Improving spectrum access for Wi-Fi

Spectrum use in the 5 GHz and 6 GHz bands

Improving spectrum access for Wi-Fi – Welsh overview

STATEMENT:

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Annex

1. Overview

Spectrum provides the radio waves that support wireless services used every day, including Wi-Fi. We have reviewed our approach to spectrum to meet future demand, address current challenges of slow speeds and congestion while enabling new, innovative applications. Certain radio spectrum bands can be used from Wi-Fi without the need to hold a licence, in other words, on a licence-exempt basis.

People and businesses in the UK are increasingly using wireless services to support everyday activities, and new applications are driving demand for faster speeds and greater reliability. This document sets out our decisions to change our existing regulations to address these issues.

What we have decided – in brief

- **Make the lower 6 GHz band (5925-6425 MHz) available for Wi-Fi and other RLAN technologies.** Opening this band will make more channels available, increase capacity and reduce congestion in existing bands caused by large numbers of devices.
- **The release of this spectrum will also enable very low power (VLP) outdoor use.** This will enable the development of new, innovative applications.
- **Remove the Dynamic Frequency Selection (DFS) requirements from channels used by Wi-Fi in the 5.8 GHz band (5725-5850 MHz).** DFS requires a router to scan for radars and to switch channel if suspected radar transmissions are detected. DFS can therefore represent a constraint for equipment manufacturers regarding quality of service and throughput as well as being the cause of connection delays for users. We are amending the requirements on this band on the basis that the risk of undue interference from indoor Wi-Fi use is extremely low. The removal of DFS will increase its use for indoor wireless applications and help reduce congestion in other bands.

1.1 Wi-Fi and other RLAN technologies provide local wireless connections to an area or premises (such as a home or public hotspot). Wi-Fi is an industry interoperability standard which represents by far the most common type of RLAN equipment available on the marketplace today and is widely used by consumers and industry. We use "Wi-Fi" as a proxy for all RLAN technologies throughout this document; the decisions set out in this document apply to all RLAN technologies.

1.2 Wi-Fi use is growing, driven by greater availability and adoption of faster broadband and the rising number and variety of connected devices and innovative applications. Recently we have seen an increase in the demand for Wi-Fi as lockdown has resulted in more people working, learning and socialising from home. In April 2020, internet users in the UK spent an average of 4 hours 2 minutes online each day, 37 minutes more each day per online adult compared with January 2020.

1.3 On 17 January 2020 (the **"January 2020 consultation"**) we set out our proposals to make the lower 6 GHz band (5925-6425 MHz) available for licence-exempt use and ease technical requirements in the 5.8 GHz band (5725-5850 MHz). In developing our consultation proposals, we had taken account of relevant factors, such as: (i) existing and future demand for wireless technologies, (ii) the current use of available spectrum, (iii) how demand can be met by both technology developments and spectrum and (iv) our technical analysis to assess whether Wi-Fi use could share the new frequencies with incumbent primary users (fixed links and satellite users) without causing harmful interference, and to consider the impact on radars of removing DFS requirements for indoor use (up to 200mW) from the 5.8 GHz band (5725-5850 MHz). Our consultation closed in March 2020. We received thirty-eight responses to our consultation from spectrum users, communications and internet service providers, manufacturers and individuals. The non-confidential responses are accessible here. We have included a summary of the responses in Annex A5 of this statement. In light of consultation responses, we have decided to proceed with our proposals.

Open the lower 6 GHz band for Wi-Fi and other RLAN technologies

1.4 We have decided to make the lower 6 GHz band (5925-6425 MHz) available for Wi-Fi and other RLAN devices on a licence-exempt basis, enabling indoor and very low power (VLP) outdoor use. Coupled with the development of new standards, we anticipate that this could provide user benefits by enabling new technologies and improvements in equipment performance.

Remove DFS requirements in the 5.8 GHz band

1.5 We have decided to remove DFS requirements for indoor use (up to 200mW) from the 5.8 GHz band (5725-5850 MHz). We expect this to make the 5.8 GHz band more useable for Wi-Fi services and reduce congestion in other channels.

Next steps

1.6 In order to implement the decisions set out in this statement, we will shortly update the interface requirements 2030¬!Q to reflect the changes that we have decided to make (which are set out in annex 3) and undertake the process to amend the regulations by making a statutory instrument.

1.7 In order to maximise the economies of scale it is important to ensure the technical requirements for Wi-Fi use in the 5 GHz and 6 GHz bands are as globally harmonised as possible. We will continue to promote harmonisation of technical requirements and a simple regulatory regime through international engagement and discussions.

2. Introduction

Background

People are increasingly reliant on wireless connectivity

2.1 Nearly 89% of UK adults have internet access in the home (as shown by Ofcom's Technology tracker March 2020, Table 49) and Wi-Fi plays a significant role in enabling this connectivity. Wi-Fi provides the final link between people's routers and the increasing number of wireless-enabled consumer electronics devices in their homes including TVs, smart appliances, games consoles, and portable/mobile devices such as smartphones, tablets, remote controllers, 3D visors, laptops etc.

2.2 There are multiple factors driving demand for Wi-Fi, such as the increasing availability and adoption of ultrafast and fibre broadband services and the growing number of applications that use Wi-Fi capable devices to connect wirelessly either to public or private networks. Individuals' and businesses' expectations of Wi-Fi devices and networks are increasing. This includes the need for a consistent and seamless experience across different devices and locations.

2.3 Wi-Fi systems provide both indoor and outdoor coverage in a range of locations, from residential premises to transport hubs, hospitals, sports stadiums, shopping centres, hotels, cafes etc. Wi-Fi also provides internet access within enterprise, commercial and industrial premises, with many organisations now moving to wireless-only solutions to increase the flexibility of production and distribution.

2.4 COVID-19 has highlighted the importance of having reliable Wi-Fi systems in people's homes. Dependency on reliable Wi-Fi networks has been driven by a rise in homeworking, home-schooling and data-intensive activities such as video calling and streaming on multiple devices at the same time. Some broadband providers have reported an increase in weekday daytime traffic of between 35% and 60% since the lockdown began. We published our UK home broadband performance, measurement period November 2019, report in May 2020 which gives more details.

Access to spectrum is critical to enable a better user experience and enable innovation

2.5 Wi-Fi can be used in the 2.4 and 5 GHz bands throughout most of the world. In the UK, 83 MHz is available for Wi-Fi use at 2.4 GHz and 585 MHz at 5 GHz (see Figures 2.2 and 2.3 below). However, there are variations between countries in the supported frequencies and the ways in which devices can connect. For instance, in the 5.8 GHz band we have made more spectrum available earlier even though that band is not available for similar Wi-Fi services and applications throughout Europe.[1]

[1] In 2017 we published our decision to extend licence-exempt Wi-Fi use to the 5.8 GHz band.

Figure 2.1: Wi-Fi channels in the 2.4 GHz band

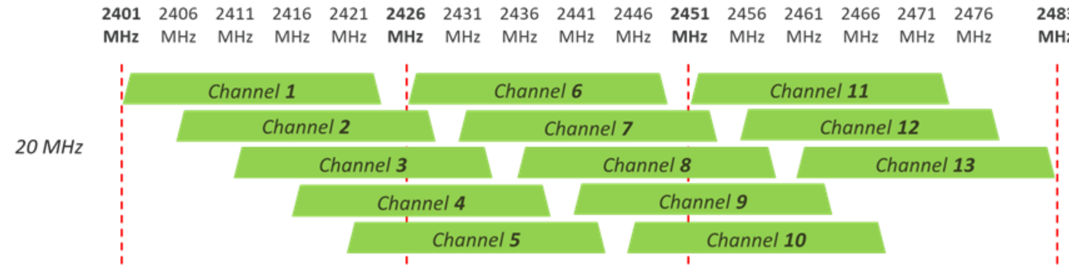
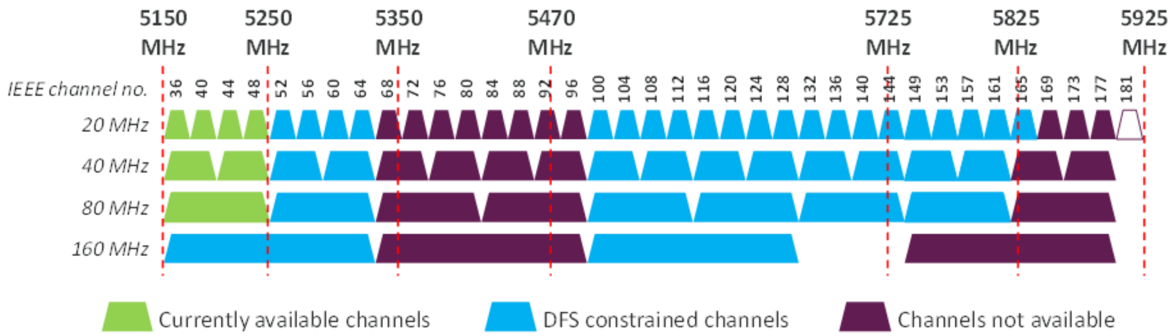


Figure 2.2: Example Wi-Fi channel plan used in the 5 GHz band[2]



2.6 The high number of connected devices within existing bands, and the limited number of Wi-Fi channels, can lead to congestion when several devices attempt to use the same Wi-Fi channel. Devices may wait for the channel to become clear (a feature known as Listen Before Talk) or reduce their data throughput to try and establish a more reliable wireless link. Both features impact latency (the time for data to be transferred across a network) and affect the quality of service. Measures to protect radar in the 5 GHz band mean that Wi-Fi devices tend to make more use of channels in the lower part of the band where there are no DFS requirements. This creates further congestion and hence may limit user experience in the band.

2.7 Additionally, broadband providers have indicated that more than one Wi-Fi channel is needed for mesh technologies to provide different multimedia platforms throughout the home. Our demand analysis in the January 2020 consultation outlined that this demand for higher throughput mesh technologies in the home will increase in the future. Opening up new Wi-Fi bands, and removing DFS requirements in the 5.8 GHz band, will offer a higher number of wider channels needed.

2.8 Some of the latest developments in Wi-Fi 6 and other RLAN technologies can mitigate the challenges highlighted above by offering greater efficiencies and better user experience. For example, Wi-Fi 6 will improve battery life, allow a higher density of wireless devices to be connected more efficiently through a new channel sharing capability and deliver four times more throughput than existing Wi-Fi technology (Wi-Fi 5). However, addressing

[2] There may be other channel plans used in the bands and the channels marked as 'not available' are currently not normally used or allowed to be used by higher power Wi-Fi devices.

spectrum availability will also be critical to improve Wi-Fi performance and functionality, to enable innovation and help address future growth in network traffic.

2.9 We have been working both nationally and internationally to assess the technical feasibility of using the 6 GHz band for Wi-Fi. In addition to these studies, we have also engaged with some of the relevant industry bodies, vendors, content providers and internet service providers.

2.10 In addition, our analysis shows, and stakeholders have indicated, that the 5.8 GHz band (5725-5850 MHz) is very lightly used due to the requirement to implement DFS in this band. As a result, we have considered removing the DFS requirement in this band to enable more efficient use of it.

2.11 In light of increasing demand for wireless connectivity and the new Wi-Fi technologies being capable of providing the capacity needed for low latency multimedia applications, we proposed to open up access to new spectrum in the lower 6 GHz band (5925-6425 MHz) and to remove the DFS requirements for the lower power indoor[3] use of Wi-Fi in the 5.8 GHz band. Following consideration of stakeholders' responses, we have decided to proceed with our proposals.

Legal background

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

Impact Assessment

2.13 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.

2.14 In preparing our consultation proposals and making our final decisions, we have considered the citizen and consumer interests relating to RLAN (including Wi-Fi). We have also considered the impact on existing users of the 5 GHz and 6 GHz bands, and on service providers, manufacturers and users of devices and applications.

[3] As set out in the Wireless Telegraphy (Mobile Repeater) Exemption Regulations 2018, "indoor" means inside premises which (i) have a ceiling or a roof; and (ii) except for any doors, windows or passageways, are wholly enclosed.

Equality Impact Assessment

2.15 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.

Our decisions will ensure optimal use of spectrum while encouraging innovation and investment in Wi-Fi and other RLAN technologies

2.16 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 optimal use is made of the radio spectrum.[4]

2.17 We consider that, in general, the optimal use of spectrum is most likely to be secured for society if spectrum is used efficiently, that is if it delivers the maximum benefits (or value) for society. Opening up the lower 6 GHz band to unlicensed spectrum use will enable RLAN technology (including Wi-Fi) developers to deploy more efficient routers which will increase spectrum efficient use. Removing the DFS requirement in 5.8 GHz will enable Wi-Fi devices to operate across these bands to deliver a better customer experience.

2.18 We have also had regard to the economic and other benefits that may arise from the use of this spectrum, and the need to encourage the development of innovative services. In addition to increasing capacity to meet demand for services delivered via existing Wi-Fi networks, there is the potential for this spectrum to be used for new Wi-Fi services which require high data rates and wider channels. Further development of Wi-Fi services has the potential to deliver significant benefits for UK consumers and businesses, including superfast broadband, greatly expanded capacity and innovative applications. We consider it important to make these bands available in a timely manner to meet consumer demand, particularly for increasing capacity of Wi-Fi services, addressing the growth in network traffic and to enable the industry to take advantage of innovation opportunities.

Structure of this document

2.19 The remainder of this document is set out as follows:

- **Section 3** explores the future demand for Wi-Fi and looks at how technology might mitigate pressure on Wi-Fi.
- **Section 4** outlines our decision to make more spectrum available for RLAN (including Wi-Fi) use in the 6 GHz band.
- **Section 5** outlines our decision to change Dynamic Frequency Selection and use of Wi-Fi in the 5.8 GHz band.

[4] Section 3(2)(a) and (b) of the 2003 Act.

- **Section 6** concludes our decisions and sets out our next steps for improving spectrum access for RLAN (including Wi-Fi).

3. Current and future Wi-Fi demand

3.1 In our January 2020 consultation we presented our analysis of current and future Wi-Fi demand, looking at changes in both residential and industrial uses.

3.2 We considered how demand for greater bandwidth, lower latency and greater coverage are critical to deliver a reliable experience and to promote innovation. We also considered the role of technological developments and access to additional spectrum in meeting future demand.

3.3 In light of stakeholders' comments, which were broadly supportive of our assessment of demand and the role of spectrum and technology in addressing it, we have decided not to modify our analysis.

Increasing number of connected devices is driving up demand for residential and industrial uses

3.4 Consumers are expecting faster internet speeds in their homes and businesses[5], and wireless capability for various applications, such as HD and UHD content, is becoming the norm.[6]

3.5 Wi-Fi is also used as a solution (off-the-shelf or customised) in many industrial sectors (such as manufacturing, enterprise, logistics and transport) to "cut the cables" in order to increase flexibility and productivity. The increasing number of connected devices and sensors is extending the uses for the Internet of Things (IoT). The vast amount of data generated by these devices is also driving demand for communication networks. Cisco forecasts a global growth from just under a billion devices in 2017 to 3.9 billion by 2022.

3.6 Enterprise users rely on Wi-Fi for most corporate connections, using mesh-based systems to coordinate fast internet access for a large number of users; mesh Wi-Fi systems consist of several routers that work together to expand the network coverage in an area.

3.7 We expect the number and variety of use cases to increase in the future.

[5] 94% of UK premises can receive superfast broadband (30Mbit/s and above) and access to ultrafast broadband (greater than 300 Mbit/s) is at 53% of homes, up from 50% (and from 36% 2017).
[6] Ofcom's Online Nation report 2020 observed that adults spent an average of 3 hours 29 minutes a day online in 2019 (up from 3 hours 11 minutes the previous year), and that 71% of people's time online is on smartphones. More than half considered their mobile to be their most important device for accessing the internet.

Greater bandwidth, lower latency and improved coverage are key to enable innovation and an improved wireless experience

Greater bandwidth

3.8 The capacity of a Wi-Fi network depends on the channel size it uses.[7] In general, larger channels enable higher data throughputs, which support services such as video calls and streaming of high definition television. Larger channels also support the network traffic generated by a higher number of connected devices. In an enterprise environment this could include corporate devices, employee devices, wireless sensors, security cameras etc. In a home there may be smart speakers, laptops, tablets, cameras, smart phones, baby monitors and many more devices all using the same Wi-Fi channel. Multiple Wi-Fi networks in an area compete for the available Wi-Fi channels. This congestion can cause a challenge to device and service providers, who seek to use channels with certain bandwidths.

3.9 Wi-Fi technologies access spectrum channels using a Listen Before Talk (LBT) protocol. Using LBT, users share the same spectrum channels. This is highly effective in lightly congested environments but can affect quality of experience where there are many users. Many off-the-shelf routers are set to use a fixed channel configuration by default[8] which may worsen the negative effects of congestion (all users would use just a few channels with lower power levels, avoiding interference whilst other channels remain unutilized). Wi-Fi performance can also be degraded by emissions from other systems using the same or adjacent bands, which further constrains the level of performance Wi-Fi can achieve in real networks.

3.10 New devices being introduced to the consumer market, such as smart glasses, may bring to the fore previously unknown challenges within the existing spectrum availability. While some stakeholders have suggested a need for wider bandwidths to use such products, some content providers viewed wider channels as less critical because they have created products to work within current spectrum availability.

3.11 Some broadband network providers indicated that residential routers are set on 80 MHz channels and they highlighted the limited number of these channels available for Wi-Fi use currently (six, of which five have additional requirements to implement DFS to protect other users). Stakeholders saw more and wider channels as important in addressing congestion and ensuring quality of experience.

3.12 Industrial uses, whilst typically requiring low bandwidth, could potentially connect a large number of devices that could overall require greater capacity.

3.13 Capacity can also be affected by DFS, due to the larger number of channels available with this requirement compared to those without a DFS requirement. Stakeholders saw bands

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[7] The Wi-Fi technology currently enables channels of 20, 40, 80 or 160 MHz, with some stakeholders anticipating 320 MHz channels in the future.

[8] For example, usually, non-overlapping channels 1, 6 and 11 in the 2.4 GHz band.

with DFS as underused, and some stakeholders' equipment avoids using these channels. We discuss DFS further in Section 5.

3.14 Our analysis concluded that spectrum is likely to become more congested in public networks, particularly where there is a combination of managed and unmanaged networks such as in shopping centres. Modern stadium deployments tend to use spectrum more efficiently because they have planned and managed deployments.

Lower latency

3.15 According to the analysis included in our Online Nation report, video content consumption is rising, a view supported by several stakeholders. Video applications include UHD (4k resolution) video in residential (broadcast television and streaming), enterprise (video conferencing) and video security.

3.16 Stakeholders also pointed to new/innovative services requiring lower latency to exploit their full potential. These include real-time or cloud-gaming; 360 video; 'holographic' video and VR/AR devices.

3.17 Our analysis indicated that wider channels, such as those that we are making available in the 6 GHz band, would support applications requiring higher data throughputs and lower latency (e.g. HD video streaming and new VR/AR applications) and provide a better customer experience.

Better coverage

3.18 Coverage is one of the main concerns raised by stakeholders as a current issue for Wi-Fi in residential, office and public environments. Irrespective of where, people are increasingly expecting a good quality of experience from Wi-Fi.

3.19 Even though techniques included in the latest Wi-Fi standards like multi-user MIMO and beamforming can increase coverage in smaller areas, this may not sufficiently resolve the issue of coverage in larger premises. Stakeholders have observed growth in the use of mesh systems to improve coverage, particularly for Gbit/s speeds. Mesh systems use several channels and require the use of a separate channel for backhaul to the main access point (AP), so stakeholders expect that to increase Wi-Fi congestion.

3.20 High-density office deployments are often managed with access points strategically installed and the Wi-Fi channels are pre-selected to maximise coverage. Enterprise providers highlighted that their ability to manage dense deployments are an important competition factor in the market. They generally design their deployments using 20 and 40 MHz bandwidths to increase the number of non-overlapping channels available (therefore maximising their ability to reuse spectrum across the office). This may limit the highest speeds available for users and may affect enterprise applications such as video conferencing.

3.21 Our analysis indicated that better use of existing spectrum and access to more spectrum will improve coverage and deliver greater capacity.

3.22 We also note that Ofcom has previously provided advice to the Department for Digital, Culture, Media & Sport on rail connectivity, pointing towards people's increasing expectation for fast and high-quality data and Wi-Fi connections on trains or metro systems.

Our projected demand analysis

3.23 Annex 6 of our consultation considered how demand for Wi-Fi could evolve, driven by the introduction and adoption of new applications and use cases, and by ever-increasing expectations of Wi-Fi users in terms of speed and quality of experience.

3.24 This analysis included new applications and use cases driving Wi-Fi demand in residential environments, where demand could grow between six and ten times over ten years driven by increases in video quality and the adoption of virtual reality devices; and public venues such as an arenas or concert halls where demand could increase by up to 15 times over the same period. However, we noted that our forecasting was subject to large uncertainties and required a significant degree of judgement.

Consultation responses

3.25 Responses to our consultation were broadly supportive of our initial demand analysis. Many (Cisco, Broadcom, TalkTalk, DSA, Federated Wireless, HPE, Nokia, Wireless Broadband Alliance, Wi-Fi Alliance) supported our general view that demand for Wi-Fi and spectrum for Wi-Fi services would substantively increase in the future. Broadcom highlighted the Wi-Fi Alliance Spectrum Needs Study 2017, which considered demand forecasts and predicted a shortfall of up to 1.6 GHz mid-band spectrum by 2025.

3.26 The DSA referenced some studies which conclude that additional Wi-Fi spectrum is required just to keep pace with the demand from existing uses, not just to allow innovative uses to develop.[9] HPE and the Wireless Broadband Alliance stated that wide contiguous mid-band spectrum for Wi-Fi is critical to meet the rapidly increasing capacity demands of UK consumers and enterprises.

3.27 The UWB Alliance did not agree with our proposals for 6 GHz suggesting that there is neither demand nor need for Wi-Fi and that there are better ways to improve use in existing RLAN bands.

Our response

3.28 The overwhelming majority of responses support our expectation that the demand for Wi-Fi services is likely to grow in the future. Based on our analysis and discussions with stakeholders, in addition to responses to this consultation, we disagree with the UWB Alliance's analysis that there is neither demand nor need for Wi-Fi.

