Supporting the UK's wireless future

Our spectrum management strategy for the 2020s

Supporting the UK's wireless future – Welsh overview

STATEMENT:

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Annex

1. Overview

Wireless communication is playing an increasingly significant role across many sectors of the economy, delivering our news, connecting us to friends and family, automating factories, supporting public services and monitoring the natural environment.

The radio spectrum (the invisible waves that enable wireless technology), is a limited resource crucial to delivering these services, and Ofcom has the job of ensuring it is used in the best interests of all in the UK. This approach sits at the heart of Ofcom's mission to make communications work for everyone.

We want to enable existing spectrum users to grow and innovate whilst also allowing new services to emerge. To do this, our spectrum management strategy for the future is informed by changes in the market, technology, and in demand from people and businesses.

We will apply greater flexibility and forward thinking management of the spectrum for both 'mass market' wireless services used by virtually everyone throughout the UK (like Wi-Fi and cellular mobile services), as well as for more specialised uses of spectrum by businesses, public sector and other organisations.

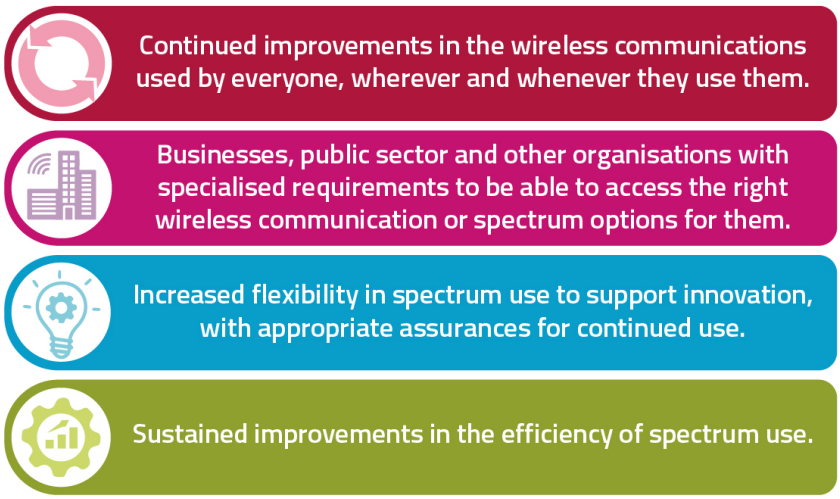
A spectrum management vision fit for the future

The increasing use of wireless connectivity across different industry sectors, and the impact of technology developments leading to new and innovative applications, is driving demand for spectrum and calling for a shift in the way we approach spectrum management.

We believe that the use of spectrum will continue to transform the way we live and work – benefiting people throughout the UK and beyond, helping to make us more productive and supporting industries across the economy.

Our spectrum management vision to enable growth and innovation centres around four key objectives.

Our spectrum management vision:



Achieving our vision

We have identified three areas of increased focus instrumental to achieving our vision. These new areas of focus sit alongside our long-established approach to spectrum management which relies on market mechanisms where possible and the use of regulatory levers as necessary.

Areas of increased focus for the next decade:

Supporting wireless innovation: Making it even easier for a broad range of users to access spectrum by:

- Making more spectrum available for innovation before its long-term future use is certain;
- Working to support innovation in new wireless technologies, including by influencing international standards and technical conditions so they are flexible enough to support new uses;
- Expanding our work to understand, assist and inform the broad range of organisations who may benefit from wireless technologies in the future.

Licensing to fit local and national services: Supporting the growing diversity of wireless services and providers by considering further options for localised spectrum access when authorising new spectrum use. Local access can suit a range of businesses and specialised services at sites like factories, airports and remote farms, which do not need to use spectrum across the whole UK. Licences for larger areas, including national licences, can support wide coverage for public mobile services.

Promoting spectrum sharing: Encouraging users to share access to spectrum with others. As innovation stimulates greater demand for limited spectrum resource, spectrum sharing becomes even more important. Alongside our flexible authorisation options, technology can help by providing new sharing tools and by creating the opportunity for a fresh approach to sharing in higher frequencies. We will encourage:

- Use of better data and more sophisticated analysis when assessing the conditions for sharing;
- Wireless systems to be more resilient to interference from their neighbours;
- An efficient balance between the level of interference protection given to one service and flexibility for others to transmit.

There is also a range of existing activities which remains essential for achieving our spectrum management vision and many of these will be influenced by the areas of focus above. Examples of these are:

- **Reviewing emerging demands across different sectors.** The role of spectrum continues to evolve to support the changing nature of the services it enables. For example, energy distribution networks will be radically different in the future to meet government climate targets and this may impact wireless connectivity demands.
- **Making spectrum available for new uses**. We are supporting trials for various commercial applications of beyond line of sight drones by assessing the impact of a number of spectrum options for drone wireless control and data delivery.

- **Developing automated spectrum management tools.** We continue to improve ways for people to access spectrum via our online authorisation process, and we continue to explore the possibility of fully automating access to shared spectrum bands. We aim to be nimbler and more efficient in identifying and providing spectrum for a broad range of users.
- **Taking a leading role in international spectrum forums**. We engage extensively in the international community and hold leading positions in key groups. This includes the committee that oversees CEPT's[1] spectrum work, specific CEPT groups dealing with mobile issues, Wi-Fi and short-range devices, and the global ITU[2] group dealing with spectrum for the majority of terrestrial services.
- **Supporting the wide availability of key wireless services.** For example, we're supporting better indoor mobile coverage by improving the regulations for mobile phone repeaters; and enabling local access to mobile spectrum for indoor use to meet a wide range of demands.
- **Taking proportionate and robust enforcement action.** We investigate and monitor spectrum use to check compliance with authorisation terms and take appropriate enforcement action.

Living our strategic vision

Our strategy isn't about a single set of deliverables or decisions or a specific end point. It's about how we will approach the spectrum management challenges of the future, and how we will drive long term changes, that will provide the foundation for new and improved services for people throughout the UK. How we put our strategic vision into practice through our everyday activities over the coming years, is key to our success.

To ensure our strategy is effective in practice, we will:

- **Communicate it widely**, beyond this statement, in terms suitable for different audiences, so that the broadest range of stakeholders understand how we operate and what to expect from us, where to find information and how to engage.
- **Embed it in how we prioritise and approach our future spectrum management work**. This will be evident in our Spectrum Roadmap (setting out our future spectrum plans across sectors and bands), which will take account of our overall strategy.
- **Assess progress.** We want to keep track of how far we have progressed in taking forward our strategy, although we recognise there are some aspects, like the level of innovation, which cannot be directly measured. As a starting point we are developing a report, to be regularly updated, that shows how spectrum is allocated, the extent to which it is shared and the different ways it can be accessed.
- **Engage in a global conversation on future spectrum challenges.** Many of the challenges and opportunities identified through our strategy are not limited to the UK, and we cannot succeed by acting alone. We are therefore committed to a global conversation on spectrum management challenges for the future.

[1] The European Conference of Postal and Telecommunications Administrations (CEPT), which comprises of 48 member countries, including all EU Member States.
[2] The International Telecommunications Union (ITU), a specialised agency of the United Nations which oversees the allocation of spectrum around the world.

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

2. Introduction

2.1 The use of the radio spectrum benefits every person and organisation in the country. It helps to deliver our news, connect us to friends and family, automate factories and support public services. It is used for every type of wireless communication, from TV and radio to the very latest smartphones. It also supports important non-communications services, such as monitoring our climate and natural environment.

2.2 These benefits would not be possible if spectrum was used in an uncontrolled way. If every wireless device could transmit at any frequency or power, they would cause harmful interference to others, degrading or preventing communications altogether. Therefore, some form of regulation is appropriate to reduce the likelihood of interference and get the best out of spectrum use.

2.3 Spectrum itself is a valuable and limited natural resource and demand is ever-increasing as new wireless technologies and systems are developed. It is therefore more important than ever before that the spectrum available is used efficiently and that we continue to explore opportunities, enabled by technology, to open up spectrum at higher frequencies. Efficient use of spectrum means it can continue to transform the way we live and work – helping to make us more productive and benefiting industries across the economy.

The role of Ofcom

2.4 Ofcom is the UK's communications regulator and our duties are set out in statute. Our principal duty is to further the interests of citizens and consumers in relation to communications matters. As part of this, we are responsible for managing spectrum to support a wider range of electronic communications services across the UK and must ensure that its use is optimised.[3]

2.5 For us 'optimal use' means that spectrum is used in a way that maximises the benefits that people, businesses and other organisations derive from its use, including the wider social value of spectrum use.

2.6 Our overall mission is to make communications work for everyone. One important element in achieving this is to ensure the radio spectrum is used in the best interests of everyone in the UK – whether this is for running businesses, providing public services, undertaking scientific research or broadcasting the news.

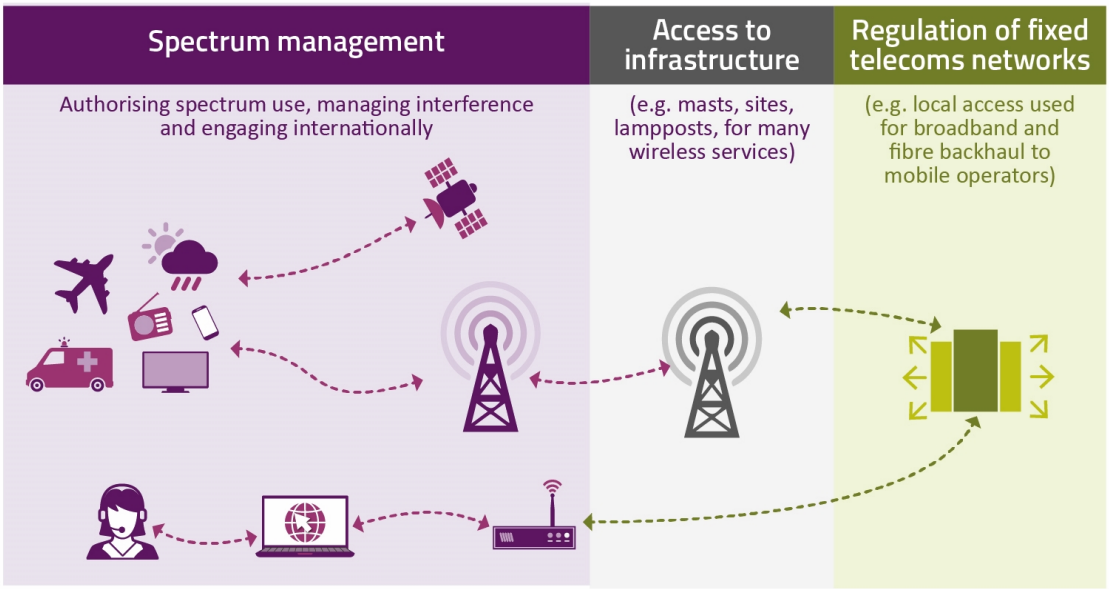
2.7 Ofcom is responsible for authorising access to spectrum and setting and enforcing the rules by which people can transmit radio waves, as well as representing the UK's interests in international forums on spectrum use. Our spectrum management work complements wider activities and functions to enable wireless communications, for example in regulating the fixed telecoms infrastructure that connects to wireless networks and broadcasting.

[3] Section 3 of the Communications Act 2003.

2.8 In addition to our spectrum management functions, we undertake a number of other regulatory activities, each of which is important for the full benefits of wireless communication to be realised. These are summarised in the diagram below.

2.9 Ofcom has specific duties related to spectrum in the UK as well as a wide range of other duties that need to be carefully balanced.[4] Further information about our legal duties is set out in Annex 3, 'Legal framework'.

Figure 1: Ofcom's wider activities supporting wireless communications



Development of our spectrum strategy

2.10 Having a spectrum strategy helps us to ensure that short and medium-term decisions fit within a longer-term framework. It also makes it clear to spectrum users how we would expect to manage spectrum, helping them to make their own longer-term decisions.

2.11 Our first strategy for managing the radio spectrum was set out in 2005[5] and most recently updated in 2014.[6] Since then, wireless communications in the UK have changed significantly.

2.12 Advances in technology, innovative applications and changes in how people and businesses use wireless communications services mean that our job is now more important than ever. These changes also mean that we need to consider updating our approach to tackle future challenges effectively and take full advantage of new opportunities.

2.13 On 4 December 2020, we published a consultation, "Supporting the UK's wireless future: Our spectrum management strategy for the 2020s". This consultation set out our proposed

[4] See, in particular, sections 3 and 4 of the Communications Act 2003 and section 3 of the Wireless Telegraphy Act 2006.
[5] 2005 Strategy
[6] 2014 Strategy

vision for spectrum management over the next 10 years. The consultation closed on 26 February 2021.[7]

2.14 Having taken account of respondents' views on our proposed strategy, we set out our decisions and our reasoning, including our consideration of relevant stakeholder responses in Annex 1 and 2 of this document.

Our use of market mechanisms and regulatory action

2.15 In our spectrum strategy consultation, published in December, we set out an overview of the core tools we use for managing spectrum. They do not represent everything we do, but they do provide the fundamental mechanisms for achieving our spectrum objectives.

2.16 We categorise them as follows: authorising spectrum use (and setting conditions for its use); managing interference through monitoring, compliance and enforcement; and representing the UK in international spectrum forums. These tools can be deployed in different ways: for example, they provide us with the ability to be more or less prescriptive about how spectrum can be used.

2.17 Since the publication of the spectrum strategy in 2005, and reiterated in our 2014 spectrum strategy update, our approach has been guided by the general principle of relying on the use of market mechanisms to determine the use of spectrum, where possible and effective, whilst undertaking regulatory action where necessary.

2.18 Where demand for spectrum exceeds supply, we may deploy specific market mechanisms, including:

- Spectrum pricing, to incentivise users to make efficient use of spectrum;
- The principle of greater licence flexibility ('liberalisation'), to enable types of use, to evolve where possible, without the need to request a technical licence variation from Ofcom;
- Auctions, when we believe there is competitive demand for spectrum as a way of enabling the market to decide the optimum allocation.
  We also enable spectrum rights to change hands by allowing spectrum trading and leasing agreements between licensees.

2.19 We recognise there are limits to a market-based approach. For example, there is an important and complementary role for Ofcom to play in ensuring the optimal use of spectrum when major changes are being contemplated and frequencies need to be recycled.

2.20 We therefore consider a combination of both market mechanisms and regulatory action may be required to achieve our spectrum management objectives.

[7] All non-confidential responses to the December 2020 consultation are available on our website.

Continued use of our existing tools to address our objectives

2.21 This statement sets out new areas of increased focus which will sit alongside our long-established approach to spectrum management.

2.22 In many cases, our existing spectrum management tools and approach are likely to provide sufficient flexibility to adapt to future developments and help us achieve our objectives.

Structure of this document

2.23 The remainder of this statement document concentrates on new areas of focus for our spectrum management strategy over the next ten years.

2.24 This document is structured as follows:

Section 3: sets out our spectrum strategy in full;

Annex 1: identifies the key themes raised by stakeholders as we developed our strategy;

Annex 2: summarises individual responses to our December 2020 consultation and addresses those on our proposed strategy;

Annex 3: sets out the legal framework within which we have developed our spectrum strategy;

Annex 4: is a glossary.

3. Our spectrum strategy

3.1 Growing demand for spectrum is being driven by increased use of wireless connectivity across different industry sectors and by the impact of new technology developments, leading to new and innovative applications. This calls for a shift in the way we approach spectrum management.

3.2 We want to enable growth and innovation for both existing and new users of wireless services through more efficient and flexible use of the radio spectrum. Our strategy will guide how we manage the radio spectrum for the next 10 years.

3.3 The strategy is shaped by our vision for spectrum management and the objectives we want to achieve. It has been developed within a wide context of trends affecting wireless services. We have considered changes in the external context; in technology development and in the way market demand for new applications is evolving.

3.4 Our work will focus on three key areas where we will prioritise action. These are instrumental in delivering our objectives, and in enabling innovation and growth across all sectors. They will be at the centre of our policy decision making. They are:

1. **Supporting wireless innovation**;
2. **Licensing to fit local and national services**; and
3. **Promoting spectrum sharing**.

3.5 Our strategy will inform the way we exercise our existing responsibilities in spectrum management, such as authorisation of spectrum use (through licensing or licence-exemption); management of interference; representing the UK in international forums etc.

3.6 This strategy is also framed within an international context. We want to create an international platform for discussion around future spectrum management challenges.

Improved wireless communication for people and businesses

Our vision for spectrum management

3.7 Our overall mission is to make communications work for everyone. One important element in achieving this is to ensure spectrum frequencies are used in the best interests of everyone in the UK – whether this is for running businesses, providing public services, undertaking scientific research or broadcasting the news.

3.8 Based on our statutory duties and functions we have identified the key strategic objectives that underpin our spectrum management vision. They are:

Spectrum management vision

Continued improvements in the wireless communications used by everyone, wherever and whenever they use them.	There is a core set of wireless services and technologies that nearly everyone uses and depends on in their everyday lives and to support businesses and public services. These currently include mobile, Wi-Fi, wireless connections (like Bluetooth) between our growing range of gadgets, broadcast radio and television services and satellite navigation. ***We want to enable these services to continue to improve, wherever and whenever people use them, to meet increasing and changing needs.***
Businesses, public sector and other organisations with specialised requirements to be able to access the right wireless communication or spectrum options for them.	Growing and innovative use of wireless communications can support the continued transformation of all types of organisations delivering different applications throughout the UK; from managing electricity networks, to controlling robots in warehouses and air traffic control. Some organisations also have specialised scientific requirements that can only be met by using specific frequencies, eg to monitor our climate. ***We want to meet the spectrum needs of potential and future users with specialised requirements.***
Increased flexibility in spectrum use to support innovation, with appropriate assurances for continued use.	We can't accurately predict what new wireless services will emerge in coming years or which ones will bring most benefit to people in the UK. ***We aim to provide flexibility in spectrum use that enables innovation to flourish. Complementing this, we will continue to ensure there are appropriate assurances for continued use of spectrum, both to support existing benefits from wireless services and to provide conditions for future investment.***
Sustained improvements in the efficiency of spectrum use.	The radio spectrum is a finite natural resource, so ultimately all new and improved wireless services for people in the UK depend on making more efficient use of this resource. ***We aim to create the conditions where efficiency of spectrum use can continue to increase over time, for example as a result of greater sharing of spectrum, deployment of new technologies and 'recycling' of spectrum from lower to higher value uses.***

Trends affecting communications have informed our work

3.9 Our vision for spectrum management has taken into account the evolving market and changing technology context. The use of wireless communication is expanding and benefiting a wide range of users from consumers to more specialised services. Additionally, technology developments are opening up opportunities for more innovative users and the ability to use higher frequencies that were not possible before. These market trends are the backdrop to our vision and its implementation.

3.10 We have identified three categories of trends affecting use of wireless, to reflect the external market context and wider socio-economic changes that are likely to rely further on wireless solutions; the technology developments and how these could enable the wireless services of the future; and how new applications could drive changes that will, in the end, increase the demand for spectrum.

3.11 The table is not exhaustive and not all the trends identified are directly linked to spectrum management. However, they could all potentially influence how spectrum is managed and used now and in the future.

Illustration of future trends potentially relevant for spectrum management

Category	Examples
Changing external context	**Healthcare and wellbeing** digital requirements will continue to diversify. This could include greater use of wearable technology and medical devices to enable preventative care, smarter diagnoses or management of long-term conditions. Such technologies could enable greater population health management. There might be greater use of automation to help care for the needs of an ageing society and those with disabilities.
	Environmental concerns will continue to change how people and businesses behave, and the economy, as the UK moves towards its 2050 greenhouse gas net zero target. There will likely be increasing focus on low-power communications services to reduce overall energy consumption. Manufacturers will look to make equipment more durable and recyclable. Spectrum will become more important in enabling other industries to reduce their environmental impact such as through asset monitoring, smart utilities management or climate monitoring. Climate changes could also result in changes to how signals propagate, affecting the risk of interference between spectrum users.
	The **resilience and security of UK infrastructure** has become increasingly crucial as the economy and people's lives become more reliant upon digital services. This is driving greater concern in ensuring the UK's telecoms infrastructure is safe and secure. This could also mean greater use of wireless communications for remote monitoring and management of critical infrastructure sites and equipment.
	The longer-term implications from **COVID-19** might include greater home or flexible working, placing greater demands on connectivity in the home. Over time

Category	Examples
	there might be population dispersal if more people opt to move away from cities and towns, placing further importance on rural connectivity.
Changing technology	Over time there will be more use of much **higher frequency bands for** wireless services. These higher frequencies allow far greater network speeds and capacity with the potential for improved consumer experiences. These spectrum bands also have different propagation characteristics and so have different management requirements.
	Radio technology will continue to progress. We anticipate continued technology evolution in areas such as beam forming, network self-optimisation, Multiple Input Multiple Output (MIMO) and Massive MIMO, compression technologies and network slicing. These advances will enable more efficient use of spectrum, alongside more products and services being able to access the spectrum they need, when they need it.
	On the one hand, deployment of increasingly **localised telecoms infrastructure** will continue, enabling more devices, more data use, and quicker connectivity responses. 5G (and in the future 6G) will likely be an important, but not the only, driver of this. On the other hand, **more centralised network functions** will enable real-time interference coordination between sites (including distributed MIMO) leading to better resource utilisation but requiring very high-speed connections within the network.
	Satellites have already transformed our lives through satellite navigation, weather monitoring, and other space-based services. Over time there will be more satellite deployments, with satellite constellations growing to potentially thousands of satellites. These could enable improved broadband internet in remote locations, and even greater insight into how our climate is changing.
	Retirement of analogue services in favour of newer digital means will continue.
Changing application demands	People and businesses will continue to have **growing capacity demands**. For example, increasing consumer use of communications devices, and the importance of AI and data analytics to improve processes mean there will be ever growing quantities of data moving across networks. Technologies such as augmented reality, virtual reality and haptic controls can have demanding latency and throughput requirements, and 3D printing can require large data transmission volumes.
	Consumers are using many **more smart devices**, both in and out of the home. This includes many previously unconnected devices being connected, and also new products and services which are being used for communications, home security, and appliance management, amongst other uses. Over time, new interfaces (like smart glasses) might become more prevalent.

