Managing the spectrum above 275 GHz

A statement on the licence-exempt use of the 275-3000 GHz band

Statement

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Contents

Section 1

Executive Summary

1.1 In December 2007, we published the Licence Exempt Framework Review (LEFR) Statement describing our policy on managing spectrum used by licence-exempt devices. One of the recommendations of the LEFR Statement was to open higher frequency bands for licence-exempt use.

1.2 The spectrum at high frequencies is characterised by severe atmospheric attenuation due to oxygen and water molecules, amongst other factors. To improve the link budget, directional antennas are used. Due to these factors and the large swathes of frequency available, the probability of harmful interference at high frequencies is low.

1.3 In this document, we propose to release the 275-3000 GHz band for licence-exempt use, subject to certain constraints such as power limits and excluding bands specified by Footnote 5.565 of the Radio Regulations for spectral line measurements. However, as Footnote 5.565 will be reviewed at the 2011 World Radiocommunication Conference (WRC-11), it will be premature to release this spectrum until the results of that conference are known. Hence, we propose to enact appropriate legislation after WRC-2011.

1.4 Given the low probability of harmful interference in the 275-3000 GHz band, our duty under Section 8(3) of the Wireless Telegraphy Act, is to make this band available for licence-exempt use. In addition, taking such an approach may encourage innovation and the emergence of new applications while reducing regulatory overheads.

1.5 The spectrum above 275 GHz is mainly used by the scientific community (radio-astronomy, space research and earth exploration satellite services) for spectral line measurements. However, other potential uses for the band include short range anti-collision radar devices, detection of skin cancer and other non destructive evaluation methods used in industrial processes.

1.6 We have used the power limits associated with non-generic short range devices (SRDs) in the 244-246 GHz band as a proxy for the power limit at 275 GHz. We believe that non-generic SRDs are a suitable proxy given that devices in the band of interest are likely to be short range and potentially be used for a range of applications. However, we propose to extrapolate this power limit appropriately for frequencies above 275 GHz to account for increased path loss with frequency.

Section 2

Introduction

Background

2.1 In December 2007, we published the Licence Exempt Framework Review (LEFR) Statement[1] describing our policy on managing spectrum used by licence-exempt devices. One of the recommendations of the LEFR Statement was to allow use of the spectrum in the 275-1000 GHz frequency range by licence-exempt devices, excluding frequencies used by radio-astronomy (RAS), space research (SRS) and earth exploration satellite services (EESS) as specified by Footnote 5.565 of the Radio Regulations. This footnote lists a number of bands occurring in the 275-1000 GHz frequency range used by the above passive services and urges administrations to protect these services.

2.2 Given the low probability of harmful interference in the 275-3000 GHz band, it is our duty under Section 8(4) of the Wireless Telegraphy Act to make this band available for licence-exempt use. In addition, taking such an approach may encourage innovation and the emergence of new applications while reducing regulatory overheads.

2.3 In September 2008, Ofcom consulted on proposals to make spectrum in the 275-3000 GHz band (excluding bands specified by Footnote 5.565) available for licence-exempt use. Stakeholder responses have been received.

Purpose of this document

2.4 The purpose of this Statement is to confirm our policy with respect to licence-exempt use above 275 GHz and to highlight that the implementation of this policy will occur after the WRC-11 conference.

2.5 We now intend to move forward with the proposals set out in the consultation document but with revised timing. Instead of moving ahead immediately we will await the outcome of the 2011 World Radiocommunication Conference (WRC-11) which plans to revise Footnote 5.565 (The new version of Footnote 5.565 is termed 'updated Footnote 5.565'). Given the high likelihood of such a decision and potential difficulties in re-allocating frequencies previously used by licence-exempt devices, it is sensible for the policy in the spectrum above 275 GHz to reflect the changes to Footnote 5.565 at the WRC-11 conference that are actually made. In this respect, Ofcom proposes to publish licence-exempt regulations in the 275-3000 GHz band after the WRC-11 conference.

2.6 Based on the *current* Footnote 5.565, the candidate bands to be made available for licence-exempt use are: 444-453 GHz, 510-546 GHz, 568-623 GHz, 711-730 GHz, 732-795 GHz, 909-926 GHz, 945-951 GHz and 956-3000 GHz. However, any revision to the current Footnote 5.565 could result in different bands from those stated above to be available for licence-exempt use.

Structure of this document

2.7 This document is structured as follows:

[1] http://www.ofcom.org.uk/consult/condocs/lefr/lefr_statement/

- Section 3 describes the current regulatory status of the spectrum of interest, the characteristics and uses of this spectrum.

- Section 4 outlines our policy decisions for the spectrum in the 275-3000 GHz band.

- Our impact assessment is set out in Annex 1 and Ofcom's views to the stakeholders' responses to the consultation are given in Annex 2.

Section 3

The 275-3000 GHz band

Introduction

3.1 Sandwiched between the infra-red and microwave (more precisely millimetre wave) parts of the spectrum is the region known as the Terahertz (THz) gap as shown in Figure 3.1 below. The 275-3000 GHz frequency range under consideration in this Statement is within the terahertz band.

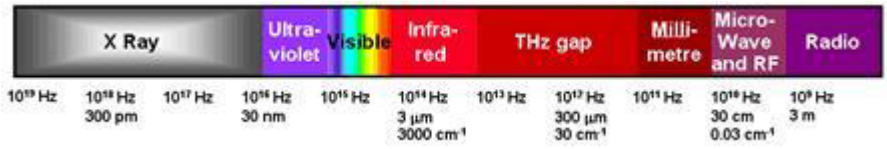


Figure 3.1: Electromagnetic spectrum showing the Terahertz region (Source: HT Consultants[2])

3.2 In this Section, we first give a brief overview of the current situation at ITU and European levels pertaining to the 275-3000 GHz band before describing the current regulatory status of this spectrum in the UK. Then, we outline the propagation characteristics and technology constraints of the spectrum above 275 GHz. Finally, we provide an overview of the uses of this spectrum.

