Improving spectrum access for Wi-Fi

Spectrum use in the 5 and 6 GHz bands

CONSULTATION:

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1. Overview

Spectrum provides the radio waves that support wireless services used by people and businesses every day, including Wi-Fi. We are reviewing our existing regulations for spectrum for unlicensed use to meet future demand, address existing problems of slow speeds and congestion, and enable new, innovative applications.

People and businesses in the UK are increasingly using Wi-Fi to support everyday activities and new applications are driving demand for faster and more reliable Wi-Fi. To meet this growing demand, we are proposing to increase the amount of spectrum available for Wi-Fi and other related wireless technologies, and to remove certain technical conditions that currently apply.

What we are proposing – in brief

We are proposing the following measures to improve the Wi-Fi experience for people and businesses:

- **Make the lower 6 GHz band (5925-6425 MHz) available for Wi-Fi. The release of this spectrum would enable also very low power (VLP) outdoor use.** This would improve performance by reducing congestion in existing bands caused by large numbers of devices and enable the development of new, higher bandwidth applications.
- **Remove the Dynamic Frequency Selection (DFS) requirements from Wi-Fi channels in the 5.8 GHz band (5725-5850 MHz).** DFS requires a Wi-Fi router to scan for radars and to switch channel if transmissions are detected. DFS can therefore represent a constraint for equipment manufacturers and cause connection delays for Wi-Fi users. The UK is currently the only country to have imposed these requirements on the 5.8 GHz band. Amending the requirements on this band could increase its use for indoor Wi-Fi and reduce congestion in other Wi-Fi bands.

1.1 Wi-Fi is a short-hand phrase to describe a type of Radio Local Area Network (RLAN). RLANs provide local wireless connections to an area or premises (such as a home or public hotspot). In this document, we use the term Wi-Fi throughout as it is by far the most common RLAN application and is widely understood by people and industry, although our proposals would make more spectrum available on a licence-exempt basis for all RLAN technologies that can meet the technical requirements.

1.2 Wi-Fi use is growing, driven by the rising number of connected devices and the arrival of innovative applications such as Augmented Reality (AR), Virtual Reality (VR) and Ultra High Definition video. As customers begin to access faster broadband through ultrafast and full-fibre connections, they are expecting higher capacity, faster speeds and greater reliability from their Wi-Fi. This applies to residential use, but also to business use and public hotspots.

1.3 Wi-Fi technologies have evolved over time to make more efficient use of the spectrum. However, to meet this growing demand, more channels and wider channels will be required.

Opening access to 5925-6425 MHz to enable innovation

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

1.5 We have carried out technical analysis to assess whether Wi-Fi use could share the band with incumbent users (fixed links and satellite users) without causing harmful interference. Our studies suggest that sharing is feasible for up to 250mW indoor and 25mW outdoor unlicensed uses. Our initial view is that these maximum limits would be sufficient to enable the envisaged use cases.

Making more efficient use of spectrum in 5725-5850 MHz

1.6 Most channels in the 5 GHz band, including 5725-5850 MHz, are subject to Dynamic Frequency Selection (DFS) requirements. These require Wi-Fi routers to scan for radars while connected and to switch channel if radar transmissions are detected. These requirements were designed to protect radars from interference. However, implementing DFS can add cost to equipment and people using Wi-Fi can be negatively affected by delays to their connection. Additionally, DFS is not required in the 5725-5850 MHz band in other countries where the band is available for licence-exempt use, which further limits the use of this band in the UK as manufacturers must create equipment specific for the UK market.

- We made the 5725-5850 MHz band available for Wi-Fi use in 2017 and said we would keep the regulations under review. Our current analysis indicates that the band is very lightly used by Wi-Fi routers in the UK, which is in part due to the UK-specific requirement to implement DFS in this band, and that the interference risk to radars from indoor Wi-Fi use is very low. We are therefore proposing to remove DFS requirements for indoor use (up to 200mW) only from the 5725-5850 MHz band to increase use of the band and reduce congestion in other channels.

Next steps

1.7 We will be consulting until 20 March 2020. We intend to reach our final position later in 2020.

1.8 We believe that Wi-Fi bands need to be as globally harmonised as possible. We intend to drive international discussion and will be engaging internationally to harmonise the technical requirements and promote the benefits of a simple regulatory regime.

2. Introduction

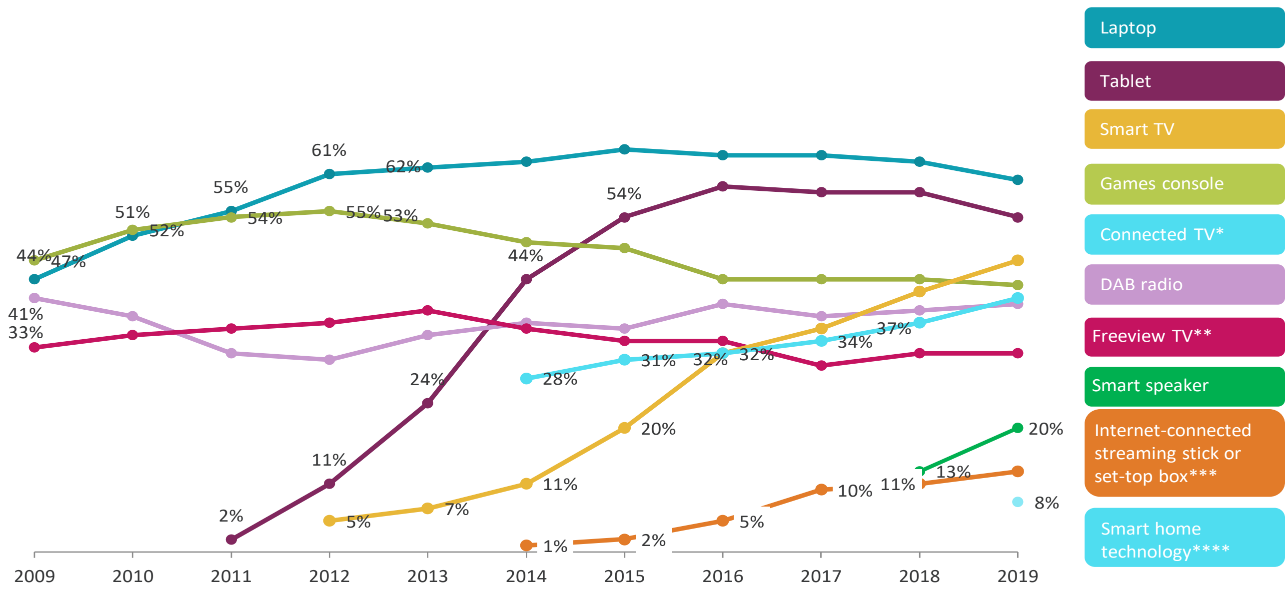
People are increasingly relying on wireless connectivity

2.1 Nearly 87% of UK adults have internet access in the home (as shown by Ofcom's Technology Tracker, March 2019, Table 52) and Wi-Fi plays a significant role in enabling wireless connectivity. It provides the final link between people's routers and the increasing number of wireless-enabled electronics devices in their homes including TVs, smart appliances and connected consoles (see Figure 2.1 below).

2.2 The increasing availability and adoption of ultrafast and fibre broadband services, together with the growing number of wirelessly-connected devices, is driving Wi-Fi demand. Individuals' and businesses' expectation using Wi-Fi is rising, including the need for a consistent and seamless experience across different devices and locations.

2.3 Wi-Fi systems are used to 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 is also being used to provide internet connections within enterprise, commercial and industrial premises, with many organisations now moving to wireless-only solutions to increase the flexibility of production and distribution.

Figure 2.1: Take-up of connected devices at home



*Source: Ofcom Technology Tracker. *Includes games console, PC, set-top box, streaming stick, internet-connected set-top box; ** Refers to Freeview as the main TV platform; ***Includes NOW TV box, Roku, Chromecast, Fire TV and Apple TV; **** Ability to control or monitor your home remotely, such as heating, lighting or seeing who is at the door, using a smartphone or other device.*

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

2.4 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. However, there are variations between countries in the supported frequencies and the ways in which devices can connect. For instance, in 2017 we published our decision to extend licence-exempt Wi-Fi use to the 5.8 GHz band, while this band is not available for Wi-Fi in other countries in Europe.

Figure 2.2: Wi-Fi channels in the 2.4 GHz band

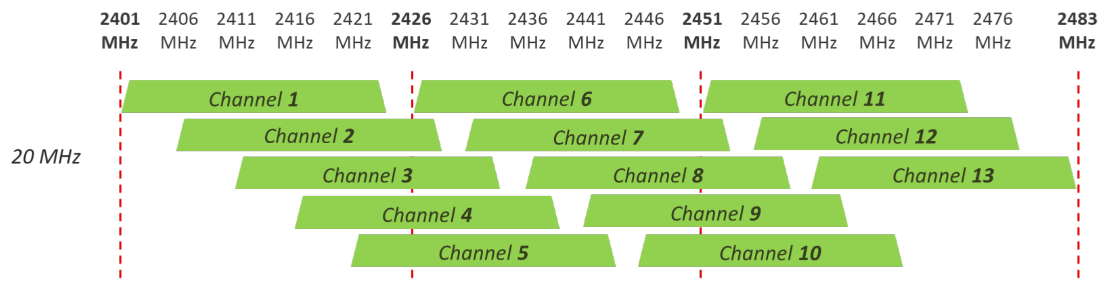
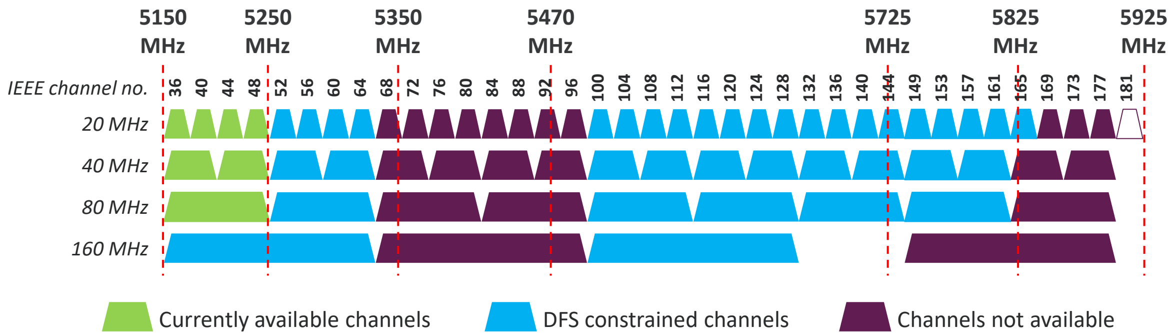


Figure 2.3: Wi-Fi channels in the 5 GHz band[1]



2.5 The high number of connected devices within existing bands may be impeding Wi-Fi performance, due to congestion. Congestion occurs when several users attempt to share the same Wi-Fi channels and often leads to a reduced quality of user experience, including buffering, lower speeds and even loss of service. With increasing numbers of devices and the emergence of new applications, demand upon these bands continues to grow, which can lead to congestion.

2.6 The highest Wi-Fi data rates are achieved in non-congested environments. For instance, an 80 MHz channel can provide a data throughput of up to 1 gigabit per second, but this may decrease significantly when there are multiple other users of the same channel. Congestion increases latency (the time for data to be transferred across a network). As such, wide, non-overlapping channels are necessary for applications requiring high data rates or low latency. Many Wi-Fi devices can access non-overlapping channels in the 5 GHz band.

[1] Channels marked as 'not available' are currently allocated for other uses and cannot be used by Wi-Fi devices.

However, congestion in the lower part of the band and a low number of channels without DFS requirements may limit user experience. Enabling or easing access to other bands, or higher parts of 5 GHz, will offer better availability of wider channels.

2.7 Development in Wi-Fi technology mitigates some of the challenges by offering greater efficiencies and better experience but addressing spectrum availability will also be critical to improve Wi-Fi functionality and encourage new uses.

2.8 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 the technical feasibility studies, we have also engaged with some of the relevant industry bodies, vendors, content providers and internet service providers.

2.9 In addition, our analysis shows, and stakeholders have indicated, that the 5725-5850 MHz band is very lightly used, in part due to the UK-specific requirement to implement DFS in this band. We have considered options to enable more efficient use of it.