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[9] For example, the DSA referenced: Steve Methley and William Webb, Quotient Associates Ltd., Wi-Fi Spectrum Needs Study 26 (2017); Rolf de Vegt et al., Qualcomm Technologies Inc., A Quantification of 5 GHz Unlicensed Band Spectrum Needs (2016).

Technological developments

3.29 Our January 2020 consultation also analysed the role of technology developments in meeting growing demand for Wi-Fi, highlighting the importance of the 6 GHz band to the development of new Wi-Fi standards and innovative applications.

6 GHz spectrum is critical for future-proofing Wi-Fi standards

3.30 In Table 3.1 below, we compare Wi-Fi 6 with the previous Wi-Fi standards. Wi-Fi 6 builds on the previous Wi-Fi standards with the intention of providing faster throughputs, lower latency, increased efficiency (capacity per MHz) of the network, enhanced performance in congested environments and better power efficiency (battery life) for devices. Having been introduced recently, Wi-Fi 6 has not yet been widely deployed in access devices.

Table 3.1: A comparison of Wi-Fi standards

	802.11ax (Wi-Fi 6)	802.11ac (Wi-Fi 5)	802.11n (Wi-Fi 4)
Year introduced	2019	2013	2009
Bandwidth (MHz)	20, 40, 80 ,160	20, 40, 80, 160	20, 40
Supported bands (GHz)	2.4, 5, 6	5	2.4, 5
Aggregate data rate (theoretical maximum)	9.6 Gbit/s	6.9 Gbit/s	600 Mbit/s
No. of client devices per access point	200-400	50-100	Fewer than 50
MU-MIMO support	D/L MU-MIMO U/L MU-MIMO	D/L MU-MIMO	No
Modulation scheme	1024 QAM	256 QAM	64 QAM
Access scheme	OFDMA	OFDM	OFDM
Spatial re-use	Yes	No	No

3.31 It is important to note that older Wi-Fi standards will continue to be used in legacy devices, which remain in existing bands. If no further spectrum is made available, Wi-Fi 6-compatible devices, which will also be backwards-compatible with older standards, will add to this incumbent group of legacy technology.

3.32 Although new Wi-Fi standards may mitigate some spectrum challenges in the existing Wi-Fi bands, they are not a comprehensive solution. As technology evolves, more efficient use of spectrum is possible but compatibility in existing spectrum will always affect the performance of new devices alongside the old ones. Congestion may be eased but it is not resolved in the long-term.

3.33 In our consultation we said that opening up new spectrum, free from legacy devices, could enable a more efficient group of devices using new Wi-Fi standards from the outset, therefore offering a more future-proof solution to Wi-Fi demand. This would also make it easier to use existing bands to support increased use of Wi-Fi.

3.34 Opening the 6 GHz band will future-proof the next generation of Wi-Fi devices and enable access to an increasing number of wide channels. Existing bands will continue to be used for a wide variety of current and legacy devices.

Consultation responses

3.35 Many respondents ([✂], Broadcom, Facebook, Intel, Cisco, CommScope, Huawei, Nokia, Tech UK, WBA, WFA, Qualcomm) agreed with our view that Wi-Fi 6 and future Wi-Fi standards will require more spectrum and wider spectrum bands. They supported our proposal to open up the lower 6 GHz band to allow wider spectrum band usage up to 80 and 160 MHz channels.

3.36 HPE and Facebook agreed that this is critical to future proof technologies and allow Wi-Fi to fulfil its full potential. In their view, this will support innovative uses such as, VR, AR, high definition video streaming, factory automation and high usage in congested environments (for example, stadiums and airport). Facebook and Tech UK pointed to this opening up of spectrum being critical to achieving wireless gigabit capabilities, improving coverage, power efficiency and lowering latency.

3.37 Several respondents (Bowden Networks, BT, Tech UK) suggested we allow only RLANs conforming to Wi-Fi 6 standards to use the band. They said that this will remove the burden of backwards capability which has caused congestion and interference in the 2.4 GHz and 5 GHz bands.

Our response

3.38 We believe the supportive comments outlined above show that our decision to open up the lower 6 GHz band is critical to future proofing Wi-Fi technologies to enable and achieve innovative use cases for beneficial consumer outcomes.

3.39 Opening the lower 6 GHz band does not preclude a provider using other RLAN (including Wi-Fi) standards than the Wi-Fi 6 standards in the band. We believe there are incentives for vendors and operators to bring new equipment standards to the market rather than use legacy technologies in the band. For instance, Wi-Fi Alliance, who manage the “Wi-Fi” brand name and associated interoperability standards, covers the vast majority of RLAN equipment on the market today and they have indicated they will only approve Wi-Fi 6 and later technologies in 6 GHz spectrum.

4. Opening spectrum for Wi-Fi in the 6 GHz band

Introduction

4.1 RLAN use, including Wi-Fi, is currently authorised in the 2.4 GHz and 5 GHz bands. To improve coverage and capacity, lower latency and ease congestion, and in view of future innovation, we proposed in January 2020 to make the lower 6 GHz (5925-6425 MHz) available for Wi-Fi use.

4.2 Having considered responses to the January 2020 consultation, we have decided to make the lower 6 GHz band available for RLAN use, including Wi-Fi. Our reasoning is set out in full in this section.

Consultation proposals

4.3 In our January 2020 consultation, we published proposals to make the lower 6 GHz band (5925-6425 MHz) available for RLAN use, including Wi-Fi. Opening up this band would make 500 MHz of contiguous spectrum available for Wi-Fi and could provide extra non-overlapping Wi-Fi channels of 20, 40, 80 and 160 MHz.

4.4 We proposed to make the band available for RLAN (including Wi-Fi) for indoor use with a maximum equivalent isotropically radiated power (EIRP) of 250mW, and outdoor use with a maximum EIRP of 25mW. Aeronautical mobile use would not be permitted, although use would be permitted within an aircraft to establish a connection with a station or apparatus within the same aircraft.

4.5 We considered that the 6 GHz band was suitable to address demand for additional Wi-Fi spectrum for three principal reasons:

a) The large amount of contiguous spectrum available would allow for wide, non-overlapping channels with the same technical conditions;

b) The adjacent 5 GHz band is already widely used for Wi-Fi, therefore similarities in the ranges achievable, router and antenna design of the two bands would enable manufacturers to invest fewer resources and implement 6 GHz more rapidly in products. This would also mean similar deployment models for infrastructure and routers for operators; and

c) The 6 GHz band should be used by more efficient Wi-Fi technologies from the outset. The latest Wi-Fi standard (Wi-Fi 6 (or 802.11ax) has been designed to support large numbers of users in congested environments through new techniques such as multi-user MIMO, OFDMA and BSS colouring. The result is a more efficient use of spectrum, improvement in throughput, better latency and less congested environments for Wi-Fi and other RLAN use. This will provide notable benefits in comparison with usage in the

2.4 GHz and 5 GHz bands, which are currently used by a wide variety of devices using earlier Wi-Fi/802.11 standards (e.g. 802.11a/b/n/ac).

4.6 In our January 2020 consultation we analysed the feasibility for RLAN to share the lower 6 GHz band with Fixed Satellite and Fixed Services.

4.7 For Fixed Satellite Services (FSS) we reviewed the CEPT sharing studies published in ECC Report 302. Satellite receivers suffer interference from the aggregation of multiple devices operating in their coverage footprint. Since satellite footprints can cover many countries, sharing studies must consider the aggregate effect of RLAN deployments dispersed over a wide geographic area, rather than just the UK alone.

4.8 Considering different future RLAN deployment scenarios in Europe by 2025, in summary CEPT studies concluded that taking steps such as limiting RLAN use to indoor only deployment and/or introducing an EIRP limit would help to ensure the protection of FSS space stations from aggregate interference. In our January 2020 consultation we agreed with these conclusions, although we proposed an indoor EIRP limit of 250mW, which was one of the different RLAN power levels included in a weighted power level distribution (1mW to 1W) that was used in the CEPT RLAN – FSS studies.

4.9 In addition to the similar studies included in ECC report 302, we undertook coexistence analysis (see Annex 2) to understand the possible impact of future RLAN devices in the 6 GHz (5925-6425 MHz) band on existing fixed links in the UK. We looked at a range of fixed link and RLAN deployment scenarios to assess under what conditions fixed links might be more sensitive to interference, and we considered sharing scenarios with maximum RLAN power levels at 25mW (14 dBm) EIRP for outdoor use and 250mW (24 dBm) EIRP for indoor use, these maximum power levels became the focus of our proposals.

4.10 Our modelling was based on:

- a statistical approach using Monte Carlo analysis, where we randomised the distribution and location of RLAN devices around the fixed link under study. This approach resulted in the percentage of instances (time) where the aggregate effect of interference exceeded the interference protection criteria;
- a Minimum Coupling Loss (MCL) analysis where we analysed possible exclusion areas around fixed links; and
- a static analysis (snapshot model) to look at whether interference was due to a single interferer, or the aggregate effect of devices in the vicinity of a fixed link. Our analysis showed that sharing is feasible for indoor only RLAN use with EIRP up to 250mW and outdoor very low power use with EIRP of up to 25mW.

4.11 We found from our modelling that there may be some scenarios where the fixed link interference criteria could be exceeded, most likely, from a single high-power device located either indoors or outdoors close to the fixed link receiver. We believe these scenarios are very unlikely to arise in practice for several reasons:

- RLAN EIRP levels are likely to be lower than those we have modelled in the MCL and static analysis. For example, 250mW indoor and 25mW outdoor use represents less

than 10% of the total forecast of power distributions modelled in the Monte Carlo analysis done in both UK and CEPT studies;
- There is a lower likelihood of interference to fixed links in open or rural areas as there are fewer premises around the link receiver where RLANs could be located;
- Higher clutter losses from buildings, trees and other obstacles in populated areas would further reduce the chances of interference unless the RLAN was located very close to the fixed link receiver.

4.12 The results of our technical analysis are broadly aligned with those of CEPT:

- The CEPT studies show that sharing would be feasible between RLANs and fixed links if the RLAN deployment is restricted to indoor only use with EIRP up to 200mW and outdoor low power use with EIRP of up to 25mW. We believe indoor and low power deployment is a better proxy for the type of demand industry stakeholders are requiring which, as set out above, includes indoor Wi-Fi and portable smart devices that require low power outdoor connections.
- The CEPT studies show that, whilst there are some scenarios where the long-term fixed link protection threshold could be exceeded when considering high power RLANs, the plausibility of these scenarios arising in practice is considered very small (although the events that exceed the protection criteria are not restricted to high-power outdoor devices). We are not allowing high power outdoor RLAN use in the UK.

4.13 The results of our analysis show that opening the 6 GHz band for Wi-Fi on a licence-exempt basis would be possible for indoor lower power and outdoor VLP uses. This could ease congestion in the other Wi-Fi bands and allow for innovation in a band with fewer legacy devices. Our analysis considered the potential for RLANs to share with existing users in the 6 GHz band. We focused on services that have a primary allocation in the United Kingdom Frequency Allocation Table, although we recognise there are other services that share the band on a secondary basis[10] (e.g. the Amateur Service and other Short Range Devices).

4.14 We also reviewed the CEPT studies on adjacent band sharing with the Radio Astronomy Service, Road – Intelligent Transport System, Communications Based Train Control and Ultra Wide Band (UWB) systems. In the absence of more comprehensive Ofcom studies we agreed with the results of the studies carried out by CEPT for these other services.

International developments

4.15 In addition to the proposals and associated studies taking place in Europe with respect to possible RLAN use in the lower 6 GHz band, we also considered proposals and studies taking place elsewhere (e.g. US, Brazil and South Korea, as set out below). This helped Ofcom to determine how likely it would be that an international marketplace with its associated economies of scale would be available for RLAN (including Wi-Fi) technologies in the future, and what sort of technical conditions were likely to be harmonised.

[10] Stations of a secondary service cannot claim protection from harmful interference from stations of a primary service to which frequencies are already assigned or may be assigned at a later date.

CEPT update

4.16 In March 2020, the Electronics Communication Committee of CEPT (ECC) approved draft CEPT Report 73 (Report A) for public consultation in response to the European Commission 2017 Mandate, an assessment and study of compatibility of RLAN systems with incumbent systems in the lower 6 GHz band (5925-6425 MHz). This Report confirmed the findings of ECC Report 302, published in May 2019, that coexistence with Fixed Service (FS), Fixed-Satellite Service (FSS) and Radio astronomy is technically feasible for indoor and low-power outdoor RLANs. The Report also concluded that coexistence with Communications Based Train Control (CBTC) systems and Road-ITS would be technically feasible if suitable measures, such as a guard-band and strict out-of-band emissions (OOBE) requirements, were included – noting that these elements would limit the available spectrum for RLAN use to less than the entire lower 6 GHz band (5925-6425 MHz).

4.17 In May 2020, ECC Report 316, containing results of additional analysis of the risk of short-term interference between RLANs and point-to-point fixed links, was approved for publication. The results did not alter the conclusions set out in ECC Report 302 or CEPT Report 73.

4.18 CEPT also carried out further analysis of the impact on RLAN spectrum use if RLAN OOBE levels from ECC Report 302 were applied. It also considered the impact of existing adjacent users on CBTC systems covered by ECC Report 290. This analysis indicated that the OOBE levels proposed in ECC Report 302 would have a significant negative impact on the spectrum being made available for RLAN use.

4.19 In July 2020, the ECC approved CEPT Report 73 (Report A) for final publication in response to the EC Mandate. It also approved draft CEPT Report 75 (Report B) in response to the EC mandate and draft ECC Decision (20) 01 for public consultation, which together set out the recommended technical parameters for RLAN systems in the 6 GHz band.

4.20 Both documents also note the amendments in the draft EEC Decision (08/01) on the harmonised use of Safety-Related Intelligent Transport Systems (ITS) in the 5875-5935 MHz frequency band including, 1) harmonized technical conditions for the frequency range, 5875-5925 MHz on a non-exclusive basis, for safety-related Road ITS and 2) non-exclusive harmonised conditions for 5915-5935 MHz band has been harmonised for safety-related Urban Rail ITS, including CBTC systems, subject to national market demand and coordination with existing Fixed Service links.

4.21 Draft CEPT Report 75 and draft ECC Decision (20) 01 recommend that WAS / RLAN equipment should operate on a non-exclusive, non-interference and non-protected basis in the 5945-6425 MHz band. They also recommend that there is no requirement for individual licensing of RLAN equipment if it falls into one of the following device categories:

- Low Power Indoor (LPI) devices, such as an Access Point or client device, which would be permitted to operate at up to 200mW EIRP for indoor use only;
- VLP Category A devices, which would be permitted to operate at up to 25mW EIRP for indoor or outdoor use, using the 6025-6425 MHz frequency band only; or

- VLP Category B devices, which would be permitted to operate at up to 25mW EIRP for indoor or outdoor use across the full 5945-6425 MHz band if a Country Determination Capability is implemented, to determine whether use of the whole band is allowed or not in a particular country.

4.22 CEPT are requesting views on proposed OOBE levels in a cover letter which will accompany draft CEPT Report 75 and draft ECC Decision (20) 01 as part of the public consultation process. In addition, CEPT are also going to carry out further technical analysis taking account of the studies underlying ECC Report 290 to assess potential OOBE levels.

Developments in the US

4.23 In October 2017, the Federal Communications Commission (FCC) published a Notice of Inquiry seeking input on "flexible access", particularly unlicensed use for Wi-Fi, in spectrum bands between 3.7 and 24 GHz. This sought detailed comment on the 3.7-4.2 GHz, 5925-6425 MHz and 6425-7125 MHz bands.[11] In October 2018, the FCC published a Notice of Proposed Rulemaking ('NPRM'), seeking comments on its proposals to make the full 6 GHz band (5925-7125 MHz) available for unlicensed Wi-Fi use.

4.24 On 23 April 2020, the FCC adopted a Report & Order on use of the 6 GHz band for Wi-Fi and other unlicensed uses. The new rules permit low-power indoor use (e.g. access points in the home, IoT networks), up to 30 dBm (1W), of the 5925-7125 MHz band. Standard-power use (e.g. access points in hotspot networks, rural broadband deployments), up to 36 dBm, of the 5925-6425 MHz and 6525-6875 MHz bands is also permitted if an automated frequency coordination (AFC) system is implemented.

4.25 Alongside this Report & Order, the FCC published a further NPRM seeking comments on a proposal to permit VLP devices to operate in the 5925-7125 MHz band.

Brazil

4.26 In April 2020, Brazilian telecoms regulator Anatel approved a revision of its radiocommunication equipment regulations to include possible use of the 5925-7125 MHz band for Wi-Fi equipment.

4.27 Anatel announced that it would specify in the following 90 days the conditions for use of the band, including coexistence with other services in the same band, access priority and power limits.

South Korea

4.28 On 25th June, the Ministry of Science and ICT (MSIT) published on their website that they propose to open 5925-7125 MHz for RLAN use. While the entire 1200 MHz range would be open for license-exempt use, usage will be limited for indoor use prior to the introduction

[11] We note that the 6425-7125 MHz band is to be studied ahead of a possible International Mobile Telecommunications (IMT) identification at the World Radio Congress 2023 (WRC-23).

of Korea's frequency sharing system (excepted for 2022). MSIT proposed the following technical limits:

- Indoor low power 250 mW, 2dBm/MHz or less (output condition)
- For connection between devices 25 mW (output condition)

4.29 Public consultation will close on 24 August 2020.

Responses to Ofcom's consultation

4.30 We received 38 responses to the January 2020 consultation, the majority of which commented on our proposals to make the 6 GHz band available for RLAN use.[12]

4.31 Most respondents were in favour of enabling use of the band for Wi-Fi and VLP outdoor use, although some issues were raised regarding various aspects of our proposals. We summarise these, alongside our response to them, below.

Technical coexistence analysis

Responses to our consultation

4.32 Most responses agreed with the technical analysis set out in our consultation, which illustrated that there would be a very low risk of undue interference to incumbent users of the 6 GHz band under our proposals.

4.33 Four responses (Tampnet, Ericsson, JRC and Huawei) noted that it is important to ensure that no harmful interference is caused to fixed links in the 6 GHz band as a result of our proposals. Tampnet asked for reassurance of protection of significant fixed links in the band, especially from high-power outdoor devices. Ericsson said that aggregate interference from RLAN devices could be an issue for fixed links in densely populated areas. JRC said that provisions to address interference and an adequate process to deal with any resulting link degradation are needed for critical energy utilities links in the band. Huawei noted that ECC Report 302 concluded that further studies are needed to fully understand the impact of licence-exempt use of the 6 GHz band on fixed services and encouraged us to consider all relevant CEPT studies in our decision.

4.34 BT noted that aggregate interference, caused by a large number of compliant devices, can be a concern for satellites. However, BT said also that due to the low outdoor power levels that we proposed and projected number of devices, it is not currently concerned.

Our response

4.35 Our technical analysis shows that no harmful interference to fixed links is likely to be caused by our decisions. We do not consider that there is a need for further analysis, noting that our analysis took into account fixed links with a variety of topologies and also included critical infrastructure links.

[12] The non-confidential responses to the consultation have been published on our website.

4.36 Furthermore, in case of harmful interference caused by non-compliant devices, we will consider taking enforcement action where appropriate.

The upper part of the 6 GHz band (6425-7125 MHz)

Responses to our consultation

4.37 A number of respondents (HPE, CommScope, [✂], Intel, Broadcom, Facebook, Wi-Fi Alliance, Cisco, DSA) suggested that we should consider opening up the upper part of the 6 GHz band (6425-7125 MHz) for unlicensed spectrum use with the same parameters we are using for the lower part of the 6 GHz band.

4.38 Respondents gave various reasons for this, including:

- The technical similarities of the lower 6 GHz band and upper 6 GHz band mean that the same approach can be applied to both (HPE, CommScope, [✂], Intel, Broadcom). Compatibility and sharing studies performed in CEPT are valid in considering both bands and the incumbent users in the UK are the same in the lower 6 GHz band and the upper 6 GHz band. One respondent (Broadcom) noted that ETSI have already created a Systems Reference Doc TR 103 524 up to 6725 MHz and a Technical Report TR 103 631 up to 7125 MHz to support such work.
- Considering the approach's applicability to the upper 6 GHz band would allow the UK to benefit from full product economies of scale (HPE, Facebook, [✂]). One respondent (Facebook) suggested this could enable the UK to benefit from the availability of new, innovative devices and technologies.
- Some respondents (Broadcom, Intel, Wi-Fi alliance) suggested that considering the upper 6 GHz band would align with the expectations of other countries. Several respondents (Cisco, Facebook, CommScope) suggested we do so to align specifically with the approach in the USA. One respondent (Commscope) noted that some CEPT member states have previously indicated that they could open up the full range on "day one" as they had few if any fixed links or satellite usage within their territory.
- Two respondents (Broadcom, DSA) argued that considering the upper 6 GHz band would enable the UK to be at the forefront of new technologies and the applicability of new standards for those technologies. These include access to 320 MHz channels which might be a key feature of the future 802.11 standard (Broadcom) and different classes of Wi-Fi devices (DSA).

4.39 However, two respondents (Ericsson, Huawei) disagreed, emphasising the upper 6 GHz band will be valuable for 5G networks. These require high data rate services which require mobility. Therefore, they suggested the approach should not be extended to ensure the full success of 5G in the future.

Our response

4.40 Our decisions in this statement are with regards to the proposals set out in the January 2020 consultation to open the lower 6 GHz band. By opening access to an additional 500 MHz we are increasing the number of channels available to support growth and innovation, with a more efficient use of the bandwidth available as a result of the new Wi-Fi 6 standard. We will continue to review use of the upper 6 GHz band to determine what the optimal use may be.

Demand for higher power use

Responses to our consultation

4.41 Six respondents highlighted a demand for higher power indoor and outdoor use and suggested implementing a geolocation database solution in RLAN equipment to manage interference with fixed links (WBA, Federated Wireless, Nokia, HPE, DSA and [✂]).

