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# E-BAND - SURVEY ON STATUS OF WORLDWIDE REGULATION

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**ISG millimetre Wave Transmission** :
https://portal.etsi.org/Portals/0/TBpages/mWT/Docs/Introduction%20of%20mWT%20ISG%20v2.pdf

# Contents

# Executive Summary

Microwave[1] is undergoing a rapid and significant transformation. Current and future mobile access networks impact the backhaul network in several ways. The main drivers are primarily huge increases in mobile capacity and enhanced coverage, as well as new topologies and architectures where backhaul platforms need to cope with ultra small hot-spot deployments. This emphasises the need to exploit the available spectrum as much as possible and in the most appropriate way.

In particular, the first two drivers, in urban and suburban environments, leads to a new and revolutionary approach for microwave backhauling. The backhauling needs to satisfy apparently conflicting requirements like increase of capacity and spectrum efficiency, very low power consumption and very low environmental impact, in a word, to reduce TCO to a minimum to make the business case of the operators become positive. Capacity is increasing while distances decrease, and base stations get nearer and nearer to subscribers. Current traditional frequencies below 50 GHz are already very crowded and exploited, hence there is a need to use higher frequency bands to future-proof networks.

Regulators have made available E-Band[2] since 2000. E-Band enables a large range of data rates up to a gigabit-per-second given the huge amount of available spectrum (10 GHz). Due to technology evolution and availability of wide channel bandwidths, the use of E-Band is of interest for the current and future needs of backhaul networks.

In recent years, E-Band had gained recognition as one of the more popular combination of Band and Carrier Aggregation (BCA). BCA is a relatively new concept enabling efficient use of the spectrum through smart aggregation, over a single physical link, of multiple frequency channels (in the same or different frequency bands) and it has recently become popular in the mobile backhaul arena to better serve the demands on the new backhaul network.

[1] Microwave in this contest refers to the wireless technology mainly used for mobile backhauling application using frequency bands ranging from 4 to 86 GHz.
[2] E-Band: Frequency bands 71-76 GHz and 81-86 GHz

# Introduction and Scope

The main scope of this document is to provide an updated overview on the regulation and spectrum allocation of E-Band.

In this context, the term regulation includes:

- The international regulations from standardization bodies, such as ITU or ETSI and from Regional Organisations, such as the 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 in the European Union and outside.

Given the market needs to effectively exploit E-Band, an exhaustive investigation has been carried out among Administrations and Regulatory Bodies to gather allocation status, licensing regimes and other relevant data.

The outcome of the analysis is described in two sources:

- The present White Paper (considering only the first edition of the database)
- The database, whose structure is discussed in Annex 0, in which the updated information country by country is collected

Part of this document is reprinted from ETSI White Paper no. 9 [1].

# 1 Overview on Regulation status

The standpoint of this document is mainly for the fixed service case.

## 1.1 General background

Since there is no unique view in literature, sometimes there is confusion and controversy about the microwave frequency band letters definitions; that letter is widely variable depending on the standardization body that introduced it in the past.

For the purpose of this document E-Band is intended to portion 71-76 GHz and 81-86 GHz.

## 1.2 Terminology and definitions

Many of the concepts related to the spectrum use do not have unique definition endorsed in ITU vocabulary; general concepts are likely understood by experts, but slight differences in terminology and their interpretation are present among Regional Organisations (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 [Appendix, section B]. ITU table allocation for V-Band and E-Band are reported in Appendix, section 0.

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 to which particular frequencies will be used. These decisions are reflected in the International and National Tables of Frequency Allocations.

Some keywords are given:

**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 the 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

## Authorisation regime

The administration decides, band by band and by "*radio application*" which type of "license" is required for operating a radio; Figure 1 (reprinted from WI SE19_41: Guidelines on how to plan Bands and Channels (Carriers) Aggregation (BCA) Fixed Service Links [**Error! Reference source not found.**]) summarises 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<br><br>Traditional procedure for issuing licences | Individual frequency planning / coordination<br><br>Simplified procedure compared to traditional procedure for issuing licences<br><br>With limitations in the number of users | No individual frequency planning / coordination<br><br>Registration and/or notification<br><br>No limitations in the number of users nor need for coordination | No individual frequency planning / coordination<br><br>No registration nor notification |

**Figure 1: Generic subdivision of authorisation and license regimes**

**Individual licensing (also referred to as "traditional licensing")** - This is the conventional link-by-link coordination, usually made under administration's responsibility; sometime, 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 P-P links 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 [3] as: "A light licensing regime" is a combination of license-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 the individual licensing; only 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.

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 license exempt case, offers the only advantage of having the data base available for helping solution of claimed interference cases.

**License exempt -** This method offers the most flexible and cheap usage but does not guarantee any interference protection. It is most popular in specific bands (e.g. 2.4 and 5 GHz) where SRD are allocated, but FS applications may also be accommodated; in addition, it is often used in bands between 57 GHz and 64 GHz (V-Band) but traditionally has been less attractive there due to the unfavourable propagation attenuation. To be noted that recently the V-Band has been extended up to 71 GHz allowing fixed outdoor application.

This method, in some scenarios, can be viewed 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.

### 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 FWA (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 communications methods used in the block (e.g. PP 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-blocks protections guidelines in terms of guard bands or block-edge masks (BEM), see i.e.: ITU-R Recommendation F.2006 [4]. 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 a lot these two components are given as follows:

- Application fee – this is a one-time charge due for the approval of frequencies 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 which can affect the fee calculation are for instance the number of transmitters and geometric considerations (area). It is frequently the use of incentives to promote use of higher frequencies.

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

In the Appendix, section F a number of real methods used by administrations to determine fees are reported.

# 2 E-Band

The following clauses summarise the CEPT, OFCOM UK, 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 data base.

## 2.1 Regulation overview

**FCC**

During 2003, the Commission adopted a Report and Order (modified by Memorandum Opinion and Order on reconsideration (see FCC - Petition for Rulemaking [5])) establishing service rules to promote non-Federal Government development and use of the "millimeter wave" spectrum in the 71-76 GHz, 81-86 GHz and 92-95 GHz bands on a shared basis with Federal Government operations.

The FCC had first produced regulation for E-Band use (ECC Report 003 [6]). 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 application uses 10 GHz duplex separation. Minimum antenna gain of 43 dBi is required, but in future it can become 38dBi. Licensing is based on "Non-exclusive Nationwide with Link Registration" and coordination is mandatory.

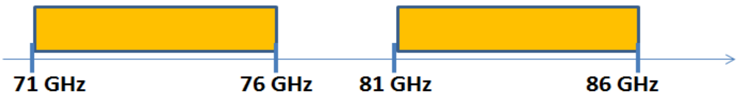


**Figure 2: FCC Frequency Plane**

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

**Table 1: FCC Technical Specifications**

| 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)[2] |
| **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 |

## CEPT/ECC

At the same time ECC has also produced ECC Report 124 [7], which, in its first release, did not foresee any specific channel arrangement apart from a generic 250 MHz slots 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).

