Supporting the UK's wireless future

Our spectrum management strategy for the 2020s

Supporting the UK's wireless future – Welsh overview

CONSULTATION:

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Annex

1. Overview

This document proposes how we will manage use of the radio spectrum - the invisible waves used for all wireless communications - in the interests of everyone in the UK over the next decade.

Radio spectrum connects our digital world, benefiting every person and organisation in the country – delivering our news, connecting us to friends and family, automating factories, supporting public services and monitoring our natural environment. There's only a limited amount of it but, used wisely, it can continue to transform the way we live and work – helping to make us more productive and benefiting industries across the economy.

Ofcom has the job of ensuring this vital resource is used in the best interests of everyone in the UK. Central to our vision for enabling even greater benefits from use of radio spectrum is support for further innovation in wireless technologies and applications. This will need to be underpinned by greater sharing of spectrum between an ever-growing number and range of users, so that new services can be introduced whilst protecting the benefits people already enjoy.

What we are proposing – in brief

To deliver our vision for the future use of spectrum, we are proposing action in three main areas. These build on our existing approach of relying on market mechanisms where possible and using regulatory levers where necessary:

Supporting wireless innovation: We are proposing to make it even easier to access spectrum by:

- Expanding our work to understand, assist and inform the wide range of organisations who may benefit from wireless technologies in the future;
- 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 decisions so they are flexible enough to support new uses.

Licensing to fit local and national services: We are proposing to support the growing diversity of wireless services and providers by considering further options for localised spectrum access when authorising new access to spectrum. 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. Larger, including national, licences can support wide coverage for public mobile services.

Promoting spectrum sharing: Spectrum is a limited resource, so as innovation stimulates greater demand for spectrum, it's even more important for users to share access with others. Technology can help by providing new sharing tools and by creating the opportunity for a fresh approach to sharing in higher frequencies. Building on existing work, we're proposing to 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.

We would continue to take a leading role in promoting such reforms internationally.

Our spectrum management vision

1.1 We have identified four strategic spectrum management objectives which together form our updated spectrum management vision. Our vision recognises the importance of both 'mass market' wireless services, that are used by virtually everyone throughout the UK (like Wi-Fi and cellular mobile services), and more specialised uses of spectrum which are critical to many businesses, public sector and other organisations. Specialised uses include, for example, climate monitoring, defence and air traffic control.

Our spectrum management vision:

We want:

1. Continued improvements in the wireless communications used by everyone, wherever and whenever they use them

2. Businesses, public sector and other organisations with specialised requirements to be able to access the right wireless communication or spectrum options for them

We aim to enable this by:

3. Providing flexibility in spectrum use to support innovation, with appropriate assurances for continued use

4. Encouraging sustained improvements in the efficiency of spectrum use

Our proposals

1.2 The purpose of this consultation is to set out how we propose to manage use of the radio spectrum over the next ten years, in order to fulfil our statutory duties and the spectrum vision outlined above. Our proposals are grouped into three strategic themes: supporting wireless innovation, licensing to fit local and national services and promoting spectrum sharing.

1.3 Separate to this consultation on our overall strategy we continue to undertake reviews of specific spectrum using sectors (e.g. space, mobile) and develop roadmaps for our work in those areas.

Supporting wireless innovation

1.4 Further innovation in wireless technologies and applications is key to enabling even greater benefits from use of radio spectrum in the future. We aim to support innovation by making it as easy as possible for different kinds and sizes of organisation to access the right spectrum for them, and by providing flexibility in spectrum use to deal with unpredictable future requirements. Reducing the barriers for new entrants can also support greater competition in wireless technologies and services.

1.5 Much of our existing work is linked to enabling innovation. For example, we offer licences especially suited to development and trialling of innovative uses of spectrum and recently

opened up access to a large amount (18.2 GHz) of spectrum suitable for innovation in the 100-200 GHz frequency range whilst protecting existing uses. [1] Potential new services that could make use of this spectrum include health screening applications and high precision product assembly.

1.6 To further accelerate the possibilities for innovation we are making proposals in three areas:

- **Understand, assist and inform:** Expand our work to understand, assist and inform the growing range of organisations who could benefit from wireless technologies in the future, including those with more specialised requirements, e.g. for very high reliability or secure communications. Helping these users to access the right spectrum for their needs could support improved public services and increased productivity in a variety of industries.
- **Spectrum for pioneers:** 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. Sometimes the demand for a band can be very uncertain, but making it available can foster innovation by enabling new entrants and existing players to develop new and unexpected technologies and applications.
- **Supporting innovation in wireless technologies:** Reduce the barriers for players 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.

1.7 Our proposals on wireless innovation support all elements of our spectrum vision and are particularly relevant to our third objective to provide flexibility in spectrum use.

Licensing to fit local and national services

1.8 Organisations of all types and sizes use spectrum, and to support this we already issue licences authorising spectrum use over geographical areas of different sizes, ranging from 50 metres to the whole of the UK. With a growing diversity of spectrum users and applications, we think getting an appropriate balance between national licences and smaller ones will be even more important in the future. This includes bands which could support mobile technology, which have generally been authorised on a UK-wide basis, and which are likely to be important for innovation.

1.9 More localised licences can suit a range of businesses needing specialised services at a specific site (e.g. wireless control of robots in a warehouse, tracking livestock on a remote farm), whereas larger, including national, licences can support services with wide coverage – including public mobile services. Local licences in bands supporting mobile technology can also support innovation in the mobile supply chain. For example, new suppliers of

[1] Supporting innovation in the 100-200 GHz range, October 2020

enterprise mobile equipment have emerged using bands available on a local basis and a 5G test bed has been launched [2] using local licences.

1.10 We propose to consider further options for localised spectrum access when authorising new access to spectrum in the future. This builds on our work last year to offer new licences that provide shared access to spectrum supporting mobile technology.

1.11 As well as complementing our work on innovation, this proposal is particularly relevant to our first two objectives: to improve the wireless communications used by everyone and for organisations to be able to access the right wireless communication or spectrum options for them.

Promoting spectrum sharing

1.12 Growing use of existing services and new demand for spectrum stimulated by innovation will mean it's even more important that different users can share access to spectrum effectively. This is necessary to enable new services to be introduced whilst protecting the benefits that people already enjoy.

1.13 One enabler of greater spectrum sharing will be our continued development and use of automated spectrum management tools where appropriate. These can allow us to authorise and modify spectrum use in near real-time by a utilising a direct interface between devices and a spectrum management database. For example, we plan to use this capability in a number of shared bands, including the 3.8-4.2 GHz band.

1.14 In addition, there is an opportunity to embed further spectrum sharing reforms in much higher frequencies as technology opens up the possibility of using those. At the time of our 2014 strategy the 'sweet spot' for spectrum demand was around 1 GHz; today technology is enabling the use of frequencies a hundred times higher. Starting with spectrum sharing as the default approach in higher frequencies could enable even greater benefits from their use over coming decades.

1.15 We've identified a range of reforms that would build on our current work and further promote the ability of different users to share spectrum:

- **Data and analysis**: Promoting the use of more realistic analysis and better data when assessing the conditions for sharing between different services. For example, use of more realistic data about the performance of equipment can allow users to operate closer together whilst still managing interference.
- **Robust systems:** Encouraging wireless systems to be more resilient to interference. For example, ensuring that receiving equipment effectively filters out signals in neighbouring bands.

[2] The SmartRAN Open Network Interoperability Centre (SONIC) has been launched by Digital Catapult in partnership with Ofcom

- **Balancing interference:** Getting a more efficient balance between the level of interference protection given to one service and flexibility for others to transmit, in order to enable spectrum access for a wide range of users.

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

1.17 Our spectrum sharing proposals are essential for progress on our fourth objective, to encourage sustained improvements in the efficiency of spectrum use, which in turn supports all our other objectives.

Next steps

1.18 We want to hear views from a wide range of people, businesses and organisations on the proposals we have identified. As well as the companies and organisations that normally engage with us and respond to our consultations, we are keen to get input from others who might be relatively new to spectrum and spectrum management.

1.19 Following the publication of this consultation we will be holding a virtual stakeholder event on our proposals – details of which will be posted on our website. The consultation closes on 26 February 2021 and we expect to publish our conclusions in Q2 2021/22.

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

2. Introduction

Ofcom manages the UK's radio spectrum - a vital national resource

2.1 Use of the radio spectrum benefits every person and organisation in the country. It helps deliver our news, connect us to friends and family, automate factories and support public services. It's used for every type of wireless communication, from TV and radio to the very latest smartphones, and for monitoring our climate and natural environment.

2.2 Although spectrum is a limited natural resource, its effective use can continue to transform the way we live and work – helping to make us more productive and benefiting industries across the economy.

2.3 These benefits wouldn't 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 beneficial to reduce the likelihood of interference and get the best out of spectrum use.

2.4 Ofcom is the UK's communications regulator and one of our functions is to make sure this vital national resource 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. We're responsible for authorising and setting the rules by which people can transmit radio waves, as well as representing the UK's interests in international fora on spectrum use.

2.5 Our spectrum management work complements our wider regulatory activities to enable wireless communications, for example in regulating the fixed telecoms infrastructure that connects to wireless networks.

Time to review our approach to managing spectrum

2.6 Ever since Ofcom was established we've recognised the importance of publishing a medium to long-term strategy for how we will manage spectrum. 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 longer term decisions.

2.7 Our first strategy for managing the radio spectrum was set out in 2005 (the "2005 Strategy")[3] and most recently updated in 2014 (the "2014 Strategy").[4] Over that period, through to today, wireless communications in the UK have changed significantly. 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.

[3] Spectrum Framework Review, June 2005.
[4] Spectrum Management Strategy, April 2014.

These changes also mean that we need to consider updating our approach to effectively tackle future challenges and take full advantage of new opportunities.

2.8 There are two trends in particular (which we expand on in Section 3) which we think make it particularly timely to review our approach:

- The growing diffusion of wireless technologies throughout all sectors of the UK's economy and society, including the public sector, supporting the UK's continued digital transformation and the productivity and quality of life benefits that can flow from that.
- Technology is opening up the possibility of using much higher frequencies than before. For example, today there are prime bands for new services above 20 GHz, whilst at the time of previous strategies the most in demand bands were around 1 GHz.

Our duties and spectrum management objectives

2.9 Ofcom's principal duty is to further the interests of citizens and consumers in relation to communications matters. As part of this, we must ensure that a wide range of electronic communications services are available across the UK, and that optimal use is made of the radio spectrum. We interpret 'optimal use' to mean that spectrum is used in a way that maximises the benefits that people and businesses derive from it, including the wider social value of spectrum use.

2.10 We permit the use of the radio spectrum either by granting wireless telegraphy licences under the Wireless Telegraphy Act 2006 (the "WT Act") or by making regulations exempting the use of particular equipment from the requirement to hold such a licence. In Annex 5 we set out in more detail the relevant legal framework which we have taken into account in making the proposals in this document.

2.11 As required by section 2B(2) of the Communications Act 2003, we have had regard to the UK Government's Statement of Strategic Priorities (SSP) for telecoms, management of radio spectrum and postal services. [5]

2.12 We have identified four strategic spectrum management objectives, which are based on our statutory duties and functions, and taken together form our updated spectrum management vision. These objectives take into account the differing needs of the many different parties who may wish to use spectrum, [6] for example, individual citizens, broadcasters, scientific researchers, government departments as well as commercial communication providers.

[5] DCMS, Statement of Strategic Priorities for telecommunications, the management of radio spectrum, and postal services, October 2019.
[6] In line with our duty under section 3(4)(f) of the Communications Act 2003 to have regard to the different needs and interests of all persons who may wish to use the spectrum.

Our spectrum management vision:

We want:

1. Continued improvements in the wireless communications used by everyone, wherever and whenever they use them
2. Businesses, public sector and other organisations with specialised requirements to be able to access the right wireless communication or spectrum options for them

We aim to enable this by:

3. Providing flexibility in spectrum use to support innovation, with appropriate assurances for continued use
4. Encouraging sustained improvements in the efficiency of spectrum use

2.13 The four strategic spectrum management objectives which comprise our spectrum management vision are:

1. **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 for the smooth running of businesses and public services. These currently include mobile calls and broadband, Wi-Fi for broadband in our homes and offices, wireless connections (like Bluetooth) between our growing range of gadgets, broadcast radio and television services and satellite navigation. We want to enable these to continue to improve, wherever and whenever people use them, to meet increasing and changing needs.
2. **Businesses, public sector and other organisations with specialised requirements to be able to access the right wireless communication or spectrum options for them.** Many organisations have more specialised wireless communication requirements that support a diverse range of applications, and which are not satisfied solely by the core services outlined above. These applications can include everything from managing electricity networks, to wireless microphones for live events, controlling robots in warehouses and air traffic control. Growing use of wireless communications can support the continued transformation of all types of organisations throughout the UK. In addition, some organisations have specialised scientific requirements that can only be met by using specific frequencies, for example to monitor our climate or study the universe using radio waves.
3. **Providing 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. But what we can do is to 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.

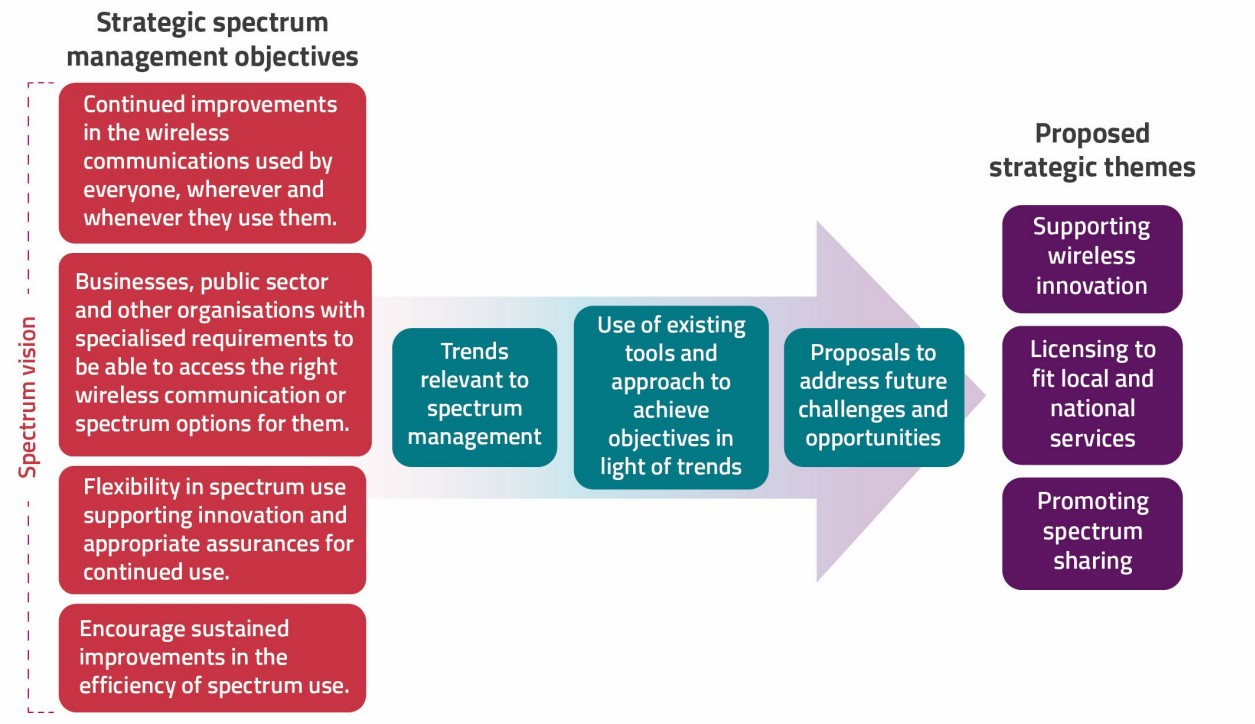
4. **Encouraging sustained improvements in the efficiency of spectrum use.** The radio spectrum is a finite natural resource, so ultimately all new and improved wireless services for people in the UK depend on making more efficient use of this resource. We aim to create the conditions where efficiency 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.

Approach and scope for this review

2.14 This document sets out how we propose to manage use of the radio spectrum over the next ten years in order to fulfil our statutory duties and the spectrum vision we have outlined above.

2.15 Our approach (outlined in Figure 1 below) has been to review relevant trends and consider how we would use our current spectrum management tools and approach to achieve each of our objectives in light of those trends. Where there are potential challenges and opportunities in achieving those objectives that might not be addressed by use of our existing tools and approach, we have developed new proposals. These proposals are then drawn together into three strategic themes.

Figure 1: Overview of our approach



2.16 The key elements of our approach are set out below.

Trends relevant to spectrum management

2.17 We have identified a range of trends which could be relevant to how spectrum is managed in the future. These draw on our own research and knowledge of the sectors we currently

work with, as well as ideas raised at a stakeholder strategy workshop we held in September 2019. We are not looking to forecast the future or identify every possible future use of spectrum, but to highlight potential developments that might influence how spectrum could or should be managed in the future. Section 3 provides an overview of trends which provide the context for future spectrum management, whilst the first part of each of sections 4-7 discuss trends relevant to each of our four objectives.

Use of existing spectrum management tools to achieve objectives in light of trends

2.18 We have considered how our current strategy, and the range of spectrum management tools at our disposal, can help to deliver against each of our objectives in the future taking account of the future trends we have identified.

2.19 Section 3 provides general background on our core spectrum management tools and our established approach of relying on market mechanisms where possible and effective and using regulatory action where necessary. This approach was set out most recently in our 2014 Strategy.

