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FINAL REPORT FOR GOOGLE

REVIEW OF SPECTRUM MANAGEMENT APPROACHES FOR E-BAND (70/80GHz) IN SELECTED MARKETS

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David Abecassis, Janette Stewart, Alex Reichl

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Analysys Mason Limited
Bush House, North West Wing
Aldwych
London WC2B 4PJ
UK
Tel: +44 (0)20 7395 9000
Fax: +44 (0)20 7395 9001
london@analysysmason.com
www.analysysmason.com
Registered in England No. 5177472

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1 Executive summary

This report prepared by Analysys Mason explores how E-band frequencies have been licensed for use in different markets around the world and identifies the regulatory regimes best suited to current and future uses of the band.

E-band is part of the Extremely High Frequency (EHF) portion of the radio spectrum (broadly 30GHz to 300GHz), corresponding to wavelengths between 1mm and 1cm, hence the term 'millimetre waves'). Internationally, E-band includes the frequencies from 71–76GHz and from 81–86GHz.

The report has been prepared in the context of growing demand for high-capacity point-to-point and point-to-multipoint wireless links, both within telecoms networks (e.g. for backhaul) and to provide high-capacity wireless connectivity to businesses and consumers, and in the context of new and innovative uses beyond conventional fixed point-to-point links. The properties of E-band frequencies, particularly the available bandwidth and the channel sizes (which, being in multiples of 250MHz, offer scope for considerably higher capacity to be delivered per link than is possible in other frequency bands allocated for fixed services use), make this band ideally suited to meeting these demands. In addition, the short wavelength of frequencies in the millimetre portion of the radio spectrum, where E-band sits, means that the potential for interference between neighbouring links is reduced, compared to the lower-frequency bands. This implies that regulators have much more scope to implement simplified coordination mechanisms for the licensing of links in E-band, compared to other frequency bands used for point-to-point services.

The overall objective of this report is thus to highlight the benefits of adopting flexible, lightly licensed approaches when allocating these frequencies, building on the properties of this band to avoid the need for fully coordinated, interference-managed approaches to assignment.

1.1 The E-band presents attractive physical properties in terms of bandwidth and spectrum management

Properties of millimetre-wave bands

In general, millimetre-wave bands above 60GHz have favourable properties for providing high-capacity wireless links, due to the large amounts of spectrum available in these bands (making wide channel widths a possibility, to achieve very-high-capacity links). This is one of the key drivers for use of millimetre-wave bands, compared to lower-frequency bands (which enable links to operate over larger distances, but with less capacity available). For example, a research report published by the UK regulator, Ofcom, illustrates the increase in capacity typically available in millimetre-wave bands, relative to link distance[1].

[1] http: stakeholders.ofcom.org.uk/binaries/consultations/spectrum-review

Figure 1.1: Properties of spectrum used for point-to-point links [Source: Ofcom, Analysys Mason, 2015]

Frequency range	Achievable distance for point-to-point links	Achievable link bandwidth for point-to-point links
Below 3GHz	Large e.g. tens of km	Small: typically below 10Mbit/s
3–10GHz	Large e.g. tens of km	Medium: up to 100s of Mbit/s per link
10–20GHz	Medium e.g. 10–20km	Medium: up to 100s of Mbit/s per link
20–50GHz	Small e.g. less than 10km	Large: 500Mbit/s and above
50GHz and above	Very small e.g. a few km	Large: 1Gbit/s or more

Frequencies in E-band (typically 71–76GHz and 81–86GHz) are particularly useful providing high-capacity wireless links for two reasons: the existing international allocation of this frequency band for fixed service use (which has the benefit that radio equipment has been developed for this band), and the availability of harmonised bandwidth (up to 2×5GHz, in multiples of 250MHz), which provides a large amount of potential capacity.

An interesting feature of E-band is that, although located high in the millimetre-wave region of the radio spectrum, where signal absorption levels are high, E-band is located above the oxygen absorption peak occurring at around 60GHz and hence the usefulness of the band (in terms of the operating ranges that are possible) is more similar to fixed services bands around 30–40GHz[2]. The physical properties of E-band spectrum also result in reduced potential for interference between systems (compared to lower-frequency bands), ensuring that multiple users can access the spectrum without constraint on the capacity or quality of links.

Technological development to facilitate the use of millimetre-wave bands has resulted in availability of highly directional antennas for use in E-band. These 'pencil beam' antennas not only make it possible to simplify coordination between links and thus adopt a flexible licensing approach to the band (due to reduced risk of interference) but they also potentially improve the performance of links in terms of their directionality and range.

Regulatory approaches to E-band spectrum

A further factor which should favour wider take-up is the flexibility in use of this band that a number of regulators have offered by opening it for use on a self-coordinated (also referred to as 'lightly licensed') basis. The self-coordinated management approach to E-band was originally introduced in the USA and a number of other markets have subsequently adopted similar approaches. A small number of regulators (two, based on our survey of selected countries around the world) have removed the need for frequency coordination for E-band altogether, and provide access to E-band on a licence-exempt (unlicensed) basis. In practice, however, the characteristics of at least one of these licence-exempt approaches (in the Czech Republic) are somewhat similar to the self-coordinated approaches in the other countries we have profiled in this report, in that E-

[2] For example, see http://stakeholders.ofcom.org.uk/consultations/70-80ghz-review/statement/

band users are required to register details of deployed links in an online database, facilitating exchange of information and interference resolution between different users of the band, without requiring regulatory intervention.

The use of these self-coordinated management approaches has the benefit of facilitating a quicker turnaround on licence applications (useful, since one of the main benefits of fixed radio links is that they can be deployed more rapidly than wired connections). Self-coordinated licensing also has the potential to reduce access costs for using the spectrum (i.e. spectrum fees), if regulators do not need to recover the cost of administering detailed frequency assignment and interference assessment within the fee for the links. The fact that regulators around the world are increasingly adopting self-coordinated management approaches in E-band is also a factor that can support the emergence of innovative applications in such bands – as evidenced in the USA, where experimental licences filed for E-band demonstrate possible new uses that may emerge in future.[3]

A growing number of countries are opening up E-band for point-to-point use based on our research. For example, Nigeria made 70/80GHz spectrum available on a self-coordinated, light licensed basis in 2015, and countries such as Indonesia and Tanzania plan to put licensing processes in place in the near future.

Overall, this makes E-band frequencies an excellent choice for deployment of point-to-point and other fixed wireless links, which can be implemented rapidly and cheaply, as well as being scalable for high-capacity provision.

1.2 An increasing number of countries are adopting flexible licensing and management approaches to E-band

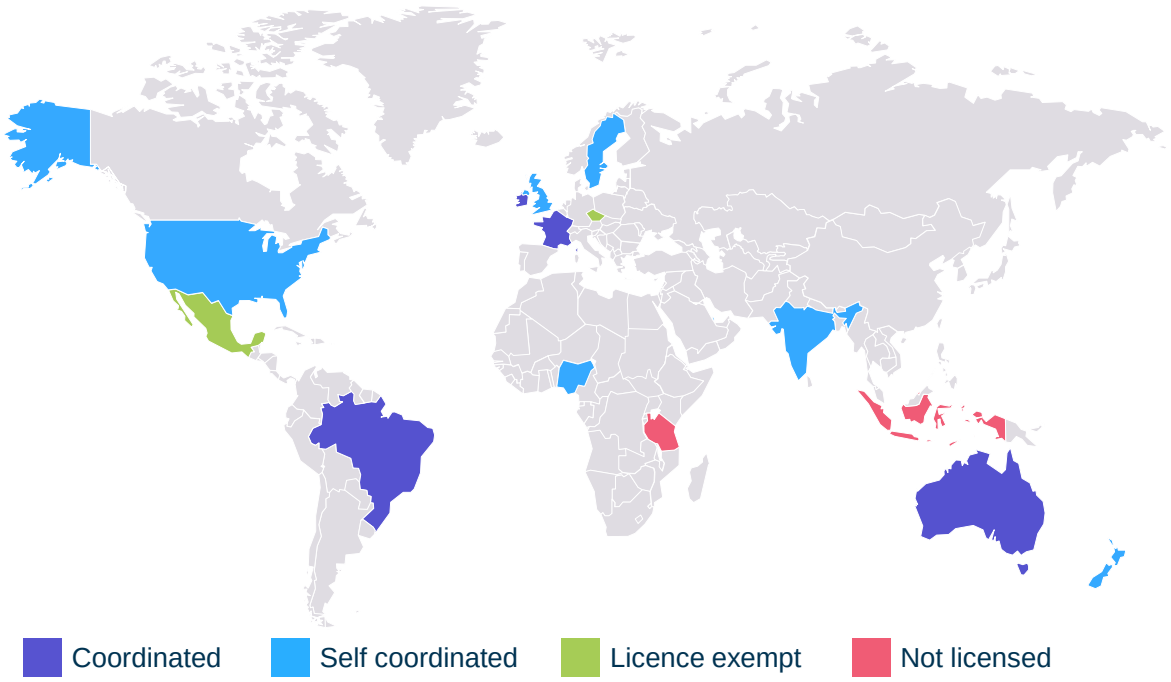
Countries surveyed

As part of this study we have surveyed the approach taken by regulators to making E-band spectrum available in 18 different markets.

The range of licensing approaches that we identified from our survey is summarised in Figure 1.2 below. It is notable that the majority of the countries surveyed have adopted either self-provided or licence-exempt approaches when opening up E-band for commercial use.

[3] https://apps.fcc.gov/els/GetAtt.html?id=163551&x=.

Figure 1.2: Illustration of E-band management approaches adopted in surveyed countries [Source: Analysys Mason, 2015][4]



One of the countries surveyed – the UK – has implemented a self-coordinated approach to part of E-band, and a coordinated, interference-managed approach to the other part. The original approach to E-band in the UK was to make the full band available on a self-coordinated basis. However, the conditions were changed following a public consultation by the UK regulator, Ofcom, in 2013, which revealed that some E-band users (mainly mobile operators, using the spectrum for mobile network backhaul) favoured that part of the band which was being more actively managed by Ofcom, in order to obtain a greater level of interference certainty which is desirable for public networks with high availability objectives. The UK's approach is profiled in the main part of this report, along with case studies on seven other countries, all of which use self-managed, light licensed and licence-exempt approaches: the USA, Mexico, Brazil, the UK, the Czech Republic, Nigeria, Qatar and Australia.