2.10 In light of increasing demand for wireless connections driven by new high capacity applications, the low probability of harmful interference and introduction of new Wi-Fi technologies, we are proposing to open up access to new spectrum in the 5925-6425 MHz band and to remove the DFS requirements on the indoor use of the 5725-5850 MHz band.[2]

Legal background

2.11 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 5 we set out in more detail the relevant legal framework, which we have taken into account in making the proposals set out in this document. This annex should be treated as part of this document.

Impact Assessment

2.12 This document represents 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.

2.13 In preparing this document, we have considered the citizen and consumer interests relating to 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.

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

2.14 Ofcom is an evidence-based organisation and welcomes responses to this consultation. Any comments about our assessment of the impact of our proposals should be sent to us by the closing date for this consultation. We will consider all comments before deciding whether to implement our proposals. For further information about our approach to impact assessments, see the guidelines 'Better policy making: Ofcom's approach to impact assessments' on our website.[3]

Equality Impact Assessment

2.15 Ofcom is separately required by statute to assess the potential impact of all our functions, policies, projects and practices on the following equality groups: age, disability, gender, gender reassignment, pregnancy and maternity, race, religion or belief, and sexual orientation. Equality impact assessments also assist us in making sure that we are meeting our principal duty of furthering the interests of citizens and consumers regardless of their background or identity. We consider that our proposals would not be detrimental to any of these equality groups.

2.16 We have not carried out separate equality impact assessments in relation to the additional equality groups in Northern Ireland: religious belief, political opinion and dependants. This is because we anticipate that our proposals would not have a differential impact in Northern Ireland compared to consumers in general. We welcome any stakeholder views on this assessment.

Notification under the Technical Standards Directive

2.17 In accordance with the Radio Equipment Directive and the Technical Standards Directive, we will shortly notify our proposed changes to the current interface requirements for short-range devices (IR 2030) to the European Commission.

Structure of this document

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

- **Section 3** explores current use and future demand for Wi-Fi and looks at how technology might mitigate pressure on Wi-Fi.
- **Section 4** considers options for making more spectrum available for Wi-Fi use in the 6 GHz band and summarises our coexistence analysis.
- **Section 5** considers Dynamic Frequency Selection and use of Wi-Fi in the 5.8 GHz band, analyses potential VLP outdoor use in the channels between 5150-5250 MHz and discusses proposals for changes in these bands.
- **Section 6** summarises our proposals and sets out our next steps for improving spectrum access for Wi-Fi.

[3] An overview and link to the guidelines can be found on our Policies and Guidelines webpage.

3. Current and future use of Wi-Fi

3.1 In this section we present the results of our market analysis and stakeholder engagement which have helped us to understand existing challenges and assess current and future levels of Wi-Fi demand. We also consider how demand could be addressed by both technology developments and increased access to spectrum.

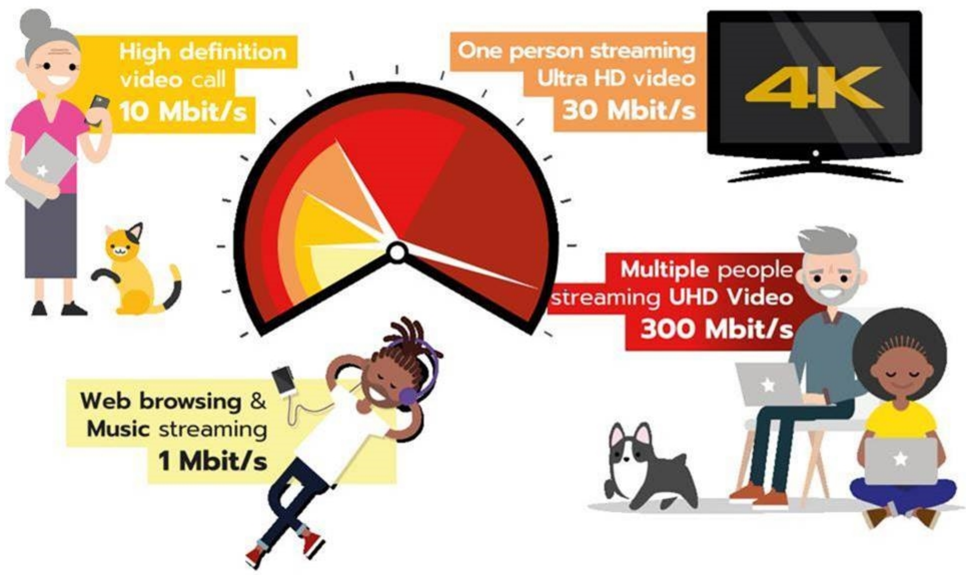
3.2 We are interested in hearing further views from stakeholders regarding future trends and drivers of demand for Wi-Fi and to what degree technological advancements could help to address this demand.

People are expecting faster internet speeds in their homes and businesses

3.3 Wireless broadband over Wi-Fi keeps expanding, with more, diverse devices accessing the network. These can have higher data rates and latency needs (gaming or high definition video streaming), in addition to long-lasting battery needs (smart appliances, digital assistants or fitness trackers) and very low bandwidths. Wi-Fi is also becoming important to provide voice services as devices support Wi-Fi calling.

3.4 Ofcom's Connected Nations report 2019 found that 94% of all UK premises can receive superfast broadband (30 Mbit/s and above). Access to ultrafast broadband (greater than 300 Mbit/s) is at 53% of homes, up from 50% (and from 36% 2017).

Figure 3.1: Examples of household internet uses



3.5 Full-fibre broadband availability increased by around 100% year-on-year to 3 million premises. We understand that Openreach plans to cover 10 million homes by 2025, and other providers have also made commitments to expand their fibre networks and provide gigabit speeds.

3.6 Wireless capability for various applications is becoming the norm. Ofcom's Online Nation report 2019 observed that adults spent an average of 3 hours 15 minutes a day online in 2018 (up from 3 hours 4 minutes the previous year), and that 75% of people's time online is on a mobile device (smartphone or tablet). More than half considered their mobile to be their most important device for accessing the internet.

3.7 In addition, our analysis of people's behaviour and experience using mobile services in the UK at home, at work and in indoor and outdoor public spaces (Mobile Matters Report 2019) found that for over two-thirds of the time people were connected to Wi-Fi rather than a cellular network (2G, 3G or 4G).[4]

3.8 People expect wireless speeds in their homes and businesses to match their fixed line broadband without buffering. Having access to faster broadband speeds therefore means customers increasingly expect and rely on their Wi-Fi to handle a wide range of high data rate applications, such as HD and UHD television.

3.9 The roll-out of 5G could also contribute to increased demand for W-Fi services. Improved performance of mobile data services will add to the overall expectation for fast connections wherever and whenever people want them, as well as seamless transitions between cellular networks and Wi-Fi, with a higher demand in indoor environments for entertainment services.

3.10 In Annex 6 we explore how demand for services over the Wi-Fi network could evolve in the future in households and public arenas.

Industrial use cases for Wi-Fi are increasing

3.11 Wi-Fi is used as a solution (off-the-shelf or customised) in many industrial sectors (such as manufacturing, enterprise, logistics and transport). 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 communications. Cisco forecasts a global growth from just under a billion devices in 2017 to 3.9 billion by 2022.

3.12 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.

3.13 Smart factories are increasingly using wireless technologies including Wi-Fi, to "cut all cables" in their production facility to increase flexibility and drive up productivity.

3.14 In addition to industrial IoT connectivity, Wi-Fi is also used in many personal IoT devices, such as fitness trackers and digital assistants. Other uses for Wi-Fi include drone connectivity and different infotainment[5] solutions inside vehicles (trains, planes and cars).

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[4] Data was collected from Android devices only.
[5] A combination of information and entertainment.

3.15 We expect the number and variety of use cases to increase in the future, driving demand for spectrum.

Current and future uses are driving the demand for Wi-Fi

3.16 To inform our analysis, we have engaged with manufacturers, enterprise providers, broadband network providers, content providers and other stakeholders on current challenges and how they see demand evolving. We have looked at bandwidth and latency requirements of different applications and the need to ensure a consistent quality of experience in the premises.

Greater bandwidth could enable new applications and data throughput

3.17 The capacity of a Wi-Fi network depends on the channel size it uses.[6] Multiple Wi-Fi networks in an area limit the availability of bigger channels which offer greater capacity. This congestion can cause a challenge to device and service providers, who seek to utilise channels with certain bandwidths.

3.18 Wi-Fi technologies access spectrum channels using a Listen Before Talk (LBT) protocol. Using LBT, users share the same spectrum channels. When a user is transmitting information, the rest would wait until it is finished, and so on. This is highly effective in lightly congested environments but can worsen quality of experience where there are many users: lower data rates, higher latency, time spent on buffering or even loss of connection. The default of many off-the-shelf legacy routers is a fixed channel configuration[7] which amplifies the negative effects of congestion: rather than expanding over the entire band, all users would use just a few channels. 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.

3.19 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 to their full potential, some content providers viewed wider channels as less critical because they have created products to work within current spectrum availability.

3.20 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). Although an 80 MHz channel can provide a data throughput of up to 1 Gbit/s, this rate can be affected by congestion from multiple users of the same channel. Stakeholders saw more channels of 80 MHz and above as critical in enabling high speed services to be used wirelessly in the home and providing a good quality of experience.

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

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

Qualcomm's A Quantification of 5 GHz Unlicensed Band Spectrum Needs study also states that higher throughput coverage in dense environments requires extensive use of 160 MHz channels and that this would be required to provide between 500 Mbit/s and 1 Gbit/s throughout the home.

3.21 Connected devices are increasingly designed to work together, creating 'smart' homes and more efficient industrial automation. Individual devices are typically low-bandwidth but could potentially be connected in large quantities that would need higher capacity.

3.22 Multiple-density or high-density housing also adds further pressure on congested spectrum bands as the number of connected devices in each household grows.

3.23 We are aware 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 and airports. Modern stadium deployments tend to use spectrum more efficiently because they have planned and managed deployments. Nevertheless, increased capacity could enable even more people to be reliably connected within all these congested environments.

3.24 Capacity is also affected by DFS, due to the larger number of channels available with this requirement compared to those without a DFS requirement. Stakeholders saw bands with DFS as underused, and some stakeholders' equipment avoids using these channels. We discuss DFS further in Section 5.

3.25 By reviewing the accessibility of existing spectrum for Wi-Fi and options for new bands, will help to meet demand from current applications as well as providing opportunities for future applications.

Lower latency can provide opportunities for innovative use cases

3.26 According to the analysis included in our Online Nation report, video content consumption is rising, a view supported by comments from several stakeholders. Video applications include UHD (4k and 8k resolution) video in residential (broadcast television and streaming) and enterprise (video conferencing) situations, and video security. The simultaneous use of various applications requires reliable connections, high speeds and greater capacity.

3.27 Stakeholders also pointed to innovations in video content which would require, in particular, lower latency to provide their full benefits. These include real-time or cloud-gaming; 360 video; 'holographic' video; and VR/AR devices.

3.28 Full-fibre broadband services enable low latency applications. As take-up of these services increases, we anticipate that this will drive growth in low latency uses in households and enterprises. This will also result in corresponding increase in demand of Wi-Fi.

3.29 Wider channels, such as those that we propose to make available in the 6 GHz band, would allow for lower latency.

Better coverage and spatial reuse would provide better customer experience

3.30 Coverage is one of the main concerns raised by stakeholders as a current issue in residential, office and public Wi-Fi environments. People's expectations are also changing in these areas: a good quality of experience from Wi-Fi is expected irrespective of the location of the router or the device they use.

3.31 Even though new Wi-Fi technologies can introduce techniques such as multi-user MIMO and beamforming to increase the coverage for higher throughputs in residential environments, this may not sufficiently resolve the issue of coverage for 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.

3.32 High-density office deployments are often managed environments where the channel selection is controlled, and APs are installed strategically to maximise coverage. Enterprise providers highlighted that their ability to manage dense deployments are an important competition factor in the market. They generally have to 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 data rate they can offer to users, affecting enterprise applications such as video conferencing.