Regulatory status of the spectrum

3.3 Article 5 of the Radio Regulations contains a table of frequency allocations (also referred to as the ITU Frequency Allocation Table) where spectrum between 9 kHz to 275 GHz is allocated to a range of radiocommunication services. However, there is no spectrum allocation beyond this upper limit but Footnote 5.565 of the Radio Regulations is relevant to the spectrum in the 275-1000 GHz band. Footnote 5.565, which is described later in this Section, relates to the protection of spectral line measurements used by passive services such as radio astronomy, space research service and earth exploration satellite service.

3.4 Following a consultation in 2008, the European Table of Frequency Allocations (ERC Report 25) has been extended to 3000 GHz. Although no services are allocated to the spectrum above 275 GHz, Footnote 5.565 is applicable to the 275-1000 GHz band.

3.5 In the UK, radio spectrum is regulated by the Wireless Telegraphy Act (WT Act) 2006. Section 8 of the WT Act 2006 allows the use of a wireless telegraphy apparatus under a wireless telegraphy licence, unless the said apparatus is exempted by appropriate regulation. The definition of wireless telegraphy as given in Section 116 of the WT Act 2006 encompasses the emission and reception of electromagnetic energy up to a frequency of 3000 GHz[3,4].

[2] www.htconsultants.com
[3] According to Section 116(3) of the WT Act 2006, the Secretary of State may by order modify the definition of wireless telegraphy by altering the frequency limit.

3.6 In the absence of any exemptions, use of the 275-3000 GHz band in the UK currently requires a wireless telegraphy licence.

Propagation and technology constraints

Propagation constraints

3.7 When radio waves travel through the Earth's atmosphere, they interact with the gaseous molecules therein resulting in an attenuation of the signal. Below 10 GHz, gaseous absorption levels can be assumed to be negligible[5]. However, as shown in Figure 3.2, this attenuation tends to increase with frequency, with peaks at certain frequencies corresponding to the resonance frequency of molecules such as oxygen and water vapour among others.

3.8 A key characteristic of the spectrum above 275 GHz is the high gaseous absorption levels which can be around a few hundreds of dB per kilometre at frequencies above 500 GHz (see Figures 3.2 and 3.3).

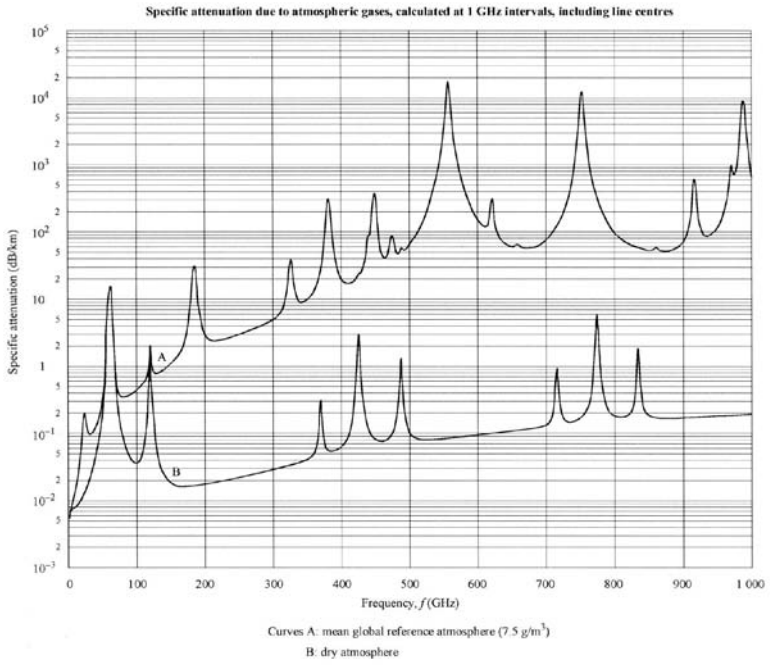
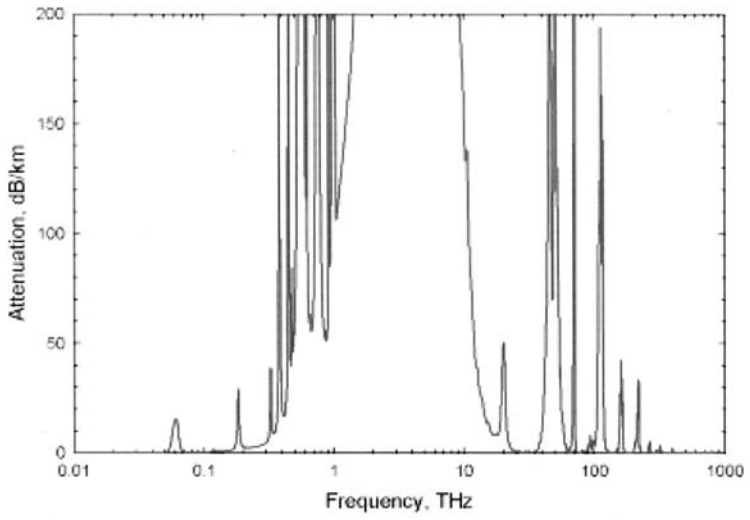


Figure 3.2: Specific attenuation due to atmospheric gases up to 1000 GHz (Source: ITU-R P. 676-5[6])

[4] This is in line with the definition of radio waves given by the Radio Regulations. Item 1.5 of Article 1 of the Radio Regulations defines radio waves as "*electromagnetic waves of frequency arbitrarily lower than 3000 GHz, propagated in space without artificial guide*".
[5] www.mike-willis.com/Tutorial/gases.htm
[6] 'Attenuation by atmospheric gases', ITU-R P.676-5.