4.42 WBA and HPE said that high-power outdoor RLANs could have important uses, including serving high-capacity outdoor venues, meeting the demand for municipal outdoor hotspots and providing rural networks to narrow the digital divide. Both argued that a geolocation database, such as an Automated Frequency Coordination (AFC) system, would enable higher power use without causing interference. This would access a register of nearby fixed links and ensure that RLANs would not operate in a location where interference might be caused.

4.43 Nokia, DSA and [✂] said in their responses that allowing higher power use of the 6 GHz band would mean that the full benefits of the band could be realised, and all three were in favour of AFC to prevent interference to incumbent users. DSA noted that AFC is an established spectrum management technique and would not be complicated to implement or use.

4.44 Federated Wireless said that our proposed power levels were too restrictive and would limit use cases and operational flexibility, therefore higher power limits are needed. It also argued that AFC in the band would allow incumbents to grow unimpeded without reducing the amount of spectrum available to meet the growing demand for unlicensed spectrum. It said that this would also benefit incumbent users as both their current and future operating characteristics can be reflected.

4.45 One response (UKWISPA/Cambium Networks) said that there was demand for more spectrum for Fixed Wireless Access (FWA) to provide gigabit connections. It suggested that more mid-range spectrum is required for FWA and that licensed FWA applications could be permitted in this band alongside RLAN deployments.

Our response

4.46 Our analysis of demand indicated that most RLAN use cases (current and future) can be addressed by low power indoor or VLP specifications and do not require a database to enable sharing between incumbent users and RLAN devices. Moreover, we consider that the technical specifications that we have decided to impose will enable the implementation of a simple regulatory solution, without the need for a more complex interference management approach. This would be beneficial to the development of a wide ecosystem of devices and we expect it would help to meet the current demand for Wi-Fi spectrum.

4.47 We do not consider that there is currently a demand for more mid-range spectrum for licensed FWA use. FWA devices may currently operate in the 5.8 GHz band under a light licensing regime, and in other mid-range bands such as 3.8-4.2 GHz.

4.48 We will continue to monitor demand for higher power RLAN use cases and may consider authorising this use in the future in bands where there are no significant restrictions.

Very Low Power outdoor use

Responses to our consultation

4.49 Several respondents (DSA, BT, HPE) supported our proposals and agreed with the licence-exempt radiated power level of up to 25 mW. Two respondents (BT, HPE) agreed that the power limits for indoor and outdoor use are necessary to manage the risk of interference to existing and future satellite services and fixed microwave links. HPE also agreed that these technical conditions would enable the envisaged very low power outdoor use cases.

4.50 One respondent (DSA) suggested we should explore whether VLP devices could operate across other segments within the 6 GHz band or even the entire band.

Our response

4.51 We note that these comments confirm that our radiated power limits are sufficient to manage the risk of interference.

4.52 As stated above, this consultation only concerned the lower 6 GHz band and our analysis of demand indicated that most RLAN use cases (current and future) can be addressed by low power indoor or VLP specifications. We will continue to review use of the upper 6 GHz band to determine what the optimal use may be.

Transport use in 5915-5935 MHz

Responses to our consultation

4.53 Three responses (Hitachi Rail, Strathclyde Partnership for Transport (SPT) and Transport for London/London Underground Limited (TfL/LUL)) highlighted coexistence with CBTC systems in the 5915-5935 MHz band as a concern.

4.54 All three of these respondents said that they are supporting the UITP Spectrum User Group initiative to prioritise Urban Rail CBTC in the 5915-5935 MHz band, with adequate protection from RLANs in the 5935-5945 MHz band. SPT also noted the proposed revised ECC Decision for safety-related ITS submitted to public consultation in 2019, which they believed would mean that Urban Rail ITS applications have to be protected from RLANs operating above 5935 MHz.

4.55 SPT and Hitachi Rail noted that they are working on an upgrade to the Glasgow Subway System to an automated CBTC metro system using spectrum in the 5 GHz band, and that they may wish to use the 5.9 GHz band for Urban Rail ITS safety-related applications in the future. TfL/LUL noted that the 2.4 GHz band is currently used on a non-protected basis for automated metro lines and Crossrail in London but that there may be a need for at least one secure band for CBTC in case of interference in the 2.4 GHz band or for replacing the signalling systems in the future.

4.56 Three responses (techUK, CommScope and Intel), however, noted that coexistence requirements with CBTC should not be disproportionate. CommScope, Intel and techUK all noted in their responses that the rollout of CBTC is currently very limited across the CEPT region and that CBTC receiver performance as detailed in ECC Report 302 and CEPT Report 71 shows significant scope for improvement. Intel stated that interference could be avoided by using more robust CBTC receivers. Intel and techUK also noted that, in the event that there is planned CBTC use in the UK, any guardband requirements imposed on RLANs should be minimised to maximise usable spectrum for Wi-Fi, while ensuring coexistence.

Our response

4.57 The frequency range above 5925 MHz already has a primary allocation for several communication services including mobile, fixed satellite and fixed links services.

4.58 At CEPT level, Ofcom has raised concerns over lack of evidence to justify the demand for 5.9 GHz spectrum for CBTC/urban rail ITS services as CBTC services are already operating in the 2.4 GHz band in the UK.

4.59 In particular, that some such systems appear to be lightly deployed across Europe and that their deployment environment appears to require a clear and virtually exclusive allocation, is in contrast to the non-exclusive status proposed in the revised ECC Decision (08)01 for all forms of ITS.

4.60 This indicates that the system is unable to distinguish between the desired CBTC signal and the much lower emissions from RLAN. This also seems to suggest that this safety related system does not employ enough system processing elements (e.g. error correction, physical layer processing, diversity, transmission retries etc.) to make the system as a whole robust. This in turn has a direct impact upon options for sharing with existing or new services.

4.61 There are no current or planned regulations to authorise safety-related CBTC/urban rail ITS use in the 5915-5935 MHz band in the UK by Ofcom. As the spectrum is allocated on a non-exclusive basis in the revised ECC Decision (08)01 for all forms of ITS, Ofcom has indicated in CEPT meetings that it only supports a partial implementation of the Decision at this time, to cover road ITS use up to 5925 MHz only. Ofcom will have to consult separately to revise the current ITS regulations in the UK and any proposals for the introduction of CBTC/Urban rail ITS use in line with revised ECC Decision could be analysed further and consulted upon at this time. It should be noted, that if any CBTC/Urban Rail ITS networks were to be considered for use in the UK the technology used would be expected to be robust enough to share with the services and applications that operate in the co and adjacent frequency bands.

4.62 Additionally, since we published the January 2020 consultation and as a result of reviewing the evidence presented in ECC Report 290 which covers CBTC sharing with existing adjacent users, we now consider that the analysis in ECC Report 302 may be overly conservative. We will provide inputs to the CEPT process based on the appropriate scenarios and OOBE levels that CBTC systems would be expected to deal with from current and future adjacent users in the UK.

4.63 As a result, we are not changing the proposals we set out in the January 2020 consultation to open the lower 6 GHz band for licence-exempt use.

Technology Neutrality

Responses to our consultation

4.64 Several respondents (Huawei, BT, Freshwave Group, Ericsson) suggested we clarify that the approach we are taking is explicitly technologically neutral. This means that technologies other than Wi-Fi could take advantage of the opening up of unlicensed spectrum to encourage innovation through a green-field approach to rules in using spectrum. This includes other wireless and mobile technologies such as LTE and 5G in the future.

Our response

4.65 While we refer to Wi-Fi technology in the consultation document, any technology meeting the technical conditions outlined in the Interface Requirements will be allowed to use the band. We use Wi-Fi in the consultation document as this is the most commonly used term for the industry standard used by most RLAN users within the existing spectrum bands.

Final decisions

4.66 Based on our review of the demand for Wi-Fi spectrum and the technical feasibility of sharing with incumbent users, and following consideration of stakeholders' responses, we have decided to make the lower 6 GHz band (5925-6425 MHz) available for RLANs for indoor use with a maximum equivalent isotropically radiated power (EIRP) of 250mW, and outdoor use with a maximum EIRP of 25mW.

4.67 Aeronautical mobile use will not be permitted. Airborne use of the relevant equipment will be permitted within an aircraft only to establish a connection with a station or apparatus within the same aircraft.

4.68 We consider that our technical specifications for use of this band will enable the implementation of a simple regulatory solution, without the need for a more complex interference management approach.

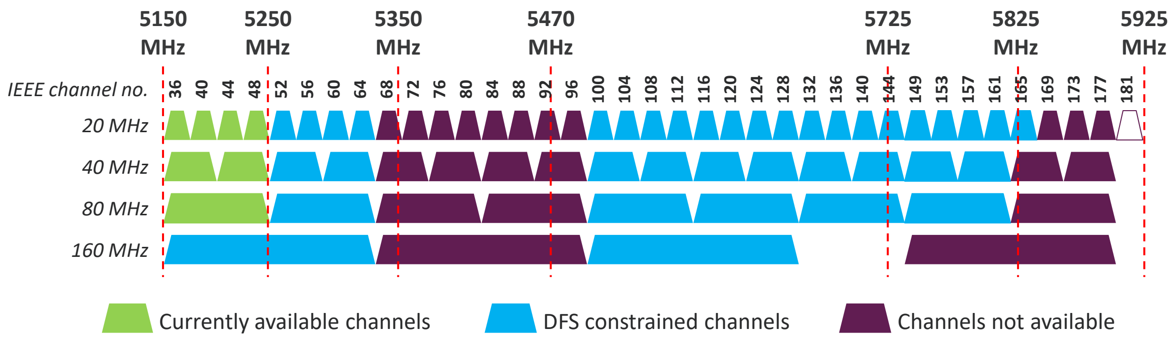
4.69 For more information on our next steps and the relevant regulations see **section 6**.

5. Making more efficient use of spectrum in the 5.8 GHz band

Introduction

5.1 Wi-Fi use is currently accessing 580 MHz of unlicensed spectrum in the 5 GHz band. Some of the available channels have Dynamic Frequency Selection (DFS) requirements to protect military and meteorological radars in these frequencies.

Figure 5.1: Example Wi-Fi channel plan in the 5 GHz band



5.2 In our January 2020 consultation we proposed to remove the DFS requirements from the 5.8 GHz band (5725-5850 MHz) for indoor Wi-Fi use on the basis that the risk of undue interference to radars from indoor Wi-Fi use is extremely low. We also invited comments on options that may be available to further use cases within the 5150-5250 MHz band, including allowing higher-power outdoor use.

5.3 Having considered responses to the January 2020 consultation, we have decided to remove DFS requirements from the 5.8 GHz band for indoor Wi-Fi use up to 200 mW EIRP. We will continue to monitor the impact of DFS requirements, outdoor restrictions and power limits on Wi-Fi use in other 5 GHz bands, including 5150-5250 MHz. Our reasoning is set out in full in this section.

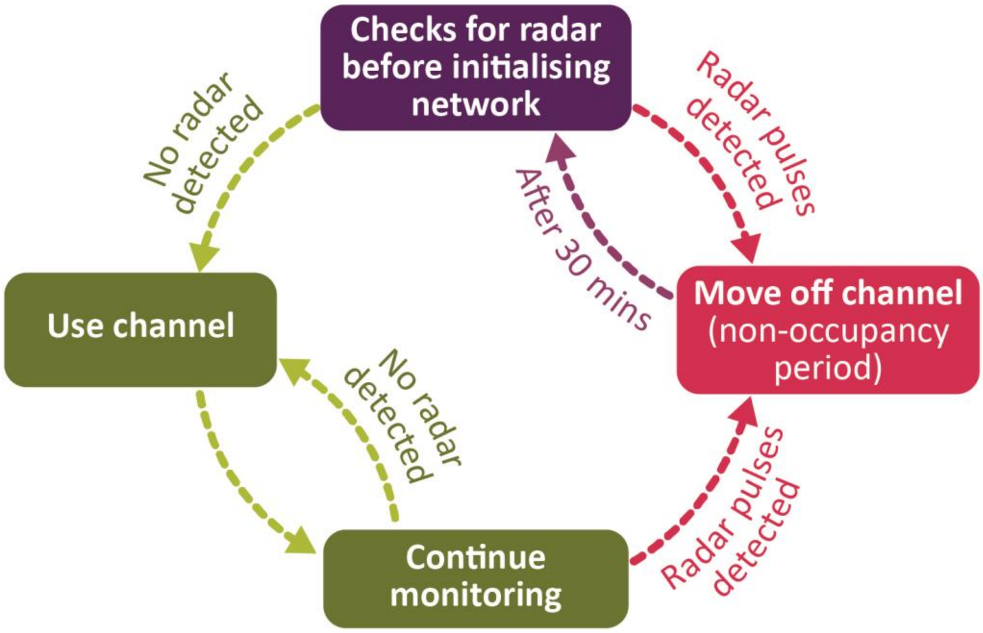
Consultation proposals

5.4 Our January 2020 consultation included proposals to remove DFS requirements from the 5.8 GHz (5725-5850 MHz) band.

5.5 Ofcom had made regulations to allow indoor Wi-Fi and other RLAN technology use in the band in 2017, based on evidence of increasing demand for Wi-Fi spectrum. To minimise the risk of interference with existing users of the band (including radars, satellites, amateur users, short range devices and road tolling systems), we set various technical parameters, including limiting Wi-Fi to low power indoor use with an EIRP limit of 200mW and DFS requirements to protect military radars.

5.6 DFS is a means of protecting radars operating in the 5 GHz band. The system detects transmissions from the radars and requires Wi-Fi devices to switch to a different channel if they detect co-channel radar pulses. The way DFS works is shown in Figure 5.2 below.

Figure 5.2: How DFS works



5.7 The 5.8 GHz band is not widely available for low-power indoor Wi-Fi use in other European countries. It has, however, been made available for Wi-Fi use without a DFS requirement in a number of countries throughout the world – including US and Canada, where it is heavily used.

5.8 Our own analysis and engagement with stakeholders had highlighted that the 5.8 GHz band was very lightly used in the UK and that it was likely that this was due to DFS requirements affecting efficient use of the band. This is for a number of reasons:

- Many Wi-Fi APs are set to default to Wi-Fi channels lower down in the band that are not subject to DFS requirements;
- If an AP selects a DFS channel and subsequently detects a radar, there is often a long channel non-occupancy period that follows before it may reselect the same channel;
- Manufacturer take-up is low as DFS can be difficult to implement and add cost to equipment;
- Consumer Wi-Fi experience can be negatively affected as the system can take time to scan channels for radars and is susceptible to false triggers, which can interrupt the connection unnecessarily; and
- International regulations are not uniform for the 5.8 GHz band – where it is authorised, it is usually without a DFS requirement, meaning that manufacturers would have to create a separate domain for the UK with UK-specific products to incorporate 5.8 GHz with DFS into routers, which is not cost-effective or efficient.

5.9 Our initial view was that removing the DFS requirements for low power indoor use only in the 5.8 GHz band would not have any significant impact on military radar uses in the UK. We also note that this approach would typically pose a similar or lower interference risk than other users of the 5.8 GHz band once building attenuation is applied, notably current outdoor use of SRDs and Road Tolling, which operate in the band without DFS requirements.

5.10 We also invited views on options to improve Wi-Fi efficiency in other 5 GHz bands, particularly in 5150-5250 MHz. At the World Radio Conference 2019 (WRC-19), the Radio Regulations were amended to allow limited outdoor RLAN use in the 5150-5250 MHz band: up to 200mW with a proviso to extend up to 1W with controlled use and by implementing antenna masks that limit power in the direction of satellites. We consider that these changes would enable innovation in the band and are therefore minded to consider how they could be implemented in the UK. We also said that we would continue to monitor developments in other 5 GHz bands to ensure that any technical requirements, including DFS, are still fit for purpose.

Responses to Ofcom's consultation

Removing DFS requirements from the 5.8 GHz band

5.11 We received 38 responses to the January 2020 consultation, of which 25 commented on our proposals to remove DFS requirements from the 5.8 GHz band.[13]

5.12 Most respondents supported our proposals to remove DFS requirements from the 5.8 GHz band, although some issues were raised regarding various aspects of our proposals. We summarise these, alongside our response to them, below.

Coexistence

5.13 [✂] highlighted interference concerns with uninhibited use of 5.8 GHz by RLANs. It said that even indoor Wi-Fi up to 200mW has the potential to cause interference to nearby radar, and that this has been flagged as a problem in countries where RLANs may use the 5.8 GHz band without a DFS requirement.

5.14 We remain of the view, in the absence of further evidence, that removing DFS requirements for low-power indoor RLANs in the 5.8 GHz band is very unlikely to cause any additional undue interference to radars in the UK. We also consider that low-power indoor RLANs pose a lower or similar interference risk compared with other incumbent users of the 5.8 GHz band operating without such requirements, including outdoor SRD use and Road Tolling.

[13] The non-confidential responses to the consultation have been published on our website.

Enforcing indoor use

5.15 Three respondents – Huawei, Nokia and RSGB – cited concerns around enforcing indoor use of RLANs in the 5.8 GHz band. RSGB said that it was not clear how RLAN devices in the band would be prevented from outdoor usage and that, in large numbers, this could lead to interference to amateur and amateur satellite services at these frequencies. Huawei and Nokia noted that it is difficult to ensure indoor use of RLAN equipment and said that they would welcome proposals to effectively manage and control indoor use in order to avoid interference to incumbent users of the band.

5.16 The current licence-exempt rules in 5.8 GHz band do not allow fixed outdoor use in the band. In case of harmful interference caused by non-compliant devices, including fixed outdoor RLAN use in this band, we would consider taking enforcement action where appropriate.

Demand for outdoor and higher-power use

5.17 Some respondents pointed to a demand for higher-power and/or outdoor use of licence-exempt devices in the 5.8 GHz band. The DSA said that the proposals were too conservative and that it hopes Ofcom will consider whether EIRP levels and power spectral density levels can be increased in the future. HPE and the WBA asked Ofcom to consider permitting controlled indoor and outdoor use of the band with a maximum transmit power of 1W EIRP, in alignment with the amended Radio Regulations for the 5150-5250 MHz band.[14] [✂]

5.18 We consider that removing DFS requirements from the low power licence-exempt use of RLANs will go a long way to addressing the demand issues in this band. We consider that the new technical constraints strike an appropriate balance between demand for RLAN spectrum and the need to protect radar use of the band.

Other options for use of 5 GHz channels

5.19 Our January 2020 consultation also invited views on other options that may be available for Wi-Fi and RLANs within the 5150-5250 MHz band. Stakeholders also provided comments on other ways to optimise use of other bands in the 5-6 GHz frequency range.

5.20 Several stakeholders (Broadcom, Wi-Fi Alliance, HPE, DSA, techUK, WBA and BT) suggested that we should work to align regulations for RLAN use in the 5150-5250 MHz band with the decision taken at WRC-19 to amend the Radio Regulations to enable outdoor use up to 200mW with a proviso to extend up to 1W with controlled use and implementing antenna masks that limit power in the direction of satellites, as well as in-car and in-train use with specific EIRP limits. Cisco also said it would support proposals to allow outdoor RLAN use in this band. We consider that these changes to the 5150-5250 MHz band would benefit

[14] We note that the WRC-19 changes to the Radio Regulations for 5150-5250 MHz have not been implemented in the UK.

innovation and are looking into ways we might be able to implement the WRC-19 decision in the UK.

5.21 CommScope said in its response that we should extend the 5725-5850 MHz band to 5895 MHz to align with US regulations for licence-exempt RLAN use. UKWISPA and Cambium Networks also commented on this band in their response, suggesting that we make 5850-5875 MHz available for light-licensed FWA use. As we have not seen evidence of widespread demand and we have not analysed the impact on safety-related ITS operating above 5875 MHz, we are not currently proposing to make either of these changes, however we may consider in the future.

5.22 TalkTalk commented that we should look to relax DFS restrictions across 5250-5850 MHz (excluding the 5600-5650 MHz band) to enable more straightforward use of Wi-Fi channels at these frequencies. We are not currently proposing to lift DFS restrictions from any other 5 GHz bands apart from 5.8 GHz as this would require further coexistence analysis. Additionally, different types of radar (including meteorological) are used in the lower bands which may be less robust to interference. However, we will continue to keep these requirements under review and may amend them in the future.

5.23 Federated Wireless and [✂] suggested in their responses that we should look at using an Automated Frequency Coordination system as an alternative to DFS requirements in the 5 GHz band in order to protect incumbents. We remain of the view that our current approach enables us to balance the need for both a simple regulatory solution and effective mitigations against interference.

5.24 Several respondents (Intel, HPE, WBA, Cisco and CommScope) raised concerns against expanding DFS requirements in the existing 5 GHz bands that require DFS to include detection of fast frequency hopping radars, saying that this would be complex and counter-productive as well as leading to a higher volume of false radar detections and subsequent loss of service. We note these concerns but are not making firm proposals or conducting further analysis at this stage.

Final decisions

5.25 Based on our analysis of current use of the band and having taken responses to our January 2020 consultation into consideration, we have decided to remove DFS requirements from the 5.8 GHz band for indoor Wi-Fi use up to 200 mW EIRP. We believe that removing the DFS requirements for indoor use only in the 5.8 GHz band will not have any significant impact on radars in the UK. Making this change will also provide significant benefits to people and businesses by allowing this spectrum to be more widely used for Wi-Fi.

5.26 More information on our next steps, including implementation of the relevant regulations, is set out in **section 6**.

5.27 Although we are not proposing to make additional changes at this time, we will continue to monitor the impact of DFS requirements, outdoor restrictions and power limits on Wi-Fi use in other 5 GHz bands.

5.28 We will also continue to explore ways in which we may be able to implement the possibility of outdoor use in the 5150-5250 MHz band as reflected in the Radio Regulations (RR) as amended at WRC-19. The revision to the RR allows for outdoor use up to 200mW with a proviso to extend up to 1W for controlled usage which implements suitable mitigations (e.g. EIRP masks) to limit power in the direction of satellites. The revision also confirmed the specific EIRP limits to be used in trains and cars. CEPT has received an EC mandate to review the existing harmonisation Decision for RLAN use in Europe in this part of the 5 GHz band. We may consider these changes and any future harmonisation work within CEPT and/or the EU in a future consultation document.