Main uses of E-band

We have found that countries which have opened E-band for licensing have largely done so to facilitate fixed point-to-point use. According to the international table of frequency allocations,[5] a number of other co-primary allocations exist in E-band, in addition to fixed point-to-point services. Some of these allocations are not currently used (e.g. we are not aware of any mobile systems operating in E-band). In a number of countries, point-to-point links share E-band capacity with other uses (predominantly government use and radio astronomy) and a number of regulators have

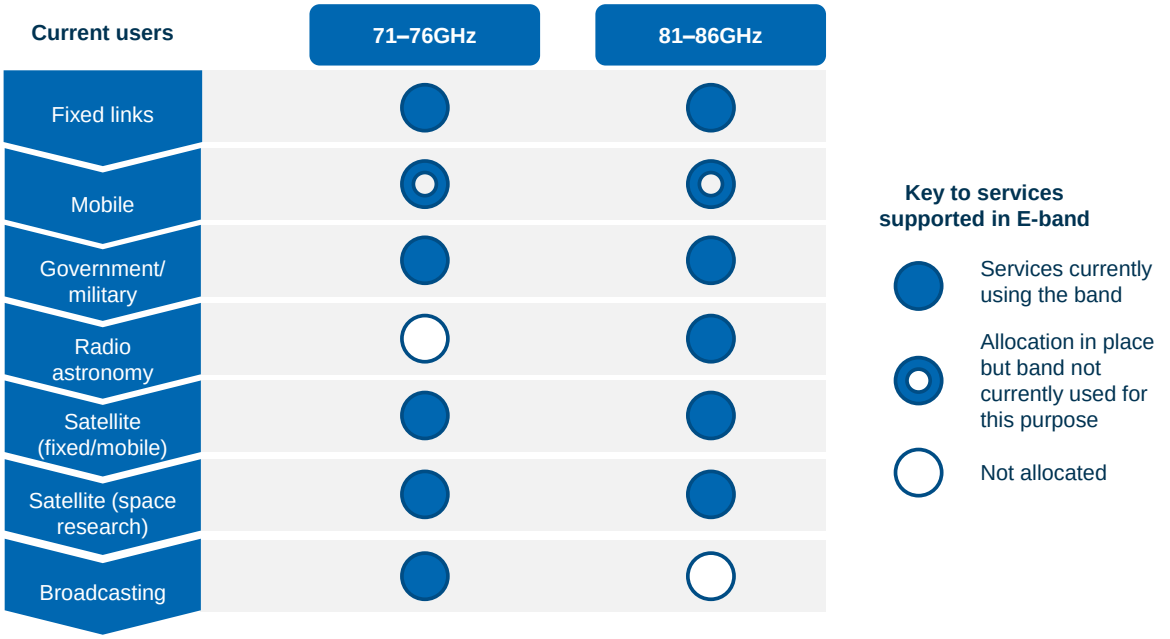
4 We also surveyed the status of the E-band in the Philippines, Peru and the DRC, but were unable to find complete information to develop case studies.

5 That is, as contained in the Radio Regulations of the International Telecommunication Union.

implemented specific coordination procedures to ensure that licensed links do not interfere with these other uses.

A summary of the allocated uses of E-band frequencies is shown in Figure 1.3 below.

Figure 1.3: Summary of international allocations in E-band [Source: Analysys Mason, 2015]



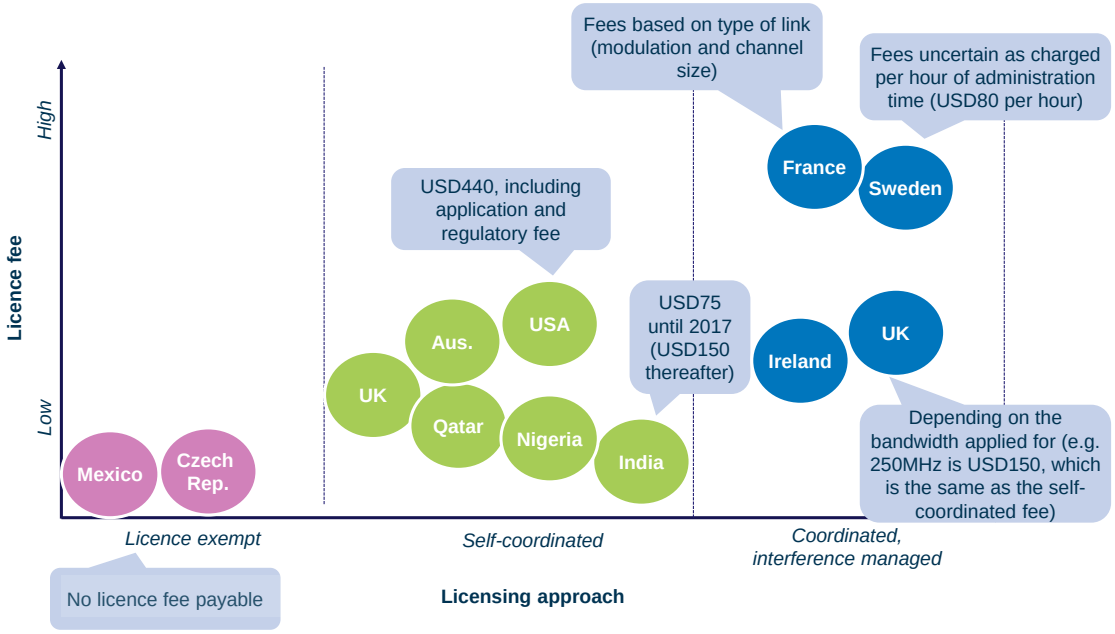
E-band spectrum fees

We have found that spectrum fees for E-band range from zero (i.e. no cost, in countries that have opted to make E-band available on a licence-exempt basis, such as the Czech Republic) to around USD150–450 for a typical self-coordinated link. In countries where E-band is licensed using a coordinated, interference-managed approach, it is not possible to determine the exact fee in all cases – in France, for example, the fee is based on the type of link (e.g. USD619 for a 250MHz bandwidth, 16QAM link) whereas in Sweden the fee is calculated based on the time to administer the licence (USD80 per hour).

An interesting finding from our research is that in a number of countries where a coordinated, interference-managed approach is used for E-band, the spectrum fee is comparable with those for the self-coordinated approaches. In Ireland and the UK for example, the fee for a coordinated E-band link can be as low as USD150, depending on the bandwidth applied for).

A summary of the range of fees that applies in the case study countries is provided below. A comparison of the fee levels broken down by component fees (application, registration, licence fee, etc.) is included in the main part of this report.

Figure 1.4: Range of spectrum fees for E-band [Source: Analysys Mason, 2015]



1.3 Self-coordinated management and light-licensing approaches appears conducive to unlocking the benefits of the E-band for upcoming needs

Based on our review of the management approaches to E-band implemented by the countries profiled in this report we have identified the key benefits of self-coordinated access to E-band, as summarised in Figure 1.5 below.

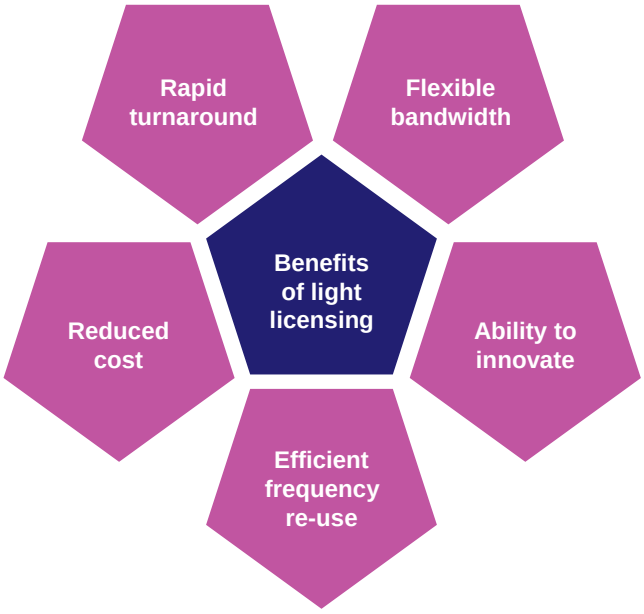


Figure 1.5: Benefits of self-coordinated, light licensing in E-band [Source: Analysys Mason, 2015]

Many of the self-coordinated management approaches being applied to E-band licensing are supported by online databases that licensees use to upload licence applications and to obtain information on available link locations, as well as details of existing use that must be protected

from interference.[6] In some cases database provision has been outsourced to commercial third parties. For example, three companies currently provide this service in the USA; a licensee can choose to register with any one of these, and systems are updated such that each database contains the full set of licensing information.

In many markets, although spectrum is earmarked for point-to-point use, there is the potential for other innovative wireless uses to make use of the same spectrum provided these can be shown to be compatible with existing point-to-point use (i.e. the self-coordinated approach to licensing typically works on a first-come, first-served basis, with incoming licensees having to ensure that their systems do not interfere with existing ones. Hence there is the possibility of innovative uses being facilitated, providing these do not interfere with the existing use as established by the online databases).

Use of E-band frequencies is still emerging in some markets (and the band is yet to be opened for use in some markets, despite an allocation for link use applying internationally). Hence although we have found limited evidence that outcomes in terms of use of the band are strongly influenced by the licensing approach, it is to be expected that the self-coordinated, light licensing approaches being implemented in a growing number of markets should reduce the cost and administrative barriers for new users to deploy systems in E-band, encouraging uptake. Furthermore, increasing update in use of E-band incentivised by light licensing should not compromise the integrity or usability of the band, thanks to its physical properties. Overall, the attractive properties of this frequency band – including the simplified licensing approaches being used – are likely to spur further innovative technology development for future use of this band.

[6] A number of countries which are implementing self-coordinated licensing have indicated that they intend to migrate to online databases but are currently using manual approaches until the online tools have been developed; these include the UK, Nigeria and Qatar.

2 Introduction

This report has been prepared by Analysys Mason Limited (Analysys Mason) to explore how frequencies in the 70–80GHz portion of the radio spectrum (commonly referred to as 'E-band') have been licensed for use in different markets around the world.

The context of this report is the growing market demand for high-capacity capability in point-to-point and point-to-multipoint wireless communications, and the favourable properties of E-band frequencies for delivering these services, and in the context of new and innovative uses beyond conventional fixed point-to-point links. E-band frequencies have been allocated internationally for fixed and mobile services by the International Telecommunication Union (ITU), although the bands are not available for use in all markets around the world, and a variety of licensing approaches are used in those countries where the bands are available.

2.1 Background and objectives for the study

Frequencies in the millimetre-wave bands above 60GHz are generally viewed as having favourable properties for providing high-capacity fixed-wireless links, due to the large amounts of spectrum available in these bands (making very wide channel widths a possibility). Frequencies in E-band (typically 71–76GHz and 81–86GHz internationally) could be particularly useful for this purpose, in view of the international allocation of this frequency band for fixed service use (such that similar equipment and services can be offered in different markets), and the flexible way in which some regulators have opted to make this band available. This is because, rather than requiring links to be individually coordinated and assigned by the regulator (as is the case with many frequency bands allocated for fixed services use lower in the spectrum), some regulators allow use of E-band frequencies on a self-coordinated (light licensed) base, or alternatively have made the band licence exempt (i.e. enabling it to be used without the need for an individual licence).

However, other regulators have opted to regulate access to E-band in the same way as conventional point-to-point links, requiring prospective users to apply for individually coordinated, interference-managed licences issued by the regulator. These licences are typically more expensive to obtain than a self-coordinated licence, in view of the additional administrative costs incurred by the regulator to issue the licence. In a number of markets, regulators have yet to put a licensing regime in place for this band.

The key objective of this study was therefore to review different management approaches for using E-band frequencies around the world, and to establish the benefits of opening up these frequencies for licensing on a self-coordinated (i.e. light licensed) basis, rather than using coordinated and interference-managed access more typical of links deployed in lower (sub-60GHz) frequency bands.

The objectives of the study were to provide:

- an overview of the status of E-band in different markets
- a comparison of licensing approach in selected markets, including the management approach, fees, technical and any other usage conditions
- conclusions on the best management approach for E-band frequencies to exploit the particular properties of this spectrum for high-speed wireless links.