Specific attenuation at sea level
(Pressure = 1013.25 hPa, temperature = 15°C, water-vapour density = 7.5 g/m^3)

Figure 3.3: Specific attenuation due to atmospheric gases over the frequency range of 10 GHz to 1000 THz (Source: Norbury *et al*[7])

3.9 In addition, outdoor wireless systems at such high frequencies may have to cope with rain attenuation and other effects such scintillations[8]. Rain can have a critical effect, particularly, in cases where high availabilities are required.

3.10 The LEFR Statement noted that at frequencies beyond 40 GHz, radio waves are increasingly subject to line-of-sight propagation because of attenuation due to obstructions and atmospheric loss due to gaseous and water vapour absorption. Due to these attenuations, wireless systems at such frequencies are likely to have limited range.

Technology constraints

3.11 As mentioned by Norbury *et al* in a report by the Rutherford Appleton Laboratories (see footnote 9), terahertz technology development has been mainly driven by scientific applications such as radio astronomy and remote sensing. While devices up to at least 1000 GHz have been demonstrated, the authors note that they remain highly specialised, expensive and limited in performance.

3.12 In fact, according to their survey of transmitter and receiver technologies, few demonstrations of radio technology have been made above 1500 GHz. According to the literature (see Siegel's paper), it is clear that the development of transmitters has been slower than that of receivers or sensors. A key challenge is to have sufficiently powerful and compact sources. The consultants at RAL identified that generating even modest power levels (of the order of tens of milliwatts) in the 100-1000 GHz range was a challenge but pointed out that with technological development, this might change. Although more expensive, an increase in power levels might be

[7] J. Norbury, C. Gibbins and D. Matheson, 'A theoretical appraisal of the highest usable frequencies', Rutherford Appleton Lab, May 2003.
[8] Scintillations are caused by turbulence in the atmospheric boundary layer.

achieved by combining multiple sources. More recently, Hwu *et al*[9] have highlighted a promising approach to achieve small size but relatively high power sources using micro-fabrication techniques to manufacture vacuum electronic terahertz sources.

3.13 The consultants at RAL also highlighted that the main reason for the difference in cost between terahertz and microwave devices was essentially due to the niche market at high frequencies such that economies of scale were not achieved.

Uses of the spectrum

3.14 The spectrum above 275 GHz is mainly used by passive services for spectral line measurements. Molecules of various compositions radiate energy at a series of discrete frequencies or spectral lines. Each molecule generates a specific set of spectral lines which are used by scientists to identify the radiating source.

3.15 While Footnote 5.565 allows administrations to use the 275-1000 GHz frequency band for experimentation and development of various active and passive services, it urges administrations to take all practicable steps to protect passive services from harmful interference until the date when the allocation table is established in the 275-1000 GHz band.

3.16 The bands specified by Footnote 5.565 are used by the following passive services: radio astronomy[10], space research service and earth exploration satellite service (EESS)[11]. Currently, the bands listed under Footnote 5.565 are: 275-444 GHz, 453-510 GHz, 546-568 GHz, 623-711 GHz, 730-732 GHz, 795-909 GHz, 926-945 GHz and 951-956 GHz. These allocations, shown in blue in Figure 3.4, comprise some 476 GHz[12] in total and represent 66 % of the spectrum at 275-1000 GHz and 17 % of the spectrum at 275-3000 GHz.

[9] R. J. Hwu and L. Sadwick, 'Terahertz sources and applications', Asia Pacific Microwave Conference (APMC) Proceedings, Vol. 5, December 2005.
[10] The bands allocated to radio astronomy are: 275-323 GHz, 327-371 GHz, 388-424 GHz, 426-442 GHz, 453-510 GHz, 623-711 GHz, 795-909 GHz and 926-945 GHz. These bands account for a total bandwidth of 422 GHz.
[11] The bands allocated to EESS and Space research service are: 275-277 GHz, 294-306 GHz, 316-334 GHz, 342-349 GHz, 363-365 GHz, 371-389 GHz, 416-434 GHz, 442-444 GHz, 496-506 GHz, 546-568 GHz, 624-629 GHz, 634-654 GHz, 659-661 GHz, 684-692 GHz, 730-732 GHz, 851-853 GHz and 951-956 GHz. These bands account for a total bandwidth of 155 GHz
[12] Note that the radio astronomy service shares certain bands with the Earth exploration satellite and space research services

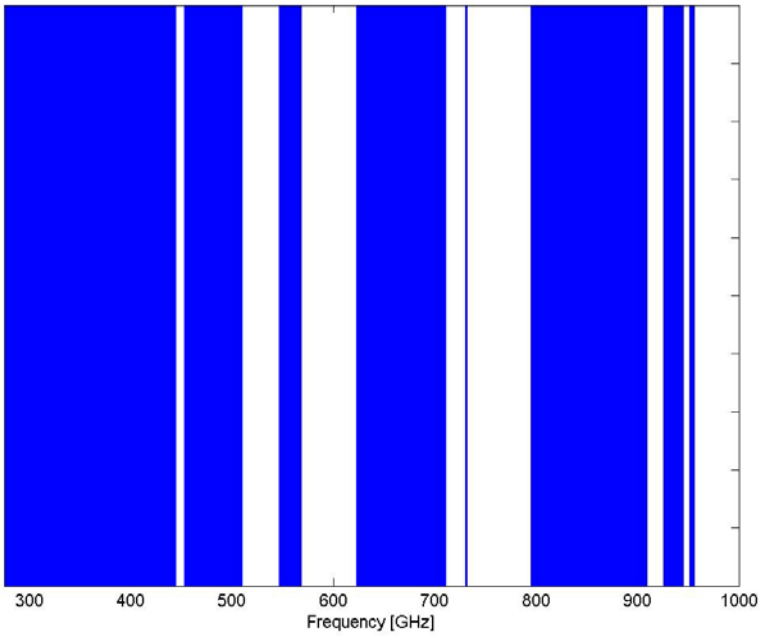


Figure 3.4: Bands (shown in blue) specified by Footnote 5.565 for spectral line measurements by passive services (radio astronomy, space research service and earth exploration satellite service).