3.33 We 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. This involves coverage and capacity considerations that could be addressed through better use of existing spectrum and more spectrum availability.

Technological improvements increase efficiency in existing bands

3.34 Technology developments have continued to improve Wi-Fi user experience. The most recent Wi-Fi standards to be made available for use in routers and other APs is known as IEEE 802.11ax, or Wi-Fi 6.

3.35 In Table 3.1 below, we compare the latest 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

	802.11ax (Wi-Fi 6)	802.11ac (Wi-Fi 5)	802.11n (Wi-Fi 4)
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

3.36 Research is ongoing into Wi-Fi 7 (or 802.11be), which aims to increase maximum throughput to 30 Gbit/s, reduce latency and improve reliability. It is not expected to be available for several years.

3.37 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.

3.38 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.

3.39 Opening some additional spectrum would provide an opportunity to maximise the benefits of new technologies without legacy products slowing the network, as is more likely to be the case in the 2.4 GHz and 5 GHz bands.

Additional spectrum and easier use of existing bands would help to meet growing demand

3.40 Our estimates show that household demand for Wi-Fi could increase by up to ten times over a ten-year period and demand in public arenas could increase up to 15 times (see Annex 6). This is supported by stakeholder views, that Wi-Fi in homes, in businesses and in public spaces will continue to increase, and that emerging uses requiring greater capacity, lower latency and better coverage will place an even greater demand on existing spectrum bands. We note that some of these use cases are indoor only, while some could require more widespread connectivity, such as smart glasses.

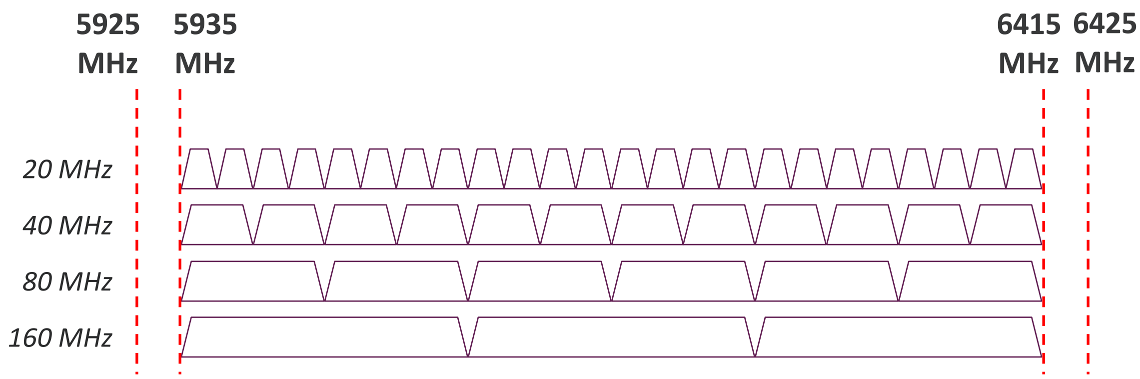
3.41 We consider that opening up new spectrum, free from legacy devices, could enable a more efficient group of devices using new Wi-Fi standards from the outset, therefore offering a more future-proof solution to Wi-Fi demand. Additionally, making it easier to use existing bands would also help to support increased use of Wi-Fi.

4. Opening spectrum for Wi-Fi in the 5925-6425 MHz band

4.1 As set out above, Wi-Fi use 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 consider that making more spectrum available for Wi-Fi, alongside technology developments, will be a key enabler in improving Wi-Fi users' experience. The lower 6 GHz (5925-6425 MHz) band is an ideal candidate for this, as it is adjacent to the 5 GHz band and has similar propagation characteristics.

4.2 Opening up the lower 6 GHz band for Wi-Fi use would make 500 MHz of contiguous spectrum available for Wi-Fi, including 24 non-overlapping channels of 20 MHz, 6 channels of 80 MHz and 3 channels of 160 MHz.

Figure 4.1: Channel plan for 5925-6425 MHz



Our proposals

4.3 Based on our review of the demand for mid-range spectrum for Wi-Fi and the technical feasibility of sharing with incumbent users, we are proposing 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.

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

4.5 We consider that the technical specifications of our proposals would 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 support the current and future Wi-Fi uses we highlight in Section 3.

Demand for spectrum for Wi-Fi in the 6 GHz band

4.6 In Section 3 we explain there is a general demand for additional spectrum for Wi-Fi use. There are several factors driving demand in the 6 GHz band specifically.

4.7 **The large amount of spectrum available in the 6 GHz band would allow for wide, non-overlapping channels.** The lower 6 GHz band provides an opportunity to open up 500 MHz of spectrum for Wi-Fi use. This is optimal for applications that require wide, non-overlapping Wi-Fi channels.

4.8 **The 6 GHz band is adjacent to the 5 GHz band, which is already widely used for Wi-Fi.** Opening up spectrum that is almost adjacent to an existing Wi-Fi band would allow for a consistent and aligned approach to unlicensed spectrum for Wi-Fi use in this range. Additionally, there are similarities in the router and antenna design of the two bands that would enable more rapid implementation and deployment since manufacturers would need to invest fewer resources into new methods and infrastructure.

4.9 **The 6 GHz band would be used by more efficient Wi-Fi technologies from the outset.** The 2.4 GHz and 5 GHz bands are currently being used by a wide variety of legacy devices, from the first Wi-Fi routers with 802.11a/b/n to the most recent 802.11ac standard. The latest Wi-Fi standard (Wi-Fi 6, or 802.11ax) will enable more efficient use of the spectrum through technical advances that improve data throughput, reduce latency and improve battery life. Wi-Fi 6 was designed from the start to support large numbers of users in congested environments such as conference venues and sports arenas using new techniques such as multi-user MIMO, OFDMA and BSS colouring.[8] The result is a better use of spectrum from the outset, improving throughput, bringing down latency and addressing congested environments more efficiently.

4.10 We have met with a range of stakeholders to inform our views on the demand for unlicensed spectrum in the 6 GHz band, including enterprise providers, equipment manufacturers, broadband network providers, online platforms and transport connectivity providers. The organisations we have engaged with have been broadly supportive of making the 6 GHz band available for Wi-Fi use and have highlighted to us that there is a need for more spectrum in this range, to enable innovation and to ease congestion on Wi-Fi in the existing bands, as we describe in Section 3.

4.11 As a result of this growing demand, several studies and consultations on reviewing the band, with a view to making it available for Wi-Fi use, are underway at an international level. We have played a very active role in supporting international studies.

[8] Multiuser MIMO and OFDMA improve the use of spectrum resources in a Wi-Fi channel, increasing the total live connections and data throughput. Basic Service Set colouring (BSS) decreases the time to establish a connection during the initial Listen Before Talk protocol and facilitates the connection to less congested Wi-Fi channels.

European developments

4.12 In December 2017, the European Commission issued a Mandate to the European Conference of Postal and Telecommunications Administrations ("CEPT") to study sharing feasibility and identify harmonised technical conditions for wireless access systems, including RLANs, in the 5925-6425 MHz band for the provision of wireless broadband services.[9]

4.13 According to the studies conducted so far (as included in ECC Report 302), CEPT expects that compatibility and coexistence are technically feasible under certain conditions (including low power, indoor-only uses) between RLANs and incumbent fixed links and satellite users. This is set out in more detail in paragraph 4.20. The CEPT studies include an analysis of UK fixed links but use RLAN deployments that are not necessarily representative of typical UK population and building distributions. We present our own analysis using what we consider to be more accurate RLAN deployments in Annex 7. According to the Mandate, the two reports from CEPT to the European Commission are expected to be finalised and submitted respectively in March and July 2020.

Developments in the US

4.14 In the United States, the 6 GHz band is also being discussed for Wi-Fi to ease congestion and promote innovation. 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.[10]

4.15 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. The Reply Phase of the NPRM closed in February 2019. If there are no issues requiring a second NPRM, this could mean that products with 6 GHz may be available in the US from late 2020.

4.16 In response to the FCC's Notice of Inquiry, there were comments from a range of stakeholders both in support of and against Wi-Fi use in the band.

4.17 We consider that people in the UK may be able to benefit from device availability and economies of scale for new, innovative technologies if this band is opened up both internationally and in the UK for similar purposes.

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[9] The Commission had observed an interest to make additional mid-range spectrum available and had previously issued a Mandate to CEPT in 2013 to identify harmonised sharing conditions in the 5350-5470 MHz and 5725-5925 MHz bands. As CEPT Report 64 (approved on 18 November 2016 by the ECC) concluded that no appropriate mitigation techniques could be identified at a European level to protect incumbent users of these bands, new opportunities were subsequently identified in the 6 GHz band.

[10] 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).

Existing use of the 6 GHz band

4.18 In the United Kingdom, the 6 GHz band is currently used by fixed links and satellites. These are licensed users with a primary allocation, meaning that it is important to ensure that compatibility can be achieved in the band between Wi-Fi and current uses.

4.19 The band is used by Transportable Earth Stations, as well as medium and high capacity, generally long-distance fixed links used for various applications including backhauling of mobile broadband networks, utilities, financial services, broadcasting, Local Authorities and Oil & Gas. Our coexistence and sharing analysis has focused on defining the sharing conditions that would minimise interference.

4.20 There are 72 holders of Permanent Earth Station licences in the 5925-6425 MHz band in the UK (as of December 2019). CEPT studies show that sharing between RLANs and Fixed Satellite Services (FSS) is feasible based on the agreed FSS technical parameters and a range of European RLAN deployment scenarios forecast to 2025. We have reviewed the CEPT analysis and, in the absence of any strong justification to change the assumptions used in the study, we agree with CEPT’s views on satellite sharing conditions in the band.

4.21 As of December 2019, there are 375 holders of Point to Point Fixed Links licences in the 5925-6425 MHz band in the UK. CEPT has undertaken detailed technical coexistence analysis between RLANs and fixed links, including analysis of links from the UK licence database. We have used the models from the CEPT studies to conduct our own analysis (explained further below), focusing on scenarios that we consider are more representative of UK fixed links geometries and RLAN deployment. Both the CEPT and our own analyses conclude an extremely low risk of interference to incumbent users under the technical conditions we are proposing.

Technical coexistence analysis

4.22 We have undertaken coexistence analysis to understand the possible impact of future RLAN devices in the 6 GHz (5925-6425 MHz) band on existing fixed links, building on the ongoing CEPT studies. We have looked at a range of fixed link and RLAN deployment scenarios to assess under what conditions fixed links might be more sensitive to interference. Based on use cases and challenges highlighted in discussions with stakeholders, we have included a range of RLAN power levels including 25mW (14 dBm) EIRP for outdoor use, 250mW (24 dBm) EIRP for indoor use and 1W (30 dBm) for either indoor or outdoor use. Our modelling is based on:

- a statistical approach using Monte Carlo analysis, where we randomise the distribution and location of RLAN devices around the fixed link under study. This approach results in the percentage of instances (time) where the aggregate effect of interference exceeds the interference protection criteria;
- a Minimum Coupling Loss (MCL) analysis where we analyse possible exclusion areas around fixed links; and

- a static analysis (snapshot model) to look at whether interference is due to a single (interferer) device, or the aggregate effect of several devices in the vicinity of a fixed link.

4.23 Our analysis shows that sharing would be feasible for indoor only RLAN use with EIRP up to 250mW and outdoor very low power use with EIRP of up to 25mW. We found from our modelling that that there may be some scenarios where the fixed link interference criteria could be exceeded (due to a single high-power device located either indoors or outdoors close to the fixed link receiver), but 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 are considering. For example, 250mW indoor and 25mW outdoor use represents less than 10% of the total forecast distribution in the CEPT studies (i.e. we would expect 90% of devices to be operating at lower power levels than we have assumed in our analysis).
- Fixed links in open/rural areas will present a low chance of interference as there are fewer premises around the link receiver where RLANs would be located.
- Fixed links in populated (built up) areas will present a low chance of interference (due to additional clutter losses) unless the RLAN is located within a few metres of the fixed link receiver.

4.24 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 proposing to allow high power outdoor RLAN use in the UK.

4.25 The results of our analysis suggest 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.

4.26 We therefore propose to open access to the 6 GHz (5925-6425 MHz) band for licence-exempt indoor only Wi-Fi use with EIRP up to 250mW,[11] and for VLP uses (both indoor and outdoor) with EIRP up to 25mW.