2.2 Countries surveyed

In total we have surveyed the approach to licensing E-band frequencies in 18 different markets around the world, from which we have selected 8 countries to present in this report as case studies contrasting different approaches.

The 18 countries we surveyed are: the USA, Mexico, Brazil, Peru, Tanzania, the Philippines, Indonesia, the UK, Ireland, France, Sweden, the Czech Republic, India, Nigeria, Democratic Republic of the Congo (DRC), Qatar, Australia and New Zealand.

On the basis of the survey, we have selected eight case studies to present in this report, representing a number of countries where regulators have used self-coordinated, light licensed or licence-exempt management approaches to E-band spectrum. The eight case studies presented in the remainder of this report are: the USA, Mexico, India, the Czech Republic, the UK, Nigeria, Qatar and Australia.

2.3 Structure of this report

The remainder of this document is laid out as follows:

- Section 3 describes the capabilities of E-band frequencies for high-capacity links, and the different licensing approaches that can be applied
- Section 4 presents the findings from our survey of E-band licensing approaches in different markets
- Section 5 provides a summary of our findings and presents our conclusions.

The report includes two annexes containing supplementary material:

- Annex A lists the abbreviations used in this report
- Annex B includes confidential responses to the survey undertaken for this study.

3 Capabilities of E-band frequencies

This section describes the characteristics of E-band spectrum, the types of service that can be delivered and the particular features of current equipment designed to use this spectrum.

3.1 High-capacity wireless links in microwave- and millimetre-wave bands

Fixed-wireless links or fixed links provide line-of-sight transmissions between two geographical locations. Fixed links are used extensively for point-to-point telecoms, as well as for point-to-multipoint telecoms to convey voice and data signals. One of their major uses is for backhaul within mobile networks (i.e. to connect wireless base stations with the mobile network backbone). Other uses include voice and data communications directly to end users as a replacement for copper or cable communications (e.g. the 'last-mile' connection) and point-to-point links with the communications networks used by various enterprises, local governments and other businesses.

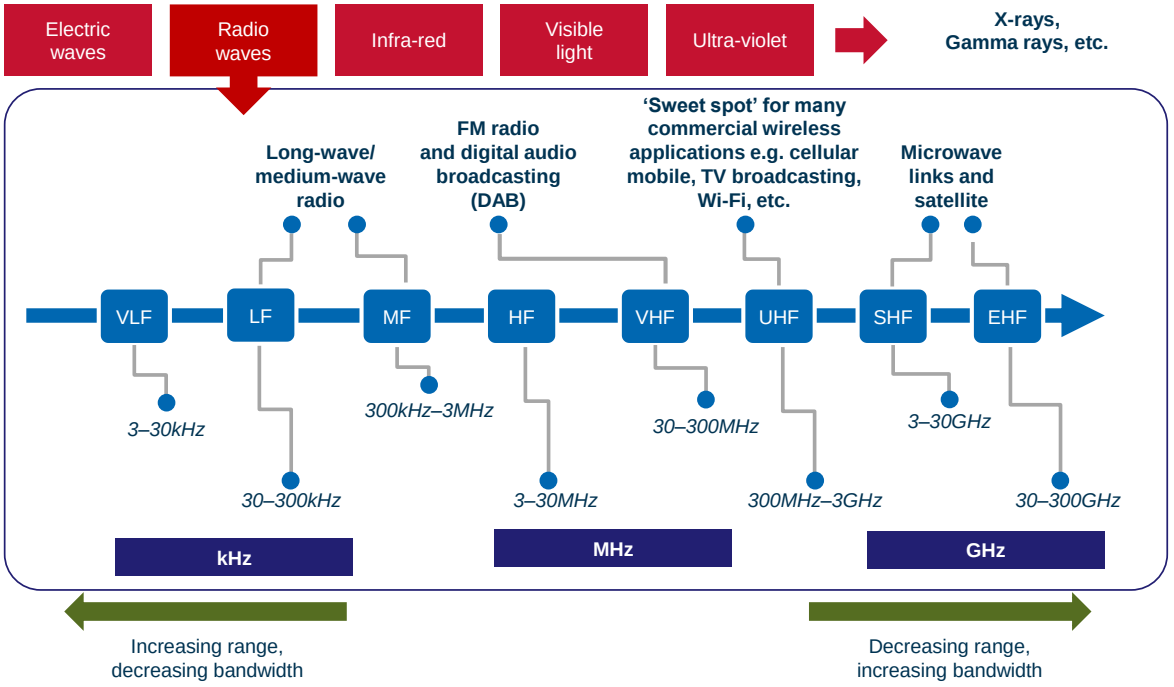
Links are therefore important to many forms of communication, such as:

- to carry traffic between cell sites in a cellular mobile network, or for sending programme information from studios to transmission sites in television and radio broadcast networks
- to provide high-speed Internet access in locations where cable or fibre connection is not available or practical
- to provide communications between buildings and facilities within an organisation (e.g. a company with several locations within a city, a government organisation, utility or transport company).

The main alternatives to deploying point-to-point or point-to-multipoint links are to use fibre-optic, copper, cable or satellite. However, even with the increasing availability of high-quality fibre-optic communications in some markets worldwide, links are generally viewed as offering certain unique advantages such as flexibility in deployment choices and rapid deployment. Collectively, point-to-point and point-to-multipoint links are often referred to as 'fixed services'.

Regulators around the world typically make a range of frequency bands available for fixed services use, ranging from selected bands below 1GHz through to various bands in the microwave (centimetre and millimetre) portion of the frequency spectrum. The choice of frequency band for a particular deployment will depend on a number of factors, including the required transmission range, capacity, location and cost. This is because the physical properties of radio waves affect the distance that the signal will travel, as well as the usable bandwidth, as illustrated in Figure 3.1 below.

Figure 3.1: Uses of the electromagnetic spectrum [Source: Adapted from diagram on Ofcom's website, 2015]



In addition to where the frequency band is located in the radio spectrum, a number of regulations make a distinction between 'congested' and 'uncongested' frequency bands when setting fees for point-to-point or point-to-multipoint use, meaning that it is cheaper to deploy links in frequency bands where there is more bandwidth available. Higher-capacity links are also better accommodated within higher frequency bands, where there is more bandwidth available and hence wider channel widths can be accommodated.

Because E-band is in the millimetre portion of the radio spectrum (where the transmission range is short, but available bandwidth is very wide) it offers significantly more bandwidth than alternative bands located lower in the radio spectrum. This is one of the key advantages of E-band frequencies, which makes these bands particularly suited to 'high-capacity' links, offering very fast speeds but over a more-limited range than would be possible in lower bands.

Lower bands, where bandwidth is scarce, are more suitable for providing longer-distance links. This is due to the physical properties of radio waves which use lower frequencies, where lower signal losses mean that waves can travel over longer distances. By contrast, in the millimetre-wave region of the radio spectrum signals are subject to higher levels of atmospheric (oxygen) absorption, giving rise to higher levels of signal distortion, which affects the maximum transmission range that can be achieved. However, because this 'oxygen absorption' effect peaks at around 60GHz it does not unduly affect E-band, and hence the bands from 70–80GHz can achieve extended transmission ranges compared to those that are achievable around 60GHz. For example, when UK regulator held a consultation on 'Review of the spectrum management approach in the 71–76GHz and 81–86GHz bands' in 2013, it estimated that the transmission range for E-band links is similar to those in the 38GHz band.

Hence, as demand for wireless data applications has grown in recent years, the demand for bandwidth to accommodate higher-capacity links has also grown. E-band frequencies are potentially well suited to meeting this requirement.

3.2 Regulatory considerations for E-band

E-band particularly benefits from being able to accommodate a high degree of frequency re-use, as a result of the short wavelengths of transmitted signals in this band. This high degree of frequency re-use allows many users to share spectrum without interference, providing a high level of efficiency in spectrum usage as well as lending itself to self-coordination of links as a means of regulating access to the band. Furthermore, technological advances in millimetre-wave radio have resulted in the commercial implementation of highly directional, narrow (pencil) beam antennas, which can further improve efficiency in usage and simplify frequency coordination. The ability for links to operate with simpler coordination than that used in other frequency bands licensed for fixed services use is a key factor that has influenced a number of regulators around the world to implement light licensed regimes for some or all of the available E-band frequencies, based on self-coordination of links.

The avoidance of need for links to be individually coordinated by the regulator has the benefit of reducing access costs to the spectrum, with regulators typically charging fees for E-band licences that are at least ten times lower than those for equivalent links in fixed services bands lower in the spectrum.

Nevertheless, some regulators worldwide have opted to apply the same licensing approach to links in E-band as is applied in other link bands lower in the spectrum, meaning that prospective users must apply for individually coordinated, interference-managed licences issued by the regulator. These licences are typically more expensive than self-coordinated licences, in view of the additional administrative costs involved for the regulator to issue them.

In this report we use the following definitions of management approach to links in E-band as the basis for comparing different regimes:

Coordinated, interference-managed access

This is the approach typically adopted by regulators around the world for frequencies used by links, which requires licensees to apply to the regulator for a licence to deploy links within a specified band. The regulator then undertakes technical coordination to confirm that the requested links can operate alongside links already licensed to use that band, and issues the licensee with an authorisation (i.e. a licence) setting out specific frequency(ies), power levels, channel configurations and other technical measures to be applied. The licensee pays the regulator a fee for issuing the licence. The fee is usually calculated based on the technical characteristics of the link, such as the frequency band applied for, channel bandwidth, number of channels and number of hops in the link.

Self-coordinated, light licensed

Using this approach, regulators still issue individual licences to operate links within the band, but each licensee takes responsibility for assigning and coordinating its links. This can be done in various ways. For example:

- in the USA, an automated coordination tool has been designed that licensees can use to coordinate the location of their links with existing uses around that location
- in the UK, link locations are assigned on a first-come, first-served basis (after licensees have checked that their requested location is available, using a database maintained by the regulator)
- in Australia, licensees wishing to receive a frequency assignment certificate must pay a firm that is accredited to provide frequency coordination. Similar to the UK, link locations are assigned in E-band on a first-come, first-served basis and licensees must first check in a database provided by the regulator that their required location is available.

Licence exempt (unlicensed)

This refers to blocks of spectrum that have been designated as exempt from individual licensing in some markets through relevant national legislation. Users of licence-exempt spectrum can generally deploy links within the specified band, assuming that their equipment complies with general conditions set out in the national legislation exempting that band.

Typically, these general conditions for exemption will have been designed to minimise interference (e.g. requiring low transmit powers in order to use the frequencies), but no individual licences are granted. Hence there is no requirement for licensees to notify the regulator of planned use, nor any requirement to coordinate with existing users. This means that there is no limit on the number of links that can be operated in a given location (and no means for existing licensees to prevent new licensees deploying systems in the same location).[7]

[7] As a result, the quality of service may be unpredictable, which is a key characteristic of licence-exempt frequency bands worldwide.