Category	Examples
	Super reliable services will become more prevalent and important. This might be for use in medical or health devices, or in power or utilities sectors. In some contexts, there might be a shift towards requiring wireless to exhibit near-equal characteristics as wired connections. There might be increasing complementarity between fixed and wireless services, beyond communication services, through product convergence and service substitution.
	Smart city & industrial Internet of Things (IoT) [8] will develop with diverse communication requirements. This might include low-power, long-range transmission or high data rate 3D video for real-time analytics. Industrial IoT uses could include smart inventory management, pallet tagging, security and sensing. Smart agriculture use cases might include precision irrigation and crop/livestock monitoring.
	Robotics and drone usage might become increasingly common, such as in industrial contexts to check assets for damage, factory automation, to provide short term connectivity or for use in environments where it would be dangerous for people. Drones might require a combination of low latency, ultra-high reliability and high download and upload speeds. There might also be increased use of robotics and automation in the home, such as for medical care.
	Connected vehicles are a reality. There will be more vehicle-to-everything communication, such as to traffic management services and enhancements to vehicle safety through intelligent transport systems and assistive driving technology. Semi-autonomous, and autonomous vehicles, will have diverse communication requirements.
	Lastly, **technology can develop in unpredictable ways**. Over time there will likely be increasing numbers of niche entrants and sub-national providers to cater for specialised requirements. Having the right spectrum available for users at the right time will enable innovation.

Delivering our vision

3.12 We have identified three areas of increased focus and action to deliver against our vision. These are informed by current trends and will guide our work addressing future spectrum management challenges.

[8] The Internet of Things (IoT) is a term used to describe the aggregate network of devices and sensors, which is able to collect and share data with people or with other devices, and to take actions based on this data. IoT has applications in different sectors, such as healthcare, utilities, manufacturing, consumer electronics, and smart cities among others.

Areas of increasing focus

Supporting wireless innovation	We will make it easier to access spectrum by: • Making more spectrum available for innovation before its long-term future use is certain, **spectrum for pioneers**; • Working to support **innovation in new wireless technologies**, • Expanding the work to **understand, assist and inform** the broad range of organisations who may benefit from wireless technologies in the future;
Licensing fit for local and national services	We will: • Support the growing diversity of wireless services and providers by considering further options for **localised spectrum access** when authorising new spectrum use. Licences for larger areas, including national licences, can support wide coverage for public mobile services.
Promoting spectrum sharing	We will encourage: • Use of better data and more sophisticated analysis when assessing the conditions for sharing; • Wireless systems to be more resilient to interference from their neighbours; • An efficient balance between the level of interference protection given to one service and flexibility for others to transmit.

Supporting wireless innovation

3.13 Further innovation in wireless technologies and applications is key to enabling even greater benefits from use of the radio spectrum in the future. Innovation will deliver against our vision of continued improvements in new and existing services and increased flexibility and efficiency in the use of the spectrum.

3.14 We will aim to support innovation by making it as easy as possible for different types of organisation to access the right spectrum to meet their needs.

3.15 We will support flexibility in spectrum use to deal with unpredictable future requirements, noting that reducing the barriers for new entrants can also promote greater competition in wireless technologies and services.

3.16 Technology developments are opening up opportunities to use extremely high frequency spectrum above 100 GHz for a wider range of wireless applications; as we work to open access to this spectrum, we want to stimulate wider thinking about the new opportunities enabled by the characteristics of this spectrum, and the different coexistence environment, which may require different approaches both nationally and internationally.

3.17 Our approach to supporting wireless innovation falls into three key areas, which we cover in more detail below; these are:

- **Spectrum for pioneers:** we will make more spectrum available for innovation before its long-term future use is certain, using flexible technical options and by retaining an ability to change licence terms.
- **Supporting innovation in wireless technology:** we will reduce the barriers for wireless innovators by placing greater emphasis on technology and service neutrality and

ensuring that companies – particularly smaller ones – are aware of the flexibility of existing technical conditions.

- **Understand, assist and inform:** we will engage with all spectrum users through an outreach programme, improved reporting and information tools.

Spectrum for pioneers

3.18 In supporting wireless innovation, we will make more spectrum available for those who want to innovate, before we determine the long-term future use of that spectrum, but without limiting options for future use.

3.19 We will offer a range of ways to ensure flexible access to spectrum, to facilitate innovation and to meet the various ways in which such demand might materialise. This will create more opportunities than might otherwise be afforded by our existing Innovation and Trial licences.[9] One example is the work we have undertaken to enable greater access to frequencies in the 100-200 GHz band in support of innovation.[10] As technology is enabling the use of spectrum above 100 GHz, we want to stimulate wider thinking about the new opportunities enabled by the characteristics of this spectrum in light of the different coexistence environments.

3.20 Our approach will:

i) **look for technical options** where use can be authorised without preventing future alternative authorisations i.e., they can technically coexist; or

ii) **retain the ability to change** the authorisation approach and conditions for use of the band in the future, if appropriate and proportionate, to maintain efficient management of the spectrum. This includes, for example, considering the use of "light licences" rather than exempting users from the need to hold a spectrum licence; using licence terms that would enable us to notify licensees to change frequency (requiring equipment and spectrum users to be 'frequency agile'); and considering setting a shorter notice period for making changes for spectrum management reasons.

3.21 Whilst supporting innovative uses, we recognise the importance placed on the benefits to the UK of existing services that rely on spectrum. To that end we undertake careful assessments of the impact on existing users when introducing new users. When coexistence is possible, we will continue to provide appropriate assurances of continued use for existing and new users. We have set out how we would support spectrum sharing by encouraging spectrum users to be 'good neighbours' in paras 3.55-3.73.

3.22 Our work to enable innovation and open opportunities for new uses will continue to be framed against international discussions on harmonisation. We recognise the importance of harmonised standards to drive innovation and economies of scale, when appropriate,

[9] Innovation and Trial licences are part of an existing licensing framework within Ofcom that supports access to spectrum for innovation on a non-commercial basis. See Innovation and Trial licensing: Guidance notes for applicants 2018

[10] Supporting Innovation in the 100 - 200 GHz band

and we also acknowledge how standards can at times set too restrictive conditions. We will continue to work internationally to ensure harmonisation solutions are to the benefit of UK services.

3.23 We want to make sure all spectrum users are aware of future potential changes as we understand the importance of a stable environment when companies are trying to attract investment. The Spectrum Roadmap will indicate future spectrum areas of focus, including potential changes in spectrum use. We believe this will give stakeholders the guidance and information they need to inform their investment options.

Supporting innovation in wireless technologies

3.24 We want to encourage innovation wherever possible to ensure consumers and businesses can benefit from new wireless applications and devices.

3.25 We will introduce further support for smaller innovators and developers by reducing the barriers to entry – perceived or real – by:

- Placing greater emphasis on promoting technology and service neutrality through our engagement in international harmonisation processes.
- Ensuring that companies – particularly smaller ones – are aware of the flexibility that existing generic technical conditions provide them.

3.26 The greater emphasis on promoting technology and service neutrality, including in the specification of rules to ensure coexistence with existing users where appropriate, will provide flexibility for new users. This is the approach we took to increasing access to spectrum in the 100-200 GHz range.

3.27 We will seek to influence the development of international recommendations and standards for equipment that are flexible enough to support a wide range of uses. We recognise the challenges in aiming to secure greater technology and service neutrality through internationally agreed harmonisation but note that this aim is also reflected in the principles developed by bodies such as CEPT. We will continue to devote the necessary resources towards supporting this aim.

3.28 Ofcom remains committed to working within international organisations and to taking a leading role in decisions about the future use of radio spectrum. We are already working with other European administrations to examine the use of airborne equipment on mobile networks. However, we note there may be circumstances where UK-specific approaches – including through the use of UK Approved Body (GB) process[11] – may provide opportunities for developers, where practical and where international agreements allow.

3.29 We will explore with Government whether the Approved Body process can be simplified and/or better coordinated in order to support innovation. At present, the burden of proof

[11] The UK Approved Body process allows a body accredited by the UK Accreditation Service (UKAS) to approve new types of equipment more straightforwardly, in accordance with the UK radio equipment regulations.

is on the developers to show that their new equipment uses appropriate techniques to access spectrum and mitigate interference.

3.30 We will seek to expand our engagement with stakeholders beyond existing licence holders to ensure they are aware of the flexibility that existing generic technical conditions provide them.

Understand, assist and inform

3.31 We will expand our programme of work to understand, assist and inform the wide range of organisations who may benefit from wireless technologies in the future. By doing this we will enable a wider range of users to access the spectrum they need when they need it, with a clear understanding of all potential options. This will ensure continued improvements in wireless services - including those with more specialised requirements e.g. for very high reliability or secure communications.

3.32 We will increase our outreach programme of work, improve and increase our reporting on spectrum management and use, and further develop our spectrum information systems to meet the needs of different stakeholders' groups with different levels of spectrum awareness.

Outreach

3.33 We will identify additional appropriate forums beyond our current platforms, to engage with organisations that are supporting UK's digital transformation.

3.34 We will expand our workshops and engagement with verticals[12] around market development and future demands as well as emerging technology. This will ensure we reach out to the sectors not traditionally spectrum orientated - for example, organisations involved in the provision of health care, smart cities, logistics and ports, manufacturing etc.

3.35 We will seek to improve the way we communicate with stakeholders, for example through the use of infographics or videos to explain and simplify what we do. We already make use of social media platforms and will seek to make use of this medium further as appropriate.

3.36 We will continue to review the way we engage; the types of engagement we make; and who we engage with.

Reporting

3.37 There is a growing appetite from stakeholders for more accessible information and updates from Ofcom. Improved reporting could also create an opportunity to encourage better coexistence, by providing licensees and other stakeholders with up to date information about the spectrum users in the neighbouring bands.

3.38 We will publish a Spectrum Roadmap, that will consider the range of market, technology and international developments affecting demand for spectrum and explore the associated

[12] By 'verticals' we mean the businesses and organisations deploying wireless connectivity solutions.

opportunities and challenges for our programme of work. We aim to enable and encourage greater utilisation of spectrum and the development of new, innovative applications. We are committed to publishing the first roadmap in Q1 of 2022.

3.39 We intend to publish a report to provide a simple and consolidated view of how much spectrum is accessible to different industry sectors; how extensively it is shared; and the options available to us for assigning spectrum to individual users.

Information tools

3.40 Our objective is to engage with all users (spectrum aware and less spectrum aware users)[13] and make sure they can access the information they need and understand the options that meet their requirements.

3.41 We are reviewing and, where necessary, upgrading our spectrum information tools, including the Spectrum Information System (SIS); [14] the interactive UK Frequency Allocation Table (UKFAT);[15] and Spectrum Map.[16] We will consider whether we could make improvements to functionality and performance, as well as whether there is additional information we can share.

3.42 We are modernising our spectrum licensing platform, leading to a single system for most Ofcom spectrum licences. It will deliver an improved online user experience for licensees; and platform tools that will add to the quality of licensing and the coordination of information shared between licensees and Ofcom. We expect online users to start to see the benefits of this programme by the middle of next year.

3.43 We will improve accessibility and navigation of spectrum-related information on our website, expand and improve the useful online guidance we provide to stakeholders, and consider whether to release more information that we collect. For example, remote spectrum monitoring data to provide additional information about the use of spectrum in geographical areas. However, in some cases we might not be able to make data publicly available. For example, due to commercial confidentiality or security concerns.

3.44 We will assess the need for Application Programming Interfaces (APIs) to access spectrum management data.[17]

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[13] **Spectrum aware:** users who may be most interested in applying for new licences and managing their existing ones. These users may seek information about existing use that may help them to plan new deployments; and about policy or technical changes that may impact their interests; **and Less Spectrum aware**: users who may need additional information, or may approach spectrum-related issues in a different way. For example, they may be more familiar with the language of technologies (e.g. 4G, Wi-Fi) than the technology-neutral terms we use to describe spectrum bands and licence products

[14] The SIS allows users to view how different frequency bands are authorised, maps licence locations and gives details on issued licences and licence trades. It draws on data from the Wireless Telegraphy Register (WTR), the Transfer Notification Register (TNR) and the UK Plan for Frequency Authorisation (UKPFA).

[15] The interactive version of the UKFAT reflects current UK spectrum allocations as well as international allocations of the ITU.

[16] The UK Spectrum Map shows how spectrum is used, by sector and by product/application on a band by band basis.

[17] We have separately been providing new ways of accessing other data we hold. For example, our Communications Market Report is an interactive data portal, containing data across telecoms, TV, radio, post and online, that can be interrogated in many ways - see https://www.ofcom.org.uk/research-and-data/multi-sector-research/cmr/cmr-

3.45 Further, we will utilise various social media channels to reach a wider audience and to promote our guides, where appropriate.

Licensing to fit local and national services

3.46 We will support the growing diversity of wireless services and providers by considering options for localised spectrum access when authorising new access to spectrum.

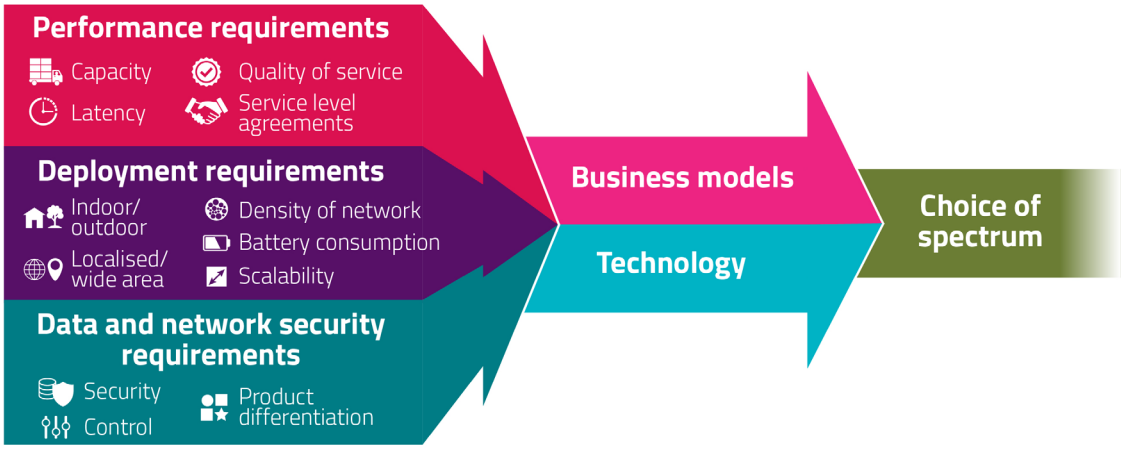
3.47 Local access can suit a range of businesses and specialised services at sites like factories, airports and remote farms, which do not need to use spectrum across the whole UK. We will continue to make spectrum available through larger, including national, licences which can support wide coverage for public mobile services.

3.48 We recognise the growing opportunities for businesses and organisations right across the economy and society to benefit from greater use of wireless communications.

3.49 Industries are increasingly engaged in a journey towards 'digital transformation', constantly evolving and innovating to achieve greater productivity, reduce costs and improve the quality of service they offer to their customers. Wireless connections are enabling different operators to achieve their digital transformation objectives. Industries such as utilities, agriculture, logistics and transport are all benefitting from this.

3.50 Different users across different sectors will have different business objectives driving a wide range of requirements (see diagram below). Wireless technology developments, including 5G and evolving LTE and Wi-Fi technology, are expected to deliver increased flexibility, reliability and capacity to help meet a broad range of performance requirements.

Different requirements for wireless solutions

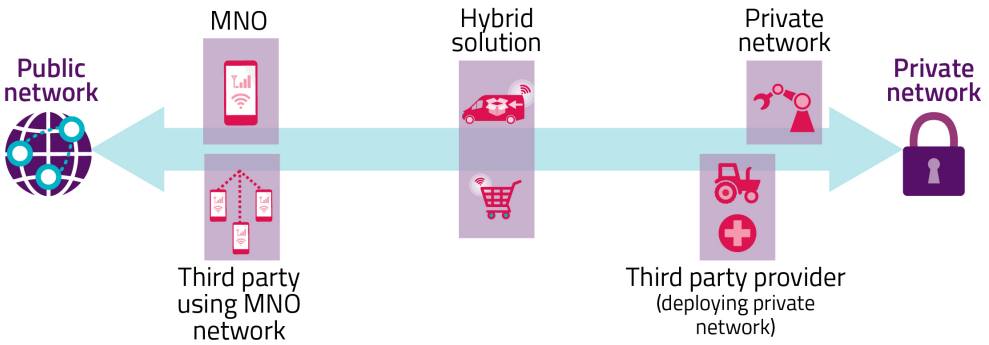


3.51 These requirements will drive the choice of technology and business model. Some of these new applications could be delivered via public mobile networks. Other users and

2020/interactive. We have also developed APIs for our Connected Nations coverage data as well as nationwide broadband and mobile coverage.

applications are likely to have requirements which may be better met by other technologies and/or network models. For example, access to radio spectrum enabling private networks.[18] This trend is likely to lead to increasing demand for localised spectrum in the future.

Potential business models for deploying wireless connectivity



3.52 We have an established authorisation framework with a range of authorisation tools to address different types of spectrum use and demand. This includes a range of licence products which users can apply for on a first-come-first-served basis, as well as licence exemptions for the use of certain types of equipment.

3.53 We continue to adapt our authorisation framework to meet changing spectrum needs. In 2019 we introduced a new licensing approach to provide localised access to a number of spectrum bands supporting mobile technology. This made spectrum in the 3.8-4.2 GHz, 1800 MHz, 2300 MHz and 24.25-26.5 GHz (for indoor-only deployment) bands available through local licences (Shared Access licences). Potential users can apply to Ofcom for coordinated access to these bands in specific locations on a first-come-first-served basis.

3.54 We also introduced a new way of accessing spectrum that is already licensed to mobile operators, but which is not being used or planned for use in a particular area within the next three years (Local Access licences).

Promoting spectrum sharing

3.55 It is more important than ever before that spectrum is used efficiently, in order to maximise its use for the benefit of consumers and business, and to support further innovation. One important way to secure increased efficiency is to promote greater sharing of spectrum between different users, wherever possible.

3.56 Enabling more users in the same or adjacent spectrum bands is inherently more efficient and beneficial, so long as we can achieve this without unreasonably degrading the quality of services provided. This relies upon an assessment of how close together these different

[18] In a public network the network capacity is shared between different users. In a private network the capacity is normally reserved for use by a single organisation, and a spike of traffic in proximity of the organisation does not have any impact on the quality of service for that organisation.

users can be without causing material impacts to each other. We believe there is more users can do to be 'good neighbours' when using spectrum.

3.57 One aspect of being a good neighbour is for the emissions of transmitters to be limited appropriately to ensure interference to other users is minimised. Additionally, if systems are not as good as they could be in protecting themselves from interference, then operators deploying those systems could experience problems when new neighbouring services are introduced.

3.58 We will encourage spectrum users to be 'good neighbours' by adopting and promoting the following approaches as a key element of our strategy to support more spectrum sharing:

- Use of better data and more sophisticated analysis when assessing the conditions for sharing; we want to take a more realistic approach to co-existence analysis.
- Wireless systems to be more resilient to interference from their neighbours; we want to encourage users to recognise the benefits of planning for the evolving radio environment in which they operate.
- An efficient balance between the level of interference protection given to one service and flexibility for others to transmit.

These are explained in more detail below.

Increasing realism in coexistence analysis at a national and international level

3.59 There is always a broad range of theoretical scenarios in which radio interference is possible between different spectrum users. However, when we are considering opportunities for more users to share spectrum, we want to ensure that we challenge the likelihood of these scenarios happening in practice and the scale of impact even if they do. This is key to making sure that we don't over-protect services and thereby limit the scope for spectrum sharing.