[11] We consider that a 250mW power limit is feasible and would promote innovation in new services. In the event, however, that the European Commission requires a 200mW power limit for this band in any future Decision following the CEPT

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?

Question 2: Do you have any comments on our technical analysis of coexistence in the 5925-6425 MHz band?

reports, we will consider revising our limit to 200mW as we recognise the importance of economies of scale for people and manufacturers. We will continue to work with CEPT and monitor developments.

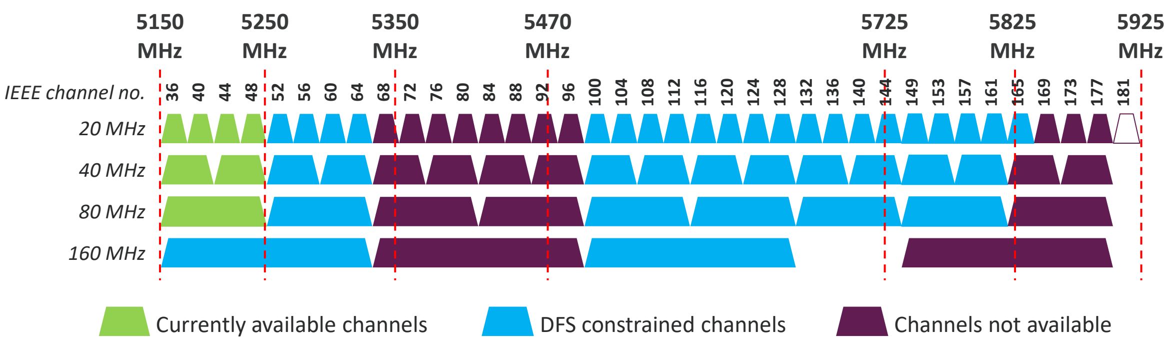
5. Making more efficient use of spectrum in the 5725-5850 MHz band

Current regulations constrain Wi-Fi across the 5 GHz band

5.1 In addition to opening up the 6 GHz band for Wi-Fi use to meet the expected growth in demand from innovative use cases and increased number of connected devices, we are proposing to review our existing regulations to ensure that they remain fit for purpose.

5.2 Wi-Fi use is currently permitted in the 2.4 and 5 GHz bands. There is 580 MHz of unlicensed spectrum available for Wi-Fi 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. There is only one non-DFS 80 MHz channel available.

Figure 5.1: Wi-Fi channels in the 5 GHz band



5.3 Some stakeholders have voiced concerns that the DFS requirements may constrain Wi-Fi performance in the 5 GHz band, particularly in 5725-5850 MHz, and therefore inhibits the effective use of the band. Some have indicated that they set the only channel without DFS as a default in routers.

5.4 The DFS requirements are intended to protect radars from the risk of harmful interference. However, our analysis indicates that the risk of undue interference from indoor Wi-Fi use to radars is extremely low.

Our proposals

5.5 In light of our analysis of existing use of the band and of the low coexistence risk, we propose to remove the DFS requirements from the 5725-5850 MHz band for indoor Wi-Fi use up to 200mW EIRP and EIRP densities up to 10mW/MHz. This would bring about wider and more efficient use of spectrum in the 5 GHz band which is available for Wi-Fi.

5.6 We note that the 5725-5850 MHz band is also used by Broadband Fixed Wireless Access (BFWA) services on a light licensed basis with DFS requirements. We are not proposing to change or remove these requirements for BFWA services.

Dynamic Frequency Selection in the 5725-5850 MHz band

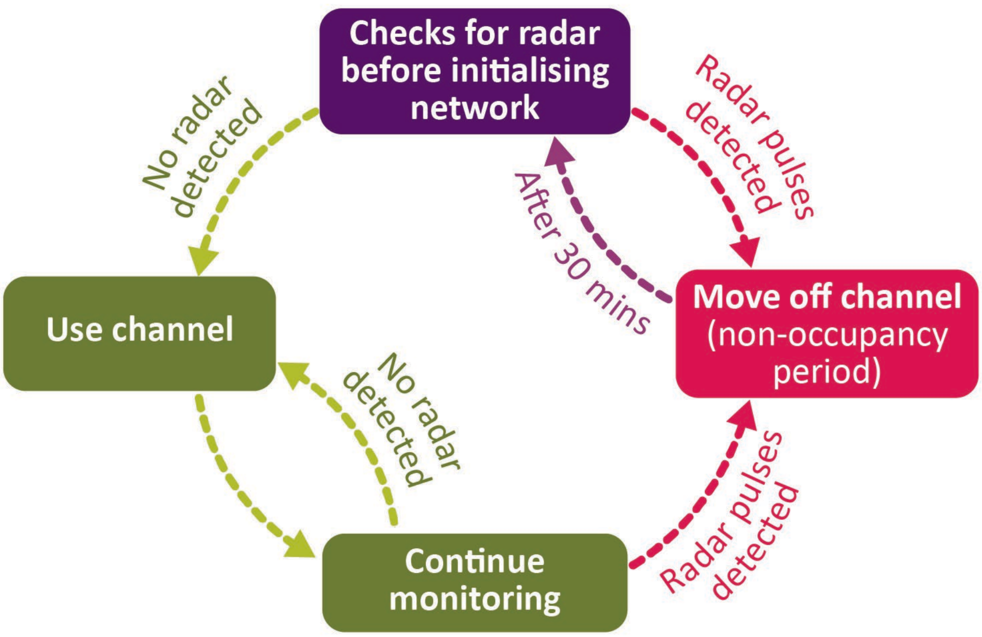
5.7 In 2017, Ofcom made regulations to allow Wi-Fi use in the 5.8 GHz band (5725-5850 MHz) on a licence-exempt basis.[12] We decided to proceed with this based on:

- evidence of increasing demand for Wi-Fi and the role of spectrum in addressing demand;
- confirmation of interest from the Wi-Fi industry and lack of compelling reasons not to make the 5.8 GHz band available;
- our analysis of potential coexistence issues with other users of the band, in view of our proposed technical parameters; and
- our judgement that this band is best placed to make a significant difference to people's Wi-Fi experience in the short term and, in particular, demand for mid-range spectrum around 5 GHz.

5.8 To minimise the risk of interference with existing users of the band (mainly radars, satellites and road tolling systems), we took a conservative approach and set various technical parameters. These included a power limitation to 200mW per channel and DFS requirements to protect military radars.

5.9 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



[12] See S.I. 2017/746, which amended The Wireless Telegraphy (Exemption and Amendment) Regulations 2010 (S.I. 2010/2512).

5.10 The 5725-5850 MHz band is not currently available for Wi-Fi use in other EU 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.

5.11 In our 2017 policy decision statement, we noted that we would continue to monitor medium- and long-term solutions for the band, including the option to re-evaluate the necessity of, or technical requirements for, DFS.

Manufacturers have highlighted difficulties with DFS

5.12 Many stakeholders we have engaged with have told us that DFS represents a constraint to good Wi-Fi performance. They indicated that this often means that there is less Wi-Fi activity in the 5 GHz channels where DFS is required, and that the 5725-5850 MHz band currently has particularly light use in the UK. Our own analysis confirms that Wi-Fi channel use tends to be concentrated in the 5150-5250 MHz band, which has no DFS requirements, while the 5725-5850 MHz band is used very minimally for Wi-Fi connections.

5.13 Some stakeholders have indicated that implementing DFS affects efficient use of the band, with some setting only channels without DFS requirements as the default in routers.

There are several reasons why DFS may be a constraint on the efficient use of spectrum in the 5725-5850 MHz band

5.14 The 5725-5850 MHz band is lightly used as Wi-Fi APs are mostly set to default Wi-Fi channels lower down the band that are not subject to any DFS requirements. Typically, users do not switch from their default configuration to use channels in the 5725-5850 MHz band. This leaves the band unused while increasing congestion in the lower frequency channels.

5.15 Additionally, if an AP does select a DFS channel and subsequently detects a radar, there is often a long channel non-occupancy period (around 30 minutes) that follows before it may reselect the same channel. This can have an impact on Wi-Fi performance.

5.16 DFS can be difficult to implement and add cost to equipment, so manufacturer take-up is also low. We note, however, that there are smartphones with 5725-5850 MHz available in the UK.

5.17 People's experience of Wi-Fi is often negatively affected by DFS. The system can take time to scan channels for radars, which leads to delays in establishing the first connection, and is susceptible to false triggers, which can interrupt the connection unnecessarily and cause the scanning process to restart.

5.18 Finally, and more specifically to 5725-5850 MHz, manufacturers have indicated that international regulations are not uniform for the 5725-5850 MHz band. It is a new band which has not been authorised globally and, where it is authorised, it usually does not have a DFS requirement. This means 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.

Other use of the band in the UK

5.19 The 5725-5850 MHz band has several permitted uses in the UK in addition to Wi-Fi:

- indoor and outdoor use for short-range devices (SRDs) with an EIRP limit of 25mW and no power spectral density limits;[13]
- outdoor Road Tolling technologies with an EIRP limit of 2W;
- military uses[14], including use by radars; and
- BFWA services with an EIRP limit up to 4W and a DFS requirement.

5.20 Additionally, this band is designated as an ISM band in the Radio Regulations for emissions from non-communication devices. ISM emissions can be a lot higher in power than those of communication devices.

5.21 Except for BFWA, none of the other uses have a requirement for DFS. However, when we extended Wi-Fi access to the 5725-5850 MHz band, we implemented DFS requirements for this band to protect radars. We said in our 2017 statement that this was a cautious approach to mitigate interference risk and that we would keep the requirements under review as they apply to this band.

5.22 In light of the available evidence on the use of the 5725-5850 MHz band for Wi-Fi since its introduction in 2017, we are reviewing the requirement for DFS to be implemented for Wi-Fi use in this band.

5.23 Our initial view is that removing the DFS requirements for indoor use only in the 5725-5850 MHz band would not have any significant impact on military radar uses in the UK. We also note that this approach would typically also pose a lower interference risk than outdoor SRD use or Road Tolling, which are operating in the band without DFS requirements. We are discussing this with the Ministry of Defence (MOD).

5.24 Making this change would also provide significant benefits to people and businesses by allowing this spectrum to be more widely used for Wi-Fi.

5.25 The DFS requirement for BFWA would be retained.

Developments in other bands

5.26 One of the outcomes from World Radio Conference 2019 (WRC-19) was to amend the Radio Regulations for RLAN use in 5150-5250 MHz band to allow limited 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. The new regulations also now specifically mention EIRP limits for in-car and in-train use.

[13] European Commission Decisions 2006/771/EC, 2008/432/EC, 2009/381/EC, 2010/368/EU, 2011/829/EU and 2013/752/EU harmonise conditions for the use of SRDs in this band.

[14] This band is a NATO class A band, meaning it is a harmonised frequency band for which a permanent essential military requirement exists in NATO Europe. The loss of or harmful interference with the military use of this frequency band, sub-band or ITU service will unacceptably degrade the operational effectiveness of NATO forces.

5.27 We consider that these changes would enable innovation by furthering use cases for portable devices and applications outdoor.

5.28 Additionally, our initial technical analysis indicates that the main interference mechanism is the aggregate effect of higher power indoor RLANs and that low power portable outdoor use would not unduly affect overall aggregate interference seen by the satellite systems.

5.29 We are therefore minded to consider how allowing low power outdoor use in the 5150-5250 MHz band could be implemented in the UK. We would also consider allowing controlled use of fixed outdoor stations up to 1W with the appropriate mask applied if stakeholders believe there is a need for such services.

5.30 We will also continue to monitor developments in other RLAN channels across the 5 GHz band and assess whether other changes would further improve Wi-Fi efficiency. The same applies to the technical requirements for DFS. We want to ensure they are still fit for purpose and are only as restrictive as is necessary to protect incumbent radar systems.

Question 3: Do you agree with our proposal to remove DFS requirements for indoor Wi-Fi up to 200mW from the 5725-5850 MHz band?

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?