6. Conclusions and next steps

Summary of our final decisions

6.1 In conclusion, we have made the following decisions:

a) To **permit licence-exempt RLAN use, including Wi-Fi, in the lower 6 GHz band (5925-6425 MHz).** Indoor use up to 250mW and outdoor use up to 25mW will be permitted; and

b) To **remove DFS requirements for the 5.8 GHz band (5725-5850 MHz)**, for low-power (up to 200mW) indoor Wi-Fi use only.

6.2 These bands will be made available on a licence-exempt (non-protected and non-interference) basis with technical parameters that provide adequate protection for other users. The technical conditions are technology neutral so, as well as Wi-Fi, we expect other similar RLAN technologies, such as licence-exempt technologies based on 3GPP standards, to be able to access the spectrum we are making available.

Next steps for implementing our policy decisions

6.3 Implementing our policy decisions involves amending: (i) the current interface requirements for short-range devices ("**IR 2030**") and (ii) The Wireless Telegraphy (Exemption and Amendment) Regulations 2010 (reg. 5).

Interface requirements

6.4 Our proposed amendments to IR 2030 were set out in Annex 8 to our January 2020 consultation. In accordance with the Radio Equipment Directive and the Technical Standards Directive, on 18 February 2020 we notified our proposed changes to IR 2030 to the European Commission. We have not received any comments or opinions from any Member State or the European Commission.

6.5 In response to our January 2020 consultation, BT[15] suggested that we should not only omit the informative footnote on DFS in the IR (as proposed in our consultation), but also clarify in the *"Channel access and occupation rules"* column of the proposed IR that DFS will not be required in the 5725-5850 MHz and 5925-6425 MHz bands. In light of this comment, we have decided to make a few minor editorial changes to clarify that the DFS requirements will not apply to RLANs using these bands.[16] We have also decided to omit the reference to the "Nominal Centre Frequency" in the informative part of the proposed IR on the basis that it is redundant.

[15] See BT's response to the January 2020 consultation, paragraph 3.7.

[16] Specifically, for greater clarity we are minded to amend the entry in that column as follows: *"Techniques to access spectrum and mitigate interference that provide at least equivalent performance to the techniques described in harmonised standards for the 5150 ~~– 5350~~ 5250 MHz ~~and 5470 – 5725 MHz~~ band~~s~~ adopted in accordance with ~~EC Decision 2005/513/EC and~~ Directive 2014/53/EC must be used."*

6.6 Additionally, we agree with Intel's comment that a higher power spectral density is needed to allow a 20 MHz channel to realise 250mW EIRP. Therefore, for the 5925-6425 MHz row, we have decided to amend the *"Transmit power/ Power density"* column so that the maximum EIRP density stated is 12.6mW/MHz, rather than 10mW/MHz. This will enable a 20 MHz channel to use an EIRP of up to 250mW.

6.7 Finally, in light of Ericsson's comment that the definition of "indoor" should not limit potential use cases by being too restrictive, we have clarified in the interface requirements what we mean by indoor use in the 5925-6425 MHz band. Equipment must not form part of a fixed outdoors installation when operating in 5925 – 6425 MHz. The Low Power Indoor apparatus may only be used within a building, onboard an aircraft[17] or in any other enclosed space with attenuation characteristics at least as strong as those of either a building or an aircraft. Aeronautical mobile use is not permitted.

6.8 The amendments to IR 2030 that we have decided to make in order to implement the decisions set out in this statement are set out in annex 3 to this document. We are planning to shortly publish an updated version of the IR 2030 on Ofcom's website to reflect these changes.[18]

Statutory instrument

6.9 We expect to consult on the proposed changes to The Wireless Telegraphy (Exemption and Amendment) Regulations 2010 to implement the policy decisions set out in this statement in Q4 2020.

[17] 'Onboard aircraft' means the use of radio links for communications purposes inside an aircraft.
[18] See Interface Requirements 2030 here: https://www.ofcom.org.uk/spectrum/information

A1. Legal Framework

Duties under the Communication Act 2003 and the Wireless Telegraphy Act 2006

A1.1 Ofcom's statutory powers and duties in relation to spectrum management are set out primarily in the Communications Act 2003 (the "**2003 Act**") and the Wireless Telegraphy Act 2006 (the "**WT Act**"). Among 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.

A1.2 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 (other things) to secure the optimal use of spectrum and the availability throughout the United Kingdom of a wide range of electronic communications services.

A1.3 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.

Duties under the Wireless Telegraphy Act 2006

A1.4 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.

A1.5 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.

A1.6 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 granted under the WT Act.

A1.7 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.

A1.8 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.

A1.9 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.

A1.10 Before making any exemption regulations, we are required by section 122(4) of the WT Act to give statutory notice of our proposal to do so. 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.

International Telecommunications Union (ITU) Regulations affecting the 5 GHz band and the lower part of the 6 GHz band (5925-6425 MHz)

A1.11 Radio Regulations governing the international use of spectrum are determined by the ITU at WRC conferences. The new version of ITU-R Resolution 229 of the Regulations after WRC-19 specifies the new requirements for use of the 5 GHz spectrum band as follows:

a) 5150-5250 MHz: Sets power limit and stipulates

i) rules associated with indoor-only use and use within trains up to 200mW EIRP and within vehicles up to 40mW;

ii) rules that allow limited outdoor use up to 200mW;

iii) rules that allow controlled outdoor use up to 1W with a suitable EIRP mask applied;

b) 5250-5350 MHz: Sets power limit; specifies use of Dynamic Frequency Selection ("**DFS**"); requires administrations to take measures to ensure the predominant number of RLANs are operated in an indoor environment (with antenna masks for those stations permitted to operate outdoors); transmitter power control or reduction of permitted power by 3dB;

c) 5470-5725 MHz: Sets power limit, DFS, transmitter power control or reduction of permitted power by 3dB.

A1.12 The band 5925-6425 MHz is allocated by ITU Radio Regulations to Fixed, Fixed-Satellite (earth to space) and mobile service on a primary basis.

EC Decisions affecting use of the 5 GHz band and the lower part of the 6 GHz band (5925-6425 MHz)

The Commission's decisions

A1.13 The EU makes legislation about the use of radio spectrum through 'Decisions'. Commission Decision 2005/513/EC has harmonised 455 MHz of spectrum in the 5 GHz band (5150-5350 MHz and 5470-5725 MHz) for RLAN/Wi-Fi. Article 4 contains the sets of technical restrictions which need to be applied. Compliance is mandatory:

a) Article 4.1 5150-5350 MHz: Sets the power limit and stipulates indoor-only use;

b) Article 4.2 5470-5725 MHz: Sets the power limit;

c) Article 4.3 5250-5350 MHz and 5470-5725 MHz: Stipulates transmitter power control;

d) Article 4.4 5250-5350 MHz and 5470-5725 MHz: Stipulates requirement for DFS.

A1.14 Commission Decision 2005/513/EC was amended by Decision 2007/90/EC which aligned the EIRP density limits in 5150-5250 MHz to those in 5250-5350 MHz.

A1.15 Another binding EC Decision - 2006/771/EC – harmonises the technical conditions for use of radio spectrum, including certain frequencies in the 5 GHz and 6 GHz bands, for a wide variety of short-range devices.[19] The conditions set out in that Decision establish a harmonised sharing environment which allows short-range devices to share the use of spectrum with each other on a non-exclusive basis, regardless of the purpose of such use. Member States may allow the use of the relevant frequency bands under less restrictive conditions or for short-range devices which are not part of the harmonised category, provided that the appropriate sharing environment in the harmonised bands is not compromised.

[19] For example, this Decision harmonises the use of the 5725-5875 MHz band for non-specific short-range devices and the use of certain frequencies including the 6 GHz band for radio determination devices (in particular, tank level probing radars operating in the 4500-7000 MHz band and level probing radars operating in the 6000-8500 MHz band).

Relevant UK regulations

A1.16 On 13 July 2017, Ofcom made regulations to allow Wi-Fi use in the 5.8 GHz band on a licence-exempt basis. Therefore, the use of Wi-Fi devices such as smartphones, tablets and laptops, is currently authorised in this band without the need for a licence, subject to compliance with the relevant technical parameters referenced in Regulation 5 of The Wireless Telegraphy (Exemption and Amendment) Regulations 2010[20], including the relevant parameters set out in Ofcom's interface requirements for short-range devices (i.e. IR 2030 – UK Interface Requirements 2030 Licence Exempt Short Range Devices).

A1.17 In the UK, the lower part of the 6 GHz band (5925-6425 MHz) is licensed to fixed links and satellite users. The use of the 6 GHz band is also permitted on a licence-exempt basis for certain specific short-range devices. For example, radio determination devices operating in the 4.5-7.0 GHz and 6.0-8.5 GHz bands, and radar level gauges operating in the 5150-7100 MHz band.[21]

[20] S.I. 2010/2512, as amended by S.I. 2011/3035, S.I. 2013/1253, S.I. 2014/1484, S.I. 2017/746, S.I. 2018/263, S.I. 2018/1140, and 2019/1450 and 2020/549.
[21] The technical parameters for these licence-exempt uses are set out in IR 2030.

A2. Coexistence studies in the lower 6 GHz band

Summary

Background, description and conclusions from our studies

A2.1 We have decided to make the lower part of the 6 GHz band (5925-6425 MHz) available for Wi-Fi use and other RLAN technologies on a licence-exempt basis.

A2.2 The lower 6 GHz band currently has a primary allocation for several communication services including mobile, fixed satellite and fixed links services. Other services operate in the band on a secondary basis including SRDs, the amateur service and UWB applications. We carried out analysis which looked at possible sharing scenarios in which current services and Wi-Fi would be able to share the band on a co-primary basis.

A2.3 To understand the sharing possibilities and risk of interference to UK fixed links, we carried out some analysis that we believe to be representative of existing fixed link geometries and of future licence-exempt Wi-Fi use in the UK. We used three different approaches to help us understand where, and how, potential interference might occur: a Monte Carlo probabilistic approach, a Minimum Coupling Loss approach, and a static (snapshot) approach. We explain the difference between these approaches later in this Annex.

A2.4 Results suggested that opening the lower 6 GHz band for Wi-Fi on a licence-exempt basis is possible for indoor medium power use (EIRP up to 250mW)[22] and outdoor very low power use (VLP) (EIRP up to 25mW), subject to a small, but unlikely, risk of interference into fixed links in environments that might not reflect realistic UK deployments. Opening the lower 6 GHz band will help meet current and future demand and facilitate new Wi-Fi use cases. The results are summarised in Table A2.1.

A2.5 CEPT undertook similar coexistence studies, using Monte Carlo, Minimum Coupling Loss (MCL) and coverage mapping approaches. These studies also suggested sharing is feasible between RLANs and fixed links if the RLAN deployment is restricted to indoor only use with EIRP up to 200mW and outdoor low power use with EIRP up to 25mW.[23] However, CEPT applied a general, non-specific deployment model whilst our studies focused on UK specific deployment scenarios. We note that the CEPT studies have not yet been completed and that more work is being carried out on in-band spectral power density for VLP RLANs and out-of-band emission limits below 5935 MHz. These studies are expected to conclude in October 2020.

A2.6 The CEPT studies also considered sharing with other services and applications including Fixed Satellite Services, Radio Astronomy Services, Road – Intelligent Transport Systems

[22] We note that CEPT studies are focused on EIRP up to 200mW.
[23] The Monte Carlo study accounts for fixed links details which are available in the UK licence database.

and Communications Based Train Control. We reviewed the CEPT analysis and, in the absence of more comprehensive Ofcom studies, we agreed with the results of the studies carried out by CEPT for these other services.

A2.7 Additionally, since we published the January 2020 consultation and as a result of reviewing the evidence presented in ECC Report 290 of CBTC sharing with existing adjacent users, we now consider that the analysis in ECC Report 302 may be overly conservative. Further evidence also shows that the OOB levels recommended in ECC report 302 could have a negative impact on the amount of spectrum available for RLAN use. As CEPT has initiated work to study this issue further we will provide inputs to the CEPT process based on the appropriate scenarios and OOBE levels that CBTC systems would be expected to deal with from current and future adjacent users in the UK.

A2.8 We will continue to engage with international organisations like CEPT to support a common regulatory regime to promote economies of scale and the development of a common product ecosystem.

Table A2.1 Summary of results and conclusions

Analysis approach	We found that
Monte Carlo *(% probability of exceeding protection criteria)*	When considering RLANs with an EIRP of 250mW (indoor) and 25mW (outdoor), the long-term FS interference criterion of I/N = -10 dB (not to be exceeded for more than 20% of the time) is met. Further, interference thresholds of -10 dB and -6 dB I/N are not exceeded for more than 0.1% of the time.
Minimum Coupling loss *(deriving a possible exclusion zone)*	For the links that are more sensitive to interference, there are only very few instances where the long-term protection criteria of I/N = -10 dB could be exceeded. However, these cases are unlikely to arise in practice since they only occur when the height of the RLAN is greater than 15 to 20 metres. Analysis of the building height data used in our modelling shows the probability of a building being above 9 metres is less than 10%. At the same time, the estimated number of overlapping instantaneously transmitting RLANs in the analysis areas[24] is no greater than a few hundred devices. In the cases where the protection criteria could be exceeded, the exclusion zone required to protect the fixed link receiver may extend to a few square kilometres. When considering a relaxed threshold of -6 dB I/N, the exclusion areas are marginally reduced.
Static "snapshot analysis"	The risk of interference generally comes from a single high-power device (either indoor or outdoor) located close to the fixed link receiver, rather than the aggregate effect of nearby RLAN devices.

[24] When the height of the interferer is set to 21m.

	When we remove the higher power devices from our analysis, interference falls below the long-term threshold of -10 dB I/N.

A2.9 This annex is structured as follows:

a) **Part 1** describes the existing services in the 6 GHz band and CEPT sharing studies.

b) **Part 2** describes the assumptions we used to select the fixed links and generate the deployments of RLAN interferers used in our studies.

c) **Part 3** gives a description of the studies, including the interference threshold criteria and the propagation models used.

d) **Part 4** presents a detailed description of results from the studies.

Part 1: Existing spectrum services in the 5925-6425 MHz band and relevant studies

A2.10 In the UK, the lower 6 GHz band is allocated for fixed satellite, fixed and mobile, services on a primary basis: satellite (Earth-to-Space) services in the 5.925-6.7 GHz band, fixed services in the 5.925-6.425 GHz band and mobile services in the 5.925-6.7 GHz band (for low-power devices, SRDs).[25]

A2.11 In the context of this band, CEPT studies[26] include sharing and compatibility analysis between RLANs and other services using the same and adjacent frequency bands: Fixed Satellite Service (FSS) in the 5925-6425 MHz band, ROAD-ITS below 5925 MHz, Communication Based Train Control (CBTC) below 5935 MHz, Radio Astronomy services and Ultra-Wide Band (UWB) systems. Relevant coexistence studies have been carried out for services sharing the band on a co-primary basis.

A2.12 There is general agreement within CEPT that sharing the band with RLAN is feasible with all the services mentioned above. We support this view and we consider that the analysis and associated assumptions are representative and applicable to the UK. We consider there is no need for further analysis, nor any justification for modifying the sharing parameters. However, we note there is still further work ongoing within CEPT around coexistence with CBTC systems in the adjacent bands and in-band spectral density for VLP devices.

A2.13 The Monte Carlo analysis carried out by CEPT calculated the percentage of time where the aggregate interference from an RLAN deployment to a fixed link would exceed the protection criteria, based on 250,000 iterations. The results showed that the long-term interference criterion (I/N of -10 dB) is not exceeded for more than 20% of the time. A Fractional Degradation in Performance (FDP) analysis showed that FDP of less than 10% is

[25] From Ofcom's UK Frequency Allocation Table UKFAT (accessed 11/11/2019) and EU Commission Decisions 2006/771/EC, 2008/432/EC, 2009/381/EC, 2010/368/EU, 2011/829/EU and 2013/752/EU (harmonised use of spectrum for SRDs). Licences are issued on First Come First Served (FCFS) approach and following technical co-ordination (on an individual link basis) with other fixed links and satellite Earth Stations.
[26] Published in ECC Report 302.

exceeded for some links. However, in most cases these interference events are highly improbable due to the unlikely geometry between the fixed link and the RLAN deployment, or as a result of the random nature of other parameters used in the analysis. The same CEPT studies showed that, if the RLAN deployment is restricted to indoor-only use, with EIRP up to 200mW, sharing is feasible.

A2.14 CEPT carried out further studies looking at the impact of short-term interference on fixed links but the results did not change the conclusions or the views we had taken on our long-term interference analysis.

Part 2: Fixed links and RLAN deployments under analysis

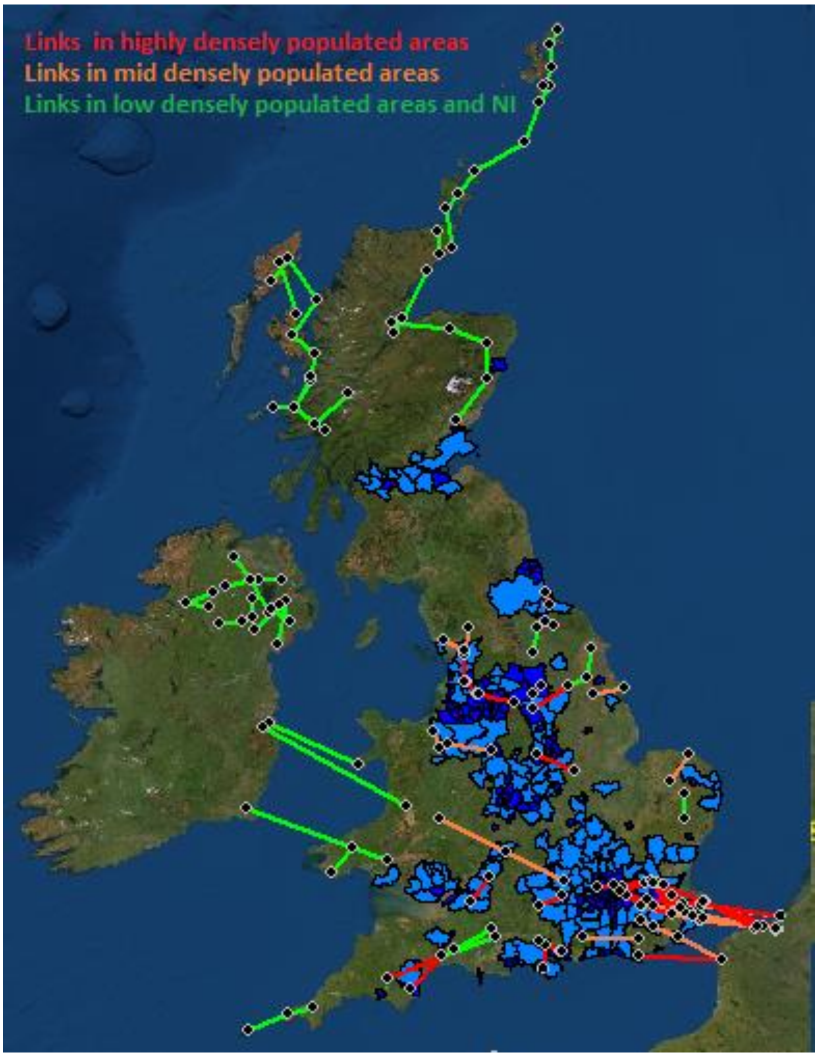
Fixed link parameters in the lower 6 GHz band in the UK

A2.15 We carried out our own analysis to understand the impact on UK fixed links based on long term interference criteria for fixed links. Our studies looked at specific links in the UK to assess the sharing potential with a likely UK RLAN deployment. Our studies differed from the CEPT analysis in that we used real locations and heights of UK premises to locate potential RLAN interfering devices. We also applied different assumptions to radio propagation and building penetration losses. In the sections below we outline the fixed link UK geometries and explain our approach for selecting fixed links and RLAN deployments.

A2.16 We examined the lower 6 GHz (5925-6425 MHz) fixed links database (as of August 2019) to understand the geometries most widely used in the UK. The lower 6 GHz band is managed by Ofcom and assigned for fixed links in accordance with our technical assignment criteria given in TFAC OFW 446.

A2.17 Our analysis considered 335 fixed link licenses issued in the UK. Around 265 of these links were located within UK landmass. Of these, 79 were located partially or completely (either one or both ends of the link) within mid and high densely populated areas, and only 49 were located within high densely populated areas. We defined the population density according to the 2011 Census data for the UK, where "mid" densely populated areas refer to local authorities where up to 50% of the cumulative population of the UK lives and "high" densely populated areas are where 50% to 80% of the cumulative population of the UK lives. Figure A2.1 shows the location of all the links from the publicly available version of the database.

Figure A2.1: Location of fixed links in the 5925-6425 MHz band



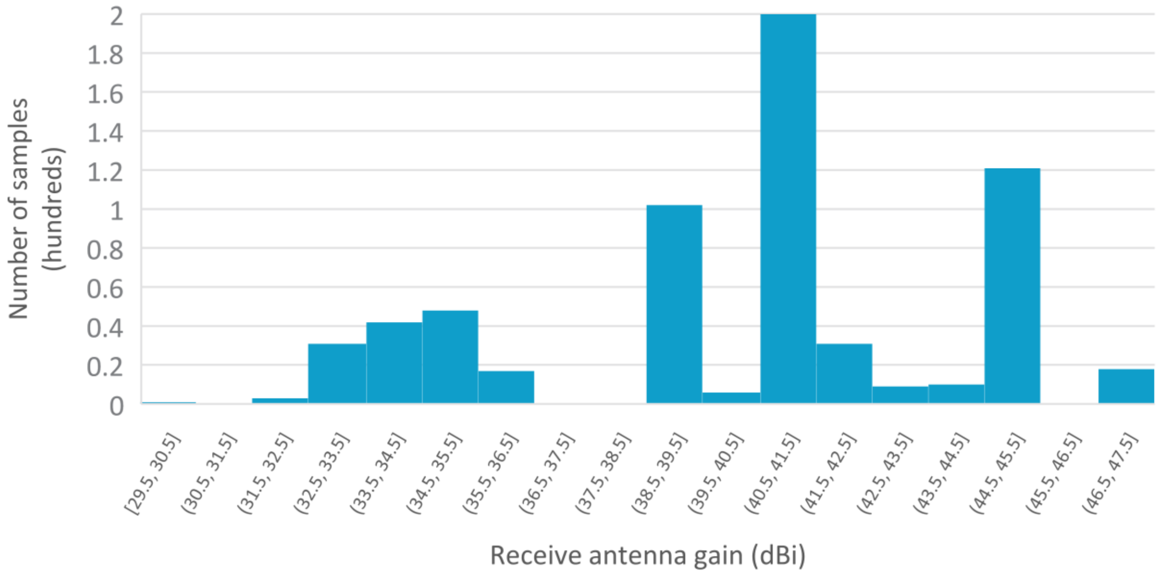
Dark blue areas represent high densely populated local authorities.
Medium blue areas represent mid densely populated local authorities.