2.20 The second part of each of sections 4-7 sets out what we plan to continue doing, utilising our current tools and approach, to effectively address each of our objectives in light of future trends.

Proposals to address future challenges and opportunities

2.21 In some cases we have identified potential challenges and opportunities in achieving our objectives that might not be fully met through the use of our existing tools and approach. In those cases we have developed proposals to update our strategy to address those challenges and opportunities in the future. These are set out in the third part of each of sections 4-7.

2.22 In many cases our proposals are relevant to achieving more than one of our objectives, and where that is the case we introduce our proposals with the first or most relevant objective and refer back where it is relevant to other objectives. We map our proposals against the relevant objective(s) in Table 9 in Section 8.

Strategic themes

2.23 Our proposals can also be grouped into three strategic themes, which would, together with the continuation of our current work, address our spectrum management objectives. These themes are summarised in Section 8, and also presented in the overview at the start of this document.

Sector specific issues are considered in sector reviews

2.24 This strategy review does not aim to review the future spectrum demands of specific sectors in detail or review the potential future use of specific bands. This is because we

separately undertake in-depth sector spectrum reviews, for example for the space, mobile, transport and PMSE (Programme Making and Special Events) sectors.

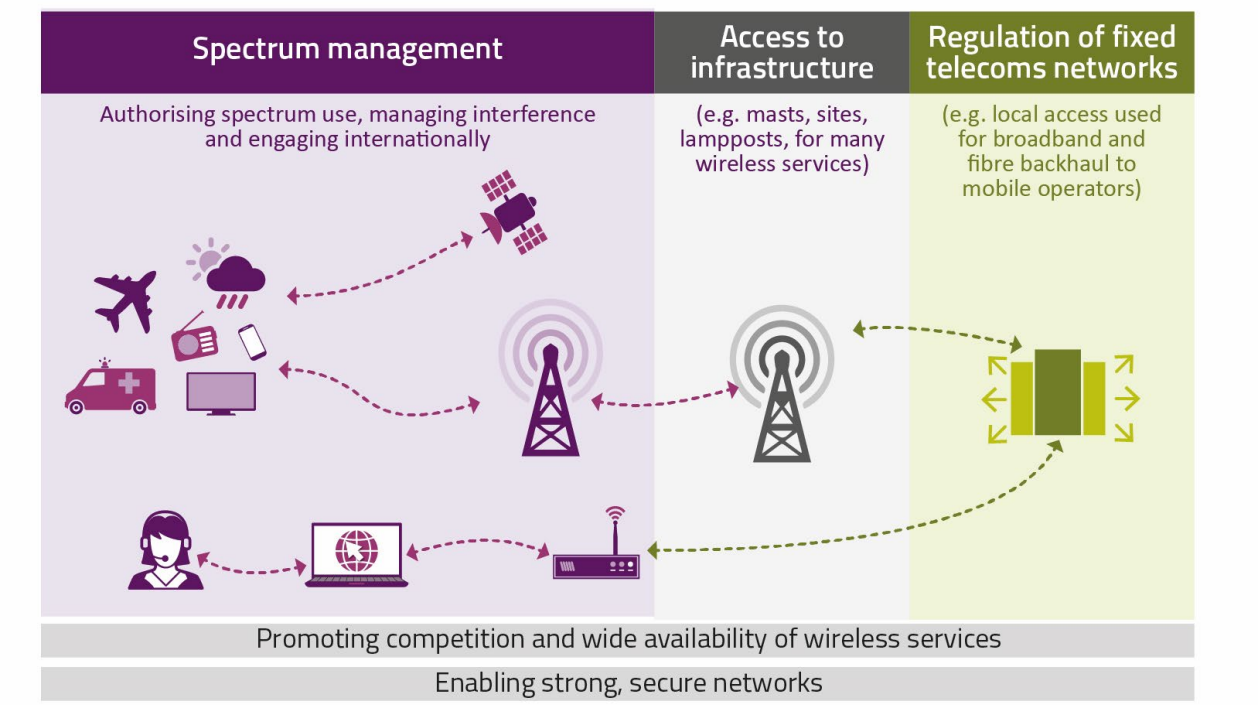
2.25 Sector reviews are initiated when appropriate to consider significant changes in particular sectors. They review trends in that sector and develop roadmaps for our work, including identifying specific bands for review and priorities for our international work where appropriate. We also propose to start publishing a broader roadmap of our future spectrum plans across sectors and bands, which will follow and complement this review of our overall strategy.

Question 1: Do you have comments on the overall approach to the review?

Our wider activities supporting wireless communications

2.26 In addition to our spectrum management functions, we undertake a number of complementary regulatory activities, each of which is important for the full benefits of wireless communications to be realised. A number of these are illustrated in Figure 2 and summarised below.

Figure 2: Ofcom's wider activities supporting wireless communications



Access to physical infrastructure

2.27 Sites for hosting active and passive communications infrastructure could be in growing demand in the future. In some cases this infrastructure will be in buildings, in others it may rely on street furniture or other outdoor structures.

2.28 The Government and Ofcom agree on the importance of enabling infrastructure rollout. DCMS' Barrier Busting Task Force has multiple workstreams considering issues such as siting communications equipment on public sector assets, streetworks and network sharing. Ofcom has a role with respect to the Electronic Communications Code to grant Code powers to operators. Code powers are a set of rights designed to facilitate the installation and maintenance of electronic communications networks.

Regulation of fixed telecoms networks

2.29 Many, although not all, wireless communication services rely on a fixed telecoms network in some way, for example to connect to an operator's core network and onward to the internet. Investment in the UK's fixed telecoms infrastructure is needed to meet growing demand, including from new wireless services.

2.30 Ofcom's approach to achieving that has been through encouraging competition between network builders. Our aim is to create the best possible conditions for companies to invest in high speed networks so customers in all parts of the UK can enjoy the benefits it provides.

Wide availability of communication services

2.31 We undertake a range of activities to support our strategy of ensuring everyone can access fast and reliable broadband and mobile services, wherever they live, work, and travel.[7] Some of these are spectrum management activities (discussed further in Section 4), whereas some are part of our wider functions.

2.32 For example, as part of our wider strategy to inform consumers and promote choice and competition, we provide information on the local availability of good quality mobile coverage through our online web checker, alongside advice on how consumers can improve their coverage experience. We are also working with providers of fixed wireless services to establish a robust and uniform approach to predicting where good quality fixed wireless broadband services can be delivered.

Promoting competition

2.33 An essential part of Ofcom's work is to promote competition to make communications work for consumers and businesses. For example, effective competition between mobile operators can drive investment and innovation and can spur the industry to offer quality and choice to consumers and businesses. Ensuring that competition is effective is an important objective in a range of our spectrum management activities, including when we consider whether a proposed trade of mobile spectrum is likely to distort competition.

[7] Better broadband and mobile… wherever you are, July 2020.

Enabling strong, secure networks

2.34 People across the UK expect and rely on strong and secure fixed and wireless networks today and in the future. Ofcom has a key role to play alongside other actors to make this happen. Ofcom continues to work closely with the Government, the National Cyber Security Centre and industry to monitor potential risks, providing guidance and advice where possible. We are also enabling the UK to ensure its infrastructure is safe by having the widest possible supply chains and access to equipment, while being aware of any specific security concerns, taking account of government guidelines and legislation.

2.35 We are building a centre of excellence for security and resilience, continuing to develop our cyber security capability and work with communications providers. Key areas of work are:

- Working with the Government to implement the outcomes of the telecoms Supply Chain Review, including providing technical advice to the Government's vendor diversification strategy.
- Ensuring all communication providers and operators of essential services adhere to their security obligations and follow relevant guidance.
- Working with industry to identify and close gaps in standards and best practice, in relation to network resilience.
- Continuing to engage with communications providers to carry out a threat intelligence-led penetration testing scheme (TBEST).

Compliance with international guidelines for limiting exposure to electromagnetic fields

2.36 All uses of spectrum generate electromagnetic fields (EMF) and there are international guidelines to help ensure services operate safely. The guidelines are published by the International Commission for Non-Ionizing Radiation Protection (ICNIRP) and include limits for the safe level of EMF.[8] These guidelines are endorsed by Public Health England (PHE) in its advice to the UK Government.

2.37 In October 2020 we published a statement setting out our decision to include a specific condition in Wireless Telegraphy Act licences requiring licensees to comply with the ICNIRP general public limits for EMF exposure.[9] We intend to apply a similar approach for equipment that is exempt from the requirement to have a licence. These changes will enable Ofcom to take appropriate action in the event of non-compliance with the ICNIRP Guidelines.

[8] https://www.icnirp.org/en/publications/index.html
[9] Proposed measures to require compliance with international guidelines for limiting exposure to electromagnetic fields (EMF), October 2020.

Impact assessment

2.38 This document represents an impact assessment as defined in Section 7 of the Communications Act 2003. Impact assessments provide a valuable way of assessing different options for regulation. They form part of best practice policy making.

Equality Impact Assessment

2.39 Ofcom is separately required by statute to assess the potential impact of all our functions, policies, projects and practices on the following equality groups: age, disability, gender, gender reassignment, pregnancy and maternity, race, religion or belief, and sexual orientation. Equality Impact Assessments (EIAs) also assist us in making sure we are meeting our principal duty of furthering the interests of citizens and consumers regardless of their background or identity.

2.40 We consider that our proposals would not be detrimental to any of these equality groups. We have also not identified any detrimental impact in relation to the additional equality groups in Northern Ireland: religious belief, political opinion and dependents. This is because we anticipate that our proposals will not have a differential impact on Northern Ireland compared to consumers in general. We welcome any stakeholder views on this assessment. Specific implementations of our spectrum management framework in a given case may have an impact on equality groups, and will have to be assessed on a case by case basis.

Structure of this document

2.41 In Section 3 we provide background information on our existing spectrum management tools, our approach to using market mechanisms, and an overview of wide-ranging market and technology trends that provide the context for future spectrum management.

2.42 The subsequent four sections (sections 4-7) focus on each of the four strategic objectives that comprise our spectrum management vision. Each section sets out:

a) the importance of the objective and trends relevant to the objective;

b) our use of our existing tools to achieve the objective now and in the future, taking account of the trends identified; and

c) proposals to address potential future challenges and opportunities that might not be addressed by use of our existing tools in light of the trends identified.

2.43 Section 8 summarises the findings of the previous four sections, including the continuing and new proposed actions that we think will help achieve our four strategic spectrum management objectives. It also brings together all of our proposals under three strategic themes and sets out next steps for the review.

2.44 Annexes 1 to 4 describe how to respond to this consultation, and the questions we are consulting on.

2.45 Annex 5 sets out the relevant legal framework.

2.46 Annex 6 gives a brief overview of some future technologies that may be relevant to spectrum management in the longer-term future.

2.47 Annex 7 is a glossary of terms used in this document.

3. Existing approach and contextual trends

3.1 This section sets out:

- An overview of our core tools for managing spectrum and our established approach to the use of market mechanisms and regulatory action. These tools do not represent everything we do but they are the foundation for most of our work, providing the capabilities and flexibility to deal with a wide range of different forms of wireless communications, spectrum users and market conditions.
- Contextual trends which could be relevant to how spectrum is managed in the future. A high-level summary outlines trends in the external context for wireless communications, technology and network architectures and wireless application demands. Three topics are highlighted as potentially being particularly relevant.

3.2 This material provides the context for the subsequent four sections which consider each of our strategic objectives and the use of our spectrum management tools in light of future trends.

Our core spectrum management tools

3.3 Our core spectrum management tools do not represent everything we do but they do provide the fundamental mechanisms for achieving our spectrum objectives. They can be categorised as follows: authorising spectrum use; managing interference through monitoring, compliance and enforcement; and representing the UK in international spectrum fora. They are underpinned by technical, policy and economic analysis, as well as strategic research and planning.

3.4 We work to continuously improve these tools, for example by implementing new systems for licensing and spectrum monitoring, in order to further increase our internal efficiency and enhance the experience for stakeholders interacting with us.

Authorising spectrum use

3.5 Ofcom authorises 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. Although we do not issue licences to certain Government spectrum users operating under Crown immunity, [10] we do still manage all spectrum. Crown immunity does not put those users outside our scope. Other public sector users do not have Crown immunity and so are authorised in the same way as other users.

[10] There is no general legal definition of a Crown body, but central government departments reporting to ministers such as the Ministry of Defence, Home Office and Department for Transport are generally considered to be Crown bodies.

We have a range of authorisation tools to deal with different types of spectrum use and demand

3.6 There are a number of different options which can be employed for authorising access to spectrum, the choice of which will depend on the nature of the application and user:

a) **Licence products.** We offer a set of products that provide access to those bands where Ofcom manages assignments to particular users. These can be:

i) **Technically assigned** where we coordinate the individual assignment of frequencies within the band;

ii) **Light licences** where an 'off the shelf' licence, that generally requires no specific assignment or co-ordination, is available on request.

b) **Block-assigned licences**. These licences enable licensees to manage their own deployments within a band. Many of the block assigned licences have been awarded via auction.

c) **Licence exemption**. Regulations authorise licence exempt use by devices that meet defined technical parameters. The user does not need a licence to use the spectrum as long as their device complies with the relevant technical parameters. Most mass-market consumer devices are licence-exempt.

3.7 We manage thousands of requests per month in relation to our licence products. These include ongoing changes in who wants to do what, where and when, whilst ensuring that new users can operate without causing problems for existing ones. We are currently evolving our spectrum licensing system to provide greater online and self-service access, improve the customer experience for stakeholders and offer greater flexibility for the future to introduce new licence products.

3.8 In addition, there are a number of mechanisms we can use to decide who will get a licence, which take account of the nature of supply and demand for spectrum in a particular band, including:

a) **First-come-first-served**. People can apply at any time for a new licence, and we will issue the licence if it can coexist with existing licensed users. This approach is often used for our technically assigned licence products. We may apply a cost-recovery fee or, if this could lead to more spectrum being demanded than is available (i.e. excess demand), then we may apply an opportunity cost-based fee, also known as Administered Incentive Pricing (AIP). [11]

b) **Unlimited.** People can apply at any time and we will issue an unrestricted number of licences, usually for a cost-recovery fee. This approach is usually used for light licences.

c) **Auction.** Auctions are used relatively infrequently but can provide a useful way to assign licences initially where there is known excess demand for spectrum.

[11] Opportunity cost is the value of alternative spectrum use forgone by society due to the current spectrum use. Also see Section 7 for our approach to pricing.

d) **Automated spectrum management tools**. These tools implement a direct interface between devices/networks and a spectrum management database and allow us to directly authorise and make changes to spectrum use in near real-time. They are potentially applicable to both managing licensed and licence exempt use. Our use and future plans for development of these tools are discussed further in sections 6 and 7.

We can specify a variety of licence conditions to suit a wide range of potential uses

3.9 Subject to the constraints set out in the WT Act, [12] when developing a new type of licence, we are able to specify the terms and conditions that we think fit in light of the specific needs and characteristics of potential uses and, more generally, our spectrum management objectives. For example, terms we can and do specify include:

- the specific frequencies of operation;
- the geographic area within which the licensee is authorised to transmit (which can range from nationwide to a very small area e.g. a 50 metre radius circle);
- licence duration, e.g. whether for a fixed duration or indefinite;
- any fees to be paid (as set out in fee regulations);
- technical conditions, e.g. the maximum power that can be transmitted;
- other limitations on deployment such the height or pointing angle of the transmitter.

3.10 Once licences or exemptions are established, there is an ongoing process to maintain, update and create new ones where appropriate, to accommodate continuing technical and market developments. These changes include adapting channel plans, dealing with new technologies, updating technical coexistence parameters, or reflecting changes in the international regulatory framework where appropriate.

Managing interference through monitoring, compliance and enforcement

3.11 Unauthorised use of the radio spectrum can cause harmful interference to others, degrading or preventing communications, and may become a public safety risk if critical services are impacted.

3.12 To manage the risk of harmful interference, we monitor spectrum use, check compliance with authorisation terms, investigate and, when appropriate, take enforcement action if harmful interference occurs. We do not guarantee interference-free spectrum, as interference can arise from a range of sources (including faulty or deficient equipment or natural atmospheric conditions).

3.13 Our work programme targets resources according to risk and includes:

- Dealing with complaints of interference from stakeholders. For example, reports of interference affecting critical safety of life services, such as aircraft communications and mobile phone networks.
- Market surveillance and enforcement to prevent harmful radio and electrical equipment being made available in the UK. Primary targets include radio frequency

[12] Section 9 of the WT Act; see paragraph A5.9.

jammers (designed to interfere with various services including satellite navigation and mobile phones) and non-compliant mobile phone repeaters.
- Proactive intervention to combat illegal broadcast stations ('pirate' radio).

3.14 We have a range of measures at our disposal, ranging from offering advice and assistance to users experiencing interference to issuing warnings, cautions, fixed penalty notices up to prosecution for offenders.

3.15 Ofcom is also responsible for ensuring that radio and electrical equipment sold in the UK does not cause interference. We do this by enforcing the Radio Equipment and the Electromagnetic Compatibility (EMC) Regulations.

3.16 To support our spectrum activities, we operate a 24/7 Spectrum Management Centre. Engineers offer advice and assistance and process specific complaints. The centre also conducts monitoring and tracing. We also have a national field force strategically located throughout the UK with a capability to investigate, identify and resolve unauthorised use or harmful interference.

3.17 We continue to develop new capabilities to more effectively investigate and prevent harmful interference and monitor compliance, for example we have introduced:

- The ability to detect and investigate interference to a wider range of wireless services including 5G and other services operating at higher frequencies.
- Greater flexibility to monitor spectrum through more mobile assets e.g. trailers, drive testing, temporary installations.
- Innovations to more effectively and efficiently enforce against/prevent interference, including forensic analysis and targeting those supplying or selling illegal equipment.
- The ability to test spectrum compliance of a wider range of wireless devices/systems in the field.