6. Conclusions and next steps

6.1 Based on our initial analysis and stakeholder engagement, we are proposing the following:

- To permit access to the 6 GHz (5925-6425 MHz) band on a licence-exempt basis with maximum EIRP levels of 250mW for indoor use and 25mW for outdoor use; and
- To remove the DFS requirements from the 5.8 GHz (5725-5850 MHz) band for unlicensed indoor use only.

6.2 We will continue to engage internationally, including contributing our studies on coexistence to the EC and CEPT in the 6 GHz and 5.1 GHz bands. As we mention in section 4, we see a benefit in having a simple regulatory regime for licence-exempt spectrum enabling economies of scale for devices. Our proposals are designed to meet demand and benefit people and businesses in the UK, while supporting a regulatory regime that would enable the timely development and adoption of Wi-Fi in this band.

6.3 For the reasons set out in this consultation document, our provisional assessment is that these proposals are:

- **objectively justified** in that we have identified increased demand for spectrum, including bands with less congestion, fewer legacy devices and wider bandwidths, and that our proposals are unlikely to increase the risk of undue interference;
- **not unduly discriminatory** against particular persons or against a particular description of persons in that they would apply to all users of relevant Wi-Fi devices (and, indirectly, to all manufacturers and sellers);
- **proportionate** to what they are intended to achieve, in that the proposed technical restrictions would be necessary to ensure that use of the relevant Wi-Fi devices would not be likely to cause undue interference or to have an adverse effect on technical quality of the current users of the relevant radio spectrum; and
- **transparent** in relation to what they are intended to achieve, in that they are clearly described and explained in this consultation document, and any technical restrictions applying to the proposed exemption regime would be clearly set out in regulations.

6.4 Our consultation will close on 20 March 2020.

The overview section in this document is a simplified high-level summary only. The proposals we are consulting on and our reasoning are set out in the full document.

A1. Responding to this consultation

How to respond

A1.1 Ofcom would like to receive views and comments on the issues raised in this document, by 5pm on 20 March 2020.

A1.2 You can download a response form from https://www.ofcom.org.uk/consultations-and-statements/category-2/improving-spectrum-access-for-wi-fi. You can return this by email or post to the address provided in the response form.

A1.3 If your response is a large file, or has supporting charts, tables or other data, please email it to RLANSpectrum@ofcom.org.uk, as an attachment in Microsoft Word format, together with the cover sheet.

A1.4 Responses may alternatively be posted to the address below, marked with the title of the consultation:

Spectrum Policy and Analysis
Ofcom
Riverside House
2A Southwark Bridge Road
London SE1 9HA

A1.5 We welcome responses in formats other than print, for example an audio recording or a British Sign Language video. To respond in BSL:

- Send us a recording of you signing your response. This should be no longer than 5 minutes. Suitable file formats are DVDs, wmv or QuickTime files; or
- Upload a video of you signing your response directly to YouTube (or another hosting site) and send us the link.

A1.6 We will publish a transcript of any audio or video responses we receive (unless your response is confidential)

A1.7 We do not need a paper copy of your response as well as an electronic version. We will acknowledge receipt if your response is submitted via the online web form, but not otherwise.

A1.8 You do not have to answer all the questions in the consultation if you do not have a view; a short response on just one point is fine. We also welcome joint responses.

A1.9 It would be helpful if your response could include direct answers to the questions asked in the consultation document. The questions are listed at Annex 4. It would also help if you could explain why you hold your views, and what you think the effect of Ofcom's proposals would be.

A1.10 If you want to discuss the issues and questions raised in this consultation, please contact Jessica Foster on 020 7981 3278, or by email to RLANSpectrum@ofcom.org.uk.

Confidentiality

A1.11 Consultations are more effective if we publish the responses before the consultation period closes. In particular, this can help people and organisations with limited resources or familiarity with the issues to respond in a more informed way. So, in the interests of transparency and good regulatory practice, and because we believe it is important that everyone who is interested in an issue can see other respondents' views, we usually publish all responses on the Ofcom website as soon as we receive them.

A1.12 If you think your response should be kept confidential, please specify which part(s) this applies to and explain why. Please send any confidential sections as a separate annex. If you want your name, address, other contact details or job title to remain confidential, please provide them only in the cover sheet, so that we don't have to edit your response.

A1.13 If someone asks us to keep part or all of a response confidential, we will treat this request seriously and try to respect it. But sometimes we will need to publish all responses, including those that are marked as confidential, in order to meet legal obligations.

A1.14 Please also note that copyright and all other intellectual property in responses will be assumed to be licensed to Ofcom to use. Ofcom's intellectual property rights are explained further in our Terms of Use.

Next steps

A1.15 Following this consultation period, Ofcom plans to publish a statement later in 2020.

A1.16 If you wish, you can register to receive mail updates alerting you to new Ofcom publications.

Ofcom's consultation processes

A1.17 Ofcom aims to make responding to a consultation as easy as possible. For more information, please see our consultation principles in Annex 2.

A1.18 If you have any comments or suggestions on how we manage our consultations, please email us at consult@ofcom.org.uk. We particularly welcome ideas on how Ofcom could more effectively seek the views of groups or individuals, such as small businesses and residential consumers, who are less likely to give their opinions through a formal consultation.

A1.19 If you would like to discuss these issues, or Ofcom's consultation processes more generally, please contact the corporation secretary:

Corporation Secretary
Ofcom
Riverside House
2a Southwark Bridge Road
London SE1 9HA
Email: corporationsecretary@ofcom.org.uk

A2. Ofcom's consultation principles

Ofcom has seven principles that it follows for every public written consultation:

Before the consultation

A2.1 Wherever possible, we will hold informal talks with people and organisations before announcing a big consultation, to find out whether we are thinking along the right lines. If we do not have enough time to do this, we will hold an open meeting to explain our proposals, shortly after announcing the consultation.

During the consultation

A2.2 We will be clear about whom we are consulting, why, on what questions and for how long.

A2.3 We will make the consultation document as short and simple as possible, with a summary of no more than two pages. We will try to make it as easy as possible for people to give us a written response. If the consultation is complicated, we may provide a short Plain English / Cymraeg Clir guide, to help smaller organisations or individuals who would not otherwise be able to spare the time to share their views.

A2.4 We will consult for up to ten weeks, depending on the potential impact of our proposals.

A2.5 A person within Ofcom will be in charge of making sure we follow our own guidelines and aim to reach the largest possible number of people and organisations who may be interested in the outcome of our decisions. Ofcom's Consultation Champion is the main person to contact if you have views on the way we run our consultations.

A2.6 If we are not able to follow any of these seven principles, we will explain why.

After the consultation

A2.7 We think it is important that everyone who is interested in an issue can see other people's views, so we usually publish all the responses on our website as soon as we receive them. After the consultation we will make our decisions and publish a statement explaining what we are going to do, and why, showing how respondents' views helped to shape these decisions.

A3. Consultation coversheet

BASIC DETAILS

Consultation title: Improving spectrum access for Wi-Fi: Spectrum use in the 5 and 6 GHz bands

To (Ofcom contact): Spectrum Policy and Analysis

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

CONFIDENTIALITY

Please tick below what part of your response you consider is confidential, giving your reasons why

Nothing	☐
Name/contact details/job title	☐
Whole response	☐
Organisation	☐
Part of the response	☐
If there is no separate annex, which parts?	________________________________

____

If you want part of your response, your name or your organisation not to be published, can Ofcom still publish a reference to the contents of your response (including, for any confidential parts, a general summary that does not disclose the specific information or enable you to be identified)?

DECLARATION

I confirm that the correspondence supplied with this cover sheet is a formal consultation response that Ofcom can publish. However, in supplying this response, I understand that Ofcom may need to publish all responses, including those which are marked as confidential, in order to meet legal obligations. If I have sent my response by email, Ofcom can disregard any standard e-mail text about not disclosing email contents and attachments.

Ofcom seeks to publish responses on receipt. If your response is non-confidential (in whole or in part), and you would prefer us to publish your response only once the consultation has ended, please tick here.

Name Signed (if hard copy)

A4. Consultation questions

A4.1 This annex lists the questions that we are consulting on.

> 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?
>
> Question 2: Do you have any comments on our technical analysis of coexistence in the 5925-6425 MHz band?
>
> Question 3: Do you agree with our proposal to remove DFS requirements for indoor Wi-Fi up to 200mW from the 5725-5850 MHz band?
>
> Question 4: Do you have any comments on other options that may be available for Wi-Fi and RLANs within the 5 GHz band?

A5. Legal framework

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

A5.1 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.

A5.2 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.

A5.3 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

A5.4 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.

A5.5 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.

A5.6 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.

A5.7 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.

A5.8 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.

A5.9 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.

A5.10 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)

A5.11 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.

A5.12 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

A5.13 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.

A5.14 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.

A5.15 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.[15] 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.

[15] 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).

CEPT's reports on the 6 GHz band

A5.16 The European Common Allocations Table shows fixed, fixed-satellite and mobile as primary services allocated in the 5935-6425 MHz and adjacent 5850-5925 MHz band.

A5.17 In December 2017, the European Commission issued a mandate to CEPT to study and identify harmonised technical conditions for WAS/RLANs in the 5925-6425 MHz band for the provision of wireless broadband services (the "**EC Mandate**"). CEPT published its first report (ECC Report 302) in May 2019 and contains studies between WAS/RLAN systems and existing incumbents in the 5925-6425 MHz band and adjacent bands. Based on the results of ECC Report 302, CEPT developed Draft Report 73 and consulted on it. According to that report, CEPT expects that compatibility and coexistence between WAS/RLAN and existing services within and adjacent to the band 5925-6425 MHz be technically feasible under certain conditions.

A5.18 By the end of 2020, CEPT is expected to develop a Decision to define harmonised technical conditions for WAS/RLANs in the 5925-6425 MHz band for the provision of wireless broadband services, taking into account the results of ECC Report 302 and CEPT Reports in response to the EC Mandate.

Relevant UK regulations

A5.19 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[16], 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).

A5.20 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.[17]

Notification under the Technical Standards Directive

A5.21 If, following consultation, we decide to proceed with our policy proposals, we will need to implement them by adopting any associated interface requirements and by making new regulations by statutory instruments (see paragraph A5.10). This would involve consulting on substituting the publication date of the 'IR 2030' version which is referenced in the

[16] 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 and S.I. 2018/1140.

[17] The technical parameters for these licence-exempt uses are set out in IR 2030.

Wireless Telegraphy (Exemption and Amendment) Regulations 2010 (reg. 5) with the final publication date of the revised IR 2030.[18]

A5.22 In accordance with the Radio Equipment Directive and the Technical Standards Directive, we will shortly notify our proposed changes to the current interface requirements for short-range devices (IR 2030) to the European Commission. The Commission and Member States will have three months in which to comment on the draft technical standard before it may be adopted. The decision as to whether to make the proposed regulations will be subject to taking into account any comments or opinion we receive from the Commission or Member States, as well as the responses to our consultation.

[18] We note that Ofcom is separately consulting on further changes to the IR 2030. See the Notice of Ofcom's proposals for changes to the licence exemption for Wireless Telegraphy Devices (11 December 2019).

A6. Current and future demand for Wi-Fi

Introduction

A6.1 In this annex we consider how future demand for Wi-Fi could grow, 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.

A6.2 We have analysed applications and uses driving Wi-Fi demand in a residential environment and in the case of a public venue such as an arena or concert hall.

A6.3 However, it should be noted that forecasting future Wi-Fi demand is subject to large uncertainties and requires a significant degree of judgement.

Residential indoor use: focus on in-home entertainment

A6.4 Demand for Wi-Fi will vary considerably from person to person and from household to household. In our estimates, we have considered **peak demand** in a **demand-heavy household**, as it is this type of demand which will determine capacity requirements.

A6.5 This means that our estimates are reflective of a connected household with active users who are also likely to be early adopters of new technologies.

Sources of demand

A6.6 We have considered the following aspects of future demand:

a) **The simultaneous activities requiring Wi-Fi bandwidth.** For example, email, browsing, video streaming, smart devices in the home.

b) **The data use rate of these activities**. We have estimated current data speeds for each activity which reflect a high-quality experience. Looking to the future, we have estimated data speeds which reflect developments in technology, adoption of new technologies and increases and changes in user expectations and behaviour.

