Ofcom
making communications work
for everyone

Supporting innovation in the 100-200 GHz range

Increasing access to Extremely High Frequency (EHF) spectrum

STATEMENT:

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Annex

1. Overview

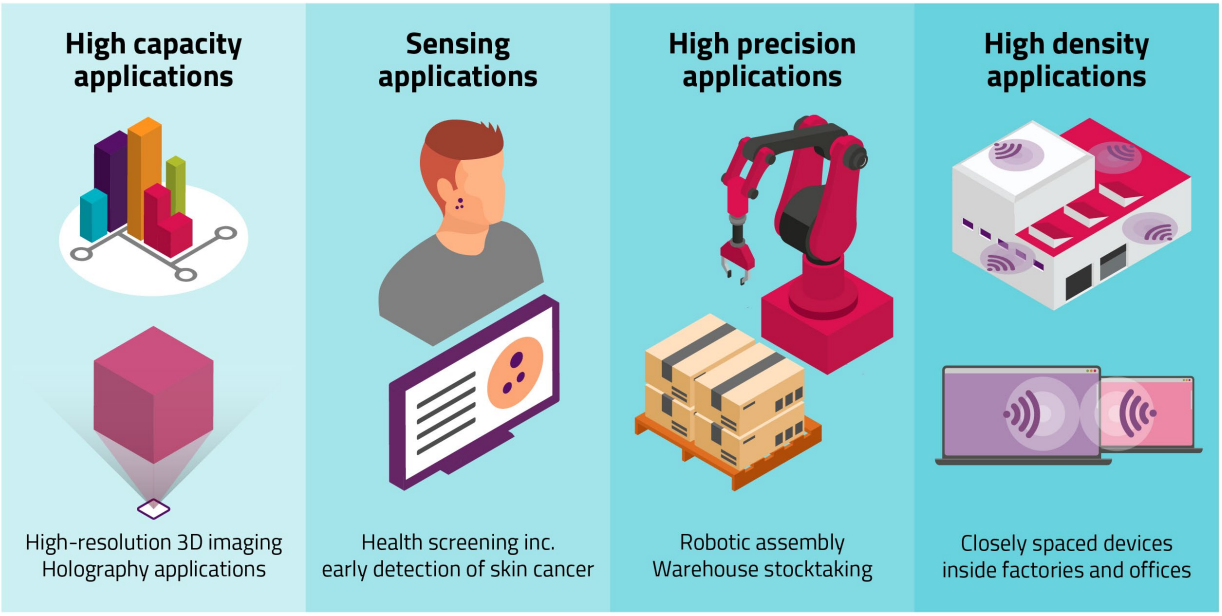
1.1 Innovative technology using Extremely High Frequency (EHF) spectrum in the 100-200 GHz range has the potential to develop new services and applications. Although these technologies are at an early developmental stage, there is a range of envisaged applications including health screening such as skin cancer detection, non-invasive quality assurance in the pharmaceutical and manufacturing industries, high-resolution positioning, security systems and high-speed data links. There is presently little ground-based (terrestrial) use of this spectrum, although there is established space use for Earth Exploration-Satellite Services (EESS), which collect weather and climate data.

1.2 We want to support innovation and enable new uses of spectrum. This statement sets out how Ofcom will license terrestrial use of three bands in the 100-200 GHz range: 116-122 GHz, 174.8-182 GHz and 185-190 GHz. Our conclusions follow consideration of responses to the consultations published in January and May 2020.

What we have decided – in brief

- To help foster innovation we will introduce a new 'Spectrum Access: EHF' licence to enable simple, flexible access to over 18 GHz of radio spectrum across three bands (116-122 GHz, 174.8-182 GHz and 185-190 GHz). Each licence will enable access to one of these bands across the UK on a non-protection and non-interference basis, with use of multiple devices permitted.
- These bands are presently used by Earth Exploration-Satellite Services ("EESS") to collect weather and climate data. The technical conditions we are stipulating for terrestrial access to these bands will protect EESS from undue interference.
- We recognise that there is uncertainty on future demand for services using this spectrum, and what the services and applications developed will be. We will review developments in 2024 and will consider whether to propose changes to our approach.
- We will not introduce provisions to authorise devices to operate on a licence-exempt basis in these bands at this stage, as we had proposed in the consultation. We may review the case for enabling licence-exempt use of these bands in future as part of the 2024 review.

Figure 1.1: Potential uses of 100-200 GHz spectrum



Background

Our proposals for supporting innovation in the 100-200 GHz range

1.3 On 17 January 2020, we published proposals for increasing terrestrial access to three bands in the 100-200 GHz range (the "**January 2020 consultation**"). We proposed to enable simple, flexible access to over 18 GHz of radio spectrum across three bands (116-122 GHz, 174.8-182 GHz and 185-190 GHz). We proposed that this spectrum could be accessed through either lower-power licence-exempt devices, or increased power devices using a new 'Spectrum Access: EHF' licence. Devices would be authorised subject to technical conditions designed to protect Earth Exploration-Satellite Services (EESS) from undue interference.

1.4 Some stakeholders told us that they would find it useful to have sight of further detail of our technical analysis in order to reach a firmer view on our proposals. In light of these comments, we published a further consultation on 20 May 2020 (the "**May 2020 consultation**"). This set out further details of the assumptions and results of the technical analysis which informed our proposals and invited any further comments which stakeholders might have. We have published the non-confidential responses to both consultations on our website.

1.5 This statement sets out our final decisions.

Summary of our decisions

1.6 We recognise the importance of the weather and climate data collected by EESS in these bands and have taken account of the concerns raised by EESS stakeholders. We will not

introduce provisions to authorise devices to operate on a licence-exempt basis in these bands at this stage, as we had proposed in the consultation.

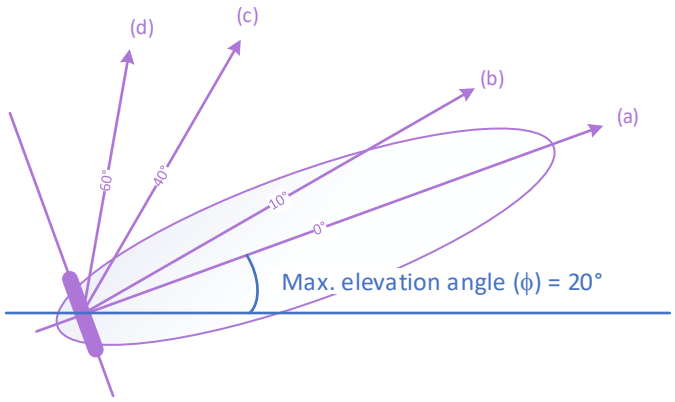
1.7 We are introducing a new licence (the 'Spectrum Access: EHF' licence) to make available the 116-122 GHz, 174.8-182 GHz and 185-190 GHz bands for terrestrial use. This approach will support innovation by enabling easier, longer-term, cheaper and more flexible access to these spectrum bands above 100 GHz.

1.8 This new licence will permit terrestrial use of the bands under the conditions shown in Figure 1.2.

Figure 1.2: 'Spectrum Access: EHF' licence technical requirements

	Power limits (*max EIRP in dBm*) and emissions restrictions on outdoor use		
USE	**116-122 GHz**	**174.8-182 GHz**	**185-190 GHz**
Indoor	55	55	55
Outdoor	55 (a)	55 (a)	55 (a)
For outdoor use, EIRP at angles (degrees°) relative to main beam in the elevation plane (a) shall not exceed:			
	13 at > 10° (b) 1 at > 40° (c) -3 at > 60° (d)	13 at > 10° (b) 1 at > 40° (c) -3 at > 60° (d)	25 at > 10° (b) 14 at > 40° (c) 10 at > 60° (d)
When devices are used outdoors, the main beam elevation angle (ϕ) of licensed devices shall not exceed 20° above horizontal.			
For all systems using bandwidths of less than 100 MHz, all of the above EIRP limits must be adjusted as follows: $$EIRP\ Reduction\ =\ 10 \times log_{10}\left({BW_{MHz}}/{100}\right)$$			

Figure 1.3: Outdoor EIRP limits including device antenna elevation angle restriction



1.9 A licence will allow use of multiple devices within a specified band across the United Kingdom on an uncoordinated shared basis. Each licence will have an indefinite duration,

with a fee of £75 payable every 5 years. The licence will permit Ofcom to give one year's notice to revoke the licence for spectrum management reasons. Airborne use will not be permitted.

1.10 Licensees will be required to keep records of locations of use and of the antenna elevation angle for outdoor use. We intend to request this information periodically to support monitoring of spectrum use and enable quick enforcement action if necessary.

1.11 In February 2020, Ofcom published a consultation on proposed measures to require compliance with international guidelines for limiting exposure to electromagnetic fields (EMF). Subject to the outcome of this consultation we may introduce further provisions to the 'Spectrum Access: EHF' licence to reflect any new conditions relating to EMF compliance. We will publish a statement on our decisions shortly.

Next steps

1.12 From today, people and businesses can apply for a 'Spectrum Access: EHF' licence using the information available on Ofcom's website.

1.13 We plan to review this new framework, taking into account international developments and evidence on the characteristics of devices, services and applications developed using these new bands, in 2024. We may review the case for enabling licence-exempt use of these bands in future as part of this.

Other bands above 100 GHz

1.14 We note stakeholders' interest in additional bands above 100 GHz, and plan to open up access to further bands above 100 GHz. At present, access to other bands for research and development purposes may be requested through our Innovation and Trial licence framework.

1.15 We plan to make the "W band" (92-114.5 GHz) and the "D band" (130-174.8 GHz) available for use in the UK and will consult on proposals in due course.

2. Introduction

Background

2.1 This document sets out our decision to enable greater access to frequencies in the 100-200 GHz range. At present, terrestrial users have limited opportunities to access this spectrum. Enabling easier, longer-term, cheaper and more flexible access to a materially greater amount of spectrum above 100 GHz, including large contiguous blocks, should support UK-based innovators and companies to harness the potential of these frequencies and develop new technologies and applications for people and businesses.

2.2 On 17 January 2020, we published a consultation entitled "Supporting innovation in the 100-200 GHz range" (the "**January 2020 consultation**").[1] This consultation set out proposals to enable greater access to three frequency bands of Extremely High Frequency (EHF) spectrum in the 100-200 GHz frequency range. We proposed that access would be granted under a two-tier authorisation regime of licence exemption and licensed use for increased power levels. We considered that this would support a range of new wireless services.

2.3 On 18 February 2020, in accordance with the Radio Equipment Directive and the Technical Standards Directive, we notified the Interface Requirement that we proposed for each of the licence exemption and licensing regimes to the European Commission.[2] The standstill period ended on 19 May 2020. We received comments from Germany and no further comments from other Member States.

2.4 The January 2020 consultation closed on 20 March 2020 and we received 14 responses.[3] Some stakeholders, in response to this consultation, told us that they would find it useful to have sight of further detail of our technical analysis in order to reach a firmer view on our proposals. We published a further technical consultation setting out additional details about the assumptions and results of the technical analysis which informed our proposals on 20 May 2020 (the "**May 2020 consultation**") in light of these comments. We invited stakeholders to provide any additional comments on our proposals as a result of the further details provided. The May 2020 consultation closed on 17 June 2020 and we received seven responses.[3] We have also held meetings with a number of stakeholders to discuss current and future use of frequencies above 100 GHz and our proposals.

2.5 This statement sets out our decisions on use of the three proposed bands in the 100-200 GHz range and our reasoning for these decisions, including our consideration of stakeholder responses to our consultations.

[1] Ofcom's consultation of 17 January 2020 entitled Supporting innovation in the 100-200 GHz range. On 7 February 2020 we published a revised version of that consultation document to incorporate a number of clarifications, including on the proposed technical conditions that would apply to licensed devices used indoors.
[2] Notification Numbers: 2020/70/UK (United Kingdom) and 2020/71/UK (United Kingdom).
[3] The non-confidential responses to the consultation were published on our website.

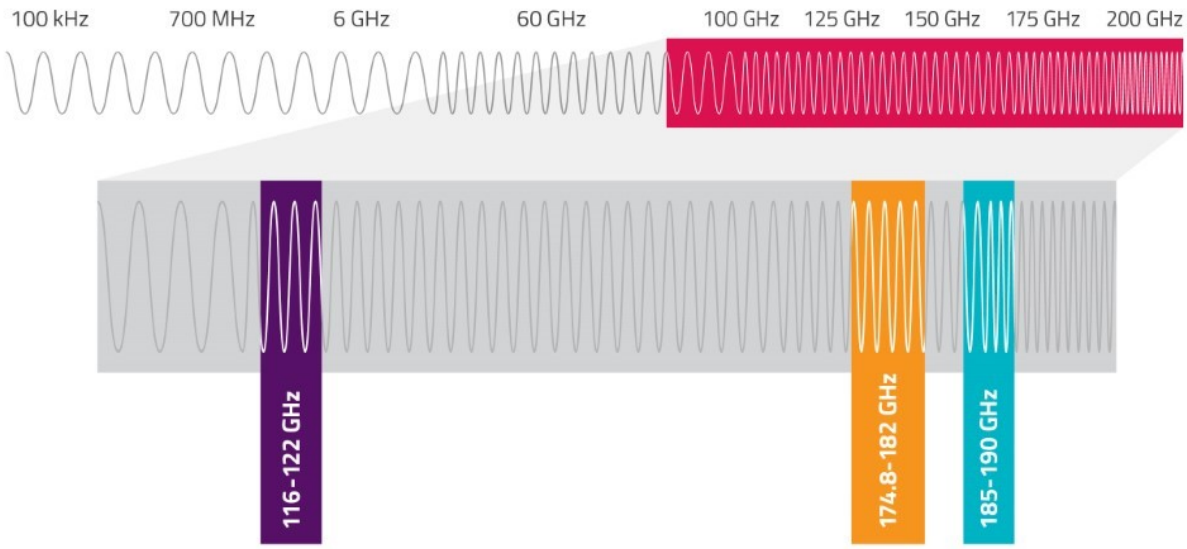
2.6 In annexes to this statement, we include a copy of the licence template for the new 'Spectrum Access: EHF' licence and the new Interface Requirement (IR 2106) which we have decided to adopt, covering the bands that we are making available.[4] We are also separately publishing guidance for applying for and holding a licence.

2.7 There is growing international activity around innovation using these bands of spectrum, including the recent decision of the Federal Communications Commission to make several bands in this range available in the US. This context should enable UK innovators to benefit from international research collaboration and increases the likelihood of economies of scale being realised from the development of new internationally compatible devices.

The bands we are making available

2.8 We are making the 116-122 GHz, 174.8-182 GHz and 185-190 GHz bands available for terrestrial use on a licensed basis, according to the conditions shown in the licence template at annex A3 and include compliance with the Interface Requirement shown at annex A2 ("IR 2106 Spectrum Access EHF").

Figure 1.1: Spectrum in the 100-200 GHz range



Legal framework

2.9 Ofcom is responsible for authorising use of the radio spectrum. We permit the use of the radio spectrum either by granting wireless telegraphy licences under the Wireless Telegraphy Act 2006 (the "WT Act") or by making regulations exempting the use of particular equipment from the requirement to hold such a licence. It is unlawful to install or use wireless telegraphy apparatus without holding a licence granted by Ofcom, unless the use of such equipment is exempted. In annex 1 we set out in more detail the relevant

[4] This new Interface Requirement (IR 2106) is also available on Ofcom's website.

legal framework, which we have taken into account in making the proposals set out in the January 2020 consultation and the decisions set out in this statement. That annex should be treated as part of this document.

Impact Assessment

2.10 Our January 2020 consultation document represented an impact assessment as defined in section 7 of the Communications Act 2003. Impact assessments provide a valuable way of assessing different options for regulation. They form part of best practice policy making.

2.11 In preparing our consultation proposals and making our final decisions, we have considered their impact on citizens and consumers, service providers, manufacturers and users of devices and applications, and on existing users of the relevant frequencies, including adjacent bands.

Equality Impact Assessment

2.12 We anticipate that our decisions would not be detrimental to any of the following equality groups: age, disability, gender, gender reassignment, pregnancy and maternity, race, religion or belief, and sexual orientation. We also anticipate that our decisions would not have a differential impact in Northern Ireland compared to consumers in general.

Securing the optimal use of spectrum

2.13 Our principal duty is to further the interests of citizens and consumers in relation to communications matters. As part of this, we must ensure that a wide range of electronic communications services are available across the UK, and that optimal use is made of the radio spectrum.

2.14 We consider that, in general, the optimal use of spectrum is mostly likely to be secured if spectrum is used efficiently and delivers the maximum benefits. Making the 116-122 GHz, 174.8-182 GHz and 185-190 GHz bands available under the conditions set out in this document will enable new uses while protecting incumbent users.

Enabling innovation

2.15 We have also had regard to the economic and other benefits which may arise from the use of this spectrum, and the need to encourage the development of innovative services. This spectrum has the potential to support a range of applications, including health screening applications, high-speed data links and non-invasive quality assurance in manufacturing. Developing services in this range could therefore deliver significant benefits for people and businesses in the UK. We consider it important to make these bands available in a timely manner so that these benefits will be realised as soon as possible and so that industry may fully take advantage of innovation opportunities.

Structure of this document

2.16 This statement contains the proposals we set out in our consultations, the responses we have received to our proposals, our decisions and our reasoning for these decisions, including our consideration of stakeholder responses. The rest of the document is structured as follows:

- **Section 3** explores current and potential future use of spectrum in the 100-200 GHz range.
- **Section 4** sets out our new licensing framework for terrestrial use of the 116-122 GHz, 174.8-182 GHz and 185-190 GHz bands.
- **Section 5** details our technical coexistence analysis.
- **Section 6** summarises our decisions and our next steps for supporting innovation in the 100-200 GHz range.

3. Current and future use of 100-200 GHz spectrum

3.1 In the January 2020 consultation, we said that spectrum in the 100-200 GHz range is currently lightly used for terrestrial applications. We proposed to open up three bands (116-122 GHz, 174.8-182 GHz and 185-190 GHz) for simple, flexible spectrum access to support the development of new and innovative services. We invited stakeholder comments on our analysis of the current use of spectrum in the 100-200 GHz range, including our specific bands, and whether there were any further bands we should consider making available on a technology neutral basis.

3.2 In this section, we examine current and future use of this spectrum in light of stakeholder responses and further analysis, and further explore incumbent uses of the three bands. We also consider other bands above 100 GHz.

Future use of 100-200 GHz spectrum: advances in technology will enable new, innovative services at higher frequencies

Consultation summary

We expect new technologies to be developed using spectrum above 100 GHz

3.3 In the January 2020 consultation, we explained that the use of frequencies above 100 GHz for new applications is becoming an increasingly practical proposition as advances in microchip technologies start to allow their operation. We noted that there is increasing activity and research into the development of new technologies and applications using bands above 100 GHz, and that a widespread availability of new devices and services is expected within a ten-year timeframe.