3.17 According to the Committee on Radio Astronomy[13] (CRAF), there are only two observation sites in Europe (in France and Spain) using the 275-1000 GHz band. These sites are typically located at high altitudes to minimise attenuation due to the atmosphere. Although there are no observation sites in the UK, we understand from UK radio astronomers that the bands specified for radio astronomy in Footnote 5.565 are used in the development of equipment.

3.18 While receivers used for radio astronomy are directed towards space to, say, identify the composition of galaxies etc, receivers onboard satellites used by the earth exploration satellite service are directed towards the Earth's surface for remote sensing purposes. If we were to allow low power use of the spectral line bands designated for the earth exploration satellite service, this might be problematic given the very low wanted signals encountered in remote sensing and the receiver pointing to the source of interference. We note that while receivers used for observation by the space research service are likely to be in orbit and pointing to outer space, the space research service share the same bands for spectral line measurements as the earth exploration service.

3.19 The aforementioned services are not the only users of the spectrum above 275 GHz. In fact, applications in fields such as medicine and security are possible due to the properties of terahertz waves. These waves are able to penetrate materials that are usually opaque to both visible and infra-red radiation. Although, terahertz waves are absorbed by metals or water, they can penetrate through fabrics, plastics, paper or

[13] www.craf.eu

oil among others[14]. Terahertz technology can be used for a wide range of applications[15] in the fields listed below:

- Medical: Detection of skin cancer by the reflection of terahertz waves off cancerous tissues.

- Industrial applications: Non destructive evaluation methods such fault analysis of large-scale integrated circuits using a laser THz emission microscope (LTEM), the fault detection of heat insulation panels or monitoring the water content of fruits/vegetables to assess damage.

- Security: Detection of explosives and narcotics based on their distinct signature in the terahertz spectra. In addition, hazardous gas such as carbon monoxide can be detected at fire sites where infra-red gas detection is not appropriate.

3.20 The above list comprises a mix of active and passive applications which are characterised by a short range of operation (a few metres) and are mostly expected to operate in a controlled environment (e.g. a laboratory). Hence, it is reasonable to envisage licence exemption for the use of spectrum by these applications.

3.21 The Rutherford Appleton Laboratories (RAL) report assessed the suitability of a range of communication systems in the 100-1000 GHz frequency. Based on the link budget, an estimate of the maximum operating frequency limit at which an application can be used is given in brackets as shown below.

- Short range point-to-point fixed links (up to ~ 440 GHz)

- Aircraft to satellite links (up to ~ 350 GHz)

- Indoor Gigabit WLAN (up to ~ 300 GHz)

- Short range radar (up to ~ 900 GHz)

3.22 Overall, the first three applications listed in paragraph 3.21 cannot operate beyond a frequency of about 440 GHz. However, the spectrum at 275-440 GHz falls within the bands protected by Footnote 5.565 (See paragraph 3.16) which cannot be used by the short range point-to-point fixed links, aircraft to satellite links and indoor Gigabit WLAN applications. Hence, these three applications will not be using the spectrum above 275 GHz under our current policy decision.

3.23 However, the short range radar application which can operate up to a maximum frequency of around 900 GHz can potentially use the spectrum above 275 GHz which is not currently protected by Footnote 5.565 (although this may change depending on the revision to Footnote 5.565 at the WRC-11 conference). In their report[16], Quotient Associates concluded that short range radar applications at high frequencies were suited to a licence-exempt regime and the high spatial/time resolution could be of assistance to drivers.

[14] I. Hosako *et al*, 'At the dawn of a new era in terahertz technology', Proceedings of the IEEE, Vol. 95, No. 8, pp. 1611-1623, August 2007.
[15] M. Tonouchi, 'Prospect of terahertz technology', 19th International Conference on Applied Electromagnetics and Communications, September 2007.
[16] 'Higher frequencies for licence-exempt applications', Quotient Associates, Indepen and University of York, February 2007.

3.24 Proof of concept of some of the applications mentioned in this section has been achieved in the terahertz band but it may take a while before some or all of the applications become common place. Key factors influencing this outcome are advances made in the terahertz technology and cost of manufacturing devices using this technology.

Section 4

Licence exempt use of the 275-3000 GHz band

Introduction

4.1 The LEFR Statement sets out two situations when use of a band should be licence-exempt, namely:

- The economic value derived from the band under a licence-exempt use is greater than the corresponding value if the spectrum was for a licensed use; or
- Harmful interference is unlikely (e.g. where the demand for spectrum in a given frequency band is less than the supply) such that the administrative overhead of licensing is unnecessary.

4.2 We next explain the basis on which our policy with respect to spectrum above 275 GHz was derived by assessing a range of options. Subsequently we present, in details, the implementation of our preferred option.

Assessment of the options

4.3 In the main, we list three policy options that can be applied to the frequency band of interest.

- **Option 1**: Do not change the regulatory status of the spectrum in the 275-3000 GHz band until such time there is clear evidence of demand.
- **Option 2**: Release the entire spectrum in the 275-3000 GHz band for use by licence-exempt devices.
- **Option 3**: Release the spectrum in the 275-3000 GHz band for use by licence-exempt devices, excluding the bands identified for spectral line measurements in Footnote 5.565.

4.4 Essentially, Option 1 is about maintaining the status quo whereby use of the 275-3000 GHz band requires a licence. As mentioned earlier, there are two (economic and interference) criteria to determine whether use of a band should be made licence-exempt or should be licensed. We assess Option 1 in the light of these criteria.