3.60 We will therefore use information regarding the real performance of equipment and services where this is available rather than particular equipment standard limits. This ensures that services and equipment performance are fairly taken account of in our coexistence analysis in a way that reflects their likely performance in practice.

3.61 It is reasonable for users providing valuable current services to be cautious about unknown future services that may wish to operate alongside them. We will therefore adopt a pragmatic approach, prioritising the coexistence analysis that offers the most opportunities for increased spectrum use. We expect to continue to consult on our co-existence analysis before the introduction of new uses to specific spectrum bands.

3.62 We will devote an appropriate level of resources to the process of ensuring analysis and information remains valid - and that standards, regulations and conditions are reviewed and adjusted as necessary. As part of this, we are updating the propagation models and datasets we use in order to keep our spectrum management framework up to date.

3.63 We are also undertaking a long-term radio noise monitoring campaign in the UK to better understand its impact and to understand how the radio noise levels have changed. This will help us to refine our approach towards coverage reporting and spectrum authorisation.

3.64 We will consider the use of authorisation tools (including automated spectrum management tools) that enable us to set technical conditions more realistically, for example by limiting deployment in certain locations, channels or at times in order to protect other users, or allowing us to adjust technical parameters over time.

3.65 In addition to implementation in the UK, we will take a leading role in promoting these reforms internationally to ensure they have the greatest benefit. We will utilise our strong position in international regulatory forums and work with other spectrum regulators to drive improvements in relevant international decisions, recommendations and standards.

Encouraging spectrum users to be more resilient to interference

3.66 We believe it is essential to encourage spectrum users to be more resilient to interference, noting it is not actually possible to guarantee spectrum will be interference-free. We wish to signal to operators that we will not generally expect to take action on interference if it is a result of the poor performance of receivers or wider systems.

3.67 When permitting new services to share with existing ones, we will continue to set and enforce appropriate technical conditions that enable existing users to continue to operate. However, it remains the responsibility of spectrum users and equipment manufacturers to manage the remaining risk of interference resulting from these technical conditions. To assist with this we will ensure our technical assumptions are made clear when dealing with specific bands and services.

3.68 Our approach to encouraging greater resilience will be progressive. We will consult with stakeholders as appropriate and will not take specific action - such as changing licence conditions or equipment specifications - without considering all relevant factors.

3.69 Our encouragement of greater resilience to interference may lead us to consider the use of differential spectrum pricing to incentivise better interference rejection capabilities.

Determining efficient protection levels

3.70 To ensure an efficient balance between the level of interference protection given to one service, and the flexibility for others to transmit, we will continue to intervene robustly to ensure equipment and systems that cause undue interference to other current or future users are brought into line or cease to operate. This is of equal importance as ensuring equipment is itself resilient to interference both now and in the future.

3.71 We consider there may be circumstances where the application of differential pricing may be appropriate to allow more efficient use of the spectrum (recognising this will not suit all cases). Setting different protection pricing levels can be very complex so we will consider this on a case by case basis, looking at creating the right incentives without distorting competition or preventing fair access to spectrum.

3.72 We consider it important to signal to stakeholders that our proposals represent a 'direction of travel' for spectrum management. Incumbent users, and new users who may become incumbents one day, need to take note of our overall strategy when deploying, redesigning or upgrading systems to ensure that they are using equipment that offers good resilience to interference and does not itself cause interference to other users.

3.73 We expect stakeholders to be ready to present evidence-based analysis to support the level of protection they may be seeking.

Conclusions and next steps

3.74 Our spectrum strategy isn't about a single set of deliverables or decisions. It's about how we will approach the spectrum management challenges of the future, and how we will drive long term changes, for example in spectrum sharing, that will provide the foundation for new and improved services for people throughout the UK.

3.75 Delivering our spectrum management vision will build on the areas of increased focus and will also leverage the established tools and approaches we use to discharge our functions. The table below summarises all aspects of our spectrum management approach: those things we will continue to do, using our established tools and approaches along with those areas of increased focus (in bold). Where approaches are relevant to achieving more than one objective, they appear in multiple rows.

Summary of our continued work and proposals to address our spectrum management objectives

Objective	**To achieve this objective, we will**
1. Continued improvements in the wireless communications used by everyone, wherever and whenever they use them	- Review demand and make spectrum available to enable improved wireless connectivity - Take a leading international role - Enable wide availability of core wireless services - **Consider further options for localised spectrum access** when authorising new access to spectrum - **Support innovation in wireless technologies**, including by influencing the development of international standards and decisions so that they have greater flexibility for new technologies and applications
2. Business, public sector and other organisations with specialised requirements to be able to access the right wireless communication or spectrum options for them	- Work with existing spectrum-using sectors and stakeholders and reach out to potential future users - Make spectrum available to suit the needs of different users and business models - Improve the quality and quantity of spectrum information - **Consider further options for localised spectrum access** (as above) - **Support innovation in wireless technologies** {as above) **Expand our work to understand, assist and inform** the wide range of organisations who may benefit from wireless technologies in the future

3. Providing flexibility in spectrum use to support innovation, with appropriate assurances for continued use	- Make spectrum available in a variety of ways, including licences specifically for innovation and trials - Continue to develop automated spectrum management tools - Define flexible spectrum rights - Promote an appropriate level of international harmonisation - Provide appropriate assurances of continued use for existing and new users - **Support innovation in wireless technologies** (as above) - **Expand our work to understand, assist and inform** (as above) - **Make more spectrum available for innovation** before its long-term future use is certain - **Promote spectrum sharing** (see below)
4. Encouraging sustained improvements in the efficiency of spectrum use	- Use market mechanisms to increase efficiency of spectrum use - Take regulatory action when necessary and proportionate to support efficient use, including recycling of spectrum - Authorise shared use of spectrum - Develop our use of automated spectrum management tools to support spectrum sharing - Promote improvements in radio performance standards - Work with Government to promote efficient use of spectrum by the public sector - **Promote spectrum sharing**, though encouraging: o Increased realism in coexistence analysis at a national and international level o Users to be more resilient to interference o An efficient balance between the level of protection given to one service and the flexibility for others to transmit - All other spectrum management strategy proposals also contribute to this objective

3.76 To ensure that our strategy is effective in practice we've identified a number of actions that follow or build on this document.

Communicate the strategy widely

3.77 We will communicate our strategy widely, beyond publishing this statement, so that the broadest range of parties understand how we operate and what to expect from us.

3.78 These include established stakeholders (who may have responded to our consultation), new spectrum users across a range of industries, public sector spectrum users, equipment manufacturers, and other regulators around the world.

3.79 To help communicate with a wider set of stakeholders, who are not familiar with spectrum or its management, we will produce an 'easy guide' (in written and/or video formats) to the strategy and spectrum management more generally.

3.80 We will continue our programme of work engaging with different industry sectors to outline the role spectrum plays in enabling connectivity and the different types of spectrum (frequency range, bands and authorisation methods).

Embed the strategy in our future work

3.81 Publication of the strategy statement is one important step, but to ensure it delivers on its promise we will embed it in how we prioritise and approach our future spectrum management work.

3.82 One specific example is the development of our Spectrum Roadmap. This will outline the changing market and technology context and will take account of our strategy in making strategic choices over what to prioritise in order to progress our spectrum vision. The Roadmap will set out future spectrum plans across sectors and bands for coming years.

Monitor our progress against the strategy

3.83 We want to keep track of our progress in taking forward our strategy. We recognise however that there are some aspects, like the level of innovation, that cannot be measured directly - and others where any measure can only be an imperfect proxy.

3.84 As a starting point we intend to publish a report to show how spectrum is allocated, the extent to which it is shared and the different ways it can be accessed. We will consider other mechanisms for tracking progress and communicating this to stakeholders, for example through our spectrum roadmap and periodic stakeholder events.

Engage in a global conversation on future spectrum challenges

3.85 Many of the challenges and opportunities identified through our strategy, particularly in relation to promoting spectrum sharing and good spectrum neighbours, are not limited to the UK, and we cannot act alone. We are therefore encouraging a global conversation on spectrum management challenges for the future.

3.86 On 6 July, we kicked off this conversation with an international stakeholder event, with more than 200 attendees. The event highlighted challenges but also our experiences to date in tackling certain issues, and a willingness to work to find solutions for the long term.

A1. Responses to our consultation – Themes

A1.1 We had extensive engagement on our proposals, and the responses from stakeholders have informed the decisions we set out in Section 3. In this section we summarise the main themes of the comments stakeholders made and our responses to these followed by a more detailed summary of the individual responses in Annex 2.

General comments on our approach

Sector specific issues

A1.2 Several stakeholders asked us to set out our approach to specific sectors or bands. As we set out in the consultation, our aim is to define our vision through the high-level objectives we want to achieve and the areas of focus that will help us deliver those. It therefore provides a longer-term framework for us to consider the needs of individual sectors and the range of specific policy issues that have been raised.

A1.3 We will address these issues through specific projects, within the context of our increased areas of focus. Annex 2 includes the summary of sector and band specific comments that we will feed into our ongoing work.

Taking a leading role internationally

A1.4 Stakeholders made comments on international issues as they relate to our specific proposals – where appropriate we address these later in this section. However, more generally, several stakeholders commented on the importance of Ofcom's engagement with international bodies, including CEPT and ITU.

A1.5 Stakeholders felt that this was important if the UK is to benefit from economies of scale. One stakeholder asked for more detail on how Ofcom intends to ensure it continues to take a leading role internationally, now the UK has left the EU and Ofcom no longer attends the Radio Spectrum Policy Group (RSPG)19 or represents the UK in the Radio Spectrum Committee (RSC)20.

A1.6 Ofcom remains influential in driving global spectrum policy and plays an active thought leadership role within the International Spectrum Community, including the CEPT and ITU. We also work closely with international partners, both inside and outside Europe, to better understand their priorities, appropriately taking these into account and making us well-placed to deliver optimal outcomes for the UK.

[19] The RSPG is a high-level advisory group that assists the European Commission on the development of radio spectrum policy.
[20] The RSC is a legislative committee composed of EU Member States representatives chaired by the European Commission, which develops and votes on technical harmonisation decisions on spectrum use across the European Union.

Public value

A1.7 Arqiva and three confidential respondents said that we need to recognise the social as well as the economic benefits of access to spectrum. One said that Ofcom needs to work for the public interest rather than private investors.

A1.8 When we seek to achieve optimal use of the spectrum we aim to do so in a way that maximises the benefits that people and businesses derive from it, including the wider social value of spectrum use. Determining the indirect value of spectrum use can be difficult but we believe we can reach robust decisions on the basis of a qualitative assessment of the relative wider social value of services. When we seek to achieve optimal use of the spectrum we aim to do so in a way that maximises the benefits that people and businesses derive from it, including the wider social value of spectrum use.

UK interests

A1.9 Some stakeholders said we should take account of UK industry interests, to support the provision of their services overseas, or the use of spectrum to advance UK objectives outside of the UK. These objectives may be commercial or public policy based, but are pursued to benefit the UK, its citizens and consumers.

A1.10 Two confidential respondents were concerned that the strategy focusses too much on domestic priorities. They said that much of spectrum used by the space sector must be coordinated internationally and that issues may arise when Ofcom's citizen and consumer focus comes into conflict with wider priorities not directly related to consumer benefits.

A1.11 Ofcom represents the UK in international forums that deal with spectrum. We can and do take account of wider UK public interests in our international representation work as we consider appropriate. These interests may include public safety, national security and governmental policies relating to economic growth. We may consider these interests even where services are not direct to UK consumers and citizens, for example by participating in international discussions on in-orbit servicing of satellites.

Trends

Trends impacting spectrum management

A1.12 We received general agreement from stakeholders that we had correctly identified the major trends. Additional comments on the identified trends are addressed in Annex 2.

A1.13 One trend that was noted by multiple stakeholders was that the strategy should have considered climate and environmental issues. Vodafone in particular thought that environmental efficiency of spectrum usage should have been a strategic objective in its own right.

A1.14 As we set out in our 2021/22 Plan of Work, we are continuing our work to analyse the sustainability of our industries. This includes how they affect the environment, and are affected by it, how technologies can help other sectors reduce their carbon footprint, and

what actions can be taken to tackle the challenges presented by climate change and the UK's net zero carbon target. We will be considering what role Ofcom could play in addressing sustainability issues within communications sectors. However, as we do not have duties relating to the environment, we do not agree that it would be appropriate to make environmental impact of spectrum use one of the objectives in our spectrum vision, at this time.

Future technology trends

A1.15 Stakeholders' responses were broadly supportive of introducing automated tools to manage spectrum more efficiently, but some responses considered such tools first need to be proven as secure and stable and assessed to see where they are necessary. Given the wide range of future potential benefits of automated spectrum management tools, we plan to continue to develop their use in the UK, judging where best to apply them.

A1.16 Many stakeholders believed Artificial Intelligence (AI) would be important for efficient spectrum management in the future. We note that the specific benefits of AI for spectrum management are quite uncertain at present, but we will monitor developments in this area.

A1.17 Stakeholders had more reservations about blockchain technology and its relevance for spectrum management.

A1.18 We received a variety of comments about the potential significance and spectrum needs of 6G. We note that research and discussion on what may be included as part of 6G is currently ongoing. As its key components become clearer, the impact on spectrum management will also become clearer.

A1.19 In general, the long-term benefits and impact of many of the technologies discussed for spectrum management are relatively uncertain at present. Nevertheless, alongside our technology discovery programme, we will continue to track, and where relevant engage on, technology developments that may be important for spectrum management in the future.

Supporting wireless innovation

A1.20 To further accelerate the possibilities for innovation we set out proposals in three areas:

- **Spectrum for pioneers:** making more spectrum available for innovation before its long-term future use is certain.
- **Supporting innovation in wireless technology:** reducing the barriers for wireless innovators by placing greater emphasis on technology and service.
- **Understand, assist and inform:** engaging with all spectrum users through an outreach programme, improved reporting and information tools.

Spectrum for pioneers

A1.21 We proposed to make more spectrum available for those who want to innovate now, before the long-term future use of that spectrum is certain, but without limiting options for future use. Stakeholder responses were broadly supportive of our proposals but commented on the importance of protecting incumbent users, harmonisation, and the implications of a new authorisation regime.

Protecting incumbent users

A1.22 Many of the responses that supported our proposals did so with the caveat that they should not adversely affect existing technologies and users. One confidential respondent went further to say that new access to spectrum used by critical infrastructure should only be allowed following the consent of existing users.

A1.23 We note these concerns and recognise the importance placed on the benefits to the UK of existing services that rely on spectrum. To that end we protect existing users appropriately by undertaking careful assessments of the impact them when introducing new users. However, as discussed in our work on 'good spectrum neighbours' we do expect existing users to appropriately design their system so that they are robust to interference.

A1.24 PMSE stakeholders specifically noted the importance of clarity on the mid to long term availability of spectrum, to support the development and manufacturing of new equipment. We recognise the importance of providing clarity and we believe our plans to periodically publish a Spectrum Roadmap should help inform investment decisions for equipment manufacturers.

Harmonisation

A1.25 Several respondents commented on the importance of harmonisation in supporting innovation, avoiding country specific allocations where possible, and on Ofcom taking a leading role internationally to secure this. Nonetheless some recognised that it can be beneficial to have a flexible approach to harmonisation and to take national decisions where appropriate.

A1.26 We share stakeholders' views that Ofcom should retain a strong position internationally and have invested considerable resource over many years to develop our international reputation. We note there are also examples of national spectrum access decisions we have taken (e.g. for the lower 6 GHz band ,100-200 GHz and for PMSE in 960-1164 MHz) which have been important to open up opportunities for improved services and innovation).

A1.27 We remain satisfied that our general approach to promote the appropriate level of international harmonisation, enough to realise its benefits but retaining flexibility where possible, is the right one.

New licensing regime/access to spectrum

A1.28 Several respondents noted that uncertainty in access to spectrum, due to flexible conditions, could be unattractive for investment as investors would need 'security of tenure' with licence periods that match investment in order to recover their costs.

A1.29 We recognise the importance of a stable environment when companies are trying to attract investment for their new products or services and believe there is more we can do to help stakeholders like investors understand the nature of spectrum access products. However, we have seen interest and take-up of licences like the 'Local Access Licence' which has a default licence period of three years and does not appear to be hindered by this shorter term. In addition, Ofcom will act proportionately, and we would only consider changes to licence conditions where objectively justified.

A1.30 Some stakeholders suggested that as a pre-cursor to enabling access, users should be able to demonstrate that their service or technology has an identified demand. We do not consider proven demand as an appropriate pre-requisite to access spectrum to support innovation, although we do take account of any evidence about future demand which is available.

A1.31 Other stakeholders noted the benefits of using automated spectrum management tools to support the flexible approach we proposed. We agree, and to that end we will continue our work to develop these types of tools as appropriate.

Conclusion

A1.32 Having carefully considered the comments of all stakeholders that responded in relation to this proposal, and taking account of the themes discussed above, we have decided to confirm our approach on spectrum for pioneers, as set out in Section 3.

A1.33 In our view, if there is the potential to derive some benefit from accessing the band before its long-term use is known, then we should consider making it available for innovation earlier. This is because waiting could potentially delay the availability of services and even stifle the opportunity for innovation. The implementation of this approach in relation to specific spectrum bands will be considered on a case-by-case basis.

Supporting innovation in wireless technologies

A1.34 We proposed to reduce the barriers for innovators to develop new wireless technologies and equipment, including by influencing the development of international recommendations and standards for equipment so they are flexible enough to support a wide range of uses.

A1.35 There was broad approval among stakeholders for our strategic objective of supporting innovation in new wireless technologies, but some stakeholders expressed reservations about our specific proposals for achieving this.

Identification of barriers to innovation

A1.36 We identified the time, cost and resources involved in developing internationally accepted equipment standards, and standards for technical coexistence, as barriers to innovation. There was firm support for this identification from many stakeholders, particularly equipment manufacturers/suppliers and companies offering 'smart' solutions for industry and homes. Mobile operators were less convinced that there were real, rather than just perceived, barriers to innovation.

A1.37 A number of stakeholders identified barriers to innovation for particular applications or in particular bands, for example for drones, Wi-Fi, in the 3.8–4.2 GHz band, and in broadcast TV bands. We are committed to seeking to reduce barriers to innovation where possible. and have noted these comments and will consider these as part of our ongoing work in these specific areas (for example we are already planning to bring forward proposals to support drones).

Technology and service neutrality

A1.38 There was broad support for our proposal to push for technology and service neutrality through international harmonisation, although some respondents questioned how easy it might be for us to achieve those outcomes.

A1.39 One challenge highlighted by stakeholders was striking a balance between usage conditions being too wide ranging and making coexistence difficult or specifying narrow conditions that limit the scope for innovation. Some stakeholders said that service neutrality may result in a higher risk of interference to existing services and suggested a rapid process to remove exemptions where interference with licensed services is seen to occur.

A1.40 We believe that liberalising spectrum use to enable innovation and ensuring appropriate protection from interference for existing users are both important and achievable. This view is supported by our work, discussed below, on encouraging spectrum users to be 'better neighbours' and adopting realistic analysis of coexistence, based on protections that are actually necessary in real-life situations rather than theoretical 'worst-case' scenarios.

A1.41 Others noted the challenges in securing greater technology and service neutrality through internationally agreed harmonisation, and the importance of Ofcom having a leading role in international discussions to achieve this.

A1.42 We note that technology and service neutrality is already reflected in the principles developed by bodies such as CEPT and will continue to devote the necessary resources to working with these bodies in order to drive technology and service outcomes in practice.

Promoting knowledge of flexibility

A1.43 Although we received a few responses on our proposal to promote knowledge about the flexibility available in spectrum authorisations, there were no suggestions that it should not

be an important aspect of our strategy. Respondents linked it to the importance of more general education on spectrum use, and the range of available licence products.

UK approach to equipment standards

A1.44 Most respondents did not offer an opinion on this issue. Of those that did respond, some supported our identification of alternative ways to bring products to market, such as through UK Notified / Approved Body processes. However, other respondents stressed what they saw as the greater importance of international harmonisation and had reservations about UK-only approaches.

A1.45 We recognise that using UK-specific routes to market may not always be appropriate for some developers of new technologies and equipment. To that extent, we understand the comments of those stakeholders who believe international harmonisation processes allow for greater economies of scale from wider markets. Nevertheless, we believe there are circumstances where UK-specific approaches – including through the use of UK Approved Body (GB) and Notified Body (NI) processes[21] – may provide opportunities for developers. We also believe it is important that UK developers of new products are fully aware of all the options available.

Conclusion

A1.46 Having considered stakeholder responses on our proposed approach to supporting innovation in new wireless technologies we have decided to confirm this proposal, as detailed in Section 3.

A1.47 We have noted comments made by some stakeholders about barriers for particular services or spectrum bands and will consult separately on tackling these specific barriers, as and when appropriate.