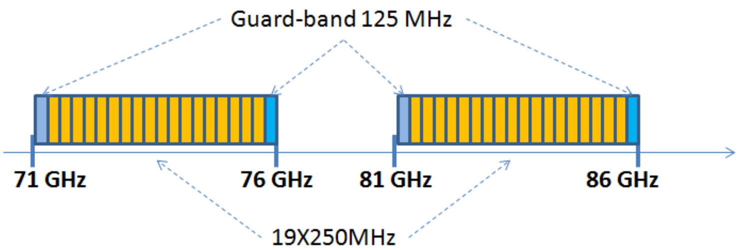


**Figure 3: Frequency plan according ECC**

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

See “5G Wireless Backhaul Proponents’ Letter”. https://ecfsapi.fcc.gov/file/10618081501789/Nokia%20June%2014%202019%20Ex%20Parte%20-%207080%20GHz%20FINAL.pdf

Later on (2009) the ECC recognized the high importance that this band was assuming for the expected high density deployment also in the 3G/4G mobile backhauling; therefore, a revision of ECC/REC(05)07 [8] was made introducing specific channel arrangements for channels size 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.

Summary of the main ETSI Technical Specifications for operation in the E-Bands are depicted in the following table:

**Table 2: ETSI - Technical Specifications**

| 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 4** (*) |
| **Minimum spectral efficiency** | According to ETSI Radio Interface capacity [RIC] |
| **Complete set of specifications** | ETSI EN 302 217 part 2 [9] |

(*) More details can be found in ETSI EN 302 217-2 [9]

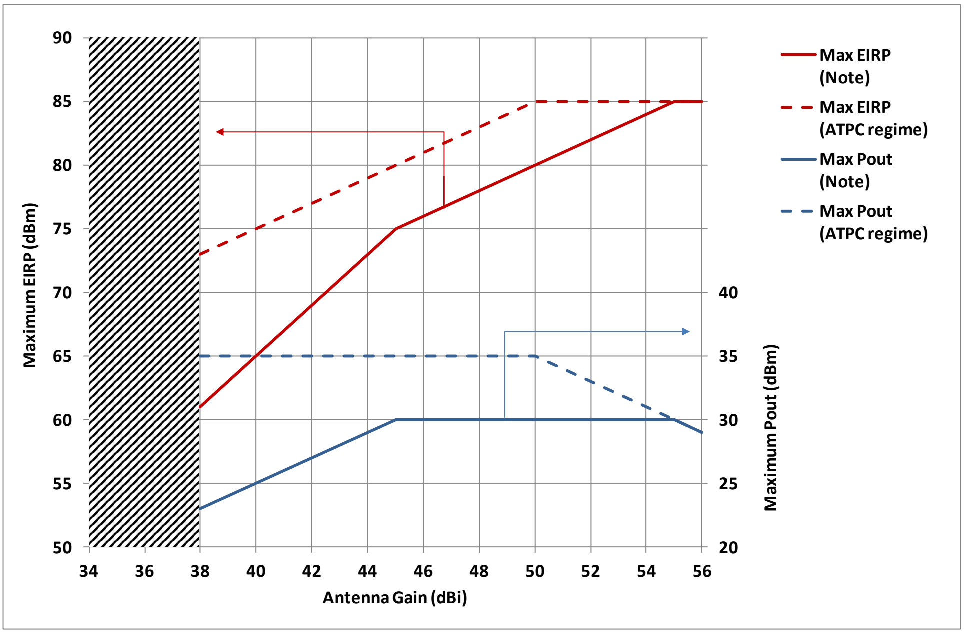



**Figure 4: Emissions limitation (ETSI EN 302 217-2-2 [9]) for the 71-76 and 81-86 GHz band**

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

A lot of administrations, also outside Europe (i.e.: see Canada and Japan), are today adopting for E-Band the frequency arrangement 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 the aggregation of channels within the bands 71-76 GHz and 81-86 GHz, to support higher capacities when necessary. Disregarding some details, we can assume that emission limits in both FCC and CEPT/ECC areas are quite similar.

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

### Special case - OFCOM UK:

From 2006 to 2009, only the UK in practice, had opened the band up to FS, ETSI developed TS 102 524 [10] (withdrawn 2009]): "Fixed Radio Systems; Point-to-Point equipment; Radio equipment and antennas for use in Point-to-Point Millimeter 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 changed the former light license regime based on a public database, to a split coordinated and self-coordinated block.

The 71-86 GHz band is subdivided into two licensing regimes separated by at 250 MHz guard band. The lower part (71.125-73.125 GHz / 81.125-83.125 GHz) is regulated as fully coordinated (link-by-link) and the upper part (73.375-75.875 GHz / 83.375-85.875 GHz) as self-coordinated (light licensing). In

September 2019 OFCOM increased the number of channels available for assignment in the coordinated portion of the band. This makes the full 2 x 2 GHz of spectrum available for assignment.

| | Coordinated | Self Coordinated |
|---|---|---|
| **Bandwidth [Error! Reference source not found.]** | • 2 x 2 GHz<br> | •2 x 2.5 GHz |
| **Channelization** | Up to 1000MHz channelization aligned to ECC/REC(05)07 [8]<br>Maximum modulation rates are mandated for higher bandwidths (64QAM @ 750MHz, 16QAM @ 1000MHz) limiting maximum throughput but providing longer theoretical link lengths.<br>Shorter link has a minimum Fade margin of 20dB (see OfW 446 [11]) | Unspecified |
| **Licensing Fees** | Bandwidth dependent, £100-900 (~110-990€) per link per year. | £50 (~55€) per link per year. |
| **Interference Management** | Centrally coordinated and interference managed access as with other lower frequency fixed link bands. | Coordination between links is the responsibility of the license holder. |
| **Perceived Benefits** | Confidence in requirements for high availability (99.99% - 99.999%) applications.<br>Favoured with mobile network operators and infrastructure providers. | Low TCO and ability for rapid deployment of high capacity fixed link services.<br>Favoured with enterprise and small business models. |
| **Perceived Challenges** | Exploitation of wider channels may be difficult where shared tower and parallel path infrastructure is used. | Potential for inaccurate or outdated link information summited by the licensee. |

**Figure 5: OFCOM E-Band Regulation Summary**

### ITU-R

In 2012 ITU-R published Recommendation F.2006 [4] that mostly reprinted the options provided by ECC/REC(05)07 [8] described above also adding the option of possible block assignment.

The following is a comparison table taken from the FCC -Memorandum Opinion and Order on reconsideration of ITU Recommendation F.2006 [4].