4 Findings from survey of E-band regulation in selected markets

In this section we present the findings from our research across the 18 countries set out in Section 2.2 above. We firstly provide a brief summary of where coordinated, interference management approaches to E-band licensing are being applied (which are not profiled through individual case studies). In the remainder of this section we then present case studies representing a range of self-coordinated/light licensed and licence-exempt approaches being applied for management of E-band. For each of the eight profiled countries, we provide:

- a brief overview of the regulatory framework, including the bodies responsible for management of spectrum and commentary on the approach taken to licensing of E-band relative to other bands available in that market for fixed services use
- a summary of the terms on which spectrum in E-band is currently available in that country, including the approach to coordinating licences and the application and usage fees that apply
- a summary of the specific requirements for accessing E-band frequencies within that country, and an indication of any planned changes to current rules.

4.1 Coordinated, interference-managed access to E-band

We found that this approach is being used in a number of countries in Europe (e.g. France, Sweden and Ireland), as well as in Brazil and New Zealand.

For countries in Europe, the European Communications Committee (ECC) of the Conference of Postal and Telecommunications Administrations (CEPT) has established a recommendation on channel arrangements for fixed services operating in E-band (71–76GHz and 81–86GHz), namely ECC Recommendation (05)07.[8] This recommends that E-band is to be used mainly for fixed point-to-point links in Europe, using a channel arrangement based on multiples of 250MHz. The recommendation also suggests that channels can be paired (for frequency division duplex operation), or unpaired (for time division duplex) and can be aggregated in multiples of 250MHz based on the capacity requirements for individual links. The recommendation does not indicate what form of management approach should be used to make E-band frequencies available in individual countries, but does refer to a separate ECC Report (ECC Report 80), which describes the implementation of self-coordinated, light licensed regimes.

Although some countries in Europe have proceeded to adopt a self-coordinated, light licensed approach to E-band use (e.g. the UK), a number of other countries (including **France, Sweden and Ireland**) have opted to implement coordinated, interference-management licensing in E-band. Using this approach, the regulator typically undertakes frequency coordination to assess the compatibility of planned links with existing links in the same vicinity. This is similar to the conventional approach taken by most regulators to license links in other (lower-) frequency bands

[8] ECC Recommendation (05)07, Radio frequency channel arrangements for fixed service systems operating in the bands 71–76GHz and 81–86GHz, published 2009, revised 2013.

allocated for fixed services use, where individual coordination of links is undertaken before licensees are issued with a location- and channel-specific licence. Although the licensing costs for coordinated, interference-managed licences are typically higher than those for the self-coordinated licences issued by other countries profiled in this report (as described in subsequent sections), some regulators that use a coordinated management approach for E-band have set licence fees at a lower level than those for other fixed services bands.

In **Ireland**, for example, the E-band licensing process implemented by the regulator ComReg enables applicants to obtain point-to-point fixed-wireless licences for around EUR150 (USD165) or less per year. Despite this lower cost, all E-band licensees must liaise with ComReg during the application process to ensure that no new interference is introduced to existing links (as with other self-coordinated management approaches described in this report, link locations are still awarded on a first-come, first-served basis, even when the management approach involves coordinated, interference-managed licensing).

Outside Europe, a number of other regulators use a coordinated, interference-managed approach for E-band links, rather than a self-coordinated approach. In **New Zealand**, for example, each link must be individually licensed in E-band, similar to other bands available for point-to-point links. There are four channelling options – 2250MHz, 1750MHz, 1250MHz and 250MHz – similar to channelling used in E-band in other countries. In New Zealand, to obtain a point-to-point wireless licence, including in the 80GHz band, applicants must apply online to the Radio Spectrum Management (RSM) unit of the Ministry of Business, Innovation and Employment. The RSM maintains an online register of radio frequencies, which holds all information on assigned frequency use. The RSM advises parties wishing to obtain a point-to-point wireless licence (including in 80GHz) to contact an approved radio engineer or certifier[9] to apply for the licence on their behalf.

A variation of this approach applies in **Brazil**, where the regulator, Anatel, requires notification of interest in use of spectrum prior to any services commencing, in order to undertake the necessary spectrum coordination.[10] In order to commence operations of point-to-point links, including in the E-band, links must be individually coordinated and licensed, and the equipment used must have certification issued or approved by Anatel.

4.2 Self-coordinated management approach to E-band

We have found that self-coordinated management approaches are being applied in a number of countries around the world, including the USA, the UK, Nigeria, India, Qatar and Australia.

The approaches used in these selected countries are described below.

9 See http://www.rsm.govt.nz/licensing/list-of-engineers-examiners/rsm-approved-are-arc-available.

10 See http://www.anatel.gov.br/legislacao/resolucoes/16-2001/231-resolucao-259#art4.

4.2.1 USA

The Federal Communications Commission (FCC) is an independent agency of the government of the USA, responsible for regulating interstate and international communications by radio, television, wire, satellite and cable in the USA. Its responsibilities span broadband communications policy, competition, spectrum management, media regulation, public safety and homeland security. Various frequency bands are available for point-to-point wireless use in the USA, spanning a range of bands from 900MHz to 95GHz. Although the authorisation of links is typically processed through licence applications individually coordinated by the FCC through its online Universal Licensing System (ULS), the FCC was the first regulator to implement a self-coordinated, light licensed regime in E-band. The FCC approach has led the way for other regulators worldwide to adopt similar approaches. Certain aspects of the FCC approach are particularly novel, such as the appointment of independent, commercial database operators to record E-band licensing information. Prospective users can choose to assign links with any one of the three appointed commercial database providers. The light licensed approach pioneered by the FCC in E-band may be one factor spurring the development new, innovative uses of this band, based upon experimental licences filed with the FCC.[11]

Overview

The FCC first announced its management approach in 2004, incorporating an interim link registration process[12] for E-band spectrum. After reconsidering this issue in 2005, the FCC made a number of changes to its initial approach.[13] In 2005, it also announced a permanent process for registering links in E-band,[14] with the appointment of third-party database managers and implementation of an automated coordination mechanism for interference management with Federal (government) use of frequencies (which in the USA are managed by the National Telecommunications and Information Administration – NTIA).

Main uses

The primary commercial use of E-band frequencies in the USA is for links, including high-speed, point-to-point wireless local area networks and broadband Internet access. Various other Federal and non-Federal radio communication services operate in these frequencies (and are the subject of the frequency coordination process via NPIA), as shown in Figure 4.1.

11 For example, :https://apps.fcc.gov/els/GetAtt.html?id=163551&x=.

12 See https://apps.fcc.gov/edocs_public/attachmatch/DA-04-1493A1.pdf.

13 See https://apps.fcc.gov/edocs_public/attachmatch/FCC-05-45A1.pdf.

14 See https://apps.fcc.gov/edocs_public/attachmatch/DA-05-311A1.pdf.

Figure 4.1: Co-primary allocations for Federal and non-Federal operations in the USA [Source: FCC, Analysys Mason, 2015]

Operations	71–74GHz		74–76GHz		81–86GHz	
	Federal	Non-Federal	Federal	Non-Federal	Federal	Non- Federal
Fixed	✓	✓	✓	✓	✓	✓
FSS	✓	✓	✓	✓	✓	✓
FSS (space to earth)			✓	✓		
FSS (earth to space)					✓	✓
Mobile	✓	✓	✓	✓		
MSS (space to earth)	✓	✓				
MSS (earth to space)					✓	✓
Space research			✓	✓		
Broadcasting				✓		
BSS				✓		

Summary of licensing process

The FCC process involves licensees first obtaining a non-exclusive nationwide licence, before entering into the coordination process. The subsequent self-coordination process for each proposed link is then two-fold: after applicants apply for a non-exclusive nationwide licence, they must then coordinate the proposed links with the NTIA use, and then register the link with the database managers. For coordination with NTIA use, there is an automated mechanism which calculates whether the proposed link will interfere with Federal operations (including radio observatories). The system is fully automated through FCC's website and the database manager's websites.

The management approach taken is thus as follows:

- The applicant should apply for a non-exclusive nationwide licence for use of E-band spectrum. This nationwide licence is the pre-requisite for registering individual point-to-point links
- The FCC issues the non-exclusive nationwide licence
- An applicant may request use of any portion of the 71–76GHz and 81–86GHz bands, for up to 5GHz in each segment, up to a total of 10GHz (applicants are also permitted to register smaller segments than this, based on individual demand)
- The licensee then coordinates its required link locations via the automated tool to ensure no harmful interference to Federal operations and radio observatories. In case of conflicts, revised filings (i.e. requests) are required before the licensee can proceed to the next step

- Once coordinated successfully, the licensee should register the link with one of the three authorised third-party database managers
- Link locations are assigned on a first-come, first-served basis.

Pricing structure

Applicants for the non-exclusive nationwide licences are required to pay the following one-off fees:[15]

- application fee of USD290
- regulatory fee of USD150 (per link).

Licences are valid for a ten-year period.

Interference management and information sharing

In accordance with the FCC rules, a licensee can complete the self-coordination process with any one of three independently-operated third-party database managers appointed by the FCC to design and manage the link registration system (currently Comsearch, Frequency Finder Inc. and Micronet Communications, Inc.).

Although a link registration can be recorded by any one of the three database managers, it is shared with each of the other two thereafter so that each database is fully up-to-date with current link locations across the band. Any member of the public can also access the registered link information through the database manager's website.

An interference protection date is generated on registration of the link with the database manager. This is intended to help facilitate the resolution of any interference between existing and planned links.

In terms of the technical conditions applying for each of the licensed links, all E-band links in the USA are subject to a power spectral density limit of 150mW (per 100MHz). Use of antennas with gains down to 43dBi is permitted by the FCC.[16,17]

15 See "Fee Filing Guide" https://apps.fcc.gov/edocs_public/attachmatch/DOC-329341A1.pdf.

16 The FCC had originally proposed that antennas should have a minimum gain of 50dBi, as a means of encouraging spectrum efficiency (because the higher-gain antennas would have narrower beam widths, akin to the 'pencil beam' characteristics envisaged for E-band frequencies. However, the FCC was persuaded to permit lower-gain antennas, with wider beam widths, on the basis that these would deliver more cost-effective service delivery (enabling wider areas to be covered) and would hence promote greater use of the spectrum.

17 It is noted that antenna gains below this are permitted in other markets, for instance in Europe (e.g. in accordance with ETSI 302-217 the minimum antenna gain is 38dBi).

4.2.2 UK

In the UK, Ofcom is the communications regulator with responsibility for the broadcasting, telecoms and postal industries. Ofcom manages a number of bands available for fixed services use, mostly on a coordinated, interference managed basis. For E-band, Ofcom has implemented a self-coordinated, light licensed approach in part of the band, comprising a 2.5GHz paired block across the 73.375–75.875GHz and 83.375–85.875GHz frequencies.[18] Originally, this self-coordinated approach was also applied across lower sub-bands comprising 71.125–73.125GHz and 81.125–83.125GHz; however, since December 2013 two separate authorisation approaches have been adopted, whereby licences in the lower sub-bands are issued by Ofcom on a coordinated, interference-managed basis. This change was made based on feedback from industry that greater stability and certainty over quality of service was required for links used in commercial mobile networks. Accordingly, Ofcom changed the management regime for the lower sub-bands to a coordinated, interference-managed approach, leaving the upper sub-bands from 73.375–75.875GHz and 83.375–85.875GHz as self-coordinated.

Overview

The self-coordinated process implemented by Ofcom is designed to enable applicants to obtain licences for point-to-point links rapidly and at a low cost. The process is two-fold: applicants first apply for a general licence, and then apply on an individual-link basis. Link locations are issued on a first-come, first-served basis. Once assigned, links must not interfere with pre-existing links, with newer licensees effectively responsible for ensuring they do not interfere with existing licensees.[19] The system is currently administered on the basis of manual applications, but it is understood that Ofcom intends migrating to an automated, online process in future.