International representation

3.18 Decisions by international institutions set the rules (or sometimes common expectations) for interference between countries and are important for two reasons in particular:

a) They can help create the conditions for economies of scale in wireless equipment by harmonising spectrum use (agreeing common use and technical conditions) across countries.

b) They enable the provision of services that cross borders, including services provided by satellite to ships and aircraft, as well as managing coordination of high-power transmissions which spill across borders (e.g. TV transmissions in south-east England that reach France).

3.19 Relevant international institutions include:

- The International Telecommunication Union (ITU), a specialised agency of the United Nations which oversees the allocation of spectrum around the world. It does so through the ITU Radio Regulations, which are amended approximately every four years by World Radiocommunications Conferences (WRCs). A specific aspect of our ITU role

is to manage 'filings' [13] for satellite orbital positions and radio frequencies on behalf of the UK.

- The European Conference of Postal and Telecommunications Administrations (CEPT), which consists of 48 member countries, including all EU Member States. Groups within CEPT undertake technical analysis to facilitate spectrum harmonisation in Europe and develop European positions for WRCs.
- ETSI (European Telecommunications Standards Institute), an independent organisation whose aim is to develop standards for telecommunications and radio equipment used by consumers, businesses and the communications industry. Ofcom's involvement is mainly through the EMC and Radio Spectrum Matters Technical Committee (ERM) where we seek to promote our position on the various spectrum-related standardisation issues. The 3rd Generation Partnership Project (3GPP) is a related organisation producing specifications covering cellular telecommunications technologies.

3.20 In addition, before leaving the European Union, Ofcom was an active member of the EU's Radio Spectrum Policy Group (RSPG), for example leading its spectrum strategy working group, and represented the UK in the Radio Spectrum Committee (RSC). Ofcom no longer attends these Groups but will continue to monitor their work and cooperate with them as appropriate following the UK's exit from the European Union.

3.21 Ofcom has invested considerable resource over many years to develop our international reputation and we have successfully been appointed to leading positions – including Chairperson roles – in a number of key groups. This includes the committee in CEPT which oversees the organisation's work on spectrum matters and approves its spectrum decisions, as well as chairing specific groups within CEPT dealing with mobile issues, Wi-Fi and short-range devices. We also currently hold the Chair of ITU-R Study Group 5, the global ITU group dealing with spectrum for fixed and mobile services. We have leveraged our international standing to influence the development of international policy in specific areas, building on our reputation for robust technical analysis and evidence-based thinking.

3.22 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 UK positions. For example, we take account of wider UK interests in the space sector, such as space launch, satellite broadband, and navigation and positioning where appropriate.

3.23 We also work closely with our international partners to better understand their priorities, appropriately taking these into account and making us well-placed to deliver optimal outcomes for the UK.

[13] Satellite filings are the mechanism for obtaining internationally recognised spectrum and orbital resources for satellites networks and systems. They are administered and overseen by the ITU.

Our use of market mechanisms and regulatory action

3.24 Our core spectrum management tools discussed above can be deployed in a number of different ways, for example they provide us the ability to be more or less prescriptive about how spectrum is allowed to be used. However, since our 2005 Strategy (and reiterated in our 2014 Strategy), our approach has been guided by a clear principle of relying on the use of market mechanisms where possible and effective, whilst undertaking regulatory action where necessary.

3.25 As a general rule, optimal use of spectrum is more likely to be achieved if detailed decisions on how spectrum is used are left to those directly engaged in its use rather than dictated centrally by the regulator. Market mechanisms ensure in principle that, where a new type of use is more valuable, and would provide greater benefits to people and businesses, there should occur changes to licences held by radio spectrum users that lead to efficient use of the spectrum. In other words, the incentives inherent in market mechanisms should bring about efficiency. We further discuss our use of market mechanisms to promote efficiency in Section 7.

3.26 Specific market mechanisms include:

- Spectrum pricing to create incentives for users to make efficient use of spectrum;
- Spectrum trading and leasing to enable spectrum rights to change hands;
- The principle of greater licence flexibility ('liberalisation') to enable change of use, where possible, without the need to request a technical licence variation from Ofcom;
- Spectrum auctions as a means to assign new spectrum licences.

3.27 Whilst auctions can be the most visible market mechanism, in practice they are employed relatively rarely as they are only used where we consider them appropriate to secure optimal use of spectrum (Ofcom has no duty to maximise revenue from the allocation of spectrum and this is never an aim of our spectrum allocations).

3.28 We also recognise that there are limits to a market-based approach. There is an important and complementary role for Ofcom to play, particularly when major changes in spectrum use are contemplated in order to recycle spectrum. Several, though not all, big changes in spectrum use have involved regulatory action, including sometimes revoking existing licences to clear a spectrum band and re-award it to new users (e.g. we have recently cleared the 700 MHz and 3.6-3.8 GHz bands).

3.29 There are a number of reasons why market mechanisms alone may not be able to deliver value-enhancing change of use:

- Changes to international agreements: decisions agreed within international institutions can be key enablers of (or obstacles to) major changes of use. As noted above, Ofcom is responsible for negotiating in relevant international institutions on behalf of the UK.
- Constraints relating to coexistence between adjacent users: a change of use can involve changes to the interference environment that may affect users of adjacent spectrum. At present, these issues can make it hard for individual market players, who do not have access to regulatory levers, to coordinate and develop an appropriate

solution (our proposals on improving spectrum sharing would reduce these issues in the future).

- Implications for competition in relevant markets: regulation may be required to prevent the concentration of key spectrum assets causing competition concerns in downstream markets.
- Relevance of wider duties and the citizen interest: where spectrum use is instrumental to delivering the citizen interest, regulatory action can have an important role to play where this would not be delivered by the market. For example, where spectrum access is essential for operations to defend the country.

3.30 Therefore, we continue to consider that a combination of market mechanisms and regulatory action is needed to achieve our spectrum management objectives.

Contextual trends for future spectrum management

3.31 We have identified a set of contextual trends that, whilst not all directly linked to spectrum management, may have the potential to influence, in the long run, how spectrum is managed and used. Table 1 provides a (non-exhaustive) illustration of major trends in the wider external context in which people use wireless communications, technology, network architectures and applications. The implications of these for spectrum management will vary significantly – some could have direct implications for how we manage spectrum, others might simply mean we need 'more of the same', or be wider issues which we address separately in work beyond this strategy.

Table 1: 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 (including the competitiveness, sustainability and diversity of telecoms supply chains). 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 there might be population dispersal if more people opt to move away from cities and towns, placing further importance on rural connectivity.
Changing technology and network architectures	Over time there will be use of much **higher frequency bands** that are not currently used for communications. These higher frequencies allow far greater network speeds and capacity, and 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** (e.g. to lampposts) will continue, enabling more devices, more data use, and quicker connectivity responses. 5G 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 stratospheric and satellite deployments, with satellite constellations getting bigger with 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.
	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 through product convergence and service substitution.
	Smart city & industrial Internet of Things (IoT) [14] 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 increasingly common. 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 likely 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 peoples' and businesses' specialised requirements. Having the right spectrum available for these users at the right time will enable innovation.

[14] 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.

3.32 Sections 4-7 consider trends which are particularly relevant for each of our strategic objectives. In addition, there are three broader trends highlighted below which we consider are relevant to multiple objectives.

Changing spectrum demands

3.33 We expect that many of the trends above, combined with further advances in technology, will together contribute to greater diffusion and adoption of wireless technologies throughout the UK's economy and society.

3.34 In particular, the continuing adoption of digital technologies is transforming businesses and organisations across different sectors. This adoption is offering gains in terms of productivity, cost reduction, sustainability and flexibility in responding to market changes. Wireless connectivity is an enabler of digital transformation as it can help maximise the benefits from innovation in fields such as robotics, AI, big data, cloud and edge computing, across different sectors.

3.35 These trends will lead to changes in provision of existing wireless services and potentially many new wireless applications, leading to new spectrum demands. These future spectrum demands may look different from today, e.g. new types of localised users with diverse performance and reliability requirements. Section 5 also discusses these trends.

Growing use of higher frequencies

3.36 Continued progress in radio technologies including the ability to utilise much higher frequencies can increase the effective supply of usable spectrum. Our 2005 and 2014 strategies had a focus on "the spectrum sweetspot" – a crunch in demand around 1 GHz – and frequencies above 3 GHz would have previously been considered too high for mobile services. Today, the prime band for 5G mobile services lies above 3 GHz, technology is being developed for frequencies above 100 GHz, and people are considering frequencies above 1 THz (1000 GHz).

3.37 These bands naturally offer higher capacity and their propagation characteristics mean that the risk of interference differs significantly from lower bands. Their propagation characteristics, with a limited range and the need for highly directional antennas, can make them both easier and more difficult to manage in terms of interference. This also means they won't be suitable for all applications as they are limited to use in short and variable ranges depending on the antenna pointing direction. On the other hand, there may also be other technologies such as radar which could make use of higher frequencies and wider bandwidths in order to provide high resolution imaging or sensing.

3.38 The move into these bands, with more capacity and fewer incumbents, might also create opportunities to apply new approaches to spectrum management, especially compared to a world where demand peaked around 1 GHz.

Other potentially disruptive technology developments

3.39 Beyond increasing the supply of usable spectrum and enabling new services, technology developments could potentially have a more disruptive impact on how we manage spectrum. One change in which we have taken a leading role (through our implementation of TV White Spaces) [15] is the use of automated spectrum management tools. These use a direct interface between devices and a spectrum management database to allow devices to request and access available spectrum in near real-time. We consider the implications of this technology in sections 6 and 7.

3.40 In addition, there are a number of technologies which might offer the prospect of changing how we regulate and manage spectrum over the longer term. For example, if devices had much more advanced capabilities to coordinate their use with others then that might reduce the need for spectrum use to be regulated to the extent that it is today.

3.41 Annex 6 surveys a number of such potential technologies. We are also considering relevant contributions to our recent call for input on emerging technologies. At this stage, we think it is too early to say whether these technologies will lead to disruptive changes for spectrum management within the next ten years. However, we will continue to ensure we understand, and where appropriate lead the development of, relevant new spectrum management technologies and techniques over time.

Question 2: Have we captured the major trends that are likely to impact spectrum management over the next ten years?

Question 3: Could any of the future technologies we have identified in Annex 6, or any others, have disruptive implications for how spectrum is managed in the future? When might those implications emerge?

[15] 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

4. Continued improvements in the wireless communications used by everyone

4.1 Everyone in the UK uses a range of core wireless services and technologies on a daily basis. Mobile calls and broadband, Wi-Fi in our homes and for businesses, broadcast radio and television services, wireless connections (like Bluetooth) between our growing range of gadgets and satellite navigation – these are all central to our lives. We want to enable these services to continue to improve, wherever and whenever people use them, to meet increasing and changing needs.

4.2 This section sets out why these core services are so important to our lives and what we do, and plan to continue doing, to help them improve. It then explains our proposals for updating our strategy to support even greater improvements in the future.

4.3 In the next section we cover more specialised needs for wireless communications and access to spectrum.

Importance of this objective and trends for the future

4.4 Some wireless services, notably broadcast radio and television, have long been an important part of people's lives in the UK. Broadcast services (now delivered over a range of wired and wireless networks) continue to be very popular and deliver social value. In 2019, people watched on average over 3 hours of broadcast TV daily and listened to over 20 hours of radio weekly. [16] Over the years broadcast TV content has gradually moved to higher resolutions and radio continues to move from analogue to digital platforms.

4.5 In addition, for most people in the UK, getting online is a major and increasing use of wireless communications, as is our growing use of connected devices. We set out below why this is likely to be a particularly important trend going forward.

People increasingly expect to be able to get online wherever they are

4.6 People expect certain communication services to be available to almost everyone across the UK, wherever they are. In particularly, there are long established expectations that fixed telephone services and broadcast TV are available to nearly everyone in the UK.

4.7 Increasingly, people also expect to be connected to the internet wherever and whenever and expect a seamless online experience while on the move. While fixed connections are part of the solution, wireless connections are also needed, particularly for the final connection to people's devices. Meeting these expectations means wide availability and coverage of different wireless communications services, that people everywhere can access easily.

[16] Media Nations 2020: Interactive Report, August 2020.

4.8 Perhaps most obviously, this need is met through the wide availability of public mobile services, providing mobile broadband connectivity to smartphones and other connected devices. Nonetheless, our research has shown that people currently spend more time online with their wireless device connected via Wi-Fi to a fixed network, than to a public mobile network (2G, 3G or 4G). [17]

4.9 In addition, even though the footprint of fibre networks is growing, there remains a role for high-quality wireless connections to deliver fixed broadband to homes and businesses, particularly where fibre connections will be costly to build. These wireless connections can be delivered through a variety of technologies, including fixed wireless access, mobile networks and a new generation of satellites.

4.10 For some applications – essential for navigation but increasingly important for many others – knowing where we are is as important as having a connection. Wide availability of a satellite positioning signal is therefore also an important requirement for many people (as well as being critical for some of the specialised applications discussed in the next section).

New technologies and services are driving demand for connectivity

4.11 The smartphone is considered to be the most important device for accessing the internet. 81% of people's online time was on mobile devices in 2019, with smartphones the device of choice. [18] They are already very sophisticated devices, relying on many different wireless technologies (in addition to mobile technologies and Wi-Fi) such as Bluetooth (e.g. for short range connections to other devices, such as speakers), satellite positioning, Near Field Communication (e.g. for contactless payments) and wireless charging.

4.12 As smartphones and other devices continue to develop and the applications used continue to become more sophisticated, greater demands are placed on wireless networks. Not only is there demand for more capacity to deliver more or better-quality content, but also for increased coverage, improved reliability and better latency (less delay in the network) to facilitate new use cases.

4.13 Smartphones (and tablets) are also used increasingly as part of different businesses' operating models, from payment systems in shops to tracking and fleet management. These devices are also being used as an alternative to laptops while on the go. Increasing use of video streaming and social media with more video content also creates demand for more capacity. Video accounted for 70% of all internet traffic in 2017.

4.14 At the same time the increasing availability, take-up and speeds of fixed ultrafast [19] and full-fibre connections is putting pressure on the wireless network in people's homes to deliver the full potential of the fixed connection. Wi-Fi is increasingly the way people connect to fixed broadband to support everyday activities. More and more office or home-based

[17] Mobile Matters, November 2020.
[18] Online Nation, June 2020
[19] Download speeds of at least 300 Mbit/s.

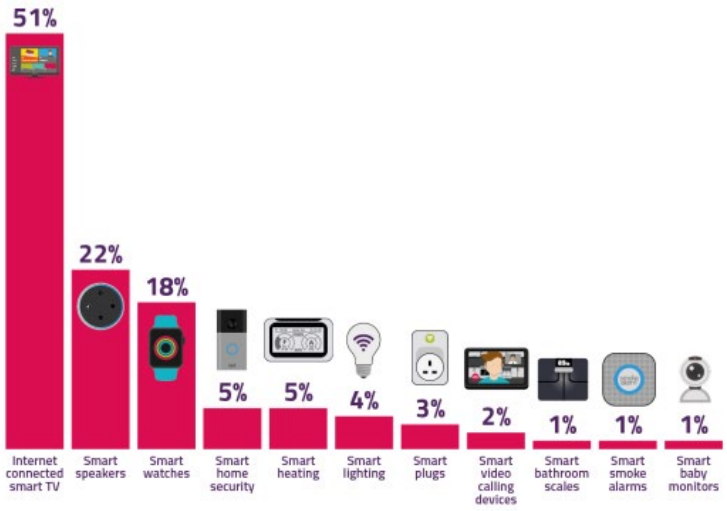
working is now done via a Wi-Fi connection making it an integral part of the modern way of working.

4.15 Higher speeds, growing numbers of connected devices and new applications are driving demand for faster, more reliable and lower/more consistent latency Wi-Fi. New applications include Augmented Reality (AR), Virtual Reality (VR) and Ultra High Definition video.

People use an increased variety of connected devices

4.16 The number of connected devices is also increasing. Whilst consumer products like garage door openers and remote keyless entry on vehicles have been around for years, consumers have a growing choice of wireless gadgets. Smart technology is making connectivity more important, bringing new features to everyday appliances like smart TVs, lighting and home security systems (see Figure 3).

Figure 3: Smart technology - incidence of internet-connected devices in the household, 2020 [20]



4.17 Businesses and public sector users also have growing opportunity to use short range wireless technologies to automate and monitor their operations. For example, many homes now have smart utility meters that can be read remotely by wireless, and wireless street lighting systems deliver instant fault detection and significant energy savings.

Continued use of our existing tools to address this objective

4.18 There are a number of ways in which our existing tools and activities support this objective and which we consider are important to continue:

- we review demand and make spectrum available to enable improved wireless connectivity;
- we take a leading international role; and

[20] Online Nation, June 2020

- we enable the wide availability of core wireless services.

We review demand and make spectrum available to enable improved wireless connectivity

4.19 We review the spectrum needs for the different core services that everyone depends on, and where appropriate, consider making spectrum available to enable improvements in those services.

4.20 As discussed above, one of the biggest drivers of change in spectrum use is growing demand for wireless broadband connectivity, whilst mobile, at home and at work, and therefore this has been a particular focus of our work to date. Examples of our work in this area are set out below.