A2.18 In order to focus our analysis, we selected a sub-set of links based on their location, antenna gain and antenna height. In Figure A2.2 and Figure A2.3 we show the distribution of the receive antenna gain and height for the links in the database.

A2.19 Antenna gain values ranged from a minimum of 29.9 dBi to a maximum of 46.6 dBi, with an average gain of 40 dBi and a median value of 41 dBi. For receive antenna height, the values ranged from a minimum of 4m and maximum of 452m[27], with an average of 24m and a median value of 23m.

[27] Although contained in the licence database, we believe this value is erroneous and has been discounted in our analysis.

Figure A2.2: Distribution of receive antenna gain in dBi: fixed links in the lower 6 GHz band

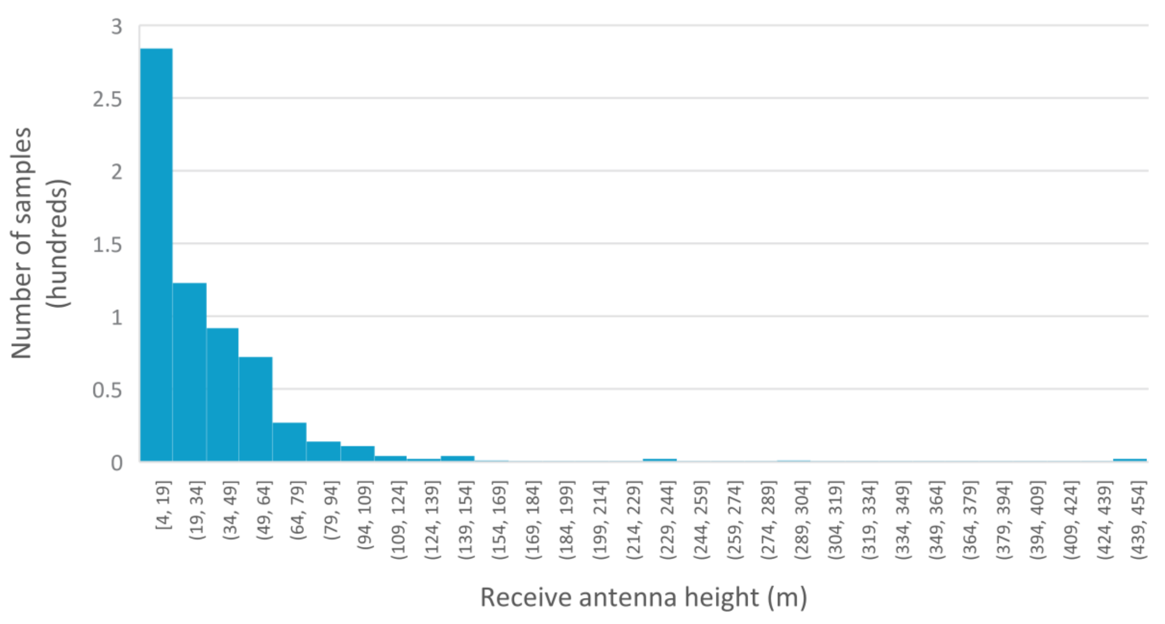


A2.20 In our modelling we used the antenna patterns derived from Recommendation ITU-R F.669[28] for single entry interference studies (MCL) and Recommendation ITU-R F.1245[29] for aggregate interference studies (Monte Carlo and snapshot).

A2.21 Fixed links in the lower 6 GHz band are assigned on a noise-limited basis. We used a system noise floor of -140 dBW/MHz.

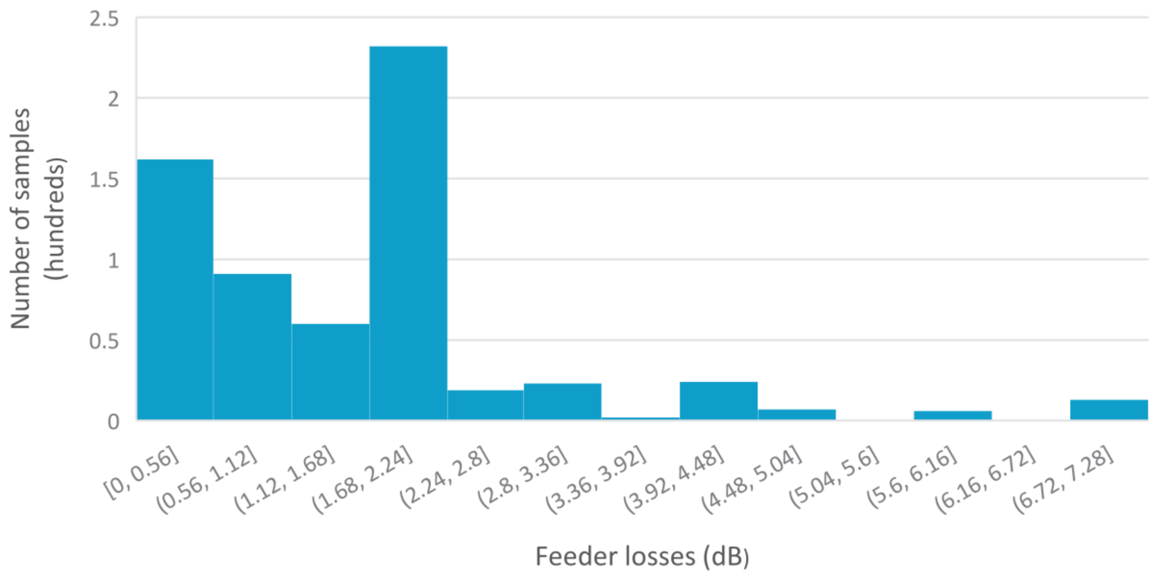
[28] Recommendation ITU-R F.699 – Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to 86 GHz.
[29] Recommendation ITU-R F.1245-3 – Mathematical model of average and related radiation patterns for point-to-point fixed wireless system antennas for use in interference assessment in the frequency range from 1 GHz to 86 GHz.

Figure A2.3: Distribution of height values: fixed links in the lower 6 GHz band



A2.22 We also looked at the distribution of feeder losses[30] contained in the licence database (see Figure A2.4). There were 110 entries associated with feeder losses of 0 dB, and 63 with feeder loss of less than 1 dB. In our analysis we used slightly higher values based on the link geometry and using information from current RF cable product sheets. We used these revised losses for every fixed link under study, even if the feeder losses stated in the database are higher than zero. We note that the values we applied are still within the range of values derived from the database and that this approach is consistent with the analysis in ECC Report 302.

Figure A2.4: Histogram of feeder losses, extracted from fixed links database (August 2019)



[30] Feeder losses are caused by the electronic devices or cabling in the path between the receiver and the antenna.

Summary of the selection criteria for fixed links used in our analysis

A2.23 From the UK fixed link database, we used the following selection criteria to determine the most representative links for our studies:

a) Population density: Both interference from aggregation of devices and from a single dominant interferer is more likely to happen in built-up areas, as there is a higher concentration of devices in the vicinity of the link.

b) Antenna height and tilt: Links with a receive antenna higher than clutter may be less sensitive to interference if the antenna tilt is pointing away from the clutter, and vice versa.

c) Antenna gain: receive links with a higher antenna gain may be more sensitive to interference if they present a negative tilt (towards the ground).

A2.24 We did not include any analysis on fixed links outside UK landmass. We believe the level of risk of interference to such links is extremely low as (i) the geometry and location of these makes them robust to interference and (ii) the probability of RLAN use in the area is very low.

A2.25 Table A2.2 summarises the links we considered in our analysis. While all of them are located within populated areas, they represent different deployment scenarios in terms of local topography, antenna gain and height. Figure A2.5 shows the location of the links.

Table A2.2: Technical characteristics of the links used in our analysis

Licence number	Receive antenna height (m)	Receive antenna gain (dBi)
1126335/1 End 1	32	35
1126335/1 End 2	15	35
1118694/1 End 1	138	34.4
1118694/1 End 2	20	34.4
0432073/1 End 1	16	45
0432073/1 End 2	26	38.7
1027086/1 End 1	240.79	46.6

Figure A2.5: Locations of fixed links used in our analysis

Topology of future RLAN deployments

A2.26 We simulated RLAN deployments based on assumptions about the number of people using devices, at what times and at which locations around a given fixed link. These assumptions are representative of a future UK environment. For each of the links analysed, we calculated a distribution of RLANs which:

a) were located within a 50km area from the fixed link receive location and boresight line gain;

b) could use licence-exempt spectrum and support the 6 GHz band;

c) were transmitting at the same time; and

d) used an overlapping channel to the fixed link receiver.

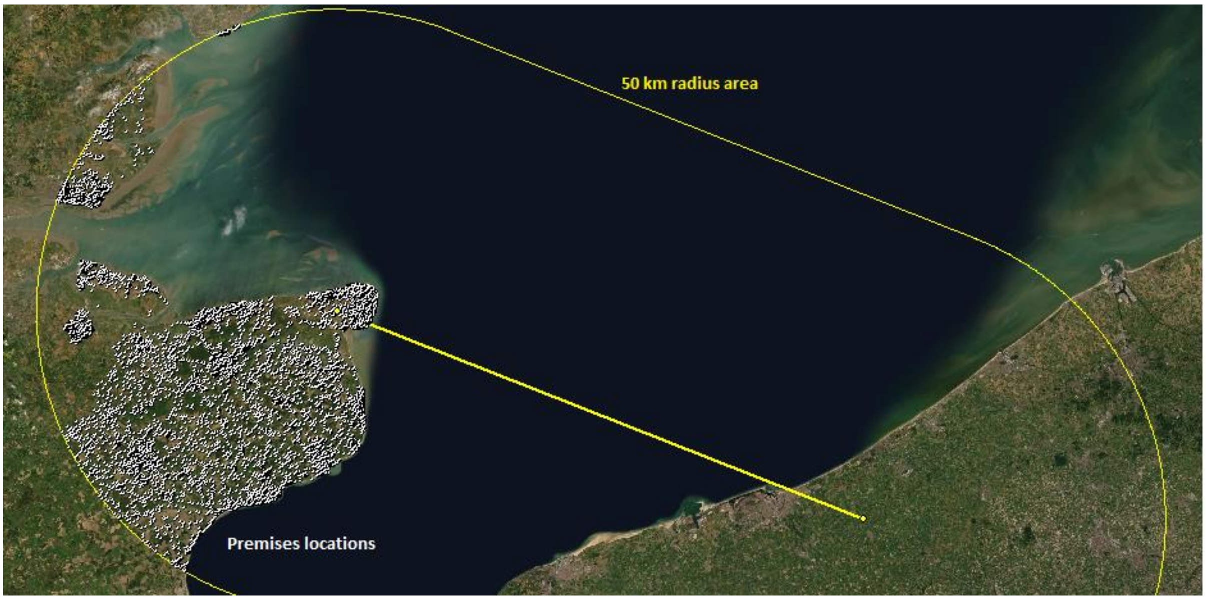
A2.27 We analysed the total number of instantaneously transmitting RLANs based on the population in a given region, and we considered additional factors, which we explain further in this section, that had an impact on the total number of simultaneously transmitting RLANs. Table A2.3 below provides an example using the estimated population of the CEPT administrations for 2025.[31]

Table A2.3: RLAN deployment example

Parametric input:	Low	Mid	High
Population estimates for 2025		768,589,000[32]	
Wireless devices operating in licence-exempt spectrum		0.9	
Busy hour factor	0.5	0.627	0.627
6 GHz factor (6 GHz/6 GHz + 5 GHz + 2.4 GHz)		0.4817	
Market adoption factor	0.25	0.32	0.5
RF activity factor per person		0.0197	
Instantaneously WAS/RLAN devices[33]	820,521	**1,317,034**	2,057,866
Overlapping RLAN devices[34]	174,360	**279,869**	437,296

A2.28 Figure A2.6 presents an example of the RLAN topology (total number and location) for one of the fixed links considered.

Figure A2.6: Example of RLAN locations within a 50km area around a Fixed Link



[31] The estimated population to 2020 in a 50km areas is circa 12,321,234, 10,083,355, 2,356,489 and 911,269, respectively.
[32] Total CEPT population 2025 used for WAS/RLAN calculations, ECC Report 302.
[33] Including RLAN at non-overlapping channels with FS receiver.
[34] We applied a 21.25% overlapping factor, derived from ECC Report Section 6.4.3.2 (Monte Carlo approach).

A2.29 In the following subsections we describe the remaining assumptions we used to derive the RLAN distributions.

Our studies used a spatial and height distribution to simulate UK-specific deployments

A2.30 The interference impact on a fixed link receiver is dependent on the distribution of the nearby RLANs. We used real geolocation information to locate each of the potential interferers derived from the latest Code-Point® datasets, which contain 1.7 million postcode units in Great Britain and Northern Ireland. Each unit contains information about the number of premises present in a postcode, including both residential and non-residential premises. We assumed a potential single client device or access point (AP) for each premises. The CEPT studies[35] followed a similar approach, but used a location grid derived from NASA's Socioeconomic Data and Applications Centre (SEDAC) named Gridded Population of the World V4 (GPWv4). This dataset provides a global composite raster grid of population density at 30 arcsecond resolution (approximately 1km at the equator) using 2025 population estimates.

A2.31 We assigned a random height value to each of the generated (premises) points. These height values were derived from the probability distribution of the height of all buildings within the area around each of the fixed links under analysis. We derived these values from the building height distribution of the latest OS MasterMap Topography Layer. In general, most building heights were representative of one or two storey dwellings. A small proportion of buildings were between three and ten floors, and only a few exceptions above this value (most notably around London).[36] CEPT studies derived a height probability using data extracted from a report on the distribution of single-family homes in the US.[37] Our approach better reflects the topology of premises in the UK because we used UK specific building data.

A2.32 We used the information included in the CEPT studies as a baseline for the types of RLAN and associated peak EIRP in our analysis, but we modified this according to our estimations of a representative future UK market device in the 6 GHz band. CEPT includes seven different types of RLAN devices:

a) Indoor: enterprise AP, consumer AP and high-performance gaming router;

b) Indoor and Outdoor: clients and stations;

c) Outdoor: high-power AP and low power AP.

A2.33 The main difference between these devices is the peak EIRP, which includes the conducted power (dBm) to the antenna, the peak antenna gain (dBi) and MIMO gain of the antenna

[35] ECC Report Section A3.2 of Annex 3.

[36] We assumed a dwelling floor of 3 metres.

[37] NAHB, The Number of Stores in Single-Family Homes Varies Across the Country, 5 August 2016 (Accessed 12/11/2019)

system (dB). The peak EIRP values assumed in the CEPT studies range from 18.5 dBm (~70mW) to 29.9 dBm (~1W).

A2.34 Body loss was not accounted for in the CEPT power distribution.[38] We assumed a body loss of 4 dB for client devices but did not consider any loss for access points.[39] We assumed a percentage of client devices in indoor and outdoor environments as 26.32% and 50% respectively. Factoring in body losses for only client devices (scaling down for 4 dB, which relates to a linear factor of 2.5), the EIRP distribution becomes the one presented in Table A2.4 below.

Table A2.4: Percentage of indoor and outdoor RLAN devices, with different peak EIRP values

Power (mW)	1000	250	100	50	40	20	13	5	1
Indoor %	0.71	9.16	4.39	13.75	1.82	12.03	40.00	12.47	5.68
Outdoor %	3.24	4.24	4.38	14.10	3.46	22.85	20.97	23.68	3.07

A2.35 The high-power APs were assigned a peak EIRP of 30 dBm (1W), according to ETSI TR 103 524. However, we excluded these devices from our RLAN distribution, leaving only outdoor use up to 25mW for client devices (representative of VLP devices).

A2.36 Lastly, we assumed a 1.5 dB polarisation mismatch loss for single entry studies and a 3 dB polarisation mismatch loss for aggregate interference studies.

Bandwidth and operating frequency distribution follow CEPT guidelines

A2.37 Table A2.5 below shows the expected future distribution of RLAN devices with different channel bandwidths in the 6 GHz band. Wider bandwidth channels (80 MHz or 160 MHz) are expected to be used more than narrower (20 or 40 MHz) channels in the 6 GHz band (as we set out in the main body of this document).

Table A2.5: Nominal channel bandwidth percentages

Bandwidth (MHz)	20	40	80	160
% in devices	10	10	50	30

A2.38 We assumed IEEE 802.11ax[40] (Wi-Fi 6) compliant equipment in our studies. As such, we derived the nominal centre frequencies (f_{cn}) based on the nominal bandwidth and different channel number increments using the following formula:

[38] Body loss refers to part of the RF signal energy that is blocked and absorbed into the human body when the terminal antenna is close to it.
[39] Same approach as the one used in the CEPT studies, as described in ECC Report 302.
[40] Cisco Frequency Bands of Operation defined in IEEE 802.11ax.

$$f_{cn} = 5940\ (MHz) + (g * 5)\ MHz\ \ where\ 1 \leq g \leq 93$$

Other factors we considered in our analysis

A2.39 When assessing the number of RLANs that could be transmitting simultaneously, we also considered factors which are related to the technical parameters of devices, in addition to the number of people who could be using a RLAN at the same time, and their locations. For example, we considered whether a next generation wireless device would support operation in licence-exempt bands or at what time of the day it would be most likely to have a greater number of client devices using the 6 GHz band.

A2.40 We used the CEPT studies as a baseline,[41] but we recognise there were different levels of conservatism in some of the assumptions.[42] Table A2.6 describes these factors and presents our view on how conservative they may be. This is relevant as these factors could impact the number of RLANs that could cause potential interference.

[41] We noted the CEPT studies include “low” and “high” parametric values for market adoption and busy hour factor.
[42] Based in our previous experience with similar factors from, for example, the RLAN devices in the 5.8 GHz band.

Table A2.6: RLAN deployment topology: other factors to consider

Factor	Value	Level of conservatism (High/Medium/Low)
Wireless devices operating in licence-exempt spectrum *This is an estimate of the percentage of data transmitted over wireless devices operating in licence-exempt spectrum. The remaining 10% is assumed to be operating under licensed conditions. We do not include SRDs in our estimates.*	90%	High
Busy hour factor *This factor describes the percentage of WAS/RLAN devices active in the busy hour.*	62.7%	High
6 GHz factor (6 GHz / (6 GHz + 5 GHz + 2.4 GHz)) *The 6 GHz factor is the percentage of WAS/RLAN devices utilising the 6 GHz frequency band. This is the ratio of spectrum available at 6 GHz to that available across the 6, 5 and 2.4 GHz frequency bands (500 MHz / 1038 MHz).*	48.17%	High
Market adoption factor (6 GHz capable devices) *The market adoption factor is the percentage of devices capable of operation at 6 GHz. A value of 32% assumes actual market projections.*	32%	Medium
RF activity factor per person *The RF factor estimates the percentage of time when the RLAN is effectively in operation and is given per person, during the busy hour. We used similar values in our 5.8 GHz Wi-Fi consultation.*	1.97%	Medium

A2.41 In summary, we considered these factors in order to simulate a realistic deployment of RLANs in the 6 GHz band, which we have used in our analysis of sharing with fixed links described in the following section. The assumptions reflect a UK-based future sharing scenario.

Part 3: Description of the analysis

We have formed our view based on different types of analysis

A2.42 We carried out three types of analysis to obtain different points of view of where and how RLAN can share with incumbent fixed links. In this section we describe our modelling in more detail before presenting our results and conclusions in Part 4.

Statistical approach: Monte Carlo analysis

A2.43 We calculated the probability of exceeding the co-primary interference threshold criteria (I/N of -10 dB) based on 10,000 Monte Carlo iterations accounting for different RLAN deployments based on the technical parameters described above.

A2.44 Additionally, we used a slightly relaxed threshold criteria of -6 dB I/N to understand the impact on the number of instances that would surpass the threshold (i.e. % of time that is exceeded).

A2.45 We present the aggregate results including the I/N of all Monte Carlo iterations from each link analysed. We also identify the percentage of time (number of events) where the -10 dB and -6 dB I/N thresholds are exceeded.

A2.46 We included two different area sizes around each fixed link in our analysis. The first considered an area up to 150km away from the fixed link receiver and boresight line gain and we also used it in our “snapshot” analysis, including RLAN devices operating at 1W EIRP. The results of the analysis showed that devices located a few kilometres away from the link contributed only very marginally, if at all, to the aggregate interference.

A2.47 We then reduced the analysis area around each link. We used the values from the CEPT MCL analysis as our starting point to derive a maximum distance where a single RLAN would cause, or increase, the aggregate effect of interference. This report showed a maximum peak distance of 44km, to which we added an additional 6km to account for aggregate effects at the edge of the area. We note that this exclusion zone is based on a 1W outdoor RLAN device and, as such, we consider it to be a very conservative analysis area.

Exclusion areas approach: Minimum coupling loss

A2.48 An MCL method estimates the required separation between interferer and victim to ensure that there is no risk of interference. We calculated the required separation around the fixed link receivers based on the MCL when the interferer is an indoor AP operating at 250mW, and an outdoor mobile device operating at 25mW. This is a very conservative approach; RLANs typically use lower EIRPs and are subject to a RF activity factor.

A2.49 We present the results against an interference threshold of -10 dB I/N and -6 dB I/N and the effect on the size of a potential exclusion area around a fixed link.

Static approach: “snapshot” analysis

A2.50 This approach looked at a single iteration of the Monte Carlo analysis described above. We used this approach to understand the extent of aggregate and single-entry interference. Our analysis area is a “buffer” zone of 150km from the fixed link receiver and boresight line gain.