Table 3: E-Band- ECC and ITU comparison

<table>
<tr><th rowspan="2">Band<br>(GHz)</th><th rowspan="2">Frequency range<br>(GHz)</th><th rowspan="2">Channel separation (MHz)</th><th colspan="2">Recommendations for radio frequency channel arrangements</th></tr>
<tr><th>ECC</th><th>ITU-R</th></tr>
<tr><td>70</td><td>71,0 to 76,0</td><td rowspan="2">250 to 2 250 (9 × 250)</td><td rowspan="7">05-07 [8]</td><td rowspan="7">F.2006 [4]</td></tr>
<tr><td>80</td><td>81,0 to 86,0</td></tr>
<tr><td>70<br>paired with<br>80</td><td>71,0 to 76,0<br>paired with<br>81,0 to 86,0</td><td>250 to 4 500 (18 × 250)</td></tr>
<tr><td>70 (upper part)<br>paired with<br>80 (upper part)</td><td>74,0 to 76,0<br>paired with<br>84,0 to 86,0</td><td>250 to 1 750 (7 × 250)</td></tr>
<tr><td>70 and 80</td><td>71,0 to 76,0<br>and<br>81,0 to 86,0</td><td>Free</td></tr>
<tr><td>70 and 80</td><td>71,0 to 76,0<br>and<br>81,0 to 86,0</td><td>Block:<br>1x 5GHz<br>5x1GHz<br>4x 1,25GHz</td></tr>
</table>

The option to subdivide a 250 MHz channel into 4x62,5 MHz or 2x125 MHz, not reported here, is foreseen in ECC 05-07 [8] only.

### ETSI standards for equipment

Also, in this case, equipment harmonized standards (i.e. those valid for CE marking and assessment under 99/05/EC Directive [12]) followed a timely step approach.

**Harmonised EN 302 217-2 [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 Harmonised EN 302 217-2 [9], which introduced also for the E-Band all the additional TX and RX harmonized parameters necessary for the case of fully coordinated deployment.

# 3 E-Band country by country overview

The following picture provides an overview on the E-Band situation worldwide as reported into the Database version 1 [see Appendix].

In green those places where E-Band is today open for Fixed services is reported, in red the places where this band is today closed is reported and the colour orange shows the places where the use of E-Band is open, but under review.

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

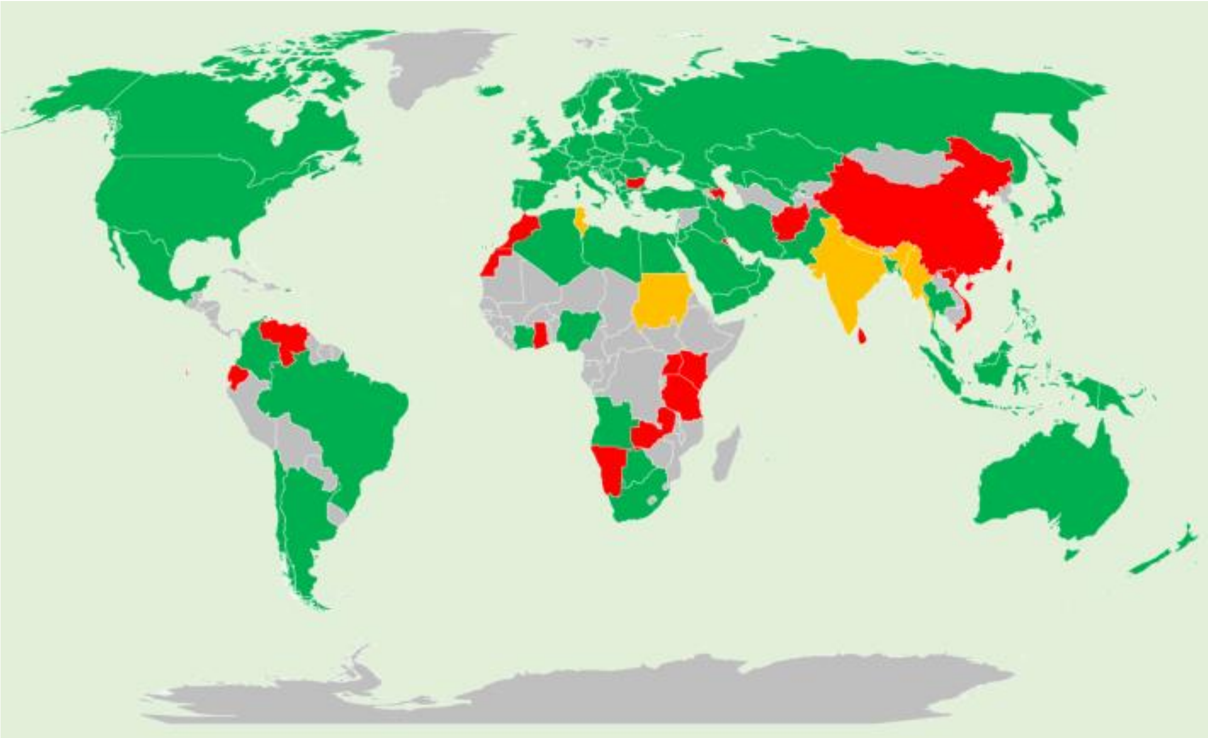


**Figure 6: E-Band worldwide situation**

Considering the 109 cases mapped in our survey, we have:

- 86 cases open (79%)
- 17 cases closed (16%)
- 6 case under review (5%)

Considering  the 92 cases obtained, aggregating the Open cases (86) and the cases under discussion (6) we observed 44 cases (47,8%) have explicitly adopted the whole band, 71-76 and 81-86 GHz, while only 12 cases (13%) have adopted a narrow frequency band.

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 bands limits are adopting the whole band.

Most of the cases are using a channel arrangement based on the 250 MHz channel, with few cases open to go below, allowing the use of 62.5 and 125 MHz segmentation. Practically in all cases a certain level of channel aggregation, nx 250 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 250 MHz and nx250 are allowed.

Regarding FDD and TDD, we can observe that FDD seems to be always permitted while TDD not allowed in at least 25 cases.

The situation, in terms of licensing methods, is by far very varied and not uniform at all. The most common regulation seems 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 are suffering from difficulties in discriminating the difference between “light licensing” and “link by link” cases. Two special cases with a double regime are also reported.

In some other countries, like US, UK, Australia and others, E-Band is regulated with a “light-licensing” regime: a self-coordinated, first-come-first-served basis regulated with a register maintained by a spectrum authority (i.e.: Appendix, section 0). In this case, a low-level fee is requested. In other countries, like Mexico and Columbia, 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:

- 35 cases adopting Link by Link regime
- 5 cases adopting Block assignment
- 8 cases with Light licensing
- 4 cases where this band is unlicensed
- 2 cases with a sort of double regime, link by link and per Block

Just to provide a “fair comparison” among the world-wide 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:

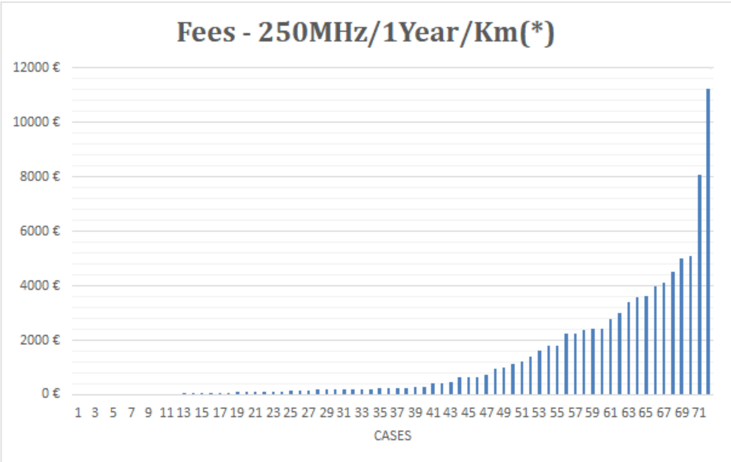



**Figure 7: Fees due for 250 MHz channel/Year/Km**

(*) The non-recurring fees, usually due for administrative procedure or other fixed costs are accounted as for a 10-year period, usually the most popular period adopted in these cases, and then 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 fee, taking into consideration 72 different cases, we observe that:

- 17% of the cases requires no fee, likely in line with an unlicensed regime
- Up to 56% cases requires less than 300€ per year
- On average the fees due for this case (250 MHZ/Year/Km) are 1 240€, but it may be worth noticing that almost of the 71% of the cases requires less than this average value.
- Almost 68% of the cases require less than 1 000€.

