point Fixed Wireless Systems".
2. CEPT/ECC/Recommendation (05)02 (02-2009): "Use of the 64 - 66 GHz frequency band for Fixed Service".
3. CEPT/ECC/Recommendation (05)07 (05-2013): "Radio frequency channel arrangements for Fixed Service Systems operating in the bands 71 - 76 GHz and 81 - 86 GHz".
4. CEPT/ERC/Recommendation 12-09 (2004), withdrawn (2009): "Radio frequency channel arrangement for Fixed Service systems operating in the band 57,0 - 59,0 GHz which do not require frequency planning".
5. ECC Recommendation (01)04: “Recommended guidelines for the accommodation and assignment of multimedia wireless systems (MWS) and point-to-point (P-P) fixed wireless systems in the frequency band 40.5 - 43.5 GHz”
6. EC Decision 2013/752/EU: “Commission Implementing Decision of 11 December 2013 amending Decision 2006/771/EC on harmonisation of the radio spectrum for use by short-range devices and repealing Decision 2005/928/EC”
7. ECC/DEC(09)01: “ECC Decision on the harmonised use of the 63-64 GHz frequency band for Intelligent Transport Systems (ITS)”
8. ECC Report 124 - Coexistence of passive and fixed service in the bands 71-76/81-86 GHz;
9. ETSI EN 302 217-2-2: "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 2-2: Digital systems operating in frequency bands where frequency co-ordination is applied; Harmonized EN covering the essential requirements of Article 3.2 of the R&TTE Directive".
10. ETSI EN 302 217-3: "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 3: Equipment operating in frequency bands where both frequency coordinated or uncoordinated deployment might be applied; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".
11. Recommendation ITU-R F.2006: Radio-frequency channel arrangements for fixed wireless systems operating in the 71-76 and 81-86 GHz bands.
12. Recommendation ITU-R F.1497-2 (02/2014):: "Radio-frequency channel arrangements for fixed wireless systems operating in the band 55.78-66 GHz".
13. ITU Radio Regulations (2012)
14. ECC Report 114 - Compatibility Studies Between Multiple Gigabit Wireless Systems In Frequency Range 57-66 GHz And Other Services And Systems (Except Its In 63-64 Ghz)
15. ECC Report 173 - Fixed Service in Europe - Current use and future trends post 2011
16. ECC Report 113 - Compatibility Studies Around 63 GHz Between Intelligent Transport Systems (Its) And Other Systems
17. ERC/REC 70-03 “Relating to the use of Short Range Devices (SRD) - http://www.erodocdb.dk/Docs/doc98/official/pdf/Rec7003e.PDF
18. FCC - Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.255 - http://www.gpo.gov/fdsys/pkg/CFR-2013-title47-vol1/pdf/CFR-2013-title47-vol1-sec15-255.pdf

19. FCC - Title 47 → Chapter I → Subchapter D → Part 101 → Subpart Q http://www.gpo.gov/fdsys/pkg/CFR-2013-title47-vol5/pdf/CFR-2013-title47-vol5-part101-subpartQ.pdf
20. FCC -Memorandum Opinion and Order on reconsideration https://apps.fcc.gov/edocs_public/attachmatch/FCC-05-45A1.pdf
21. TR 102 555: "Technical characteristics of multiple gigabit wireless systems in the 60 GHz range System Reference Document"
22. TR 102 400: Intelligent Transport Systems (ITS); Road Traffic and Transport Telematics (RTTT); Technical characteristics for communications equipment in the frequency band from 63 GHz to 64 GHz; System Reference Document"
23. OFCOM UK: Review of the Spectrum Management Approach in the 71-76 GHz and 81-86 GHz bands. http://stakeholders.ofcom.org.uk/consultations/70-80ghz-review/
24. ECC Report 132 on "Light Licensing, Licence-Exempt and Commons"
25. ECC Report 80 on "Enhancing Harmonisation and Introducing Flexibility in the Spectrum Regulatory Framework"
26. E3NETWORK - Energy Efficient E-Band transceiver for backhaul of the future networks. http://www.ict-e3network.eu/
27. MiWaves - Beyond 2020 Heterogeneous Wireless Networks with Millimeter-Wave Small Cell Access and Backhauling. http://www.miwaves.eu/
28. IPHOBAC-NG - Integrated Photonic Broadband Radio Access Units for Next Generation Optical Access Networks. https://www.ist-iphobac.org/ng/
29. Results of Questionnaire - Revision of the ECC Report 173 on spectrum requirements and technology trends for the fixed services in Europe post-2011, related to frequencies higher than 50 GHz. See ECC Project Team SE19 contribution SE19 (15)04
30. ECO Frequency Information System (EFIS) - http://www.efis.dk/
31. CEPT Recommendation T/R 22-03 (1990) – "Provisional recommended use of the frequency range 54.25-66 GHz by terrestrial fixed and mobile systems"
32. Recommendation ITU-R F.1100 (09/1994), suppressed 05/05/00 – "Radio-frequency channel arrangements for radio-relay systems operating in the 55 GHz band"
33. Resolution 726 WRC-1997 – "Frequency bands above 30 GHz available for high-density applications in the fixed service" (footnote S5.547 in ITU Radio Regulations)
34. Recommendation ITU-R F.1497-0 (05/2000) – "Radio-frequency channel arrangements for systems in the fixed service operating in the band 55.78-59 GHz"
35. ECC Report 003 – "Fixed service in Europe current use and future trends post-2002"
36. FCC - Petition for Rulemaking - http://www.fwcc.us/pdffiles/10-153%202012.10.05%20NOI%20Cmnts%20AS%20FILED.pdf
37. New Radio Equipment Directive - European Commission - http://ec.europa.eu/enterprise/sectors/rtte/radio-equipment-directive/index_en.htm
38. http://standards.ieee.org/findstds/standard/802.11ad-2012.html
39. FCC - Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.3 - http://www.gpo.gov/fdsys/pkg/CFR-2013-title47-vol1/pdf/CFR-2013-title47-vol1-sec15-3.pdf

40. The European Table of Frequency Allocations and Applications in The Frequency Range 8.3 KHz to 3000 GHz (ECA Table). http://www.erodocdb.dk/Docs/doc98/official/pdf/ercrep025.pdf

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