For that part of E-band that Ofcom now manages on a coordinated basis, the licence approach is similar to other coordinated, interference-managed frequency bands available for fixed services use, and fees are calculated based on the bandwidth of the link being applied for.

Main uses

In the UK, E-band frequencies are currently available for use by point-to-point links, either indoors or outdoors.

There are a number of other allocations applying in parts of the E-band, including radio astronomy in the upper channels.

18 See http://www.ofcom.org.uk/consult/condocs/licensing7176/statement/.

19 See "Guidance Notes for Self Co-ordinated License and Interim Link Registration Process in the 71.125-75.875GHz and 81.125-85.875GHz bands," OfW 369, March 2007; available at http://www.ofcom.org.uk/radiocomms/ifi/licensing/classes/fixed/scl/ofw_369.pdf.

Figure 4.2: E-band frequency allocation in the UK[20] [Source: United Kingdom Frequency Allocation Table, 2015]

	71–74GHz	74–76GHz	81–84GHz	84–86GHz
Fixed	✓	✓	✓	✓
Fixed–satellite	✓	✓	✓	✓
Mobile	✓	✓	✓	✓
Mobile–satellite	✓		✓	
Broadcasting		✓		
Broadcasting–satellite		✓		
Radio astronomy			✓	✓
Space research		✓	✓	

Summary of licensing process

As indicated above, there are now two separate authorisation approaches for E-band in the UK:

- Ofcom coordinates links within the lower 2×2GHz part of the band, thus providing greater certainty for licensees on the link quality and interference management
- The upper 2×2.5GHz spectrum is subject to a self-coordinated, light licensed management approach.

For those frequencies coordinated by Ofcom, licensees are allowed access to a number of predetermined channels of various sizes, as set out in Figure 4.3 below.

Number of channels	Channel size
1	2×1000MHz
1	2×750MHz
2	2×500MHz
4	2×250MHz
8	2×125MHz
16	2×62.5MHz

Figure 4.3: Details of channel sizes available in the Ofcom coordinated E-band spectrum [Source: Ofcom Spectrum Management approach in the 71–76GHz and 81–86GHz bands, 2015]

Ofcom undertakes interference management for the requested links in the coordinated part of the band, to derive the required operating parameters of neighbouring links such that interference is

[20] See http://stakeholders.ofcom.org.uk/binaries/spectrum/spectrum-information/UKFAT_2013.pdf.

minimised.[21] Following a successful frequency assignment, each link will require a non-transferable point-to-point wireless licence, which is renewed annually.[22]

For the self-coordinated portion of the band, the approach is as follows:[23]

- The applicant applies to Ofcom to become a nationwide licensee with the authorisation to register point-to-point wireless links in the UK. This is free of charge
- Once accepted as a licensee, the applicant can apply to register links on an individual link basis. The fee is GBP50 per link, inclusive of the first year's licensing fee
- Link locations are assigned on a first-come, first-served basis
- Responsibility for interference management rests with the licensee; before registering the link the licensee needs to check in Ofcom's database that the requested location(s) are available.

At present, the application process is manual, with the links database maintained by Ofcom (not publicly available). However, the process is expected to become fully automated in future.

Pricing structure

Fees for the Ofcom coordinated channels are based on a fee rate derived from the average fee amount for links in the 38GHz band, which is the nearest coordinated frequency band used by fixed services to E-band in frequency terms managed by Ofcom at the time of the decision (December 2013). The fees vary by channel size and are applicable until December 2018, five years after their first implementation.

Channel size (MHz)	Annual fee per channel
<250MHz	GBP100
250MHz	GBP225
500MHz	GBP450
750MHz	GBP675
1000MHz	GBP900

Figure 4.4: Details of fee levels for Ofcom coordinated E-band links [Source: Ofcom Spectrum Management approach in the 71–76GHz and 81–86GHz bands, 2015]

Licences for which the self-coordinated approach is used have a GBP50 fee, which includes the charge for registration of the first link for the first year of the licence; further links registered under the licence are charged at a flat rate of GBP50 per link, per year.

21 See http://licensing.ofcom.org.uk/binaries/spectrum/fixed-terrestrial-links/guidance-for-licensees/tfac/ofw446.pdf.

22 See http://licensing.ofcom.org.uk/binaries/spectrum/regulations-technical-reference/General_Licence_Conditions.pdf.

23 See http://licensing.ofcom.org.uk/binaries/spectrum/fixed-terrestrial-links/downloadable-forms-resources/OfW_369_Guidance_Notes_65_70-80GHz_final.pdf.

Interference management and information sharing

For the self-coordinated portion of the band, interference management is the responsibility of the licensee and links are assigned on a first-come, first-served basis. Ofcom maintains a database of E-band links and the licensee must check the database to confirm that links can be deployed in that location (or if operation in that location would cause interference with existing users).

A 250MHz guard band separates the self-coordinated frequencies at 73.125–73.375GHz and 83.125–83.375GHz from the coordinated frequencies at 71.125–73.125 and 81.125–83.125GHz, in order to minimise adjacent channel interference into the coordinated frequencies.

The maximum effective isotropic radiated power (EIRP) is 55dBW in the self-coordinated channels.[24]

4.2.3 Nigeria

The NCC (Nigerian Communications Commission) is the independent national regulatory authority for the telecoms industry in Nigeria. The NCC has recently enabled access to E-band for point-to-point use, with the aim of easing pressure on other frequency bands allocated to the fixed service and used for 3G and 4G backhaul, given the expected rise in demand as 4G networks are rolled out. E-band frequencies can be used for backhaul, last-mile and enterprise point-to-point wireless applications in Nigeria.

The NCC has made available two 2.875GHz portions in uplink and downlink directions of the band (within the 71–74GHz and 81–84GHz ranges). We understand that the bands 74–76GHz and 84–86GHz are not available for use.

Overview

The NCC has recently (in 2015) put a licensing framework in place for the use of E-band, based upon a channel plan that aligns with the relevant recommendations of the radio communications sector of the International Telecommunication Union (ITU-R). Confirmation that E-band is open for licensing was published by the NCC in a public notice.[25] A basic channel spacing of 250MHz is specified, allowing for aggregation of channels up to 2.875GHz for those applications requiring high throughputs, as shown in Figure 4.5 below.

Figure 4.5: Technical specifications for use of 70/80GHz in Nigeria [Source: Analysys Mason, 2015]

Frequency band	Channel plan	Channel bandwidths
70GHz (71.125–75.825GHz)	ITU R F.2006-3-12	Minimum of 250MHz Maximum of 2.875GHz

24 Maximum transmitter power delivered to the antenna is 30dBW and minimum antenna gain is 38dBI.

25 http://www.ncc.gov.ng/index.php?option=com_content&view=category&id=67&Itemid=81.

Frequency band	Channel plan	Channel bandwidths
80GHz (81.125–85.875GHz)	ITU R F.2006-3-12	Minimum of 250MHz Maximum of 2.875GHz

A guard band of 125MHz is planned at both ends of the bands. Each licence is initially limited to a term of one year, with optional renewal. Renewal is automatic provided that the licensee meets all obligations, such as ensuring that harmful interference is not caused to existing links and participating in a process of coordinating and resolving interference problems between licensees as required.

Main uses

Currently only the lower part of the paired band (71–74GHz and 81–84GHz) is available for point-to-point use in Nigeria. The allocation of the full E-band at a national level is shown in Figure 4.6 below:

Figure 4.6: E-band frequency allocation in Nigeria [Source: NCC,[26] 2015]

Operations	71–74GHz	74–76GHz	81–84GHz	84–86GHz
Fixed	✓	✓	✓	✓
FSS (space to earth)	✓	✓		
FSS (earth to space)			✓	✓
Mobile	✓	✓	✓	✓
MSS (space to earth)	✓			
MSS (earth to space)			✓	✓
SRS		✓	✓	
Broadcasting		✓		
BSS		✓		

Summary of licensing process

It is understood that the intention is for the band to be administered online. However, this system is not yet available and so licences are currently processed manually.

Applicants are required to complete an application form entitled 'Application for Frequency Assignment 70/80GHz e-band,[27] and to provide the following documents:

- A copy of the certificate of incorporation of the company from the Corporate Affairs Commission (CAC)
- One passport-sized photograph of each of two authorised representatives of the company
- The technical details of the proposed equipment(s)

26 See http://www.ncc.gov.ng/index.php?option=com_content&view=article&id=1654&Itemid=96.

27 See http://www.ncc.gov.ng/index.php?option=com_docman&task=doc_download&gid=666&Itemid=.

- An electromagnetic compatibility (EMC) certificate for the proposed equipment(s) or type approval certificate(s) from the country of origin
- A copy of the receipt for processing fee (NGN10 000 or USD50).

Multiple E-band links can be applied for within one application. The completed application, together with its attachments, is to be returned to NCC. The spectrum licence will be processed within 90 days of receipt of a properly completed application form and the specified payment.

A 'use it-or-lose it' condition also applies to the spectrum licence, with licensees having 12 months within which to roll out a service.

Pricing structure

Each licence is valid initially for one year from the date it is issued, with an option for renewal on such terms and conditions as the NCC may stipulate.

For each licence application, a processing fee of NGN10 000 (USD50) applies. According to the NCC, the licence fee per hop is then calculated using the formula below:

- The annual price per hop in the link[28] is calculated as = (U) × (F1) × (F2) × (N+1)

Where:

- U = Unit Price: NGN18 000 **(USD90)**
- F1 = Band Factor (set to 0.1 for the 71–76/81–86GHz frequency bands)
- F2 = Bandwidth Factor, 8 = 250MHz, 16 = 500MHz
- N = Total number of RF Channels (for N + 1 systems)

For example, we calculate for one hop of 250MHz bandwidth:

Price per hop = (U) × (F1) × (F2) × (N+1) per annum

= 18 000 × 0.1 × 8 × 1

= NGN14 400 **(USD72)**

Alternatively, for one hop of 500MHz bandwidth:

Price per hop = (U) × (F1) × (F2) × (N+1) per annum

= 18 000 × 0.1 × 16 × 1

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[28] Fixed links can be deployed either with a single 'hop', which is a transmitter sending information to a receiver, or multiple hops, whereby the distance of the link is extending through use of intermediate transmitters (or relays) within the link.

= NGN28 800 **(USD145)**

Interference management and information sharing

The NCC notes that 'the highly directional pencil beam characteristics of the band will permit systems to be engineered in close proximity without causing interference'. The NCC also notes that since the band is considered to be shared, it is expected that a licensee will take reasonable steps to ensure that harmful interference is not caused to existing users.

It is also noted in the NCC's published information that:

- In the 74–76GHz band, stations in the fixed, mobile and broadcasting services shall not cause harmful interference to stations of the fixed-satellite service or stations of the broadcasting-satellite service operating in accordance with the decisions of the appropriate frequency assignment planning conference for the broadcasting-satellite service (WRC-2000).
- The 81–81.5GHz band is also allocated to the amateur and amateur-satellite services on a secondary basis (WRC-2000).