Understand, assist and inform

A1.48 We proposed to expand our outreach work through proactive engagement with different industries, increase reporting of our spectrum management activities, and improve our information tools.

Outreach

A1.49 Respondents were supportive of our proposals to continue and increase our outreach work, particularly to engage with less spectrum aware groups, and appreciated the work that we had already done to engage with a range of industries. Some offered specific suggestions for this outreach work, such as greater use of social media, educational programmes for local businesses, and greater stakeholder engagement prior to consultations, beyond 'calls for input'.

[21] Approved/Notified Body processes allow a body accredited by the UK Accreditation Service (UKAS) to approve new types of equipment more straightforwardly, in accordance with the UK Radio Equipment Regulations.

Reporting

A1.50 There was a general consensus on Ofcom's proposal to provide more information through reporting, including for a Spectrum Roadmap. Some respondents acknowledged the positive link between greater reporting and our 'good neighbours' proposals, because greater information about spectrum use in neighbouring bands could encourage better coexistence between different services. Others made requests for specific improvements, including more transparency in publishing open data, more accessible technical information on interference assessments and details of devices causing interference.

Information Tools

A1.51 There was support from stakeholders for our proposal to improve our information tools. Specific improvements suggested including easier spectrum licensing, step by step guides, greater transparency of utilisation and interference data, improvements to the Spectrum Map and UKFAT and a tool that enables users (particularly less spectrum aware users) to search for available spectrum by type of use or application, rather than by frequency. There were differing views in relation to accessing data from Ofcom's spectrum monitoring systems – some were supportive, but others noted commercial confidentiality risks and security sensitivities.

Conclusion

A1.52 Given this wide stakeholder support we have decided to confirm our proposals to expand our outreach work. It is also clear from the responses received that there is appetite for more accessible information, and so we have decided to take forward the range of initiatives for improved reporting and information tools set out in Section 3.

Licensing to fit local and national services

A1.53 Stakeholders were generally supportive of our proposal to consider further options for localised spectrum access. However, stakeholders from the mobile sector in particular were sceptical about our proposals in this area.

Demand for local access

A1.54 The majority of stakeholders agreed that there is likely to be greater demand for local access in the future. Some mobile stakeholders said demand for local access is unclear.

A1.55 Take-up of private networks in Germany and the growth of Citizens Broadband Radio Service (CBRS)[22] in the USA were cited by stakeholders as evidence of this demand. In addition to the potential use cases that we mentioned in the consultation, stakeholders commented that local access will also be increasingly required for programme-making and special events (PMSE) and some unmanned aerial vehicle (UAV) use cases. Some

[22] The 3550-3700 MHz band in the USA with three different priorities for access. By use of shared spectrum technology this band can be used by organisations for their own private networks.

recommended that Ofcom report regularly on uptake and use of local access in bands where it is enabled, to inform the industry on the level of demand for local licensing in the UK and the extent to which spectrum sharing policies are increasing the use of spectrum and delivering optimal use.

A1.56 We are grateful for the information provided by stakeholders about future demand and we will continue to assess demand for local access in given spectrum bands. We are monitoring the uptake of Shared Access and Local Access licences and will look at how best to make this information publicly available.

Continued need for national and wide area access

A1.57 Stakeholders from across different sectors responded that it is important that Ofcom does not underestimate the continued need for national or wide-area licensing and authorisation of spectrum for a variety of use cases including utilities, TV and radio, satellite, drones, and public mobile.

A1.58 As we set out in the consultation, national licences will continue to be important for services where we expect there to be national demand. The proposal in our strategy is not about applying a local approach in all circumstances but acknowledging that with increasing demand for local access it is even more important to get the balance right. This is particularly true in the context of increasing usability of high frequency bands, where propagation characteristics may make local licensing more feasible and desirable.

Spectrum sharing and efficient use of spectrum

A1.59 A number of stakeholders, mainly from the mobile sector, said that spectrum sharing should only be considered where there is clear demand for spectrum that cannot otherwise be made available, and where it can be demonstrated that the benefits exceed those which could be realised through national spectrum licences for national operators. They said that sharing should not be a goal in itself but bring tangible net benefits to users of spectrum.

A1.60 We were cautioned by some stakeholders not to conflate spectrum use with spectrum efficiency. They said that first come first served access to spectrum may exclude higher value applications with longer investment cycles. And the investment case for widespread networks, which may be predicated on serving a suite of applications, may be undermined if some of those applications are instead served by users accessing spectrum directly with lower spectrum fees. One respondent was concerned that local licensing contributes to geographic fragmentation of spectrum and that the priority should be to facilitate the provision of services by MNOs to industrial and business users where there is demand. They considered Local Access Licences in parallel with national licensing to be an attractive alternative to local licensing.

A1.61 It was suggested by some stakeholders that, where possible, spectrum newly identified for mobile services should be cleared of existing users of spectrum and licensed nationally. However, it was acknowledged that this may not always be possible and that local licensing

might be more spectrally efficient in high frequency bands, including millimetre waves. For example, Telefonica and BT both noted that use in 26 GHz may be mainly concentrated in high demand areas, and therefore leaving geographic areas where local access may be an efficient use of the spectrum where it is not otherwise being used.

A1.62 We agree that sharing is not a goal in itself. Considering further options for local licensing is intended to deliver benefits to people and businesses across the UK, by supporting the growing diversity of wireless services and providers.

A1.63 We appreciate the responses from the mobile sector and recognise that some local services can be provided by national networks. However, we also believe it is important to support the provision of local and private networks that may offer additional services to local users, as well as increasing competition in the provision of those services.

A1.64 As we set out in the consultation, in responding to the challenge of differing demands from different users, we recognise that there is no one-size-fits-all solution when it comes to the appropriate geographic area to license. There are advantages and disadvantages to any approach. We will need to consider the most efficient way to authorise spectrum access taking into account the characteristics and existing use of a given band, and the nature of anticipated future demand. The introduction of Local Access licences has created an opportunity to limit some of the potential inefficiency caused by national licensing (which carries a greater risk that spectrum will not be used in some areas).

The Nations and rural users

A1.65 Several respondents raised the specific connectivity challenges in Scotland and Wales and particularly for rural areas. The importance of local licensing for empowering local network provision, enabling community groups, public sector organisations and local ISPs to acquire spectrum, was highlighted. We agree that local licensing could be important for addressing these connectivity challenges.

Time-based sharing and automated access

A1.66 Several stakeholders commented that, in addition to our consideration of geographical sharing, we should also be giving greater consideration to the fact that future demand might include use cases with short-term requirements. They argued that the current Shared Access Licence and Local Access Licence process does not support this type of application, and is too cumbersome for this purpose.

A1.67 Stakeholders were supportive of more automation of the licence application process for Shared Access and Local Access licences, which would increase the speed with which applications could be processed and allow Ofcom to manage increasing volumes of licence applications.

A1.68 Ofcom already has examples of authorisation using time-based sharing, including PMSE licensing. In its response, the BBC suggested that the way in which Ofcom manages existing PMSE spectrum is a good model to learn from for localised and short-term spectrum access.

A1.69 We already consider applications for Shared and Local Access licences with short terms of less than a year.[23] In our Plan of Work 2021/2 we said we will explore a fully automated authorisation approach for access to the shared bands which could provide a platform for more efficient access to more spectrum in the future.

A1.70 A small number of stakeholders thought we should go further and supported more dynamic sharing approaches. In their view, such approaches could enable opportunistic use of both new bands and as well as previously licensed bands. A stakeholder said that the benefits of such an approach could outweigh the costs. However, Vodafone warned against promoting 'innovation for innovation's sake' and argued there needs to be demand for dynamic spectrum access, reflecting the reality of use of spectrum (e.g. timescales for deployment, site acquisition).

A1.71 We will continue to develop automated spectrum management tools to support spectrum sharing. However, although there are potential benefits to more opportunistic access to spectrum, introducing these technologies can result in additional costs that may not be justified depending on the situation. Therefore, we will consider whether and how to deploy based on the facts of specific cases.

Conclusion

A1.72 We acknowledge that there is significant uncertainty over how much demand there will be for local access in the future, and there is some risk to making spectrum available before demand is certain. In line with our duties, we will continue to have regard to both existing demand for spectrum use and the demand which is likely to arise in future. Having taken account of stakeholders' comments, we have decided to consider further options for localised spectrum access when authorising new access to spectrum, as proposed in our consultation.

A1.73 This element of our strategy is setting a direction of travel rather than identifying particular candidate bands. We note the many points raised by stakeholders, and that these will all have to be considered when we are assessing the appropriateness of local approaches to spectrum authorisation in any given case.

Promoting spectrum sharing

A1.74 We proposed a number of measures to encourage spectrum users to be 'good neighbours'. These proposals fell into three categories:

- Increase realism in coexistence analysis at a national and international level.
- Encourage spectrum users to be more resilient to interference (in addition to minimising their own emissions outside their allocated spectrum).

[23] See Shared Access Licence: Guidance Document; Local Access Licence: guidance document

- Apply efficient protection levels, by which we mean an efficient balance between the level of interference protection given to one service and flexibility for others to transmit, in order to give spectrum access to a wide range of users.

Importance of 'good neighbours'

A1.75 Support for the 'good neighbours' principle was almost unanimous. There was particularly strong support from satellite operators and from companies involved in 'smart' technology. No respondents objected to the idea in principle.

A1.76 However, some respondents – particularly incumbent spectrum holders - urged us to proceed with caution to ensure valuable existing services would not be put at risk from interference.

A1.77 Given the strong support. and noting the need expressed for caution, we have decided to make the 'good neighbour' approach a key aspect of our spectrum strategy going forward as outlined in Section 3.

Realism in coexistence analysis

A1.78 We proposed to apply greater realism in analysis of coexistence between spectrum users, at both a national and international level by:

- Promoting the use of real service characteristics in coexistence studies;
- Regularly reviewing the appropriateness of the propagation models and associated datasets we use;
- Considering the use of authorisation tools that enable us to set technical conditions more realistically at a national level.

A1.79 Most respondents supported our proposals, but some urged caution in the practical application of the principle. One theme was that performance achieved in real-life tests should be incorporated into equipment standards to set recognised benchmarks. We will continue to work to drive improvements in equipment standards both in the UK and internationally.

A1.80 Having considered all the responses on this issue, we continue to believe that the principle of using realistic assessments of potential interference will increase the scope for spectrum sharing. We will adopt a pragmatic approach, prioritising the coexistence analysis that offers the most opportunities for increased spectrum use – and least risk of disruption to existing users (where this risk is not exacerbated by poor receiver performance).

A1.81 On equipment standards, we note that actual performance will always be better than the applicable regulations and harmonisation measures, as these provide only minimum regulatory conditions.

Resilience to interference

A1.82 We said spectrum users should ensure their equipment is resilient to interference and that we would not normally take action in cases where interference occurred as a result of poor receiver performance.

A1.83 Most respondents supported the general principle, with some feeling strongly that not enough progress had been made on the issue so far. Almost all the other respondents who commented in detail expressed reservations about the practicalities of driving our proposals forward. Some identified issues specific to their own sectors or to particular spectrum bands. Some pointed out that expensive equipment may have been bought and installed in good faith, based on current circumstances, but may in future be susceptible to interference.

A1.84 Historically, spectrum users were assigned distinct frequency ranges, with guard bands to protect themselves and/or neighbouring users from interference. Equipment did not necessarily need to be as resilient as possible to interference, because in many cases there was little risk of receiving unwanted emissions from other users in the same or neighbouring spectrum bands.

A1.85 This situation is changing due to ever greater demand for spectrum. If frequencies are not used as efficiently as possible – including with greater sharing – there is clear barrier to further innovation. We therefore continue to believe our proposal to encourage spectrum users to be more resilient to interference is important.

Efficient protection levels

A1.86 We said we would consider introducing differential 'protection pricing' for spectrum users, so users pay more in fees the more protection they require. We also said we would expect spectrum users to provide a greater level of evidence-based analysis when inputting to the process to define protection levels.

A1.87 A number of stakeholders were concerned about the idea of differential pricing, saying that setting prices would be complex and controversial, and questioned how it would work in practice. Some said that Ofcom should consider pricing advantages for operators who use more efficient equipment, rather than penalise users of old equipment with increased fees.

A1.88 We have noted the strongly expressed reservations about establishing differential pricing depending on the level of protection required by one service compared to another.

A1.89 However, differential pricing could be a valuable tool in certain circumstances. It would allow users a choice about which protection level to request depending on their specific needs in each band, and on their intended use and on the type of equipment. A lower level of protection would attract lower fees because such protection increases the opportunities for sharing the spectrum.

Conclusion

A1.90 Having considered all the responses, we received on the question of promoting the sharing of spectrum – and on the principle of users being 'good neighbours' – we have decided to adopt the proposals set out in our consultation. Spectrum Sharing will have a critical role to play to enable increased growth and innovation from both existing and new services. Efficient use of this scarce resource through more realistic coexistence analysis, increased resilience to interference and efficient protection levels, will allow more users to access spectrum and deliver new services that will benefit everyone in the UK.

A1.91 We have considered consultation responses, including concerns about the issue of differential spectrum pricing. In light of stakeholders' comments, we confirm that differential pricing may encourage efficient use of spectrum in specific cases, but also clarify that we do not expect to rely on it as a blanket approach. .

A1.92 We will consult further on any changes to specific spectrum authorisations or equipment standards as necessary.

A2. Responses to our consultation – Detail

A2.1 We received 49 responses to the consultation, of which six were confidential. A list of the non-confidential respondents is shown in the table below.

A2.2 Where points are not addressed elsewhere (i.e. in Annex 1) we address these in this section.

List of non-confidential responses received

5G New Thinking	ESOA	Joint Radio Company	SOS – Save Our Spectrum
APWPT e.V.	European Utility Telecom Council	Langley Mr C	SpaceX
ARPAS UK	Federated Wireless Inc	Mavenir	Telefónica UK Limited
Arqiva	Filtronic	Mediathand	Telet Research
BBC	Global Mobile Suppliers Assoc	Nano Avionics UK Ltd	The Scotland 5G Centre
BEIRG	Global VSAT	Nokia	UKWISPA
BT	Hatherland Mill Farm	Ofcom Advisory Committee Scotland	Viasat
CommScope	Huawei	Ofcom Advisory Committee Wales	Vodafone
DTG	Hughes Europe & Echostar Mobile Limited	Robinson Mr P	Voice of the Listener & Viewer
Dynamic Spectrum Alliance	Innovation Lambda	Shaw Mr J	Woodward Mr J
e2E Services	Intelsat	Sky UK Limited	

Part I – Comments on Ofcom's spectrum management strategy

Our approach and tools

Stakeholder comments	Ofcom response
Sector and band-specific issues Several stakeholders suggested we should have greater consideration of specific sectors or sector specific issues (also see section on sector and band specific comments below).	In-depth consideration of sector issues and spectrum requirements are undertaken as part of our sector strategy reviews and through specific projects. Also see paragraph A1.2.
Timeframe for the review BEIRG questioned whether the 10-year timeframe adequately reflected the potential future changes in spectrum management Telet Research said that 10 years is a long time period, and it might have been better to have split into immediate, mid-term and long-term aspirations.	We believe that ten-years represents a reasonable timeframe for our spectrum management strategy; a longer timeframe would be subject to much greater uncertainties. Nonetheless we will continue to track industry and technology changes and will reflect on the continued appropriateness of our strategy in light of these.
Non-communications services A confidential respondent said that the spectrum vision concentrates on national UK use for communications and does not say much about non-communications services.	Our second objective, 'businesses, public sector and other organisations with specialised requirements to be able to access the right wireless communication *or spectrum options* for them' does include non-communications services. For example, we noted specialised scientific requirements, including to monitor our climate or study the universe using radio waves. And we also recognise a range of other important non-communications services, for example radar for defence and maritime use.

Stakeholder comments	Ofcom response
Working with Government and other UK organisations with spectrum interests A confidential respondent said that there should be an additional objective in our vision, to work effectively in partnership with other UK organisations with spectrum interests.	We agree that it is important that Ofcom works effectively in partnership with other UK organisations with spectrum interests, including government departments, agencies such as the UK Space Agency and the Met Office, and industry bodies. As we set out in the consultation, we engage closely with the Government and UK industry to ensure that we understand and are able to take account of all UK interests in the development of our policies and UK positions for international forums. And we work with Government to promote efficient use of spectrum by the public sector.

Appropriate assurances for continued use of spectrum A confidential respondent said that ensuring "appropriate assurances for continued use of spectrum" is a very important aim, and given the need to ensure current users and existing services are not impacted, this could be treated as a discrete strategic objective of the review in its own right. It is also the case that different sectors will have different views of what "appropriate assurances" are / need to be based upon their business models. Hughes Europe and Echostar, Telefonica, Arqiva, BEIRG and Global Mobile Suppliers Assoc all noted the importance of certainty and 'security of tenure' in spectrum for incentives to invest. 5G New Thinking suggested that Ofcom should include a minimum duration of at least five years in Shared Access Licences, to give sufficient security of tenure to make investment attractive. Intelsat agreed that spectrum sharing should be promoted as a means to maximise efficient use of spectrum, but said it should be done in a manner that safeguards the current and future use of the bands by the existing users, and complies with ITU Resolutions and international standards. An opportunity to one industry should not be made at the expense of creating regulatory uncertainty or unnecessary restrictions to others. Telefonica said that the most important factor in spectrum sharing is that the incumbent rights are respected and interference is avoided, for example through appropriate protection mechanisms and / or commercial agreements, and that Ofcom should only intervene where necessary to address competition concerns and market failures..	We agree that appropriate assurances for continued use of spectrum is a very important aim. We recognise that many of the services we benefit from today have required significant commercial investment, and that sufficient certainty over access to spectrum is necessary to sustain those benefits and enable new investments that people will benefit from in the future. Appropriate assurances for continued use of spectrum has prominence in our high-level objectives and our consultation set out a number of ways in which we achieve this in practice through appropriate licence terms, technical conditions and interference management. We undertake careful assessments of the impact on existing users when introducing new users. However, as discussed in our work on 'good spectrum neighbours' we do expect existing users to appropriately design their system so that they are robust to interference. Our justification for the licence terms for the Shared Access licences is set out in our statement. We will continue our market-based approach of relying on the use of market mechanisms where possible and effective, whilst undertaking regulatory action where necessary.

Stakeholder comments	Ofcom response
International Stakeholders made comments on international issues as they relate to our specific proposals. However, more generally, several stakeholders commented on the importance of Ofcom's engagement with international bodies, including CEPT and ITU. Stakeholders felt that this was important if the UK is to benefit from economies of scale. Dynamic Spectrum Alliance and Innovation Lambda responded that Ofcom's approach to promote international harmonisation while retaining flexibility where possible is appropriate. Telefonica was keen to understand further details on how Ofcom intends to ensure it continues to take a leading role, given the fact that the UK has now left the EU and Ofcom no longer attends RSPG, and no longer represents the UK in the RSC. Dynamic Spectrum Alliance welcomed Ofcom's approach of promoting spectrum sharing internationally. They said that the UK has been historically supporting flexible spectrum management frameworks and should share good experiences and best practices internationally. The BBC said that UK stakeholders benefit from the UK having a strong position in international regulatory forums and influencing international decisions, but we need to respect that other countries and regions require different solutions for different problems.	We agree with stakeholders that engagement with international bodies is very important for the reasons we set out in section 3 of the consultation. Ofcom remain at the forefront of work within the ITU and CEPT, currently holding a number of Chair and Vice Chair roles within these institutions. Following the UK leaving the EU, Ofcom no longer attends the EU's Radio Spectrum Policy Group (RSPG), and the Radio Spectrum Committee (RSC) but we continue to monitor their work and cooperate with work as it arises in CEPT. Many spectrum management issues around the world are common, such as limiting interference, increasing sharing, maximising the efficient use of spectrum and balancing different uses and needs. However, we recognise that countries around the world have a variety of regulatory frameworks and policy objectives and may face different issues and implement different regulatory solutions to those in the UK. We actively look to learn from our international engagement.

UK international interests Two confidential respondents were concerned that the strategy focusses too much on domestic priorities. They said that much of spectrum use by the space sector must be coordinated internationally. They also added that issues may arise when Ofcom's citizen and consumer focus comes into conflict with wider priorities not directly related to consumer benefits. A confidential stakeholder said we should promote the UK's objectives in international forums, and therefore ensure the maximum benefits for spectrum use in the UK, as well as for UK companies operating overseas. The BBC said that Ofcom should take into account the use of spectrum in furtherance of UK objectives outside the UK. These objectives may be commercial or public policy based, but are pursued to benefit the UK, its citizens and consumers. The BBC believes that Ofcom should be considering the wider range of benefits that spectrum use overseas brings back to the UK, and does not believe that UK interest in spectrum use outside the UK has been adequately considered. A confidential respondent suggested that the list of institutions detailed in paragraph 3.19 of our December 2020 consultation was not complete. They said that space spectrum has to be harmonised internationally and need Ofcom to promote and defend UK space interests globally. The UK has influence in other regional groups acting on behalf of Crown Dependencies and overseas territories, where Ofcom can support UK government and industry interest overseas. Additionally, , there are sector specific groups, covering space agencies, radioastronomy, meteorology and defence as well as standards bodies where the UK are actively engaged.	Ofcom represents the UK in international forums that deal with spectrum. We can and do take account of wider UK public interests in our international representation work as we consider appropriate. These interests may include public safety, national security and governmental policies relating to economic growth. We may consider these interests even where services do not provide direct services to UK consumers and citizens, for example by participating in international discussions on in-orbit servicing of satellites. We agree that the list of institutions list in the consultation was not exhaustive of all the bodies that Ofcom participates in.