A2.51 This approach was most useful when analysing RLAN deployments that included high-power devices (operating at EIRP higher than 250mW and less than 1W). We identified the worst interferer for a given iteration and recalculated the results once the device had been removed from the distribution. Using this approach, if the interference is dominated by the worst interferer, the new I/N results are lower, and remain similar if interference is generated from the aggregate effect of nearby devices.

Common assumptions used in our analysis

We applied a long-term interference criteria threshold

A2.52 There are two main criteria to protect fixed links against harmful interference, namely long-term protection criteria and short-term protection criteria.[43] In brief:

- Long-term interference degrades the bit error performance and availability of a system by reducing the fade margin that is available to protect the fixed service system against fading. In sharing and compatibility studies, long-term interference is usually characterised as the interference power that is not to be exceeded for more than 20% of the time, at the victim receiver input.
- Short-term interference is the term used to describe the highest levels of interference power that occur for less than 1% of the time, at the victim receiver input.

A2.53 In our analysis we used the long-term protection criteria only. We are of the view that this metric gives enough information about how likely it is that a service provided by a fixed link in the 6 GHz band would be degraded as a result of interference from RLAN systems.

A2.54 We used two propagation methods with a different approach for clutter losses. We used recommendation ITU-R P.452-16 as a baseline propagation model (with p =20 %), adding the value of the clutter loss at the receiver end and along the entire propagation path.[44]

A2.55 We applied two different approaches to account for the effect of nearby clutter. Clutter refers to objects, such as buildings or vegetation, which are found on the surface of the Earth but are not part of the terrain. Clutter around a radio transmitter/receiver terminal can have a significant effect on the overall propagation. We considered clutter effects both along the path and at the propagation receive end:

[43] Recommendation ITU-R F.758-7 fully describes the two criteria.
[44] Recommendation ITU-R P.452-16 describes a prediction method for the evaluation of interference between stations on the surface of the Earth at frequencies from about 0.1 GHz to 50 GHz and it takes into account clear-air and hydrometeor scattering environments. In this method, clutter losses can be applied in either or both ends of the path.

a) Clutter correction at the receive end, applying values from Recommendation ITU-R P.2108. To apply the statistical model of this recommendation we assumed that the fixed link receiver was within the clutter and the terminals located in urban and suburban environments. We also assumed that the distance between terminals was greater than 250m. Clutter loss values in this case range up to ~30 dB. We note that this approach should not be applied to distances below 250m and that might be the limiting factor in calculating the overall path loss. However, the number of instances where the Rx/Tx distance is less than 250m is low (less than 5%) so we do not believe it would have a significant impact on the overall path loss value, and we used a second method to account for distances below 250m which provides a more conservative approach to the path losses.

b) Clutter correction along the path, without applying any height correction at the receive end. Values ranged between 0 dB and 10 dB.

We used a single value for building entry losses

A2.56 We applied building penetration losses when the RLAN device is located indoors. In line with our studies in our consultation on enabling opportunities for innovation, we applied a 12 dB attenuation value. We derived this value from Recommendation ITU-R P.2109[45]. We understand that in some instances the real building entry loss will be higher than 12 dB, and as such, the risk of interference is decreased. Equally, in other cases we might be applying a lower loss which may lead to an increased risk of interference to or from other users. We note that the CEPT also uses the same ITU recommendation but applies different attenuation values for two types of buildings: 17 dB loss for traditional buildings and 32 dB loss for thermally efficient buildings. Our approach to entry losses is more conservative.

Part 4: Findings and conclusions

A2.57 In this section we present our results and conclusions on the potential for RLAN to share with incumbent fixed link users in the 6 GHz band.

Our analysis suggests sharing is feasible

A2.58 Results from the three different types of analysis showed that sharing is feasible when the deployment scenarios are limited to VLP devices outdoors (25mW) and RLAN indoors (up to 250mW). We noted that there could still be some scenarios where the threshold could be exceeded, but the likelihood of such scenarios arising in practice is very low and the associated risk is manageable.

A2.59 The interference scenarios relate to very specific geometries (RLAN devices in line-of-sight of the fixed link receiver) that we believe are unlikely to occur in practice due to several reasons:

[45] We derived the 12 dB from a 70/30% split between traditional and thermally efficient building entry loss value from CDFs.

a) RLAN EIRP levels are normally lower than those we are considering. For example, 250mW indoor represents less than 10% of the total forecast distribution in the CEPT studies.[46] Estimates for outdoor 20mW EIRP are circa 20% and decrease to circa 4% for 40mW EIRP.

b) There is a low chance of interference to fixed links in open/rural areas (where there is more likelihood of a line-of-sight path between RLAN and fixed link receiver due to lack of clutter) as there are fewer premises around the link receiver where RLANs could be located.

c) The effect of higher clutter losses in populated areas means there is a lower chance of interference unless the RLAN is located very close to the fixed link receiver.

A2.60 Additionally, we noted that, as a result of decisions regarding Earth Stations on-board Vessels (ESVs) used in the 5925-6425 MHz band at the World Radiocommunication Conference 2003, the assignment criteria in the UK includes a minimum fade margin value of 35 dB for this band. This is 25 dB higher than the fade margin considered in upper and lower bands assigned to fixed links, and it provides additional mitigation for interference from RLAN.

Results of the Monte Carlo analysis

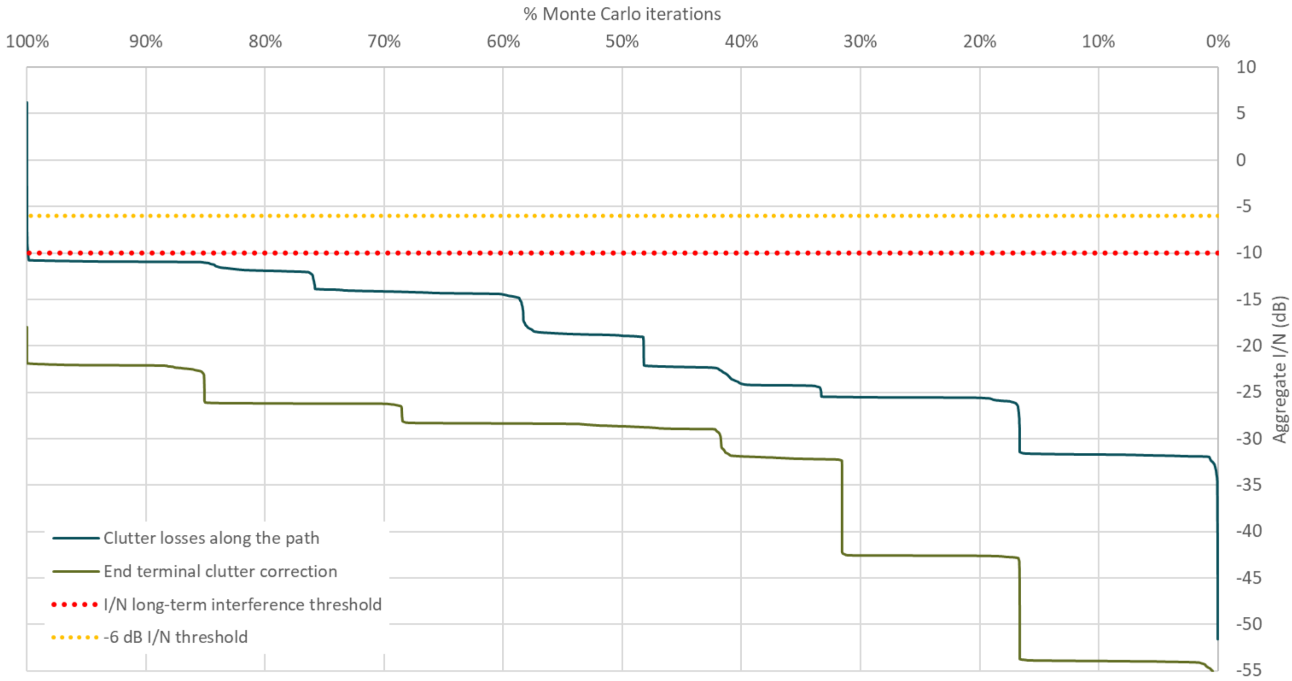
A2.61 We carried out a Monte Carlo analysis on a representative set of UK fixed links using the RLAN deployment described in Part 2 of this annex. For each link we generated 10,000 Monte Carlo iterations, randomizing the RLAN parameters and the locations of the interfering RLANs based on the postcode and density of population data of the 50km area surrounding the fixed link receiver.

A2.62 The result is the mean and standard deviation value of the aggregate I/N per iteration. We then collated the aggregated I/N values shown in Figure A2.7.

A2.63 The results showed that, when considering clutter losses along the path[47], there were only a very small percentage of cases where the aggregate I/N could exceed the long-term interference protection criteria of -10 dB, and less than 0.1% of cases where a threshold of -6 dB I/N could be exceeded. Fewer than 0.01% of events would be linked to an aggregated I/N more than -5 dB but less than 5 dB, and fewer than 0.004% would exceed an I/N of 5 dB. There were no cases where the I/N protection criteria was exceeded when clutter losses at the fixed link receiver were considered.

[46] These estimates are summarized in ECC Report 302.
[47] And applying no end terminal height correction.

Figure A2.7: Aggregate I/N vs Percentage of Monte Carlo iterations



A2.64 As described below, the aggregate I/N exceeds or is close to the protection limit due to a single dominant interferer in the majority of cases. We noted that the two most sensitive link receivers which show higher values of aggregated I/N are both located in densely populated areas, in which the possible locations where a single interferer could be located are higher than in less built up areas. However, we note that we did not exclude any locations within the first or second Fresnel zones that we would usually assume to be clear when planning a fixed link.

A2.65 The CEPT Monte Carlo analysis showed that only 0.54% of the 250,000 simulation iterations for the analysed receivers had aggregate I/N exceeding -10 dB. Our studies are broadly in line with these results; the small difference is likely to be due to the more UK-specific assumptions in our study and the fact that we used fewer Monte Carlo iterations (10,000 compared to 250,000).

Results of the static (snapshot) analysis

A2.66 This analysis calculated the I/N from an aggregation of several RLANs in the vicinity of the fixed link receiver. We included indoor and outdoor RLAN with an EIRP of 1 W. The results showed that the receive link most sensitive to interference was the one associated with licence number 1118496/1 (the receive end was in the Hackney Wick area of London).

A2.67 Results showed that the I/N resulting from the worst interferer was 4.40 dB. The interferer is located ~170m away from the fixed link location, close to the boresight line gain of the antenna (Figure A2.8). In this case, the transmission path loss is dominated by the free space path loss (around 94 dB).[48] Once this device is removed from the RLAN distribution, the aggregated I/N drops to -15.2 dB which is below the long-term interference criterion value of -10 dB I/N.

A2.68 In practice, this geometry is very unlikely to happen. Firstly, there is only a ~4% probability (according to CEPT) that the RLAN will be an outdoor 1 W device. Secondly, our approach was based on very conservative assumptions (for example, the antenna pattern will offer better spatial discrimination than we have assumed in our model). Thirdly, the lower 6 GHz band assignment criteria present a minimum fade margin of 35 dB (25 dB higher than in the upper 6 GHz band) that might be sufficient to overcome the necessary path loss to comply with the long-term interference threshold.

Figure A2.8: Detail of snapshot analysis. Location of fixed link receiver and possible interferer

Results of the minimum coupling loss analysis

A2.69 We carried out a single-entry interference analysis to determine the extent of any potential restriction areas in the vicinity of a fixed link receiver. As a single-entry analysis, the interfering RLAN[49] can be located at any given point within the vicinity and boresight line gain of the fixed link.

A2.70 The Monte Carlo analysis helped us identify which of the links we have studied would be most sensitive to interference. Links 1126335/1 and 1118496/1 show the closest I/N mean values to the protection threshold of -10 dB I/N. For the minimum coupling loss analysis, we selected the link 1126335/1 and also included link 0432073/1. Both ends of this link are in sparsely populated areas, where it is unlikely that clutter losses would contribute to a

[48] In this example, we referred to the results when the path losses include the receive end clutter correction from ITU R. P.2108.
[49] An indoor access point at 250mW with a polarisation mismatch loss of 1.1 dB and a Building Entry Loss (BEL) of 12 dB.

shielding of the receiver against interference from nearby locations. With this, we explored how a possible exclusion area would increase when the fixed link receiver is in an open area, which is a common deployment scenario.

A2.71 The results include the curves corresponding to different heights of 3m, 6m, 9m and 21m for the RLAN interferer (Figure A2.9: and Figure A2.10). The shaped areas around the link represent locations where a device would potentially cause interference.

A2.72 The results from analysing link 1126335/1 (Figure A7.9:) showed that the maximum potential area around the link includes the line-of-sight path between both ends (approximately 21km), with a maximum area of approximately 66km.^{2} This area greatly reduces when the RLAN height is decreased; it would only extend a few meters when the interferer is at height of 3m or 6m. We note that according to the cumulative distribution of the probabilities of building heights in the area surrounding the link, the likelihood of premises with heights above 9m is less than 10%. Additionally, the estimated population within the greatest area will reach circa 500,000 people in 2025. According to the RLAN distribution we have used in the study, this would lead to circa 180 instantaneously transmitting RLANs as potential interferers within this area.

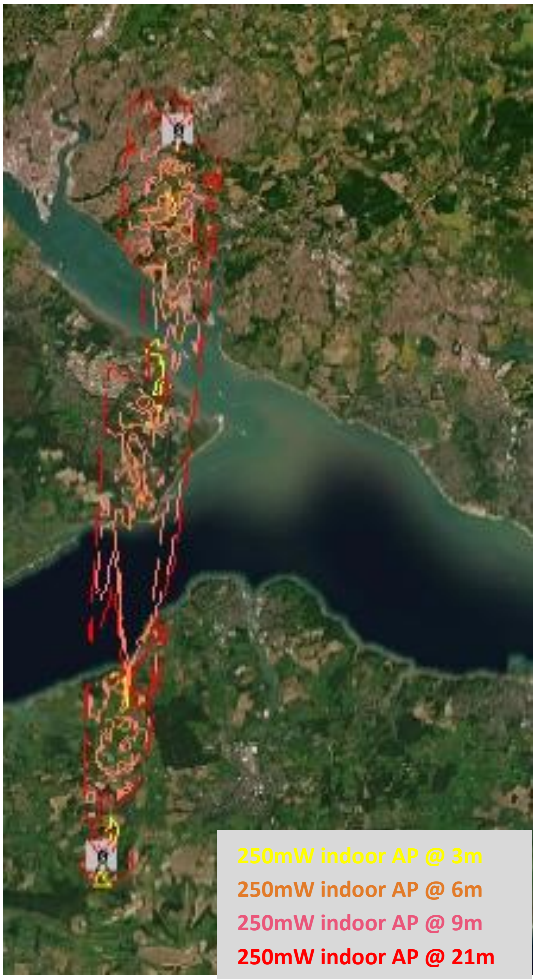
Figure A2.9: Exclusion areas (MCL). Variable RLAN height, 250mW indoor access point, Link Licence No. 1126335/1, London area

A2.73 The results from analysing link 0432073/1 (Figure A7.10) showed that the maximum potential area around the link would include the line-of-sight path between both ends, with a maximum area of approximately 130km.^{2} The estimated population within the greatest area will reach circa 130,000 people in 2025. According to the RLAN distribution we have used in the study, this would lead to circa 50 (overlapping) instantaneously transmitting RLANs nearby.

A2.74 The potential exclusion zones reduce in size if a more relaxed interference threshold criteria (-6 dB I/N) is considered. However, the reduction is marginal for building heights below 10 meters, and less than 15% for up to 21 meters.

A2.75 In summary, exclusion areas increase with higher RLAN height and EIRP, but due to the topology and geometry of the fixed links, only a few locations within the areas are likely to be used for RLAN. For the most common RLAN types (low to medium EIRP and low height), areas become very small in size, or even negligible.

Figure A2.10: Exclusion areas (MCL). Variable RLAN height, 250mW indoor access point, Link Licence No. 0432073/1, Isle of Wight area



A3. Changes to Interface Requirement 2030

We have decided to modify one row of, and add a further new row to, Interface Requirement 2030 (IR 2030). The new technical parameters set out in IR 2030 will form part of the requirements with which individuals will be required to comply when operating in the 5725-5850 MHz and 5925-6425 MHz frequencies (once we have put the new exemption regime on a statutory footing). Modifications and additions to the 5725-5850 MHz row, as currently set out in IR 2030, are in red. Modifications to the 5925-6425 MHz row, compared with the version we published in January, are in red. The current version of IR 2030 can be found on our website. We intend to update it shortly to reflect these changes.

Modification of row IR2030/8/3 currently covering the 5725-5850 MHz band

Interface Number / Notification number / Date	Normative Part								Informative Part
	Application	Comments to application	Frequency band	Comments to Frequency band	Transmit power / Power density	Comment to Transmit power / Power density	Channelling	Channel access and occupation rules	Reference
IR2030/8/3 2017/	Wireless Access Systems (WAS)	Equipment must not form part of a fixed outdoors installation when operating in 5730 – 5850 MHz	5725 – 5850 MHz		Maximum mean EIRP of 200mW and maximum mean EIRP density of			Techniques to access spectrum and mitigate interference that provide at least equivalent performance to the techniques described	~~See footnote[50] for information.~~ ~~Nominal Centre Frequency (MHz)~~

~~[50] Although a matter for users to determine, if Dynamic Frequency Selection and Transmit Power Control are implemented as elements of the techniques to access spectrum and mitigate interference referred to under 'Channel access and occupation rules', one possible approach may be to apply Dynamic Frequency Selection and Transmit Power Control as specified in EN 301 893 (applied to this band in the same way as applied to the 5150 – 5350 and 5470 – 5725 bands), except with respect to Dynamic Frequency Selection detection radar test signals; where Dynamic Frequency Selection detection radar test signals as specified in EN 302 502 (as applied to WAS equipment) may be applied."~~

		Aeronautical mobile use is not permitted. Equipment may be used airborne, within an aircraft, only to establish a connection with a station or apparatus within the same aircraft.			10mW/MHz in any 1 MHz band			in harmonised standards for the 5150 – ~~5350~~ 5250 MHz ~~and 5470 – 5725 MHz~~ band~~s~~ adopted in accordance with ~~EC Decision 2005/513/EC and~~ Directive 2014/53/EC must be used.	~~5745, 5765, 5785, 5805, 5825~~

New row to cover the 5925-6425 MHz band

Interface Number / Notification number / Date	**Normative Part**								**Informative Part**
	Application	**Comments to application**	**Frequency band**	**Comments to Frequency band**	**Transmit power / Power density**	**Comment to Transmit power / Power density**	**Channelling**	**Channel access and occupation rules**	**Reference**
XXYYYYY	Wireless Access Systems (WAS)	Equipment must not form part of a fixed outdoors installation when operating in 5925-6425 MHz.	5925 – 6425 MHz		Maximum mean EIRP of 250mW for Low Power indoor and 25mW for Very Low			Techniques to access spectrum and mitigate interference that provide at least equivalent performance to the techniques described	~~Nominal Centre Frequency (MHz) 5945, 5965, 5985, 6105, 6125, 6145, 6165, 6185, 6205,~~

		Aeronautical mobile use is not permitted. The Low Power Indoor apparatus may only be used within a building, onboard an aircraft or in any other enclosed space with attenuation characteristics at least as strong as those of either a building or an aircraft. 'Onboard aircraft' means the use of radio links for communications purposes inside an aircraft. ~~Equipment may be used airborne, within an aircraft, only to establish a connection with a station or apparatus within the same aircraft.~~			Power indoor and Outdoor. Maximum mean EIRP density of ~~10mW/MHz~~ 12.6mW/MHz in any 1 MHz band			in harmonised standards for the 5150 – ~~5350~~ 5250 MHz ~~and 5470 – 5725 MHz~~ band~~s~~ adopted in accordance with ~~EC Decision 2005/513/EC and~~ Directive 2014/53/EC must be used.	~~6225, 6245, 6265, 6285, 6305, 6325, 6345, 6365, 6385, 6405~~

A4. Glossary

2003 Act: The Communications Act 2003 (c. 21)

2G, 3G, 4G and 5G: Second, third, fourth and fifth generation mobile phone standards and technology.

AFC: Automated Frequency Coordination

AP: Access point. A hardware device that allows other Wi-Fi-compatible devices to connect to a wired network. For example, an AP can be part of or connected to a router within the premises.

AR: Augmented Reality. An interactive video technology that overlays computer-generated information (e.g. images, text, sound) over real-world images or video. A type of VR.

Beamforming: A technique that controls and focuses a wireless signal towards a specific receiver, creating a faster and more reliable connection.

BFWA: Broadband fixed wireless access

BSS colouring: basic service set colouring, which decreases the time to establish a connection during the initial Listen Before Talk protocol and enables the connection to less congested Wi-Fi channels.

CBTC: Communications Based Train Control

CDF: Cumulative distribution function

CEPT: European Conference of Postal and Telecommunications Administrations

dBi: Decibel isotropic. A measure of antenna gain.

dBm: The power ratio in decibels (dB) of the measured power referenced to one milliwatt (mW).

DFS: Dynamic Frequency Selection. A system that makes Wi-Fi routers change frequency when a radar using the same frequency is near.

Earth station: A station located either on the Earth's surface or within the major portion of the Earth's atmosphere and intended for radio communication with one or more satellites or space stations.

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

EIRP: 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).

ETSI: European Telecommunications Standards Institute

FCC: Federal Communications Commission (US)

FDP: Fractional degradation in performance

Fixed link: A terrestrial-based wireless system operating between two or more fixed points.

FS: Fixed service

FSS: Fixed satellite service. Two-way communication links between earth stations, usually at fixed locations, and one or more satellites.

Gbit/s: A data-rate of one gigabit per second.

GHz: Gigahertz. A unit of frequency of one billion cycles per second.

IEEE: Institute of Electrical and Electronics Engineers. The IEEE sets Wi-Fi specifications, typically beginning '802.11'. The most recent generation of standards, 802.11.ax, is also known as Wi-Fi 6.

I/N: Interference over noise

IoT: Internet of Things. A system of connecting any electronic device to the internet and to other connected devices.