A6.7 It is difficult to forecast future demand for several reasons. Firstly, we do not have accurate estimates of data speeds for applications which are still in the early stages of development. Secondly, the take up of these activities is unknown and may also be affected by changes in use trends, for example the impact of the use of a younger demographic. Thirdly, there may be other future technology developments which are as yet unknown, and which may have an exponential impact on speed requirements.

A6.8 Our detailed assumptions for this scenario are as follows:[19]

[19] Ofcom's Technology Tracker 2019, especially Tables 16, 137 and 138, has been used to inform the assumptions on current and future device use in the home.

a) Four active users in the household. Some users are multi-tasking i.e. carrying out different online activities simultaneously.

b) There are several smart devices in the home, for example smart speakers, wireless security devices and wearable devices, and the number of these devices increases over time.

c) All household consumption is via Wi-Fi. We acknowledge that this may not always be the case – for example, people may prefer TVs to have a wired connection to guarantee quality of service. However, as we are estimating a demand-heavy household, we are assuming Wi-Fi connectivity throughout the home.

d) Video quality increases over time, and there may be adoption of Augmented Reality or Virtual Reality technologies in the future.

e) There are mesh networks in the home, even though they may not be in use in the average household. Several stakeholders raised the increasing popularity of mesh networks in our discussions.

A6.9 Our analysis shows that household demand could increase by up to six times over a ten-year period. This is, for the most part, driven by increases in video quality and the adoption of Virtual Reality devices. However, it is worth noting that newer video codecs and better video compression techniques may have an impact in reducing video speed requirements in the future; this is something which is not reflected in our estimates.

Projecting current demand

A6.10 We have also considered an alternative approach to estimating future demand. This initially takes an average household's monthly data use and converts this into an average peak data rate. Our starting point is the total monthly household data use in 2019 of 315 GB (according to Ofcom's Connected Nations 2019) which we convert into a Mbits per peak second figure.

A6.11 We then apply a 26% year on year linear growth rate in our projections. This is the 2017-2018 growth rate and is lower than that of previous years (which range from 30-93%). For comparison, Cisco forecasts a 21% UK growth rate and a 26% global growth rate from 2017-2022; Ovum forecasts a 31% global growth rate from 2017-2023. This growth in total data consumption may be driven by the introduction of new applications, more data-intensive use of current applications, as well as more time spent connected to the Internet. We also account for mesh networks in our estimates.

A6.12 If we base our future demand estimates on a projection of current demand, household demand for Wi-Fi could increase by up to ten times over a ten-year period.

Public venue: arena

A6.13 In this scenario we consider **peak demand** per access point (AP) in an arena or stadium environment and how this may evolve over five- and ten-year periods, as visitors to the stadium may desire a more immersive and content-rich experience.

A6.14 We estimate aggregated peak demand by considering the simultaneous activities which would require Wi-Fi bandwidth and the data use rates of these activities.

A6.15 We assume 200 users per AP. In 2020, we assume that 25% of these users are active users of the arena's Wi-Fi.[20] This increases to 35% in 2025 and 45% in 2030.[21] This figure is likely to increase over time due to user-preference and also due to mobile devices sometimes being automatically connected to Wi-Fi hotspots. Other active users could be using mobile data instead.

A6.16 We estimate two types of users – those carrying out basic browsing activities and those carrying out video-related activities. The split of people carrying out these activities evolves over time; this reflects changes in user behaviour and potentially a change in user demographic. The video-related activities can be further split into those continuing to carry out more standard video-related activities, and those who adopt some form of Virtual Reality or Augmented Reality video services.

A6.17 We assume that user activity is generally correlated. This means that demand is likely to be concentrated into specific peak times, for example during breaks in sports matches or between sets at a music concert. It also means that demand may be within the same activity category, for example watching videos (instant replays, replays on demand, live interviews) or social media (uploading photos and videos). This compares to uncorrelated user activity in a different public place like a café, where people will be carrying out completely different types of activities at different times.

A6.18 We also assume that user activity takes place only on smartphones. This is because smartphones are more portable than other devices, and it is less likely that people will take other devices to events with them. This means that video quality is assumed to be Standard Definition (SD) in 2020, rising to High Definition (HD) quality in 2025 and 2030.

A6.19 Our analysis shows that demand for Wi-Fi in an arena environment could increase by up to 15 times over a ten-year period. This increase is primarily driven by our assumption that there will be some degree of Virtual Reality or Augmented Reality use in 2030.

[20] Ofcom's Communications Market Report 2018 states that "For 75% of the time Android users with access to 4G mobile technology were using apps, they were connected to Wi-Fi." This is a six percentage point increase since 2016.
[21] Ofcom's Communications Market Report 2018 states that "34% of adults said they look for free Wi-Fi when they're out and about, increasing to 45% of under-35s".

A7. Coexistence studies in the 5925-6425 MHz band

Summary

Background, description and conclusions from our studies

A7.1 We are proposing to make the lower part of the 6 GHz band (5925-6425 MHz) available for RLAN/Wi-Fi use on a licence-exempt basis.

A7.2 The lower 6 GHz band is currently used for several communication services including mobile, fixed satellite and fixed links services. Our proposal sets out a sharing arrangement in which current services and RLAN/Wi-Fi would share the band on a co-primary basis.

A7.3 To understand the sharing possibilities and risk of interference to UK fixed links, we have carried out some analysis that we believe is representative of existing fixed link geometries and of future licence-exempt RLAN/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.

A7.4 The results of our analysis suggest 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), with only a very small and unlikely risk of interference into fixed links, in environments that might not reflect realistic UK deployments. We believe opening the band for these uses would meet future demand and facilitate new Wi-Fi use cases.

A7.5 CEPT has undertaken similar coexistence studies, using Monte Carlo, Minimum Coupling Loss (MCL) and coverage mapping approaches. These studies also suggest 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. The Monte Carlo study accounts for fixed links details which are available in the UK licence database. However, CEPT applies a general, non-specific deployment model whilst our studies have focused on UK specific deployment scenarios. We note that the CEPT studies have not yet been finalised and that more work is being carried out.

A7.6 The CEPT studies have also considered sharing with other incumbent users in the 6 GHz band and services in adjacent bands including the Fixed Satellite Service, Radio Astronomy Service, Road – Intelligent Transport System and Communications Based Train Control. We have reviewed the CEPT analysis and, in the absence of any strong justification to change the assumptions used in these studies, we agree with CEPT's views on sharing with these other services.

[22] We note that current CEPT studies support usage of up to 200mW.

A7.7 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 A7.1: 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 exceeded for less 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 – 20m. Analysis of the building height data used in our modelling shows the probability of a building being above 9m is less than 10%. At the same time, the estimated number of overlapping instantaneously transmitting RLANs in the analysis areas[23] 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. When we remove the higher power devices from our analysis, interference falls below the long-term threshold of -10 dB I/N.

A7.8 This annex is structured as follows:

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

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

c) **Part 3** explains the analysis framework, including the interference threshold criteria and the propagation models used.

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

d) **Part 4** presents a detailed description of results from our three analysis studies.

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

A7.9 In the UK, the lower 6 GHz band is allocated for mobile and fixed services: 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).[24] In addition, IR2030 includes radio determination applicable to Tank Level Probing Radar (TLPR) in the 4.5-7.0 GHz band; coexistence studies have been already carried out by CEPT.[25]

A7.10 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 in a co-primary basis.

A7.11 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, studies on fixed links, including analysis of the potential for short-term interference, have not yet been concluded and there is still further work ongoing within CEPT.

A7.12 With regards to analysis between RLANs and fixed links, the Monte Carlo analysis carried out by CEPT calculates 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 Monte Carlo iterations. The results show that the long-term interference criterion (I/N of -10 dB) is not exceeded for more than 20% of the time. Additionally, a Fractional Degradation in Performance (FDP) analysis showed that FDP of less than 10% is 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 that they occur as a result of the random nature of other parameters used in the analysis. The same CEPT studies show that, if the RLAN deployment is restricted to indoor-only use, with EIRP up to 200mW, sharing is generally considered to be feasible.

A7.13 Some CEPT countries which use a different assignment criterion from the UK in this band have proposed carrying out additional analysis which would look at developing a new

[24] 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.
[25] As included in ECC Report 139.
[26] Published in ECC Report 302.

short-term interference analysis of RLAN interference into FS. We believe that in this band we already have some further mitigation for interference as a result of uplift in the fade margins used in the UK planning criteria for FS due to satellite Earth stations on board vessels operating in this band. We will continue to engage actively within CEPT in further studies but at this stage we believe that the long-term interference analysis is more relevant.

Part 2: Fixed links and RLAN deployments under analysis

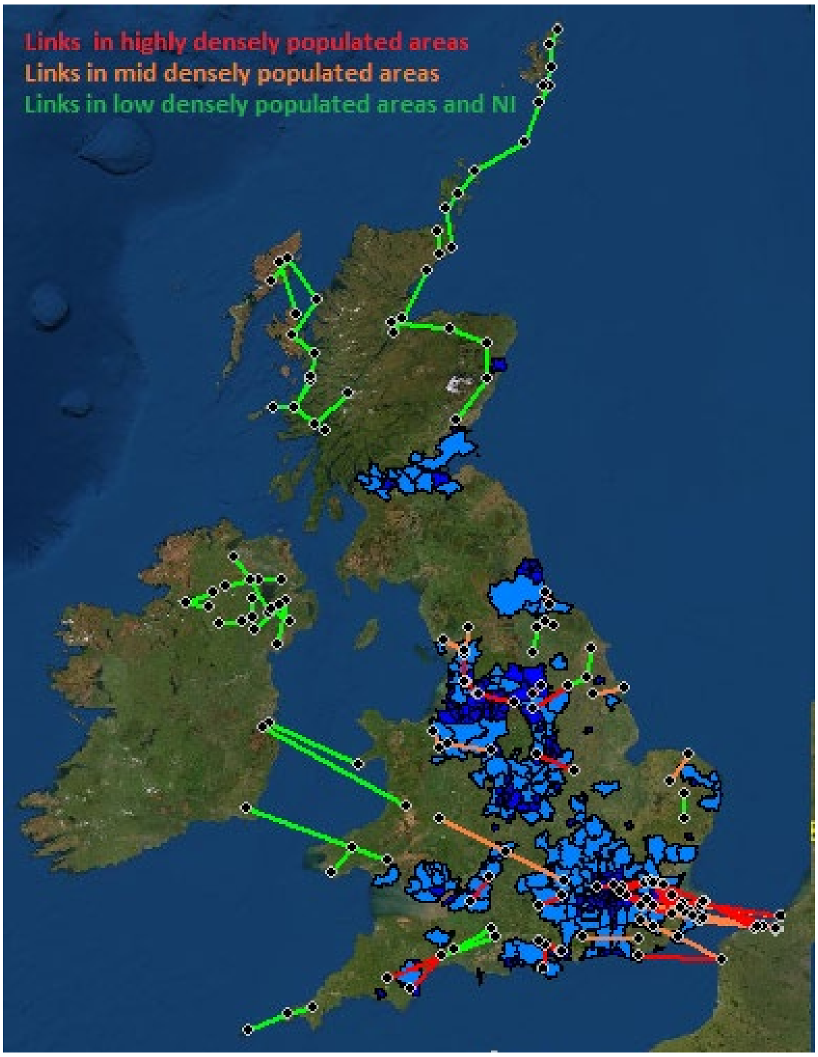
Fixed link parameters in the lower 6 GHz band in the UK

A7.14 We have carried out our own analysis to understand the impact on UK fixed links based on long term interference criteria for fixed links. Our studies look at specific links in the UK to assess the sharing potential with a likely UK RLAN deployment. Whilst CEPT uses different, non-UK sources, our studies use real locations and heights of UK premises to locate potential RLAN interfering devices. We also apply 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.

A7.15 We have 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.

A7.16 As of August 2019, there are around 335 fixed link licenses issued in the UK. Around 265 of these fixed links are located within UK landmass. Of these, 79 are located partially or completely (either one or both ends of the link) within mid and high densely populated areas, and only 49 are located within high densely populated areas. We define 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 A7.1 shows the location of all the links from the publicly available version of the database.