Stakeholder comments	Ofcom response
Social value of spectrum Arqiva and three confidential respondents said that we need to recognise the social as well as the economic benefits of access to spectrum. John Wood said that Ofcom needs to work for the public interest rather than private investors. The Ofcom Advisory Committee for Wales said that efficient use of spectrum should not be the only goal – effective use of spectrum for citizens, organisations and businesses is an important principle too. They said that, spectrum can be used efficiently by a range of (technical and economic) measures, but not be effectively used from the perspective of the user. In particular, for those groups whose needs do not readily meet spectrum efficiency-based criteria, e.g. rural communities. Arqiva also added that the following points: (i) it is vital that Ofcom's approach to spectrum is joined up with wider policy objectives that Government and Ofcom has in relation to the sectors it covers; (ii) it is not sufficient to take decisions on spectrum in isolation, the views and impacts of any changes on society, existing users, and the costs of any changes or transitions should be fully taken into account; (iii) Ofcom needs to ensure that citizens are not socially or economically disadvantaged by changes to access of services that use the spectrum; (iv) Ofcom needs to ensure that citizens have access to services that are trustworthy, cost-effective and secure.	See paragraph A1.7 regarding social value. As we set out in Section 2 of our consultation, our spectrum management work complements out wider regulatory activities to enable wireless communications and services. We engage closely with Government, including having regard to the UK Government's statement of Strategic Priorities for telecoms, management of radio spectrum and postal services.

Stakeholder comments	Ofcom response
Market mechanisms Whilst supporting market mechanisms to incentivise spectrum efficiency, Vodafone believes there is a need to review whether the existing approach is achieving the policy goals sought by Ofcom and Government, and whether there is a danger of auctions and the annual licence fees based on them amounting to a tax on mobile users and a constraint on investment. They said they will respond on these points in the forthcoming review of mobile markets.	As Vodafone notes, we will develop a strategy for our approach to the mobile sector
Critical infrastructure A confidential respondent said that securing and enhancing critical infrastructure should be a priority. As critical infrastructure increasingly relies on spectrum, that spectrum needs to be adequately protected; they do not support relaxing existing protection criteria.	We agree that critical infrastructure is a priority. This is key aspect of our high-level objective to ensure that businesses, public sector and other organisations with specialised requirements are able to access the right wireless communication or spectrum options for them.
Public sector spectrum release Telefonica responded that there is more to be done in the area of public sector spectrum release. They suggested opening up the lower 2.3 GHz band for mobile use.	We continue to explore opportunities to make more public sector spectrum available for wider use and the lower 2.3 GHz band is under consideration through ongoing discussion with the MOD. We must understand and take account of the needs of public sector users before any decisions can be made, but we remain committed to ensuring that we maximise the overall efficient use of spectrum in bands utilised by the public sector.

Stakeholder comments	Ofcom response
Electromagnetic fields (EMF) John Wood was concerned that the strategy does not address public safety concerns, including around exposure to electromagnetic fields. He said that the International Commission for Non-Ionising Radiation Protection (ICNIRP), which publishes international guidelines to ensure services operate safely, does not command the confidence of the wider public.	In the UK, Public Health England takes the lead on public health matters associated with radiofrequency electromagnetic fields, and has a statutory duty to provide advice to Government on any health effects that may be caused by exposure to EMF. PHE's main advice is that EMF exposure should comply with the ICNIRP Guidelines. We note that ICNIRP is the formally recognised non-governmental organisation in the field of non-ionising radiation protection for the World Health Organisation (WHO) and, the International Labour Organisation (ILO) and the European Union (EU). Ofcom takes into account the advice of PHE in relation to EMF in our management of the radio spectrum. We have recently taken action to require spectrum users to comply with the ICNIRP general public limits.
'Use it or share it' Innovation Lambda thought the strategy underplayed the principle of 'use it or share it'. The Advisory Committee for Scotland said that Ofcom should consider "Use it or Lose it" or "Use it or Share it". They suggested that MNOs will choose not to deploy 5G in rural areas and in such cases it would be more efficient use of the UK's spectrum if local ISPs and businesses (e.g. salmon farms) could make use of this key spectrum when it is not used in local areas.	The licences that Ofcom issues define rights to use spectrum but do not provide exclusive use. Therefore, we can and do enable shared access to spectrum by authorising additional use in bands that have already been licensed, while taking account of any impact on existing users of the band. For example, we have enabled third party access to licensed mobile spectrum through Local Access Licences.

Stakeholder comments	Ofcom response
Miscellaneous comment John Shaw said that we were recycling spectrum management concepts from the Cave Report and Res 951[24] studies.	John Shaw did not supply detailed reasons for his views.
Strategy implementation and Roadmap Telefonica looked forward to Ofcom setting out a plan with details of the steps and actions we intend to take in the priority areas identified. Vodafone noted that it would have been useful to set out the Spectrum Roadmap at the same time as the consultation.	As set out in section 3, the actions to take forward our strategy will be embedded throughout our spectrum management work going forward. We plan to publish a consultation on our Spectrum Roadmap in Q3 2021/22.
Sector reviews BEIRG said it is vital that the outputs of sector reviews are cross-referenced with all other sectors. In the past, Ofcom have not always looked holistically at spectrum management and BEIRG seek assurances that each review will be considered against the wider needs and demands of other sectors, for example to consider how the needs of fixed links or the aeronautical sector impact PMSE.	Although sector reviews naturally tend to be driven by developments in one particular sector, in considering any potential change in spectrum use we consider the full range of spectrum users that may be impacted.

[24] Resolution 951 (Rev.WRC-07) was titled 'Enhancing the international spectrum regulatory framework'.

Trends

Cross-cutting trends

Stakeholder comments	Ofcom response
Climate change John Wood, Hatherland Mill Farm, Innovation Lambda and the Ofcom Advisory Committee Wales made comments that the strategy should have considered climate and environmental issues. Vodafone in particular thought that environmental efficiency of spectrum usage should have been a strategic objective in its own right.	Please see paragraphs A1.13-A1.14 of this statement.
Higher frequency bands Vodafone agreed that usage of higher frequency spectrum will increase, but whilst consideration of 100 GHz+ is a useful research area it cannot be a substitute for providing adequate stocks of lower frequency spectrum. The European Utility Telecom Council commented that major new wide area data technologies are emerging using spectrum below 500 MHz. A confidential response said that there is likely to be an increase in low and mid band spectrum demands (including 7-24 GHz) for 5G over the next 10 years. Another confidential response said that science services had been using higher frequencies for decades and that applications dependent on their use should be protected.	We note these comments and agree that higher frequency bands are not necessarily applicable for all applications and there will continue to be demand for low and mid band spectrum.

Stakeholder comments	Ofcom response
Noise floor The BBC suggested that increasing incidences and levels of interference together with increases in the radio noise floor was a major trend which we had implicitly recognized in our consultation but not explicitly acknowledged. Hughes Europe and Echostar Mobile suggested that we had captured the major trends but that there were two trends not reflected. These were threat of wide interference from 5G devices and beyond and the multi-dimensional nature of spectrum management that needs to be considered. They suggested that the interference environment could be more significantly impacted than we describe.	We recognise the importance of the increase in human made noise and we have already mentioned this in paragraph 7.100 to the December 2020 consultation. We are also carrying out studies to characterise the radio noise floor.
Low power communications Huawei suggested that an increasing focus on low-power communications may not necessarily be the case as lower power means lower coverage and potentially higher levels of network densification.	We agree that low power may not be an appropriate solution in all cases.
Covid-19 Ofcom Advisory Committee Wales agreed with our identification of trends but as a fall out from the pandemic, emphasised the importance of resilience and performance of networks.	We agree the importance of resilience and performance in network. Ofcom's plan of work 2021/22 (see page 39) contains details of planned work relating to network security and resilience.

Stakeholder comments	Ofcom response
Fixed-mobile convergence BT suggested that a trend was the growing move towards convergence of fixed and mobile services and a service neutral regulatory approach will become increasingly important.	We acknowledge that there is a move towards fixed-mobile convergence.
New technology Ofcom Advisory Committee Wales suggested that a further trend was that growing awareness, interest and understanding of new technology is creating new expectations in spectrum management (e.g. greater flexibility, capability and engagement). A confidential respondent suggested that important future network trends relate to the growth and expansion of intelligent infrastructure on the network platform. Key drivers of this evolution are the creation of automated intelligent machines and the internet of senses.	We acknowledge both these stakeholder suggestions.
Time domain Telet Research said that the consultation covered frequency sharing well but did not look at time domain. It also noted that the use of spreading codes may allow management of interference between different users.	Sharing spectrum in time can be facilitated by automated spectrum management tools which we discussed in Section 7 of the consultation. We also recognised in Annex 6 of the consultation, that future technology developments may reduce the resource assignment time and allow automated tools to schedule resources in near real-time in the future.

Stakeholder comments	Ofcom response
Retirement of analogue services BT suggested that an additional trend was that, over time, services such as broadcasting will be delivered over fixed networks rather that wireless. There will be an increased onus on Ofcom to ensure that broadcasting spectrum remains optimally and efficiently used. Mediathand expressed similar views. Vodafone also commented that a situation is evolving where consumers are expecting to watch content at a time and place that suits them which has implications for communications networks (in the widest sense) and the spectrum they consume.	We have identified the retirement of analogue services as a trend in Table 1 of our December 2020 consultation.
Drones ARPAS suggested additionally adding drones to the table on page 40 of the consultation.	We agree that drone usage is a trend and that this would be suitable to add for future publication.
Private 4G/5G markets Ofcom Advisory Committee Scotland felt that we had not captured all the major trends with only limited mention of the implications of spectrum policy to help enable the success of private 4G/5G markets and the challenges of how to address existing conflict in spectrum allocations.	In our consultation we advised that we are proposing to publish a Spectrum Roadmap which will indicate key market, technological and international developments, review how demand is changing across different sectors and set out a roadmap for future spectrum work.

Future technology trends

Stakeholder comments	Ofcom response
Artificial Intelligence (AI)	We note that the benefit of AI technologies spectrum management is quite uncertain at present and particularly within the ten-year time frame of our

There was near-consensus on the importance of the AI in boosting automated and efficient spectrum management in the future from those that commented on this technology. UKWISPA and Innovation Lambda believe that AI may come to dominate because it will outperform existing tools. Ofcom Advisory Committee Wales believed that AI is enabling automated spectrum management including opportunities to make spectrum available to innovators on a real-time, pay-as-you-use basis.	spectrum strategy. Nevertheless, alongside our technology discovery programme, we will continue to monitor technological developments that may be important for our approach to spectrum management.
Blockchain There was much more reservation about Blockchain technology and its relevance for spectrum sharing from CommScope, 5G New Thinking, Telet Research and other respondents. CommScope for example said that this technology needs further study to determine if it can be applied for spectrum management purposes and that it could drive exorbitant demand for power consumption.	As recognised in our December 2020 consultation, Blockchain faces limitations in terms of the very high level of processing and therefore power consumption which is problematic for battery powered terminal devices. Setting up and implementing the blockchain ledger has a higher cost than existing transactional arrangements. It could also drive large amounts of data across the network using up valuable capacity and require significant computing resources. However, like the other technologies, the ten-year time frame may change these limitations.
Self-configuring networks UKWISPA and DTG encouraged us to explore self-configuring network technology and believed it can have a big impact on spectrum management in the future. e2E Services and Sky said that it already has disruptive implications.	We acknowledge the comments received regarding self-configuring networks. Self-configuring networks are based on multiple technologies, many of which are still emerging. These technologies have often been developed independently for different scenarios, increasing the number of features to consider when implementing them. This will lead to high complexity and challenging implementation processes.
Automated spectrum management tools Scotland 5G Centre and 5G New Thinking believed that automated spectrum management tools can help in automated sharing and in industrialising spectrum management. However, Telefonica and Hughes Europe and Echostar Mobile said that such tools and systems need to be proven as secure and stable on a case-by-case basis then assessed if they	As noted in the consultation, given the wide range of future potential benefits of automated spectrum management tools, we plan to continue to develop their use in the UK. However, introducing this technology can result in additional costs and complexity, so there is a need to judge where and how it will make sense to deploy automated tools, focusing on bands where it is likely to be most relevant and can bring the greatest benefits.

are necessary, or whether simple, low-cost basic mechanisms might be more desirable . Similarly, SpaceX cautioned on the use of these systems with Non-Geostationary satellite systems (NGSO) and considered that tools like Spectrum Access System (SAS) are untested and likely inappropriate for managing spectrum the NGSO context.	
6G Mavenir said the implications of this technology depend on when it is launched. It will use spectrum around 90 GHz and above, which is now used for space science. CommScope mentioned that each successive generation of wireless has required roughly double the amount of spectrum, and 6G may require incumbents to vacate a frequency band, so it is critical that we determine what spectrum will be used. Another confidential respondent said that there is a risk that the higher data rates and lower latency of 6G will lead to an increased digital divide between those able to access it and those that cannot, e.g. due to economic and geographical constraints. As a consequence, it is essential that policy makers ensure and facilitate the deployment of different and diverse communication technologies - especially satellite - to complement terrestrial network capability so that 6G coverage is maximised, and that the greatest social and economic benefits are realised.	Research and discussion on what may be included as part of this technology is currently ongoing. As its key components become clearer, the impact on spectrum management will also become clearer but 6G is currently not expected to be significant until the 2030s timeframe and so outside of the timeframe associated with our current spectrum strategy. We will continue to monitor developments in this area in preparation for when spectrum allocations may be necessary for this technology.
3000 GHz range and above SpaceX advised to take a "light touch" regulatory approach to providing access to these frequency bands. This approach should focus on encouraging experimentation and innovative spectrum use cases.	We acknowledge the importance of this spectrum range to support innovation and with technology progression over the next 10 years, we expect there will be opportunities to newly authorise very large amounts of spectrum that could facilitate, for example, new high bandwidth services (multiple 100s of Gbps) or other innovations. As part of our programme to review spectrum management challenges, we have already organised an event with stakeholders looking at enabling more use of Terahertz spectrum bands.

Spectrum for pioneers

Stakeholder comments	Ofcom response
Protect incumbent users Many of the responses that supported our proposals did so with the caveat that the proposals should not adversely affect the existing technologies and users. This was the position of many such as Arqiva, Sky, the Joint Radio Company and several confidential responses, with one individual also suggesting greater protection particularly for those users with weak signals. The ESOA suggested a public consultation should take place before any decision to allow terrestrial services to share satellite bands. This view was shared by another confidential respondent that suggested that access into bands of certain critical infrastructure should only be allowed following consent from stakeholders to the proposed use.	We note the concerns of stakeholders that our proposals, as described, should not negatively impact their services. As stated in our December 2020 consultation, we recognise the importance placed on the benefits to the UK of existing services that rely on spectrum. Similarly, we also know that if there is insufficient assurance about continued access to spectrum to deliver services and some scientific uses, then some of those benefits would not exist. Our December 2020 consultation stated that, among other things, we would continue to provide appropriate assurances of continued use for existing and new users. To this end we set out a comprehensive strategy which explained how we would support spectrum sharing by encouraging spectrum users under the programme of being 'good neighbours'. One aspect of the 'good neighbours' programme is encouraging spectrum users to ensure their equipment is as resilient to interference as possible. As such, we will continue our work with equipment manufacturers and users to raise awareness of the impact of receiver performance. This will be especially important as we continue to share spectrum and the users in neighbouring bands could change.

Stakeholder comments	Ofcom response
Continued access to spectrum APWPT commented that the PMSE community needed clarity on the mid to long term availability of spectrum. APWPT also noted that PMSE manufacturers and users needed this guidance to help make decisions on investment in developing and manufacturing of new innovative equipment.	We will periodically publish a 'Spectrum Roadmap' that will, among other things, indicate potential future changes in spectrum use. This should give PMSE equipment manufacturers, as well as other business sectors, the guidance and information they need to make informed investment decisions.
Harmonisation Dynamic Spectrum Alliance and Nano Avionics both commented on the benefits derived from EU harmonisation for new applications. The Dynamic Spectrum Alliance and one other confidential respondent also commented that they wanted to see Ofcom continue to play a leading role internationally, including promoting its aims in relation to innovation. Sky expressed its support for the proposed flexible approach to harmonisation to take national decisions where appropriate. Vodafone, with some reservation was also supportive. It noted the length of time it can take to secure full harmonisation and welcomed steps that could shorten the period of time before devices are made available, particularly if taking such steps could also inform improvements to the harmonisation exercise. Huawei said that where possible, country-specific allocations of spectrum should be avoided because of the risk of increased equipment costs and that making spectrum available in this way has to weighed against the opportunity cost especially if there is potential for an alternative certain use.	As discussed in Annex 1, we recognise and agree with stakeholders' views that Ofcom should retain a strong position internationally. We note there are examples of national spectrum access decisions we have taken (e.g. for the lower 6 GHz band and 100-200 GHz) which have been important to open up opportunities for improved services and innovation. To this end, we remain of the view that our proposed general approach to promote the appropriate level of international harmonisation, enough to realise its benefits, but retaining flexibility where possible, is the right one.

Stakeholder comments	Ofcom response
Certainty of access Several respondents such as Arqiva noted that uncertainty in access to spectrum could be unattractive for investment. Huawei also considered that our approach had underestimated the impact of change on users and incentives to invest. UKWISPA also commented that investors would need 'security of tenure' in order to recover the cost of equipment and their investment. This was similar to the view expressed by the Ofcom Advisory Committee Scotland which commented that the time period for spectrum allocation should match the financial return timeframe. The Committee further commented that the current 3-year licence period for current shared spectrum is insufficient.	Please see paragraph A1.29.
Automated spectrum management tools Stakeholders such as Innovation Lambda suggested using automated spectrum management tools to set parameters for accessing spectrum for innovation. This view was reiterated by a confidential responder. Both a confidential respondent and BT commented on the benefits of utilising automated spectrum management tools to underpin the flexible approach we proposed. BT also observed how the speed of automation would have an impact on the speed at which services can be made available to the customer.	As noted above, we plan to continue to develop the use of automated spectrum managed tools in the UK, focusing on bands where they are likely to be most relevant and can bring the greatest benefits.

Stakeholder comments	Ofcom response
Establishing demand Several stakeholders suggested that as a pre-cursor to enabling access, users should be able to demonstrate that their service or technology has an identified demand. One confidential respondent said that issuing licences beyond Innovation and Trial licences should be evidenced to ensure it is proportionate and in response to demand. DTG expressed similar concerns about allowing access to bands by users that had not yet established a demand. Huawei also shared its view that there is not the demand for opportunistic spectrum access as users prefer stable and guaranteed access. They suggested that it would be more helpful for spectrum released for innovation to be restricted to small and well-defined areas of a band. BEIRG considered that as well as testing viability alongside potential sharers, trials should be used to prove whether there is sufficient demand. Vodafone commented that spectrum must not become cluttered with failed technologies.	Please see paragraph A1.30. While Ofcom issues Innovation and Trial licences which support research, development and trialling of innovative uses, these are for a time limited period. Innovation and Trial licences do not allow the deployment of commercial or operational networks or systems and are not appropriate for applicants seeking to acquire a licence for long term access. On that basis we do not consider that the existing Innovation and Trial licensing system is a viable substitute, or that it offers any greater reassurance to investors.
2 stage licences Dynamic Spectrum Alliance commented that in the early stages of innovation the existing Innovation and Trial licences are sufficient but proposed a second stage to the licensing process that would support commercial operations.	In relation to the DSA suggested that the Innovation and Trial licence should form part of a 2-step process that would support a commercial operation. However, as above, given the characteristics of an Innovation and Trial licence we do not consider this to be a viable proposal.