ISM band: Industrial, Scientific and Medical band. Frequencies defined by the ITU as reserved (internationally) for purposes other than telecommunications.

ITU: International Telecommunications Union. Part of the United Nations with a membership of 193 countries and over 700 private-sector entities and academic institutions. ITU is headquartered in Geneva, Switzerland.

LBT: Listen before Talk protocol. When spectrum users in unlicensed bands share the same channels. LBT causes their devices to detect ('listen for') other users transmitting information and waiting for this to finish before they transmit ('talk'). This avoids interference but can worsen device performance in congested bands.

Mbit/s: A data-rate of one megabit per second. There are 1000 megabits in a gigabit (Gb)

Mesh systems or networks: A wireless network comprising many connected devices (or nodes) that can deliver better wireless coverage than a single Access Point.

MHz: Megahertz. A unit of frequency of one million cycles per second.

MCL: Minimum coupling loss. The *minimum* distance *loss* including antenna gain measured between antenna connectors.

MIMO: Multiple-input and multiple-output

Monte Carlo Analysis: A mathematical method to draw a statistical output from repeating random sampling analysis.

mW: Milliwatt. A derived unit of power in the International System of Units (SI). A milliwatt is one thousandth ($1x10^{-3}$) Watts.

NPRM: Notice of proposed rule-making, a public consultation notice issued when an independent agency of the United States government is making a change to domestic rules or regulations.

OFDM: Orthogonal frequency-division multiplexing

OFDMA: Orthogonal frequency-division multiple access

RLAN (or WLAN): Radio (Wireless) Local Area Network. A radio access system used to provide wireless access between computer devices. RLANs are intended to cover smaller geographic areas like homes, offices and, to a certain extent, buildings being adjacent to each other.

SRD: 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.

Throughput: The rate of data delivery.

VLP: Very low power. In this document, we use VLP to refer to devices up to 25mW.

VR: Virtual Reality. An interactive and immersive video technology that simulates realistic images and other information in a virtual setting. It can be used in both individual user and industry applications (such as gaming and medical training). See also AR.

W: Watt. A derived unit of power in the International System of Units (SI).

WAS: Wireless Access Systems

Wi-Fi: Commonly used to refer to radio local area network (RLAN) technology, specifically that conforming to the IEEE 802.11 family of standards. Such systems typically use one or more access points connected to wired Ethernet networks, which communicate with wireless network adapters in end devices such as PCs. It was originally developed to allow wireless extension of private LANs but is now also used as a general public access technology via access points known as “hotspots”.

WRC: World Radiocommunication Conference. An international conference organised by the ITU to review and revise radio regulations, held every three to four years. The most recent WRC (WRC-19) was held in Egypt, October-November 2019.

WT Act: The Wireless Telegraphy Act 2006 (c. 36)

A5. Summary of consultation responses

A5.1 This Annex provides a summary of the comments received from stakeholders in response to our consultation, published on 17th January 2020, along with our responses to these comments.

A5.2 Where stakeholders have made the same, or similar, comments on more than one question we have included the response under the most relevant question. Where we have addressed comments in the main chapters of the statement, we have included a cross-reference.

A5.3 A total of 32 responses were received from the following stakeholders:

Broadcom Inc.	BT	Cisco Systems Inc.
CommScope	Decawave (Qorvo)	Dynamic Spectrum Alliance (DSA)
Ericsson	EMEA Satellite Operators Association (ESOA)	Facebook
Federated Wireless	Freshwave Group	Gamma Telecom Holdings Ltd.
Hewlett Packard Enterprise (HPE)	Hitachi Rail	Huawei Technologies
Intel Corporation	Intelsat	Joint Radio Company (JRC)
Mr L. Cropley	Nokia	Qualcomm Europe Inc.
Radio Society of Great Britain (RSGB)	Sky	Strathclyde Partnership for Transport (SPT)
TalkTalk	Tampnet	techUK
Transport for London and London Underground Ltd (TfL and LUL)	UKWISPA and Cambium Networks	UWB Alliance
Wi-Fi Alliance	Wireless Broadband Alliance (WBA)	

A5.4 We also received 6 responses from stakeholders who requested their name, part of their response, or their entire response be kept confidential ([✂]).

Question 1 – Do you have any comments on our proposal to open access to the 5925-6425 MHz band for licence-exempt Wi-Fi use?	
Stakeholder comments	**Our response**
Most respondents agreed with our proposal to open up the 5925-6425 MHz band for RLAN use (including Wi-Fi). They said that this will provide much needed additional spectrum, avoiding future congestion and interference in areas of very high traffic density. They also noted that it will provide significant societal and economic benefit to the UK, enable innovation and will promote investment in new technologies. The proximity to the existing 5 GHz band means that 6 GHz chipsets will be available quickly (from mid-2020).	We note these comments agreeing with our demand analysis. Further information on our view of demand and the benefits of releasing more spectrum is set out in section 3 of this document and in the January 2020 consultation.
A small number of respondents disagreed with our proposals. They cited concerns including: there being no need for the proposed rule change (Decawave), a concern around prioritising CBTC systems in 5915-5935 MHz band to protect them from RLAN interference (TFL/LUL, SPT, Hitachi Rail), a concern over loss of access to required bandwidths for the future ([✂]) and a concern that RLAN devices will impact on incumbents more than our consultation suggests (UWB Alliance).	We note the concerns raised over our proposals, particularly concerns over interference to CBTC systems and the impact on incumbent users. In our January 2020 consultation we presented an analysis of the potential for RLAN devices to share with incumbent users of the spectrum. Absent of any detailed comments on our analysis, we are satisfied that the risk of interference remains low. We address CBTC in section 4 of this statement. We remain committed to working with all spectrum users, protecting incumbent users and considering making new spectrum available when requirements arise.
Broadcom, BT, Cisco, CommScope, Facebook, HPE, Intel, Qualcomm, Wi-Fi Alliance, WBA noted the enhancements that will be brought with the latest IEEE 802.11ax (Wi-Fi 6/6E) technology, and Broadcom and WBA highlighted next generation (IEEE 802.11be) technologies, including enhanced data rates and emerging high-bandwidth, low-latency use cases.	We note the comments on the enhancements that will be brought about with new technology, wider channels and lower latency. We address the developments in technology in section 3.
Qualcomm, Nokia, techUK said that Wi-Fi 6E and 5G NR-U devices will be able to leverage wider channels, lower latency and additional capacity to	We note the benefits that could be brought by new technologies such as Wi-Fi 6E and 5G NR-U.

deliver greater network performance and support more users at once, even in very dense and congested environments.	
Facebook said, with lower latency, next generation Wi-Fi opens up opportunities for new VR/AR use cases, while Broadcom, HPE and Qualcomm noted Wi-Fi 6E is ideal for enabling 5G services in the 6 GHz band that require gigabit speeds.	
WBA said there is an immediate demand for high bandwidth multimedia and internet connectivity within aircraft. They encouraged us to define Wi-Fi use within an aircraft fuselage as indoor use.	Our technical conditions permit airborne use of RLAN equipment in the 6 GHz band within an aircraft only to establish a connection with a station or apparatus within the same aircraft. In-plane Wi-Fi use is therefore permitted.
Cisco, HPE, techUK, WBA and ([✂]) said it will bring significant benefits for enterprise environments and would be a welcome enhancement for real-time services. Cisco highlighted Wi-Fi connected stadiums where real time delivery of services can enhance customer experience, improve safety and security, manage point of sale activities and provide connectivity for media outlets. Similarly, HPE, techUK and WBA said warehouse management and factory automation will benefit from more channels, very low latencies and wide bandwidths offered by Wi-Fi 6E. Nokia sees opportunities for both mass-market and enterprise use.	We note the benefits our proposals could bring for enterprise environments including stadiums, warehouse management and factory automation. Our demand analysis considered how future demand for Wi-Fi in a public venue, such as a stadium or concert hall, could evolve over a five- and ten-year period as users desire a more immersive and content-rich experience.
UKWISPA said consideration should be given to enabling licensed outdoor operation of FWA in a similar manner to the licenses in 3800-4200 MHz.	We address comments on the demand for higher-power use of the 6 GHz band, including for FWA, in section 4.
Decawave noted that the UK already permits unlicensed use in most of the spectrum under consideration, based on the Wireless Telegraphy (Ultra-Wideband Equipment) (Exemption) Regulations 2015. These regulations allow and support all of the applications envisaged on a license-exempt basis, albeit at power levels that would require the Wi-Fi industry to adjust	The Wireless Telegraphy (Ultra-Wideband Equipment) (Exemption) Regulations 2015 limit the maximum peak power to -30 dBm (0.001mW) in the 4.8-6.0 GHz band and 0 dBm (1.0mW) in the 6.0-8.5 GHz band. These power levels are considerably lower than the 250mW limit we are proposing and would severely constrain Wi-Fi

their technology to the rules, rather than changing the rules to fit their technology.	coverage, requiring many more access points with an associated increase in cost, congestion and latency, negating many of the benefits of new Wi-Fi technology.
UWB Alliance said that UWB is used in critical industrial applications. They said, in consideration of industrial use of Wi-Fi, the impact on existing wireless systems must be considered, including the effect on licensed-exempt systems such as UWB. They thought that our consultation failed to consider the significant use of UWB in, for example, automotive and consumer applications and inaccurately understated the potential RLAN impacts. They said our analysis (in para 4.18 to 4.31) does not include currently licence-exempt uses which gives a false impression there is no impact.	We reviewed the analysis of aggregate interference from RLAN to UWB presented in ECC Report 302. The probability that the sensitivity reduction to UWB communications and location tracking devices exceeds 3 dB ranges from 0.0024% to 3.3% depends on the scenario considered. For UWB sensing devices, the probability that the sensitivity reduction is more than 3 dB varies from 0.042% to 1.7%. As there has not been any evidence undermining ECC Report 302 results, we consider that there is a low probability of interference. Therefore, we consider it appropriate to proceed with our proposals.
UWB Alliance said that allocating more spectrum for RLAN does not promote innovation. They contended that innovation would be finding better ways to share the channel, achieve more efficient access schemes, reduce the interference footprint of each RLAN device.	We consider that improvements for Wi-Fi and other RLANs are best met by a combination of standards improvements and releasing further spectrum. Our full reasoning is set out in section 3 and in our January 2020 consultation.
Decawave and UWB Alliance said they strongly support including requirements for transmit power control and duty cycle restrictions in the regulations.	RLAN equipment will be required to comply with the technical conditions set out in IR2030.
UWB Alliance said that paragraph 2.9 [of our consultation] states that the band is lightly used. They contended this analysis fails to consider the large number of uses under licence-exempt rules and fails to consider current trends in licence-exempt technologies other than RLAN.	Paragraph 2.9 of our consultation refers specifically to the 5725-5850 MHz band. We maintain the view that this band is very lightly used by Wi-Fi (compared to, for example, the 5150-5250 MHz band) due to the requirement to implement DFS to protect radar. Our decision will improve access to this band for RLAN by removing the DFS requirement for indoor only use with EIRP up to 200mW.

One confidential respondent ([✂]) said they would like to see a "duty of care" placed on service providers to ensure that this new national resource is used wisely to maximise the benefit for all sectors of the UK. They suggested that service providers should be encouraged to move to a model of better designed RLANs to prevent them using all the available spectrum (e.g. 3 x 160 MHz channels) to support marketing claims.	Ofcom is required to exempt radio stations, equipment or apparatus from the need to hold a wireless telegraphy licence where their use is not likely to involve any undue interference to other legitimate use of radio spectrum. We consider the technical requirements to enable sharing with incumbent users are sufficient for efficient use of spectrum.
One confidential respondent ([✂]) suggested that we engage with IEEE to explore possibilities for the removal or optimisation of legacy PHY headers that are part of the existing draft 802.11ax standard, to remove inefficiencies around backwards compatibility with 2.4 and 5 GHz bands. Similarly, Gamma thought the 6 GHz band should be reserved for 802.11ax devices leaving legacy device standards in the 2.4 and 5 GHz bands.	Backwards compatibility is often an important consideration for consumers. When upgrading to a Wi-Fi 6 router, consumers may be re-assured that their older wireless devices will still work like normal. As older devices are replaced, we would expect the inefficiencies around backwards compatibility with 2.4 and 5 GHz bands to be mitigated accordingly.
ESOA commended us on our approach to opening up the 5925-6425 MHz band in a manner consistent with the results of the CEPT studies. They acknowledged the important role we have played in international studies and requested our support in advocating a well-balanced approach in other CEPT countries.	We note the comments commending us on our input to CEPT on this issue. We describe our engagement with CEPT in more detail in section 4.
The RSGB wished to point out that the amateur and amateur satellite service have not been recognised as a stakeholder in our consultation. However, they took a positive view of the objectives behind our initiative.	We recognise that there are other services, such as the amateur and amateur satellite service, that may use the band on a secondary basis.
Mr Cropley did not have any specific comments on our consultation questions. He would like us to arrange a repeater with internet that can be accessed from an access point with no licence from 5+ miles away to feed contingency community Wi-Fi. He asked if we could specify affordable equipment to achieve this, or whether pmr 446 or a cb channel could be used for this purpose.	The comments made by Mr Cropley fall outside the scope of our consultation. To the extent that he is interested in information on how spectrum sharing can be used to provide Wi-Fi services to local communities, we note our recent statement on Enabling opportunities for innovation.

A confidential respondent thought the relentless pursuit of stronger/faster internet speeds, without thorough investigation into the safety of such applications, is extremely alarming, and said that the expansion of Wi-Fi must stop now.	We are not responsible for setting electromagnetic field (EMF) safety levels. As an expert health body, Public Health England (PHE) takes the lead on public health matters associated with radiofrequency electromagnetic fields, or radio waves. Ofcom authorises and manages the use of radio frequencies and we take into account PHE's advice when carrying out our functions. We also test EMF levels to ensure they comply with the internationally agreed guideline levels and have recently consulted on measures to require compliance with these international guidelines. We also note that some licence-exempt low power radio equipment (such as mobile phone handsets and Wi-Fi routers) is designed such that it is compliant with the ICNIRP Guidelines by default e.g. it may be touch safe and cannot be installed in a way that would breach the ICNIRP Guidelines.
<u>Opening the upper 6 GHz band</u> Broadcom, Cisco, CommScope, Dynamic Spectrum Alliance, Facebook, HPE, Intel, Wi-Fi Alliance and WBA thought that we should make the whole band 5925-7125 MHz available for Wi-Fi (either now or in the near future). Wi-Fi Alliance noted that future generations of Wi-Fi (beyond Wi-Fi 6) will be designed for extremely high throughput and will require even more spectrum capacity.	We address all points relating to the demand for 6425-7125 MHz in section 4 of the main document.
However, Ericsson and Huawei thought the upper 6 GHz band should be allocated for IMT. Ericsson asserted that the 6425-7125 MHz band would be of great value to ensure the full success of 5G. Huawei welcomed the availability of the 5925-6425 MHz band for licence-exempt WAS/RLAN, to the extent it will complement future availability of 6425-7125 MHz for deployment of licensed IMT networks.	We note that there is an Agenda Item (1.2) for the next World Radiocommunication Conference (WRC-23) that will consider an allocation for IMT in the upper 6 GHz band. We will continue to monitor international developments before taking a decision on this band.

Broadcom noted that opening access to the 6425-7125 MHz band would enable 3 x 320 MHz channels, which they expect to be a key feature of the 802.11be standard.	We agree that opening access to the 6425-7125 MHz band would enable more wider channels. However, we have decided not to open the full 6 GHz band for RLAN at the present time. We will keep this decision under review.
CommScope, HPE and Intel said that compatibility studies are equally valid for the upper 6 GHz band as the incumbents are the same. They noted that opening up the whole band would align the UK with North America and bring economies of scale.	Although the incumbent uses of the 5925-6425 MHz and 6425-7125 MHz bands are the same, UK fixed links in the upper band have different fade margins. We therefore consider that further coexistence analysis would be needed, which we are not proposing to carry out at this time.
Dynamic Spectrum Alliance believed we should explore whether VLP devices could operate across other segments within the 6 GHz band, or even the entire band.	We address the demand for VLP RLAN use in the 6425-7125 MHz band in section 4 of this document.
<u>Automated Frequency Coordination (AFC)</u> Dynamic Spectrum Alliance, Federated Wireless, HPE, Nokia, WBA and a confidential respondent ([✂]) thought that we should consider the use of a database approach, such as an automated frequency coordination system. They said it would make for efficient use of spectrum in the UK and allow higher-power indoor and outdoor operations with fewer operating restrictions on unlicensed devices. Dynamic Spectrum Alliance believed an AFC mechanism is particularly practical in the 5925-6425 MHz band given the incumbents and could facilitate other uses such as fixed wireless broadband and enterprise IoT networks. Similarly, Federated Wireless said it would ensure incumbent operations can continue to grow unimpeded while maximising the amount of spectrum to meet exponential growth in unlicensed capacity. HPE and WBA pointed to high capacity outdoor venues that are desperate for additional spectrum that would otherwise be disallowed under our proposals, as well as rural broadband scenarios. Wi-Fi	 We set out our views on implementing a database solution, such as AFC, for the 6 GHz band in section 4 of this document.

Alliance urged us, as a follow-up to our consultation, to consider outdoor Wi-Fi deployments, possibly on a frequency coordinated basis, while ensuring protection of incumbent operators.	
Technology neutrality BT, Ericsson, Freshwave Group, Huawei, Nokia and techUK thought that the band should be technology neutral to allow other wireless services (including LTE-LAA, MulteFire and 5G NR-U). BT thought that the proposed changes to Interface Requirement IR2030 may benefit from further clarity in this respect. UWB Alliance recommended that the technical requirements enable innovation and not limit the band to conventional RLAN. Freshwave Group said that, for the avoidance of doubt, they would like our post-Consultation statement to confirm whether the lower 6 GHz band will be available to other compatible wireless technologies. Huawei made a similar point, saying that the exclusive reference to Wi-Fi had caused misunderstanding among stakeholders not familiar with the technology neutrality of the UK's regulatory framework. Ericsson thought it might be appropriate to wait for CEPT testing on 6 GHz to conclude before finalising the licence conditions and said the definition of indoor should not limit potential use cases by being too restrictive. Several respondents said this should be considered a green field band to allow for innovation, and not as an extension of the 5 GHz band.	We address technology neutrality in section 4. Our decisions will not preclude the use of the band by other services, provided they meet the technical conditions outlined in IR 2030 (see Annex 3). In response to BT's point, we provide our comments on changes to IR 2030 under Q3 below. In response to Huawei's comment, we use the term Wi-Fi as it is the most common type of RLAN equipment and is widely understood by consumers and industry. However, our decisions apply to all RLAN technologies that can meet the relevant technical conditions. In response to Ericsson, we have clarified what we mean by indoor use. The Low Power Indoor apparatus may only be used within a building or onboard an aircraft or any other enclosed space with attenuation characteristics at least as strong as those of either a building or an aircraft. 'Onboard aircraft' means the use of radio links for communications purposes inside an aircraft. Aeronautical mobile use is not permitted.
International harmonisation Broadcom, Cisco, Ericsson, Gamma Telecom, Intel and Intelsat said that technical licence conditions in the band should be harmonised and urged us	

to continue to pursue this through international collaboration or wait for CEPT developments to decide the final technical regulations. Gamma thought that taking a divergent approach for access to the 5925-6425 MHz band within the UK would drive up cost and harm competitiveness. Intelsat wished to emphasize that harmonisation is vital for the protection of FSS space receivers which will require joint efforts at the European level, and requested we continue to promote the proposed approach in international forums.	We address international harmonisation points in section 4. We will continue to monitor international developments.
<u>Communications Based Train Control (CBTC)</u> Cisco noted that, since publication of our consultation, Working Group FM appears to have agreed to a European-wide allocation for Communications-Based Train Control (CBTC) from 5925-5935 MHz. They said that, to the extent the UK has no plans to deploy CBTC technologies above 5925 MHz, we should be free to set our own rules for 5925-5935 MHz, including making it available for license-exempt devices. techUK made a similar point, saying we should be free to create our own rule for the 5925-5945 MHz spectrum if CBTC is not utilised above 5925 MHz. However, Hitachi Rail, SPT and TfL / LUL said they support the UITP Spectrum User Group initiative in favour of prioritising the 5915-5935 MHz band for CBTC, with adequate protection from RLANs in the 5935-5945 MHz band and from road ITS in the 5875-5925 MHz band. Hitachi Rail and SPT are planning to use the 5 GHz band in the Glasgow Subway project and asserted that CBTC must be protected in order to avoid interference issues. TfL / LUL said that, although London metro lines and Crossrail are using the 2.4 GHz band, they need a secured band in case there are problems in using the 2.4 GHz band or when there is a need to replace the signalling system in	We address comments on potential use of the 5915-5935 MHz band for Intelligent Transport, including CBTC, in section 4.

the future. They noted that CBTC systems are not protected from interference in the 2.4 GHz band. SPT and TfL / LUL suggested that the urban rail sector requires priority over 20 MHz of contiguous spectrum in the 5915-5935 MHz band and referenced a proposed revised ECC Decision. CommScope and Intel thought that, given the extremely limited roll out of CBTC across the CEPT region, the use of guard bands is disproportionate as a solution to the protection requirements of CBTC. techUK made a similar point, saying guard bands should be minimised but co-existence should be ensured. All three respondents suggested there may be scope for improvement of CBTC receiver performance when compared to similar Wi-Fi performance.	
<u>Bandwidth and channel plan</u> One confidential respondent ([✂]) said that limiting channel bandwidth to 80 MHz in the new 6 GHz band would provide a valuable protection against deliberate or inadvertent occupation of large swathes of new spectrum. However, Broadcom noted that wide bandwidth channels are necessary to support reliable single user gigabit throughput, and thought our proposals were a good first step in promoting investment in new technology (e.g. manufacturing of 160 MHz client devices). Cisco and HPE said that Wi-Fi needs to increase its capability to stay ahead of data consumption, meaning more and wider channels. HPE said enabling up to six, gigabit capable, 80 MHz channels will ensure consumers and businesses can keep up with demand. Cisco said that wide channels are particularly useful to manage large data files such as video, enabling transmission of data quickly over the air, thereby ensuring that the shared	Our demand analysis (presented in section 3) has shown that wider channels offer greater capacity and, together with lower latency and improved coverage, will be key to enabling innovation and improved wireless experience. However, we recognise that there are technologies, such as 5G NR-U, that may utilise smaller channel bandwidths. Therefore, we do not consider it necessary to set a minimum, or maximum, channel bandwidth in the technical regulations.