Figure A7.1: Location of fixed links in the 5925-6425 MHz band

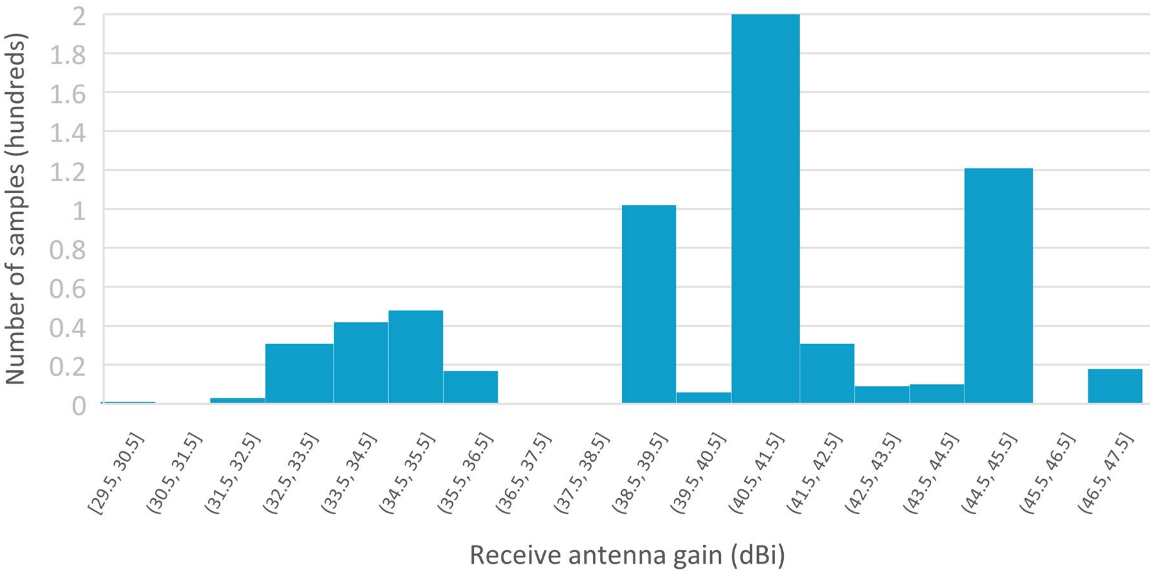


Dark blue areas represent high densely populated local authorities.
Medium blue areas represent mid densely populated local authorities.

A7.17 In order to focus our analysis on the most representative links, we first performed an audit on the data contained in our 6 GHz licence database. We then selected a sub-set of links based on their location, height and antenna gain. In Figure A7.2 and Figure A7.3 we show the distribution of the receive antenna gain and height for the links in the database.

A7.18 For receive antenna gains, the values range 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.

Figure A7.2: Distribution of receive antenna gain values: fixed links in the lower 6 GHz band

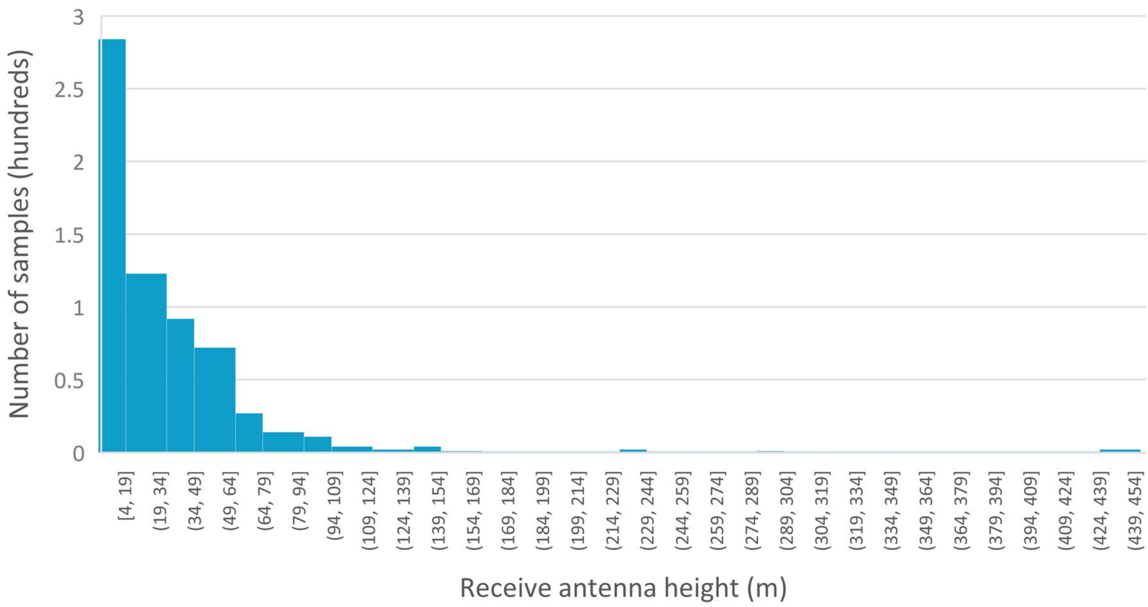


A7.19 In our modelling we have used antenna patterns derived from Recommendation ITU-R F.669[27] for single entry interference studies (MCL) and Recommendation ITU-R F.1245[28] for aggregate interference studies (Monte Carlo and snapshot). Fixed links in the lower 6 GHz band are assigned on a noise-limited basis. We have used a system noise floor of -140 dBW/MHz.

A7.20 For receive antenna height, the values range from a minimum of 4m and maximum of 452m[29], with an average of 24m and a median value of 23m.

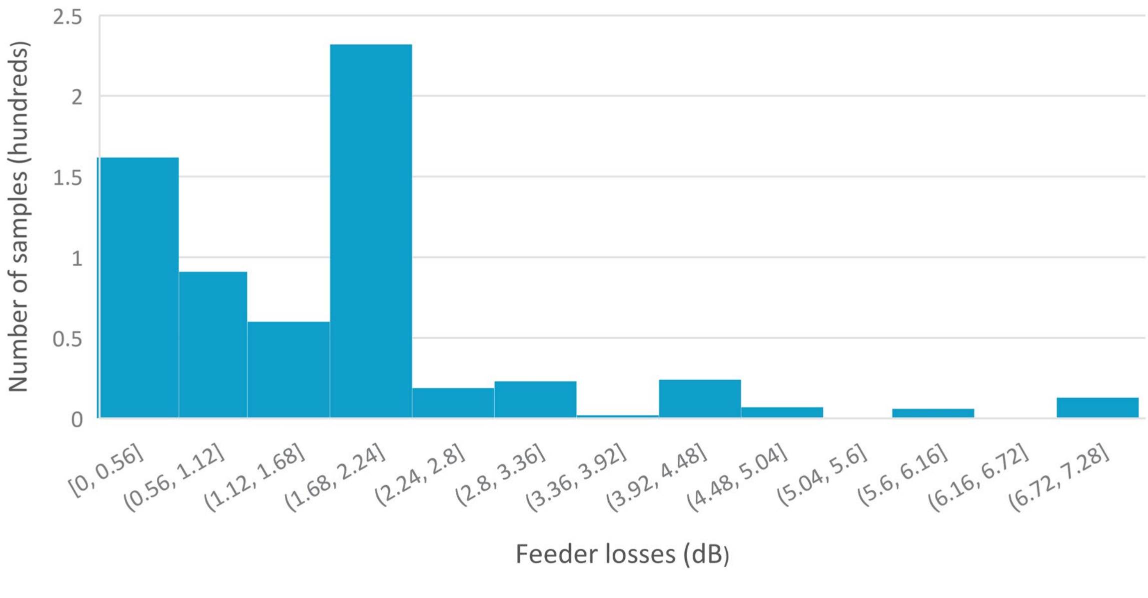
[27] Recommendation ITU-R F.699 – Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to 86 GHz.
[28] Recommendation ITU-R F.1245-3 – Mathematical model of average and related radiation patterns for point-to-point fixed wireless system antennas for use in interference assessment in the frequency range from 1 GHz to 86 GHz.
[29] Although contained in the licence database, we believe this value is erroneous and has been discounted in our analysis.

Figure A7.3: Distribution of height values: fixed links in the lower 6 GHz band



A7.21 We have also looked at the distribution of feeder losses[30] contained in the licence database (see Figure A7.4). There are 110 entries associated with feeder losses of 0 dB, and 63 with feeder loss of less than 1 dB. In our analysis we have used slightly higher values based on the link geometry and using information from current RF cable data sheets. We use 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 are applying are still within the range of values derived from the database. This approach is consistent with the analysis in ECC Report 302.

Figure A7.4: 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

A7.22 From the UK fixed link database, we have 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).

A7.23 We have not included any analysis on fixed links outside UK landmass. We understand 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.

A7.24 Table A7.2 summarises the links we have considered in our analysis. While all of them are in populated areas, they represent different deployment scenarios in terms of local topography, antenna gain and height. Figure A7.5 shows the location of the links within the UK landmass.

Table A7.2: 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 A7.5: Locations of fixed links used in our analysis

Topology of future RLAN deployments

A7.25 Our analysis aims to understand the potential impact of future RLAN into fixed links. We have 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 calculate a distribution of RLANs that:

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

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

c) are transmitting at the same time; and

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

A7.26 We analyse the total number of instantaneously transmitting RLANs based on the population in a given region, and we consider additional factors, which we explain further in this section, that impact the total number of simultaneously transmitting RLANs. Table A7.3 below provides an example using the estimated population of the CEPT administrations for 2025.[31]

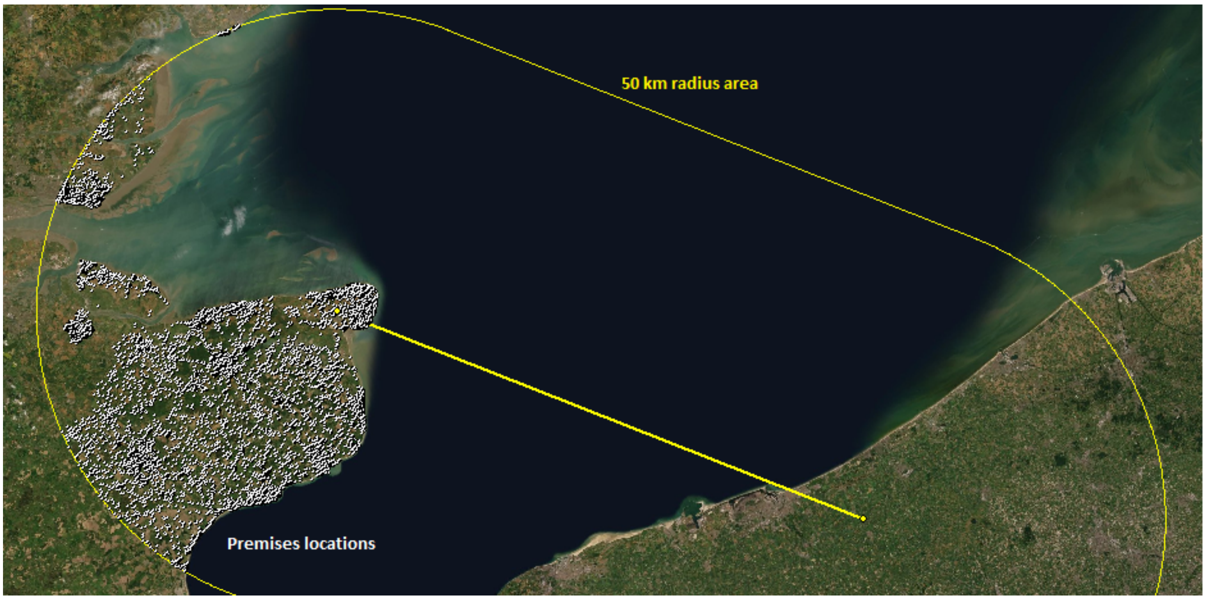
Table A7.3: RLAN deployment example

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

A7.27 Figure A7.6 presents an example of the RLAN topology (total number and location) for one of the fixed links considered.

[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 apply a 21.25% overlapping factor, derived from ECC Report Section 6.4.3.2 (Monte Carlo approach).

Figure A7.6: Example of RLAN locations within a 50km area around a Fixed Link



A7.28 In the following subsections we describe the other assumptions we have used to derive the RLAN distributions.