4.5 From our review of the uses of the 275-3000 GHz spectrum in Section 3, it is clear that the technology for this frequency range is still under development. At this stage, a set of applications (excluding scientific use) suitable to such a band is still tentative, let alone the applications that will eventually be using the band in the future. Given this situation, we believe that it is unreasonable to apply the economic criterion in determining the spectrum management approach to the 275-3000 GHz band.

4.6 Regarding the interference criterion, the studies (report by Quotient Associates and others) commissioned by Ofcom in preparation of the LEFR indicate that radio congestion and hence harmful interference are unlikely above 105 GHz. The LEFR

consultation document[17] listed three reasons to substantiate a lower likelihood of congestion[18] at higher frequencies. The reasons are:

- The high propagation loss limits the range of the interfering signals.
- Use of directional antennas at high frequencies mitigates the impact of interference.
- Large swathes of frequency imply a low probability of co-channel collision.

4.7 There is therefore a low probability of harmful interference caused by licence-exempt devices in the spectrum above 275 GHz. Under Section 8(4) of the Wireless Telegraphy Act 2006 (WT Act 2006), it is our duty to make exemption regulations for the use of stations or apparatus that is unlikely to involve undue interference. Hence, we do not favour Option 1.

4.8 In addition, we do not believe a spectrum reserve for licensed or light-licensed use is justified in the 275-3000 GHz band. As argued in the LEFR Statement, a spectrum reserve above 275 GHz can only be justified if an application is expected to emerge in the future with the following characteristics:

a) It is unable to operate in the presence of other co-channel uses.

b) It cannot be accommodated at other frequencies.

4.9 Of the potential applications for the terahertz band as discussed in Section 3, we identified that only short range point-to-point fixed links were not suitable for licence-exempt use and instead were more appropriate to use a light-licensed spectrum. Today, many links of this type are capable of operating in the presence of other co-channel uses, when assisted by various interference avoidance and mitigation technologies. With advances in such technologies, we infer that condition (a) is unlikely to apply. In addition, as mentioned in the LEFR Statement, the amount of spectrum (about 40 GHz) proposed for light-licensing in the 105-275 GHz band is more than sufficient bandwidth to accommodate the (unlikely) emergence of applications which may be intolerant of co-channel uses. Hence, we conclude that condition (b) above is also unlikely to apply.

4.10 On balance, therefore, we believe that a spectrum reserve is not justified.

4.11 The release of the entire spectrum in the 275-3000 GHz band for licence-exempt use according to Option 2 may affect the activities of the science community utilising the bands designated for spectral measurement lines. Given the generous amount of spectrum available in the 275-3000 GHz band, we believe there is no need for such an approach.

4.12 Our preferred approach is Option 3 where we respect use of the spectrum (as specified by Footnote 5.565) for spectral line measurements but make the remainder of the spectrum in the 275-3000 GHz band available for licence-exempt use given that harmful interference is unlikely to occur at such frequencies. Taking such an approach may encourage innovation and the emergence of new applications while reducing regulatory overheads. This approach also recognises that scientific users

[17] http://www.ofcom.org.uk/consult/condocs/lefr/lefr.pdf
[18] Congestion refers to the potential for radio devices to generate harmful interference towards other devices.

have to use specific frequencies pertaining to spectral lines of molecules which is set by nature.

4.13 Ofcom has a general duty to ensure optimum use of the spectrum (Section 3(2) of the Communications Act 2003) and to encourage innovation (Section 3(4) of the Communications Act 2003). Hence, making the spectrum available in the 275-3000 GHz band (excluding the 'updated' Footnote 5.565) for use by licence-exempt devices is in line with our duties. We discuss the timing of our policy decision in the next sub-section.

Our proposals

4.14 We consulted on the upper limit for the band under consideration. The WT Act 2006 assumes that the spectrum extends up to 3000 GHz, which is also the upper limit of the definition of radio waves in the Radio Regulations (item 1.5 of Article 1). One of the stakeholders agreed with an upper limit of 3000 GHz while other stakeholders did not put forward alternatives. Given that 3000 GHz is a sensible upper limit based on the definition of radio waves used in the Radio Regulations, Ofcom will use this value as the upper limit to the band under consideration.

4.15 In the consultation process, half of the respondents expressed the view that Ofcom should wait for the outcome of the WRC-11 conference before making a decision on the 275-3000 GHz band. This is because agenda item 1.6 at WRC-11 will review the bands protected by Footnote 5.565 between 275 GHz and 3000 GHz.

4.16 Given the high likelihood of such a decision and potential difficulties in re-allocating frequencies previously used by licence-exempt devices, it is sensible for the policy in the spectrum above 275 GHz to reflect the changes to Footnote 5.565 at the WRC-11 conference. In this respect, Ofcom proposes to publish licence-exempt regulations in the 275-3000 GHz band after the WRC-11 conference.

4.17 Based on the current Footnote 5.565 (see paragraph 3.16), the candidate bands to be made available for licence-exempt use are: 444-453 GHz, 510-546 GHz, 568-623 GHz, 711-730 GHz, 732-795 GHz, 909-926 GHz, 945-951 GHz and 956-3000 GHz. However, if Footnote 5.565 is revised at WRC-11, the bands made available for licence-exempt use will differ from that stated above.