3.4 Spectrum in the EHF range,[5] particularly above 100 GHz, exhibits different properties from the lower ranges of spectrum. These include short propagation distances, small wavelengths and the availability of large contiguous bandwidths. This means that these frequencies are well suited to a wide range of applications including:

a) **High capacity applications**. Frequency bands above 100 GHz offer progressively higher bandwidths and hence significantly more capacity than lower frequency spectrum. This means that this spectrum can facilitate new extremely high data-rate communications and applications. These might include future high-resolution 3D imaging and holography applications.

b) **Sensing applications**. Bands above 100 GHz propagate through physical objects in different ways to lower frequency bands. This makes them suited to detecting, for

[5] Article 2.1 of the ITU Radio Regulations defines Extremely High Frequencies (EHF) as the frequency range between 30 and 300 GHz.

example, defects within some types of manufactured products, including pharmaceuticals, which cannot be detected in other frequency bands. It also makes them well suited to enabling more effective health screening, including the early detection of skin cancer.

c) **High precision positioning applications**. The high level of signal reflections from objects in these bands, coupled with the large bandwidths available, make the bands well suited to being used for high precision positioning applications. These might include supporting the robotic assembly of high precision products, the precise storage and stocktaking of products in warehouses, and detecting outdoor small movements in building structures.

d) **High density applications**. The properties of bands above 100 GHz mean they could be used by closely spaced devices and systems enabling higher density of use, for example inside factories and offices where there are larger numbers of wirelessly connected devices and systems. The bands could also be used for very high-speed, short-range connections in dense applications, such as between microchips and circuit boards. This is possible owing to the easier interference management characteristics of these bands.

There is increasing international activity looking at bands above 100 GHz

3.5 In the January 2020 consultation we noted growing international interest in bands above 100 GHz. In recent years spectrum above 100 GHz has been made available for terrestrial use in the European Union, US and Japan. Most recently, the Federal Communications Commission (FCC) in the US has decided to make four bands available for use by unlicensed devices (116-123 GHz, 174.8-182 GHz, 185-190 GHz and 244-246 GHz).

3.6 At International Telecommunication Union (ITU) level, the 2019 World Radio Conference (WRC-19) agreed further work to develop recommendations on sharing and adjacent-band compatibility between passive and active services above 71 GHz, including the 116-122.25 GHz and 174.8-191.8 GHz bands, noting that past technological developments have led to viable communications systems operating at increasingly high frequencies. It was also agreed to undertake work to consider new allocations for the radiolocation service in the frequency band 231.5-275 GHz, and new identification for radiolocation service applications of frequency bands in the range 275-700 GHz to enable decisions to be taken at the 2027 WRC.

3.7 We also noted that, the European Conference of Postal and Telecommunications Administrations (CEPT) had developed recommendations and a report[6] on radio frequency channel / block arrangements for fixed wireless systems in a number of bands allocated to the fixed service above 92 GHz.[7] Furthermore, the CEPT working group on short-range devices (ECC PT SE24) was carrying out studies for various sensor types and scenarios of

[6] ECC Recommendation (18)01; ECC Recommendation (18)02; and ECC Report 282.
[7] These are 92-94 GHz, 94.1-100 GHz, 102-109.5 GHz, 111.8-114.25 GHz (often referred to as the "W Band"), 130-134 GHz, 141-148.5 GHz, 151.5-164 GHz and 167-174.8 GHz (often referred to as the "D Band").

ultra-wideband radiodetermination applications within the 116-260 GHz frequency range, following ETSI Technical Report 103 498 on the technical characteristics for Short Range Devices (SRD) equipment using Ultra Wide Band technology (UWB) and radiodetermination applications.

3.8 Taking account of these factors, we considered that there was a strong case to open up bands in this range to support innovation, with scope for international research collaboration and economies of scale.

Summary of developments

3.9 Since publishing the January 2020 consultation, further potential applications for EHF spectrum, including applications which are still under development, have emerged.

3.10 Among other uses, spectrum above 100 GHz has been identified as important to facilitating the next generation of integrated systems and technology, sometimes referred to as '6G' systems. At a PolicyTracker webinar in July 2020, stakeholders identified these systems as able to build a new "Internet of Skills", merging computing, communications, storage and Artificial Intelligence (AI). As part of this, the radar and sensing properties of frequencies above 100 GHz are considered very useful for emerging mobility, health and security uses. Other potential uses might include temporary communications links, for example for special events or disaster relief.

3.11 In June 2020, the 6G Flagship published 11 new white papers exploring possible future uses of frequencies above 100 GHz as part of local, interconnected systems and system management. These would include backhaul links for fast, reliable networks and sensing, localisation and imaging applications, due to the fine resolution achievable in all physical dimensions using these frequencies.

International updates

3.12 ECC PT SE24 continues to examine radiodetermination applications within the frequency range 116-260 GHz. This technical work is due to be finalised by April 2021, with an ECC Report due to go to public consultation in September 2021. This process may result in the ERC Recommendation on Short Range Devices[8] being updated. Subject to due process, this could also be adopted by the European Commission into an EU harmonising instrument. We are continuing to engage with this work as part of ECC PT SE24.

3.13 In July 2020 CEPT submitted to the ITU-R the radio channel/block arrangements for fixed wireless systems that had been developed within CEPT for a number of bands above 92 GHz (see paragraph 3.7) and we are engaging within the ITU-R to further this work. We will also engage in other ITU-R areas of work on bands above 100 GHz, including to share our own technical analysis on coexistence in the 116-122.25 GHz and 174.8-191.8 GHz bands.

[8] The ERC Recommendation on Short Range Devices (SRD) sets out a common approach that European countries can adopt nationally.

Consultation responses

3.14 Of the 21 total consultation responses we received to the January 2020 and May 2020 consultations, several commented on technological advances and possible future uses, taking a positive view of our objectives to enable innovation in EHF spectrum.

3.15 Professor Steven Gao (University of Kent) said in his response that that there was a clear trend of wireless systems using higher frequencies, with the next waves being 100-300 GHz and then 300-3000 GHz (3 THz). He noted research across this range, and said that wireless systems at these frequencies offered the advantages of wide available bandwidths and being able to use compact antennas and circuits. Some of the potential future uses he highlighted include:

- compact radars for high resolution imaging, for example to use in airport security checks;
- medical imaging applications;
- high-speed wireless communications for short-range indoor applications; and
- the next generation of mobile technology, '6G' applications.

3.16 The Dynamic Spectrum Alliance (DSA) agreed with our proposals and said that the proposal bands had the potential to support a range of new wireless services including high-capacity, high-density, high-precision and sensing applications. It also saw good potential for internationally compatible devices.

3.17 Facebook said in its response that its Terragraph system uses EHF spectrum to provide low-cost, multi-gigabit mesh wireless networks, providing fibre-equivalent speeds wirelessly. This system operates in the 60 GHz band, but Facebook noted that frequencies above 100 GHz also have the potential to provide the next generation of Fixed Wireless Access and wireless backhaul. Nokia also commented on the potential of frequencies above 100 GHz to enable fixed operations in large contiguous blocks in the future, as well as their role in sensing applications and SRDs in the context of 6G.

3.18 [✂]Three supported releasing the proposal bands for innovation and the development of new mobile and fixed technologies. It considered that this would support not only the applications identified in the consultation document but also undefined future uses.

3.19 The Radio Society of Great Britain (RSGB) took a positive view of the objectives behind our proposals, and said that radio amateurs have achieved effective communications in the 100-200 GHz range using narrowband systems.

3.20 [✂] said that bands above 100 GHz may be used [✂] in the future. In particular, it noted a number of uses of spectrum [✂].

3.21 A number of EESS stakeholders provided information on the expected future expansion of space use of bands above 100 GHz. We consider this further in paragraph 3.33.

Analysis and conclusions

3.22 We note the additional potential uses of 100-200 GHz spectrum identified in responses to our consultations, and continuing international activity looking at these frequencies and beyond. We maintain the position set out in the January 2020 consultation that the small wavelengths, short propagation distances and wide bandwidths available in this range make the bands we consulted on well suited to a range of applications.

3.23 We also recognise that innovative research is at an early stage, so there is currently some uncertainty surrounding future uses of these bands. We consider that a flexible, technology neutral regulatory approach to opening up spectrum within this range could be expected to enable new, innovative uses to flourish.

Current use in the UK: most use is by satellite services

Consultation summary

3.24 As set out in the January 2020 consultation, the spectrum above 100 GHz is internationally allocated to a variety of active and passive services.[9]

3.25 For terrestrial use in the 100-200 GHz range, there are primary (134-136 GHz) and secondary (122.25-123 GHz and 136-141 GHz) allocations for amateur radio. Short range devices are permitted to operate in the UK in the 122-123 GHz band on a licence-exempt basis, subject to a maximum EIRP of 20 dBm[10]. The 122-123 GHz band is also designated internationally for Industrial, Scientific and Medical (ISM) applications, including industrial microwave ovens and magnetic resonance equipment. Additionally, there are allocations for fixed wireless and mobile services across the 100-200 GHz range in the Radio Regulations. These are not currently used in the UK, but we expect to see demand in the future.

3.26 Additionally, Ofcom's Innovation and Trial licences offer access to spectrum above 100 GHz for the research, development and trialling of innovative uses of the radio spectrum, subject to a number of constraints. These include a one-year licence period and operational and commercial use not being permitted. There are currently five Innovation and Trial licences in the 100-200 GHz range.

Earth Exploration-Satellite Services

3.27 The predominant use of spectrum bands above 100 GHz in the UK is by passive EESS, which observe the characteristics of the Earth and its natural phenomena from sensors onboard satellites for purposes including weather forecasting. All allocations to EESS in the 100-200 GHz range are primary allocations, meaning that they share the spectrum on equal

[9] See also the UK Frequency Allocation Table.
[10] The 122-123 GHz and 244-246 GHz bands are harmonised for use by short-range devices (SRDs) at European level.

conditions with other primary services, and that they must be protected from undue interference caused by other services.

3.28 There are many frequencies in the 100-200 GHz range allocated to passive EESS in the UK, including 114.25-122.25 GHz and 174.8-191.8 GHz, which overlap with our proposed bands. In addition, several bands, including the 114.25-116 GHz, 182-185 GHz and 190-191.8 GHz bands, are designated as 'no emissions' bands under the Radio Regulations.

3.29 There are other space services allocated in the UK to bands in the 100-200 GHz range which either do not use the bands we proposed to make available for terrestrial use or are unlikely to be at risk of undue interference from terrestrial use, including active EESS, Radio Astronomy, Inter-Satellite and Space research.

3.30 Active EESS are relatively less sensitive to interference compared with passive sensors and there are no allocations for active satellite services in these bands. Inter-Satellite and Space research activities operate in space and do not point at the Earth and, as such, are unlikely to be at risk of interference. To the best of our knowledge, there is no current or planned Radio Astronomy use of frequencies above 100 GHz in the UK.

Consultation responses

3.31 The January 2020 consultation invited comments from stakeholders on our analysis of the current and potential future use of spectrum bands in the 100-200 GHz frequency range. While several respondents said that sharing with passive EESS should be feasible based on the properties of spectrum in this range, some stakeholders considered that we had not captured the importance of the existing services in the bands we proposed to make available.

3.32 The European Centre for Medium-Range Weather Forecasts (ECMWF), [✂] and the Science and Technology Facilities Council (STFC) said that the bands we consulted on are not lightly used, but rather are extensively used for critical EESS operations, taking global measurements for weather forecasting and climate monitoring. [✂] stated that the bands were vital for both operational weather forecasting and for climate studies; the STFC said the bands were crucial for the prediction of weather and natural disasters, and also used for fundamental scientific research in support of astrophysics. ECMWF and [✂] said that passive EESS observations in the 174.8-182 GHz and 185-190 GHz bands in particular have a very high impact. Observations from the proposed bands are used for a range of important operational services that support UK sectors including public weather advice, advance warnings of threat to life and property, emergency management, air quality, transport, health, energy, agriculture, tourism, business and commerce and defence. The National Centre for Earth Observation (NCEO) also stressed the importance of these bands for weather forecasting including hazards and for climate monitoring, in particular the 174.8-192 GHz range. It further noted the recent development of novel radars focused on the study of water vapour and ice in the 100-200 GHz range, including one developed in the UK at 199.5 GHz.

3.33 Additionally, ECMWF said that the importance of these bands was set to increase further, highlighting plans to use sensors operating in these bands on a new constellation of small satellites, to provide high temporal resolution equivalents of current missions. In their joint response ESA and EUMETSAT ("ESA/EUMETSAT") noted that additional sensors had been deployed in these bands or would be deployed shortly, and provided details of the sensor parameters.

3.34 Respondents provided information on the value of improved weather forecasting accuracy, which draws on measurements taken from multiple bands of spectrum including those covered by our proposals. The STFC said that the socio-economic benefit of Numerical Weather Prediction in the 27 EU Member States had been estimated at €61 billion each year.[11] The NCEO stated that the value of benefits to the UK economy from weather-related public service warnings was estimated at £1.5bn per year.

Analysis and conclusions

3.35 We recognise the importance of the current and future EESS uses of the bands we consulted on, as well as other bands in the 100-200 GHz range, for weather forecasting, including extreme weather forecasting, and for climate monitoring. We recognise that this use of these bands – together with a number of other spectrum bands – delivers a number of benefits to citizens and consumers, including services related to safety of life.

3.36 Nonetheless, we think that enabling further use of these bands in coexistence with passive EESS use would better support optimal use of the spectrum. The EESS sensors which take readings in these bands are placed on non-geostationary satellites which orbit around the Earth with a constantly moving instantaneous field of view on the surface of the Earth. This means that any given part of the UK will only be within the instantaneous field of view of an EESS sensor for a short period of time each time it passes over that area.[12]

Specific bands above 100 GHz

3.37 Our proposals were to open up the 116-122 GHz, 174.8-182 GHz and 185-190 GHz bands.

3.38 We explained that we considered these EHF bands to be most suitable for coexistence with existing allocations and for internationally compatible devices which might emerge in the future owing to:

a) the **physical properties of these bands** which are particularly suited to shared use between existing and new users. In these bands, propagation losses and the absorption of the signals by physical objects are higher compared with lower frequency bands, which reduces the likelihood of interference between different spectrum users. In addition, as a consequence of the short signal wavelengths, 100-200 GHz bands can use

[11] Source: EUMETSAT Polar System – Second Generation.
[12] ITU-R Recommendation ITU-R RS.1861 sets out the parameters for 8 sensor types within these frequency bands. This includes information on the repeat periods which ranges from 6 to 29 days and the size of the instantaneous field of view, typically less than 250 km^2 (approximately 9 km radius).

small sized antennas, with relatively high directivity and narrow beams. This means that most devices are likely to have some directivity and narrow beams, which also reduces the risk of interference.

b) the **limited current use of these bands in the UK**. Under the Radio Regulations, the 116-122 GHz, 174.8-182 GHz and 185-190 GHz bands are allocated for primary use to Earth Exploration-Satellite Services, Inter-Satellite and Space research (passive). Of these categories, we are only aware of EESS use which would need to be considered for the purposes of avoiding undue in-band interference from terrestrial users, based on current use and the sensitivity of passive EESS sensors.

c) **the potential for internationally compatible devices** to be developed for these bands. The FCC has decided to make the proposed bands available on an unlicensed basis in the US; and the 116-134 GHz band is also available for terrestrial use by broadcast auxiliary services in Japan. Opening up similar bands in the UK has the potential to provide international economies of scale for research and development in the future use of frequencies above 100 GHz and into the development and manufacture of future receiver and transmitter equipment, which is likely to drive future demand for access to this spectrum.

3.39 In the consultation we said that enabling simple access to a materially greater amount of spectrum above 100 GHz, including large contiguous blocks of at least 5 GHz, should support UK-based innovators to more fully explore the potential of these frequencies, including for wide bandwidth or increased power services beyond the initial trial stage.

3.40 We also invited stakeholders to comment on any further bands above 100 GHz that we could consider making available on a technology and service neutral basis and what benefits might be realised by doing so. We noted in our review of the spectrum used by fixed wireless services[1] the increasing interest in 92-114.5 GHz (W Band) and 130-174.8 GHz (D Band) and indicated that we would take steps to consider how to make this spectrum available for high capacity fixed wireless links.[13]

Consultation responses

Overall objectives

3.41 The DSA supported our decision to target these specific bands. It thought that new internationally compatible devices are likely to emerge in the targeted bands, offering economies of scale, in particular in view of the FCC's decision to make several bands in this range available in the US. Three also supported the release of the proposed bands.

3.42 BT, Facebook, Nokia, the RSGB and Professor Stephen Gao were also in favour of the objective to open up access to spectrum in the 100-200 GHz range, while not offering

[13] As set out in our 2018 Review of spectrum by fixed wireless services, we anticipated that use of bands above 100 GHz, such as the D and W bands, for fixed wireless links would involve more short, high capacity connections for use by smaller mobile cells and last mile fixed wireless access broadband services.

specific comments regarding our assessment of the potential benefits of the proposed bands. [✂]

The D (130-174.8 GHz) and W (92-114.5 GHz) bands

3.43 Several responses suggested that we should consider prioritising making the D and W bands available. The NCEO thought that the W band should be prioritised above the three proposed bands. Nokia noted that the mobile community appeared to place a high priority on making D and W bands available for fixed wireless services, as these bands might be used in future mobile networks.

3.44 BT welcomed our proposals but said it had a greater interest in the availability of the D and W bands, which it said could help to realise dense and heterogenous 5G networks and be of importance to future mobile network architecture. For the W band, it suggested a licensed approach using an online system that would instantly confirm licences. It thought that the D band should be block allocated to mobile network operators for self-management, as this could support innovative solutions for mobile infrastructure without the need to request individual licences.

Other bands

3.45 EESS stakeholders suggested that we should prioritise other bands above 100 GHz due to their concerns around potential interference. ECMWF and [✂] said that we should consider any bands in the 100-200 GHz range that are not important for EESS and critical services. This would mean excluding our proposed bands as well as 148.5-151.5 GHz and 164-167 GHz. ESA/EUMETSAT said that we should focus on increasing use in bands above 100 GHz already allocated to fixed and mobile services or radiodetermination in the Radio Regulations. Their response also noted that WRC-19 identified a number of spectrum blocks above 200 GHz (275-296 GHz, 306-313 GHz, 318-333 GHz and 356-450 GHz) for potential future fixed and mobile use, which would have no need for EESS protection. [✂] also noted that WRC-19 had identified over 100 GHz of spectrum in the 275-450 GHz range which could be used for land mobile and fixed use.