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

A7.29 The interference impact on a fixed link receiver is dependent on the distribution of the RLANs in nearby locations. We have 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 have assumed a potential single client device or access point (AP) for each premises. The CEPT studies[35] follow a similar approach, but use a grid location 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.

A7.30 We have assigned a random height value to each of the generated (premises) points. These height values are derived from the probability distribution of the height of all buildings within the area around each of the fixed links under analysis. We have derived these values from the building height distribution of the latest OS MasterMap Topography Layer. In general, although the distribution is subject to localised variations, the bulk of the building heights relate to one or two storey dwellings. There is a small proportion of buildings with between three and ten floors, and only a few exceptions above this value (most notably

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

around London).[36] CEPT studies derive a height probability using data extracted from a report on the number of stories and distribution in single-family homes in the US.[37] We believe our approach better reflects the topology of premises in the UK because we use UK specific building data and the values are extracted from distributions of confined areas.

A7.31 We have 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 have 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

A7.32 The main difference between these devices is the peak EIRP, which comprises the conducted power (dBm) to the antenna, the peak antenna gain (dBi) and MIMO gain of the antenna system (dB). Overall, the peak EIRP values assumed in the CEPT studies range from 18.5 dBm (~70mW) to 29.9 dBm (~1W).

A7.33 Body loss is not accounted for in this power distribution.[38] We have accounted for a body loss of 4 dB for client devices but have not considered any loss for access points.[39] The percentage of client devices in indoor and outdoor environments is 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 A7.4 below.

Table A7.4: 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

A7.34 The high-power APs were assigned a peak EIRP of 30 dBm (1W), according to ETSI TR 103 524. However, we have excluded these devices from our RLAN distribution, leaving only outdoor use up to 25mW for client devices (representative of VLP devices).

A7.35 Lastly, we have assumed a 1.5 dB polarisation mismatch loss for single entry studies and a 3 dB polarisation mismatch loss for aggregate interference studies.

[36] We assume a dwelling floor equates to 3 meters.
[37] NAHB, The Number of Stores in Single-Family Homes Varies Across the Country, 5 August 2016 (Accessed 12/11/2019)
[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.

Bandwidth and operating frequency distribution follow CEPT guidelines

A7.36 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 A7.5 below shows the expected future distribution of RLAN devices with different channel bandwidths in the 6 GHz band.

Table A7.5: Nominal channel bandwidth percentages

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

A7.37 We have assumed IEEE 802.11ax[40] compliant equipment in our studies. As such, we have derived the nominal centre frequencies (f_{cn}) based on the nominal bandwidth and different channel number increments based on the nominal frequency:

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

Other factors we consider in our analysis

A7.38 When assessing the number of RLANs that could be transmitting simultaneously, we have 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 consider 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.

A7.39 We use the CEPT studies as a baseline,[41] but we recognise there are different levels of conservatism in some of the assumptions.[42] Table A7.6 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. The higher the level of conservatism, the greater the number of potential interferers within an area.

[40] Cisco Frequency Bands of Operation defined in IEEE 802.11ax.
[41] We note 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 A7.6: 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

A7.40 In summary, we have taken these factors into account 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 initial view based on different types of analysis

A7.41 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

A7.42 We have 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.

A7.43 Additionally, we have 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).

A7.44 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.

A7.45 We have 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.

A7.46 We then reduced the analysis area around each link. We have 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 have 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

A7.47 An MCL method estimates the required separation between interferer and victim to ensure that there is no risk of interference. We have 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.

A7.48 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

A7.49 This approach looks 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.

A7.50 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 will be lower, but results will remain similar if interference is generated from the aggregate effect of nearby devices.

Common assumptions used in our analysis

We apply a long-term interference criteria threshold

A7.51 There are two main criteria to protect fixed links against harmful interference, namely long-term protection criteria and short-term protection criteria.[43] The distinction between the two is:

- 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.

A7.52 In our analysis we have 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.

A7.53 We have used two propagation methods with a different approach for clutter losses. We have 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]

A7.54 We have 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 have 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 assume that the fixed link receiver is within the clutter and the terminals are located in urban and suburban environments. We also assume that the distance between terminals is 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 use 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 range between 0 dB and 10 dB.

We have used a single value for building entry losses

A7.55 We apply building penetration losses when the RLAN device is located indoors. In line with our studies in our consultation on enabling opportunities for innovation, we have applied a 12 dB attenuation value. We derive 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

A7.56 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

A7.57 Results from the three different types of analysis show that sharing is feasible when the deployment scenarios are limited to VLP devices outdoors (25mW) and RLAN indoors (up to 250mW). We note 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.

A7.58 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 derive the 12 dB from a 70/30% split between traditional and thermally efficient building entry loss value from CDFs.

a) RLAN EIRP levels would normally be 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) 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) would present a low chance of interference as there are fewer premises around the link receiver where RLANs would be installed.

c) Fixed links in populated areas would have a low chance of interference unless the RLAN is located very close to the fixed link receiver, due to the effect of the higher clutter losses included in the link budget.

A7.59 Additionally, we note that, as a result of decisions regarding Earth Stations on-board Vessels (ESVs) use 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 might provide additional mitigation for interference from RLAN.

Results of the Monte Carlo analysis

A7.60 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, randomising:

a) Locations of the interfering RLANs based on the postcode and density of population data of the 50km area surrounding the fixed link receiver.

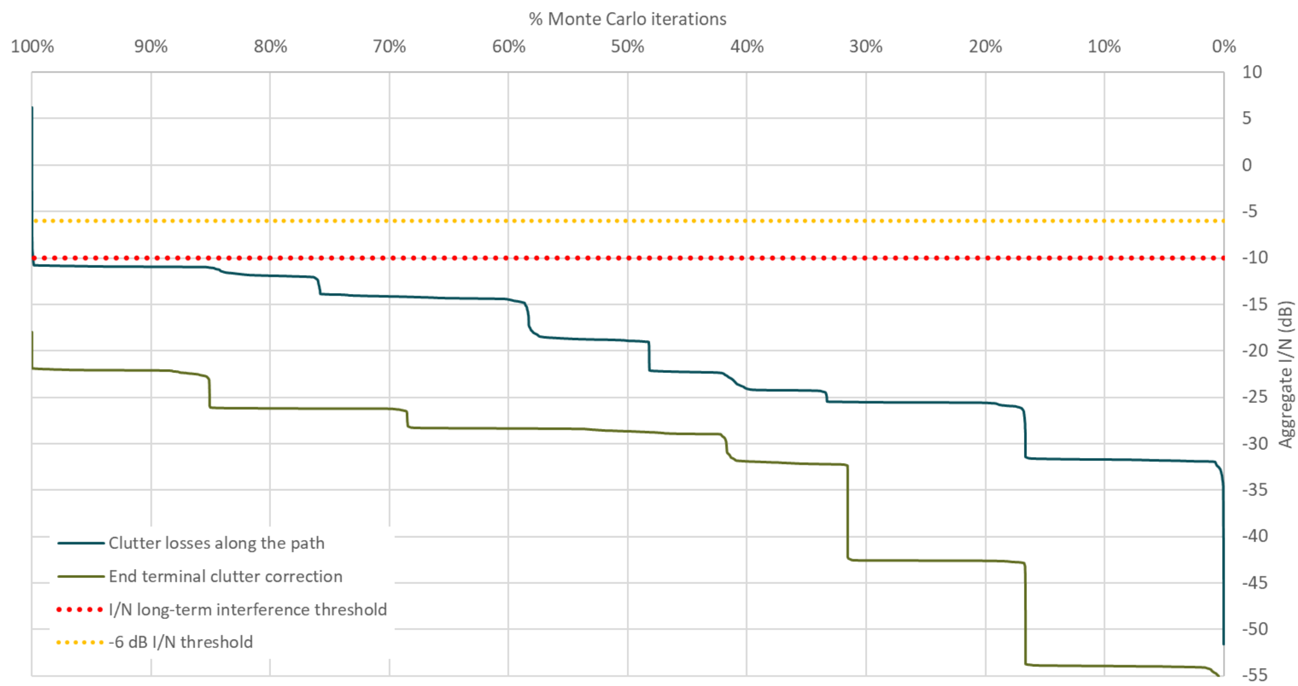
b) RLAN parameters (i.e. EIRP, bandwidth, etc.)

A7.61 The result is the mean and standard deviation value of the aggregate I/N per iteration. We then collate the aggregated I/N values to create the I/N Complementary Cumulative Distribution Function (CCDF), shown in Figure A7.7.

A7.62 The results show that, when considering clutter losses along the path[47], the aggregate I/N would exceed the long-term interference protection criteria of -10 dB and a threshold of -6 dB I/N in only a very small percentage of cases (less than 0.1%). 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. No exceedance events have been recorded when considering clutter losses at the fixed link receiver end.

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

Figure A7.7: Aggregate I/N vs Percentage of Monte Carlo iterations



A7.63 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 note 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 do not exclude any locations within the first or second Fresnel zones that we would usually assume to be clear when planning a fixed link.

A7.64 The CEPT Monte Carlo analysis shows 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

A7.65 This analysis calculates 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).

A7.66 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 A7.8). 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.

A7.67 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 is 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 A7.8: Detail of snapshot analysis. Location of fixed link receiver and possible interferer

Results of the minimum coupling loss analysis

A7.68 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.

A7.69 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 refer 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 explore how a possible exclusion area would increase when the fixed link receiver is in an open area, which is a common deployment scenario.

A7.70 The results include the curves corresponding to different heights of 3m, 6m, 9m and 21m for the RLAN interferer (Figure A7.9: and Figure A7.10). The shaped areas around the link represent locations where a device would potentially cause interference.

A7.71 The results from analysing link 1126335/1 (Figure A7.9:) show that the maximum potential area around the link would include 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 (overlapping) instantaneously transmitting RLANs as potential interferers within this area.

Figure A7.9:2 Exclusion areas (MCL). Variable RLAN height, 250mW indoor access point, Link Licence No. 1126335/1, London area

A7.72 The results from analysing link 0432073/1 (Figure A7.10) show 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 in the area.

A7.73 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.

A7.74 In summary, exclusion areas will 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 A7.10: Exclusion areas (MCL). Variable RLAN height, 250mW indoor access point, Link Licence No. 0432073/1, Isle of Wight area

A8. Proposed updates to Interface Requirement 2030

We are proposing a modification to one row of, and addition of a new row to, Interface Requirement 2030 (IR 2030). The technical parameters set out in IR 2030 would form part of the requirements with which individuals must comply when operating in the 5725-5850 MHz and 5925-6425 MHz frequencies. Modifications and additions are in red. All other requirements set out in IR 2030 would remain the same. The current version of IR 2030 can be found on our website.

Proposed 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 Aeronautical mobile use is not permitted. Equipment may be used airborne, within an aircraft, only to establish a connection with a	5725 – 5850 MHz		Maximum mean EIRP of 200mW and maximum mean EIRP density of 10mW/MHz in any 1 MHz band			Techniques to access spectrum and mitigate interference that provide at least equivalent performance to the techniques described in harmonised standards for the 5150 – 5350 MHz and 5470 – 5725 MHz bands adopted in accordance with EC Decision 2005/513/EC and Directive 2014/53/EC must be used.	~~See footnote[50] for information.~~ Nominal Centre Frequency (MHz) 5745, 5765, 5785, 5805, 5825

[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."~~

		station or apparatus within the same aircraft.							

Proposed addition of a 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)	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.	5925 – 6425 MHz		Maximum mean EIRP of 250mW indoor and 25mW outdoor. Maximum mean EIRP density of 10mW/MHz in any 1 MHz band			Techniques to access spectrum and mitigate interference that provide at least equivalent performance to the techniques described in harmonised standards for the 5150 – 5350 MHz and 5470 – 5725 MHz bands adopted in accordance with EC Decision 2005/513/EC and Directive 2014/53/EC must be used.	Nominal Centre Frequency (MHz) 5945, 5965, 5985, 6105, 6125, 6145, 6165, 6185, 6205, 6225, 6245, 6265, 6285, 6305, 6325, 6345, 6365, 6385, 6405

A9. 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.

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.

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)