4.2.4 India

In India, the Telecom Regulatory Authority of India (TRAI) is the independent regulator for the telecoms industry. The Department of Telecommunications (DoT) is the government department responsible for setting telecoms policy. The DoT's scope also includes frequency management. The TRAI, in conjunction with the DoT, has implemented a self-coordinated, light licensed regime for the full E-band spectrum, comprising the frequency bands 71–76GHz and 81–86GHz.[29] This approach has been in place since August 2014. The principal use expected of the spectrum is for point-to-point links as part of high-capacity mobile backhaul networks for 2G/3G/4G services. At the time of implementing the self-coordinated approach, the TRAI indicated that it did not believe it was practical to adopt a coordinated, interference-managed approach to the band, given the number of License Service Areas (22) and number of mobile telecoms service providers (TSPs) in India which were expected to apply to use the frequencies. Additionally, the TRAI indicated its view that an 'exclusive-basis' assignment approach could lead to hoarding and underutilisation of the spectrum.

Overview

The TRAI's decision published in August 2015 was to make E-band frequencies available for use on a self-coordinated, light licensed basis. In line with ITU-R recommendations that have also been adopted in other regions (e.g. Europe), E-band is available in India based on a 250MHz channel plan, although channels can be aggregated in multiples of this. Each 250MHz channel is charged at a rate

[29] See http://www.trai.gov.in/WriteReadData/Recommendation/Documents/MW%20Reco%20Final29082014.pdf.

of INR10 000 (USD150), but the regulator has opted to apply a 50% discount on fees for the first three years of the band being available. Hence fees are currently INR5000 (USD75).

Once assigned, links must not interfere with pre-existing links (i.e. locations are awarded on a first-come, first-served basis), with newer licensees effectively responsible for ensuring that they do not interfere with existing licensees.

Main uses

Since August 2014, the primary use of E-band frequencies in India has been microwave point-to-point links. However, the band is allocated for use for a number of purposes, as set out in Figure 4.7 below.

Figure 4.7: E-band frequency allocation in India[30] *[Source: DOT National Frequency Allocation Plan, 2015]*

	71–74GHz	74–76GHz	81–84GHz	84–86GHz
Fixed	✓	✓	✓	✓
Fixed–satellite	✓	✓	✓	✓
Mobile	✓	✓	✓	✓
Mobile–satellite	✓		✓	
Broadcasting		✓		
Broadcasting–satellite		✓		
Radio astronomy			✓	✓
Space research		✓	✓	

Summary of licensing process

Licensees are required to register their links in a database that is maintained by the Wireless Planning and Coordination (WPC) department of the DoT in India. An online registration process is available so that licensees can apply via a web portal.

Licence applicants follow an online registration process at www.wpc.dot.gov.in in the appropriate frequency band category, and must also provide the WPC office with a hard copy of the relevant application form and a copy of the printout of their identification documentation. Licensees are notified of the status of their application via the website.

Pricing structure

E-band carriers are charged at INR 10 000 (USD75) per annum for each 250MHz channel applied for (noting that channels can be aggregated in multiples of 250MHz). For the first three years from allocation of the first channel in E-band, a 50% discount is applied (i.e. channels licensed today cost INR5000). This price is to be reviewed in 2019, five years after allocation of the band.

30 See http://www.wpc.dot.gov.in/Docfiles/National%20Frequency%20Allocation%20Plan-2011.pdf.

To avoid spectrum hoarding, a 'use it or lose it' roll-out obligation is associated with the licences, with a 12-month time limit for achieving the roll-out goal. Licensees which fail to meet the obligation may have the spectrum taken back, with link locations assigned to the next applicant on the waiting list.

Interference management and information sharing

Interference analysis is the responsibility of licensees in India. Prior to link registration, licensees are able to use the WPC link database to check for any potential interference. Links are assigned on a 'first-come, first-served' basis and WPC maintains a waiting list for access to specific bandwidths.

4.2.5 Qatar

The Supreme Council of Information and Communication Technology ("ictQATAR") has a wide-ranging mandate which includes overseeing and developing the information and communications technology sector in Qatar. In 2014, ictQATAR established an independent Communications Regulatory Authority (CRA) to encourage and support an open and competitive telecoms market and ensure that consumer rights are protected. The CRA is also responsible for regulating the postal sector and access to digital media, and for regulation of communications, including radio spectrum management. The CRA completed a wide-ranging public review of its policy for allocating and assigning radio spectrum in 2010. All spectrum management activities are being undertaken in light of this policy. The CRA has implemented a self-coordinated, light licensed management regime for 65GHz, 70GHz and 80GHz bands.[31]

Overview

Users of E-band frequencies in Qatar are issued with non-exclusive national licences, allowing them to deploy point-to-point wireless links anywhere within the State of Qatar. There is no individual frequency planning or co-ordination function undertaken by CRA for E-band. A licensee must provide the CRA with technical and location details of planned transmitters at least ten working days prior to any new deployment, in a pre-agreed format, and this information forms a schedule to the national licence.

The envisaged use of E-band is for point-to-point links as part of mobile backhaul networks, or links for the purposes of providing telecoms connections between buildings within an organisation, including offshore. According to the licensing guidelines, eligible applicants for licences are:

- the holders of public mobile telecoms networks and public fixed telecoms networks licences

[31] See http://www.cra.gov.qa/sites/default/files/documents/Guidelines%20for%20Fixed%20Radio%20Spectrum%20Licenses.pdf.

- private network facilities (government and private corporations / companies), for their own inland or offshore private use only.

A maximum effective isotropic radiated power (EIRP) of +55dBW applies in E-band, as well as in the 65GHz band. Licences are issued on the basis of a 250MHz channel plan (noting that licensees can aggregate multiple 250MHz channels up to a maximum of 4.75GHz).

Main uses

Based on information published by the CRA, as well as links, other uses of E-band frequencies in Qatar are as follows.

Figure 4.8: National usage of the 80GHz band in Qatar [Source: Communications Regulatory Authority,[32] 2015]

Operations	71–74GHz	74–76GHz	81–84GHz	84–86GHz
Fixed	✓	✓	✓	✓
FSS (space to earth)	✓	✓		
FSS (earth to space)			✓	✓D
Mobile	✓	✓A	✓C	✓C
MSS (space to earth)	✓			
MSS (earth to space)			✓	
Broadcasting		✓B		
Space research (space to earth)		✓	✓	
Radio astronomy			✓	✓

Key: A = Future civil systems; B = Space science services; C = Radio astronomy applications; D = Future fixed systems.

Summary of licensing process

There is currently no online system in place for the submission of licence applications, and so applicants must be submitted in writing. The 70GHz and 80GHz licence application guidelines and forms are available on the CRA's website.[33]

A summary of the licensing process is as follows:

- A licensee submits an application along with qualifying documentation (identification documents, etc.)

32 See http://www.cra.gov.qa/sites/default/files/documents/Qatar%20National%20Frequency%20Allocation%20Table%20%28QNFAT%29.pdf.

33 See http://cra.qa/sites/default/files/documents/Guidelines%20for%20Fixed%20Radio%20Spectrum%20Licenses.pdf.

- The CRA reviews the application and confirms whether further coordination is required for international coordination purposes
- No coordination between E-band links is undertaken by the CRA, and so if the application can proceed without the need for international coordination (e.g. for offshore links), the link details are recorded in a database and payment is requested.

Pricing structure

The pricing structure for the 70GHz and 80GHz bands is normally available on the CRA website, but at the time of publishing this report it was not listed.[34]

According to a 2013 consultation document, the annual fee per link proposed by CRA for spectrum above 40GHz was QAR500 (USD137).

Interference management and information sharing

Licences are issued based on a condition that neighbouring links must not cause interference to one another, and licensees are expected to resolve interference problems among themselves. Link locations are assigned on a first-come, first-served basis.

4.2.6 Australia

The Australian Communications and Media Authority (ACMA) is the converged regulator for Australia's communications and media industries, overseeing regulation for telecoms, broadcasting, radio communications and the Internet. Its key responsibilities include issuing/renewal of telecoms, broadcasting and radio communications licences, regulating content, planning and management of radio frequency spectrum. ACMA issues three primary forms of spectrum licence depending on the category/band of use – apparatus licences, class licences and spectrum licences. For links, an apparatus licensing regime generally applies, for which various bands are offered for licensing. Under the apparatus licensing regime, individual licences are coordinated and issued by ACMA to licensees who are permitted to operate equipment in the specified band and at specified locations. Frequency coordination is hence undertaken by ACMA for all bands used for links, except for the 57.2–58.2GHz, 71–76GHz, and 81–86GHz bands, which are available on a self-coordinated, light licensed basis.

Overview

For E-band spectrum in Australia, comprising the frequency bands 71–76GHz and 81–86GHz, ACMA has implemented an apparatus licensing regime similar to that for other frequency bands allocated for fixed services use, whereby licences are site-based and available over-the-counter on

[34] See http://www.cra.gov.qa/en/regulatory/spectrum-management/spectrum-licensing/spectrum-fees.

a first-come, first-served basis. In contrast to other frequency bands used for point-to-point links where ACMA undertakes frequency coordination between individual links to avoid interference, in E-band the approach is based on self-coordination of links (i.e. licensees are responsible themselves for ensuring that proposed links do not cause interference to existing ones). This self-coordinated approach has been in place since 2007, with the latest revision of the approach being published in July 2015 (relating to use of the 57.2–58.2GHz band, also on this basis). ACMA indicates that E-band is typically used for high-capacity, short-haul data links.

The management approach implemented by ACMA enables applicants to obtain point-to-point fixed licences rapidly for a one-time issuance cost of AUD493 (USD360), which can be paid upfront or in instalments, plus an annual renewal fee of AUD4 (USD3). A licence is valid for up to five years. An additional annual licence tax is also charged, based on the bandwidth and geographical location of the links (which is further described below).

The licensing process is online enabled, with all required information accessed through ACMA's website.

Main uses

E-band frequencies are currently available in Australia for terrestrial point-to-point links.

The various other radio services[35] with allocations to operate in the 71–76GHz and 81–86GHz band in Australia are shown in Figure 4.9.

Figure 4.9: Radio communication services in the 71–76GHz and 81–86GHz in Australia [Source: Analysys Mason, 2015]

Operations	71–74GHz	74–76GHz	81–86GHz
Fixed	✓	✓	✓
FSS (space to earth)	✓	✓	
FSS (earth to space)			✓
Mobile	✓	✓	✓
MSS (space to earth)	✓		
MSS (earth to space)			✓
SRS		✓	✓
Broadcasting		✓	
BSS			
Radio astronomy			✓

35 See "Australian radiofrequency spectrum allocations chart" http://www.acma.gov.au/~/media/Spectrum%20Transformation%20and%20Government/Publication/pdf/spectrum_chart2013%20pdf.pdf.

Summary of licensing process

The management approach applying for E-band frequencies in Australia is as follows:[36]

- The applicant must carry out frequency self-coordination from an accredited organisation, which then issues a frequency assignment certificate
- Responsibility for interference management rests with the licensee; before registering the link, the licensee needs to check in ACMA's database that the requested location is available
- The applicant should apply for an apparatus licence for each individual proposed link, and include their frequency assignment certificate with their application in order for ACMA to issue the licence
- Point-to-point link details, including transceiver locations, are recorded in ACMA's Register of Radio communications Licences (RRL). The data on the RRL is available for download free of charge.