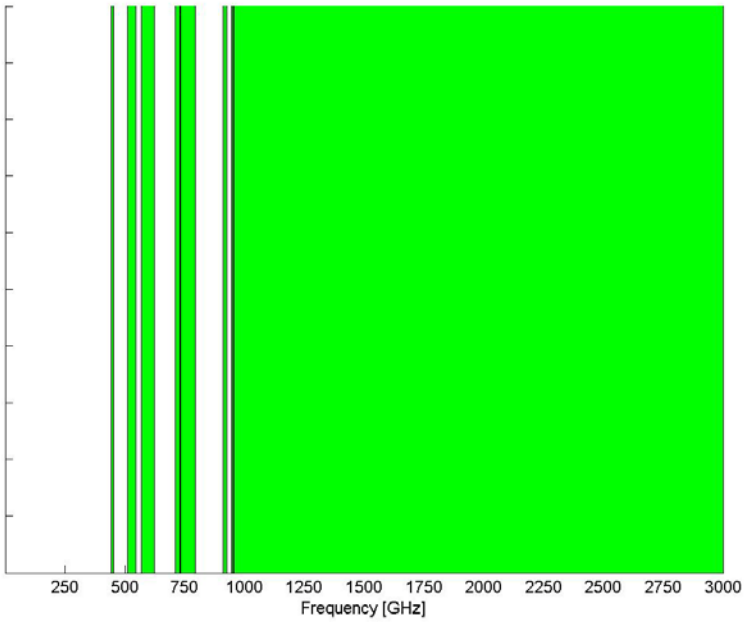


Figure 4.1: Bands (shown in green) are those we propose for licence-exempt use (this is based on the current Footnote 5.565 and may change when the footnote is updated at WRC-11)

Technical conditions

4.18 Licence-exempt use of spectrum is typically allowed on the basis of certain constraints such as power levels, duty cycles, bandwidth etc. However, setting these constraints is somewhat complicated by the absence of any specific technology or standards applicable to the 275-3000 GHz band and by the uncertainty surrounding the applications that will emerge for this band. As a result, we need a proxy for this purpose. We have selected the exemption rules associated with non-generic short range devices (SRDs) in the 244-246 GHz band. We believe that non-generic SRDs are a suitable proxy given that devices above 275 GHz are likely to be short range and potentially be used for a range of applications. According to Annex 1 of the ERC Recommendation 70-03, the only constraint on non-generic SRDs at 244-246 GHz is a power limit of 100 mW EIRP[19] (effective isotropic radiated power).

4.19 Hence, we will also set an EIRP limit of 100 mW (i.e. 20 dBm) at 275 GHz. This limit is scaled with frequency across the 275-3000 GHz band using a positive gradient of 20 dB per decade as shown in Figure 4.2. It should be noted that the limit will not apply to passive bands identified under the 'updated' Footnote 5.565.

[19] The effective isotropic radiated power (EIRP) is defined as the product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna.

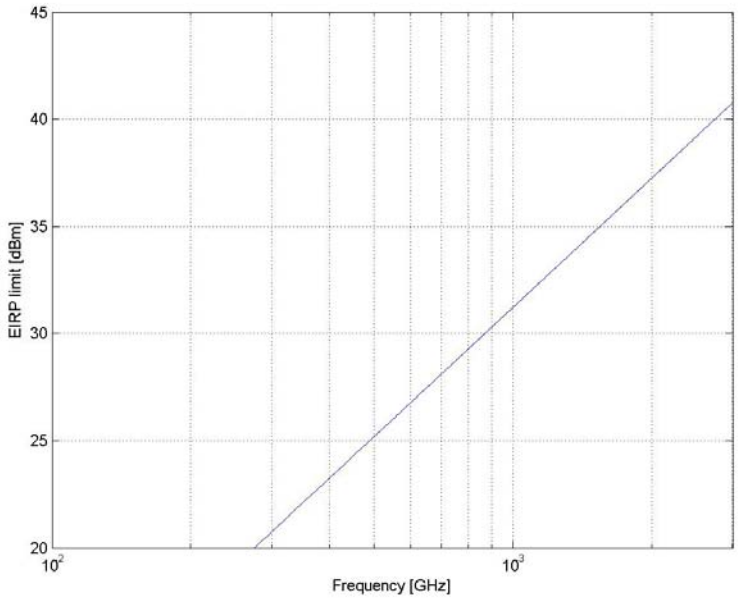


Figure 4.2: Variation of the EIRP limit with frequency over the 275-3000 GHz band

4.20 This scaling accounts for the deterioration in the free-space radio propagation link budget with the square of frequency for a specific receiver antenna gain[20]. Because of this, a high-frequency high-power transmitter effectively generates the same amount of co-channel interference as a low-frequency low-power transmitter.

4.21 Use of a device operating with an EIRP below the limit specified in Equation 1.1 will be exempted from the need of a licence. This applies to the frequency range of 275-3000 GHz, with the exclusion of bands specified by the 'updated' Footnote 5.565.

$$P_{\text{limit}} = 20 + 20 * \log_{10}(f/275) \qquad \text{[Equation 1.1]}$$

where P_{limit} is the peak EIRP limit[21] in dBm, and f is frequency in GHz. Equation 1.1 applies over the frequency range of 275-3000 GHz, excluding the bands specified by the 'updated' Footnote 5.565.

4.22 We also highlight that despite the above power limit, users should respect radiation hazard limits[22] as stipulated by the Health Protection Agency, bearing in mind that they may be amended from time to time. As new applications emerge in the spectrum above 275 GHz and research[23] on the health impacts of radiation at these frequencies is carried out, the radiation hazard limits may be extended beyond the current upper frequency limit of 300 GHz.

[20] This assumes that over short distances, other frequency-dependent attenuation effects such as gaseous and water vapour absorption may be ignored.
[21] ERC Recommendation 70-03 only specifies an EIRP limit of 100 mW for non-generic SRDs in the 244-246 GHz band. Given the low likelihood of interference due to significant propagation losses in the terahertz band, we set the limit as a peak EIRP limit.
[22] A. McKinlay *et al*, 'Advice on limiting exposure to electromagnetic fields (0-300 GHz)', Documents of the NRPB, Vol. 15, No. 2, 2004.
[23] K. Kawase, 'Terahertz imaging – new steps towards real-life applications', 12th International Conference on Terahertz electronics, pp. 553-554, 27 Sept -1 Oct 2004.