3.46 Nokia said that allowing fixed operations in a large contiguous block of spectrum (in the order of a tens of GHz or more blocks) would be of great interest in the future. [✂]

3.47 Professor Steven Gao said that we should consider making further bands above 100 GHz up to 1 THz (1000 GHz) available, to support the development of technology using increasingly high frequencies. [✂]

Analysis and conclusions

The proposed bands

3.48 Our assessment of the case for enabling greater terrestrial use of the 116-122 GHz, 174.8-182 GHz and 185-190 GHz bands has not changed. We continue to consider that making these bands available for terrestrial use will create opportunities for research collaboration and collective innovation, and that in future people and businesses in the UK may be able

to take advantage of a system of internationally compatible devices with economies of scale.

3.49 We acknowledge that the ITU Radio Regulations do not currently include terrestrial allocations to the three bands covered by our proposals, which are allocated to EESS (passive), space research (passive) and inter-satellite services. However, consistent with Art. 4.4 of the Radio Regulations,[14] this does not prevent administrations from authorising terrestrial use of these bands, provided that interference is not caused to other authorised spectrum users.

3.50 In line with this, in the January 2020 consultation we proposed that devices would be authorised subject to certain technical conditions to protect EESS from the risk of interference. In sections 4-5 of this statement we conclude that, taking account of issues raised in the consultation, our technical conditions would be expected to protect EESS in these bands from undue interference.

3.51 In the January 2020 consultation we also explained that Inter-Satellite and Space research activities operate in space and do not point at the Earth, so are unlikely to be at risk of undue interference from terrestrial users.

Other bands above 100 GHz

3.52 We note the comments from stakeholders that we should look to increase use of the bands already allocated to fixed and mobile services in the Radio Regulations. We plan to make the W band (92-114.5 GHz) and the D band (130-174.8 GHz) available for use in the UK for high capacity fixed wireless links and will consult on proposals in due course. We are considering these bands separately.

3.53 We have also taken account of responses asking us to consider other bands in the 100-200 GHz range and above. We plan to make further bands above 100 GHz available in future and will consider options to further expand the available blocks of contiguous spectrum to enable wider bandwidths.

Final conclusions

3.54 We have considered the information provided by stakeholders on the current and future use of bands above 100 GHz. It is clear that terrestrial research and innovation in bands above 100 GHz, whilst at a relatively early stage, has the potential to develop new technologies and applications which could deliver benefits for citizens and consumers across many sectors. We remain of the view that our decision to enable simple, more flexible access to a materially greater amount of spectrum above 100 GHz, particularly in large contiguous blocks, should support UK-based innovators to more fully explore the

[14] Article 4.4 of the Radio Regulations provides that "Administrations of the Member States shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations, except on the express condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations."

potential of these frequencies beyond initial trials. Where trials are successful, innovators would be able to move to commercialise applications and devices without spectrum access being a barrier.

3.55 We recognise the importance of the current and future EESS uses of the bands we consulted on, as well as other bands in the 100-200 GHz range, and that this delivers a number of benefits to citizens and consumers, including services related to safety of life. Nonetheless, we continue to think that enabling further use of these bands in coexistence with EESS use would better support optimal use of the spectrum.

3.56 Taking account of these factors, and the results of our technical analysis set out in section 5, we have decided to open up terrestrial use of these bands. However, in view of the importance of EESS services using these bands we have decided to require the use of a 'Spectrum Access: EHF' licence. We set out our reasoning and approach in section 4.

3.57 In view of the early stage of technological developments and ongoing international activity around these bands we plan to review this new approach in 2024.

3.58 We plan to open up access to further bands above 100 GHz for use in the UK, including the D and W bands. We will consult on proposals in due course.

4. New licensing framework

4.1 In this section we consider the points raised by respondents in their comments on our proposals to authorise devices on a licence-exempt basis for lower power use, and to create a 'Spectrum Access: EHF' licence to authorise increased power use in these bands. We set out the reasoning for our decision to proceed with our proposals to create a 'Spectrum Access: EHF' licence to authorise terrestrial use of the 116-122 GHz, 174.8-182 GHz and 185-190 GHz bands. We note at the outset that, in light of points raised in the consultation which we discuss further below, we will not proceed with our proposals to authorise devices to operate on a licence-exempt basis in these bands at this stage.

4.2 We consider comments on the technical analysis underpinning our proposals separately in section 5.

Ofcom proposed a new authorisation framework to support innovation

4.3 In the January 2020 consultation we noted the potential benefits of increased innovation in new technologies using spectrum above 100 GHz. At present, terrestrial access to the proposed frequencies can only be obtained by applying for an Innovation and Research licence (used for research, development and testing purposes) or a Demonstration and Trial licence (used for demonstrating and trialling new equipment).

4.4 These licences are available for any frequency within the radio spectrum subject to coordination and availability. They permit the use of radio spectrum for innovative purposes[15] for a time-limited period of up to 12 months, subject to a fee of £50 per year for each location for an Innovation and Research licence and £50 per month per location for a Demonstration and Trial licence. Deployment of commercial or operational services is not permitted. Equipment must not cause undue interference to any other authorised services and no protection is given from undue interference received from other authorised services. Full details of the proposed equipment, usage and location must be provided to Ofcom, with notification of any changes.[16]

4.5 We proposed that to support the development and availability of new products and services we would take steps to enable easier, longer-term, cheaper and more flexible access to spectrum above 100 GHz throughout the product development stage by:

- authorising devices to operate in the proposed bands at lower powers on a licence-exempt basis, and
- making available a new 'Spectrum Access: EHF' licence to authorise increased power use of the proposed bands.

[15] Under the terms of the licences, Ofcom permits testing and development of wireless telegraphy (radio) equipment; scientific research and experimentation; and trials and demonstrations of radio apparatus, applications and technologies.
[16] See Innovation and Trial licensing guidance notes.

4.6 To enable innovative activity across different sectors and consistent with the principle of technology neutrality, we proposed to authorise the fixed or mobile use of any device which met the proposed technical conditions.

4.7 We proposed technical restrictions to avoid causing undue interference to EESS, based upon our coexistence analysis. We also proposed restrictions to protect users of adjacent bands.

4.8 We recognised that there was uncertainty on future demand for services using this spectrum, and what the services and applications developed would be. We said that we would keep developments under review and might propose further changes to how we authorise the use of these bands in future.

Consultation proposals for licence exemption

4.9 In section 4 of the January 2020 consultation we proposed to authorise devices to operate in the proposed bands at lower powers on a licence-exempt basis. For indoor use we proposed to authorise devices to operate on a licence-exempt basis up to a maximum power level of 40 dBm EIRP. For outdoor use, we proposed maximum power levels of 20 dBm or 40 dBm EIRP according to the band.[17] We further proposed reduced maximum EIRP levels at specified angles relative to main beam in the elevation plane for outdoor use.[18]

4.10 We explained that under sections 8(4) and 8(5) of the WT Act, we must make regulations to exempt stations and apparatus from the requirement to be licensed if certain conditions are met.[19]

4.11 We further noted that:

a) our proposed technical conditions would mean that new users would be unlikely to cause undue interference to EESS;

b) given the short range and high capacity of this spectrum, the risk of multiple terrestrial users causing or receiving undue interference to each other would be lower than for frequency bands below 100 GHz;

c) allowing spectrum use on a licence-exempt basis would offer the simplest, most flexible access to the spectrum, without regulatory and administrative burdens or financial cost for innovators, future vendors or future users of devices;

d) licence exemption presents some potential disadvantages compared with a licence-based authorisation approach. It offers less certainty that technical conditions will be followed to avoid undue interference; ensuring compliance with technical requirements may be more challenging as regulators hold less information about who

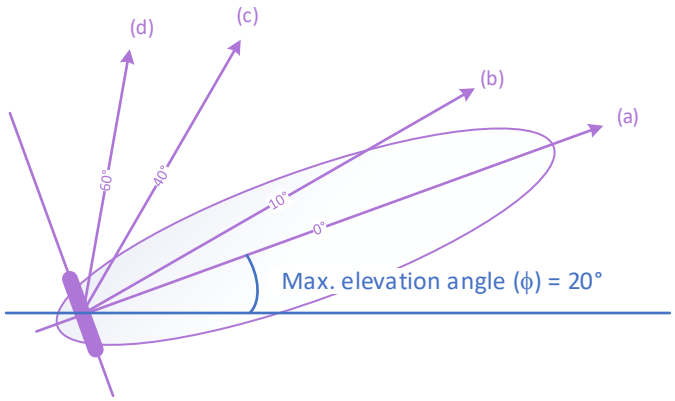
[17] For outdoor use, we proposed maximum power levels of 20 dBm EIRP in the 116-122 GHz and 174.8-182 GHz bands and 40 dBm EIRP in the 185-190 GHz band.
[18] For the 116-122 GHz and 174.8-182 GHz bands we proposed that the maximum permitted EIRP levels would be 13 dBm at >10°, 1 dBm at >40° and -3 dBm at >60°; for the 185-190 GHz band the proposed levels were 25 dBm at >10°, 14 dBm at >40° and 10 dBm at >60°.
[19] See annex A1.10.

is operating under a licence exemption regime. It can also be more challenging to change the authorisation approach at a later date if devices are authorised to operate on a licence-exempt basis.

Consultation proposals for 'Spectrum Access: EHF' licence

4.12 In section 5 of the consultation we noted that we expected potential future devices and applications to be developed requiring power levels beyond those covered by our licence exemption proposals. We proposed to introduce a new 'Spectrum Access: EHF' licence to enable increased power use of these bands, with a maximum permitted power for indoor and outdoor use of 55 dBm EIRP (point (a) in figure 4.1). In addition to the EIRP restrictions at specified angles relative to main beam in the elevation plane for outdoor use[20], shown at points (b), (c) and (d) in figure 4.1, we also proposed that in the case of outdoor use the installed antenna main beam elevation angle must not exceed 20 degrees above horizontal (angle ϕ in figure 4.1).

Figure 4.1: Proposed outdoor EIRP limits including device antenna elevation angle restriction



4.13 We explained that for increased powers we considered a licensing regime to be more appropriate than licence-exempt use because:

a) in principle increased power levels could increase the risk of causing undue interference;

b) the additional technical requirements regarding antenna installation elevation angle would require an appropriate compliance regime;

c) it would provide a higher degree of confidence in compliance with the technical requirements including the installation requirement. Under a licensing regime, the elevation installation requirements would be a clear condition of spectrum access as set out in the relevant licence documentation, and each licensee would be required to be able to demonstrate compliance. In the event of suspected non-compliance,

[20] We proposed the same reduced permitted EIRP levels at specified angles relative to main beam in the elevation plane for outdoor use as for the licence exemption proposal. For the 116-122 GHz and 174.8-182 GHz band we proposed that these would be 13 dBm at >10°, 1 dBm at >40° and -3 dBm at >60°; for 185-190 GHz the proposed levels were 25 dBm at >10°, 14 dBm at >40° and 10 dBm at >60°. See figure 4.1 for a diagram illustrating the angles.

enforcement would be considerably more straightforward under a licensing regime (compared to a licence-exempt regime) as Ofcom would hold records of authorised users, enabling easier identification of potential sources of undue interference due to non-compliance with the technical conditions set out in the licence;

d) it would also provide more flexibility to make changes to how we authorise the use of these bands at a later date, noting the uncertainty about which future devices and applications would make use of these frequencies, and the greater potential risk of interference owing to the increased power level.

4.14 We proposed that the terms of the 'Spectrum Access: EHF' licence should facilitate easy, flexible and inexpensive spectrum access. Accordingly, we proposed that:

a) a licence would permit uncoordinated shared nationwide access[21] to the spectrum in one of the 116-122 GHz band, the 174.8-182 GHz band or the 185-190 GHz band;

b) licensees would be able to use any part of their selected band;

c) there would be no limit to the number of devices which a licensee could deploy in the band, nor any device registration requirements; and

d) fixed or mobile use would be permitted.

4.15 We considered that this approach took account of the low likelihood that new users would encounter interference from other terrestrial users, and the likelihood that in most cases new users would not require a very high degree of protection from interference from other terrestrial users, at least in the near-medium term as new devices and applications are developed.

Consultation proposals for technical and non-technical conditions

Proposed technical conditions for licence exemption and 'Spectrum Access: EHF' licence

4.16 In addition to the core proposed technical conditions for licence-exempt and licensed use described in paragraphs 4.9 and 4.12 we also proposed that:

- airborne use would not be permitted;
- out of band emission limits must not exceed -10 dBm/MHz.

[21] We said that this approach would maximise flexibility for licensees and reflected the very low risk of interference between users given the large amount of available spectrum, the higher reduction in signal level with propagation distance and the likelihood that increased power use such as data links would use highly directive antennas with narrow beams in these bands. We also noted that future devices might be designed to have the potential to detect when other devices are using the same frequencies and to use this information to move to a channel with a lower level of use by other devices and applications.

Proposed non-technical provisions for the 'Spectrum Access: EHF' licence

4.17 In paragraphs 5.30 to 5.48 and annexes A8-A9 of the consultation we set out the proposed non-technical provisions of the 'Spectrum Access: EHF' licence. These conditions included that:

- Any frequency or bandwidth could be used within the selected frequency band;
- The licence would allow use of equipment within the United Kingdom and UK territorial sea. The proposed authorisation would also extend to the Channel Islands and the Isle of Man;
- The licence would be for an indefinite duration with a payment interval of 5 years for a £75 fee;
- The licence would permit Ofcom to give 3 years' notice to revoke the licence for spectrum management purposes;
- Licensees would be required to keep records of device location and, for outdoor use, the angle of antenna installation;
- Ofcom would have a number of powers to monitor spectrum use and take enforcement action where needed.

Responses to Ofcom's consultations

4.18 We received a number of comments about our proposals, covering five broad themes:

a) the importance of EESS (passive) services and the weather and climate data they collect using these bands;

b) the potential for innovation using these bands;[22]

c) the extent to which respondents agreed that the proposed technical conditions could be expected to protect EESS from harmful interference;

d) the potential impact, were harmful interference to EESS to occur; and

e) assurance and compliance considerations.

4.19 In general, non-EESS stakeholders were broadly positive about the proposals, whereas EESS stakeholders expressed concerns over the potential for interference and compliance risks should terrestrial devices be authorised to operate using the proposal bands.

New authorisation framework

Non-EESS stakeholder responses to the consultations

4.20 BT, the DSA, Facebook, Nokia, Three and Professor Stephen Gao supported our proposals to open up these bands. [✂]

[22] We consider stakeholder responses on the value of the data collected in the three bands by passive EESS and the potential for innovation using these bands in section 3.

4.21 [✂]

4.22 The DSA welcomed the proposals, considering that new internationally compatible devices are likely to emerge in the targeted bands; authorising devices to operate on a licence-exempt basis would give innovators the opportunity to exploit economies of scale, establish international research collaborations and launch commercially without needing to worry about spectrum access.

4.23 Facebook supported the use of licence-exempt or lightly licensed frameworks in EHF bands. It noted that there is less potential for interference in EHF spectrum due to its propagation characteristics, and that Fixed Wireless Access and Wireless Backhaul systems using EHF would have narrower beams than current systems, which would further decrease the potential for interference.

4.24 Three supported the proposals including increased power use, considering that this might compensate for the propagation characteristics of high frequencies, especially in outdoor deployments. However it considered that it would be difficult to manage and police the beam elevation angle below 20 degrees, particularly for outdoor deployments. Three welcomed the technology neutral approach which it saw as important to enabling developers to establish new technologies but anticipated that standards bodies would in future finalise specifications for these bands.

4.25 Nokia agreed with the proposals, with a preference for the licensing approach, which it considered would allow for a better control of higher power devices in order to protect EESS. It further noted that coexistence with other services should be less challenging given the short range of these bands, and considered that the technical simulations underpinning the proposals represented a worst case scenario and that the real impact of the introduction of low power devices on EESS sensors in the considered bands would be lower than evaluated in the studies.

4.26 [✂] noted that any authorisation approach should take account of the clear potential [✂]. This might require changes to the authorisation approach [✂].

4.27 The RSGB indicated that they were comfortable with the proposals but expressed concern should the bands be significantly expanded to override protections provided to international passive allocations under ITU-R RR 5.340.

EESS stakeholder responses to the consultations

4.28 EESS stakeholders emphasised the importance of these bands to scientific research, in particular for weather forecasting and climate monitoring. As a result, they raised concerns about the potential for harmful interference to the sensitive EESS systems used, and the impact that such harmful interference might have. In view of this they stressed the importance of monitoring and compliance.

4.29 The ECMWF urged us to reconsider our proposals, noting the importance of the bands for weather forecasting and climate monitoring. Furthermore, the ECMWF and [✂] raised concerns that some of the assumptions used in the technical analysis would in their view

significantly underestimate the potential impact to the existing services using these bands, and called for the use of realistic worst case scenario assumptions. However [✂] supported our proposals to introduce a new EHF licence, provided EESS would receive the necessary protection, noting that Ofcom could use its powers to vary the licence terms or, in extreme cases, revoke licences, should harmful interference occur.

4.30 ESA/EUMETSAT expressed concerns on whether the proposed technical conditions for licence-exempt devices would provide appropriate protection for passive EESS. They suggested Ofcom should study the impact of devices with main beam elevation angle spanning from 0 to 90 degrees, as they considered some deployments would wish to use an elevation angle of above 20 degrees, notwithstanding the elevation angle restriction criterion. For licence-exempt devices they proposed that an additional restriction to cap the maximum elevation angle should be required, noting that the technical analysis assumed a maximum elevation angle limitation to 20 degrees but that this was not stipulated as a requirement in our licence exemption proposals.

4.31 ESA/EUMETSAT requested clarification on how the proposed operational conditions (indoor restrictions and elevation-based EIRP mask for outdoor use) would be enforced. They proposed that appropriate spectrum monitoring policies, devices deployment control mechanisms and effective spectrum enforcement strategies would be needed, including mechanisms to address observed interference to passive EESS from the aggregation of licence-exempt devices. They recognised that a licensing regime would facilitate the enforcement of the operational conditions but sought clarification of the mechanisms envisaged for checking compliance and interference monitoring and mitigation.

4.32 ESA/EUMETSAT stressed that interference would affect the accuracy of data and its use for services such as Numerical Weather Prediction. They noted that any interference would initially be expected to be at a low level and hence undetectable, so any affected measurements would be incorrectly interpreted as valid. Over time aggregate interference could be expected to grow and be identifiable, but they cautioned that by this stage it would be too late to introduce provisions to address this. This scenario would result in erroneous and increasingly wrong measurement data being used for forecast systems and climate records until they were flagged as obviously corrupted data and consequently disregarded.