resource of Wi-Fi spectrum is available for other uses. Dynamic Spectrum Alliance also said that the focus of the 6 GHz band will be for applications that can leverage larger channel sizes. Gamma said the 6 GHz band should be prioritised for higher bandwidth applications and spectrum should be allocated in, say, 40 MHz and not 20 MHz blocks. They contended there is a chance spectrum could be used inefficiently if Access Points in close proximity are not configured with due consideration to their neighbours. Dynamic Spectrum Alliance said our rules should seek to optimise the performance of the new non-overlapping 160 MHz channels. Huawei and Nokia pointed out that 5G NR-U will utilise channel bandwidths in multiples of 20 MHz, in addition to carrier aggregation, to deliver high data rates. UWB Alliance said our technical requirements should not dictate a specific channel width or channelization of the band, nor a modulation technique. This would enable innovative approaches that fit the spectral limitations (PSD, duty cycle etc.) in the future.	
HPE though that a guard band at the upper band edge should not be required, and a 10 MHz guard band at the lower band edge would provide sufficient protection for incumbent services operating in the adjacent band. However, they thought it might be advantageous to introduce a 20 MHz guard band and proposed modifying the band plan formula: $fc\text{n} = 5950 \text{ MHz} + (g*5) \text{ MHz where } 1 \leq g \leq 93$ Broadcom noted that the channel plan in the IEEE 802.11ax standard is still evolving and channels may have a start point of 5945 MHz to allow for	We do not intend to implement a guard band at the lower 6 GHz band edge. Our full technical criteria for licence-exempt use of the band are set out in the amendments to IR 2030 (Annex 3) and in section 4 of this document.

global harmonisation, as other countries may encourage a 20 MHz guard band to protect ITS. Cisco noted that, in Appendix A8 of our Consultation, we present the Nominal Centre Frequency in megahertz of each 20 MHz wide channel between 5935-6415 MHz. Cisco expects that a new ETSI harmonised standard (EN 303 687) will contain a channel plan with nominal centre frequencies (for 20 MHz channels) of: 5935, 5955, 5975, 5995, 6115, 6135, 6155, 6175, 6195, 6215, 6235, 6255, 6275, 6295, 6315, 6335, 6355, 6375, 6395, 6415. Cisco urged us to ensure that our final decision gives equipment manufacturers the ability to harmonize with ETSI standards for the channel plan and centre frequencies. Ericsson, on the other hand, thought that we should not follow the Wi-Fi channel plans, but instead allow for a more efficient and innovative use of spectrum by allowing for any channel multiple of 20 MHz.	 Considering the comments received on channel plan, we have decided to remove the references to Nominal Centre Frequencies from the update to IR 2030 for the 6 GHz band. While the channel plan we published was informative only, we consider that this change clarifies that manufacturers may use any channel plan enabling use of spectrum in the 5925-6425 MHz range.
Question 2 – Do you have any comments on our technical analysis of coexistence in the 5925-6425 MHz band?	
Stakeholder comments	**Our response**
Most respondents agreed with, or had no comments on, our technical analysis. Some commended us on our approach of using fixed link parameters from the UK licence database and real-world data for deployment scenarios and environment. A confidential respondent ([✂]) submitted their own coexistence analysis that agreed with our conclusions on sharing with the Fixed Service. None of the respondents raised any specific concerns over our analysis, although UWB Alliance and Decawave thought the conclusions drawn in ECC Report 302, on which our analysis is based, were flawed. Decawave believed assumptions around population estimates, market adoption factor (for	We address comments on our technical analysis in section 4. We note that most respondents agreed with, or made no comment on, our analysis. We said that there would be a very low risk of undue interference to incumbent users of the 6 GHz band under our proposals. However, some respondents still thought our analysis was highly conservative and overestimated the risk of interference. Some respondents questioned specific parameters used in our models (such as the market adoption factor). Some thought certain parameters were too relaxed, while others thought the same

6 GHz devices) and RF activity factor will mean the number of simultaneously operating RLAN devices is higher than estimated. They also said the value of 4 dB body loss for every client device is not realistic and the average polarisation loss should be replaced with a distribution. Ericsson also thought the market adoption factor seemed to be a relaxed value and asked us to reconsider this parameter. On the other hand, HPE thought that the market adoption factor (for 6 GHz devices) and busy hour factor were conservative and possibly lead to an overestimation of the RF activity factor. They also thought the body loss value of 4 dB applied to VLP devices was conservative, citing ECC Report 286 which found considerably higher attenuation values.	parameters were too conservative. None of the respondents proposed any alternative values for us to consider. One respondent submitted an independent analysis that agreed with our conclusions on sharing with the Fixed Service. We have not seen any evidence which has caused us to consider that there is a need for any further technical analysis.
Cisco also thought that some values used in our analysis (polarisation mismatch and building entry loss) resulted in highly conservative and overprotective results. They said that our analysis demonstrated that introducing Wi-Fi into the 6 GHz band will not result in the long-term interference criteria to fixed links to be exceeded. Moreover, the existence of “further mitigation for interference as a result of uplift in the fade margins used in the UK planning criteria” for fixed links strongly argues against further need to explore short-term interference analysis. However, Ericsson said they would like to highlight the importance of the short-term interference in case of Fixed Service protection, which can cause errors in the received signal even in unfaded conditions.	We note the comments from Cisco and agree that long-term interference is the most appropriate sharing criteria for assessing interference with UK fixed links.
Wi-Fi Alliance and WBA thought that our analysis overestimated the risk of interference, for example, by applying a more conservative building entry loss value (12 dB instead of more generally accepted 20 dB). However, they noted our results still confirmed that sharing is feasible. Wi-Fi Alliance said	We note the comments from Wi-Fi Alliance and WBA, and the demand for Wi-Fi in public places. However, at present we are not considering limited and site-restricted outdoor Wi-Fi deployments. We will monitor developments and keep this decision under review.

that, given fixed links are designed with considerably more interference margin, we may wish to evaluate limited and site-restricted outdoor Wi-Fi deployments. The demand for Wi-Fi in public places is significant and growing.	
Huawei noted that CEPT are undertaking additional studies on fixed links and urged us to ensure protection of the Fixed Service by considering all studies when specifying the licence exemption regulations for the 5925-6425 MHz band.	We note the comments from Huawei. We believe our technical regulations will protect incumbent users of the band from undue interference.
Gamma said our technical analysis appeared sound and the conclusions are logical. They agreed that, while interference to fixed links is possible, it is highly unlikely to occur in practice.	We note that Gamma agrees that interference to fixed links is highly unlikely to occur in practice.
Intelsat said that while our technical analysis focused on fixed links, the same conditions (to exclude 1W indoor and outdoor use) are required to also protect FSS uplinks. They commended our approach to only allow low power indoor and very low power outdoor use in the band.	We note the comments from Intelsat on the requirement to protect FSS uplinks.
HPE and WBA said it is important to emphasise that the results of our analysis are supported by other independent analysis provided in ECC Report 302, Draft ECC Report 316 and CEPT Report 73. Sky and Wi-Fi Alliance made a similar point.	We note that our studies are in line with the conclusions of other analysis undertaken within CEPT.
<u>Power limits</u>	
One confidential respondent ([✂]) said that for applications where 160 MHz width channels are technically justified, power and mode of operation restrictions should apply to limit their spectral impact.	We do not see a technical justification for restricting the power of devices using a 160 MHz channel, which could limit the development of new innovative services.
Decawave said that coexistence studies carried out in ECC Report 302 have shown, at the proposed power levels, many UWB installations will not be able to continue to operate reliably. They would like us to reduce the power	We have responded to the comment on potential interference to UWB under Question 1 above.

levels to ensure continued viability of the existing installations. Similarly, UWB Alliance said they would strongly support incentives to use much lower power than traditional RLAN to improve device density, reduce interference footprint and improve coexistence.	We do not agree that much lower power would necessarily reduce interference and improve coexistence. Our demand analysis shows that coverage is a key enabler to improving wireless experience. Reducing power would require more devices (e.g. access points) to provide the same level of coverage as a single higher-power device. This would lead to a higher density of devices, requiring more channels, increasing congestion and latency.
UWB Alliance said that our consultation refers to VR/AR applications as a driving need for this proposal and such applications require far less than the 250mW, or even the 25mW power levels suggested.	VR/AR applications are just one example of use cases for the 6 GHz band. We provide examples of other use cases in section 3.
Cisco, Facebook, HPE, Sky, Wi-Fi Alliance and WBA agreed with our analysis that Wi-Fi in the 5925-6425 MHz band could successfully share with incumbents at power levels up to 250mW indoor and 25mW outdoor. Facebook said these power levels will support a variety of use cases, including new innovative VR/AR use cases. Dynamic Spectrum Alliance said our rules for radiated power and power spectral density should be optimised for 160 MHz (and future 320 MHz) channels, rather than for 20 MHz channels. They said that a reasonable radiated power spectral density limit is 8 dBm/MHz for low power indoor only Wi-Fi base stations. However, Intel suggested 11 dBm/MHz for a 20 MHz channel, for a total power of 24 dBm (250 mW). WBA made a similar point, saying 12.59mW/MHz will enable a 20 MHz channel to realise 250mW average EIRP. This is important because Wi-Fi control signalling is done conducted on 20 MHz channels and this would allow the same total power for all Wi-Fi bandwidths.	We disagree that our rules for radiated power and power spectral density should be optimised for 160 MHz channels. The band is being made available on a technology neutral basis and there may be some RLAN use cases that are more suitable to lower bandwidth channels. We agree with the comments that a power spectral density of 11 dBm/MHz in any 1 MHz band would allow a 20 MHz channel to realise 250mW EIRP. We have decided to update the technical regulations (IR 2030) accordingly.
Ericsson pointed out that CEPT studies had used a power level of 200mW (instead of 250mW used in our analysis) and requested that we wait and follow CEPT developments to decide the final EIRP limit, as well as potential	We note the comments from Ericsson, but we do not need to wait for CEPT development before setting our technical regulations since our

mitigation techniques for the Fixed Service. However, Cisco thought that we should not make any decisions based on “what ifs” or future contingencies. ESOA considers that our proposed power limits are adequate to protect FSS satellite receivers, thus creating a sustainable sharing framework for the benefit of all industries and consumers in the UK.	decision does not preclude devices from operating at lower power levels. We note ESOA’s comments that our proposed power limits will protect satellite receivers.
<u>Interference / Enforcement issues</u> BT noted that they operate both satellite networks and fixed microwave links in the 5925-6425 MHz band and were concerned that these bands remain available, that interference from shared licence-exempt use is appropriately controlled and risks are mitigated to an acceptable level. They also said that, in relation to fixed satellite services, the aggregate interference to receivers on satellites is a concern. Ericsson and Nokia also said that incumbents needed to be protected before considering an allocation for RLANs. JRC noted that the energy utilities operate fixed links in the lower 6 GHz band and these would need to be protected as primary licensed users of the spectrum. They encouraged us to establish provisions to address interference subject to the “Polluter Pays” principle. Tampnet said they are a significant user of the lower 6 GHz band to provide high capacity fixed links between offshore structures used by the energy sector. They were concerned that CEPT studies show Wi-Fi can cause coexistence issues for fixed links particularly when in the beam of the antenna of the victim link, and urged us to develop suitable policies to control, monitor and enforce to ensure licensed users are protected.	We note that BT has reviewed the CEPT studies and our technical sharing analysis and agree that our proposed power limits will reduce the risk of interference to fixed links to an acceptable level. We further note that, based on the very low levels proposed for outdoor Wi-Fi use and the projected numbers of such systems, BT are content that sharing with fixed satellite services is feasible. In response to the comments from JRC and Tampnet, we have a well-established and robust system for dealing with interference cases should they arise. We address this further in section 4 of this document. Our analysis, supported by other studies, has shown that the likelihood of interference to Fixed Links is very small, and we have a robust system for dealing with interference should it arise.

ESOA wished to emphasise that since FSS space receivers see aggregate interference from devices operating in the whole footprint, protection requires consideration at a regional level. They also noted that the UK has responsibilities to avoid causing interference to satellite systems serving other countries and regions.	We concur that the UK has responsibilities to avoid causing harmful interference to satellite systems and we note that ESOA considers our proposed power limits are adequate to protect FSS satellite receivers.
Question 3 – Do you agree with our proposals to remove DFS requirements for indoor Wi-Fi up to 200mW from the 5725-5850 MHz band?	
Stakeholder comments	**Our response**
Broadcom, BT, Cisco, CommScope, Dynamic Spectrum Alliance, Facebook, Freshwave Group, Gamma, HPE, Intel, Nokia, Qualcomm, Sky, TalkTalk, techUK, UKWISPA, Wi-Fi Alliance, WBA and two confidential respondents ([✂]) agreed with our proposals to remove DFS requirements for indoor Wi-Fi use from the 5.8 GHz band. They said it was a welcome enhancement that would allow the UK to harmonise with other countries that do not require DFS, that it will increase the competitive supply of devices, that it would lead to a more efficient distribution of traffic across the 5 GHz band and would provide significant opportunities for enterprise and services provider networks.	We note that the majority of respondents that expressed a view agreed with our proposals to remove the DFS requirements in the 5.8 GHz band.
Ericsson said they were neutral on this question but would welcome proposals from Ofcom on how to control indoor usage and not interfere with incumbents. Huawei, Nokia and RSGB made similar comments. RSGB noted that large scale outdoor use could cause interference to weak-signal receivers including the amateur and amateur satellite services.	We comment on stakeholder concerns surrounding the enforcement of indoor use in this band in section 5 of this document.
BT noted that we propose to remove the requirements for DFS in the 5.8 GHz band by deleting only an informative (rather than normative) provision within the IR 2030. They noted that the references to the channel	We agree with BT's comments regarding modifications to IR 2030 and have made appropriate amendments.

occupancy requirements set out in the 5 GHz harmonised standards for Wi-Fi are still referenced for the band in our proposed amendment to IR 2030. They suggested it may be appropriate to add an explicit statement that DFS is not required (and also for the equivalent entry for the new lower 6 GHz band).	
Cisco cited the enterprise market where robust implementation of DFS ensures customers get the most access to all available spectrum. They cautioned that the complaints of consumer manufacturers should not cause regulators to declare DFS technology bankrupt.	We note the comments from Cisco.
A confidential respondent ([✂]) said that the widespread adoption of existing spectrum in the 5 GHz band had been significantly impeded by DFS restrictions and false-positive DFS trigger events.	We note the comments from the confidential respondent.
<u>Radar in the 5725-5850 MHz band</u>	
One confidential respondent ([✂]) disagreed with our proposal and raised concerns over interference from RLAN to military radar, and from radar into RLAN. They said that interference to radar in the 5725-5850 MHz band is a problem today, and the removal of DFS has the potential to make the situation worse. However, HPE, Wi-Fi Alliance and WBA supported our view that the risk of undue interference from indoor Wi-Fi use to radars is extremely low. Wi-Fi Alliance said that most of the energy from indoor Wi-Fi transmissions will not reach the radar. The limited amount of Wi-Fi signal energy that may propagate outside of a building structure would be further attenuated by separation distances and obstacles between the Wi-Fi device and the radar receiver.	We address stakeholder comments on interference to military radar in section 5 of this document.
Broadcom noted that removing the DFS requirement would remove the additional and significant burden and cost required to develop algorithms to	We note stakeholder comments supporting the removal of DFS from the 5.8 GHz band.

detect different radar signatures in overlapping channels in the 5 GHz band; a burden that is specific to the UK only at this time. BT said that DFS is a significant barrier to the use of the band for Wi-Fi and it appears to be a disproportionate measure to protect radar given the very low potential for interference. Cisco noted that meteorological radars in Europe have either concentrated their operations in the band 5600– 5650 MHz or have moved into the band 5350– 5470 MHz. Therefore, countries not deploying military radars could safely open up 5725 to 5850 MHz without the need for DFS.	
<u>Power limits</u> Cisco asserted that indoor operation of Wi-Fi at 200mW EIRP without DFS will not impose a higher risk than Short Range Devices which are currently allowed to operate outdoor with at 25mW EIRP (via either the Commission Decision for SRDs or via the CEPT/ECC Recommendation for SRDs). Dynamic Spectrum Alliance said our power limit of 200mW EIRP (spectral power density of 10mW/MHz) and indoor only operation is viewed as overly conservative, bordering on the disappointing. They hope that, in time, we will consider whether indoor EIRP levels and EIRP power spectral density levels can be increased.	We respond to stakeholder comments on the demand for higher-power use of the 5725-5850 MHz band in section 5 of this document.

International harmonisation Cisco noted that the balance of European counties had not seen fit to open the 5725-5850 MHz band for RLAN. They cautioned that most manufacturers will be looking to create a product that can be sold throughout Europe [and removing the DFS requirement in the UK] alone may not change the basic dynamic that has caused the band to be lightly used. However, HPE said their equipment can and would be software upgraded to permit access to these channels, meaning businesses and consumers can gain rapid access to the band following timely action by Ofcom. CommScope, Intel and techUK noted that the Czech Republic is considering a similar relaxation and encouraged us to work with them on a common approach for indoor usage to help drive the equipment ecosystem. Wi-Fi Alliance said the DFS requirement in the 5725-5850 MHz band is unique to the UK and requiring a widespread technology like Wi-Fi to conform to a patchwork of national regulations represents challenges to economies of scale, technological advancement, consumers and economic interests.	We will continue to promote harmonisation of technical requirements and promote a simple regulatory regime through international engagement and discussions.
Question 4 – Do you have any comments on other options that may be available for Wi-Fi and RLANs within the 5150-5250 MHz band?	
Stakeholder comments	**Our response**
Some respondents suggested changes we should consider in the 5150-5250 MHz band. We also received comments on other sub-bands within the 5 GHz band. Federated Wireless and ([✂]) highlighted the opportunity to use AFC to manage incumbent protection.	We have addressed comments on other options for the 5 GHz band in section 5 of this document.

Gamma said they had no specific comments but recommended that the UK does not diverge from consensus in and between other major geographic markets. UWB Alliance said Extremely Low Power is an option for the rapidly expanding market for AR/VR. A portion of the band set aside for ELP would provide clear portions of the band for both licensed and unlicensed incumbent users.	
<u>Changes to the 5150-5250 MHz band</u> Broadcom, Dynamic Spectrum Alliance, Wi-Fi Alliance and WBA noted the outcome of WRC-19 to amend the international Radio Regulations for RLAN in the 5150-5250 MHz band to allow controlled outdoor operation up to 1W EIRP. Broadcom, HPE, Wi-Fi Alliance and WBA encouraged us to adopt a higher outdoor level up to 4W EIRP to align with some other countries such as the US, Canada, India, Japan, New Zealand, Mexico and South Korea (noting limitations such as antenna elevation masks). Wi-Fi Alliance said that the 4W EIRP limit with appropriate antenna elevation mask had been proven as an effective mitigation constraint for outdoor RLAN deployments. Cisco said that emission masks could be used to protect satellite systems from aggregate interference from outdoor RLAN devices. BT and techUK supported further work to look at how low power outdoor use (including in trains and automobiles (techUK)) could be implemented in the UK following changes agreed at WRC-19.	We will continue to explore ways in which we may be able to implement the possibility of outdoor use in the 5150-5250 MHz band as reflected in the Radio Regulations as amended at WRC-19. We consider that these changes would enable innovation in the band and are therefore minded to consider how they could be implemented in the UK.

Aligning 5725-5850 MHz with 5150-5250 MHz HPE thought we should align the 5725-5850 MHz band with 5150-5250 MHz, to allow unrestricted indoor use up to 200mW EIRP and controlled indoor and outdoor use up to 1W EIRP.	We consider that our decision to remove the DFS requirement for indoor use up to 200mW EIRP strikes an appropriate balance between demand for RLAN spectrum and the need to protect radar use of the band. Our reasoning is set out in full in section 5 of this document.
DFS use in other parts of the 5 GHz band One respondent said that many RLAN providers and equipment vendors would welcome the removal of DFS restrictions for all channels across the 5 GHz band. TalkTalk thought we should relax the DFS requirement for indoor Wi-Fi in the 5250-5725 MHz band (excluding 5600-5650 MHz). They said that while there is a need to protect meteorological radar, it was less obvious that state-of-the-art military radar in the 5250-5850 MHz band required protection from low power indoor Wi-Fi access points. Cisco, CommScope, HPE, Intel and WBA were concerned about proposals for expanding DFS requirements in the 5 GHz band to include detection of fast frequency hopping radars.	We will continue to monitor developments in other parts of the 5 GHz band to ensure that any technical requirements, including DFS, are still fit for purpose.
Opening up the 5850-5895 MHz band CommScope noted that the FCC is considering opening the 5850-5895 MHz band for licence-exempt use, which would make 160 MHz and a second 80 MHz channel useable for Wi-Fi. They suggested we consider a similar move in the UK. UKWISPA said that the band 5850-5875 MHz, if made available, would not require DFS and could be used by FWA operators as a channel to be used	We have not seen evidence of widespread demand for opening the 5850-5895 MHz band and would need to consider the impact on Intelligent Transport Systems operating above 5875 MHz. As such, we are not currently proposing to make changes, but we will keep this band under review and may consider it in the future.

immediately after a DFS 'hit'. They suggested a light licensing approach might be appropriate.	
<u>Alignment at 5730 MHz</u> RSGB noted that they had previously asked Ofcom to consider a new option around 5725-5730 MHz, where some Wi-Fi channels are not available as they overlap the 5725 MHz boundary. They suggested a small re-alignment to 5730 MHz would enhance availability of Wi-Fi channels below 5730 MHz, with the dual benefit of mitigating demand for the more sensitive applications above, including amateur usage at 5760 and 5840 MHz.	We note the comments from RSGB but we are not proposing to make any changes to the 5 GHz channel plan at the current time.