Few administrations release the use of the cross polar (XPIC) for free and some others charged it at 50%.

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

# 4 Current and future uses of the band

## 4.1 E-Band deployment Use Cases

E-band was introduced at the beginning of 2000 and substantially if not extensively used until a few years ago. E-Band is gaining popularity as a new alternative to traditional frequency bands and has experienced major growth among the backhaul bands in recent years with a forecast to represent up to 20 percent of new deployments in 2020 (see Ericsson, Sep 2015, Microwave Towards 2020 Report [13]).

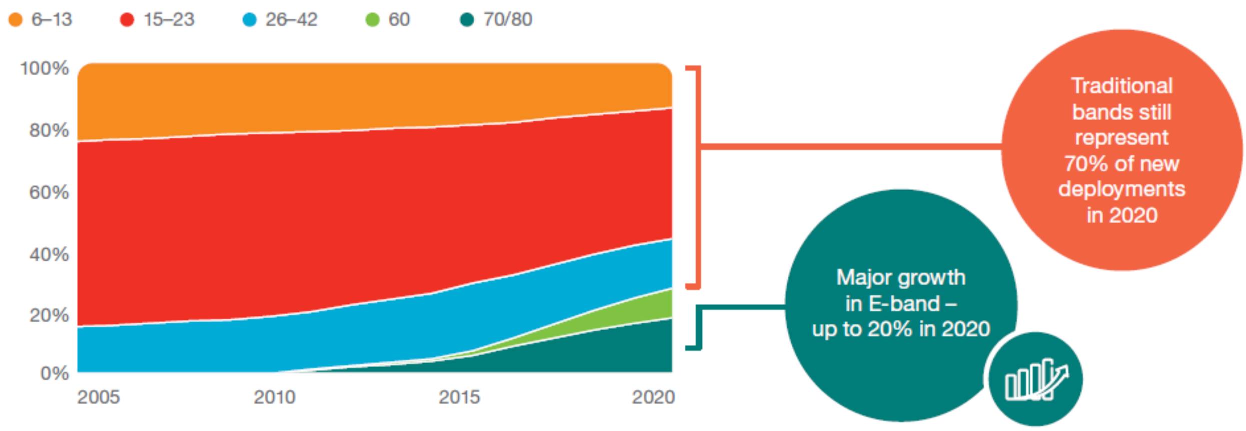



**Figure 8: New deployment share per frequency range [GHz]**

The advantages of E-band with respect to traditional microwave bands can be summarised as:

- Wide spectrum available 71-76 & 81-86 GHz
- Wider range of channels size, from 62.5 MHz in some regions up to 2GHz and more. This aspect enables the possibility to cover a wider range of needs and enables a solution for very high capacities of up to 10 Gbps and more at low TCO. The next figure, taken from ETSI, provides the relation between Capacity, Channel spacing and modulation schemes.
- E-Band characteristics can cover the most popular 5G uses cases, requiring high capacity over relative short hops (densification) up to 2 km.
- Wide channel allows to provide very low latency performances even lower than 20 microseconds.
- E-Band is a fundamental component of the new BCA approach (see hereafter) to satisfy use cases for up to 20 Gbps up to 10 km.

- Last but not least, many countries adopted a light licensing regime and/or low spectrum fees to encourage the use of this band.

| Capacity (Mbit/s) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Modulation schemes | Channel separation (MHz) | | | | | | | | | |
| | 62,5 | 125 | 250 | 500 | 750 | 1000 | 1250 | 1500 | 1750 | 2000 |
| QPSK | 71 | 142 | 285 | 570 | 855 | 1 140 | 1 425 | 1 710 | 1 995 | 2 280 |
| 16QAM | 142 | 285 | 570 | 1 140 | 1 710 | 2 280 | 2 850 | 3 420 | 3 990 | 4 560 |
| 32QAM | 219 | 438 | 875 | 1 750 | 2 625 | 3 500 | 4 375 | 5 250 | 6 125 | 7 000 |
| 64QAM | 262 | 525 | 1 050 | 2 100 | 3 150 | 4200 | 5 250 | 6 300 | 7 350 | 8 400 |
| 128QAM | 306 | 612 | 1 225 | 2 450 | 3 675 | 4 900 | 6 125 | 7 350 | 8 575 | 9 800 |
| 256QAM | 350 | 700 | 1 400 | 2 800 | 4 200 | 5 600 | 7 000 | 8 400 | 9 800 | 11 200 |

**Figure 9: Capacity and modulation schemes for various channel separation (see ETSI ATTM TM4: Future revision of EN 302 217-2 [9])**

## 4.2 Band and Carrier Aggregation

Band and Carrier Aggregation (BCA) (see ETSI GR mWT 015 [14]) is a new technology that has recently become popular in the mobile backhaul arena to better serve the demands on the new backhaul network.

BCA is a relatively new concept enabling efficient use of the spectrum through smart aggregation, over a single physical link, of multiple frequency channels (in the same or different frequency bands).

Combining multiple frequency bands over the same radio link can provide several benefits, over and above straight throughput increase, leading to more efficient use of available spectrum.

BCA could be implemented through different arrangements, depending on the application and specific use case. The most popular BCA arrangement observed today is between E-band and one of the 15/18/23 GHz bands to achieve hop length up to 10 km, capacities more than 20 Gbps using a single dual band antenna (see ETSI GR mWT 015 [14] and WI SE19_41 [2]).

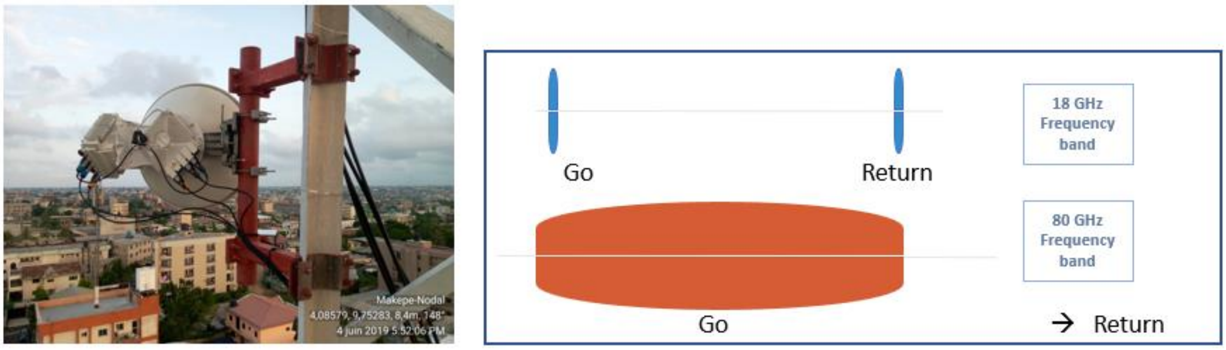



**Figure 10: Actual BCA installation picture**

The result is a payload with different steps in terms of capacity/availability as per the well-known concept of adaptive modulation, but with more capacity and higher numbers of capacity steps. The main development with BCA is that in comparison to adaptive modulation, more and different degrees of freedom in link budget are possible.