4.21 However, our work on core wireless services for everyone does not only focus on these obvious areas of major growth. For example:

- We have reviewed [21] the spectrum available for satellite broadband services, which can be used for provision of broadband in remote locations, recognising the potential benefits of a new generation of low earth orbit satellites.
- We are making available spectrum for small scale DAB radio, which will provide an affordable route to broadcasting via terrestrial digital radio for small commercial and community radio stations. [22]

Example: Reviewing demand and spectrum for wireless broadband

4.22 We continue to analyse demand for wireless broadband in order to gain a better understanding of future spectrum requirements, prioritise our work and support our engagement with international processes such as preparation for World Radio Conferences. We published our first Mobile Data Strategy review in 2014, [23] updated this in 2016, [24] and in 2018 published our approach to enabling 5G in the UK (our work reviewing other, more specialised, sectors is outlined in Section 5).

4.23 Each of these documents set out a number of bands which could be made available to enable the provision of improved wireless broadband services, and we have worked to release many of those bands over time. Figure 4 shows spectrum options which cater for varied needs from all players, big and small, supporting innovation and enabling a range of players to enter the market for communications equipment and services.

[21] See our 2017 Space spectrum strategy. We are currently refreshing this in light of developments in the space sector.
[22] Licensing small-scale DAB, April 2020.
[23] Mobile Data Strategy, May 2014.
[24] Mobile Data Strategy: Update on our strategy for mobile spectrum, June 2016.

Figure 4: Different approaches for enabling wireless access [25]

4.24 An overview of our recent work on spectrum suitable for 5G and Wi-Fi is set out below.

Example: Making available spectrum for 5G mobile

4.25 5G is the latest mobile technology which brings greater speed, capacity and functionality to mobile services. We are now well advanced in making key 5G bands available in the UK. In 2018 we auctioned first half of the primary 5G bands (3.4-3.6 GHz), being among the first in the world to do so. We have cleared spectrum in the 700 MHz band (see box below) and cleared the whole 3.4-3.8 GHz such that there are no exclusion zones or other restrictions. In 2019 we added the 24.25-26.5 GHz band to our spectrum sharing framework for indoor-only deployment. We are in the process of awarding the 700 MHz and 3.6-3.8 GHz bands.

Clearing spectrum in the 700 MHz band

In August 2020 we finished work on clearing the 700 MHz band for mobile. This involved many TV transmitters changing the frequency they used. We planned the new frequencies for the TV transmitters, ensuring neighbouring transmitters didn't interfere with each other and negotiated agreements with other countries to make sure our spectrum use didn't interfere with theirs.

When the TV transmitters changed frequencies millions of Freeview TV viewers had to retune their TV sets to pick up the new frequencies. Fortunately, this is generally a simple and quick process, and a support phone line and website were available for people who had any difficulties. In-home support was offered to viewers who had more challenging retune problems, and in a very small number of cases aerials needed to be replaced.

As well as TV viewers, users of wireless microphones in the theatre and TV production industries also had to change their equipment to operate in new spectrum bands as a result of 700 MHz clearance. Ofcom set up the 700 MHz clearance programme, collaborating with many partners (Arqiva, DCMS, TV broadcasters, Digital UK and Freeview and DMSL) to ensure the project completed on schedule and under budget.

[25] Spectrum bands with borders are soon to be authorised.

Example: Making spectrum available for Wi-Fi and similar technologies

4.26 Wi-Fi technologies have evolved over time to make more efficient use of the spectrum and support faster connections around the home and office. However, to meet growing demand, more channels and wider channels will be required. 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 suitable for Wi-Fi and similar wireless technologies, for example Bluetooth, LoRa and SigFox, used for everything from health tracking to smart cities.

We take a leading international role

4.27 As discussed in Section 3, we take a leading role in key international spectrum fora, influencing outcomes in line with UK interests as international cooperation on spectrum management is critical to securing increased benefits from spectrum use in the UK. It is our desire to continue that strong influence and drive developments in spectrum authorisation and standards. This is particularly important for mass market services and technologies, such as mobile and Wi-Fi, because decisions taken internationally can provide the opportunity for equipment and device manufacturers to exploit economies of scale from harmonisation and standardisation (also see paragraphs 6.25-6.29 on promoting an appropriate level of international harmonisation).

4.28 Ofcom has consistently put considerable resource and effort into our international spectrum work in order to maximise our opportunity to influence relevant international developments. For example:

- We played a key role internationally in the identification of early 5G spectrum bands (700 MHz, 3.4-3.8 GHz and 26 GHz) and we continue to influence international debates with regards to future bands for 5G. We will continue to be active in promoting 3.4-3.8 GHz, 26 GHz, 40 GHz (40.5-43.5 GHz) and 66-71 GHz as 5G bands in CEPT and in ITU, ensuring that the harmonised technical conditions developed are appropriate to facilitate 5G whilst ensuring sensitive incumbent services are adequately protected.
- We take a leading international role in relation to satellite communications, including new satellite services that can help deliver improved broadband services to people in locations that are hard to serve with other networks. We played a key role in establishing an appropriate international regulatory framework for low earth orbit satellite constellations and for improved broadband services on aircraft.

4.29 As well as influencing outcomes in international spectrum fora, we have also led in opening access to many important spectrum bands for consumer services, with the UK being one of the first countries in the world to do so, for example the 5G bands and lower 6 GHz band noted above.

We enable the wide availability of core wireless services

4.30 As described earlier in this section, many wireless services have become essential to the way we live our lives nowadays. Some services are nearly universally available already

(broadcast TV and satellite positioning) and wireless connectivity between devices can be used anywhere the devices can go.

4.31 In addition, we want people across the whole of the UK to be able to access better broadband and mobile services, so everyone can benefit from the services they deliver. To enable improved access to these services, we have taken a range of spectrum management actions:

- **Availability of mobile services**. In situations or locations where deployment of wireless services is not necessarily economically viable, we have attached coverage obligations to certain spectrum rights to extend the footprint of the cellular network. There are also locations where it might be otherwise difficult to get mobile coverage, so we have made spectrum available for mobile repeaters that extend the coverage beyond the operators' network.
- **Availability of fixed broadband services**. In very hard-to-reach areas, where rollout of fixed broadband may be very costly, the availability of wireless broadband options can be important. As noted above we have been working to enable further improvements in satellite broadband services. In addition, one of the potential uses for spectrum we have made available in 3.8-4.2 GHz is the provision of fixed wireless broadband services.

4.32 In addition, we undertake non-spectrum management actions to support the wide availability of services, like improving mobile coverage information for consumers, as part of our wider role (discussed in Section 3).

Proposals to address future challenges and opportunities

4.33 In addition to the continuation of our existing work set out above, we consider that the proposals summarised in Table 2, and discussed below, would contribute to achieving our objective of continued improvements in the wireless communications used by everyone in the future.

Table 2: Proposals contributing to continued improvements in the wireless communications used by everyone, wherever and whenever they use them

Proposal	Contribution to objective	Detail set out
Licensing to fit local and national services. Consider further options for localised spectrum access when authorising new access to spectrum.	Would enable a range of players to offer national as well as locally provided services using mobile technology, potentially improving the options available for users of mobile services.	Below

Supporting innovation in wireless technologies. Including influencing the development of international standards and decisions so that they have greater flexibility for new technologies and applications.	Would create the conditions for new consumer wireless devices and technologies to be developed by a wider range of organisations and to be more quickly made available to users.	Paragraphs 4.43-4.52

Licensing to fit local and national services

There is likely to be increasing demand for localised access to spectrum

4.34 Most types of licences that we offer are for a particular location or site, for example the licences we issue for satellite earth stations, or fixed links between two specific points. A notable exception to this is where we have auctioned national block assigned licences. These licences are often, though not always, used for the provision of mobile services. 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 (although provision of national mobile services may not always require national licensing in every band used, if, for example, certain bands are used only for extra capacity in certain locations).

4.35 In future we expect there to be a growing number of instances where spectrum users with smaller geographic footprints could benefit from acquiring licences for spectrum – for example to deploy a private network at a specific site. These users include the wide variety of new spectrum users discussed in Section 5, such as those wishing to deploy a private network at a hospital, factory, distribution centre or farm (perhaps where a public 5G network would not yet be available). Some new users may be particularly interested in gaining access to bands supported by (or that may in the future be supported by) mobile technology, because of the equipment ecosystem that could lead to wider availability and lower cost equipment. The same bands may also have benefits for providing public mobile services, including providing additional capacity for those services.

We propose to consider further options for localised access when authorising new access to spectrum

4.36 In responding to the challenge of differing demands from different users, we recognise there isn't a one-size-fits-all solution when it comes to the appropriate size of the geographic area to license, as there are advantages and disadvantages to any approach. For example:

- **Authorising relatively small geographic areas** makes it more likely that users will apply for spectrum rights only for the geographic areas where they need to deploy their services, leaving spectrum elsewhere available for others. However, if a spectrum user wishes to provide a service over a wide area, this may present risks. Such a user would need to acquire (or aggregate) a number of small licences to cover a wider area, and it

may risk having geographic gaps in areas where licences were already acquired by other users. [26] Another potential drawback is an increased requirement for managing the interference between different users, possibly leading to an unlicensed geographic area between two licensed users in which neither can deploy.

- **Authorising a larger geographic area** can be beneficial for provision of services with wide coverage (as noted above), giving flexibility to licensees as to where to deploy. But conversely there is a greater risk that the spectrum would not be used in some areas. This could be inefficient if others would be prepared to deploy services but are not able to access spectrum in those areas. In addition, acquiring a licence covering a large geographic area could be a barrier for players with a small geographic footprint.

4.37 However, there are a number of options which could allow a degree of mixing and matching between different sizes of the geographic area to be licensed:

- **Offering licences with different geographic extents in different parts of the country** to respond to varying demands. Certain areas could be covered by licences with a wide geographic footprint, while other areas could have licences with a smaller geographic size. This might be appropriate, for example, if spectrum use cases vary significantly across the UK, perhaps between urban and rural areas.
- **Adopting different geographic authorisation approaches in different frequencies** within the same band or in similar adjacent bands. For example, we offer localised shared access licences in the 3.8-4.2 GHz band, which is adjacent to the 3.6-3.8 GHz band where we are awarding national licences.
- **Offering Local Access licences in parallel with national licences.** Local Access licences allow users to access spectrum in locations where that spectrum is not being utilised by the national licensee and the national licensee has no plans to deploy. We offer Local Access licences in a number of spectrum bands used to provide mobile services. [27]
- **Indoor authorisation in parallel with outdoor licensing**. In certain cases (e.g. if transmission is low power or at higher frequencies), authorisation for indoor-only use of radio equipment may be able to co-exist with authorisations for outdoor use. An example of this is our indoor-only licences for 26 GHz, which could co-exist with future authorisations for outdoor use.

4.38 Determining the most appropriate approach will often involve the use of regulatory judgement on the relevant trade-offs in the specific circumstances of each case. However, overall, we consider that local options for accessing spectrum are likely to be increasingly important in the future given the growing range of uses and users that may benefit from this. These benefits could apply to both the core services discussed in this section as well as more specialised services discussed in the next section.

[26] There are mechanisms that can enable users to aggregate licences without risking geographic gaps across licences. For example, it is possible is to have an auction with small geographic areas that minimises the chances of users only winning part of their bids. These mechanisms are likely to increase the complexity of authorising spectrum use, and therefore should only be implemented where the additional complexity is justified.

[27] Local Access licences are available within any frequency band covered by the Mobile Trading Regulations. See paragraph 2.6 in the 'Local Access Licence Guidance' document for the list of frequencies.

4.39 Therefore, we propose to consider further options (such as those outlined above) for licensing spectrum use over smaller geographic areas when authorising new access to spectrum. [28]

4.40 This 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. Local licences in bands supporting mobile technology can also support innovation in the mobile supply chain, for example new suppliers of enterprise mobile equipment have emerged using bands available on a local basis. Another example is the use of local licences by Digital Catapult to deploy a 5G testbed. [29]

4.41 This approach would build on how we manage bands used by other sectors, which are primarily licensed for smaller geographic areas, and our work last year to provide localised access to a number of shared and mobile bands (Shared Access and Local Access licences respectively, also see paragraphs 5.25-5.27).

4.42 The above addresses the initial authorisation of licences. However, the optimal geographic licensing arrangement for a band could naturally change over time, for example as new use cases emerge. The ability to trade spectrum rights provides a route for users to respond to these changes. Spectrum trading could help to achieve a more efficient outcome by increasing or decreasing the geographic areas spectrum users have access to. However, where the costs or complexity of transactions are too high or there are other potential barriers, trades (that would otherwise be efficient) may not happen, particularly if there are a large number of needed trades between users (we discuss spectrum trading further in Section 7). Therefore, the potential for trading does not remove the need for carefully considering the initial geographic extent of licences.

Question 4: Do you agree that there is likely to be greater demand for local access to spectrum in the future? Do you agree with our proposal to consider further options for localised spectrum access when authorising new access to spectrum?

Supporting innovation in wireless technologies

4.43 Continued improvements in the services discussed in this section will depend on ongoing innovation. There is already a high level of innovation in many of the communication services and devices that people use, and much of our work in making spectrum available, for example spectrum to support 5G services (discussed above), supports that.

4.44 One area where we think there could be an even greater scope for future innovation is in the growing range of connected devices used by consumers, businesses and public sector

[28] For the avoidance of doubt, this proposal does not affect the decisions that we have made in relation to the 700 MHz and 3.6-3.8 GHz licences to be awarded in our forthcoming auction.
[29] This joint programme with Ofcom, the "SmartRAN Open Network Interoperability Centre (SONIC)" is funded by DCMS and will facilitate interoperability testing for large and small companies, as well as enabling evaluation of solutions such as Open RAN.

users. These often use 'short range' wireless technologies (like Bluetooth, LoRa and SigFox); typically transmit using lower power to communicate over relatively short distances and/or with low data rates, and can access certain bands for 'free' because they are exempt from licensing.

Licence exemption supports innovation, but some players may face or perceive regulatory barriers in launching new technologies and devices

4.45 Licence exemption can be particularly beneficial for innovation, as developers of new short-range devices and technologies don't need to obtain licences and users of exempt devices can just turn on and go. However, some barriers may exist, or be perceived to exist, for smaller players in developing and launching new exempt technologies and devices. This is because the processes necessary to place a new exempt short-range device or technology on the market can require significant resources, including to:

- **Develop technical coexistence conditions.** Establishing the conditions for new short-range applications to be able to coexist with existing uses is normally carried out at European level by a range of parties working together in CEPT. This common approach is often beneficial to achieve the economies of scale that make devices affordable to consumers, but developing new conditions often requires complex engineering analysis which takes time to complete, and potentially many meetings with relevant experts.
- **Develop equipment standards.** Other specific aspects of equipment, such as its unwanted emissions and its spectrum sharing techniques, need to be specified in more detail in an equipment standard. This is done through processes that, similarly to the CEPT work, can be complex and involve many meetings with relevant experts.

4.46 An alternative to a new standard has been to use a UK Notified Body [30] for approving new types of equipment. In practice, however, this route has seldom been used. One reason could be that Notified Bodies' main area of expertise has tended to be in testing equipment to standards rather than in carrying out interference analysis. Another reason could be that standards provide a clear benchmark for compliance that alternative methods of compliance may not.

We're proposing actions to further reduce the barriers for new technologies and devices

4.47 The technical spectrum usage conditions for licence exempt devices developed in CEPT groups should be written in a technology and service neutral way, only specifying the least restrictive technical conditions necessary to ensure coexistence with existing uses. Although this is already an aspiration, in practice the coexistence work undertaken in CEPT

[30] A conformity assessment body accredited by UKAS (the UK's National Accreditation Body) as having competence in relevant conformity assessment procedures for radio equipment to be placed on the market in accordance with UK Radio Equipment Regulations

and the resulting conditions can sometimes be driven by, and end up being tailored to, specific technologies or applications.

4.48 The best current example of more flexible conditions are those specified for the 'non-specific SRD' (Short Range Device) category. Greater flexibility means that companies need only ensure that their technology is consistent with these general 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.

4.49 We propose to further support smaller players and start-ups in innovating and developing new products by:

- Placing greater emphasis on promoting technology and service neutrality in international harmonisation processes.
- Ensuring that companies – particularly smaller ones – are aware of the flexibility that generic technical conditions provide them (this would also be an element of our proposals to further understand, assist and inform spectrum users, see paragraphs 5.30-5.43).

4.50 More generally, where we identify or are informed about obstacles to innovation, we will consider reducing or removing those obstacles where appropriate.

4.51 In addition, we will discuss with the Department for Business, Energy and Industrial Strategy (BEIS) the options for manufacturers of innovative products to bring their products to market quickly in the UK in the future, including the future role of UK notified bodies.

4.52 This proposal would be beneficial for the development of consumer wireless devices, as well as specialised wireless applications discussed in the next section.

Question 5: Do you agree with the actual and perceived barriers identified for innovation in new wireless technologies, and our proposed ways of tackling those?

5. Wireless communications for organisations with specialised requirements

5.1 Many businesses, the public sector and other organisations depend on a range of specialised wireless communication services in addition to the mass market wireless communication services discussed in the previous section. There are also scientific requirements to use specific frequencies, for example to monitor our climate or study the universe using radio waves. Taken together, these users represent the vast majority of our licensees.

5.2 We want these organisations to be able to access the right wireless communication or spectrum options for their specialised needs. We believe that this can support improved productivity and services across many different industries, better public services as well as greater scientific understanding of the earth, our climate and beyond.

5.3 This section outlines the wide range of users and applications that have specialised spectrum requirements, what we currently do to help them get access to the right spectrum, and our proposals for the future.