4.33 The UK Space Agency (UKSA) said it was important that coexistence with EESS was demonstrated, given that measurements made within these bands are key inputs to weather forecasting and climate studies. [✂] noted that the UK has invested in observations that use this spectrum, largely through ESA and EUMETSAT. [✂] was keen to ensure that the existing and future use of the spectrum allocated to Earth Observation remains protected and requested reassurance on this point, including consideration of all cases that might lead to undue interference and proposed mitigations, efficacy and practical enforcement. On the specific proposals, [✂] was unsure over how the differing indoor/outdoor criteria could be effectively enforced without placing a high inspection and monitoring burden on Ofcom. On this basis, it suggested that it might be better to have a licensed regime, at least initially, for all higher power devices wherever located. [✂] was

supportive of the licensing proposals provided that the power limits and mitigations were effective. It also urged Ofcom to retain powers to vary the license terms or in extremis revoke licenses, in a timely manner, if harmful interference were to occur.

4.34 The NCEO stressed the importance of the proposal bands for weather forecasting and climate monitoring and suggested that Ofcom should not pursue authorising licence-exempt outdoor use between 174.8 and 192 GHz. The NCEO further suggested a two-stage approach comprising an initial trial assessment period with a time-limited authorisation for devices to operate on a licence-exempt basis, ideally using other bands in the 100-200 GHz range. A monitoring programme could verify the actual patterns of signal emissions and enable longer-term arrangements to be introduced if considered suitable. The NCEO considered that this assessment would allow for more confidence in regulations. On our licensing proposals, the NCEO considered that this would facilitate enforcement of the operational conditions but sought clarification on the mechanisms envisaged for conformance checking and interference monitoring and mitigation.The NCEO also urged technical analysis to consider potential interference from the full range of conditions.

4.35 The STFC noted that the 100-200 GHz frequency range is extensively used for Earth observation (climate monitoring and weather predictions) and fundamental scientific research in support of astrophysics. It argued that it is not possible to define a "safe" power density threshold, as current EESS instruments do not have the spectral resolution to distinguish between the natural atmospheric signal and radio frequency interference; in its view, interference cannot be studied or mitigated. The STFC said that the Numerical Weather Prediction (NWP) system assumes that interference in the protected bands can be neglected. As a result, interference might give rise to unidentified systematic measurement errors, leading to less accurate weather and climate related measurement systems. Whilst the STFC noted that the link between interference levels and NWP forecast error is currently unknown, it cautioned that interference could have significant socio-economic impacts including risk to human life should, for example, storm track predictions and forecasts for hurricane landfall times and locations become less accurate.

4.36 On our specific proposals, the STFC thought that given the potential impact to EESS some of the potential disadvantages of licence-exempt authorisations discussed in section 4.4 of the January 2020 consultation would have a higher probability of occurrence. The STFC also perceived a higher potential for spectral pollution and possibly complex harmonic frequency content from increased power use which would exacerbate the impact on EESS, and thought that in the absence of a strict Electro-Magnetic Compliance standard for consumer electronics there would be a need for careful evaluation of product characteristics prior to release, and the introduction of national/global monitoring capabilities to ensure compliance.

4.37 In response to the May 2020 consultation the ECMWF, Met Office and UKSA commented that additional technical factors should be considered, and suggested an extended consultation to allow time for the additional studies to complete, to confirm or otherwise that coexistence will be achieved.

Our response

We will open up the bands for terrestrial use in coexistence with EESS

4.38 As set out in section 3, we recognise both the potential for innovation using these bands and the importance of the data collected by passive EESS and the critical services these enable, providing benefits for citizens and consumers.

4.39 As set out in the January 2020 consultation, in order to ensure that devices authorised under our proposals would not cause harmful interference to EESS using the proposed bands, our analysis took account of the relevant ITU-R recommendations ITU-R RS.2017[23] and ITU-R RS.1861[24]. In our consultations we set out how we applied these recommendations in our analysis, and the cautious assumptions that were used. We provide more details of this and additional technical factors raised in the consultation in section 5, which concludes that our proposals would not be expected to cause harmful interference to EESS.

4.40 As detailed in section 5, we have considered the effects of additional factors raised by stakeholders on our coexistence analysis. We have not considered it necessary to seek further comments from stakeholders on this sensitivity analysis, as suggested by the ECMWF, Met Office and UKSA. This is because consideration of these additional factors has resulted in only small changes to the level of modelled protection available to EESS services[25], or would not be expected to have a material impact on it. As a result, consideration of the additional factors raised by stakeholders has not changed our conclusion that we would not expect undue interference to EESS to occur.

4.41 We recognise that future EESS users of the proposed bands may have different characteristics to those currently operating. We have taken account of the new sensor characteristics provided by ESA/EUMETSAT in our analysis in section 5 but acknowledge that we might need to refine the authorisation parameters for these bands in future to take account of further developments, or other future users with primary allocations in these bands.

4.42 Whilst it remains our assessment that our proposed technical conditions of authorisation would be expected to avoid harmful interference to EESS, we recognise that stakeholders

[23] Recommendation ITU-R RS.2017-0 (08/2012): Performance and interference criteria for satellite passive remote sensing. This provides information on the performance and interference criteria for satellite passive remote sensing of the Earth and its atmosphere for microwave passive sensors. This recommendation identifies required performance criteria for satellite passive remote sensing of the Earth's land, oceans and atmosphere; minimum availability of passive sensor data and permissible interference levels for passive sensors; and permissible interference levels and reference bandwidths for interference assessments or sharing studies. This recommendation also sets an interference level which should not be exceeded for more than a percentage of the stated sensor viewing area or measurement time.

[24] Recommendation ITU-R RS.1861 (01/2010): Typical technical and operational characteristics of Earth exploration-satellite service (passive) systems using allocations between 1.4 and 275 GHz. This provides typical technical and operational characteristics of Earth exploration-satellite service (passive) systems using allocations between 1.4 and 275 GHz for utilization in sharing studies. This recommendation provides a consistent set of parameters for each band to support worst-case static analyses and dynamic analyses to determine interference levels into passive sensors.

[25] See figure 5.2.

are concerned about the risk of interference arising from non-compliance with these conditions. We also recognise that technology using these bands is at an early developmental stage, with some uncertainty around future device characteristics, deployments and applications.

4.43 Furthermore, we have taken account of the additional information provided on the potential impact of harmful interference, were this to occur. In particular, we have noted that it cannot be assumed that the EESS sensors or systems using sensor data would detect interference, in particular at low levels, with the potential for inaccurate measurements feeding into weather forecast and climate monitoring systems. Higher levels of interference would be detectable but render the data unusable. Whilst data verification systems are in place and sensor readings from these bands are combined with other readings, we recognise that these bands, in particular the upper bands, provide important weather and climate information including for extreme weather forecasting.

4.44 We have, therefore, considered whether to proceed with our proposals, and whether to make any amendments.

4.45 As set out in paragraph 4.10 above, we must make regulations to exempt stations and apparatus from the requirement to be licensed if their establishment, installation or use is not likely to involve undue interference with wireless telegraphy or to result in other adverse consequences set out in section 8(5) of the WT Act.

4.46 Having taken account of consultation responses, we do not consider that these conditions are clearly met at present. We consider that the proposed technical conditions of authorisation would be expected to avoid harmful interference to EESS, in accordance with the relevant ITU-R Recommendations. However, we have taken account of the concerns raised by EESS stakeholders about the potential impacts of undue interference, were this to occur following non-compliance with the technical conditions of authorisation.

4.47 On this basis, and taking account of the wider uncertainties about the characteristics of future terrestrial use of these bands, we will not introduce provisions to authorise devices to operate on a licence-exempt basis in these bands at this stage. There are a number of reasons for this:

a) licence exemption offers less certainty than licence-based authorisation that technical conditions on use will be followed, and hence that undue interference will not occur. Under a licensing regime, anyone wishing to use this spectrum would need to apply for a licence, with compliance with the technical conditions on use set out as a clear condition of spectrum access in the relevant licence documentation;

b) verifying and enforcing compliance with licence exemption rules would be more challenging as we would not hold information about who is operating on a licence-exempt basis, or where they are located;

c) it is more challenging to change the authorisation approach at a later date for a band where licence-exempt devices are operating.

We will introduce the 'Spectrum Access: EHF' licence for all terrestrial use

4.48 Instead, we will extend our proposed 'Spectrum Access: EHF' licence to apply to use of these bands at any power level up to 55 dBm EIRP. This approach will realise the benefits of enabling greater terrestrial access to these bands for innovation whilst enabling greater EESS confidence in the interference environment for a number of reasons:

a) the technical requirement requiring the antenna main beam elevation angle not to exceed 20 degrees above horizontal would apply to all outdoor use;

b) anyone wishing to access this spectrum would need to apply for a licence, with the device antenna elevation requirements and other technical conditions being set out as clear conditions of spectrum access in the relevant licence documentation;

c) in the event of suspected non-compliance, verification and enforcement would be considerably more straightforward under a licensing regime as Ofcom would hold records of authorised users, enabling easier identification of potential sources of undue interference from non-compliance with the technical conditions set out in the licence. Our approach to compliance and monitoring use is detailed in paragraphs 4.95- 4.104.

4.49 Authorising only licensed use at this stage will also provide more flexibility to make changes to how we authorise the use of these bands in future.

Innovation benefits

4.50 We consider that this approach will support innovation and longer-term investment and could enable earlier commercialisation, in particular for products for specialist use.

4.51 Terrestrial access to the proposed bands is currently possible using an Innovation and Research licence or Demonstration and Trial licence, as described in paragraph 4.3. Introducing the 'Spectrum Access: EHF' licence will enable longer-term, cheaper and more flexible access to spectrum for trials and innovation as:

- Commercial and operational deployments will be permitted; spectrum access will be authorised beyond the research, testing and trial/demonstration phases, including at wider bandwidths and higher powers than are currently permitted for terrestrial use above 100 GHz;
- The 'Spectrum Access: EHF' licence will be for an indefinite period, with a £75 fee payable per 5 year period. This will cover unlimited devices and locations;
- Whilst licensees will be required to keep records of the location and, for outdoor use, antenna elevation angle, and provide this or other information to Ofcom on request, they will not be required to provide full technical details of equipment and usage to Ofcom, nor to notify Ofcom in advance of any changes to these details or device location for approval.

4.52 We recognise that requiring new spectrum users to hold a licence does not offer all the potential benefits of a licence exemption regime, such as facilitating wide scale innovation and consumer device availability through there being no requirement for each user to secure a spectrum authorisation. However, we consider that the light-touch requirements

of the 'Spectrum Access: EHF' licence are unlikely to create barriers over the next few years as technologies using these frequencies are at an early stage of development. On this basis, for the coming time period we think that requiring a licence to access these bands is unlikely to constrain innovation and device availability.

4.53 We intend to review this framework in 2024, at which point we will review evidence of emerging technologies, antenna and emission characteristics and the outcome of international activity, including work within the ITU-R and CEPT. As part of this review, we may re-examine the case for authorising licence-exempt use of these bands.

Technical and non-technical licence provisions

4.54 In paragraphs 4.21-4.37 we summarised stakeholder comments on our proposed authorisation approach. We consider comments relating to the proposed technical conditions for permitted power levels and the elevation restriction for outdoor use in section 5. In this section we consider responses on other elements of our proposed technical and non-technical conditions, including concerns raised by stakeholders regarding the potential for electromagnetic frequencies to have an adverse impact on human health. We do not address points raised about the specific proposals for licence exemption, given that we are not implementing this element of our proposals.

Responses to proposed technical conditions and our response

Frequency bands

4.55 In the January 2020 consultation we proposed that:

a) each licence would authorise the licensee to use the 116-122 GHz band, the 174.8-182 GHz band or the 185-190 GHz band on a shared uncoordinated basis;

b) licensees would be able to use any part of their selected band; and

c) there would be no limit to the number of devices which a licensee could deploy in the band, subject to compliance with the technical provisions.

4.56 We have considered general stakeholder comments on the proposal bands in section 3. On the specific authorisation proposals Nokia considered that the properties of bands above 95 GHz made them well-suited for flexible use without requiring complex sharing arrangements. [✂] We note that we have chosen to apply uniform technical requirements across each band to enable a larger amount of contiguous spectrum and a simple approach. We have based our technical requirements on the parts of the band where the least attenuation would be expected.

4.57 We have therefore decided to implement these proposals.

Indoor, outdoor and airborne use

4.58 In the January 2020 consultation, we proposed that, subject to the specified technical conditions, both indoor and outdoor use would be permitted by the licence. We explained

that, in line with the definition of "indoor" set out in the Wireless Telegraphy (Mobile Repeater) Exemption Regulations 2018, for the purposes of our proposals "indoor" meant inside premises which: (i) have a ceiling or a roof; and (ii) except for any doors, windows or passageways, are wholly enclosed. We also proposed that, as an additional safeguard against undue interference to EESS, and potentially Radio Astronomy sites in France and Spain, airborne use would not be permitted.

4.59 Stakeholder concerns around potential interference and compliance risks were primarily focused on outdoor use, given the expected attenuation of indoor emissions from the high building loss levels at these frequencies. We consider these elements in paragraphs 4.95-4.104 and section 5.

4.60 We received the following comments on our proposals regarding indoor, outdoor and airborne use:

a) The DSA observed that many of the envisioned use cases are for indoor use and expected that the potential for interference caused by indoor devices would in practice be further reduced due to the high building penetration attenuations that occur at these frequencies. The NCEO said that coexistence would be possible for indoor applications. However, the UKSA raised concerns that there might be risks associated with indoor use, if the specific building and deployment characteristics were to result in lower than expected attenuation.

b) As noted in paragraph 4.31, clarification was requested by ESA/EUMETSAT about how Ofcom would enforce compliance with the different technical conditions for indoor and outdoor use and the elevation-based EIRP mask for outdoor use. [✂] was unsure about how the difference conditions for indoor and outdoor use could be effectively enforced without placing a high burden on Ofcom. Three considered that it would be difficult to manage and police the beam elevation angle restriction.

c) The STFC noted that interference risks would be substantially aggravated if new devices were to be deployed not at ground level, but from air-borne platforms (UAV, HAPS, balloons, or even a LEO CubeSat). The ECMWF told us that airborne use would carry greater risk of causing interference as most of the water vapour in the atmosphere is in the planetary boundary layer, whose top can be at a height of between a few tens of metres and a few kilometres.

4.61 Our provisions on indoor use would not be expected to result in interference to EESS given that ECC report 190 states that the indoor/outdoor attenuation will be greater than 60 dB. We acknowledge that there is a risk that in some specific cases attenuation could be lower. However, given the definition of "indoor" we judge that this risk is small, and that the probability of such a scenario resulting in interference to EESS is low.

4.62 Any device operating in an environment which does not meet the definition of "indoor" in section 4.58 would be required to meet the technical conditions for outdoor use. For greater clarity, we have specified the meaning of "outdoor use" in the Interface Requirement. We address our approach to compliance and assurance in paragraphs 4.95-4.104 below.

4.63 We proposed different licence conditions for indoor and outdoor use to take account of the relatively high building penetration losses at these frequencies, and to provide additional flexibility for antenna patterns of devices used indoors, such as in a lab environment.

4.64 We proposed to authorise fixed and mobile use in order to enable the widest range of innovative activity. The proposed technical conditions will apply to all licensees and they must ensure that they comply with the elevation angle restrictions for outdoor use. We have decided to adjust the wording of the requirement expressed in the January 2020 consultation as "outdoor installations"' to "outdoor use"' to capture the potential for non-fixed use to make use of more dynamic deployments. However, the technical requirement remains the same.

4.65 Consistent with our proposals, the 'Spectrum Access: EHF' licence will not permit airborne use. This will provide an additional safeguard against undue interference to EESS.

Out of band emission limits and protection of passive bands

4.66 ESA/EUMETSAT requested further information to address the protection of the 'passive bands' 114.25-116 GHz, 182-185 GHz and 190-191.8 GHz which are covered by the provision 5.340 of the Radio Regulations.

4.67 Provision 5.340 of the Radio Regulations states all emissions are prohibited in the 114.24-116 GHz, 182-185 GHz and 190-191.8 GHz bands. This means that there must be no intentional emissions within the bands and that any adjacent services must not exceed the protection criteria specified in Recommendation ITU-R RS.2017.

4.68 The protection criteria that apply to the RR 5.340 bands are the same as for EESS bands. We consider that where the in-band technical conditions are applied to protect EESS, the adjacent passive bands will be afforded a greater level of protection as the residual emissions into the adjacent band will be significantly lower compared to in-band.

4.69 Nonetheless, in the January 2020 consultation we also proposed maximum permitted out of band emission limits of -10 dBm/MHz. This is a level which aligns with both ETSI EN 305 550[26] for 122-123 GHz and FCC regulations. We have decided to make editorial changes to the licence and the Interface Requirement to clarify that -10 dBm/MHz is defined as an EIRP level.

4.70 We consider that these restrictions will provide additional protection to the 114.25-116 GHz, 182-185 GHz and 190-191.8 GHz 'no emission bands', and help to maintain the sharing environment for other adjacent bands, including the licence-exempt use of short range devices in the 122-123 GHz band.

[26] Devices using 122-123 GHz under the existing licence exemption provisions may operate up to 100mW (20 dBm) EIRP.

EIRP density limit

4.71 ESA and EUMETSAT suggested that EIRP density limits per 200 MHz should be expressed in line with Recommendation ITU-R RS.2017.

4.72 The proposed technical licence conditions specify an absolute EIRP limit based on our analysis using a minimum bandwidth of 100 MHz. Given the benefits of using very large bandwidths above 100 GHz (as noted in paragraphs 3.4, 3.15 and 3.17) we expect that in practice licensees will generally wish to use wider bandwidths. By setting an absolute EIRP limit, the power spectral density from a device will decrease as the bandwidth increases. On this basis, we do not consider it necessary to set EIRP density limits per 200 MHz.

4.73 In order to provide an additional safeguard to ensure that the spectral density of any narrowband use would not rise above that of a 100 MHz system, we have decided to introduce a clarifying provision in the licence conditions that an EIRP reduction must be applied to systems using bandwidths less than 100 MHz. This reduction will apply to all EIRP limits[27] specified in the licence:

$$EIRP\ Reduction\ =\ 10 \times log_{10}\left({BW_{MHz}}/{100}\right)$$

Responses to proposed non-technical conditions and our response

Frequency

4.74 We proposed that:

a) the licensees would be authorised to use the selected frequency band and that any frequency or bandwidth may be used within the band, subject to the technical conditions of the licence;

b) the licensees would be able to apply for a licence variation to move to a different band covered by the same licensing product.