4.23 In November 2008, we published a statement on the concept of multiple classes of spectrum commons[24]. Each class is intended to have applications with broadly similar interference generating characteristics as determined by an interference indicator. The Interference Indicator of an application captures its potential to cause interference based on the geographic or spatial, time and frequency domains. Three spectrum classes are proposed, namely low interference class, core class and high interferers.

4.24 As discussed in this Statement, applications using the 275-3000 GHz band are unlikely to cause harmful interference due to power restrictions and propagation characteristics of the band; which is part of the rationale for making this band (excluding the passive bands) available on a licence-exempt use. Hence, the 275-3000 GHz is categorised as a Low Interference Class within a spectrum commons classes framework. As the name suggests, a Low Interference Class is relevant to very low interferers whose usage of resources (spectrum, time and spatial) is so low that polite rules[25] are not required. So no polite rules are specified for the spectrum above 275 GHz.

Next steps

4.25 This Statement describes our policy intent with respect to licence-exempt use of the spectrum above 275 GHz, noting that the implementation of this policy will occur after the WRC-11 conference once Footnote 5.565 has been updated as anticipated. Assuming that such updates take place, Ofcom will then publish exemption regulations which will specify appropriate interface requirements and applicable frequencies.

4.26 We view the release of the spectrum above 275 GHz for licence-exempt use as part of a broader strategy of encouraging innovation and removing regulatory overheads. We aim to encourage discussion about our policy for this band at international level and will support initiatives to produce harmonised standards at higher frequencies.

[24] http://www.ofcom.org.uk/consult/condocs/scc/statement/

[25] Polite rules require devices to account for other users and act responsibly by making a fair use of resources in the frequency, time and geographic (coverage and density) domains.

Annex 1

Impact assessment

Introduction

A1.1 The analysis presented in this annex represents an impact assessment, as defined in section 7 of the Communications Act 2003 (the Act).

A1.2 Impact assessments provide a valuable way of assessing different options for regulation and showing why the preferred option was chosen. They form part of best practice policy-making. This is reflected in section 7 of the Act, which means that generally we have to carry out impact assessments where our proposals would be likely to have a significant effect on businesses or the general public, or when there is a major change in Ofcom's activities. However, as a matter of policy Ofcom is committed to carrying out and publishing impact assessments in relation to the great majority of our policy decisions. For further information about our approach to impact assessments, see the guidelines, Better policy-making: Ofcom's approach to impact assessment, which are on our website: http://www.ofcom.org.uk/consult/policy_making/guidelines.pdf

A1.3 Based on a consultation on our proposals for the spectrum above 275 GHz, we will make spectrum in the 275-3000 GHz range available for licence-exempt use subject to certain power limits and excluding the bands designated for spectral line measurements according to Footnote 5.565 as revised at the WRC-11 conference. Our policy for licence-exempt use above 275 GHz will be implemented after the WRC-11 conference.

The citizen and/or consumer interest

A1.4 By removing regulatory overheads, the release of the spectrum in the 275-3000 GHz band may encourage innovation and the emergence of new applications of value to citizens and consumers in line with our duties under Section 3 of the Communications Act 2003. Potential new applications for this band include short range anti-collision radar devices, detection of skin cancer and other non destructive evaluation methods used in industrial processes. However, given that it is unclear at this stage which applications will be successful and when this will happen, it is difficult to estimate the economic benefits to citizens and consumers.

A1.5 As we are removing regulatory barriers, our policy should not result in additional cost to users. We are also accounting for the use of certain bands for spectral line measurements by the scientific community. Hence, our policy is not detrimental to these users, particularly as our policy will take into account the revision to the passive bands at the WRC-11 conference.

A1.6 Although it is difficult to quantify the cost and benefits resulting from our policy, we believe that on balance, it is better to make the spectrum in the 275-3000 GHz band available for licence-exempt use subject to certain restrictions. This is because of the low likelihood of harmful interference in this band.

Assessment of the options

A1.7 An impact assessment is underpinned by an appraisal of the policy options. This is addressed in Section 4 and is therefore not repeated here.

Annex 2

Summary of stakeholder responses and Ofcom's views

There were four respondents to the 275 GHz consultation document. We summarise the stakeholders' responses (in italics) to each consultation question according to themes, where applicable, and provide Ofcom's views.

Question 1: Is 3000 GHz a reasonable value for the upper frequency limit for licence-exempt use?

One of the respondents agreed with setting the upper limit with 3000 GHz, in alignment with the definition of radiowaves in the Radio regulations. Other respondents did not suggest other alternatives to the upper limit.

Ofcom's view:

Given that 3000 GHz is a sensible upper limit based on the definition of radio waves used in the Radio Regulations, Ofcom will use this value as the upper limit to the band under consideration.

Question 2: Do you agree with the constraints specified for licence-exempt use of the 275-3000 GHz band?

i) Half of the respondents were of the view that Ofcom should wait for the outcome of WRC-11 where the list of spectral lines for passive services above 275 GHz is expected to be updated.

In addition, one of the respondents expressed that there is uncertainty in the band as to which spectral lines may be of value to the scientific community in the future and also in terms of the equipment used in the band which may interfere with passive services. Given this situation, the respondent suggested that licensed use of the band is more appropriate as this is more conducive to move certain users to other parts of the spectrum if the need arises.

Another respondent suggested that the spectrum above 275 GHz should be made available on a licensed basis as it would be easier for re-allocation of frequencies if needed by scientific uses.

Ofcom's view:

Given the review of Footnote 5.565 at the WRC-11 conference, Ofcom agrees that it is sensible for the licence-exempt regulations in the spectrum above 275 GHz to reflect the changes to Footnote 5.565 at the WRC-11 conference. Therefore, Ofcom proposes wait until after the WRC-11 conference to publish licence-exempt regulations in the 275-3000 GHz band.