Supporting innovation in wireless technologies

Stakeholder comments	Ofcom response
Identification of barriers to innovation There was firm support for our identification of barriers to innovation from some stakeholders. UKWISPA said it agreed and welcomed Ofcom's proposed ways of tackling the barriers. The Joint Radio Company said it was challenging to break the "perennial problem cycle" surrounding spectrum access, vendor support and viable market for solutions once they have been developed. It was increasingly important to make the UK an attractive place to experiment and develop a wide range of new technology – including wireless innovation. Others expressing agreement with our identification of barriers included Innovation Lambda, mediathand, and the Voice of the Listener and Viewer. Among the MNOs, BT, Telefonica and Vodafone all offered a measure of agreement for our objective of supporting innovation. Vodafone said it agreed with our identification of the barriers to innovation but said it believed, in most cases, the barriers were perceived rather than actual. Telefonica went further, saying it did not see any significant barriers to innovation in new wireless technologies. APWPT agreed with our identification of potential barriers to innovation, but said no additional constraints should be imposed on the existing users The Ofcom Advisory Committee for Wales acknowledged there was already scope to support a growing range of devices used by microbusiness and SMEs based on low power and low data rates in licence-exempt bands – but said there were other barriers to innovation for higher power, longer range	We note the general support for our overall aim of removing barriers to innovation, even though many respondents did not address this question in great detail. Having considered the responses to our December 2020 consultation, we remain committed to adopting all reasonably practical means to remove barriers to innovation. It may well be the case that detailed questions raised by some respondents need to be considered further in subsequent consultations. We will do this separately on a case by case basis.

Stakeholder comments	Ofcom response
applications. BT was another respondent to say the promotion of innovation was important in licensed as well as unlicensed bands.	
Barriers to innovation for particular applications or bands The Ofcom Advisory Committee for Wales along with ARPAS and BT identified drones as an important future technology, and urged Ofcom to make it easier for drones to gain access to spectrum. Telet Research said MNOs were "dragging their feet" on granting local access to spectrum they hold, and charging unrealistic administration fees while not using much of the spectrum they hold. The Dynamic Spectrum Alliance said there was not sufficient spectrum for Wi-Fi. It noted that Ofcom had correctly identified the increasing availability, take-up and speeds of fixed ultrafast and full-fibre connections and that this was putting pressure on the wireless network in people's homes. The Dynamic Spectrum Alliance urged Ofcom to open access to the 6425-7125 MHz frequency range to licence-exempt Wi-Fi. A confidential respondent said limited access to a crucial spectrum band for its satellite services was a barrier to innovation. Mediathand and an individual respondent said the major barrier to spectrum innovation is legacy broadcasting technologies. Consumers require ever more advanced technical features on their TVs which are not practical with old technologies. Broadcasters have the opportunity to free up more than 70% of their consumed capacity by reshaping their TV offering using very secure, robust, low latency IP multicast to directly reach all screens using existing infrastructure.	Barriers for particular applications and bands raised by some respondents, although beyond the scope of this strategy document, may need to be considered further separately in separate consultations and through our international engagement. For example, we are currently exploring spectrum and authorisation options to support growing demand for beyond-line-of-sight drone use.

Stakeholder comments	Ofcom response
Technology and service neutrality Arqiva said Ofcom had to strike a difficult balance between urging usage conditions that are too wide ranging - and hence making coexistence difficult - or specifying narrow conditions that limit scope for innovation. It said the balance *"arguably leans towards more relaxed conditions and difficult coexistence"*. Arqiva added that it recognised the focus on short range devices, but said it was also necessary to address the impact on all devices as the result of any proposed innovation. The BBC said that as well as a significant benefit technology and service neutrality also carried a higher risk of interference to existing services, such as broadcasting and broadband. The BBC said it was essential that in addition to an effective system of exemptions to radio requirements there should be an equally rapid process to remove exemptions where interference with licensed services is seen to occur. DTG said that although technology and service neutrality can lower barriers to innovation, there was a risk that the more generic the technical conditions the more difficult it will be to have coexistence rules that allow efficient spectrum sharing. Huawei said that while service neutrality may be welcome in the case of licence exempt generic short range devices (SRDs), it did not consider that service neutrality was beneficial in all licence exempt bands. It identified the use of the 5.9 GHz band harmonised for intelligent transport systems (ITS) on a licence exempt basis. BT said a technology-neutral approach would allow bands such as 5/6 GHz (that are licence-exempt) to support technologies such as 5G NR-U in addition to Wi-Fi in future.	The responses of those stakeholders who addressed the issue of Ofcom pressing for technology and service neutrality clearly illustrate a theme of our overall spectrum strategy: namely, the balance between liberalising spectrum use to enable innovation whilst also ensuring protection from interference for incumbents (and their potential future applications). Both are important. However, we continue to believe we should encourage innovation wherever possible to ensure consumers and businesses can benefit from new wireless applications and devices. In general, we believe this is made more possible through placing a greater emphasis on promoting technology and service neutrality. As noted elsewhere in this document, this general emphasis is made possible by adopting realistic approaches to coexistence, based on protections that are actually necessary in real-life situations rather than theoretical 'worst-case' scenarios.

Stakeholder comments	Ofcom response
Two confidential respondents considered it very difficult to be technology neutral while retaining protection to highly sensitive systems.	
Harmonisation Telefonica said it was important for Ofcom to continue with its international engagement and devote effective resources to ensuring that the UK influences the agenda and seeks to achieve co-ordination and harmonisation of spectrum. Telefonica sought details of how Ofcom could maintain a leading role, given the UK's departure from the EU had removed it from key bodies. Nokia too said a common European approach in establishing technical coexistence conditions and equipment standards played a major role in achieving economies of scale and opening the market to harmonised technologies and equipment. The Ofcom Advisory Committee for Wales said international standardisation work could enable network and customer equipment to be developed for rural fixed wireless access (FWA). The European Utility Telecomm Council said markets were becoming ever more global, and spectrum harmonisation between the UK and other countries was more essential than ever. The UK must recognise problems such as interference due to the international misalignment of spectrum. Joint Radio Company said solution providers were seeking to address global markets rather than 'UK only' solutions Vodafone said international agencies such as CEPT already tried to write standards in as technology-neutral a manner as possible but were faced with	Ofcom remains committed to working within international organisations and to take a leading role in decisions about the future use of radio spectrum (see also below). We recognise the value harmonisation can deliver in terms of economies of scale and spectrum efficiency. However, we note there may be circumstances where a UK-only approach is more appropriate, where practical and where international agreements allow. We recognise the challenges in aiming to secure greater technology and service neutrality through internationally agreed harmonisation but note that this aim is also reflected in the principles developed by bodies such as CEPT. We will continue to devote the necessary resources towards supporting our international objectives.

Stakeholder comments	Ofcom response
coexistence evidence submitted by contributors that supported their own products/applications. Vodafone said it supported Ofcom's aspirations, but was not optimistic regarding how achievable this is. The same points were made by Sky.	
Promoting knowledge of flexibility The Ofcom Advisory Committee for Scotland said the range of wireless users was increasing, in particular via private 5G, and a lack of understanding of how to acquire spectrum for private and/or local uses was a potential barrier for innovation. The Ofcom Advisory Committee for Wales said early stage start-ups and microbusinesses undertaking development are often highly knowledgeable about their specific device requirements - but often seem to be lacking in awareness of appropriate bands to use and/or perceive flexibility of licensing to be low. It said greater engagement, support and information would help resolve this. Vodafone said it supported Ofcom's proposals to ensure that companies are aware of the flexibility that generic technical conditions provide them, it had concerns about the funding of such activities.	Although we received few responses on our proposal to promote knowledge about the flexibility available in spectrum authorisations, there were no suggestions that it should not be an important aspect of our overall strategy. As noted in the December 2020 consultation, the best current example of flexible conditions are those specified for the 'non-specific SRD' (Short Range Device) category. Companies need only ensure that their technology is consistent with these technical conditions, rather than having to develop new conditions for their new application. In addition, generic harmonised standards exist which allow a broad range of devices to be placed onto the market. We will seek to expand our engagement with stakeholders other than existing licence holders to ensure they are aware of the options open to them. One of our key objectives is to raise general awareness of spectrum and expand the knowledge of new and existing stakeholders.
UK approach to equipment standards Among those supportive of our identification of UK-specific approaches, 5G New Thinking said it agreed that international-level coexistence and equipment standards can serve as a barrier to innovation, and that more flexible non-specific regulation can mitigate this.	We recognise that using UK-specific routes to market may not always be appropriate for some developers of new technologies and equipment. To that extent, we understand the comments of those stakeholders who believe international harmonisation processes allow for greater economies of scale from wider markets. Nevertheless, we believe there are circumstances where UK-specific approaches – including through the use of

Stakeholder comments	Ofcom response
Sky said organisations seeking to innovate would benefit from product conformance, certification and approval processes which are easy to understand and cost effective to implement. Ofcom could assist further in this area, particularly for SMEs. CommScope said it had noticed a reluctance among notified bodies to get involved, particularly in the absence of either a suitable recognised standard or a very stable/mature 'draft' standard. This has the effect of delaying take up and deployment of new services. CommScope said it is a situation the Notified Body route to market was established to resolve - but to date has not delivered.	UK Approved Body (GB) and Notified Body (NI) processes – may provide opportunities for developers. It is not for Ofcom to determine what approach is best for businesses wishing to place new products on the market. That is for the business itself to determine and will depend on particular circumstances. However, we believe it is important that UK developers of new products are fully aware of all the options available. We remain committed to exploring with Government (BEIS) whether the Approved/Notified Body processes can be simplified and/or better coordinated in order to support innovation. At present, the burden of proof is on the developers to show that their new equipment uses appropriate techniques to access spectrum and mitigate interference.

Understand, assist and inform

Stakeholder comments	Ofcom response
Outreach - Support for greater engagement with stakeholders Nokia welcomed the proposals to improve outreach with stakeholders. Joint Radio Company acknowledged that Ofcom engages effectively with existing and future spectrum users through a range of consultations, specialist working groups, Tech UK and webinar sessions. However, they added that a flexible and accessible approach to future engagement was needed through the combination of physical and online formats. DTG and Innovation Lambda were both appreciative of Ofcom's engagement with private and public sector organisations through a series of workshops. They both agreed with Ofcom's engagement with funding bodies and venture capital bodies recognising that the telecoms market is too often considered difficult to understand by those entities. DTG added that engagement was useful to organisations that rarely engage with Ofcom and other spectrum stakeholders. Huawei noted that better understanding of verticals, businesses and other new potential users of spectrum was needed. Nano Avionics UK requested that Ofcom provide more elaboration of engagement proposals and outreach programmes.	We agree with the benefits of greater engagement with our wide and increasing range of stakeholders. Section 3 sets out how we will take our outreach work forward.

Outreach - Suggestions for outreach activities An individual respondent felt that method of communicating with stakeholders was unsatisfactory and suggested that better and more complete information should be presented by means of the mainstream media including social media. Ofcom Advisory Committee for Scotland suggested that Ofcom empower local businesses by rolling out an educational programme to help them understand how to acquire spectrum to fit their business needs. Two confidential respondents said that they saw the benefit in holding industry engagement prior to formal consultations are issued. One suggested that this could be in addition to the existing process of "calls for input" prior to consultations. The other noted that Ofcom's engagement with stakeholders prior to consultations has improved in recent years, but there was still more that could be done. A confidential respondent said spectrum is generally not given enough consideration when new services are planned. It suggested that emphasis for outreach should be for new entrants and should focus less on spectrum but more about covering topics that will require spectrum. It noted the difficulty of engaging with new entrants and smaller organisations that are not spectrum literate who will often make plans based on implicit assumptions of spectrum availability where in reality, that spectrum may not be as available. The Ofcom Advisory Committee Wales cited the low take-up of shared access in specific bands in Wales and further commented that this was a result of a low level of understanding of spectrum. It suggested that that one approach to bridging the gap in understanding would be to provide	We acknowledge and welcome the range of suggestions that stakeholders have made. Section 3 sets out how we will take our outreach work forward utilising a range of different channels to engage with different audiences.

Stakeholder comments	Ofcom response
targeted information, outreach and engagement to those individuals and communities who can best exploit them.	
Reporting – support for Spectrum Roadmap Vodafone and a confidential respondent welcomed Ofcom's plan to prepare a Spectrum Roadmap. The confidential respondent suggested this should cover availability of new spectrum bands, including internationally harmonised bands as well as potential new bands. It further commented that the Spectrum Roadmap will be a "critical enabler of innovation".	We will proceed with our proposal to publish a Spectrum Roadmap periodically. The Spectrum Roadmap will provide a forward indication of how demand for spectrum is changing and our plan of work to meet evolving demand. It will consider the range of market, technology and international developments affecting demand for spectrum and explore the associated opportunities and challenges for our programme of spectrum management and release.
Reporting - link to 'good neighbours' Some respondents linked reporting to the 'good neighbours' concept. They felt that reporting could create an opportunity to encourage better coexistence by providing stakeholders and licensees with up to date information on who is using a particular band in a vicinity.	We agree with this observation.

Stakeholder comments	Ofcom response
Reporting – Stakeholder suggestions Some respondents requested more transparency in publishing open data, others requested more accessible technical information. An individual respondent asked that technical detail of interference assessments be more accessible and details of actual devices causing interference be published each year, so trends can be readily seen. Arqiva noted that any information made available must be "up to date and relevant". Huawei responded that it was useful for Ofcom to regularly report on the number and nature of issued Shared Access Licences (e.g., at 3800-4200 MHz and 26 GHz) and Local Access Licences in mobile bands. It added that this would help industry better understand the level of demand for local licensing in the UK. The same could apply to Ofcom's other frameworks, such as TV White Space deployments.	We welcome stakeholder suggestions for how to improve our reporting. The reporting measures we intend to take forward are set out in Section 3.

Stakeholder comments	Ofcom response
Information tools – suggested improvements UKWISPA noted that improvements to information tools, such as the Spectrum Maps and UKFAT were necessary. Nano Avionics requested the development of an automated frequency licensing scheme. Others endorsed the development of Application Programming Interfaces (APIs) and improvements to Ofcom's website. Joint Radio Company noted that Ofcom's existing tools were not adaptable to the needs of different users. They cited the experience of Energy Network Operators to support this claim. Joint Radio Company further noted that the situation hinders potential innovation. DTG and Innovation Lambda were supportive of access to the information collected by Ofcom's remote spectrum monitoring systems. However, others such as, the Scotland 5G Centre, DTG, CommScope and, 5G New Thinking noted the risk around commercial confidentiality and security sensitivities. Arqiva echoed this view and further stressed the importance of up to date and relevant information noting that any actions to improve the quality of data and its accessibility was welcomed. Scotland 5G Centre stated that Ofcom should do more to provide easy step-by-step guides and information. It suggested that the licensing process should be made easy as this will encourage innovation.	We note the general support for our proposal to improve our information tools. We will continue to ensure that any improvements to our information tools will have a more stakeholder focus, bearing in mind the issues of concern around commercial confidentiality and security sensitivities. Section 3 sets out the improvements we plan to take forward at this stage.

Licensing to fit local and national services

Stakeholder comments	Ofcom response
Demand for local access The majority of stakeholders agreed that there is likely to be greater demand for local access in the future. Scotland 5G Centre said that take-up of private networks in Germany is a demonstration of the increasing demand, while 5G New Thinking, Federated Wireless and a confidential respondent cited the growth of CBRS in the USA. Stakeholders noted other uses that may also have increasing demand for local access. SOS, the BBC and BEIRG commented that local access will also be increasingly required for PMSE. e2E Services said that a local approach could suit the use case of small commercial UAV businesses. Joint Radio Company noted that some very localised spectrum access requirement is anticipated for potential on-site systems. Mavenir agreed that there would be demand, as long as the product ecosystem in such bands is matured and readily available. They said that launching services in "new spectrum" is challenging, especially for smaller businesses and enterprises, due to an immature ecosystem. Telefonica and Vodafone said that demand for local access in the future is unclear. Telefonica and Huawei suggested Ofcom report regularly on uptake of local access in spectrum bands where it is enabled, in order to inform the industry on the level of demand and establish the extent to which spectrum sharing policies are increasing the utilisation of spectrum and delivering optimal use. The Advisory Committee for Scotland also encouraged Ofcom	Please see paragraph A1.56 Our area of emphasis to consider further options for licensing spectrum use over smaller geographic areas may be particularly relevant to bands that support, or may in the future support, mobile technology, given the benefits of local applications being able to take advantage of the mobile equipment ecosystem.

Stakeholder comments	Ofcom response
to publish the number of licences awarded, to show how regulatory policy is translating into business and economic success. Telefonica said there may be greater demand in specific bands that is created as a result of a utilisation trend in that band. They gave the example of 26 GHz, where they said use for mobile services may be mainly concentrated in areas of high demand, leaving relatively large geographic areas where local access would be an efficient use of the spectrum.	
Continued need for national and wide area access Stakeholders responded that it is important that Ofcom does not underestimate the continued need for nationally allocated or licensed spectrum for a variety of applications. Examples included: • data scanning and transport drones (ARPAS); • connectivity for smart grid assets and devices (European Utility Telecom Council); • TV and radio (Arqiva); • satellite use, including for broadband connectivity and TV broadcast services (SpaceX, ESOA, Global VSAT, Intelsat and a confidential respondent). Although some satellite stakeholders did note that terrestrial local licensing may have an impact in bands which are normally shared between Fixed Satellite Service earth stations and terrestrial use, such as the 3.8 – 4.2 GHz band.	Please see paragraph A1.58
Spectrum sharing and efficient use of spectrum *Spectrum sharing should address clear demand and deliver net benefits*	*Spectrum sharing should address clear demand and deliver net benefits* Please see paragraphs A1.62-A1.63.

Stakeholder comments	Ofcom response
Huawei and the Global Mobile Suppliers Association said that sharing should not be considered a goal in itself; they, similarly to Telefonica, argued that sharing should only be considered where there is a clear demand for spectrum, that will deliver value that would not otherwise be realised, and where the benefits of sharing outweigh the costs. BT said that the benefits from local licences need to exceed the benefits from providing national spectrum licences for national operators. Vodafone warned that Ofcom needs to take care not to conflate spectrum utilisation with spectrum efficiency. Maximising spectrum efficiency means we achieve the best social and economic outcomes for the UK. It is not a given that this equates to gaining maximum usage of spectrum. For example, allowing opportunistic first-come-first served use could exclude higher value applications that have longer investment cycles. Alternatively, they argue the investment case for widespread networks may be predicated on serving a suite of applications, and if some of those applications are instead served by users accessing spectrum directly, the investment case for the scale network risks being undermined, damaging welfare overall. Huawei noted that many new industrial or business users who might wish to access spectrum on a local basis are still in the early stages of quantifying their spectrum needs and forming strategic partnerships, including with the MNOs. This should be accounted for in addressing the geographic nature of new spectrum authorisations – the opportunity cost of locally licensing excessive amounts of spectrum may far exceed any perceived value creation which industrial or business use might bring. With this background, Huawei considers it is important for regulators to proceed in a measured way and	*National licensing is preferable for mobile networks* The availability of national licences can be important for services for which we expect there to be national demand. The benefit of making mobile services widely available is one of the reasons we have authorised mobile bands on a national basis. For example, this year we awarded the 700 MHz and 3.6-3.8 GHz bands by auction on a national basis. However, the provision of national mobile service may not always require national licensing in every band used if, for example, certain bands are used for extra capacity in certain locations. We acknowledge that Local Access Licences is one element for addressing this, but as discussed in our statement on Enabling wireless innovation through local licensing it is not the only one. *Promoting investment* Ofcom shares the Government's ambition for the UK to become a world leader in 5G, and in carrying out our functions and exercising our powers, we must (among other things) have regard to the desirability of encouraging investment and innovation in relevant markets. *Local licensing more suited to high frequencies* We acknowledge the observations that the propagation characteristics of higher frequencies can mean that co-existence between local licensees can be easier to manage.