4.75 We have received no comments on these proposals and have decided to implement them.

Geographical boundaries

4.76 We proposed that:

a) the licence would allow use of equipment within the UK and UK territorial sea; and

b) the proposed authorisation would also extend to the Channel Islands and the Isle of Man.

4.77 We have not received any comments on these proposals, and have decided to implement them.

[27] In cases of bandwidths below 100 MHz the EIRP reduction shown must be applied to the maximum EIRP and also the reduced permitted EIRP levels at specified angles relative to main beam in the elevation plane.

Duration of the licence

4.78 In the January 2020 consultation we proposed that the licence would:

a) be for an indefinite duration with a payment interval of 5 years; and

b) permit Ofcom to give 3 years' notice to revoke the licence for spectrum management purposes.

4.79 The NCEO suggested a two-stage approach comprising an initial trial assessment period with a time-limited authorisation for devices to operate on a licence-exempt basis. A monitoring programme could verify the actual patterns of signal emissions and enable longer-term arrangements to be introduced if considered suitable. The NCEO considered that this assessment would allow for more confidence in regulations.

4.80 [✂]

4.81 We have taken account of stakeholder comments in our decision to only permit licensed spectrum access at this stage, and to review our approach in 2024. This approach provides us with flexibility to take account of new evidence and developments.

4.82 We have considered whether to also introduce a time-limited authorisation approach at this stage. It remains our view that innovation will be best supported by a simple licensing framework, keeping any administrative burden and cost to the minimum necessary. We consider that an indefinite notice period provides more flexibility and is administratively simple for licensees.

4.83 Taking account of these stakeholder suggestions, and noting that we might consider it appropriate to amend the authorisation parameters for these bands in future, we have decided to prescribe a notice period for revoking the licences for spectrum management reasons of one year, instead of the three-year period that we initially proposed. This is because we consider that a shorter notice period will enable us to take swifter action to enable efficient use of the spectrum, in the event that we consider this to be necessary.

4.84 We have also revised the proposed conditions regarding licence revocation and variation to add Ofcom's power to notify the licensees by a general notice (to be posted on Ofcom website) in accordance with schedule 1 paragraph 6(b) of the WT Act, which is in line with our General Licence conditions.

Spectrum trading

4.85 We proposed that, subject to certain conditions to be set out in legislation, the licensee would be able to transfer their spectrum rights and obligations in the following ways:

a) outright total transfer of all rights to another party; or

b) concurrent transfer of all rights so two or more parties jointly hold the licence.

4.86 We proposed that partial transfers would not be possible.

4.87 We have not received any comments on these proposals and have decided to proceed with them. Implementing these proposals involves amending the relevant regulations[28] and licences will not be tradable until this has taken place. We plan to consult on these amendments in due course.

Access and inspection

4.88 We proposed that, in accordance with our standard conditions, the licence would include a condition that reserves to Ofcom the right to access and inspect the licensee's radio equipment. We have not received any comments on this proposal and have decided to implement it.

Modification, restriction and closedown

4.89 We proposed that the licence would include a condition that reserves to Ofcom the right to modify, restrict or close down the use of its radio equipment, should we have reasonable grounds to believe that the licensee has breached the terms of their licence, or we consider this necessary in the event of a national or local state of emergency being declared. We have not received any comments on this proposal and have decided to implement it.

Provision of information to facilitate optimal spectrum use

4.90 We proposed that the licence would include standard conditions to require licensees to provide, on request, general information regarding their equipment and use of frequencies. To assist monitoring and compliance, Schedule 1 to the draft licence included specific provisions requiring licensees to compile and maintain accurate written records of the location of devices (postal address or National Grid Reference) and antenna main beam elevation angle for outdoor use. It also included a requirement for licensees to submit other information to Ofcom in such manner and within such period as specified by Ofcom.

4.91 As set out above (see paragraphs 4.24, 4.31, 4.33, 4.34 and 4.36) some stakeholders raised concerns about risks of non-compliance with the technical conditions. Some sought more information on how Ofcom would monitor compliance and take action to detect and stop potential causes of interference to EESS. In light of these comments, we have decided to strengthen our approach to information provision to facilitate monitoring and swift action in the case of suspected non-compliance by:

a) Requiring licensees to maintain accurate written records of **both** the postal address (including postcode) **and** National Grid Reference (to 1m resolution) of the radio equipment[29] or, in case of **mobile use**, of the centre of any 5km radius within which the radio equipment is used. This is in addition to the requirement to maintain accurate written records of the antenna main beam elevation angle for outdoor use;

[28] The Wireless Telegraphy (Spectrum Trading) Regulations 2012 (S.I. 2187/2012).
[29] In the January 2020 consultation we proposed to require only one of these elements.

b) Requesting information on planned device locations in the licence application form; and

c) Requesting device location and outdoor antenna elevation information periodically. We anticipate contacting licence holders around twice each year.

4.92 Ofcom publishes details of the licences it grants in the Wireless Telegraphy Register (i.e. Ofcom's Spectrum Information System). Consistent with this approach, we expect to publish some information on these new licences in our register, including the licensees' name and the technical details associated with each new licence.

Determination of fees

4.93 We proposed that the new licence would be subject to a cost-based fee. In line with the fee payable for the Business Radio light licensing products, we proposed a fee of £75 payable every 5 years.

4.94 We have not received any comments on this proposal and have decided to proceed with it. To implement this decision, we plan to consult on the necessary changes to the Wireless Telegraphy (Licence Charges) Regulations 2011 (as amended) (the **"Fees Regulations"**) in due course. In the meantime, we expect to charge any new licensee on the basis of regulation 6 of the Fees Regulations.[30]

Compliance approach

4.95 Paragraphs 4.24, 4.31, 4.33, 4.34 and 4.36 above set out several concerns raised by stakeholders regarding potential compliance challenges relating to terrestrial use of these bands and sought further information on how these would be managed.

4.96 We believe that our decision to authorise use under the terms, provisions and limitations of a licence rather than authorising licence-exempt use mitigates these concerns.

4.97 Any licensee will be responsible for ensuring compliance with the terms, provisions and limitations of the licence. This includes different technical requirements for indoor and outdoor use and the antenna main beam elevation angle requirement for outdoor use. We consider these requirements proportionate to the risk of interference associated with indoor and outdoor use and should enable a wider range of innovation activity in indoor-only contexts. The terms, provisions and limitations are set out in the licence documentation; additional information is provided in the licensing guidance.

4.98 Ofcom has statutory powers to protect and manage the radio spectrum. These powers include provisions to address contraventions of licence terms, provisions and limitations. These are detailed on our website. For example, where there are reasonable grounds to believe that there is or has been a contravention of terms, provisions and limitations of a

[30] Regulation 6 of the Fees Regulations provides that: *"Where a sum is not prescribed by regulations made under section 12 of the Act whether on the issue of a licence or subsequently, there shall be paid to OFCOM such sum as OFCOM may in the particular case determine"*.

licence Ofcom may serve a Contravention Notice. Ofcom also has the powers to prosecute, warn, caution or serve a fixed penalty notice or issue a financial penalty.

4.99 As set out above, the 'Spectrum Access: EHF' licence will include specific terms and conditions to enable us to monitor and enforce compliance with the licence conditions (see, in particular, paragraphs 4.88-4.91 above). For the avoidance of doubt, we have decided to insert additional text to make it clear on the face of the licence and the relevant Interface Requirement that the licence is issued on the basis that "*interference is not caused by the Radio Equipment to other authorised spectrum users and that the Radio Equipment will not be protected from interference caused by other authorised spectrum users*" [31] (i.e. "*on a non-protection and non-interference basis*" [32]). We may revoke the licence for the reasons set out in the licence, including if the conditions of the licence are breached or a licensed device is causing interference to other authorised spectrum users.

4.100 We are satisfied that these provisions set out an appropriate framework which makes clear the requirements on licensees and will help us monitor spectrum use and take enforcement action where necessary.

4.101 We plan to undertake monitoring activity to verify that spectrum use is consistent with the licence conditions and gather evidence on emerging technologies and deployment scenarios.

4.102 In its comments on our analysis the STFC perceived a higher potential for spectral pollution and possibly complex harmonic frequency content from increased power use which would exacerbate the impact on EESS. The STFC also raised concerns that compliance challenges might arise from there not being a strict Electro-Magnetic Compliance standard for consumer equipment in these bands.

4.103 Whilst we recognise that there is currently no international standard for equipment in the 'Spectrum Access: EHF' licence bands, the Radio Equipment Regulations compliance process does not mandate the application of a standard. We also anticipate that suitable standards may emerge over time.

4.104 The Radio Equipment regulations 2017 set out the regulatory framework for radio equipment being made available in the UK, including a requirement that radio equipment must be constructed so that it both effectively uses and supports the efficient use of radio spectrum in order to avoid harmful interference. Making available means any supply for distribution, consumption of radio equipment in the course of a commercial activity.

Limiting exposure to electromagnetic fields (EMF)

4.105 Two stakeholders raised concerns about the potential for electromagnetic frequencies to have an adverse impact on human health and the environment, noting that 5G systems will make use of higher frequencies and new technologies. On this basis, they questioned the safety of making use of spectrum bands in the frequency range 100-200 GHz and asked

[31] See Schedule 2 to the licence template.
[32] See row 9 ("Authorisation regime") of the Interface Requirement.

why no risk assessments had been carried out for such millimetre wave frequencies. It was also suggested that any decisions should be delayed pending further information and assessment.

Our response

4.106 In performing our spectrum management duties, we take into account the advice on EMF exposure from the relevant public health authorities. Public Health England (PHE) currently has the statutory responsibility for public health issues in England, and its guidance also forms the basis for advice in Scotland, Wales and Northern Ireland.

4.107 PHE's main advice about radio waves is that the Guidelines of the International Commission on Non-Ionising Radiation Protection (ICNIRP) should be adopted for limiting exposure. These Guidelines apply for frequencies up to 300 GHz. ICNIRP is a non-profit independent scientific organisation set up specifically to investigate possible adverse health effects from non-ionising radiation. It is formally recognised by the World Health Organization and is consulted by the European Commission.

4.108 In February 2020 we published a consultation proposing to introduce a specific condition in Wireless Telegraphy Act licences requiring compliance with ICNIRP Guidelines for the protection of the general public for all radiocommunications equipment that is authorised to transmit at powers above 10 Watts EIRP. We also proposed to adopt a similar approach for equipment that is licence-exempt. We have reviewed responses to the EMF consultation and will shortly publish a statement on our decisions.

4.109 The 'Spectrum Access: EHF' licence authorises devices to transmit at powers up to 55 dBm, which is greater than 10 Watts EIRP. As a consequence, should we decide to implement our EMF proposals, we would amend our guidance and licence templates for this licence to incorporate the provisions relating to EMF, and vary any existing 'Spectrum Access: EHF' licences to incorporate the new conditions in due course.

4.110 We note that current licensed 5G deployments are re-using frequencies that have been in use for many years to deliver mobile and other services, such as TV broadcasting, satellite connections, and point-to-point microwave links. We will continue to follow the advice of the relevant public health bodies on EMF exposure.

Conclusions

4.111 Having carefully reviewed responses to our consultation, we remain of the view that it is appropriate to introduce a new authorisation framework for the proposed bands. However, having taken account of stakeholder responses, in particular those regarding the importance of the data collected by EESS using these bands, concerns about compliance and also the uncertainty around future developments, we have decided to require any potential user, including those operating at lower power levels, to hold a licence. We have also decided to make some amendments to the proposed licence terms and conditions to support monitoring and enforcement. This approach should provide EESS stakeholders with a greater confidence about the interference environment. The full requirements are

set out in annexes A2 (Interface Requirement 2106) and A3 ('Spectrum Access: EHF' licence template).

4.112 We propose to review this approach in 2024 and will review evidence of emerging technologies, antenna and emission characteristics and any international developments. We may then reconsider the suitability of a licence exemption approach for these bands.

4.113 For the reasons set out in this section, we consider that the licensing approach that we have decided to adopt is:

a) **objectively justified** in that we have identified likely increased future demand for access to this spectrum for use by innovative services and products. The proposed licence would permit spectrum use under technical conditions that would continue to ensure protection for EESS and other spectrum users;

b) **not unduly discriminatory** against particular persons or against a particular description of persons in that the licence conditions will apply to all users of devices licensed to these frequency bands (and, indirectly, to all manufacturers and sellers), and our technical restrictions would not be expected to increase the risk of undue interference to incumbent users;

c) **proportionate** to what it is intended to achieve, in that the technical and non-technical licence conditions that we have decided to impose will ensure that new users of the bands would not be expected to cause undue interference to incumbent users and will not create unnecessary administrative burdens to new users; and

d) **transparent** in relation to what it is intended to achieve, in that any technical and non-technical conditions applying to the new licensing approach will be clearly set out in the relevant licences.

4.114 As stated in section 3, we plan to make further bands above 100 GHz available in future. We consider that the 'Spectrum Access: EHF' licence framework is a model which could be introduced to other bands in the EHF range and above to enable innovative activity, in particular for bands above 100 GHz. The light licence format can enable spectrum bands to be opened up quickly, whilst retaining scope to make adjustments to how spectrum use is authorised in the light of technological developments and user experience. We would consult on any proposals to extend this licence to new bands, including consultation on the specific technical conditions appropriate to each band, such as coexistence with existing users.

5. Coexistence with EESS

Introduction

5.1 In this section we address the comments raised by respondents on our technical analysis published in Annex 6 to the January 2020 consultation, and the additional detail on our coexistence results presented in the May 2020 consultation.

5.2 Stakeholders provided comments in support of many aspects of our analysis. However, some EESS stakeholders commented that additional factors should be considered, including variation in atmospheric attenuation, apportionment of the interference margin (modelled protection available) between systems, effect of radiowave scattering from buildings or precipitation and the impact of orientation of deployed devices.

5.3 In this section we explain why, having taken account of these additional factors, we remain of the view that authorising use of the 116-122 GHz, 174.8-182 GHz and 185-190 GHz bands through the 'Spectrum Access: EHF' framework would not be expected to cause undue interference to incumbent users.

Our proposals

5.4 In the January 2020 consultation we proposed to impose certain technical constraints for authorising spectrum access in the 116-122 GHz, 174.8-182 GHz and 185-190 GHz bands. These constraints included maximum EIRP levels for indoor and outdoor use. For outdoor use we also proposed to place limits on the EIRP at increased angles relative to the main beam in the elevation plane, with a further limit on the elevation of the main beam. We proposed these limits to ensure that there would be reduced emissions towards EESS sensors.

5.5 In our assessment of potential interference to EESS we extended the analysis in the ECC Report 190[33] to account for the different coverage footprints and sensitivities of the EESS sensors used in each of the proposed frequency bands. We also included the effect of terrestrial devices using narrow beam antenna systems which reduce the signals radiated upwards into space.

5.6 In our coexistence analysis we made a number of assumptions, all of which lead to the modelled protection to EESS being an underprediction of the actual protection that may be available. The effect of all of these assumptions will be additive which indicates that our predicted protection will be cautious and a lower bound. The assumptions included:

a) **Device power** - All devices were modelled as operating at their maximum permitted power level. In practice, it is likely that not all applications require operation at the maximum permitted power or that all licensees will wish to use maximum power. This

[33] Compatibility between Short-Range Devices (SRD) and EESS (passive) in the 122 to 122.25 GHz band.

assumption is likely to lead to an overestimate of emissions radiated towards the EESS sensors.

b) **Device duty cycle** - All devices were modelled as operating on a continuous basis (i.e. a 100% duty cycle). This increases the joint effect of emissions from different devices at any given time and leads to the lowest estimate of protection margin. The ECC Report 190 recognised that in practice devices are likely to operate with a duty cycle below 50%.

c) **Device bandwidth** - It is likely that EHF devices operating in these frequency bands will use bandwidths greater than 1 GHz. Our licence conditions impose restrictions defined as absolute EIRP levels, which means that the use of wider bandwidths will lower the power spectral density and increase the modelled protection margin. For 1 GHz bandwidth the increase would be 10 dB compared to our analysis using 100 MHz. This means that there would be 10 times more protection to EESS than our modelling predicts.

d) **Operating frequency** - Atmospheric attenuation varies depending on frequency and the elevation angle of the path through the atmosphere. There is a significant difference in the attenuation across each of the frequency bands and where within the band a device operates will affect the signal level received by EESS sensors. In our cautious assessment we used the lowest propagation loss for each frequency, modelling the lowest protection margin available.

e) **Propagation losses** - Propagation losses due to free-space path loss and atmospheric attenuation were taken into account in our analysis. However, for low elevation angles, it is likely that there will be further losses due to the presence of terrain and clutter such as buildings and vegetation. These additional factors, which are likely to provide further protection to EESS, were not included in our assessment.

f) **Device directivity** - We included the effect of the directivity of the antennas used by devices for terrestrial applications. This directivity reduces the emission of signals from the devices towards the EESS. However, the antenna pattern we have used in our modelling coupled with the assumption of equal probability of main beam elevation between -20 and 20 degrees leads to a likely overestimation of sidelobe emissions in the direction of EESS. This assumption means that protection to EESS will in practice be higher than we have predicted.

g) **EESS protection criteria** - In our assessment of aggregate interference margin, we have used the ITU-R RS.2017 maximum interference level as an absolute limit and we have not considered the exceedance of this level permitted by ITU-R RS.2017[34] in percentage

[34] Limb sounders: -189 dBW/10 MHz may be exceeded for up to 1% of a 24 hour period in the 116-122 GHz, 174.8-182 GHz and 185-190 GHz bands.
Nadir sensors: -166 dBW/200 MHz may be exceeded by devices in 0.01% of a 2,000,000 km^2 area in the 116-122 GHz band.
Conical and Nadir sensors: -163 dBW/200 MHz may be exceeded by devices in 0.01% of a 2,000,000 km^2 area in the 174.8-182 GHz and 185-190 GHz bands.

time or area. This means we have applied a greater level of protection to EESS than is required by ITU-R RS.2017.

5.7 Based on the predicted level of protection across all bands and our cautious modelling assumptions, our provisional conclusion was that the proposals to authorise future terrestrial use of these bands would not be expected to affect the operations of EESS.