Pricing structure

There are two types of charge applicable:[37]

- Licence charge: to recover the direct costs associated with spectrum management
  - one-off issuance charge of AUD493 (USD360)
  - annual renewal/instalment charge of AUD4 (USD3)
- Annual licence tax: to recover the indirect costs associated with spectrum management and to provide an incentive for efficient spectrum use
  - This varies with the bandwidth of the spectrum access (per kHz) and the density of the geographical location
  - It can be calculated by multiplying the relevant figure from Figure 4.10 by the bandwidth of the spectrum access (per kHz)
  - The minimum tax is AUD38.60 (USD28)
- Additional charges apply to obtain the frequency assignment certificate, which must be issued by a company accredited by ACMA to undertake radio frequency assessments.

36 See "Radiocommunications Assignment and Licensing Instructions": http://www.acma.gov.au/~/media/Spectrum%20Engineering/Information/pdf/RALI%20FX20%20Millimetre%20Wave%20Point%20to%20Point%20Self%20Coordinated%20Stations.pdf.

37 See "Apparatus License Fee Schedule": http://www.acma.gov.au/~/media/Economics%20Advisory/Information/pdf/Apparatus%20licence%20fee%20schedule%20April%202015.pdf.

Figure 4.10: Annual licence tax (AUD per kHz) by geographical location in Australia [Source: Analysys Mason, 2015]

Spectrum location	Geographical location				
	Australia wide	High density	Medium density	Low density	Remote area
>51.4GHz	0.0115	0.0012	0.0012	0.0001	0.0001

Licences are issued for a maximum duration of five years.

Interference management and information sharing

ACMA records E-band link details in the RRL. This data is available for all to access, to assist in the planning and coordination of future links, without the involvement of ACMA. On its website, ACMA also publishes information on the licences that have been issued and the names of licensees; this information is available for download free of charge.

It is the responsibility of a licensee to self-coordinate its proposed links based on the information available through the RRL and with the help of an accredited person.

The licences carry the condition "*No interference shall be caused to any radio communications station as service and no protection from interference by such stations or services shall be afforded*". The regulator basically expects licensees to cooperate and manage the interference issues without involving ACMA.

Failure to undertake self-coordination causing interference to the proposed links or to other existing links can lead to financial penalties.

4.3 Licence-exempt access to E-band frequencies

As an alternative to using a self-coordinated, light licensed management approach, regulators in the Czech Republic and Mexico have opted to make E-band frequencies available for use on a licence-exempt basis. The difference between these and the self-coordinated approaches described in the previous section is that licence-exempt spectrum can be accessed by an unspecified number of users in a given location (unlike light licensed spectrum, where self-coordination typically gives licensees responsibility to coordinate any new links with existing users in the vicinity of the proposed location). Although licence-exempt spectrum offers maximum flexibility in use (with typically no fees applying), there is a downside to a largely unregulated operating environment (i.e. usage is on a non-interference, non-protected basis, with no knowledge of what other systems are using the spectrum in the same location).

A summary of the approach to E-band in the Czech Republic and Mexico is provided below.

4.3.1 Czech Republic

The CTU (Český telekomunikační úřad or Czech Telecommunication Office) is the regulator for electronic communications and postal services in the Czech Republic. It decided to take a licence-exempt approach to the use of E-band spectrum, where links can be deployed in frequencies between 71–76GHz and 81–86GHz without the need for licensing or fees.

Overview

The licence-exempt or unlicensed approach applied to E-band spectrum in the Czech Republic means that spectrum between 71.125–75.875MHz and 81.125–85.875MHz may be used for point-to-point links without the user needing to apply for an individual authorisation or licence or pay a fee. This is subject to a requirement for the bandwidth occupied by the transmission to be a minimum of 250MHz, and there are a number of power and interference conditions that must be adhered to.[38]

Although individual licences are not issued, potential point-to-point link users in E-band are required to communicate their planned use of the band to the web portal https://vor-kmitocty.ctu.cz. This requires submission of a form providing information including location, antenna height, channel(s) being used, link bandwidth and product name. The submission of this completed form is considered as the authority to commence use of the spectrum.

This unlicensed approach has been in place for the bands 74–76GHz and 84–86GHz since April 2008,[39] and was extended to the full E-band in May 2010.[40] Amendments in 2013 also included definition of the minimal width of occupied bandwidth and a reduction of the spectrum available by including guard bands of 125MHz on both borders of the frequency bands (in accordance with the CEPT plan).

Main uses

In the Czech Republic, E-band frequencies are currently available for use by point-to-point links, both indoor and outdoor. Other services that have E-band allocations in the Czech Republic are set out in Figure 4.2 below.

Figure 4.11: E-band frequency allocation in the Czech Republic[41] [Source: Radio Spectrum Utilisation Plan for the frequency band 59–105 GHz, 2015]

	71–74GHz	74–76GHz	81–84GHz	84–86GHz
Fixed	✓	✓	✓	✓

38 See http://www.ctu.eu/164/download/VOR/VO-R_23_09-2013-05_en.pdf.

39 See http://www.ctu.eu/164/download/VOR/VOR-23-04-2008-4-AN.pdf.

40 See http://www.ctu.eu/164/download/VOR/VOR-23-05-2010-7-AN.pdf.

41 See http://www.ctu.eu/164/download/Measures/General_Nature/RSUP/CZE_RSUP-P-23-02-2010-04_eng.pdf.

	71–74GHz	74–76GHz	81–84GHz	84–86GHz
Fixed–satellite	✓	✓	✓	✓
Mobile	✓	✓	✓	✓
Mobile–satellite	✓		✓	
Broadcasting		✓		
Broadcasting–satellite		✓		
Radio astronomy			✓	✓
Space research		✓	✓	

Pricing structure

Due to the unlicensed nature of the CTU's approach to E-band there are no fees associated with using this spectrum in the Czech Republic.

Interference management and information sharing

It is the responsibility of the operator of the links to avoid harmful interference with existing links deployed by other providers, as well as other parties that use the spectrum for different services (for example, fixed satellite and radio astronomy services). If harmful interference is caused to any user of the spectrum for different services, the operator of the affected point-to-point link(s) is responsible for making the necessary modifications to its system in order to minimise the interference. If this does not happen, the regulator has the authority to terminate the use.

The technical data provided by the point-to-point link operator is released publicly on the CTU website, so that the operators can prevent and resolve any instances of interference between themselves.

4.3.2 Mexico

The telecoms regulator in Mexico, Instituto Federal de Telecomunicaciones (IFT), is an independent body which operates under the country's transport and communications ministry (SCT). It is responsible for regulating, promoting and overseeing the development and near-universal coverage of telecoms and broadcasting services in Mexico, and replaces the formerly Comisión Federal de Telecomunicaciones. IFT has made frequencies available in E-band, comprising the 71–76GHz and 81–86GHz bands, on a licence-exempt basis.[42] This approach has been in place since March 2012 and allows the spectrum to be used for the operation of fixed point-to-point systems with no spectrum fees applying.

[42] See http://www.ift.org.mx/sites/default/files/contenidogeneral/espectro-radioelectrico/espectro-radioelectrico-en-mexico-vp.pdf.

Overview

IFT has made E-band spectrum licence exempt for use by point-to-point links[43]. This system has been in place for use of the 71–76GHz and 81–86GHz spectrum since the Agreement of 9 March 2012 passed into law.[44] Power limits and antenna conditions are stipulated within the licence-exemption regulations, which users must adhere in order to prevent interference.

Main uses

E-band has been available on a licence-exempt basis for point-to-point use in Mexico since 2012. The band is allocated for use for a number of purposes, as set out in Figure 4.12 below.

Figure 4.12: E-band frequency allocation in Mexico[45] [Source: DOT National Frequency Allocation Plan, 2015]

	71–74GHz	74–76GHz	81–84GHz	84–86GHz
Fixed	✓	✓	✓	✓
Fixed–satellite	✓	✓	✓	✓
Mobile	✓	✓	✓	✓
Mobile–satellite	✓		✓	
Broadcasting		✓		
Broadcasting–satellite		✓		
Radio astronomy			✓	✓
Space research		✓	✓	
Amateur			✓	
Amateur–satellite			✓	

Pricing structure

As E-band is to be used without licence permit or registration, there is no cost associated with its use.

Interference management and information sharing

Licence-exempt operation is on a no-interference, no-protection basis. It is up to the point-to-point link provider to ensure that its operations do not cause harmful interference to any other users of the spectrum. There is a specific requirement to protect the operation of radio astronomy observations based at the Large Millimeter Telescope in the Sierra Negra Volcano-Pico de Orizaba. To protect this installation, no links can be deployed within a 100km radius of the observatory.

43 See http://www.ift.org.mx/espectro-radioelectrico/bandas-de-frecuencias-del-espectro-radioelectrico-de-uso-libre.

44 See http://dof.gob.mx/nota_detalle.php?codigo=5237903&fecha=09/03/2012.

45 See http://www.ift.org.mx/sites/default/files/contenidogeneral/espectro-radioelectrico/cnaf-cft-28022012-1.pdf.

5 Summary of findings and conclusions

The objective of this study has been to survey the management approaches being implemented for access to E-band frequencies around the world, with a view to identifying the most commonly used and preferable approach(es) to apply, in the context both of the use of E-band spectrum for point-to-point links as well as new and innovative uses beyond conventional fixed point-to-point links. A summary of our key findings and conclusions is provided below.

5.1 Summary of findings

Our key findings in each of the main areas of review – main uses of the band (including uses other than links), licensing approach and spectrum fees– are summarised below.

Main uses

All of the countries surveyed where E-band frequencies are available for use have made the band available for use by fixed point-to-point links. The technical conditions of use vary between countries but the band is typically available for use in channels of 250MHz (which can be aggregated to provide wider channels as required to match the capacity requirements of the link). These channel sizes are sufficiently large compared to those in lower-frequency bands allocated for fixed services use that they create the capability to support very high capacity (high data rate) links. Based on the propagation characteristics of E-band, usage will typically be short hop, high-capacity links (although it has been noted in a number of publications issued by regulators that the location of E-band above the oxygen absorption peak at 60GHz is such that the typical range of an E-band link can be similar to links operated in fixed services bands such as 38GHz.

Although E-band is allocated internationally for terrestrial fixed service use, there are a number of other allocations applying in different parts of E-band, such as for fixed satellite services, mobile services, radio location (i.e. military) and radio astronomy. A number of the countries surveyed for this report have put in place particular coordination measures to protect operation of radio astronomy observatories for example (e.g. in the USA and Mexico). Although the band includes allocations for fixed satellite and mobile services, we are not aware of any countries where these services are in operation in E-band and it is clear from the study that the principal use is for point-to-point links.