Importance of this objective now and trends for the future

Spectrum users have diverse and specialised needs

5.4 Organisations that make specialised use of wireless communications or other specialised use of radio spectrum, today span many parts of the UK economy, including the public sector. Examples of sectors and applications with long established requirements are shown in Table 3 below. Some of these applications provide wireless infrastructure to support the delivery of the core services discussed in Section 4, including fixed wireless backhaul to mobile basestations and satellite broadband services.

Table 3: Examples of sectors and wireless applications with specialised requirements

Aeronautical	A wide range of specialised radio equipment is used onboard aircraft, and on the ground for communication with aircraft, as well as radars for air traffic control and navigation purposes.
Amateur Radio	Amateur radio, sometimes known as ham radio, is a hobby that enables participants to experiment with and learn about radio and to communicate with other radio amateurs around the world.
Business Radio	Provides narrowband and wideband communications for applications that can be of critical importance to a large variety of users, including utilities, transport operators, hospitals, industrial sites and taxi firms.

Defence	The defence sector uses a wide range of radio equipment in support of operations and training, including point to point communications, weapons calibration, airborne telemetry, radar and remotely controlled vehicles.
Earth observation	Earth observation satellites collect data about the earth and its atmosphere that is used for weather forecasting, environmental monitoring, climate change research and many other applications.
Emergency Services	The emergency services rely on several radio technologies, including a new national Emergency Services Network, to provide communications capabilities needed to keep citizens safe and to provide rescue services.
Fixed links	High capacity point to point wireless links used for a variety of networks, including connectivity to mobile base stations to support mobile services (covered in Section 4), corporate networks and control networks for utilities.
Maritime	A range of specialised radio equipment is used, including for communication between ships and with coast stations, as well as satellite, radar and beacons, used for navigation and the safety of shipping.
Programme Making & Special Events (PMSE)	Wireless services, such as wireless cameras and microphones, used in activities including news gathering, sports events, live concerts, films, theatre, religious, cultural and educational activities.
Satellite communications	In addition to satellite broadcasting and broadband for consumers, satellites are used for a variety of specialised applications, such as connectivity to ships, aircraft, satellite news gathering and defence use.
Space science	Includes radio astronomy and space research which contribute to our knowledge of the universe. Also provides information about space weather, which is vital to mitigate the risks to critical infrastructure from solar activity.

5.5 Within the public sector there are a very diverse range of spectrum users – ranging from publicly funded scientific research (including radio astronomy), to emergency services and military communications on land, in the air and at sea. In many cases the predictability and quality of spectrum access is critical for the public sector to fulfil its aims.

5.6 The above sectors generally have well established and understood requirements as access to spectrum is already essential to their business or for achieving their organisational objectives. Their requirements can include:

- High degrees of reliability and very low latency, either in a local area, for example wireless microphones used for live events; or over a wide area, for example critical communications for electricity networks or the rail network.
- Operations in locations not well served by mass market services – for example utilities infrastructure in remote locations, connectivity to oil rigs, boats in coastal water and aircraft flying over the UK, or rockets launching satellites from UK spaceports.

- Very 'quiet' spectrum, due to the need to monitor very faint and/or distant natural radio emissions, for example for radio astronomy or measuring certain environmental characteristics from space. These applications also sometimes need to use very specific frequencies dictated by the physical properties of the matter being studied.
- Ability to deal with bursts of unpredictable demand, for example to support emergency services and live news reporting from major (unscheduled) news events or incidents.
- The need to control all data in a network for security reasons.

There are growing opportunities for wireless communications across many more sectors

5.7 In addition to these well-established uses, there are growing opportunities for businesses and organisations right across the economy and society, including public sector users, to benefit from greater use of wireless communications.

5.8 As we set out in our 2019 document 'Supporting the expanding role of wireless innovation in UK industry', all industries are increasingly engaged in a journey towards "digital transformation". Businesses are 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 players to achieve their digital transformation objectives. Industries such as utilities, agriculture, logistics and transport are all benefitting from this.

5.9 Wireless connectivity, remote sensors, control and automation are also changing the way businesses deliver their services. Developments in the use of Artificial Intelligence (AI) and robotics, augmented and virtual reality (AR and VR) and the Internet of Things (IoT) have potential to support digital transformation further. The benefits from successfully using these different technologies to deliver industrial digitalisation are far reaching, and wireless connectivity is crucial to this.

5.10 A study for the 2017 Made Smarter Review estimated the positive impact of faster innovation and adoption of industrial digitalisation technologies could be as much as £455 billion for UK manufacturing over the next decade.

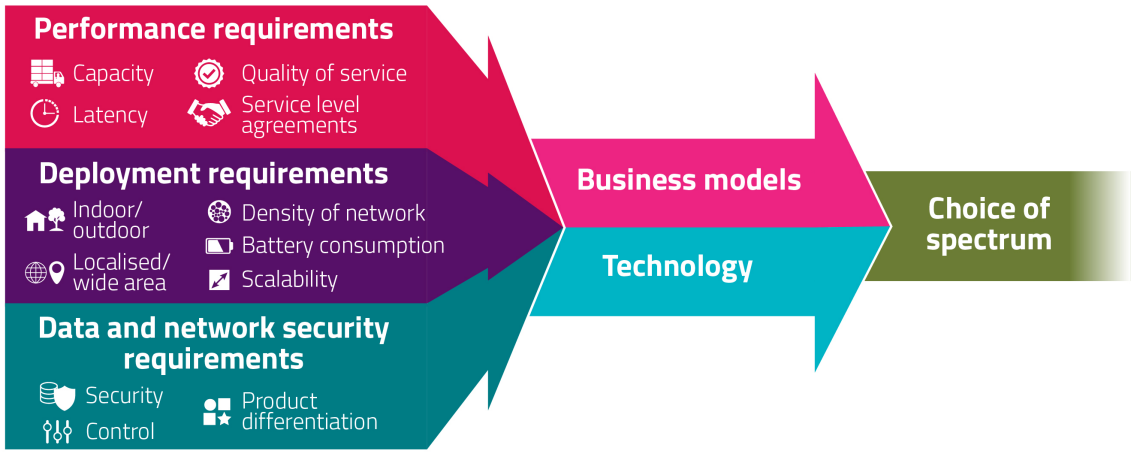
Some new users and applications will have specialised spectrum requirements

5.11 Like existing users, new users are likely to have a wide range of requirements, everything from high reliability communications for critical infrastructure, low latency communications for manufacturing, to low cost / delay-tolerant sensors for smart cities and agritech (see Figure 5 below).

5.12 Some of these new applications might be supported by public mobile networks utilising services similar to consumers. 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 wider range of performance requirements. For these use cases

our existing approach (discussed in the previous section) of supporting continued improvements in the (mass market) services used by everyone may be sufficient.

Figure 5: Different requirements for wireless solutions by businesses



5.13 However, many other users and applications (e.g. utilities, some manufacturers) 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 [31] could deliver greater control over security, resilience and reliability for various uses. In addition, the availability of a variety of wireless options could promote competition and innovation in the provision of services to these users.

Continued use of our existing tools to address this objective

5.14 There are a number of ways in which our existing tools and activities support this objective and which we consider are important to continue:

- we work with existing spectrum-using sectors and stakeholders and reach out to potential future users;
- we make spectrum available to suit the needs of different users and business models; and
- we improve the quality and quantity of spectrum information we provide.

We work with existing spectrum-using sectors and stakeholders and reach out to potential future users

5.15 The nature of spectrum demand within different sectors continually changes over time as technology advances and the needs of different businesses change. Therefore, we have ongoing engagement with stakeholders in order to maintain and improve our understanding of their spectrum use and future spectrum requirements. This engagement

[31] 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.

informs our work on managing and developing the framework for spectrum authorisation, including spectrum licensing, licence exemption, pricing policy and international policy.

5.16 In addition, from time to time we undertake more in-depth sectoral reviews. These are used to refine our understanding of the spectrum challenges facing specific sectors, and to develop policy priorities and a roadmap of actions to implement those priorities. Previous reviews have included the PMSE review, space spectrum strategy, and review of spectrum used by fixed wireless services . We are currently refreshing our space spectrum strategy given the recent pace of change in that sector.

5.17 However, whilst many existing spectrum users already engage with us directly or via trade bodies about their spectrum requirements, others – particularly newer spectrum users – are likely to be less aware of spectrum use or the regulatory environment in which they need to operate, and may be more reliant on the spectrum choices of manufacturers or service providers. Two examples of where we have reached out to new user groups is our work to support wireless innovation in UK industry and engagement with new players in the space sector.

5.18 In addition, with a much longer time horizon, we keep track of emerging technologies which although not visible in the current demand from spectrum users, may change demand for spectrum in the future. [32]

Example: Supporting wireless innovation in UK industry

5.19 We have been engaging with private and public sector organisations in the UK and internationally to understand the evolving connectivity requirements emerging from different industry sectors. Many of these sectors and their suppliers have not traditionally engaged with spectrum or Ofcom.

5.20 We carried out a series of workshops to bring together players representing different sectors' needs and continue engaging with different users bilaterally or hosting webinars and seminars. [33] Topics have included manufacturing, health, agritech, smart cities and connected rural locations. We have learned how different business models work for different industries and how different technologies are used. These varied requirements mean that spectrum needs to be authorised in a range of ways.

Example: Engaging with new players in the space sector

5.21 The space sector is one area where new start-ups, universities and international companies are seeking to build or deliver wireless services in the UK. Over the last three years, we have reached out to a growing and diverse group of players in the space sector to explain

[32] This forms part of our Technology Discovery programme of work which recently issued a call for inputs on a wide range of technologies, not just those related to spectrum. We will publish a summary of outcomes from this programme in due course.

[33] Ofcom's *supporting wireless innovation workshops* and engagement on *Enabling wireless innovation through local licensing* have adopted wide outreach and sector specific approaches. In addition, we are using wider networks, sector representatives, innovation hubs and research institutions to engage with players interested in our map of technology solutions business models and spectrum bands.

the importance of spectrum and delivered several 'teach-ins' on space spectrum regulation.

5.22 We have encouraged new space actors to engage with us on their projects at an early stage so we can learn more about their needs and advise them on relevant regulatory processes. We have also engaged with the wider space community such as funding bodies and venture capital funds to help them understand spectrum management in the space sector.

We make spectrum available to suit the needs of different users and business models

5.23 As set out in Section 3, we have an established authorisation framework with a range of authorisation tools to address different types of spectrum use and demand, and which enables access to spectrum for the wide range of sectors outlined above. This includes a range of licence products which users can apply for on a first-come-first-served basis via our website as well as licence exemptions for certain types of equipment.

5.24 We continue to update our authorisation framework to meet changing spectrum needs from new and existing spectrum users and ensure optimal use of spectrum. One example where we have made additional spectrum available to suit the needs of different users and business models is the provision of shared access to bands supporting mobile technology.

Example: Shared access to bands supporting mobile technology

5.25 There has been growing interest in the use of mobile technology to meet local wireless connectivity requirements in a range of sectors, such as manufacturing, enterprise, logistics, agriculture, mining and health.

5.26 In 2019 we introduced a new licensing approach to provide localised access to a number of spectrum bands supporting mobile technology.[34] 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). People can apply to Ofcom for coordinated access to these bands on a first-come-first-served basis.

5.27 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).

We improve the quality and quantity of spectrum information we provide

5.28 The availability of good quality and accessible information about spectrum makes it easier for stakeholders to plan changes in their own use and to engage more closely with Ofcom's spectrum management plans. In our 2014 Strategy we committed to improving the quality

[34] Enabling wireless innovation through local licensing, July 2019.

and quantity of information made available on spectrum use and have made a number of improvements since then:

- **Spectrum Information System (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) and the Transfer Notification Register (TNR).
- **UKFAT** and **UK Spectrum Map** – The interactive version of the UK Frequency Allocation Table (UKFAT) reflects current UK spectrum allocations as well as international allocations of the ITU. [35] The UK Spectrum Map is a dashboard showing how spectrum is used, by sector and by product/application.
- **Open data –** Ofcom follows open data principles, making the data we collect and create available to the public wherever possible. We have released a variety of spectrum open data including data related to mobile signal strength along the rail network, data from our Space Spectrum Strategy and an open version of the WTR. [36]
- **Spectrum demand service** – We provide a spectrum demand requests webpage, aimed at new and existing spectrum users, that offers a point of contact for parties who would like to access spectrum not currently authorised by Ofcom.
- **Wider international work** – we have contributed to the Spectrum Inventory Project run by the European Commission and continue to contribute to the ECO Frequency Information System (EFIS), the major repository of information on spectrum utilisation across Europe.

Proposals to address future challenges and opportunities

5.29 In addition to the continuation of our existing work set out above, we consider that the proposals summarised in Table 4 (with detail in Section 4 and below) would contribute to achieving our objective of businesses, public sector and other organisations with specialised requirements being able to access the right wireless communication or spectrum options.

[35] It is accompanied by documents with sector allocations for satellite, meteorology and civil/military shared allocations.
[36] https://www.ofcom.org.uk/research-and-data/data/opendata#accordion__target-92004 Since 2014, the Wireless Telegraphy Register (WTR) has been improved and expanded to provide information on transmission parameters (including power and antenna characteristics) and includes other non-tradable licences not previously noted. We note that the renewables sector and wind farming planners use this source of open data for critical planning work.

Table 4: Proposals contributing to businesses, public sector and other organisations with specialised requirements being able to access the right wireless communication or spectrum options

Proposal	Contribution to objective	Detail set out
Licensing to fit local and national services. Consider further options for localised spectrum access when authorising new access to spectrum.	Would support the provision of wireless services at specific sites or areas, providing more options for organisations with specialised needs, including those looking to utilise mobile technology.	Section 4, paragraphs 4.36-4.42
Supporting innovation in wireless technologies. Including influencing the development of international standards and decisions so that they have greater flexibility for new technologies and applications.	Would create the conditions for new wireless devices and technologies, potentially tailored for a range of more specialised applications, to be developed by a wider range of organisations and to be more quickly made available to users.	Section 4, paragraphs 4.43-4.52
Expanding our work to understand, assist and inform the wide range of organisations who may benefit from wireless technologies in the future.	A wider range of organisations will be able to make informed choices about their use of spectrum, and we will be in a better position to make spectrum available in an appropriate way for their needs.	Below

Expanding our work to understand, assist and inform stakeholders

5.30 As noted above, there is a growing range of organisations who could benefit from wireless technologies in the future, and many of these (and their suppliers) have not traditionally engaged with spectrum issues or with Ofcom as a spectrum manager. But their requirements and choices are important for our future management of spectrum, in addition to the growing and changing spectrum needs from existing stakeholders.

5.31 Given the opportunity for even greater innovation in wireless services and downstream applications in the future, and building on our engagement to date, we think that an expanded programme of activities is important to:

a) **Understand:** Ensure we understand the diverse needs of businesses, public sector and other organisations, now and in the future, to inform our spectrum management work.

b) **Assist and inform:** Help to improve understanding of spectrum and provide information that will assist stakeholders in their choice of wireless technology, and, where appropriate, spectrum access options.

5.32 This programme would include three elements: outreach, reporting and information tools. Table 5 below summarises these three elements and the activities we are proposing.

5.33 As we want to use our resources most effectively, we would like to hear stakeholders' views on what kinds of improved reporting and information would be most useful for them in responses to this consultation.

Table 5: Summary of proposed activities to understand, assist and inform spectrum users

Theme	Proposed activities
Outreach Raising awareness of spectrum and Ofcom's role, expanding the knowledge offered to and gained from existing and new stakeholders	**Proactive engagement** with different industries and sectors, including participating in sector events and acting in partnership with other organisations where appropriate
Reporting Increased reporting to raise awareness of our spectrum management activities, and our outlook for the future of spectrum use and spectrum management in the UK	A new **Spectrum Roadmap** publication, to provide a forward indication of how spectrum demand is changing across different sectors and our expected future work
Information tools Making available the best tools for all spectrum users, providing high quality and quantity of information on spectrum use and choices	Reviewing and, where appropriate, **upgrading our existing information tools** to offer improved functionality and potentially more information **Modernising Ofcom licensing tools** to improve stakeholder experience

Outreach

5.34 We propose to expand our engagement with different industry sectors to learn more about their requirements and show how wireless solutions can support their digital transformation. This would involve engaging in new ways with organisations interested in digital transformation, and sharing information that will stir interest in other organisations, helping them to make informed choices about wireless connectivity.

5.35 This would also include growing our engagement and collaboration with organisations who are supporting the UK's digital transformation and consider the development of a variety of tools to reach a diverse audience. We already collaborate with others, including DCMS, which is running several digital innovation trials covering different sectors such as health, housing and tourism. We also support further cooperation between the UK's regulatory authorities where coordination between different regulatory regimes is important to support new services and innovation, as we have been doing with the CAA and UK Space Agency to coordinate regulatory efforts on UK space launch.

5.36 Our engagement will also take account of our proposals to support greater spectrum sharing (detailed in Section 7), for example by making users, vendors and manufacturers more aware of the importance of interference resilient equipment.

Spectrum and wireless reporting

5.37 Ofcom's annual reports include statistics on our spectrum licensing and enforcement activities, as well as updating on our progress against Ofcom's priorities as set out in our annual Plan of Work. However, we believe there is scope to provide additional reporting on spectrum issues and wireless transformation specifically.

5.38 We propose to publish a Spectrum Roadmap, which would indicate key market, technological and international developments; review how demand for wireless solutions is changing across different sectors; and set out a roadmap for future spectrum work.