The following picture reports, as a simple example, what can be obtained as capacity versus availability for a 7.5 km link in a rain rate zone of 42 mm/h. The frequency resources are one 56 MHz channel @ 18 GHz with XPIC and 1000 MHz channel @ 80 GHz.

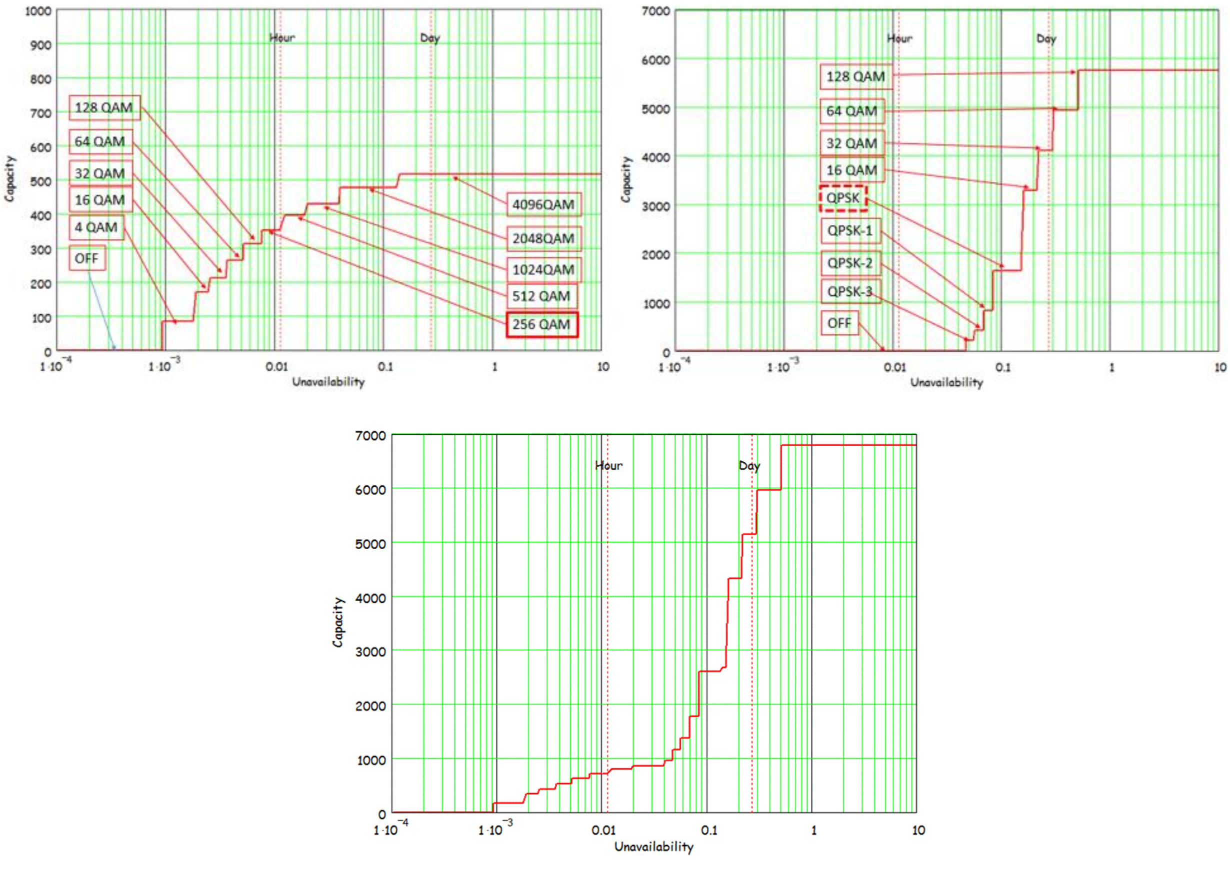



**Figure 11: Capacity vs availability with BCA of 18 GHz and E-Band**

Manipulating these degrees of freedom make it possible to reach different advantages, on top of a huge baseline level of capacity with respect to a traditional approach, ranging from more efficient use of the spectrum to a way to decongest some portions of frequency spectrum (e.g. removing the boundary to use channels belonging to the same bands).

## 4.3 E-Band deployment statistics

### 4.3.1 US Data

Figure 12 shows a snapshot of links that were registered in the US until the beginning of 2019. Note that the blue line is a cumulative line that is the running sum of links added minus links deleted every year. The big deletions in 2016 and 2017 were the result of the FCC instructing a few licensees to clean up their data. According to this data, E-Band link population in US are around 20 000 links.

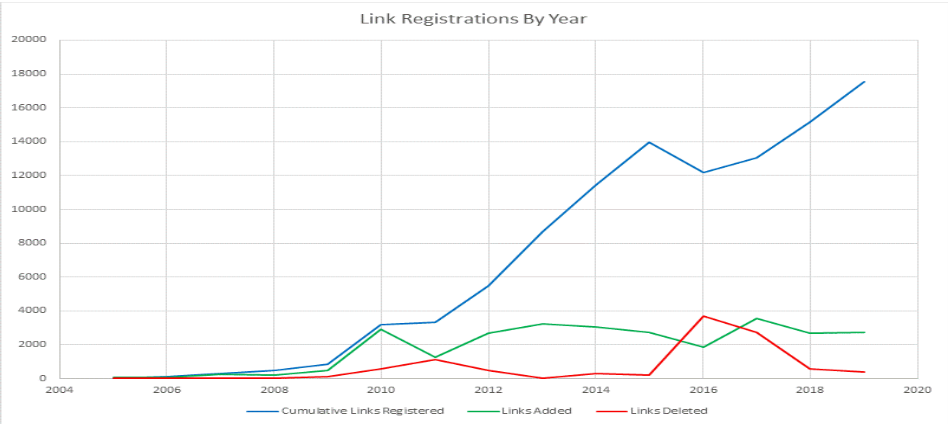



**Figure 12: E-Band Deployment in the US**

Considering that the channel arrangement is not defined in the US, the channel separation breakdown should be noted. The majority of the links, 63%, are using CS=1250 MHz; the exotic 350 MHz is gaining 9%. Wider channels (10 GHz and 5 GHz) are increasing in number both at around 3%.