Licensing approach

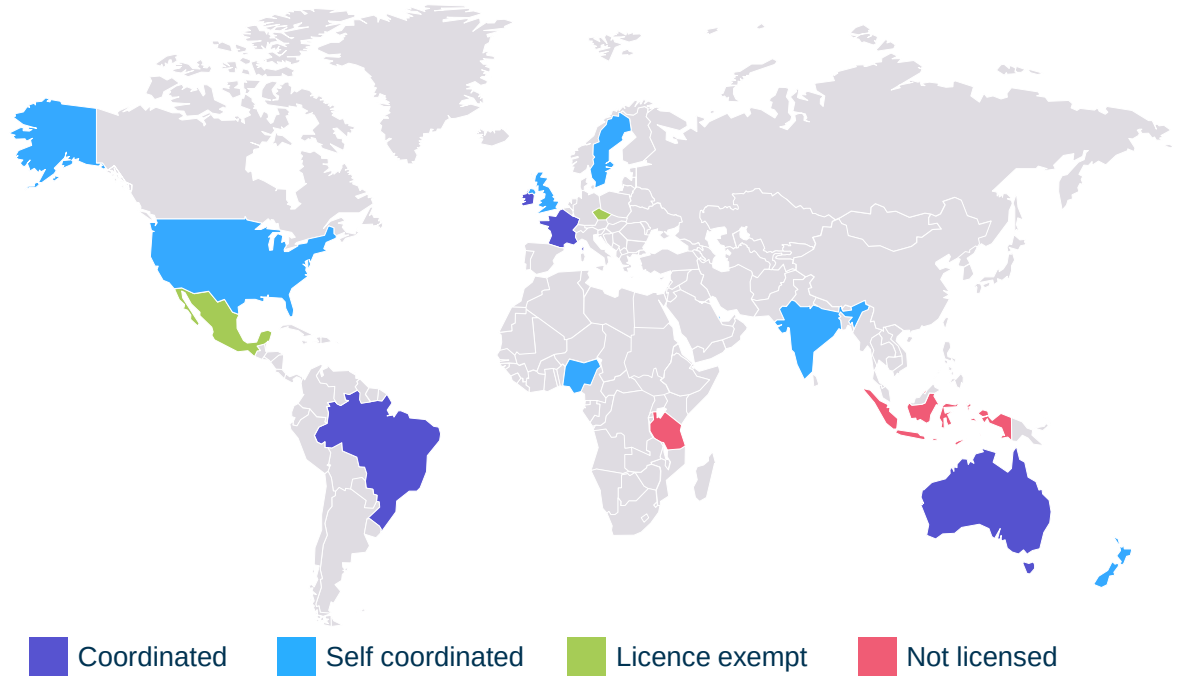
From the survey, we gauged that a number of the countries considered (France, Sweden, New Zealand, Ireland and Brazil) have implemented a management approach for E-band frequencies that is similar to other frequency bands allocated for fixed services use below 60GHz (i.e. requiring links to be individually coordinated and interference managed). A growing number of countries are using self-coordinated, light licensed approaches to E-band spectrum use,

including the USA, the UK, Nigeria, India, Qatar and Australia. We have identified two countries – the Czech Republic and Mexico – where use of E-band frequencies for links is on a licence-exempt (unlicensed) basis.

Contact with regulators in some of the markets surveyed indicated that a licensing regime is not yet in place for E-band, although it might be under consideration – Indonesia and Tanzania fall into this category. We were not able to find accurate information formally confirming the status of E-band licensing in the DRC, Peru or the Philippines, although our understanding is that E-band has not yet been opened for licensing in these markets.

The range of licensing approaches applying within the countries surveyed as part of the study is illustrated below.

Figure 5.1: Illustration of E-band management approaches adopted in countries surveyed [Source: Analysys Mason, 2015][46]



Spectrum fees

We have found that the fees associated with E-band use vary depending on the type of management approach being applied, with E-band links in countries where the band is assigned via self-coordinated, light licensing typically charged at lower cost than in countries where a coordinated, interference-managed approach is used by the regulator. However, it is noted that even in countries where coordination is applied, licensing fees are still typically lower for E-band links compared to links deployed in other frequency bands (e.g. Ireland and New Zealand). In the

46 We also surveyed the status of E-band in the Philippines, Peru and the DRC, but were unable to find complete information to develop case studies.

two countries where E-band frequencies are available for use on a licence-exempt basis, there are no spectrum fees.

A summary of fees in each of the countries surveyed, split according to fees paid upon application, registration fees (where applicable)[47] and licence fees, is shown in Figure 5.2 below.

Figure 5.2: Fees associated with E-band licensing [Source: Analysys Mason, 2015]

Market	Application fee (USD)	Registration fee (USD)	Licence fee (USD)
USA	290	150	-
Australia	-	Minimum of 27, varying by bandwidth and location density	350
New Zealand	-	-	135
UK (self-coordinated frequencies 73.375–75.875GHz and 83.375–85.875GHz)	75 (inclusive of the first link registration cost)	75 for every subsequent link	-
UK (fully managed frequencies 71.125–73.125GHz and 81.125–83.125GHz)	-	Varies by bandwidth from 150 for licences of <250MHz to 1350 for licences of 1000MHz	-
Czech Republic	No fee	No fee	No fee
France	-	107	Variable amount based on modulation and channel size, e.g. USD512 for 250MHz with 16/32 QAM
Sweden	80 per hour of administration time	52 per transmitter	-
India	-	75 (for the first three years, from 2014), 150 thereafter	-
Mexico	No fee	No fee	No fee
Brazil	No information		
Qatar	-	137 per link	-
Ireland	-	-	Varies by bandwidth: <3.5MHz costs USD107 while >40MHz costs USD161
Nigeria	USD50	USD72 for 250MHz	-
Peru	No information		
Indonesia	Licensing regime not yet in place		

47 Registration fees apply to the fee to register the location of links within the national licensing database, if required based upon the management approach for E-band being used in that country.

Market	Application fee (USD)	Registration fee (USD)	Licence fee (USD)
Tanzania	Licensing regime not yet in place		
Philippines	No information		
DRC	No information		

Interference management and information sharing

The approach to interference management varies depending on the management approach that has been implemented for access to the band. For countries where the band is available on a licence-exempt basis, there is no interference management and operation is on a 'best-effort' (no-interference, no-protection) basis. For countries where self-coordination is applied, responsibility for interference management rests with the licensee, and in countries where links are individually coordinated, interference assessment is typically undertaken by the regulator.[48]

There is a general trend towards making licensing information available online, but so far the licensing process for E-band is fully automated only in the USA, Australia and India (in India, paperwork must also be submitted manually in addition to online application). In the UK, Nigeria and Qatar, the regulator has indicated its intention to develop fully automated online systems for E-band licensing but manual processes are being applied until such time as the online systems are available. In the Czech Republic, although use of E-band frequencies is on a licence-exempt basis, the regulator publishes information online on the use of the band (based on fixed services operators being required to register the E-band frequencies they use in an online system), although there is no obligation on users to cooperate on interference resolution (unlike in the countries where self-coordination applies).

5.2 Conclusions

Based on the survey conducted for this study, we can draw the following conclusions:

- E-band is allocated on an international basis for use by fixed services. The countries that have opened the band for licensing have generally made the band available for point-to-point use. In establishing this use, regulators have generally been influenced by the properties of E-band frequencies (large bandwidth, short propagation range), which make the band particularly suited to delivery of high-capacity wireless links.

- The channel sizes used in E-band (commonly multiples of 250MHz, based on ITU-R and CEPT recommendations) are sufficiently large compared to those used in frequency bands available for fixed services use lower in the spectrum that they create the capability to support very high-capacity (high data rate) links. Thus, the band is ideally suited to provide the sort of high-capacity backhaul link required in 4G mobile networks and other high-capacity systems.

[48] The exception to this is New Zealand, where applicants must obtain a frequency coordination certificate from an authorised third-party assessor.

- It is generally recognised that the properties of frequencies in E-band present an opportunity for regulators to implement point-to-point wireless licensing with simplified coordination procedures compared to the traditional methods of coordinating individual links against high availability criteria that are typically applied in other fixed services frequency bands (lower in the spectrum). In one of the countries we surveyed (the UK), the regulator recently decided to reserved part of E-band for links assigned on a coordinated, interference managed basis (whereas previously all of the E-band frequencies available for use in the UK were managed on a self-provided basis). The UK regulator, Ofcom, indicated in a consultation document issued to propose the changes that the reason for reserving part of the band for coordinated, interference managed links is that some users of the band (mainly mobile operators) had expressed a view that the regulator should be more involved in frequency coordination of links in order to increase certainty that links will not suffer interference. This would be important for these users since links are being used within public mobile networks, requiring high levels of link availability and greater certainty on interference-free operation.

- Although located high in the millimetre-wave region of the radio spectrum, where signal absorption levels are high, E-band is located above the oxygen absorption peak occurring at around 60GHz and hence the usefulness of E-band (in terms of the operating ranges that are possible) is more similar to fixed services bands around 30–40GHz.

- In countries where E-band is available for use, the spectrum fees applying per link do not typically represent a barrier to use, typically being lower than those applying in fixed services frequency bands lower in the spectrum. Where self-coordinated, light licensed approaches are used, fees are typically per link (rather than on a per-MHz basis), in recognition of the physical properties of E-band making it particularly suited to delivery of high-bandwidth links.[49] This applies irrespective of the management approach to the band in some cases (e.g. in Ireland, where low spectrum fees apply despite the band being administered on a coordinated, interference-managed basis).

- In principle it is noted that in many markets, although spectrum is earmarked for point-to-point use, there is the potential for other innovative wireless uses to make use of the same spectrum provided these can be shown to be compatible with existing point-to-point use (i.e. the self-coordinated approach to licensing typically works on a first-come, first-served basis, with incoming licensees having to ensure that their systems do not interfere with existing ones. Hence there is the possibility of innovative uses being facilitated, providing these do not interfere with the existing use as established by the online databases). None of the countries surveyed as part of this work showed existence of such innovative uses at present.

- Use of E-band frequencies is still emerging in some markets (and the band is yet to be opened for use in some markets, despite an allocation for link use applying internationally). Hence although we have found limited evidence that outcomes in terms of use of the band are

[49] This reflects the fact that fee structures are designed to encourage the most efficient use, which in E-band can include deployment of high-bandwidth links without disadvantaging other users.

strongly influenced by the licensing approach, it is to be expected that the self-coordinated, light licensing approaches being implemented in a growing number of markets should reduce the cost and administrative barriers for new users to deploy systems in E-band, encouraging uptake. Furthermore, increasing update in use of E-band incentivised by light licensing should not compromise the integrity or usability of the band, thanks to its physical properties.

Annex A Abbreviations used in this report

Figure A.1: List of abbreviations [Source: Analysys Mason, 2015]

Abbreviation	Meaning
ACMA	Australian Communications and Media Authority
CEPT	Conference of Postal and Telecommunications Administrations
CRA	Communications Regulatory Authority of Qatar
CTU	Český telekomunikačníúřad or Czech Telecommunication Office
dBW	Decibels relative to a Watt
DoT	Department of Telecommunications in India
E-band	Part of the Extremely High Frequency (EHF) band internationally, broadly 30–300GHz. E-band is specifically the frequencies from 71–76GHz and 81–86GHz
ECC	European Communications Committee
EIRP	Effective Isotropic Radiated Power
FCC	Federal Communications Commission of the USA
GBP	Great British Pound
GHz	Giga Hertz i.e. one billion hertz
IFT	Ifetel (Mexico)
INR	Indian Rupees
ITU	International Telecommunication Union
ITU-R	Radio communications sector of the ITU
MHz	Mega Hertz, i.e. 1 million hertz
QAM	Quadrature Amplitude Modulation
TRAI	Telecom Regulatory Authority of India
USD	United States Dollar
WPC	Wireless Planning and Coordination (function of the DoT in India)