5.39 There are other areas where we could consider publishing additional information, and we would be interested in feedback on whether these would provide significant value for different users, and potential users, of spectrum. For example:

- providing consolidated updates about our spectrum decisions and outreach activities; or
- highlighting examples of wireless innovation that are supporting the UK's wireless future, beyond mobile and wireless broadband (which are reported in our 'Connected Nations' reports).

Information tools

5.40 The needs of stakeholders that are newer to spectrum issues may differ significantly from those of existing users of spectrum. Existing 'spectrum aware' users may be most interested in applying for new licences and managing their existing ones; information about existing use that may help them to plan new deployments; and policy or technical changes that may impact their interests, for example.

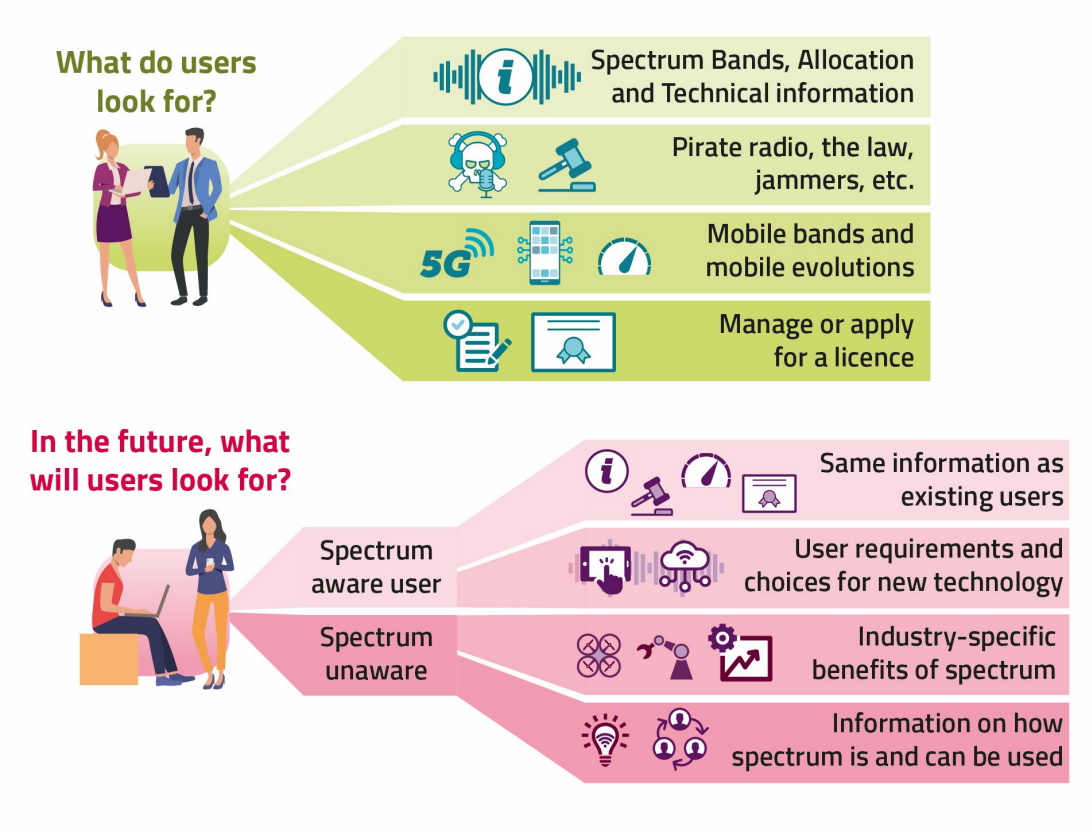
5.41 Less spectrum aware users may need additional information, or may approach spectrum-related issues in a different way – for example, they may be more familiar with the language of technologies (e.g. 4G, Wi-Fi) than the technology-neutral terms we use to describe spectrum bands and licence products. Figure 6 illustrates the current requirements of stakeholders and suggests what the future requirements of different stakeholders might be.

5.42 There is a range of current and proposed future work to further improve the quality and accessibility of our information tools, and better meet stakeholders' needs. We will:

- Review and, where necessary, upgrade our spectrum information tools, including the SIS, WTR, TNR, interactive UKFAT and Spectrum Map. This review will consider whether there are changes we can make to improve functionality and performance, as well as whether there is additional information we can share.

- As noted in section 3 (paragraph 3.7) we have already begun work to modernise our spectrum licensing platform, with some expected benefits being the creation of a single system for most Ofcom spectrum licences, an improved online user experience for licensees and platform tools that will add to the quality of licencing and coordination information shared between licensees and Ofcom. In addition, automated and self-service spectrum management tools may be considered which will enable users to manage their accounts and licensing choices in a more efficient way.

Figure 6: Spectrum information users now and in the future



5.43 In addition, we could also consider further actions, for example:

- Exploring how we can improve the accessibility and navigation of spectrum-related information on our website, taking into account the needs and interests of different types of users.
- Considering whether it would be possible, and useful to stakeholders, to make available additional types of information that we collect. For example, whether there are ways our remote spectrum monitoring data could assist users by providing additional information about the use of spectrum in geographical areas. However, we recognise that in many cases there will be reasons why data cannot be made publicly available, for example commercial confidentiality or where there are security concerns.

- Assessing the need for Application Programming Interfaces (APIs) to access spectrum management data. [37]

Question 6: Do you agree with Ofcom's proposals to improve our outreach and reporting activities, and spectrum information tools?

a) Are there additional ways that Ofcom could better engage with existing and future users and providers of wireless communications?
b) Please explain any specific areas where you believe more or better provision of information could provide value to stakeholders

[37] 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-2020/interactive. We have also developed APIs for our Connected Nations coverage data as well as nationwide broadband and mobile coverage

6. Flexibility supporting innovation and assurances for continued use

6.1 Few people could have predicted the many ways that spectrum is used today and the innovations that this use supports. This is why flexibility in spectrum use is so important and has long been a key principle of our approach. Equally many of the services we benefit from today have required significant commercial investment. Sufficient certainty over access to spectrum is necessary to sustain those benefits and enable new investments that people will benefit from in the future.

6.2 This section explains the continuing importance of providing flexibility in spectrum use to support innovation and of providing appropriate assurances for continued use. It sets out what we currently do, and plan to continue doing, to achieve this objective, and identifies a proposal to support this objective in the future.

Importance of this objective and trends for the future

Flexibility is important because we cannot know with certainty what future innovations will look like

6.3 A common theme throughout this document is that innovations in wireless applications, services and technologies have the potential to bring significant benefits to people in the UK in many ways – including improved communication services, increased business productivity and better public services. In carrying out our radio spectrum functions, we are required to have regard to the desirability of promoting the development of innovative services. [38]

6.4 In Section 3 we outlined a range of trends driving developments in new wireless applications and technologies. However, innovation is driven by industry and other players, and we cannot know in advance what it will look like. For example, we cannot accurately predict what new wireless applications will emerge and which ones will bring the greatest benefit to people and businesses in the UK.

6.5 We also cannot be certain who will do the innovating. Innovation can come from existing spectrum users, for example innovating within spectrum bands to which they already hold rights by introducing new, higher performance technologies. New entrants may try ideas for new applications and services, some of which may drive demand for capacity on existing networks or create new and different spectrum demands.

6.6 In addition, innovation can occur at different levels in the value chain, including:

- New applications that benefit from wireless connectivity, such as augmented and virtual reality, connected vehicles, or industrial IoT applications.

[38] s.3(2)(c) WT Act

- New communication services, e.g. new generations of mobile systems, or deployment of satellite networks comprising thousands of small satellites.
- New radio technologies and equipment, for example continued technical evolution of techniques such as Massive MIMO.

6.7 Therefore, our aim is to provide flexibility in our regulatory framework to allow the emergence of a wide range of new spectrum uses. We want to ensure, as far as possible, that access to spectrum is not an inhibitor to innovation, or to users' ability to provide services that deliver benefits to people and businesses.

Flexibility is likely to be even more important in the future

6.8 Flexibility in our regulatory framework has always been important, but arguably it will be even more so in the future. As discussed in Section 5, we are seeing adoption of wireless technology even more widely throughout the UK's economy and society, as well as its combination with innovations in other fields such as robotics and artificial intelligence.

6.9 Compared to a world where spectrum use was once concentrated in a few sectors with relatively static applications, growing diffusion of wireless technology has the potential to generate many more use cases, for a greater variety of users, and employing a wider range of wireless technologies and providers. These conditions could lead to even greater unpredictability in how spectrum will be used in the future and hence the growing importance of flexibility in how spectrum can be accessed and used.

Appropriate assurances for continued use will remain important

6.10 Whilst the degree of flexibility in spectrum use is one dimension of how spectrum users access spectrum, the other equally relevant dimension is the extent of assurances of continued use. Providing appropriate assurances for continued use of spectrum will remain an important aim for spectrum management for a number of reasons discussed below.

6.11 First, and perhaps most obviously, people in the UK already gain huge benefits from wireless communications which depend on use of spectrum. Changes to spectrum use could negatively impact those benefits if existing services can no longer be provided. However, this may not always be the case, for example where the same benefits can be delivered through different means, including migration of existing services to different frequencies.

6.12 Second, existing benefits would not exist and new ones may not emerge if there is too little assurance over continued access in order to support commercial investment. Some infrastructure investments to support use of spectrum can be long term and so will particularly benefit from appropriate assurances about access to that spectrum.

6.13 Finally, some scientific uses of radio spectrum depend on continued access to specific radio frequencies for measurements, and for that access to be sustained over a long period, in order to realise the science benefits from those measurements (for example to understand long term trends about changes to our climate).

Continued use of our existing tools to address this objective

6.14 There are a number of ways in which our existing tools and activities support flexibility and appropriate assurances for continued use, which we plan to continue in the future:

- we make spectrum available in a variety of ways, including licences for innovation and trials;
- we continue to develop automated spectrum management tools;
- we make spectrum rights as flexible as we can;
- we promote an appropriate level of international harmonisation; and
- we provide appropriate assurances of continued use for existing and new users.

We make spectrum available in a variety of ways, including licences specifically for innovation and trials

6.15 As discussed above, innovation doesn't happen just in one way or by one type of player. To accommodate this, we provide a range of different ways of accessing spectrum, providing different rights to use spectrum that meet different needs for quality of service, certainty of tenure and ease of access. These options are broadly split between licensing spectrum use and exempting devices (see Section 3). In Section 4 we noted that licence exemption has been particularly beneficial for innovation, as developers of new exempt devices and technologies do not need to obtain a licence or pay a fee, and users of exempt devices can just turn on and start using the device.

6.16 We believe these options will continue to offer the flexibility to make spectrum available in different ways to enable a diverse range of new wireless services and technologies in the future. In addition, for some wireless innovators, their first step may be the use of one of our innovation and trial licences discussed below.

Innovation and trial licensing

Innovation and trial licences offer quick and inexpensive access to spectrum, for a temporary and time-limited period, for:

- testing and development of wireless telegraphy (radio) equipment;
- scientific research and experimentation; and
- trials and demonstrations of radio apparatus, applications and technologies.

We can consider access to any frequency band, subject to availability and coordination with existing authorised users. Equipment must not cause harmful interference to any other authorised services and are not protected from the possibility of harmful interference from other authorised services.

Licences allow the ability to run trial scenarios involving customers but not the deployment of a commercial and/or operational service. Licensees will still need to consider what is the best long-term frequency and authorisation option for their operational / commercial service following the trial.

In addition to innovation and trial licensing, testing and development work is exempt from licensing for certain frequencies under 960 MHz if transmissions can be carried at sufficiently low power and/or screened from neighbours. [39]

We continue to develop automated spectrum management tools

6.17 Automated spectrum management tools that offer a direct interface between devices/networks and a spectrum management database can allow spectrum use to be authorised and modified in near real-time.

6.18 In addition to the potential efficiency benefits of these tools (discussed in Section 7), they can support more flexible spectrum licensing arrangements by making it easier and quicker to implement changes to spectrum access. More manual approaches to changes take longer to communicate to spectrum users and may require manual reconfiguration of equipment (the decision whether to exercise flexibility in particular cases will still remain a policy decision based on the facts of the case).

6.19 Two examples of the flexibility that automated spectrum management tools can, in principle, support are:

- Changing the frequency assigned to specific users / devices. For example, TV White Space devices automatically had their frequency of operation updated as the 700 MHz band was cleared. No intervention by the user was necessary to ensure continued use. We are also planning to use such tools to implement this flexibility in 'shared bands',

[39] Under 'suppressed radiation conditions': the radiated field strength, measured at a specified distance from the boundary of the premises, must not exceed given limits within certain frequency bands. See Innovation and Trial licensing: Guidance notes for applicants, 2018.

including the 3.8-4.2 GHz band (we have already made the necessary provisions in licences).

- Enabling access rights to change over time. For example, users may wish to start with opportunistic access (e.g. accessing spectrum only when unused by a higher priority user), but over time migrate to a higher priority level, offering greater surety of access, perhaps subject to a relevant fee. This could support innovation by providing low barriers to entry whilst offering a route to more secure access if business models develop.

6.20 Given the wide range of future potential benefits of this capability, we plan to continue to develop its use in the UK and to continue to take a leading role internationally (building on our experience in TV white spaces). The most promising bands for its use are likely to be where an equipment ecosystem already exists or has good prospect of developing. For example, its use in the 3.8-4.2 GHz band could benefit from the ecosystem for the 3550 MHz to 3700 MHz (CBRS) band in the USA.

6.21 However, introducing this technology can result in additional costs and complexity and not all its functions and corresponding benefits will be relevant in every case. Sometimes less costly and/or complex alternatives may already exist. Therefore, we still need to make judgements as to where and how it will make sense to deploy, focusing on bands where it is most relevant and can bring the greatest benefits.

We define flexible spectrum rights

6.22 We are responsible for defining the rights to use spectrum, including through issuing individual licences. Over time the use made of spectrum can change as new technologies or services emerge. Therefore, it is important that spectrum rights provide flexibility and are constrained only to the extent that we consider proportionate to achieve optimal use of spectrum, including for protecting other spectrum users from harmful interference. Greater flexibility in spectrum use was introduced through a policy of liberalisation following our 2005 Strategy.

6.23 We define transmission rights primarily through a combination of limits on the power levels of individual transmitters, and, in the case of block assigned bands, block edge masks which specify the extent of interference permitted into adjacent frequencies. These conditions provide flexibility, minimising the technical constraints on spectrum use, whilst managing interference on other users. Nonetheless, it is not always possible to be completely technology neutral. New technologies – unforeseen when the initial technical conditions were set – may not always be compatible with those conditions or may be less efficient if they are. For example, CEPT is currently amending or revising technical conditions for a range of bands supporting cellular technology to ensure that they are suitable for the use of 5G technology.

6.24 In addition, recognising the difficulty in specifying completely future proof technical conditions, we also consider requests to vary technical licence conditions. We generally look favourably on requests to vary the conditions where doing so would not adversely

impact other existing users, or those users that would be impacted have agreed to it through separate arrangements (for example a commercial agreement) with the party requesting the change.

We promote an appropriate level of international harmonisation

6.25 International harmonisation of spectrum – where particular bands are made available in similar ways in different countries in order to enable similar use across those countries - can significantly influence the benefits from use of those bands. 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.

6.26 We take a leading role in the key international spectrum fora in which harmonisation takes place. The most visible harmonisation measures are generally those which relate to service allocations at either a European or global level. However, harmonisation does not only arise from the formal decisions of bodies like CEPT and ITU, but can also happen in practice if a number of countries adopt similar stances to particular bands.

6.27 For example, we have enabled greater access to frequencies in the 100-200 GHz range. In doing so, we noted growing international activity around innovation using bands above 100 GHz, including the decision to make several bands in this range available in the USA. This has potential to provide international economies of scale for research and development in the future use of frequencies above 100 GHz.

6.28 There can however be a downside to some international harmonisation initiatives if they are too prescriptive and unnecessarily limited to a narrow a set of services or technologies. Whilst such decisions might not directly restrict how spectrum can be used in the UK, they may limit the conditions under which spectrum is made available in other countries, making it harder for new technologies and applications to benefit from international economies of scale.

6.29 Therefore, our general approach is to promote the appropriate level of international harmonisation, enough to realise its benefits, but retaining flexibility where possible. Our proposal in Section 4 focuses on one specific aspect of this, in relation to short range wireless devices.

We provide appropriate assurances of continued access for existing and new users

6.30 As discussed above, providing appropriate assurances for continued access is important for both existing and new users of spectrum. We will continue to provide appropriate assurances through appropriate licence terms; managing the risk of harmful interference, and consideration of technical conditions when introducing new users.

6.31 **Licence terms.** We issue licences with a term that gives assurance of continuity of access over a sufficiently long period. Many of the licences we issue are of indefinite duration, but may be revoked by Ofcom for spectrum management reasons where this is objectively

justifiable, subject to a minimum notice period specified in the licence. This notice period is typically, but not always, five years.

6.32 **Interference management**. We manage the risk of harmful interference, by monitoring spectrum use, checking compliance with authorisation terms, investigating and, when appropriate, enforcing if harmful interference occurs (see Section 3 for details). However, we do not guarantee interference-free spectrum.

6.33 **Technical conditions**. When introducing new services, we carefully consider the necessary technical constraints to place on them, in order to take account of existing users and manage the risk of harmful interference [40] being caused to them. In Section 7 we set out our proposals on how to undertake this work whilst promoting spectrum sharing.

6.34 Analysis of technical conditions feeds into our national licensing authorisation work, for example when determining the technical licence conditions for new services. It is also important for our international work when dealing with services that cross international borders (for example maritime or satellite communications) to ensure that changes to international regulations do not result in harmful interference to services in the UK.