Stakeholder responses to EESS coexistence modelling

Our modelling approach

Stakeholder response

5.8 We received the following comments on our modelling approach:

a) ESA/EUMETSAT concurred with the use of the approach and methodology outlined in ECC Report 190 for the assessment of potential interference using the protection criteria from Recommendation ITU-R RS.2017 and EESS technical parameters from Recommendation ITU-R RS.1861. ESA/EUMETSAT also acknowledged the alignment of results provided in Table 3.1 of the May 2020 consultation, including the exceedance of the protection criteria that occurred when assuming main-beam coupling of terrestrial device antenna and EESS sensors. They agreed that such alignment would not be kept as the terrestrial devices would not be expected to track the satellite.

b) The ECMWF and [✂] raised concerns that some of the assumptions used in the technical analysis would significantly underestimate the potential impact of the proposed changes to the existing services using these bands and called for the use of worst-case scenario assumptions. The NCEO also urged technical analysis to consider potential interference from the full range of conditions; the STFC said that the real-world effect of radio frequency interference should be assessed prior to deploying systems in these bands.

c) Nokia viewed the Ofcom proposal as a generalisation of ECC Report 190 providing an extension of the band accessible to SRDs with licensed higher power use that would allow better control of higher power devices in order to protect EESS. They considered that the technical simulations underpinning the proposals represented a worst-case scenario and that the real impact of the introduction of low power devices on EESS sensors in the considered bands would be lower than evaluated in the studies.

d) The DSA said that due to the large amount of spectrum being made available that the likelihood of interference from multiple devices at any given frequency would be reduced.

Our response

5.9 We welcome the confirmation of our core modelling assumptions, methodology and the importance of the constant movement of the EESS sensors. We note that the protection criteria we have used, given in Recommendation ITU-R RS.2017, were developed in

collaboration with earth observation scientists within the specialist group of ITU-R Study Group 7. We consider points raised on specific elements within our modelling below.

Future applications and deployment scenarios

Stakeholder response

5.10 ESA/EUMETSAT said that the modelling and assumptions were generic and may not cover all future scenarios, and that information was missing on terrestrial devices deployment scenarios required to model the aggregate interference from terrestrial devices into EESS (passive) sensors.

Our response

5.11 We acknowledge that we took an application agnostic approach to our coexistence modelling in order to support our aim in releasing these EHF bands to encourage innovative use of the spectrum. The development of technologies to use these bands remains at an early stage, so there is not yet clarity on which technologies and devices might wish to use these bands. As a consequence, we have taken a technology neutral approach to defining appropriate technical conditions to ensure EESS protection from undue interference. We have developed these conditions on the basis of cautious modelling assumptions to provide a sufficient protection margin that will enable the operation of multiple devices. Given the uncertainties about the future technologies that will be deployed and the extent to which spectrum will be used by multiple devices (i.e. device density) we consider this approach to be more appropriate than basing our analysis on an estimation of potential device density.

Atmospheric losses

Stakeholder response

5.12 Whilst stakeholders recognised that propagation losses are higher above 100 GHz than in lower bands, we received the following comments on our approach to taking account of atmospheric losses:

a) ECMWF and [✂] highlighted that as the atmospheric attenuation in the 116-122 GHz band is influenced by oxygen, it is less variable than the upper two bands and the calculations were probably reasonable;

b) ECMWF, NCEO and [✂] highlighted that water vapour content and hence the associated loss is highly variable in the UK and that cold dry conditions should be considered in the assessment for the 174.8-182 GHz and 185-190 GHz bands;

c) The UKSA, Met Office and ECMWF provided analysis[35] of the Total Column Water Vapour (TCWV), the total weight of water per square metre, based on two studies using TCWV data collected from satellite observations. Observations from 40 years of

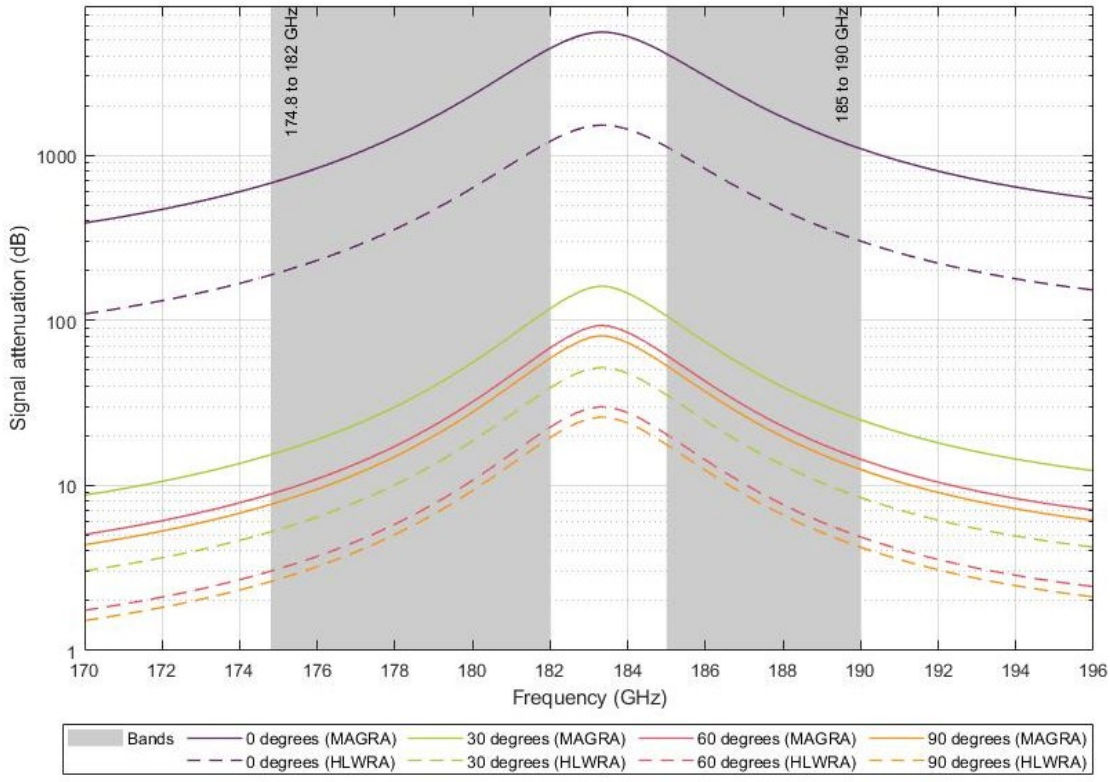
[35] https://www.ofcom.org.uk/__data/assets/pdf_file/0013/201091/ecmwf-metoffice-uksa.pdf

data showed that a TCWV of 5 kg/m^2 occurs widely across the UK on between 1% and 3% of days, lower values of 2 kg/m^2 were observed in limited geographical areas within the UK on 0.1% of days. A second analysis over a shorter period of 5 years showed 5 kg/m^2 occurring on approximately 10% of days and values of 2 kg/m^2 on less than 5%. They concluded that there would be less attenuation for an atmosphere with a TCWV of 2 kg/m^2 compared to the mean annual global reference atmosphere used in our analysis and that the power limits in the 174.8-182 GHz and 185-190 GHz bands should be reduced to reflect this.

Our response

5.13 We note the concerns raised by stakeholders and acknowledge that our initial analysis considered a mean annual global reference atmosphere (MAGRA) which is likely to be representative for a high proportion of the time but will not take into account the lower water vapour levels that occur for a limited number of days in a year. To consider the impact of a cold and dry conditions we have undertaken sensitivity analysis to assess the effect of this specific case.

Figure 5.1: Comparison of global annual mean reference and high latitude winter reference atmospheres

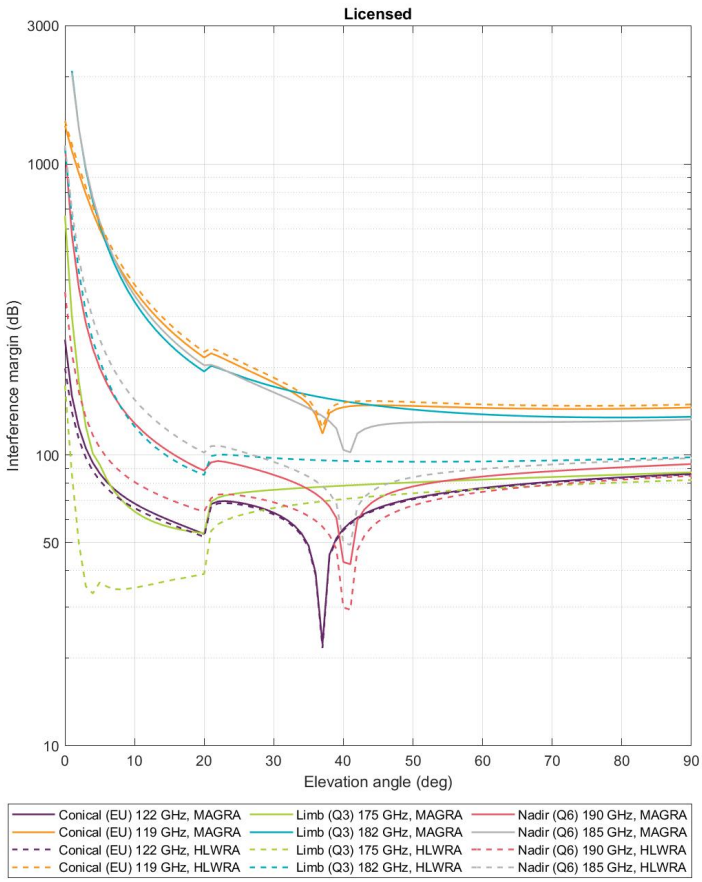


5.14 The Recommendation ITU-R P.676 Annex 1 line by line calculation of gaseous attenuation on slant paths requires profiles of water vapour, temperature and pressure from the ground to 100 km altitude. For a cold, dry atmosphere we have obtained these profiles from the Recommendation ITU-R P.835 high latitude winter reference atmosphere

(HLWRA)[36]. The profiles are valid for latitudes higher than 45 degrees which is appropriate for the United Kingdom. There is significant variation in the attenuation due to atmospheric gases which is dependent on the elevation angle of the slant path. To highlight this dependence, the losses calculated using the two reference atmospheres are given in figure 5.1 for 4 different elevation angles. The solid line uses the MAGRA as shown in our original analysis[37] and the dashed line represents the HLWRA.

5.15 In figure 5.2, we present the comparison of predicted protection available to EESS modelled with MAGRA and HLWRA. The solid and dashed lines represent our analysis using the MAGRA and HLWRA, respectively.

Figure 5.2: Sensitivity analysis of predicted aggregate interference margins for MAGRA and HLWRA using the average antenna pattern for licensed devices[38]



5.16 This sensitivity analysis highlights that there is no significant variation in the interference margin in the 116-122 GHz band, which is to be expected as the band is centred on an oxygen absorption line which is not as variable as water vapour. The small difference

[36] The HLWRA water vapour profile has a TCWV of 4.3 kg/m^2 and the atmospheric temperature and pressure profiles have surface values of -16 °C and 1011 hPa respectively.
[37] In figure A6.2 of the January 2020 consultation.
[38] The solid lines reproduce figure 3.2 of our May 2020 consultation for licensed devices.

observed between the solid and dashed curves for the Conical (EU) sensor is due to the variation in the temperature and pressure profiles of the two reference atmosphere models.

5.17 The aggregate interference margins for the 174.8-182 GHz and 185-190 GHz bands are reduced when the HLWRA is applied but the minimum levels for all sensors remain above those for the conical sensor in the 116-122 GHz band which had the least margin originally and which has not varied significantly with these different assumptions.

5.18 We observe a greater reduction of atmospheric losses at low elevation angle paths, as shown by the curves for the Limb (Q3) sensor. These paths travel the furthest distance through the atmosphere and will be more affected by a low level of water vapour than the shorter paths at higher elevation angles. It should be noted that at low elevation angles there is also likely to be additional attenuation due to the terrain and clutter which we have not accounted for in our assessment.

5.19 We recognise that there are a small number of days in a year when the water vapour level may fall below the HLWRA (4.3 kg/m^2). However, in view of the assumptions we have applied in our analysis, described in paragraph 5.6, our view remains that significant protection will still be available to the EESS sensors and a reduction of power limits is not required in the 174.8-182 GHz and 185-190 GHz bands. We also note that due to their non-geostationary orbits, the probability of EESS sensor presence in areas experiencing low water vapour content is likely to be low, given the number of sensors and their repeat periods.

Terrestrial device antenna modelling

Stakeholder response

5.20 We received the following comments on our approach to modelling terrestrial device antennas:[39]

a) STFC stated that the use of highly directional antennas was an idealised assumption and that it should be assumed that real devices would not live up to the theoretical basis of the Ofcom and ECC studies;

b) ESA/EUMETSAT expressed concerns about the limitation of the main beam elevation angle to 20 degrees and thought than a worst-case scenario considering 0 to 90 degree elevation should be considered. They stated that a basic link budget analysis showed that one outdoor device at 20 or 40 dBm EIRP is sufficient to exceed the EESS protection criteria, assuming main beam to main beam coupling;

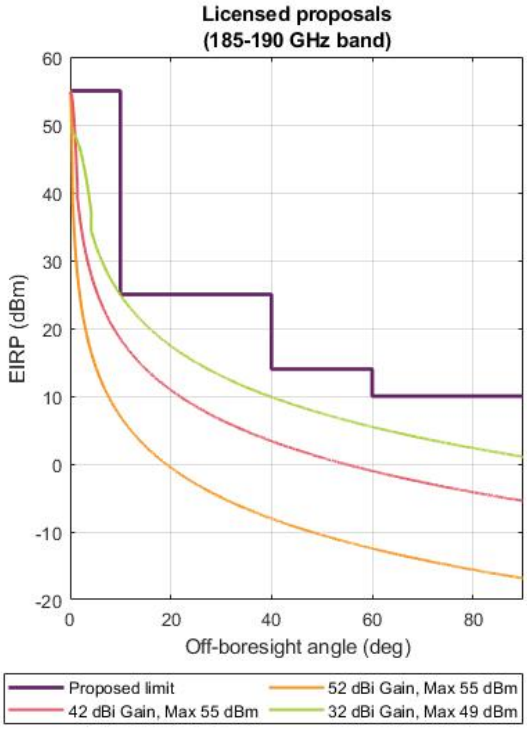
c) However, the DSA, Facebook and Nokia all considered that narrow antenna beams would be expected in devices at these frequencies, which would reduce the signals radiated into space.

[39] As described in A6.16-A6.19 of the January 2020 consultation.

Our response

5.21 We recognise that antennas and their radiation patterns will vary in practice from our modelling and this guided our decision to propose EIRP limits. For outdoor use, our licence conditions also require EIRP restrictions at angles relative to main beam in the elevation plane and will ensure that either antenna directionality or an overall power reduction will be required as shown in Figure 5.3.

Figure 5.3: Illustration of interaction between the proposed EIRP limits and antenna directivity



5.22 In our licence conditions for outdoor use we have taken a cautious approach in restricting the main beam elevation to below 20 degrees. However, our analysis showed marginal differences when the main beam elevation range was extended up to 30 degrees. An equal probability in azimuth is realistic as there is no reason to favour any specific angle, but this is not true of the elevation angle. We don't consider that modelling of all devices in the range of 0 to 90 degrees in elevation, as suggested by ESA/EUMETSAT, would be realistic. Our licence conditions ensure that main beam to main beam coupling between terrestrial devices and EESS sensors will not be permitted as devices operating with elevation greater than 20 degrees will be non-compliant.

Apportionment of EESS interference margin to consider in-band and adjacent band allocated services

Stakeholder response

5.23 ESA/EUMETSAT agreed that EESS (passive) protection criteria are set in recommendation ITU-R RS.2017. However, when considering the need for sharing the spectrum, they stated that the interference margin should be apportioned to take into account the potential for interference to arise from other allocated services, both in-band and in adjacent bands.

5.24 Sharing and compatibility studies are being undertaken for Radiodetermination applications within the frequency range 116-260 GHz in ECC PT SE24. In the context of this work, ESA/EUMETNET/EUMETSAT have proposed an apportionment margin methodology[40]. If the approach was agreed this would reduce the maximum interference level specified in Recommendation ITU-R RS.2017 based upon the number of allocated services and an equal apportionment of the potential interference. They identified five concurrently operating[41] services in the 116-122 GHz band[42], and seven in the upper bands[43]. The proposed apportionment margins are 7 dB for the 116-122 GHz band and 8.5 dB for the 174.8-182 GHz and 182-190 GHz bands. If accepted, this approach would reduce the available protection margins by these amounts.

Our response

5.25 Whilst we recognise that adjacent band systems could have an impact on the interference environment, we have not applied the apportionment methodology put forward by ESA/EUMETNET/EUMETSAT to ECC PT SE24 to our coexistence analysis. There is no agreed method for the application of apportionment within ITU-R or CEPT. We note that the equal apportionment margin values proposed by ESA/EUMETNET/EUMETSAT in ECC PT SE24 are likely to be an overestimation, as all systems would need to be operating at the same maximum power at the same time and in the same frequency band. We also note that apportionment of the maximum interference level between different services was not considered in the ECC Report 190. However, even with our cautious assumptions the magnitudes of the predicted protection margins are well in excess of the proposed apportionment values. We do not therefore consider that any further adjustments are required to take account of in-band and adjacent band allocated services. We will continue to engage in the ECC PT SE24 work on this topic.

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[40] Document number: SE24 WI71#7-05. Further elements on EESS (passive) protection. ESA, EUMETNET, EUMETSAT, 26/05/20 (https://www.cept.org/ecc/groups/ecc/wg-se/se-24/client/meeting-documents/?flid=27825)

[41] They recognised in the paper that Fixed Service (FS), Mobile Service (MS) and Radionavigation and Mobile Satellite Service (MSS) and Radionavigation-satellite will not operate at the same time in the same place. The proposed apportionment margin is $10 \times \log_{10}$(number of services).

[42] **116-122 GHz**, 7 services: FS adjacent band above and below; MS adjacent band above and below; Inter Satellite Service (ISS) in-band and adjacent band above; Spectrum Access: EHF licence in-band (1 service).

[43] **174.8-182 and 185-190 GHz**, 11 services: FS adjacent band above and below; MS adjacent band above and below; ISS in-band and adjacent band above and below; MSS above (1 service); Radionavigation adjacent band above; Radionavigation-satellite adjacent band above; Spectrum Access: EHF licence in-band.

Scattering and reflections

Stakeholder responses

5.26 ECMWF, [✂] and NCEO raised concern that scattering by cloud hydrometeors and raindrops was not considered in our modelling. NCEO and STFC highlighted that scattering and reflections can occur at these frequencies from surfaces such as buildings or bodies of water.

Our response

5.27 Any scattering due to water vapour in the atmosphere is likely to be a dispersion mechanism rather than a focusing one, and energy can be scattered in any direction. When scattering occurs, it is not likely to affect emissions from all transmitters in the same way. The overall effect considering multiple interference paths is likely to be small. We also note that scattering occurs when there is water vapour in the atmosphere. In these conditions, atmospheric attenuation will be more significant. When there is low atmospheric attenuation, there will be a low risk of scattering.