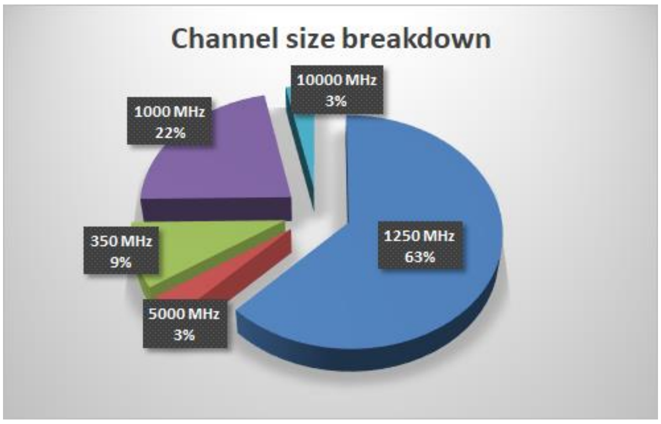



**Figure 13: Channel separation breakdown**

### 4.3.2 UK Data

Here is a snapshot of the license registrations in the UK until the beginning of 2020. The left-hand figures consider the self-coordinated cases and on the right-hand the coordinated cases.

Figures reported are based on the cumulative number of registered licenses – this may also include granted licenses but where links are inactive. It should also be noted that links decommissioned during the year are likely to be reported the year after. Uncoordinated cases represent the majority of E-Band deployment in the UK in a proportion of around 10 to 1. A flattening of new link registrations in the uncoordinated cases can be seen from 2017 while the coordinated cases continue to climb steadily.

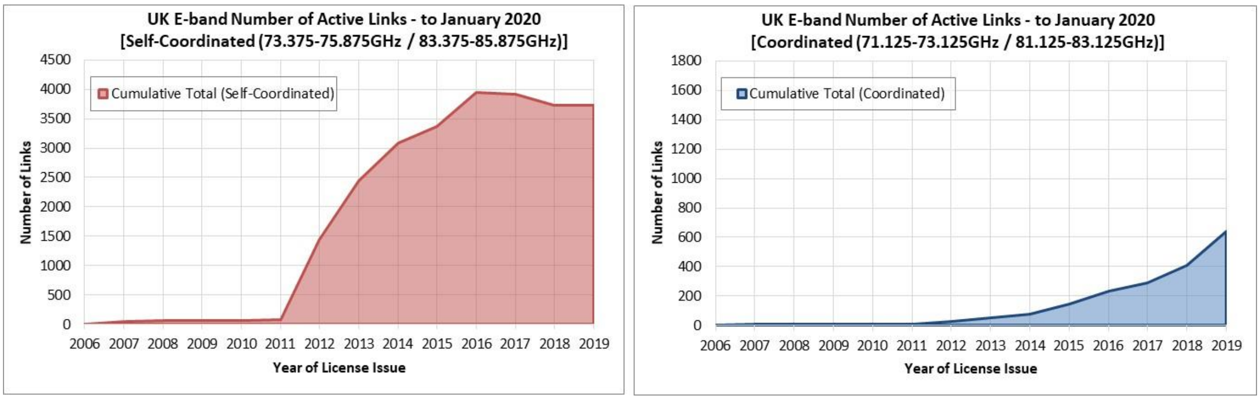



**Figure 14: E-Band Deployments in the UK**

The link length distribution for the two cases are shown in Figure 15. The coordinated case distribution is centred around 1 km with an average link length of approximately 1.36 km while the uncoordinated case is more distributed including plenty of cases above 10 km (average link length around 3.79 km).

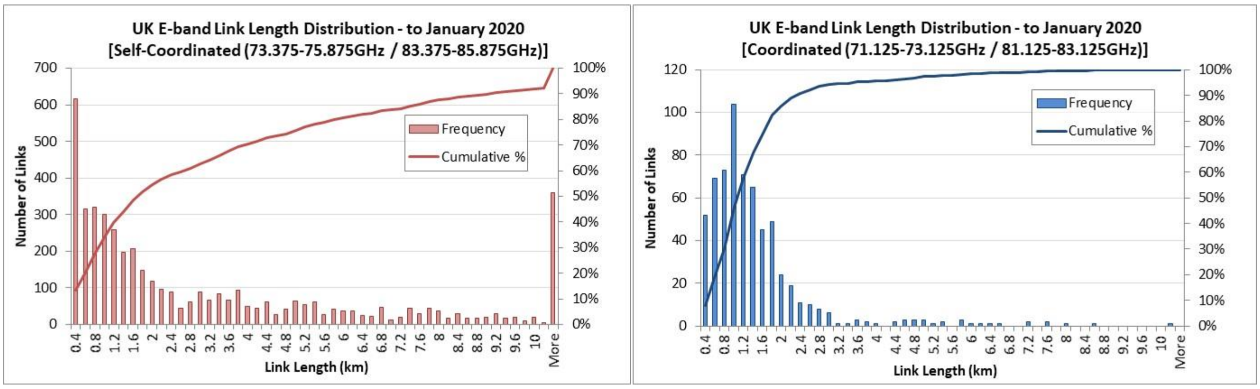
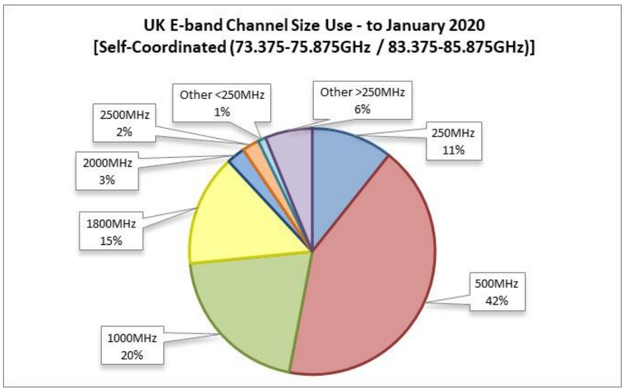



**Figure 15: E-Band Link Lengths in the UK**

The channel size breakdown for the two cases is shown in Figure 16. The most popular channel size for the coordinated part is 250 MHz while for the self-coordinated part larger channel sizes are preferred.



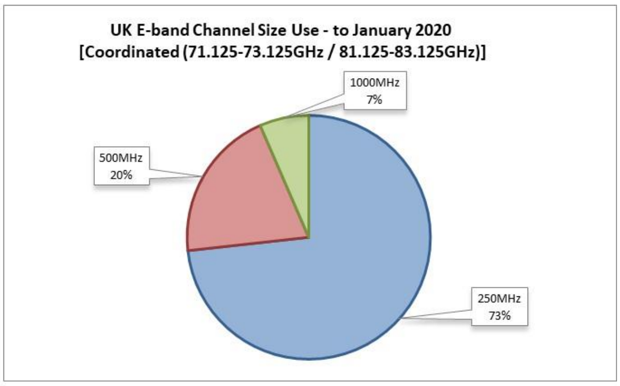




**Figure 16: E-Band Channel Size in the UK**

## 4.4 E-band Deployment: Operator Example – BT (UK)

**Target architecture:**

Currently around two thirds of BT(EE) cell sites are backhauled using microwave transmission. BT are following a fibre first initiative for 5G and beyond, however, fibre is not universally available – initial forecasting suggests 10%-15% of sites in urban areas will require E-Band backhaul. Radio transmission links will be unilateral in 5G areas (no sharing) however channel plans are coordinated between co-located operators to enable multiple operators to deploy on shared sites with parallel links. As 5G rollout progresses to more suburban and rural areas the percentage of sites requiring wireless backhaul, including possible applications for E-Band/MW dual-band solutions, are expected to increase significantly.