Proposals to address future challenges and opportunities

6.35 In addition to the continuation of our existing work set out above, we consider that the proposals summarised in Table 6 would contribute to achieving our objective of providing flexibility in spectrum use to support innovation, with appropriate assurances for continued use.

Table 6: Proposals contributing to objective of providing flexibility in spectrum use to support innovation, with appropriate assurances for continued use

Proposal	Contribution to objective	Detail set out
Supporting innovation in wireless technologies. Including influencing the development of international standards and decisions so that they have greater flexibility for new technologies and applications.	Supports greater flexibility in international standards and decisions, which could enable greater innovation in short range wireless technologies, particularly by smaller players.	Section 4, paragraphs 4.43-4.52

[40] Interference to radio communications is considered harmful if: it creates danger, or risks danger, in relation to the functioning of any service provided by means of wireless telegraphy for the purposes of navigation or otherwise for safety purposes; or it degrades, obstructs or repeatedly interrupts anything which is being broadcast or otherwise transmitted by means of wireless telegraphy and in accordance with a wireless telegraphy licence, or a grant of recognised spectrum access or otherwise lawfully. https://www.ofcom.org.uk/spectrum/interference-enforcement/troubleshooting-interference/reporting-interference#:~:text=Interference%20to%20radio%20communications%20is,or%20otherwise%20for%20safety%20purposes

Expanding our work to understand, assist and inform the wide range of organisations who may benefit from wireless technologies in the future.	Helps organisations to make informed choices about spectrum, so they can choose the form of spectrum access that offers the appropriate level of flexibility and assurances over continued use to suit their needs.	Section 5, paragraphs 5.30-5.43
Spectrum for pioneers: Making more spectrum available for innovation before its long-term use is certain.	Would provide additional spectrum options suitable for parties wishing to develop new wireless applications and technologies.	Below
Promoting spectrum sharing by encouraging spectrum users to be "good neighbours". A range of reforms that would build on our current work and further promote the ability of different users to share spectrum.	By encouraging spectrum users to be good neighbours (e.g. more resilient to interference) it is more likely that spectrum use can be changed without negatively impacting other users in neighbouring frequencies or locations.	Section 7, paragraphs 7.51-7.102

Spectrum for pioneers: making more spectrum available for innovation before its long-term use is certain

The long-term future use of a band is not always certain

6.36 As noted above we can't know in advance what innovation will look like or who will innovate, so aim to offer a range of ways of accessing spectrum with sufficient flexibility in how it can be used in order to facilitate innovation.

6.37 However, enabling access to spectrum when its future use is uncertain raises challenges, as choices need to be made about the technical conditions, geographic size and authorisation mechanism to be used. Although we aim for allowing flexibility in spectrum use by imposing only such restrictions which we consider necessary to address the risk of harmful interference, technical conditions and authorisation mechanisms can inevitably restrict some uses and be more suitable for some patterns of demand than others.

6.38 If the potential future uses and users of a band are uncertain, then one approach is to wait until there is more clarity. This can allow us to optimise the release of the band to best support uses that are likely to bring the greatest benefits to citizens and consumers. Releasing spectrum early and then needing to make changes to better suit uses that emerge later can risk additional costs and delays (e.g. if initial users need time to relocate or adapt to changes), particularly if devices are initially exempted from licensing. This is because it can be difficult to contact the users of those devices about the change because we would not normally know their identity. However, always waiting until future use is more certain might delay the availability of services or reduce the opportunities for other services to emerge.

We propose to make some spectrum available for innovation when its future use is still uncertain

6.39 Our proposed approach is to make some spectrum available for innovation when its future use is still uncertain. In doing this we would allow for the possibility of updating our authorisation approach if and when the future use of the band becomes clearer at a later stage, through one or both of:

a) Looking for **technical options** where use can be authorised without preventing future alternative authorisations, i.e. they can technically coexist. For example, this may be possible with low power indoor use which in some cases can be authorised without precluding a future outdoor high-power use, particularly at higher frequencies. This is the approach we have taken to the initial authorisation of spectrum in the 26 GHz band. [41]

b) **Retaining the ability to change** the authorisation and conditions for use of the band in the future, if necessary and proportionate for efficient management of the spectrum. This includes:

i) Considering the use of light licences rather than exemption of devices to take into account the potential for sharing spectrum in the future, [42] as light licensing makes it more straightforward to change the authorisation approach to meet future demand. In addition, it is possible that use of automated spectrum management tools will make it practically possible, when justified, to change technical conditions or authorisation rights within the band even when devices are exempt (also see paragraphs 6.17-6.21 above).

ii) Considering licence terms that would enable us to notify licensees to change frequency, in cases where we assign specific frequencies. This would require equipment and spectrum users to be "frequency agile" within a particular range, so that (for example) the band can be more easily reorganised at a later date if necessary.

iii) Considering setting a shorter notice period for making changes for spectrum management reasons. This would still provide stakeholders with a reasonable period of time to access the spectrum, while enabling us to take swifter action to enable efficient use in the event that we consider this to be necessary and proportionate.

6.40 Making spectrum available on these terms would provide more opportunities for innovation than waiting until potential uses of the band become clearer, whilst providing more options for use and security of ongoing access than the temporary 'innovation and trial' licences (see above).

[41] See Enabling wireless innovation through local licensing, 2019
[42] See paragraph A5.14(a) in annex 5

6.41 One specific example where we have recently applied the approach in (b) (i) and (iii) above is the release of Extremely High Frequency (EHF) bands between 100 and 200 GHz. We note that the 'Spectrum Access: EHF' licence framework could be introduced to other EHF bands.

Question 7: Do you agree that it is important to make more spectrum available for innovation before its long-term use is certain? Do you have any comments about our proposed approach to doing this?

7. Encouraging sustained improvements in the efficiency of spectrum use

7.1 Radio spectrum is a finite natural resource. While technology developments are enabling more information to be carried over spectrum and making higher frequency bands more usable than ever before, there will continue to be growing demand for frequency bands that are already extensively used. Facilitating new and improved wireless services for people and businesses in the UK will depend on making more efficient use of this precious resource.

7.2 This section focuses on how we create the conditions for sustained improvements in the efficiency of spectrum use over time, for example as a result of greater sharing of spectrum, use of market mechanisms and 'recycling' of spectrum from lower to higher benefit uses. The actions and proposals in this section are complementary to those in Section 6, which focused on greater flexibility in spectrum use, as flexibility is another means of enabling greater efficiency of use.

Importance of this objective and trends for the future

Rising demand means that increasing the efficiency of spectrum use will continue to be important

7.3 Section 3 outlined the many trends which could lead to growing demand for wireless communications in coming years across many sectors, for example for transport, connected cities, health and utilities. Growth in wireless communication could increase demand for spectrum, and, as spectrum is a limited resource, this growing demand will need to be accommodated through using spectrum more efficiently.

7.4 The use of new technologies will enable spectrum to be used more efficiently, allowing more information to be carried over a given amount of spectrum in a given area. For example, MIMO capabilities in new technologies enable multiple streams of data to be sent over the same frequencies; and better interference cancellation techniques may allow for increased density of deployments in an area.

7.5 In addition, as new technologies enable the use of much higher frequencies, this can allow huge amounts of additional capacity to be made available for applications that can make use of those frequencies.

7.6 However, although new technologies and use of higher frequencies can mitigate the impact of increased demand, we think there is likely to continue to be excess demand in many bands, and hence benefits from increasing spectrum efficiency in other ways (such as spectrum sharing discussed below).

7.7 This is partly because history shows that improving technical efficiency generally stimulates demand for connectivity, as costs falls and more applications emerge. In addition, not all

(perhaps many) applications will be able to benefit from the use of much higher frequencies due to their propagation characteristics.

Spectrum sharing will continue to be an important means of increasing efficiency

7.8 Spectrum sharing involves the same spectrum band being accessed by multiple users and/or for different type of uses. Spectrum can be shared by separating users in one or more of frequency, geography, or time. By allowing different users to offer more wireless services, spectrum sharing can bring benefits to people and businesses and ensure that spectrum is used as efficiently as possible.

7.9 Spectrum in the UK has long been shared in a variety of different ways. For example:

- Multiple users can share spectrum for a similar type of use, for example Business Radio users share with each other.
- Users with different types of use can share spectrum, for example fixed links and satellite and Shared Access licensees share the 3.8-4.2 GHz band.
- Sharing can also be enabled by particular techniques that ensure equipment is "polite". For example, equipment in some licence exempt bands can be required to work around other users, e.g. using polite protocols such as 'listen before talk' in Wi-Fi.

7.10 Our 2014 Strategy (and our 2016 Framework for spectrum sharing), identified spectrum sharing as increasingly important to serve growing demand for spectrum. Given the continued growth in demand noted above, we consider that sharing will continue to be an important mechanism for increasing efficiency going forward.

Continued use of our existing tools to address this objective

7.11 The previous sections have set out a wide range of tools, activities and proposals which will all ultimately contribute to increasing the efficiency of spectrum. In addition, there are a number of existing tools and activities which are particularly relevant to encouraging greater spectrum efficiency and which we plan to continue in the future:

- We use market mechanisms including spectrum pricing and trading, to create incentives for efficient use and to enable spectrum to get into the hands of users whose use will create the greatest benefits for people in the UK.
- We take regulatory action, including to support recycling of spectrum (for example to move existing users from a band), where necessary and proportionate.
- We enable greater spectrum sharing, including by:
  - authorising shared use of spectrum;
  - promoting improvements in radio performance standards; and
  - developing our use of automated spectrum management tools.
- We work with the Government to promote efficient use of spectrum by the public sector.

7.12 In addition, as technology opens up the possibility of using higher frequencies that could not previously be utilised, we will consider authorising access to spectrum in bands that have not previously been authorised (as we have recently done in the EHF bands).

We continue to use market mechanisms to increase the efficiency of spectrum use

Enabling and facilitating spectrum trading

7.13 Spectrum trading provides an important mechanism for increasing the efficiency of spectrum use as it enables spectrum to migrate into the hands of those that can make best use of it. Most of the licences we issue are tradeable, [43] allowing users and potential users of spectrum to buy and sell their spectrum rights and obligations. [44] Trades can be full or partial (i.e. selected frequencies or locations), time-limited, or concurrent (i.e. the rights and obligations become held by both parties). In the case of spectrum for mobile services, a spectrum trade may be subject to a competition assessment before it can be authorised. [45]

7.14 Trading is potentially helpful for a number of our objectives. Changes in ownership can support recycling of spectrum. Trades can result in changes to the geographic extent of licences, for example allowing subdivision of a larger licence into smaller ones, or shifting the geographic boundary between adjacent users (in effect allowing one user to create more interference into the other than under the original licences).

7.15 Although there have been over 15,000 spectrum licence transfers notified to Ofcom since 2009, spectrum trading in some licence categories is 'thin', with low rates of turnover and a limited number of buyers and sellers. In licence categories where there is significant trading activity (e.g. business radio) many trades are undertaken due to business restructuring. In the high value block assigned bands, a small number of trades have taken place, but are infrequent. [46]

7.16 The relative thinness of spectrum trading is not necessarily a concern in itself, as the nature of spectrum means that a lower level of transactions would be expected than other commodities. Unlike many other commodities, spectrum is not suited to be standardised for trading purposes. [47] The characteristics of radio spectrum, in the context of communications, differ markedly according to bandwidth, frequency and geography.

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[43] Trading of radio spectrum licences has been possible since late 2004. It is currently allowed in most licence classes and governed by trading regulation. See The Wireless Telegraphy (Spectrum Trading) Regulations 2012 and The Wireless Telegraphy (Mobile Spectrum Trading) Regulations 2011.

[44] Spectrum trades involve the transfer of the rights and obligations conferred by a licence granted under the WT Act. The trading of these rights and obligations is known as "Spectrum Trading", see Trading Guidance Notes, OfW513, March 2020. As a simple shorthand, we refer to these trades as the "trading of spectrum licences" or "spectrum trades".

[45] See reg. 8(e) of the Wireless Telegraphy (Mobile Spectrum Trading) Regulations 2011.

[46] Most recently, Ofcom consented to an application from EE Limited to trade its unpaired 2.6 GHz spectrum (2595-2620 MHz) from its Spectrum Access licence no. 1191194 to Telefonica UK Limited.

[47] Copper, sugar, steel, oil, gas, real estate, etc., are traded commodities. For example, copper is traded on the London Metal Exchange (LME) where it must conform to standards set by the exchange.

Further, because of interference, the value of radio spectrum can be affected significantly by neighbouring users and uses.

7.17 Following earlier efforts to simplify spectrum trading, [48] we consider that the administrative process for spectrum trades is straightforward (requiring a single form to be submitted to us). There is also clear information published on who holds which licences [49] so that parties who may wish to trade are able to identify each other. In addition, we sometimes help to put parties in contact where there is a potential interest in a trade but one party experiences difficulties in establishing contact with the other (and where we have the permission of the person whose details we are passing on). Trades involving a competition check can take a little longer, but our aim is to complete all trades within 42 days. [50]

7.18 Consequently, we are not aware of significant transaction costs that arise from regulatory requirements. However, we recognise that there may be other transaction costs or barriers that licensees may face, for example in determining complex technical and commercial arrangements for a trade. Therefore, we continue to welcome feedback from stakeholders on other actions we might take that could further reduce the transaction costs of, or barriers to, trading. For example, whether there are further improvements to the availability of information about spectrum licences that could facilitate trading (also see Section 5 on improvements to spectrum information).

7.19 We also recognise that we are not the only party that can help facilitate spectrum trading, and that (like in many other markets) commercial third parties can undertake supporting activities, for example to assist where there are complex technical or legal matters to be negotiated and agreed, or to coordinate multiple buyers and sellers.

7.20 In addition, some types of licences allow spectrum leasing where users can permit others to use their licensed spectrum without the need to inform Ofcom or gain our permission. The obligation to meet the technical conditions on the use of the spectrum remains with the licensee, who is responsible for the use made by the lessee. We have seen limited use of leasing and currently do not plan to extend it to other licence types.

Spectrum pricing

7.21 Spectrum pricing is an additional tool used to create incentives for spectrum to be used efficiently.

7.22 Where the demand for spectrum is greater than what is available (i.e. there is excess demand), we set fees based on the concept of opportunity cost – the value of alternative spectrum use which is denied by the current user. These fees, known as 'administered incentive pricing' (AIP), are a proxy for a market price and promote efficient use by ensuring that users face an appropriate price signal.

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[48] Simplifying Spectrum Trading: Spectrum leasing and other market enhancements, June 2011.
[49] Details of spectrum trades can be accessed and downloaded via our Spectrum Information Portal
[50] Most standard transfer requests are dealt with within a couple of days providing the application meets the trading criteria. The time required where a competition check is necessary can vary. The recent trade of 2.6 GHz spectrum from BT/EE to Telefonica took 20 days to complete.

7.23 Our approach to setting AIP-based fees is set out in our 2010 Revised Framework for Spectrum Pricing (SRSP). Where spectrum is not in excess demand then we set fees to recover our costs associated with managing that spectrum.

Other market tools

7.24 As part of reviewing our strategy we have surveyed alternative market-based tools or concepts that might potentially be relevant to spectrum management. These range from ideas being discussed by academics practising in the field of market and auction design, to those that have been implemented to some degree by one or more spectrum regulators. For example:

- **'Depreciating licences**' is a concept that has been proposed by some economists as a means of promoting more trade in thin markets. A licence holder would declare a price at which it is willing – and obliged – to sell the spectrum rights and pays an annual licence fee based on this declaration.
- **Foothold auctions,** where a spectrum licence is periodically re-auctioned, but the incumbent user is given an advantage in the auction and compensation if it is outbid. A potential application of foothold auctions, and depreciating licences, was suggested in the context of the FCC's award of 3.5 GHz spectrum. [51]
- **Congestion triggers**, where spectrum licences are initially allocated at administrative cost in the expectation in the near term of no excess demand, but higher fees (or some other method of managing congestion) may be triggered if some measure of excess demand is met. For example, in Hong Kong, a "Spectrum Utilisation Fee" is applicable if there is 75% occupation in a spectrum band.

7.25 In addition, it is conceivable that some of the technologies outlined in Annex 6 could in the future open up new possibilities in market design, for example to automate spectrum trading and determination of pricing.

7.26 However, at present we consider that our current market tools (discussed above) combined with the various options we have for regulatory action where necessary (discussed below) are likely to continue to be appropriate and sufficient for encouraging more efficient use of spectrum. In particular, as discussed above, we do not consider that the relative thinness of spectrum trading is necessarily a concern in itself. We also note that most of the above ideas are not currently available under Ofcom's existing statutory powers.

7.27 Nonetheless, we recognise the ongoing research efforts in the field of market and auction design and will continue to engage with new ideas as appropriate.

7.28 In addition, we have previously noted the potential use of incentive auctions, where participants can sell spectrum rights as well as purchase rights. At present we do not consider that we have the necessary powers to conduct incentive auctions. In particular we

[51] See Milgrom, Weyl and Zhang (2017) Redesigning Spectrum Licences

do not have the power to retain the receipts of an auction and make these (or a proportion of these) available to participants in the auction.

We take regulatory action when necessary and proportionate to support efficient use, including recycling of spectrum

7.29 The emergence of new technologies and applications can create the conditions where spectrum efficiency can be increased by 'recycling' of bands from one use to another.