5.28 The effect of scattering and reflections from buildings would be more static than the scattering from the atmosphere but will be influenced by the dimensions, orientation and materials of buildings. Again, this would not affect emissions from all transmitters in the same way but is most likely to be relevant for sensors at low elevation angles where there is greater atmospheric loss; at these angles there is also likely to be loss due to diffraction from terrain and clutter which we have not accounted for in our assessment.

5.29 We acknowledge that scattering will occur both within the atmosphere and from building surfaces. We would expect that in some cases scattering and reflections from the environment may cause a variation in the predicted interference margin, but this would be negligible in the context of the lower bound of our modelled protection described in paragraph 5.6.

Future EESS sensors

Stakeholder responses

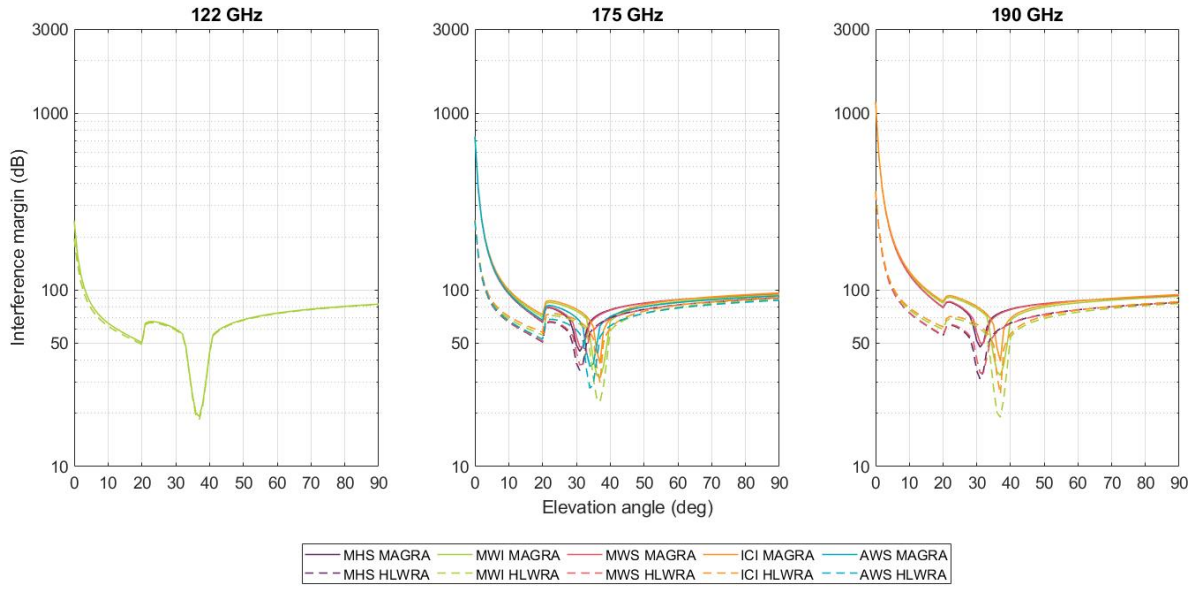
5.30 ESA/EUMETSAT said that further sensors are in development and due to be included in Recommendation ITU-R RS.1861 and provided the relevant characteristics for the MHS, MWS, MWI, ICI and AWS sensors.

Our response

5.31 We have conducted sensitivity analysis using the parameters provided by ESA/EUMETSAT for the MHS, MWS, MWI, ICI and AWS sensors, this is presented in figure 5.4. These results show that the MWI sensor in the 116 -122 GHz band is the most sensitive of the new sensors. The MWI results are similar to those obtained for the conical sensor in figure 3.2 of our May 2020 consultation. The aggregate interference margin exceeds 50dB for the majority of elevation angles, only falling below this value between 32 and 40 degrees at

122 GHz. In the 174.8-182 GHz and 185-190 bands, higher interference margins are observed for the new sensors.

Figure 5.4: Predicted aggregate interference margins for future EESS sensors using the average antenna pattern for licensed devices[44].



Conclusions

5.32 We have taken account of stakeholder responses which offered a range of views on our coexistence analysis and the underlying assumptions which informed the proposed 'Spectrum Access: EHF' technical licence conditions. In general, non-EESS Stakeholders were supportive of our proposals while the EESS community considered that our assumptions were not conservative enough in some areas, such as atmospheric attenuation, apportionment of the interference margin between systems, scattering and reflection and device antenna elevation angle.

5.33 We have carefully assessed the factors raised by EESS stakeholders. We have concluded that our core assumptions are cautious, therefore our modelling indicates a lower bound of the protection that will be available to EESS. The implicit additional protection provided from these assumptions would be expected to compensate for any additional interference risk identified by the EESS community in their responses. As a result, we consider that our technical conditions are appropriate to support multiple devices and we do not consider it necessary to make any adjustments to the 'Spectrum Access: EHF licence' technical licence conditions.

[44] Equivalent to figure 3.2 for licenced devices in our May 2020 consultation using the ESA sensor parameter.

6. Summary and next steps

Summary of our decisions

6.1 In summary, we have decided to introduce a new licence (the 'Spectrum Access: EHF' licence) for authorising access to the proposed frequency bands in the 100-200 GHz range (i.e. the 116-122 GHz, 174.8-182 GHz and 185-190 GHz frequency bands). The technical and non-technical conditions that we have decided to impose are discussed in the previous sections of this document. These conditions are shown in the licence template at annex A3 and include compliance with the Interface Requirement shown at annex A2 ("IR 2106 Spectrum Access EHF").

Summary of the changes to our consultation proposals

6.2 For ease of reference, we summarise below the changes that we have decided to make to our consultation proposals following consideration of stakeholders' responses. Our reasoning for these changes is set out in the previous sections of this document.

Licensing framework

6.3 Instead of introducing a licence exemption regime for low power devices, as initially proposed, we have decided to require any new terrestrial spectrum user to hold a 'Spectrum Access: EHF' licence.

Technical conditions

6.4 Figure 6.1 shows the 'Spectrum Access: EHF' technical licence conditions.

Figure 6.1: 'Spectrum Access: EHF' licence technical requirements

	Power limits (*max EIRP in dBm*) and emissions restrictions on outdoor use		
USE	**116-122 GHz**	**174.8-182 GHz**	**185-190 GHz**
Indoor	55	55	55
Outdoor	55	55	55
For outdoor use, EIRP at angles (degrees°) relative to main beam in the elevation plane shall not exceed:			
	13 at > 10° 1 at > 40° -3 at > 60°	13 at > 10° 1 at > 40° -3 at > 60°	25 at > 10° 14 at > 40° 10 at > 60°
When devices are used outdoors, the main beam elevation angle of licensed devices shall not exceed 20° above horizontal.			
For all systems using bandwidths of less than 100 MHz, all of the above EIRP limits must be adjusted as follows: $$EIRP\ Reduction\ =\ 10 \times log_{10}\left({BW_{MHz}}/{100}\right)$$			

6.5 For greater clarity, we have decided to make some minor changes to the relevant Interface Requirement ("IR 2106 Spectrum Access EHF") and Schedule 2 to the 'Spectrum Access: EHF' licence:

a) we have introduced a clarifying provision that an EIRP reduction must be applied to systems using bandwidths less than 100 MHz;

b) we have clarified that the -10 dBm/MHz limit for out-of-band emissions refers to the Equivalent Isotropic Radiated Power (the "EIRP"), and added this provision to Schedule 2 to the 'Spectrum Access: EHF' licence;

c) we have specified that the licence is issued on the basis that "*interference is not caused by the Radio Equipment to other authorised spectrum users and that the Radio Equipment will not be protected from interference caused by other authorised spectrum users*" [45] (i.e. *"on a non-protection and non-interference basis"* [46]);

d) we have amended "outdoor installations" to "outdoor use";

e) we have amended "EIRP at angles relative to main beam in elevation" to "EIRP at angles relative to main beam in the elevation plane"; and

[45] See annex A3 ('Spectrum Access: EHF' licence template) Schedule 2.
[46] See annex A2 (Interface Requirement 2106) row 9 ("Authorisation regime").

f) we have clarified the meaning of "outdoor use".[47]

Non-technical conditions

6.6 We have decided to make the following changes to the proposed non-technical conditions:

a) the notice period for revoking the 'Spectrum Access: EHF' licence for spectrum management reasons will be one year, instead of three years[48]. We have also removed the reference to a "Short Term Licence" in condition 2 ("Licence Term") of the licence template since these licences will have an indefinite duration;

b) we have amended the proposed conditions regarding licence revocation and variation to add Ofcom's power to notify the licensees by a general notice (to be posted on Ofcom website) in accordance with schedule 1 paragraph 6(b) of the WT Act, which is in line with our General Licence conditions; and

c) we have strengthened the licence requirement to keep written records of the details of the location of radio equipment, and provide this information to Ofcom upon request, by requiring licensees to maintain accurate written records of both the postal address (including the post code) and the national grid reference (to 1m resolution) of the radio equipment or, in case of mobile use, of the centre of any 5km radius within which the radio equipment is used.[49]

Next steps for implementation

6.7 From today, people and businesses can apply for a 'Spectrum Access: EHF' licence using the information available on Ofcom's website.

6.8 Implementing the policy decisions set out in this document involves making new regulations by statutory instruments. In particular, we need to amend: (i) The Wireless Telegraphy (Spectrum Trading) Regulations 2012, (ii) The Wireless Telegraphy (Licence Charges) Regulations 2011 (the **"Fees Regulations"**) and (iii) The Wireless Telegraphy (Register) Regulations 2012. We plan to consult on these amendments in due course. In the meantime, the 'Spectrum Access: EHF' licences will not be tradable and we expect to charge any new licensee on the basis of regulation 6 of the Fees Regulations.

2024 review

6.9 We intend to review this new framework in 2024, at which point we will review evidence of emerging technologies, antenna and emission characteristics and the outcome of

[47] Any device operating in an environment which does not meet the definition of "indoor" is required to meet the technical conditions for outdoor use. "Indoor" means inside premises which: (i) have a ceiling or a roof; and (ii) except for any doors, windows or passageways, are wholly enclosed.
[48] See annex A3 ('Spectrum Access: EHF' licence template) condition 3(a).
[49] This is in addition to the requirement to maintain accurate written records of the antenna main beam elevation angle for outdoor use. See annex A3 ('Spectrum Access: EHF'licence template) Schedule 1 paragraph 4.

international activity, including work within the ITU-R and CEPT. As part of this review, we may re-examine the case for authorising licence-exempt use of these bands.

Further bands above 100 GHz

6.10 Access to other bands above 100 GHz for research and development purposes may be requested through our Innovation and Trial licence framework.

6.11 We note stakeholders' interest in additional bands above 100 GHz, and plan to open up access to further bands above 100 GHz. We consider that the 'Spectrum Access: EHF' licence framework is a model which could be introduced to other bands in the EHF range and above, in particular those above 100 GHz, to enable innovative activity in bands where coexistence with existing users needs to be considered. We would consult on any proposals to extend this licence to new bands, including consultation on the specific technical conditions appropriate to each band.

6.12 Separately, we plan to make the W band (92-114.5 GHz) and the D band (130-174.8 GHz) available for use in the UK and will consult on proposals in due course.

A1. Legal framework

A1.1 Our statutory duties derive from both European and domestic legislation, specifically from:

a) the Common Regulatory Framework[50] for electronic communications networks and services, in particular, the Framework Directive and the Authorisation Directive;

b) any relevant Decisions of the European Commission which bind the UK as to the use of the spectrum to be awarded;

c) the Communications Act 2003 (the "2003 Act") and the Wireless Telegraphy Act 2006 (the "WT Act"), which transpose the provisions of the directives referred to above into national law; and

d) Ofcom's general duties.

A1.2 Ofcom's statutory powers and duties in relation to spectrum management are set out primarily in the 2003 Act and the WT Act. Amongst our functions are the making available of frequencies for use for particular purposes and the granting of rights of use of spectrum through wireless telegraphy licences and licence exemptions.

Duties under the 2003 Act

A1.3 Our principal duties under the 2003 Act, when carrying out our functions and exercising our powers, are to further the interests of citizens and consumers, where appropriate by promoting competition. In doing so, we are also required (among other things) to secure the optimal use of spectrum and the availability throughout the United Kingdom of a wide range of electronic communications services.

A1.4 We must also have regard to: (i) the desirability of promoting competition in relevant markets; (ii) the desirability of encouraging investment and innovation in relevant markets; (iii) the different needs and interests, so far as the use of the electro-magnetic spectrum for wireless telegraphy is concerned, of all persons who may wish to make use of it; and (iv) the different interests of persons in the different parts of the United Kingdom, of the different ethnic communities within the United Kingdom and of persons living in rural and in urban areas.

A1.5 In performing our duties, we are required under section 3(3) of the 2003 Act to have regard in all cases to the principles under which regulatory activities should be transparent, accountable, proportionate, consistent and targeted only at cases in which action is needed.

[50] The Common Regulatory Framework comprises the Framework Directive (Directive 2002/21/EC), the Authorisation Directive (Directive 2002/20/EC), the Access Directive (Directive 2002/19/EC), the Universal Service Directive (Directive 2002/22/EC) and the Directive on privacy and electronic communications (Directive 2002/58/EC), as amended by the Better Regulation Directive (Directive 2009/140/EC). We note that the Common Regulatory Framework has been replaced by the European Electronic Communications Code (the "Code"). The Code was published in the Official Journal of the EU on 17 December 2018, and Member States have until 21 December 2020 to implement the provisions in domestic law.

A1.6 Section 4 of the 2003 Act requires Ofcom to act in accordance with the six Community requirements, which give effect to the requirements of Article 8 of the Framework Directive.[51]

Duties under the WT Act

A1.7 Additionally, in carrying out our spectrum functions we have a duty under section 3 of the WT Act to have regard in particular to: (i) the extent to which the spectrum is available for use, or further use, for wireless telegraphy; (ii) the demand for use of that spectrum for wireless telegraphy; and (iii) the demand that is likely to arise in future for such use.

A1.8 We also have a duty to have regard to the desirability of promoting: (i) the efficient management and use of the spectrum for wireless telegraphy; (ii) the economic and other benefits that may arise from the use of wireless telegraphy; (iii) the development of innovative services; and (iv) competition in the provision of electronic communications services.

The licence-exemption regime

A1.9 Under sections 8(3) - 8(3B) of the WT Act, Ofcom may make regulations exempting from the licensing requirements under section 8(1) the establishment, installation or use of wireless telegraphy stations or wireless telegraphy apparatus of such classes or description as may be specified in the regulations, either absolutely or subject to such terms, provisions and limitations as may be specified.

A1.10 Under sections 8(4) and 8(5) of the WT Act, we must make regulations to exempt stations and apparatus from the requirement to be licensed if their establishment, installation or use is not likely to:

a) involve undue interference with wireless telegraphy;

b) have an adverse effect on technical quality of service;

c) lead to inefficient use of the part of the electromagnetic spectrum available for wireless telegraphy;

d) endanger safety of life;

e) prejudice the promotion of social, regional or territorial cohesion; or

f) prejudice the promotion of cultural and linguistic diversity and media pluralism.

[51] In summary, the Community requirements are requirements: a) to promote competition in communications markets; b) to ensure that Ofcom contributes to the development of the European internal market; c) to promote the interests of all European Union citizens; d) to act in a manner which, so far as practicable, is technology neutral; e) to encourage, to the extent Ofcom considers it appropriate, the provision of network access and service interoperability for the purposes of securing efficiency and sustainable competition in communications markets and the maximum benefit for the customers of communications network and services providers; and f) to encourage such compliance with certain international standards as is necessary for facilitating service interoperability and securing freedom of choice for the customers of communications providers.

A1.11 In accordance with the requirements of section 8(3B) of the WT Act, the terms, provisions and limitations specified in the regulations must be:

a) objectively justifiable in relation to the wireless telegraphy stations or wireless telegraphy apparatus to which they relate;

b) not such as to discriminate unduly against particular persons or against a particular description of persons;

c) proportionate to what they are intended to achieve; and

d) transparent in relation to what they are intended to achieve.

The licensing regime

A1.12 Ofcom is responsible for authorising civil use of the radio spectrum and achieves this by granting wireless telegraphy licences under the WT Act. Under section 8(1) of the WT Act, it is unlawful to establish or use a wireless telegraphy station or install or use wireless telegraphy apparatus except under and in accordance with a wireless telegraphy licence.

Licence conditions

A1.13 Article 6 of the Authorisation Directive provides that rights of use for radio frequencies may be subject only to the conditions listed in the Annex to the directive. Part B of the Annex, which sets out conditions which may be attached to such rights of use, includes an obligation to provide a service or to use a type of technology for which the rights of use for the frequency has been granted, including, where appropriate, coverage and quality requirements, as well as conditions relating to the effective and efficient use of frequencies. Section 9(1A) of the WT Act confirms that the terms, provisions and limitations of a licence for the use of spectrum for the provision of an electronic communications network or service must fall within Part B of the Annex to the Authorisation Directive.

A1.14 The terms, provisions and limitations of a spectrum licence must not duplicate the obligations already imposed on the licensee by the general conditions set by Ofcom under section 45 of the 2003 Act (WT Act, section 9(6)).

A1.15 Under section 9(7) of the WT Act, Ofcom may only impose terms, provisions and limitations which are:

a) objectively justified in relation to the network and services to which they relate;

b) not unduly discriminatory;

c) proportionate to what they are intended to achieve; and

d) transparent in relation to what they are intended to achieve.

Spectrum fees

A1.16 Under section 12 of the WT Act Ofcom may prescribe in regulations the sums payable in respect of wireless telegraphy licences other than those awarded by auction. When doing

so, section 122(7) of the WT Act enables Ofcom to make different provisions for different cases and to make incidental provisions. This power enables us to recover the cost of administering and managing WT Act licences. However, section 13 of the WT Act permits us to recover sums greater than those we incur in performing our spectrum management functions, to reflect a range of spectrum management objectives. In particular, in order to provide incentives - Administered Incentive Pricing ("AIP") - to licensees to use their spectrum more efficiently. This power goes to discharging a range of duties under section 3 of the WT Act which require us to efficiently manage the radio spectrum.

Spectrum trading

A1.17 Whilst a licensee cannot assign its licence to another party, spectrum trading is a process that allows the holders of certain wireless telegraphy licences granted by us under section 8 of the WT Act to transfer the licence rights and obligations to another person. Such a transfer involves the notification to Ofcom and the grant by us of a new licence to the transferee.