**Target Radio Planning:**

Radio links are planned to 99.99% atmospheric availability; 1+0 and 2+0 configurations are allowed based on deployment scenario. Links can provide 6 Gbps at up to 1.5 km with 500 MHz channels and 256QAM in 2+0 XPIC configuration. Radio units support the PTP boundary clock for supply of phase sync to a 5G gNB slave clock.

**Deployment Topologies:**

Where fibre deployment is not feasible a single E-Band radio hop between a hub site (fibre) and sub-tended (child) site is used. A maximum of 3 sites is supported from a hub site in star topology (hub site capacity is monitored and upgraded accordingly with 2nd 10GE fibre backhaul when necessary).

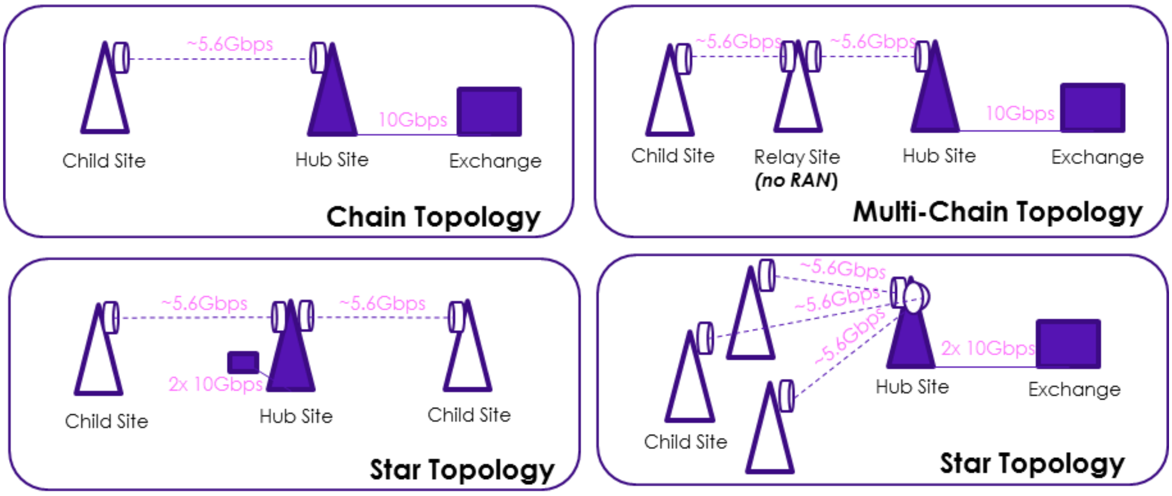



**Figure 17: BT E-Band deployment topology**

Due to capacity constraints, a two-link chain E-Band child site topology (with no RAN at the relay site) can be supported as an exception but avoided unless no other connectivity options are available.

# 5 Conclusions

The current status of E-Band is captured using a wide range of sources allowing us a good level of cross check. Considering the Fixed Service applications standpoint, then 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 this band.

These points are:

- A not homogeneous regulation both in terms of emission limitations and license/coordination methods, adopted country by country.
- We reported an enormously different level of fees due for a link license, mainly due to a lot of different models adopted for fees calculation, sometimes too expensive, discouraging deployments.

It is foreseen to maintain the database connected to this document updated.

Should the reader have information, corrections and/or suggestions, to improve the document, please provide them to the rapporteur.

# Appendix: Database

What is reported in this document is updated to version 1 of the database distributed with White Paper 9 [1] in a zip file when first released. This file is now updated as of June2020.

The database, an excel file, that includes all the information countries by countries. Here is what each column reports:

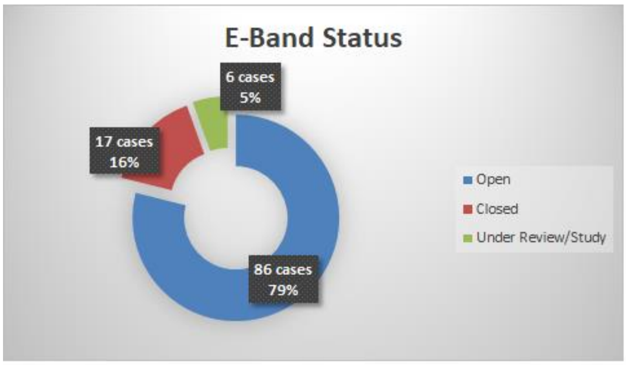
- The ITU region (see B)
- The name of the Telecommunications Regulatory Authorities
- The website
- The name of the country
- The column E reports the frequency band/s
- The column F reports the "Status of the band"
    - Three possible case: Open; Closed; Under Discussion
- The column G reports "Channel spacing" [MHz]
    - The basic channel spacing
    - Whether 125/62.5 MHz are allowed
- The column H reports "Max n"
    - Reports the maximum number of channels can be aggregated to obtain a wider channel
- The column I reports "FDD - TDD"
    - Four possible cases: FDD&TDD; FDD only; TDD only; Unknow(=empty)
- The column J reports "License Regime"
    - the cases foreseen are: Link by link; Block assignment; Light licensing; Unlicensed; Link by link and Block; Licensed; Double regime; Unknow(=empty)
- The column K reports "Minimum antenna gain [dBi]"
- The column L reports "License cost Estimation for 250MHz/Year [Euro]"
    - This column reports an estimation of the license cost for the case of 250MHz channel for one year and for a hop length of 1 Km when relevant.
    - X=unknown
- The column M reports "XPIC Charged? Yes/No"
    - This column report where XPIC is for free or if some discount on the fees is applied
- The column N reports "License Cost Estimation for 1000 MHz/Year [Euro]"
    - Scope is to derive clues on the how EBAnd is charged, linearly or not
- The column O reports "Note"
    - This column reports additional useful info, usually link to specific documents

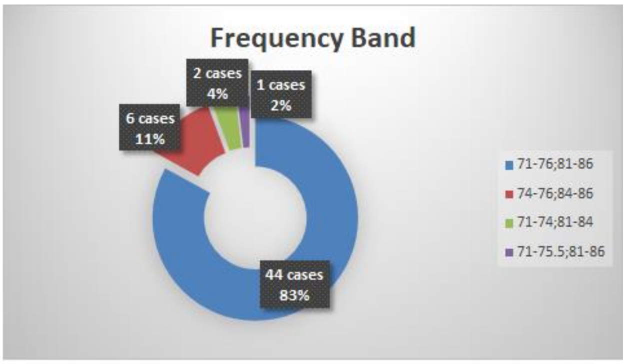
**Empty cell means unknown except for the License cost Estimation where** X **= unknown**

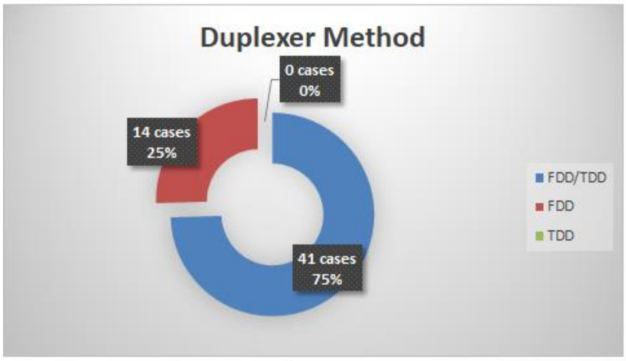
Even if all the efforts have been put in place in filling this database with proper and validated information, it is likely that errors remain, in particular due to misinterpretation of the input data.