Stakeholder comments	Ofcom response
account for the opportunity cost of locally licensing excessive amounts of spectrum bands which are harmonised for mobile communication networks. In contrast, Innovation Lambda said wide adoption of spectrum sharing techniques is essential to ensure both continued spectrum access to current users, and, at the same time foster new innovative uses. They believe it is important to enable shared access to bands unless it is clear that this is not possible, and Ofcom should consider shifting the narrative about spectrum management from 'whether spectrum can be shared' to 'how spectrum will be shared'. *National licensing is preferable for mobile networks* Huawei argued that local licensing contributes to the geographic fragmentation of spectrum and should not be considered as a first option, especially if it compromises the availability of large contiguous bandwidths for high performance IMT. Huawei consider that the huge investments by MNOs over the past decades in the UK's mobile communication network infrastructure should be exploited to the greatest extent possible to address the connectivity needs of vertical use cases (local and wide-area). As such, Huawei considers that priority should be given the facilitate the provision of service by MNOs to industrial / business users – where there is demand – using the MNOs large scale network assets. They suggested that the needs of industrial and business users can be met by obligations on MNOs to provide solutions to these users in the form of customised services (including private networks) via slicing of the MNOs public networks, or direct leasing of spectrum from MNOs by these users (as per Ofcom's Local Access Licensing framework). Local licensing should be considered as a secondary option, and in cases where industrial and business users'	

Stakeholder comments	Ofcom response
connectivity requirements cannot be addressed by the MNOs' large-scale networks. Vodafone believes that Ofcom is correct to consider further options for localised spectrum access, but not at the expense of national awards of spectrum where needed. Nokia said that while spectrum sharing continues to gain relevance, 'exclusive' licensed spectrum that provides certainty for investment and adequate coverage and quality of service continues to be relevant not only for public mobile networks, but also for some vertical applications, for example for URLLC services. *Promoting investment* Telefonica said it is vital that Ofcom has regard to the desirability of encouraging investment when making decisions on spectrum matters. Promoting investment is a priority for Government and should be a priority for Ofcom. The regulatory regime managed by Ofcom, including its management of spectrum, must support and incentivise continued investment and the rollout of mobile services to keep pace with rising consumer and business demand and ensure the UK is a leader in 5G. Ofcom should remain alert to the risk of making decisions that could undermine the substantial economic investments that have already been made, or that could disincentivise or weaken future investment cases. Vodafone said Ofcom's goals should be to provide a regulatory environment that encourages sustainable investment. *Local licensing more suited to high frequencies*	

Stakeholder comments	Ofcom response
Huawei noted that local licensing would be more spectrally efficient in high frequency bands (e.g. mm-waves) where poor radio propagation characteristics allows greater frequency re-use, in contrast to low band (<1 GHz) and mid bands (1-7 GHz), which they say are the 'sweet spot' for wider area mobile macro-cellular coverage, and thereby suitable for wide area licensing.	
Safeguarding current and future use by existing users Intelsat and ESOA suggested that where there are bands shared between satellite and terrestrial services, local terrestrial licences should be limited geographically (perhaps to indoor use) so as not to produce a barrier to the deployment of satellite earth stations, in urban and rural locations.	As discussed in our statement on Enabling wireless innovation through local licensing, we appreciate that regulatory certainty is important to enable earth station users to make investment decisions. However, we also note that there are growing and competing demands on the spectrum used by earth stations from other services which can also deliver a range of benefits. We consider that spectrum sharing though local licensing could allow a broader range of services to operate to support growth in both areas.
Time-based sharing and automated access The BBC, APWPT, DTG, Dynamic Spectrum Alliance, and Innovation Lambda commented that future demand might include use cases with short-term requirements, and that we should allow for short-term spectrum use. DTG and Innovation Lambda gave the example of TV production, where it might be useful to have a Local Access Licence that lasts a couple of days or weeks. The BBC suggested that short-term access might be required for a sporting venue where TV coverage is required for a specific event. The BBC said that Ofcom does not currently consider short-term licences in its thinking on local spectrum access. The BBC believes that Ofcom should offer flexibility in spectrum access duration as well as location. They	Please see paragraphs A1.68-A1.71. The process to issue a Local Access licence is different to a Shared Access licence, and includes engagement with the incumbent licensee, who will consider the application and may raise an objection (e.g. they have deployments in the area requested, or plans to deploy in that area). Our work to implement a fully automated authorisation approach does not currently consider Local Access Licences.

Stakeholder comments	Ofcom response
suggested that the way in which Ofcom manages existing PMSE spectrum is a good model to learn from for localised and short-term spectrum access. BT said that Ofcom should automate its licensing process in existing shared bands, as some private network applications, such as temporary emergency networks and special events, require rapid issue of licences. The Scotland 5G Centre said that removing barriers to access Shared Access licences is important. A roadmap to automated access, tools and systems is required, as the current process will not scale to meet demand. DTG, Dynamic Spectrum Alliance and Innovation Lambda said that automation of the Local Access Licence application process would both increase the speed with which applications could be processed, and allow Ofcom to reduce the overhead of managing increasing volumes of licence applications. Global Mobile Suppliers Association considered that existing spectrum authorisation frameworks based on individual licensing and licence exemption in distinct frequencies respectively, as available today, are sufficient to cater for all foreseen intra-service spectrum sharing scenarios for innovative use cases. Where there might be demand for dynamic / opportunistic intra-service spectrum sharing, these can already be catered for using licence exempt bands. Therefore they do not see a need for additional spectrum sharing frameworks to cater for such dynamic / opportunistic use.	
Dynamic sharing	Please see paragraphs A1.70-A1.171.

Stakeholder comments	Ofcom response
Nokia said that looking towards the future and the developments that are considered for 6G and the use of high and even-higher frequency bands (up to terahertz), access to spectrum on very specific geography/time period / frequency will increase and therefore the use of spectrum on a local basis will gradually increase. Such use will require considering new tools of spectrum management to allow a more dynamic access to spectrum resources to accommodate different usage patterns and facilitate efficient and higher spectrum reuse. Sky said licensing processes should be streamlined, especially for spectrum for short term and / or local use. Automated processes should be introduced wherever possible, and these should incorporate the visibility of available spectrum at the time of making an application. Scotland 5G Centre and 5G New Thinking strongly encouraged Ofcom to consider further localised licensing options, particularly around the area of automated spectrum sharing. Federated Wireless urged Ofcom to consider licensing approaches that enable opportunistic use of both new bands as well as previously licensed bands. Rather than requiring users to apply for a first-in-time right to a specific geographic area, as Ofcom's current local area licensing rules permit, the use of an automated dynamic sharing database solution would permit users to "right-size" their spectrum demands – requesting access to the exact amount of spectrum in the exact geographic area that they need. This opportunistic approach is currently being implemented in the US CBRS band.	

Stakeholder comments	Ofcom response
Federated Wireless also noted that in our consultation we noted the advantages of an automated approach to our shared access rules, but expressed concerns about the cost and complexity associated with the technology. Federated Wireless believes an automated approach has numerous advantages that outweigh the costs. 5G New Thinking said careful choices of automated spectrum sharing tools are critical to the success of localised access at an impactful scale.	
Harmonisation The BBC said that economies of scale for non-public networks would be maximised for UK citizens and consumers by adopting harmonised approaches internationally, for example by agreeing common frequency ranges and, where possible, aligned authorisation regimes for their use internationally. They noted that the different approaches to date taken by, for example, the UK and Germany in licensing local access to parts of the C-band have not led to any economies of scale in equipment manufacture or portability. Processes adopted in the UK may not be 'exportable' to other territories with different regulatory frameworks.	We agree that harmonisation can provide the opportunity for equipment and device manufacturers to exploit economies of scale, as well as the ability for devices to roam between countries. We recognise that countries around the world have a variety of regulatory frameworks and policy objectives and may face different issues and implement different regulatory solutions to those in the UK, and we actively look to learn from our international engagement with others. In making the 3.8-4.2 GHz band available, our position was that providing regulatory certainty on access to spectrum in this band will provide a considerable incentive for manufacturers to produce the equipment users need.[25]
The Nations and rural users The Ofcom Advisory Committee for Scotland, Scotland 5G centre, and Ofcom Advisory Committee for Wales raised the specific connectivity challenges in the Scotland and Wales respectively, and particularly for rural areas.	Please see paragraph A1.65.

[25] See paragraph 3.21 of our statement 'Enabling wireless innovation through local licensing'

Stakeholder comments	Ofcom response
The Advisory Committee for Scotland said that sharing gives local community groups, public sector organisations and local ISPs the ability to acquire local spectrum at reasonable prices. As new technologies such as Open RAN and 5G Mobile Core as a Service drive down the cost of physically providing a mobile network, the ability of smaller organisations to acquire sufficient spectrum to operate a local 5G service in areas of need becomes feasible. The Advisory Committee for Wales responded that bundles of 'local access' licences in specific geographic location make new business models economic and reduce risk for new entrants, and are one potential way to make provision of Fixed Wireless Access provision work in rural Wales. The Advisory Committee for Wales agreed with the trend of diffusion of wireless capabilities into new sectors, and said that such developments is unlikely to be solely about coverage for mobile broadband, but rather the underpinning of national and rural innovation capabilities in key sectors, e.g. agriculture, energy and transport. Scotland 5G Centre welcomed consideration of licences to support different geographies. Whilst local licences are well-suited to spot solutions, further consideration at a national level is required to support a coordinated approach to address rural Scotland specifically. Access to licences to support wide geographic coverage is encouraged however, consideration also needs to be applied to how higher frequency licences could also be utilised on a small geographic footprint. Scotland 5G Centre consider that the new 5G business model for rural locations will be driven by new providers. Appropriate and efficient access	

Stakeholder comments	Ofcom response
to local and shared licences will be the lifeblood to enable new business models for new and smaller operators, These new business models are a result of market failure by the incumbent MNOs and its unrealistic to believe 5G will be deployed in locations where 3G/4G is currently not cost effective. Ofcom need to do more to encourage alternative models and deployment of neutral host services, addressing widescale market failure (in rural Scotland). Reducing the cost of development and assessing the value and contribution to public services.	
Spectrum sharing in non-mobile bands Telefonica said that sharing is a "two-way street". Access should not be focussed just on mobile bands, but equally to other bands.	A local licensing approach may be particularly relevant to bands that support, or may in the future support, mobile technology, given the potential benefits of local applications being able to take advantage of the mobile equipment ecosystem. However, geographic sharing of spectrum is not necessarily focussed only on mobile bands. Most types of licences that we offer are for a particular location or site, and the bands where we have auctioned national block assigned licences (which are often used for mobile services) are a notable exception to this. The approach we have decided to adopt builds on how we manage bands used by other sectors, which are primarily licensed for smaller geographic areas.
Need for licence-exempt spectrum DTG, Dynamic Spectrum Alliance and Innovation Lambda all commented that in the home, most traffic is and will most likely continue to be carried over licence-exempt spectrum. They believe that Ofcom should ensure enough licence-exempt spectrum is available to allow the consumer market to grow.	As we set out in the consultation, we review spectrum needs and, where appropriate, consider making spectrum available. This includes demand for spectrum that can be accessed by devices under licence-exemption. For example, we have recently authorised access to the lower 6 GHz band (5925-6425 MHz) for indoor and very low power outdoor use. This band is

Stakeholder comments	Ofcom response
	suitable for Wi-Fi and similar wireless technologies, for example Bluetooth, LoRa and SigFox, used for everything from health tracking to smart cities.
Local Access licences in the 700 MHz and 3.6 GHz bands Arqiva, Innovation Lambda, Scotland 5G Centre, 5G New Thinking and DTG said that the 700 MHz and 3.6 – 3.8 GHz bands should be brought into the Local Access licence regime, and that their exclusion does not seem to align with our strategy.	These spectrum bands were awarded by auction in April 2021. As we set out in our March 2020 Statement on the Award of the 700 MHz and 3.6 – 3.8 GHz spectrum bands (para. A2.16), we would not expect access to newly awarded bands to be possible straight away (and possibly not for some considerable time), as the licensees will need time to decide where they intend to use the frequencies themselves.
Indoor use Huawei recommends that indoor use could be promoted starting with bands that are not considered suitable for outdoor deployments due to restrictions for the protection of incumbents (they note that this might include 3.3 – 3.4 GHz and 4.5 – 5 GHz).	We acknowledge this approach and do make spectrum available for indoor use; for example we made the 24.25-26.5 GHz band (the lower 26 GHz band) available for indoor use as part of our Shared Access licence framework.
Interference to satellite systems A confidential respondent commented that localised in this context tends to refer to distance along the ground, but radio waves can potentially cause harmful interference to satellite systems. This needs to be taken into account when terrestrial services share bands with space services.	We recognise that all users of a band, including in some cases space services, may need to be considered when considering compatibility with other services
Mobile Network Codes Joint Radio Company said that we should give additional attention to policy and management of mobile network codes (MNCs) and numbering. The allocation of MNCs is intrinsically linked to private network operation, spectrum sharing, and localised licensing.	We addressed issues regarding numbering resources and MNCs in our statement on enabling wireless innovation through local licensing (see paragraphs 3.218 to 3.221 and Annex 1 pages 28-34). We continue to monitor demand for numbering resources, to engage with stakeholders to understand scenarios where demand is likely to arise and how we might manage that demand.

Stakeholder comments	Ofcom response
Licence fees The Advisory Committee for Scotland and 5G New Thinking said that the cost of microwave backhaul licences could be a potential barrier that could impact commercial viability of private 5G networks. 5G New Thinking said that Ofcom can should do more to reduce the costs of smaller operators deploying rural networks, including reviewing Fixed Wireless Access licence fees which pertain to backhaul links for rural 5G. They propose targeted, sector-specific alteration to fees in support of the wider aims of the strategy consultation. Vodafone said that Ofcom must ensure that spectrum is accessed on equitable terms, with no special treatment given to particular classes of users, and everyone paying their way fairly. They express concerns about some users accessing spectrum at lower charges, and that users of multi-service networks should not be 'punished' by having to pay more for spectrum than those securing access to spectrum directly.	We use spectrum pricing to create incentives for spectrum to be used efficiently. Where demand for spectrum is greater than what is available (i.e. there is excess demand) we set fees based on the concept of opportunity costs – the highest value of alternative spectrum use that is denied by the current user. These fees are known as 'administered incentive pricing' (AIP). Where spectrum is not in excess demand we set fees to recover our costs associated with managing that spectrum. Further detail is available in the consultation, paragraphs 7.21-7.23. Our approach to setting AIP-based fees is set out in our 2010 Revised Framework for Spectrum Pricing (SRSP). In the SRSP we set out our pricing principles, and explain why it will generally not be appropriate to provide AIP concessions in order to promote innovation.

Promoting spectrum sharing

Stakeholder comments	Ofcom response
The principle of 'good neighbours' EMEA Satellite Operators Assoc (ESOA), Global VSAT and Intelsat said satellite operators already have considerable incentives to be 'good neighbours'. They said that the spectrum available for satellite use is limited	The responses we received indicate we were correct to identify being a 'good neighbour' as an important means to promote sharing and so ensure more efficient use of the spectrum. We have therefore decided to make the 'good neighbour' approach key to our spectrum strategy going forward.

Stakeholder comments	Ofcom response
by the available allocated bands and most bands are heavily shared among different satellite operators and users. CommScope and BT said all three of our core proposals on this matter were important. Telet Research said it strongly supported the proposals. It said that as devices become more intelligent they are better able to cope with interference. Sky and Arqiva agreed Ofcom had identified the correct proposals, but warned us to adopt a cautious approach with respect to existing spectrum users and to take account of product and infrastructure life cycles. Nokia said encouraging spectrum use on a 'good neighbours' basis required revising existing sharing conditions to improve efficiency'. It said that some of the proposed actions should be taken not only at national level, but in coordination at regional and international level to assure that services benefitted from harmonised technical rules. An individual respondent, Paul Robinson, said a mechanism for arbitration was essential and that the 'good neighbour' policy would not work unless the regulations "had "teeth"". Another individual, John Shaw, opposed the proposals, saying the implication was that service providers and users could no longer expect interference free operation.	We acknowledge that being a 'good neighbour' is not the only requirement for ensuring a more efficient use of spectrum. We have noted the comments of respondents identifying other factors we need to take into account. We also recognise that the needs of existing spectrum users must be a key part of our considerations – as was made clear in our December 2020 consultation.
Principle of applying 'realism' in analysis There was strong support for greater realism in analysis from some MNOs, mediathand, Hughes Europe & Echostar Mobile, and Nano Avionics. Telefonica said such measures should not just be considered in the context of shared spectrum, but also be applied to other areas of	We note the wide support for the principle behind our proposals to use greater realism in coexistence analysis. However, we also acknowledge the reservations of some respondents urging us to proceed with caution. It is reasonable for users providing valuable current services to be cautious about unknown future services that may wish to operate alongside them.

Stakeholder comments	Ofcom response
spectrum. It agreed that technical conditions for licensed spectrum had tended to rely on overly conservative models. Vodafone noted the example of sharing mobile spectrum with third parties through local licences or leasing – it said filters were much better in reality than was assumed in coexistence analysis. However, it said realistic modelling might not yield as much increased spectrum efficiency as might be expected, because the difference between theoretical and real-world models was already being exploited downstream by spectrum licensees. BT said the experience of mobile to TV interference, following the release of spectrum in the 800 MHz band, provided a good example of how interference may in practice be less severe than predicted. The BBC urged us to adopt a more cautious approach to 'realism'. It said the use of more realistic analysis was only sensible if the performance achieved in tests is incorporated into relevant equipment standards. Otherwise, there was a risk that subsequent users may bring into use equipment which, while meeting relevant specifications, does not meet the assumptions made in the earlier coexistence analysis. The Voice of the Listener and Viewer said it supported increased realism in coexistence analysis at a national and international level, but warned it remained vitally important for all spectrum users to control interference.	We note the points raised that reflecting current equipment performance may not necessarily guarantee future equipment performance unless the standards are changed. However, we note that performance will always be better than the equipment standards and harmonisation measures, as these provide minimum regulatory performance conditions for equipment. Actual equipment performance may also demonstrate that improved levels of performance are possible. We do not therefore consider it necessary to amend standards levels in many cases, as these have to take account of all possible deployment scenarios and temperature ranges which may not occur in the UK. We agree it may not always be possible to achieve perfect accuracy in coexistence analysis, and that some degree of conservatism is always to be expected. For that reason, we restate our intention to consult further on approaches to specific spectrum bands
Importance of up-to-date analysis and information 5G New Thinking said equipment and deployments evolve over time and the sharing environment can change. It said Ofcom should predefine a process for making agile changes to any part of an automated coexistence process,	We acknowledge the importance of up-to-date analysis and information to ensure that the balance between promoting innovation and protecting existing services is maintained.

Stakeholder comments	Ofcom response
as a natural extension of our existing ability to make changes to various parameters. The BBC said that as equipment standards improve there may be scope for further gains in spectrum efficiency. However, this would require an ongoing overhead in equipment monitoring and standardisation work, and updating the algorithms used in licensing. Only if Ofcom was prepared to commit to resourcing that overhead should we proceed in this way. Hughes Europe & Echostar Mobile noted the complexity, cost and the time needed to update coexistence studies over time. DTG also said coexistence studies should be periodically reviewed if it is observed that the UK market is significantly different to the standards used for initial studies. It said the process of updating would require personnel and budget that Ofcom would have to make available. Other respondents urged more openness from MNOs in support of realism in coexistence analysis. For example, ESOA and Intelsat said Ofcom could improve realism if it made information available on the extent of deployment of existing systems. This could help to determine realistic assumptions for planned future deployment scenarios in potential new mobile bands. Huawei said databases could be used to relax initial technical restrictions over time but was not convinced by our suggestion in the December 2020 consultation that technical restrictions could be tightened in future if necessary. It said this was not conducive to investment.	However, it is difficult to predict the course of wireless technology in future with any certainty. The introduction of innovative new services may increase the potential for interference in future. But improvements in equipment operated by existing users may mean their services can coexist with new neighbours. It is important that coexistence relationships are fully understood. We note the comments of those respondents wishing to see a greater availability of information about deployments of existing MNO systems. However, there are some limits on the details we can supply. Firstly, we consider advice from HM Government as to the potential implications of disclosure of the location of mobile phone masts on national security matters. Secondly, we acknowledge that some details of the current and future deployment of systems may be commercially sensitive. However, we do supply information about mobile coverage.

Stakeholder comments	Ofcom response
Principle of greater resilience to interference Most respondents supported the general principle that spectrum users should themselves be resilient to interference, although many did not expand on their reasons for agreeing with our proposals. Among those expressing clear support, Telefonica said more could be done to foster a regime to improve receiver performance, but there had been little action or progress in this area over the last few years in the UK. SpaceX said it wholeheartedly supported Ofcom's aim to encourage users to be more resilient to interference. It alleged there was a tendency among some other operators to design systems that are overly sensitive to interference in an effort to limit spectrum access for competitors. It said Ofcom should adopt 'sunsets' for protections given to incumbents, in order to create incentives to use technology that is more robust. Almost all the other respondents who commented in detail about resilience to interference expressed reservations about the practicalities of driving our proposals forward. Some identified issues specific to their own sectors or to particular spectrum bands. As noted, these issues are not addressed in this statement, which is focussed instead on the principles underpinning our overall spectrum strategy.	Historically, spectrum users were assigned distinct frequency ranges, with guard bands to protect themselves and/or neighbouring users from interference. Equipment did not necessarily need to be as resilient as possible to interference, because in many cases there was little risk of receiving unwanted emissions from other users in the same or neighbouring spectrum bands. This situation is changing. The current growth in demand for spectrum shows no signs of slowing, with more and more innovative systems and devices coming to the market. If spectrum is not used as efficiently as possible – including with greater sharing of available frequencies - it presents a clear barrier to further innovation. We therefore continue to believe our proposal to encourage spectrum users to be more resilient to interference is important. Spectrum can never be entirely interference-free. We wish to signal that we will not generally expect to take action if interference is the result of poor receiver performance.
Impact on incumbent spectrum users DTG said encouraging users to be more resilient to interference was a good principle, but some applications are more susceptible to interference than others (such as live video streaming and PMSE or satellite receivers).	We believe it is in the interests of all parties that equipment deployed for communications purposes is resilient to interference. At the same time, as stated in our December 2020 consultation, we wish to stress the importance of also ensuring that new equipment does not itself emit harmful interference to other users. The balance between these two elements is

Stakeholder comments	Ofcom response
Arqiva said that while certain equipment standards were lax in terms of filtering (to ease production and minimise cost), equipment made to those standards generally performed better. Intelsat and ESOA said Ofcom's policy seemed to be aimed at certain users but not others e.g. IMT mobile systems. They said the policy would benefit from some general conditions to ensure that it is applied fairly and consistently. A requirement to accept greater interference at the receiver will always have an impact on the service, which does not seem to be recognised or acknowledged in Ofcom's discussion. A confidential respondent said greater resilience should only be expected where this is reasonable, and the responsibility needs to be shared. The onus should not solely be on the incumbent to be more resilient - the new service must also have a clear responsibility not to cause unwanted emissions. Another confidential respondent said unwanted emissions must be adequately controlled as there is nothing a receiver can do to filter these out. Two individuals, Carl Langley and John Shaw, said spectrum users can only be resilient up to a point. No amount of selectivity or filtering can remove wideband interference.	important. It is also important to note that services using particular frequency bands may change in future. It is understandable that existing users have concerns that equipment they deployed in good faith in the past may not attract the same levels of protection in future if it is not sufficiently resilient to interference. We acknowledge there are a number of factors to take into account before we can make changes to what we require from users of particular spectrum bands or of particular industry sectors. These include costs and the lifetime of equipment (see below). These will be addressed on a case by case basis, taking into account that we would normally expect good equipment performance and resilience to interference. Also see paragraphs A1.84-A1.85.
Cost and practicality of new requirements Vodafone said the desire for greater resilience must be tempered with practicality. It said existing spectrum users cannot be expected	We acknowledge the concerns expressed by a number of stakeholders about equipment lifetime and potential costs related to updating systems to comply with any new approach to equipment resilience. These issues will be relevant in any assessment we make towards allowing spectrum bands to be shared more widely in future.