Ofcom is aware that post-2011, additional spectral lines may be deemed useful by the scientific community. However, the timing of such events is unclear. If additional spectral

lines are deemed useful by the scientific community post-2011, Ofcom will give due consideration as to whether these should be re-allocated to scientific uses.

While licence-exempt authorisations are expected to be for an indefinite period, there might be specific circumstances under which we would wish to revoke an authorisation. If the need arises for such a revocation, a review will be carried out taking into account a number of considerations, one of which is the practicality of clearing the band. If the latter is decided following a detailed consultation, we would expect that, where notice was necessary, the notice period would be of a reasonable length of time to allow licence-exempt usage to 'naturally' decline within the band. An example of a typical notice period used in the past ('The future of the 418 MHz band for licence exempt equipment'[26]) is 8 years. This is just for illustration purposes as the length of the notice depends on the circumstances.

Ofcom recognises that there are potential difficulties with re-allocation of frequencies if previously used by licence-exempt devices. However, given the low probability of harmful interference in the 275-3000 GHz band, it is our duty under Section 8(4) of the Wireless Telegraphy Act to make this band available for licence-exempt use

ii) One of the stakeholders stated that the consultation document refers to aircraft-to-satellite communications as a possible use for the band. The respondent viewed that aircraft-to-satellite communications in the band may affect space and ground based telescopes if the aircrafts are visible to the telescopes.

Ofcom's view

In paragraph 3.23 of the consultation document, it is highlighted that aircraft-to-satellite communications was considered as a possible use by a RAL (Rutherford Appleton Laboratories) report. We added in paragraph 3.24 of the consultation document that based on the assumptions used by RAL, aircraft-to-satellite communications had a maximum operating frequency limit of about 350 GHz.

The spectrum between 275 GHz and 350 GHz is within the bands specified by the current Footnote 5.565 for use by passive services. Based on our policy decision, an active application such as aircraft-to-satellite communications is not allowed in the bands protected by Footnote 5.565.

iii) Consideration of EIRP limits is not sufficient to assess impact of interference on passive sensors. The sensitivity of passive sensors should also be considered and this can vary according to bands. The assessment needs to also consider aggregate interference and other operational conditions of the active services

Ofcom's view

As stated in this Statement, it is not clear which licence-exempt applications will emerge in the relevant spectrum above 275 GHz. Given this situation and the absence of standards and technologies pertaining to this spectrum, it is difficult to make an assessment of aggregate interference as the density of licence-exempt devices is not known. The power levels put forward have been set at relatively low levels. If future passive receivers were to suffer from interference from licence exempt devices operating in the adjacent bands, potential remedies such as the use of better filters at the passive receivers might be considered.

[26] http://www.ofcom.org.uk/static/archive/ra/publication/press/1999/21dec99a.htm

Nevertheless, if an interference situation does arise, Ofcom will consider requests for revoking or amending licence-exempt authorisation by following appropriate procedures in such circumstances. This may include a consultation on the subject.

iv) The Radio Society of Great Britain (RSGB) representing radio amateurs felt that the technical constraints for the band are too conservative below 500 GHz. The respondent proposed for the technical constraints (2-4 W erp power, listen before transmit) to be based on 5GHz RLANs and to apply to all bands excluding Earth Exploration Satellite Service (EESS). The proposed constraints were suggested for review by end of 2011.

Ofcom's view

Most of the spectrum between 275 GHz and 500 GHz (except for the 444-453 GHz band) is within the bands currently specified under Footnote 5.565 which are excluded from our proposals for licence exempt usage. The bands listed under Footnote 5.565 are allocated for use by radio astronomy, space research service and the earth exploration satellite service (EESS).

The respondent suggested use of bands allocated to passive services excluding EESS. Although there are no UK radio observatories, the band allocated to the radio astronomy service is used in the development of radio astronomy equipment. Using the bands allocated to the radio astronomy service for radio amateur services at the power levels (roughly a factor of 10 higher than our proposals for licence-exempt devices) mentioned above may result in interference to the development of radio astronomy equipment.

The bands listed under Footnote 5.565 are used for spectral line measurements. A set of spectral lines is specific to a particular molecule and passive users are not necessarily able to migrate to other bands to detect presence of the same molecule. Conversely, radio amateurs are able to use spectrum below 275 GHz (where there is allocation to the radio amateur service) to satisfy their needs.

On balance, Ofcom views that the bands listed under Footnote 5.565 should be protected.

v) Although no radio observatories in the UK use the 275-3000 GHz band, equipment in this band is developed in UK labs. It is important that research is not compromised by licence-exempt equipment used in the vicinity of the labs.

Ofcom's view

The bands proposed for licence-exempt use clearly excludes all the bands listed under Footnote 5.565, including those listed for radio-astronomy services. Hence, there will be no co-channel use between licence-exempt devices and a radio-astronomy station.

Regarding a possibility of out-of-band interference, this is highly unlikely given our proposed significant in-band power restrictions on licence-exempt devices in the relevant parts of the 275-3000 GHz band. In addition, the shielding provided by buildings should provide further protection to equipment being developed in the labs from out-of-band emissions from the licence-exempt devices.

As for use of the licence-exempt devices in the labs, it is likely that those responsible for the management of the labs can control access into these areas and prevent utilisation of licence-exempt devices if this is deemed harmful.

Overall, we consider that the research will not be compromised provided appropriate measures as mentioned above are taken by the responsible parties of the research labs.

vi) Although the radio observatory sites using the 275-3000 GHz band are located abroad, they are or will be used by UK scientists. There should be appropriate regulation agreed at a worldwide level to protect these sites.

Ofcom's view

While Ofcom can work with its international counterparts to this effect, we cannot provide any guarantee of success as this is beyond our jurisdiction.