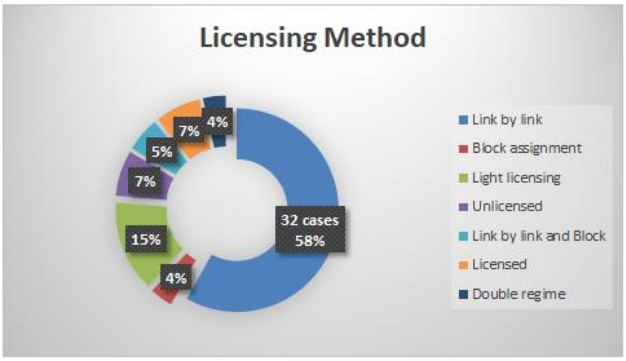
The sources of data have been variegated, ranging from single contributors, websites of administrations and regulators and other sources, such as the last Questionnaire - Revision of the ECC Report 173 related to frequencies higher than 50 GHz [15] and the ECO Frequency Information System [16].

# A. E-Band Database- Snapshot



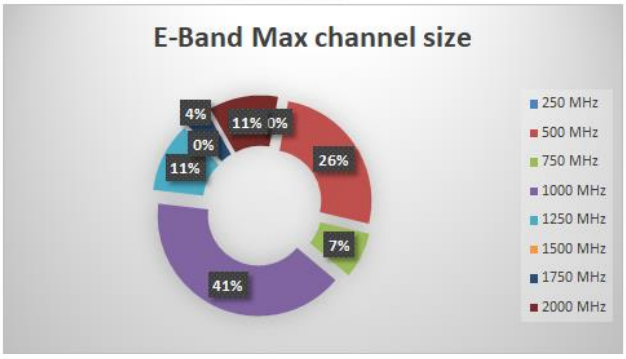




**Table A.1: E-Band Database summary**

| License Cost Estimation for 250MHz/Year | | |
|---|---|---|
| No fees | 12 cases | |
| Average | 1 239.6 € | |
| Median | 240.0 € | |
| # case below average and % | 51 cases | 85% |
| # case below Median and % | 37 cases | 62% |
| # case with Fee at no zero | 60 cases | |
| # case | 72 cases | |

## B. ITU Region

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

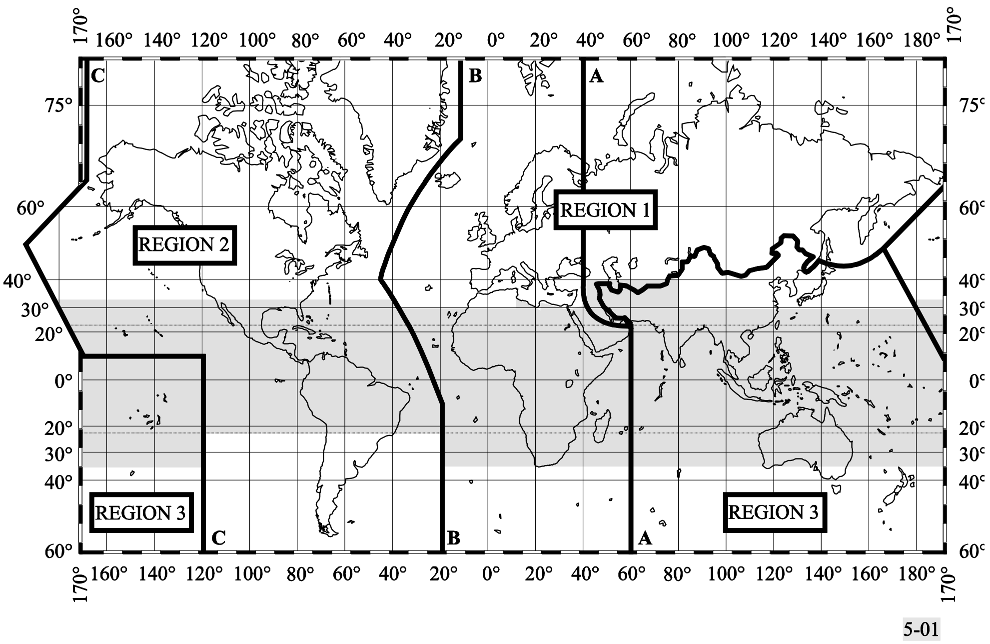



Figure B.1: ITU region

## C. Table Of Frequency Allocation For E-Band

These tables are from ITU Radio Regulations [17]

**Table C.1: Portion: 57-66 GHz**

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

Table C.2: Portion: 71-76 & 81-86 GHz

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

## D. US - FCC Regulation For E-Band

Abstract of US Title 47, Part 101, subpart Q of the Code of Federal Regulations [18].

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 will:

(1) Complete coordination with Federal Government links according to the coordination standards and procedures adopted in Report and Order, FCC 03-248 [19], 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 of an FCC Form 601 [20] 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 [20] has been filed.

## E. ETSI-CEPT: Technical Background For Self-Coordination

Here is an extract from Annex 3 of ECC Recommendation (09)01 [21]

To assist the planning of P-P fixed links, self-coordination approach, similar to the “light licensing”, described in ECC Report 80 [3**Error! Reference source not found.**], 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 to protect 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 authorised 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 coordinated 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).

## F. Example of E-Band Fee

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

**Case#1**

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

- Application Processing /one-time payment, for each link/radio route
- License / 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 depends on channel bandwidth.

**Case#2**

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

- Nationwide authorization not 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 voices:

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

It is similar to Case #1, but here 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

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

| 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 |

C2, Population coefficient, tries to account if a specific area is congested or not. The higher the frequency band, the less the fees are. In this case E-Band is charged ten time less with respect 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:

Annually 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 as usually the frequency bands and the channel bandwidth, but also the region (High Density Geographic Area) and if the frequency band has or not high Demand. The last point that should be pointed out is the fact that the Hop Length is considered, and the fees are directly proportional to it.

Our Database provided a lot of links to the administrations websites, where this information is available.

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19. FCC 03-248 (US Title 47, Part 101, subpart Q of the Code of Federal Regulations: https://ecfr.io/Title-47/Section-101.1523)
20. FCC Form 601 (US Title 47, Part 101, subpart Q of the Code of Federal Regulations: https://ecfr.io/Title-47/Section-101.1523)
21. Annex 3 of ECC Recommendation (09)01: USE OF THE 57 - 64 GHz FREQUENCY BAND FOR POINT-TO-POINT FIXED WIRELESS SYSTEMS (see https://www.ecodocdb.dk/download/a5bcf903-bb19/REC0901.PDF)
22. 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"

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