A1.18 Ofcom has the power under section 30 of the WT Act to make regulations to authorise the transfer to another person by the holder of a wireless telegraphy licence of rights and obligations arising by virtue of such a licence. When doing so, section 122(7) of the WT Act enables us to make different provisions for different cases and to make incidental provisions.

A1.19 Under section 30(4) and (5) of the WT Act, transfers that fail to comply with such regulations (or with certain conditions in licences) will be void. Under section 30(6) of the WT Act, a transfer is void if it fails to comply with a direction given by Ofcom in exercise of a power conferred by such regulations.

The Wireless Telegraphy Act register

A1.20 Section 31 of the WT Act permits Ofcom to make regulations to establish and maintain relevant information in a register. Ofcom has made the Register Regulations and established the Wireless Telegraphy Act Register, which provides information about who is licensed to operate services in specific frequencies or geographical areas.

A1.21 The register provides basic information about licensees such as names, contact details, class of licence, the band(s) of frequencies and, where appropriate, the geographical area of operation. It does not provide precise details about individual transmitters due to security concerns. The register supports the spectrum transfer process by providing basic information about allocated spectrum to the market.

The international context

ITU Regulations

A1.22 The spectrum above 100 GHz is mainly used by the scientific community: Radio-Astronomy, Space research and Earth Exploration-Satellite Services. Other spectrum uses which are permitted in certain bands above 100 GHz include short range devices.

A1.23 Radio Regulations governing the international use of spectrum are determined by the ITU at WRC conferences. According to the Radio Regulations, the 116-122 GHz, 174.8-182 GHz and 185-190 GHz bands are allocated for primary use to Earth Exploration-Satellite (passive), Inter-Satellite and Space research (passive).

Making statutory instruments to implement our policy decisions

A1.24 Implementing the policy decisions set out in this document involves making new regulations by statutory instruments. Before making any regulations, we are required by section 122(4) of the WT Act to give statutory notice of our proposal to do so to. Under section 122(5), such notice must state that we propose to make the regulations in question, set out their general effect, specify an address from which a copy of the proposed regulations or order may be obtained, and specify a time period of at least one month during which any representations with respect to the proposal must be made to us.

A2. Interface Requirement 2106

Table 3.1: Minimum requirements for the use of: ECS equipment operating in the 116-122 GHz and 174.8-182 GHz bands

Mandatory (1 – 10)	
1. Radiocommunication Service	Fixed or Mobile Service
2. Application	Electronic communications services
3. Frequency band(s)	116-122 GHz and 174.8-182 GHz
4. Channelling	N/A
5. Occupied bandwidth	N/A
6. Direction / Separation	N/A
7. Maximum Transmit Power / Power Density	55 dBm EIRP The maximum permitted EIRP must be adjusted for systems using bandwidths of less than 100 MHz as follows: $$EIRP\ Reduction\ =\ 10 \times log_{10}\left({BW_{MHz}}/{100}\right)$$ This applies to the maximum permitted EIRP levels for both the main beam EIRP and, for outdoor use, the EIRPs at angles relative to main beam in the elevation plane. <u>Additional requirements for outdoor use</u> For outdoor use, EIRP at angles relative to main beam in the elevation plane shall not exceed: • 13 dBm at >10 degrees • 1 dBm at >40 degrees • -3 dBm at >60 degrees For outdoor use, the main beam elevation angle shall not exceed 20 degrees above horizontal <u>Out of band emissions</u> Out of band emissions must be limited to -10 dBm/MHz EIRP.
8. Channel access and occupation rules	N/A
9. Authorisation regime	A licence is required. These licences are issued on a non-protection and non-interference basis.

	Radio equipment is not permitted to be used airborne.
10. Additional essential requirements	None
Informative (11-13)	
11. Frequency Planning	-
12. Planned changes	-
13. Reference	-
14. Notification	2020/71/UK
15. Remarks	Definition of outdoor use Any device operating in an environment which does not meet the definition of "indoor" is required to meet the technical conditions for outdoor use. "Indoor" means inside premises which: (i) have a ceiling or a roof; and (ii) except for any doors, windows or passageways, are wholly enclosed.

Table 3.2: Minimum requirements for the use of: ECS equipment operating in the 185-190 GHz band

Mandatory (1 – 10)	
1. Radiocommunication Service	Fixed or Mobile Service
2. Application	Electronic communications services
3. Frequency band(s)	185-190 GHz
4. Channelling	N/A
5. Occupied bandwidth	N/A
6. Direction / Separation	N/A
7. Maximum Transmit Power / Power Density	55 dBm EIRP The maximum permitted EIRP must be adjusted for systems using bandwidths of less than 100 MHz as follows: $$EIRP\ Reduction\ =\ 10 \times log_{10}\left({BW_{MHz}}/{100}\right)$$ This applies to the maximum permitted EIRP levels for both the main beam EIRP and, for outdoor use, the EIRPs at angles relative to main beam in the elevation plane. Additional requirements for outdoor use

	For outdoor use, EIRP at angles relative to main beam in the elevation plane shall not exceed: • 25 dBm at >10 degrees • 14 dBm at >40 degrees • 10 dBm at >60 degrees For outdoor use, the main beam elevation angle shall not exceed 20 degrees above horizontal <u>Out of band emissions</u> Out of band emissions must be limited to -10 dBm/MHz EIRP.
8. Channel access and occupation rules	N/A
9. Authorisation regime	A licence is required. These licences are issued on a non-protection and non-interference basis. Radio equipment is not permitted to be used airborne.
10. Additional essential requirements	None
Informative (11-13)	
11. Frequency Planning	-
12. Planned changes	-
13. Reference	-
14. Notification	
15. Remarks	Definition of outdoor use Any device operating in an environment which does not meet the definition of “indoor” is required to meet the technical conditions for outdoor use. “Indoor” means inside premises which: (i) have a ceiling or a roof; and (ii) except for any doors, windows or passageways, are wholly enclosed.

A3. Spectrum Access: EHF licence template

Wireless Telegraphy Act 2006

Spectrum Access: EHF

Sector/Class/Product:	xxxxxx – Spectrum Access: EHF
Licence number:	
Licensee:	
Company registration:	
Licensee address:	
Email:	
Date of issue:	xx xxxx 202x
Valid from:	xx xxxx 202x
Payment interval:	5 year

1. The Office of Communications (Ofcom) grants this wireless telegraphy licence ("the Licence") to [LICENSEE] to establish, install and use wireless telegraphy stations and/or wireless telegraphy apparatus as described in the schedules to this Licence (together "the Radio Equipment") subject to the terms set out below.

Licence Term

2. This Licence shall continue in force until revoked by Ofcom or surrendered by the Licensee.

Licence Revocation and Variation

3. Pursuant to schedule 1 paragraph 8 of the Wireless Telegraphy Act 2006 ("the Act"), Ofcom may not revoke this Licence under schedule 1 paragraph 6 of the Act except:

   (a) at the request, or with the consent, of the Licensee;
   (b) if there has been a breach of any of the terms of this Licence;
   (c) in accordance with schedule 1 paragraph 8(5) of the Act;
   (d) if it appears to Ofcom to be necessary or expedient to revoke the Licence for the purpose of complying with a direction by the Secretary of State given to Ofcom under section 5 of the Act or section 5 of the Communications Act 2003;
   (e) for reasons related to the management of the radio spectrum provided that in such a case the power to revoke may only be exercised after at least one year's notice is given in writing.

4. Ofcom may only revoke or vary this Licence in accordance with schedule 1 paragraphs 6, 6A and 7 of the Act.

5. Where Ofcom exercise their power to revoke or vary the Licence in accordance with schedule 1 paragraph 6 of the Act, the Licensee shall be notified in writing or by a general notice. Any general notices will be posted on the Ofcom website.

Transfer

6. This Licence may not be transferred. The transfer of rights and obligations arising by virtue of this Licence may however be authorised in accordance with regulations made by Ofcom under powers conferred by section 30 of the Act[52].

Changes to Licensee details

7. The Licensee shall give prior notice to Ofcom in writing of any proposed changes to the Licensee's name, email address and/or address as recorded in this Licence.

Fees

8. The Licensee shall pay to Ofcom the relevant fee(s) as provided in section 12 of the Act and the regulations made thereunder on or before the fee payment date shown above, or on or before such dates as are notified in writing to the Licensee.

9. If the Licence is surrendered, revoked or varied, no refund, whether in whole or in part, of any amount which is due under the terms of this Licence, payable in accordance with any regulations made by Ofcom under sections 12 and 13(2) of the Act will be made, except at the absolute discretion of Ofcom.

Radio Equipment Use

10. The Licensee shall ensure that the Radio Equipment is established, installed and used only in accordance with the provisions specified in the schedules to this Licence. Any proposal to amend any detail specified in any of the schedules to this Licence must be agreed with Ofcom in advance and implemented only after this Licence has been varied or reissued accordingly.

11. The Licensee shall ensure that the Radio Equipment is operated in compliance with the terms of this Licence and is used only by persons who have been authorised in writing by the Licensee to do so and that such persons are made aware of, and of the requirement to comply with, the terms of this Licence.

Access and Inspection

12. The Licensee shall permit any person authorised by Ofcom:

    (a) to have access to the Radio Equipment; and

    (b) to inspect this Licence and to inspect, examine and test the Radio Equipment,

    at any and all reasonable times or, when in the opinion of that person an urgent situation exists, at any time, to ensure the Radio Equipment is being used in accordance with the terms of this Licence.

[52] See Ofcom's website for the latest position on spectrum trading and the types of trade which are permitted.

Modification, Restriction and Closedown

13. Any person authorised by Ofcom may require the Radio Equipment or any part thereof, to be modified or restricted in use, or temporarily or permanently closed down immediately if in the opinion of the person authorised by Ofcom:

    (a) a breach of this Licence has occurred; and/or

    (b) the use of the Radio Equipment is, or may be, causing or contributing to undue interference to the use of other authorised radio equipment.

14. Ofcom may require any of the Radio Equipment to be modified or restricted in use, or temporarily closed down either immediately or on the expiry of such period as may be specified in the event of a national or local state of emergency being declared. Ofcom may only exercise this power after a written notice has been served on the Licensee or a general notice applicable to holders of a named class of licence has been published.

Geographical Boundaries

15. Subject to the requirements of any coordination procedures notified to the Licensee pursuant to Schedule 1 to this Licence, the Licensee is authorised to establish, install and use the Radio Equipment in the United Kingdom, United Kingdom territorial sea (measured in accordance with section 1 of the Territorial Sea Act 1987), the Channel Islands and the Isle of Man.

Interpretation

16. In this Licence:

    (a) the establishment, installation and use of the Radio Equipment shall be interpreted as establishment and use of wireless telegraphy stations and installation and use of wireless telegraphy apparatus for wireless telegraphy as specified in section 8(1) of the Act;

    (b) the expression “interference” shall have the meaning given by section 115 of the Act;

    (c) the expressions “wireless telegraphy station” and “wireless telegraphy apparatus” shall have the meanings given by section 117 of the Act;

    (d) the schedule(s) form part of this Licence together with any subsequent schedule(s) which Ofcom may issue as a variation to this Licence; and

    (e) the Interpretation Act 1978 shall apply to the Licence as it applies to an Act of Parliament.

Issued by the Office of Communications (Ofcom)

Spectrum Access: EHF
SCHEDULE 1 TO LICENCE: xxxxxx

Description of Radio Equipment

1. References in this schedule to the Radio Equipment are references to any wireless telegraphy station or wireless telegraphy apparatus that is established, installed and/or used under the schedules to this Licence.

Interface Requirements for the Radio Equipment

2. Use of the Radio Equipment shall be in accordance with the following Interface Requirement:

   IR 2106 Spectrum Access EHF

Special conditions relating to the Radio Equipment

3. Radio Equipment is not permitted to be used airborne.

4. During the period that this Licence remains in force, unless consent has otherwise been given by Ofcom, the Licensee shall compile and maintain accurate written records of the following details relating to the Radio Equipment:

   I. The postal address (including postcode) and National Grid Reference (to 1m resolution) of the Radio Equipment or, in case of mobile use, of the centre of any 5km radius within which the Radio Equipment is used; and
   II. Antenna main beam elevation angle measured in degrees above horizontal for outdoor use.

5. The Licensee shall submit to Ofcom in such manner and within such period as specified by Ofcom, such other information in relation to the Radio Equipment, or any wireless telegraphy station or wireless telegraphy apparatus which the Licensee is planning to use, as Ofcom may from time to time request. Such information may include, but is not limited to, information in relation to the radio frequency, transmitted power and date of first use for wireless telegraphy stations or wireless telegraphy apparatus to be established, installed or used within such timeframe and in such areas as Ofcom may reasonably request.

Coordination at frequency and geographical boundaries

6. The Licensee shall ensure that the Radio Equipment is operated in compliance with such coordination procedures as may be notified to the Licensee by Ofcom from time to time.

Interpretation of terms in this schedule

7. In this schedule:

   a) "IR" means a United Kingdom Radio Interface Requirement notified by Ofcom in accordance with Article 8 of Directive 2014/53/EU of the European Parliament and of the Council on the harmonisation of the laws of the Member States

relating to the making available on the market of radio equipment (known as the Radio Equipment Directive).

Spectrum Access: EHF
SCHEDULE 2 TO LICENCE: xxxxxx

References in this schedule to the Radio Equipment are references to any wireless telegraphy station or wireless telegraphy apparatus that is established, installed and/or used under the schedules to this Licence.

This Licence is issued on the basis that interference is not caused by the Radio Equipment to other authorised spectrum users and that the Radio Equipment will not be protected from interference caused by other authorised spectrum users.

1. When operating, the Licensee must transmit and receive within the limits set out below.

[The licence will authorise use in one of the following bands]

The maximum permitted EIRP must be adjusted for systems using bandwidths of less than 100 MHz as follows:

$$EIRP\ Reduction\ =\ 10 \times log_{10}\left({BW_{MHz}}/{100}\right)$$

This applies to the maximum permitted EIRP levels for both the main beam EIRP and, for outdoor use, at angles relative to main beam in the elevation plane.

Permitted Frequency Band	**Maximum power levels**	**For outdoor use, EIRP at angles relative to main beam in the elevation plane shall not exceed**	**Antenna pointing restriction for outdoor use**	**Out of band emissions**
116-122 GHz	55 dBm max EIRP	13 dBm at >10 degrees 1 dBm at >40 degrees -3 dBm at >60 degrees	Main beam elevation angle shall not exceed 20 degrees above horizontal.	-10 dBm/MHz EIRP.

Permitted Frequency Band	**Maximum power levels**	**For outdoor use, EIRP at angles relative to main beam in the elevation plane shall not exceed**	**Antenna pointing restriction for outdoor use**	**Out of band emissions**
174.8-182 GHz	55 dBm max EIRP	13 dBm at >10 degrees 1 dBm at >40 degrees -3 dBm at >60 degrees	Main beam elevation angle shall not exceed 20 degrees above horizontal.	-10 dBm/MHz EIRP.

Permitted Frequency Band	Maximum power levels	For outdoor use, EIRP at angles relative to main beam in the elevation plane shall not exceed	Antenna pointing restriction for outdoor use	Out of band emissions
185-190 GHz	55 dBm max EIRP	25 dBm at >10 degrees 14 dBm at >40 degrees 10 dBm at >60 degrees	Main beam elevation angle shall not exceed 20 degrees above horizontal.	-10 dBm/MHz EIRP.

Interpretation of terms in this schedule

1. In this schedule:

   a) “dBm” means the power level in decibels (logarithmic scale) referenced against 1milliwatt (i.e. a value of 0 dBm is 1 milliwatt);

   b) “EIRP” means the equivalent isotropically radiated power. This is the product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain), measured during the “on” part of the transmission; and

   c) “Outdoor use” means any device operating in an environment which does not meet the definition of “indoor”. “Indoor” means inside premises which: (i) have a ceiling or a roof; and (ii) except for any doors, windows or passageways, are wholly enclosed.

A4. Glossary

Antenna gain Directivity of an antenna, measured in dBi. An antenna with no directivity, or a 0 dBi gain, is described as isotropic.

Azimuth Rotation of the whole antenna around a vertical axis.

CEPT The European Conference of Postal and Telecommunications Administrations.

ECC Electronic Communications Committee – one of the three business committees of the European Conference of Postal and Telecommunications.

EESS Earth Exploration-Satellite Services – a satellite application for collecting data on changes to the Earth's atmosphere and weather conditions.

EHF Extremely High Frequency – frequencies between 30 and 300 GHz.

EIRP Equivalent Isotropically Radiated Power. This is the product of the power supplied to the antenna and the absolute antenna gain in a given direction.

Elevation With reference to an antenna, elevation is the angle between the main beam pointing direction and the local horizontal plane.

ERC European Radiocommunications Committee – legacy committee that merged with the European Committee for Telecommunications Regulatory Affairs in 2001 to form the ECC.

ETSI European Telecommunications Standards Institute.

EUMETSAT The European Organisation for the Exploitation of Meteorological Satellites – an intergovernmental organisation with an objective to establish, maintain and exploit European systems of operational meteorological satellites.

FCC Federal Communications Commission.

GHz Gigahertz – 1,000,000,000 (or 10^9) oscillations per second.

Indoor Inside premises which have a ceiling or a roof; and except for any doors, windows or passageways, are wholly enclosed. This definition is set out in the Wireless Telegraphy (Mobile Repeater) Exemption Regulations 2018.

IR Interface Requirement – the UK Interface Requirements contain the requirements for the licensing and use of specified devices in specified frequency bands. They are notified by Ofcom in accordance with Article 8 of Directive 2014/53/EU of the European Parliament and of the Council on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment.

ISM Industrial, Scientific and Medical applications (of radio frequency energy) – operation of equipment or appliances designed to generate and use locally radio frequency energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of telecommunications. This definition is set out in the Radio Regulations.

Isotropic radiator A frequency source radiating the same intensity of radiation in all directions, such as an antenna with a 0 dBi gain.

ITU International Telecommunications Union – a specialised agency of the United Nations for information and communication technologies, consisting of 193 Member States and over 700 private-sector entities and academic institutions, headquartered in Geneva.

Radio Regulations International regulations governing the use of radio spectrum and satellite orbits. Together with the Telecommunications Regulations and the Constitution and Convention of the ITU, they form an intergovernmental treaty to which ITU Member States are bound.

SRD Short range device. Short-range devices are usually mass-produced devices that are used in numerous applications like alarm systems, door openers, medical implants, radio frequency identification, intelligent transport systems or local communication equipment such as Wi-Fi routers.

WRC World Radio Conference – event organised by the ITU every four years to review and, as necessary, revise the Radio Regulations.

WT Act Wireless Telegraphy Act 2006.