Stakeholder comments	Ofcom response
to proactively remediate their equipment against unknown potential future adjacent usage. The BBC said Ofcom should weigh up concerns about interference against the risk that tighter specifications might push up prices for consumer devices without resulting in tangible spectrum efficiency gains. Using tighter equipment specifications (whether 'more realistic' or not) would only be a valid approach when standards and specifications are altered to match the assumptions used. The European Utility Telecomm Council said it wanted to draw attention to the long life and reliability required of assets in some sectors, including the utilities sector. CommScope and Hughes Europe & Echostar Mobile were among other respondents to say consideration should be given to the cost and lifetime of the equipment under consideration. The ESOA said where users have purchased and are using equipment that fully complies with the regulations at the time, they should be entitled to use that equipment for a reasonable period. UKWISPA said it was concerned that 'encouragement' for users to be more resilient to interference may lead to a perception of penalty rather than encouragement. Nano Avionics said the benefits of requiring greater resilience depended on the actual technical characteristics proposed. It said interference resilient equipment can be a barrier to entry into the market because of its expense. This could discourage newcomers and start-ups from developing new technologies, stifling innovation.	On equipment standards, we note that actual performance will always be better than the applicable regulations and harmonisation measures, as these provide only minimum regulatory conditions. Particular circumstances will be considered separately on a case by case basis, but we wish to signal clearly that we will not generally expect to take action as a result of poor performance by receivers or wider systems. Also see paragraphs A1.84-A1.85.

Stakeholder comments	Ofcom response
Differential spectrum pricing The BBC noted the suggestion of 'tiered spectrum pricing' depending on the level of protection required, and said it welcomed Ofcom's proposal that this should only be introduced "where appropriate". The BBC said it was not appropriate for public service broadcasting, for example. The ESOA supported the idea of differential pricing but said Ofcom should reward users of improved equipment with reduced licence fees, rather than penalise users of old equipment with increased fees. DTG was also concerned about the use of differential pricing. It said setting prices would be complex as many factors would need to be taken into consideration Without safeguards for existing users, it could be envisioned a case where a newcomer in the band might pay to obtain more protection than incumbent users have, which would most likely affect the business case and operation of the incumbent users. Hughes Europe & Echostar Mobile also expressed concern about the use of pricing to incentivise better interference rejection capabilities and differential protection. It said that the principle was sound from a spectrum efficiency point of view, but setting appropriate prices would require careful evaluation of many factors whose effects might not be easy to map. A confidential respondent said services for the public good should not be forced to dilute their protection due to a limited ability to pay, compared to commercial services.	Please see paragraphs A1.88-A1.89.

Stakeholder comments	Ofcom response
Different approaches to spectrum management depending on circumstances Arqiva said the overall 'good neighbour' approach could actually be interpreted as the 'dirty neighbour' approach. In the case of a service such as broadcasting, that cannot adapt in practice, additional interference may not be acceptable. APWPT said PMSE applications require interference free spectrum to be able to provide the expected quality of service. BEIRG agreed, saying it was in fundamental disagreement with any measures that reduced the interference protections for licensed co-ordinated use. Joint Radio Company said LTE was not well suited to sharing with other technologies. As such, the opportunity for coexistence may be limited by technology type, which would imply that such technologies would be seen as potential innovation blockers. Joint Radio Company also said its members operate mission critical networks, including for the reliable operation of the UK's electricity and gas networks. As such, a high degree of protection from interference is required to avoid power blackouts. Vodafone said it agreed with our proposal that incumbents must be able to justify why their usage should be protected. However, it warned against conflating spectrum usage with spectrum efficiency. If one service is overwhelmingly more valuable than another – in either economic or social terms – then it is quite possible that a loss of quality in service may be of greater cost than the gain to another user.	It is clear that the caution some stakeholders have expressed about our proposals for sharing spectrum are determined by the knowledge and experience of their own equipment and systems. Their concerns are noted and will be taken into account as our spectrum strategy is taken forward to practical implementation. We understand that spectrum usage covers a very wide variety of users and sectors and that different circumstances may warrant different approaches in order to achieve the best outcomes for both businesses and consumers. We note that our December 2020 consultation made it clear that future decisions will be rooted in evidence. In setting out our proposals we said we would expect stakeholders to provide a greater level of evidence-based analysis when engaging in the process of defining protection levels - particularly where it could have an impact on sharing in the band. Based on such evidence, there can be different approaches to different circumstances as appropriate. It could result in high levels of protection for some services, where necessary.

Stakeholder comments	Ofcom response
One confidential respondent said it did not agree with our proposal. It said interference protection should be based only on what is required by the service. If others can transmit and still comply with the protection there is opportunity. If they cannot, there is no opportunity.	
Overall balance of protection and flexibility to transmit The ESOA said improvements in efficiency can be achieved by either a reduction of the out-of-band emissions of the transmitter or by the receiver accepting a higher level of interference. It is difficult to see how these two options can be fairly judged against one another. It said this was made more difficult still when the transmitter and receiver are in different services. ESOA said that Ofcom's focus seemed to be much more on receiving equipment than transmitting equipment. Intelsat agreed, saying it supported the concept of balancing protection of services with flexibility in transmissions - but said both transmitter and receiver have a role in any compatibility issue. Innovation Lambda encouraged Ofcom to keep a balanced approach when evaluating the expected performance of devices - based not only on the latest standards (which take time to update), but also on what is currently available on the market and the device life cycle.	There are two sides to coexistence: the prevention of emissions that are harmful to other users, and the resistance of systems and equipment to potential interference. Both are equally important and we consider both sides. As noted, we already specify limits on emissions from transmitting devices as part of our authorisation conditions. We will continue to ensure these are set appropriately to ensure interference is not caused to others. We have some direct control over emissions through licence conditions and our influence in harmonisation work. On the other hand, receiver efficiency is less clearly defined. For this reason, the discussion in the December 2020 consultation on receivers used by incumbents was necessarily more detailed, because it involved exploring a wider range of issues (including the sharing of spectrum; the development of more realistic coexistence analysis; greater resilience to interference etc.).

Part II - Sector and band-specific comments

A2.3 As noted in Section 4, we received a number of stakeholder comments to our consultation which asked us to consider our policy on distinct sector-specific or band-specific issues. These are summarised at a high level in the table below. We will consider these as part of our ongoing work, including our reviews of specific spectrum using sectors and in developing our Spectrum Roadmap.

List of stakeholder comments on sector-specific or band-specific issues

Sector	Name	Concern or issue
Mobile network operators	BT	Request review of Annual Licence Fees (ALFs) Request review of long-term changes to the use of spectrum currently used for TV broadcast and the role of regulatory flexibility in achieving this.
	Telefónica	Comments regarding Public Sector Spectrum Release, specifically suggesting that the lower 2.3 GHz band should be opened up for mobile use, and request an update on the 1.4 GHz band (1427-1452 MHz). Supports allocation of 3.8-4.2 GHz for mobile use. Requested a long term plan in respect of spectrum release for mobile, and the 26 GHz more specifically. Recommends Ofcom consider new innovative approaches to licensing in the 26 GHz band, such as a Club Licensing mechanism.
Programme Making and Special Events	APWPT	Ofcom should consider PMSE and its spectrum demands in this review. Request to coordinate PMSE access with other regulators and through ITU-R. Concerns regarding protection of PMSE in the DECT band.
	BEIRG	Concerns regarding protection of PMSE in the DECT band. Comments on the principle of licence fees for PMSE. Comments regarding an absence of outdoor annual Fixed Site Coordinated licences for UHF wireless microphone users encourages inappropriate use of the Shared UHF licence.

Sector	Name	Concern or issue
Satellite /Space	Intelsat	Request Ofcom to open the full frequency range 14.0-14.5 GHz for additional use by satellites to improve connectivity not only in airplanes, but also in trains and vehicles.
	Space X	Encourage Ofcom to allow non-GSO access to the whole 14 – 14.5 GHz band, to maintain current regime around 28 GHz (market mechanism) and to introduce non-GSO band splitting in the absence of coordination.
	Viasat	Comments relating to multiple ITU filings for the same NGSO system. Requests that Ofcom consider the potential adverse impact of segmentation of satellite bands
	Confidential response	Comment on the opening up of 14.25 GHz to 14.5 GHz within the Ku band to satellite services on a non-individual terminal licensed basis.
	Confidential response	Comments on Ofcom International influence regarding space services.
	NanoAvionics	Suggests additional focus be put on space activities
Broadcasting	BBC	Comments on international engagement and UK spectrum policy where there is UK interest in spectrum use outside the UK, in addition to spectrum use within the UK.
Others	Ofcom Advisory Committee Scotland	Comments regarding the growth in private 4G/5G markets and conflict in existing spectrum allocations.
	Dynamic Spectrum Alliance	Encourages Ofcom to open access to the entire 5925-7125 MHz frequency range-'6 GHz band' to licence-exempt Wi-Fi and to enable the use of standard power indoor / outdoor Wi-Fi.
	Joint Radio Company (JRC)	Comments on mobile network codes and numbering. Request regarding access to wider channels in the VHF band.
	Hatherland Mill Farm	Comments re allocation of spectrum to terrestrial TV.
	Carl Langley	Comments on Ofcom's publication of data relating to interference cases.

Sector	Name	Concern or issue
	Huawei	Recommends indoor use could be promoted in 3.3 – 3.4 GHz and 4.5 – 5 GHz bands.

A3. Legal framework

A3.1 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"**).

Duties under the Communications Act 2003

A3.2 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 (among other things) to secure the optimal use of spectrum and the availability throughout the United Kingdom of a wide range of electronic communications services.

A3.3 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 desirability of ensuring the security and availability of public electronic communications networks and services;[26] (iv) 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 (v) 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.

A3.4 In performing our duties, we are required under section 3(3) of the 2003 Act to have regard in all cases to the principles under which regulatory activities should be transparent, accountable, proportionate, consistent and targeted only at cases in which action is needed.

A3.5 In carrying out certain regulatory functions, including Ofcom's spectrum management functions, section 4 of the 2003 Act requires Ofcom to act in accordance with the following requirements: a) to promote competition in communications markets; b) to promote the interests of all members of the public in the United Kingdom; c) to act in a manner which, so far as practicable, is technology neutral[27]; d) to encourage, to the extent Ofcom considers it appropriate, the provision of network access and service interoperability for the purpose set out in s.4(8)[28]; e) to encourage such compliance with certain international standards as is necessary for the purposes set out in s.4(9)[29]; and f) to promote

[26] Section 3(4)(ea) of the 2003 Act, added by S.I. 2019/246, Sch.1(1) para.2.
[27] According to s.4(6A) of the 2003 Act, this requirement does not apply to the imposition, in relation to a wireless telegraphy licence, of a limitation of a kind falling within section 9ZA(1) of the WT Act; or (b) the review, variation or removal of such a limitation.
[28] The purpose of securing: (i) efficiency and sustainable competition, (ii) efficient investment and innovation, and (iii) the maximum benefit for the customers of communications providers and of persons who make associated facilities available.
[29] For facilitating service interoperability, end-to-end connectivity, the changing by end-users of their communications provider, the retention by end-users of their telephone numbers after a change of communications provider; and securing freedom of choice for the customers of communications providers.

connectivity and access to very high capacity networks by members of the public and businesses in the United Kingdom.

Duties under the Wireless Telegraphy Act 2006

A3.6 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.

A3.7 We also have a duty to have regard to the desirability of promoting: (i) the efficient management and use of the spectrum for wireless telegraphy; (ii) the economic and other benefits that may arise from the use of wireless telegraphy; (iii) the development of innovative services; and (iv) competition in the provision of electronic communications services.

The licence-exemption and licensing frameworks

A3.8 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 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. [30]

A3.9 Section 8(5) of the WT Act sets out the criteria we need to consider when making regulations to exempt equipment. These are if the installation or use of a station or apparatus 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) inhibit the development of effective arrangements for the sharing of frequencies;[31]

e) endanger safety of life;

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

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

A3.10 A wireless telegraphy licence may be granted subject to such terms, provisions and limitations as Ofcom think fit (WT Act, s. 9(1)). However, this power is subject to certain constraints. In particular:

[30] Section 8 of the WT Act.
[31] Section 8(5)(ca), added by 2020/1419 Sch.1(3) para.81(3).

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

b) Ofcom may only impose terms, provisions and limitations which are: a) objectively justified in relation to the network and services to which they relate; b) not unduly discriminatory; c) proportionate to what they are intended to achieve; and d) transparent in relation to what they are intended to achieve (WT Act, s. 9(7)).

A3.11 Section 9(4) of the WT Act sets out a non-exhaustive list of the terms, provisions and limitations that Ofcom may impose, including Ofcom's powers to attach conditions to a spectrum licence requiring the licence holder to enter into a wholesale roaming access agreement.[32]

Spectrum fees

A3.12 Under section 12 of the WT Act Ofcom may prescribe in regulations the sums payable in respect of wireless telegraphy licences other than those awarded by auction. When doing so, section 122(7) of the WT Act enables Ofcom to make different provisions for different cases and to make incidental provisions. This power enables us to recover the cost of administering and managing WT Act licences. However, section 13 of the WT Act permits us to recover sums greater than those we incur in performing our spectrum management functions, to reflect a range of spectrum management objectives. In particular, in order to provide incentives - Administered Incentive Pricing ("AIP") - to licensees to use their spectrum more efficiently. This power goes to discharging a range of duties under section 3 of the WT Act which require us to efficiently manage the radio spectrum.

Spectrum trading and leasing

A3.13 Whilst a licensee cannot assign its licence to another party, spectrum trading is a process that allows the holders of certain wireless telegraphy licences granted by us under section 8 of the WT Act to transfer the licence rights and obligations to another person. Such a transfer involves the notification to Ofcom and the grant by us of a new licence to the transferee.

A3.14 Ofcom has the power under section 30 of the WT Act to make regulations to authorise the transfer to another person by the holder of a wireless telegraphy licence of rights and obligations arising by virtue of such a licence. The transfer of rights and obligations for most licences are regulated by the Wireless Telegraphy (Spectrum Trading) Regulations 2012 (as amended). The transfer of rights and obligations for Public Wireless Network and some Spectrum Access licences is regulated separately by the Wireless Telegraphy (Mobile Spectrum Trading) Regulations 2011 (as amended).

[32] Section 9(4)(ca), added by S.I. 2020/1419 Sch.1(3) para.83(3).

A3.15 Spectrum leasing (the sub-letting of licence rights to third parties) is available only to certain classes of licence and a licence variation is required in order to grant permission for leasing to be offered. Ofocm has published guidance on the process for applying for a spectrum trade or, where eligible, applying for permission to lease the rights to use spectrum.[33]

A3.16 Section 30A[34] of the WT Act imposes on Ofcom a general duty to allow leasing or transfer of all spectrum licences, and the transfer of all grants of recognised spectrum access, subject to certain limitations. For example, such duty does not apply where the licence is granted free of charge, or the duration of the licence does not exceed twelve months.

The Wireless Telegraphy Act Register

A3.17 Section 31 of the WT Act permits Ofcom to make regulations to establish and maintain relevant information (including information relating spectrum leasing)[35] in a register. Ofcom has made the Register Regulations [36] and established the Wireless Telegraphy Act Register, which provides information about who is licensed to operate services in specific frequencies or geographical areas. [37] The register supports the spectrum transfer process by providing basic information about allocated spectrum to the market.

[33] Ofcom's Trading Guidance Notes (12 March 2020).
[34] Added by S.I. 2020/1419, Sch.1(3) para.86.
[35] Section 31(3)(c), added by S.I. 2020/1419, Sch.1(3) para.87(b).
[36] The Wireless Telegraphy (Register) Regulations 2012, as amended.
[37] See the information available on Ofcom's "Spectrum Information Portal" at:
https://www.ofcom.org.uk/spectrum/information/spectrum-information-system-sis/spectrum-information-portal

A4. Glossary

2G, 3G, 4G, 5G and 6G Second, third, fourth, fifth and sixth generation mobile phone standards and technology.

AI Artificial intelligence. A term that applies to a range of different technologies that can be implemented to create intelligent agents able to perform autonomous functions.

API Application programming interface.

BEIS Department for Business, Energy and Industrial Strategy.

Bluetooth Wireless standard for short-range radio communications between a variety of devices such as laptops, headsets, printers, mobile phones, speakers.

CBRS Citizens Broadband Radio Service. The 3550-3700 MHz band in the USA with three different priorities for access. By use of shared spectrum technology this band can be used by organisations for their own private networks.

CEPT The European Conference of Postal and Telecommunications Administrations.

DSA Dynamic Spectrum Access. This is a technology for a variety of reconfigurable radio equipment allowing it to select the frequency on which it will operate at a given location and over a given period of time to optimise the use of available spectrum and avoid interference with other radios or other systems.

ETSI European Telecommunications Standards Institute.

EU European Union.

Gbps Gigabyte per second.

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

ICNIRP International Commission for Non-Ionising Radiation Protection.

IMT International mobile telecommunications.

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

ISP Internet service provider.

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

LoRa a proprietary low power, wide area network modulation technique.

LTE Long term evolution. A 4G mobile communications standard.

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

Massive MIMO A MIMO system with a large number of antennas.

MIMO Multiple-input and multiple-output. The use of multiple antennas at both the transmitter and receiver to improve communication performance.

MNC Mobile network code.

MNO Mobile network operator.

MOD Ministry of Defence.

Ofcom The Office of Communications.

PMSE Programme-making and special events. A class of radio application that supports a wide range of activities in entertainment, broadcasting, news gathering and community events.

RSC Radio Spectrum Committee. A legislative committee composed of EU Member States representatives chaired by the European Commission, which develops and votes on technical harmonisation decisions on spectrum use across the European Union.

RSPG Radio Spectrum Policy Group. A high-level advisory group that assists the European Commission in the development of radio spectrum policy.

SAS Spectrum Access System. A frequency coordination system that manages the Citizens Broadband Radio Service (CBRS) in the USA.

SigFox a low power, long range low-speed communication technology.

SIS Spectrum Information System. This provides information on how radio spectrum is issued in the UK, including the types of Wireless Telegraphy (WT) Act licences available from Ofcom and details of tradable licences.

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

TNR Transfer Notification Register. This provides information on licences which have been traded or are in the process of being traded.

TV White Spaces TV White Space devices make use of frequencies within 470 MHz to 790 MHz which are unused in the vicinity of the device after receiving operation parameters calculated by a White Space database.

UAV Unmanned aerial vehicle.

UKFAT UK Frequency Allocation Table. This details the uses (referred to as 'allocations') to which various frequency bands are put in the UK. It also shows internationally agreed spectrum allocations of the International Telecommunications Union (ITU).

UKPFA UK Plan for Frequency Authorisation. This provides information on which frequencies have been allocated and whether these can be traded.

VHTS Very high throughput satellite.

Wi-Fi Commonly used to refer to wireless local area network (WLAN) technology, specifically that conforming to the IEEE 802.11 family of standards.

WHO World Health Organisation.

WTR Wireless Telegraphy Register. This provides information about who is licensed to operate services in specific frequencies or geographic areas.

WT Act Wireless Telegraphy Act 2006.