7.30 Such changes can sometimes be delivered by market mechanisms, however (as explained in Section 3) major changes often require some form of regulatory action to be taken. In these cases, subject to a minimum notice period specified in the licence, we may consider revoking existing licences for spectrum management reasons where this is objectively justifiable. [52] This notice period is often five years but we sometimes set a shorter notice period where appropriate. [53]

7.31 An additional regulatory tool to support efficient use is the ability to make spectrum available on the basis that users have access only when they need it. For example, for Shared Access licences, users must start transmitting within six months, and continue to be operational afterwards. If spectrum is not used in this timeframe or is subsequently no longer used, we may revoke the licence with one month's notice.

We authorise shared use of spectrum

7.32 The licences that we issue 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, whilst taking account of any impact on existing users of the band.

7.33 In line with our 2014 Strategy, we have further increased spectrum sharing, for example, introducing additional shared access into a number of bands and enabling third party access to licensed mobile spectrum (see paragraphs 5.25-5.27).

7.34 We intend to continue to authorise shared use of spectrum where we identify appropriate opportunities. In some cases, automated spectrum management (discussed below) will be an important tool for doing this.

7.35 In addition, progress in introducing further spectrum sharing will depend on how well different spectrum can coexist with their spectrum 'neighbours', i.e. users adjacent in geography and/or frequency. We set out proposals to promote spectrum sharing by encouraging spectrum users to be 'good neighbours' below.

[52] See paragraphs 6-8 of Schedule 1 to the WT Act.
[53] For example, the notice period for revoking the 'Spectrum Access: EHF' licence for spectrum management reasons is one year. See Supporting innovation in the 100-200 GHz range: Increasing access to Extremely High Frequency (EHF) spectrum

We continue to develop automated spectrum management tools to support spectrum sharing

7.36 Section 6 set out the flexibility benefits of automated spectrum management tools and our intention to continue to develop our use of them. These tools can also support more efficient sharing of spectrum by allowing access to spectrum that might be unused with conventional spectrum licensing, including:

- opportunistic access to bands with static and/or dynamic primary users (e.g. as we have implemented in TV White Spaces, where exempt devices share with TV broadcasting and wireless microphones); or
- making frequencies automatically available for new users when not used by previous users (e.g. as we are planning to implement in some shared bands, starting with 3.8-4.2 GHz).

7.37 In addition, authorising consumer devices in this way can improve sharing with other services, potentially enabling them to access more spectrum. This is because the conditions necessary to protect some services from interference (e.g. prohibiting use in some very specific locations) might otherwise necessitate licensing, and hence preclude the use of consumer products. If consumer devices can locate their position and be controlled by a database, then it is possible for them to protect certain services whilst still be exempted from licensing.

7.38 Related to the above, if the database records the location and frequency of every exempt user, it can also make it faster and easier to locate sources of interference compared to exempt devices without database connection. This is because we would otherwise not hold the location of individual devices and so need to manually track down the source of interference. Automated spectrum management tools may also help support a more realistic approach to managing coexistence (see paragraphs 7.73-7.78 below) which can also support spectrum sharing.

7.39 However, although there are a number of potential benefits, introducing this technology can result in additional costs, which might not be justified depending on the situation. Therefore, we will consider whether and how to deploy based on the facts of specific cases.

We continue to promote improvements in radio performance standards

7.40 In our 2014 Strategy we set out an objective to promote improvements in the performance of all of the components of radio systems in order to support more efficient use of spectrum. These improvements include the ability of transmitters to minimise out-of-band emissions and the ability of receivers to screen out radio signals transmitted in adjacent bands.

7.41 For transmitters, we specify out-of-block emissions as part of our authorisation conditions and will continue to ensure that these are set appropriately to ensure interference is not caused to other users.

7.42 For receivers, we have sought improvements to performance at a national level in the UK by engaging with stakeholders, and at a European level by engaging with CEPT / ECC and ETSI groups. In ETSI, we participated in writing Harmonised Standards for the Radio Equipment Directive and we focused on some specific areas (e.g. DTT receivers, 2.4 GHz licence exempt devices, Primary Surveillance Radar, L band MSS receivers). We have made improvements to the minimum requirements for several products and succeeded in changing the way that groups in CEPT / ECC consider receivers when conducting compatibility studies.

7.43 We will continue this work, including advocating further improvements to Harmonised Standards, and prioritising standards affecting consumer equipment where the spectrum user (the consumer) does not have enough influence over the manufacturer to encourage better receiver performance.

7.44 We will also continue our engagement with equipment manufacturers and major spectrum users, including the public sector, to raise awareness of the impact that receiver performance may have on their systems, especially as the spectrum users in neighbouring frequencies may change over time.

We work with Government to promote efficient use of spectrum by the public sector

7.45 The public sector is one of the biggest users of spectrum. The principles for how we seek to improve spectrum efficiency in bands used by public sector users are the same as for spectrum used by other sectors. Spectrum sharing, recycling of spectrum from one use to another, spectrum pricing and improvements in transmitter and receiver performance all have important roles to play. In some cases, the mechanisms used for applying these principles are slightly different, as we do not issue licences to certain Government spectrum users operating under Crown immunity (as explained Section 3).

7.46 We continue to work with Government to encourage efficient use of spectrum by the public sector, including raising awareness of spectrum issues across public sector users, advising on spectrum pricing and, where appropriate, working towards greater spectrum sharing or recycling of spectrum from public sector to other uses.

Spectrum sharing and release

7.47 We have continued to support delivery of the Public Sector Spectrum Release Programme. This includes providing updated advice to Government on likely demand from commercial users, advice on how to frame a revised target of releasing 750 MHz of spectrum below 10 GHz by 2022, and technical input to help define protection requirements.

7.48 This work has enabled the release of the upper 2.3 GHz and 3.4 GHz bands; opening up part of the 8 GHz band for fixed services; additional spectrum for shared use at 2390 MHz; and the availability of the 5.8 GHz band for low power licence exempt use.

7.49 Work is continuing in a number of other areas. For example, as noted above we are engaging with public sector users to help them understand the impact that receiver

performance may have on their systems. In addition, we recognise that automated spectrum management tools could potentially support commercial services sharing with government applications in the future. For example, if the latter are unpredictable in the timing and location of their requirements then these tools would enable sharing users to change frequency on a dynamic basis.

Public sector spectrum pricing

1.2 We advise the Treasury on the spectrum fees to be paid by government departments for their use of spectrum below 15.7 GHz, applying the same opportunity cost principles we apply in our pricing work elsewhere. These fees provide incentives for users to ensure that their spectrum use is planned efficiently, which can in turn facilitate use by other public sector or commercial users.

Proposals to address future challenges and opportunities

7.50 In addition to the continuation of our existing work set out above, we consider that the proposal discussed below, complemented by our other proposals throughout the rest of this document, would contribute to sustained improvements in the efficiency of spectrum use.

Table 7: Proposals contributing to encouraging sustained improvements in the efficiency of spectrum use

Proposal	Contribution to objective	Detail set out
Promoting spectrum sharing by encouraging spectrum users to be "good neighbours"	By enabling different spectrum users to more closely coexist with their neighbours, spectrum sharing can be increased and more efficient use can be made of spectrum.	Below
All other proposals	All other proposals would contribute to more efficient use of spectrum as they enable new services, greater flexibility and innovation.	Sections 4, 5 and 6

Promoting spectrum sharing by encouraging spectrum users to be "good neighbours"

7.51 One of the most important ways to enable sustained improvements in the efficiency of spectrum use is through greater sharing of spectrum. Spectrum sharing depends on different spectrum users coexisting with others in the same -or adjacent- geographic areas and/or frequency bands. If different users can live closer together without their services being materially impacted, i.e. be 'good spectrum neighbours', then more users will be

able to share spectrum. This will enable new services to be introduced whilst protecting the benefits that people already enjoy.

7.52 One aspect of being a good neighbour is for the emissions of transmitters to be limited appropriately to ensure interference is minimised to other users. As noted above we already specify these as part of our authorisation conditions. Additionally, if systems are not as good as they could be at rejecting interference from their neighbours, then they could experience problems when new neighbouring services are introduced. Our proposals below include setting clear expectations so that this shouldn't happen.

7.53 In practice if spectrum users are good neighbours this means that the 'risk area' around a receiver, where transmitters may cause interference, can be reduced. The box overleaf provides an example that illustrates how the size of the risk area can be reduced to less than half its original size.

7.54 We are therefore proposing a number of measures, which build on our existing work, to encourage spectrum users to be 'good neighbours' and reduce the areas of risk around receivers. These proposals fall into three categories:

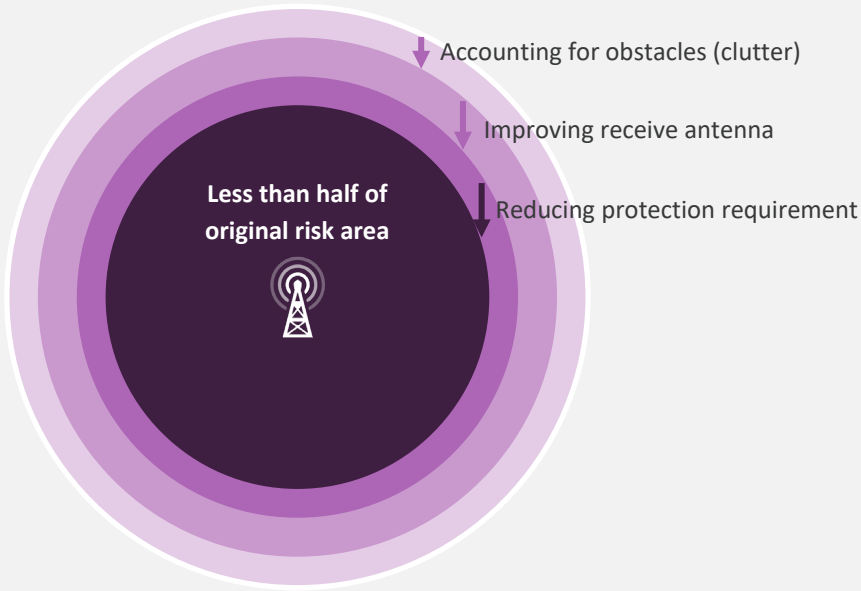
- Use of more realistic analysis when assessing the conditions for sharing between services.
- Wireless systems to be more resilient to interference from their neighbours, in addition to our existing approach to minimise the emissions outside their allocated channel.
- An efficient balance between the level of interference protection given to one service and flexibility for others to transmit in order to enable spectrum access for a wide range of users.

7.55 Because of the international nature of spectrum management, some of our proposals are related to how we will seek to engage and influence international recommendations, decisions and studies that are developed by people working within the ITU or CEPT. Other proposals are more specifically focused on steps we can take at a national level, for example related to our own licence products.

7.56 Our proposed actions are summarised in Table 8 on page 73 and detailed in the following three sub-sections.

Being a good spectrum neighbour: how better modelling and enhanced receivers improve spectrum efficiency

The image below illustrates the scale of risk areas using an example.[54] We start with a simple receiver model, with the risk area shown by the outermost circle, and show how this area can be reduced and the circle shrunk - thereby permitting closer neighbours - by applying more realistic technical assumptions.



The first reduction is from making the propagation model more realistic, accounting for obstacles in the real world (like trees and buildings) instead of assuming clutter-free terrain. The second is from the receiver using an antenna that focuses more on the direction it needs to receive from and less on the directions of interferers. The final reduction is from the receiver reducing its protection requirement, i.e. it can increase its tolerance to interference by allowing a 15% rise in the unwanted power detected at the receiver.

Each of the individual changes in this example reduce the risk area by between 20% and 30%, and combined they amount to more than 50% reduction. While the size of each circle in the example would be different for different services, our proposals should have the overall effect of reducing the risk area, whilst still allowing services to use their receivers effectively. This would increase the ability of services to share and enable more efficient use of spectrum.

[54] This is a stylised representation of the size of the risk area, which in reality would not have the shape of a circle

Table 8: Our proposals to encourage better neighbours and reduce the size of risk areas

1. Increase realism in coexistence analysis at a national and international level

a) Promote the use of real service characteristics in coexistence studies, including:
   i. Using real, good quality equipment characteristics. Equipment always performs better than the regulatory limits.
   ii. Considering specific station locality and realistic deployment scenarios wherever possible.
   iii. Seek to increase data availability for coexistence studies.

b) Regularly review the appropriateness of the propagation models and associated datasets we use, including in:
   i. our licensing platform; our national coexistence studies; and our international work, in order to ensure these are appropriate models or datasets for the scenarios we are studying.

c) Consider the use of authorisation tools that enable us to set technical conditions more realistically at a national level, including:
   i. Using coordination or deployment restrictions, including those managed by automated spectrum management tools, to allow us to: account for specific sharing scenarios and apply limits in certain geographical locations only; and limit aggregate interference without needing to set cautious parameters.
   ii. Providing flexibility to allow us to amend technical conditions over time as we gain more evidence of deployment and equipment performance.

2. Encourage spectrum users to be more resilient to interference

a) Make the technical details of our interference assessment more accessible.

b) Communicating that we would not generally expect to take action as a result of poor receiver/system performance.

c) Consider use of pricing to incentivise better interference rejection capabilities where appropriate (see also 3 a) below).

This is in addition to continuing our work to promote improvements in radio performance standards (see paragraphs 7.40-7.44 above).

3. Efficient protection levels

a) Introduce differential "protection pricing" for spectrum users, so users pay more for the more protection they require, where appropriate.

b) Clarify that we expect stakeholders to provide a greater level of evidence-based analysis when inputting to the process to define protection levels, particularly where it could have an impact on sharing in the band.

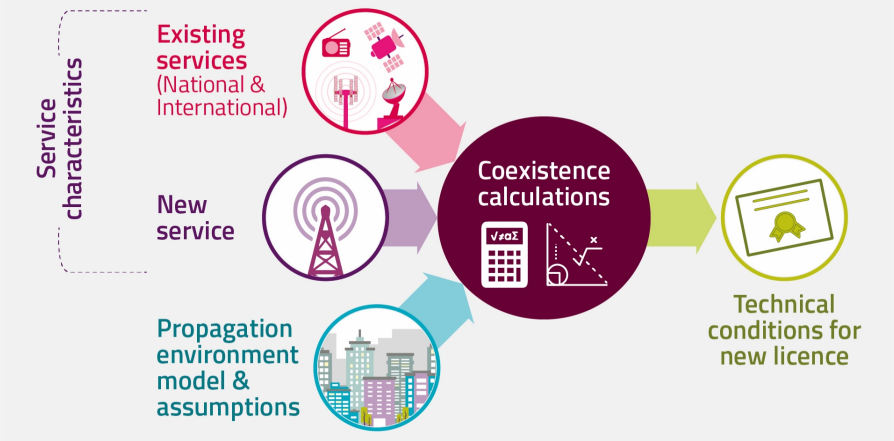
Increase realism in coexistence analysis at a national and international level

7.57 When we introduce new services as neighbours or sharers to a band, coexistence analysis is used to determine whether the new service will cause interference to, or suffer interference from, existing services (see box below). These studies inform the type of new services that might be possible and the restrictions placed on them.

Co-existence analysis: Why we set technical conditions for transmitting services and how we calculate them

We set technical conditions for all transmitters to ensure that different services, or different spectrum users, can happily co-exist without causing harmful interference to one another.

Therefore, when we introduce a new user to a band, we need to set the technical conditions for that new service. We decide what these technical conditions are by undertaking coexistence calculations, taking into account the service characteristics of both the existing and new services, and the propagation environment model and assumptions.



Ensuring that we have accurate information on service characteristics, and that we are using the most appropriate propagation models and assumptions on the environment, is important for ensuring that we can reduce exclusion areas.

7.58 Our approach to this coexistence analysis process depends on the type of service involved. For example, with an internationally coordinated service such as the Fixed Satellite Service we need to take the existing international regulations into account. When such regulations are updated, we carry out and provide inputs to coexistence studies, in collaboration with other international regulators and industry stakeholders. On the other hand, for national services like Business Radio, we set national coordination rules informed by our own coexistence studies and implement them in our licensing systems.

7.59 There are many sources of uncertainty affecting these studies, which tend to rely on a series of assumptions. If the assumptions and methodologies don't sufficiently consider the possible risks or scenarios, then the risk of harmful interference to either service could be under predicted. As a result, there may need to be additional margins to ensure interference is not caused. However, if these margins are too great or the assumptions and methodologies are too risk averse, then it can be difficult to introduce new neighbours or sharers, or those new sharers may be unnecessarily constrained in power or density, even when that isn't necessary. Studies often tend towards the more risk averse approach to ensure that interference is not caused, even when the probability of worst-case assumptions occurring is very low.

7.60 By making studies more realistic and reducing the uncertainties affecting them, then there would be less need for an additional margin to allow for these uncertain factors, making it easier to introduce new users. We set out three proposals to make studies more realistic below.

Promote the use of real service characteristics

7.61 We are proposing to use, and promote the use of, more realistic, service and good quality equipment characteristics in our national and international work, as follows:

Increase use of real, good quality equipment characteristics

7.62 Real equipment is designed to meet regulatory limits, accounting for manufacturing margins (production spread, design margins etc.) in a range of different environmental conditions as set in the relevant standards. As such, it will always out-perform those regulatory limits – often by a large amount. [55] Instead of using the emission and receiver performance indicated by regulatory limits, we propose to use characteristics based on real good quality equipment performance, where we can.

7.63 As there will be equipment with different performance levels available in the market, we will set out our approach to these parameters as part of our analysis. Even with new technologies, where equipment is not widely available when we are conducting our studies, we may need to make some assumptions based on similar equipment, or approaches coming out of our engagement in international bodies. Where we use

[55] See ERC Recommendation 74-01, ECC Report 249 and ECC Recommendation (19)02 on the transmit side, and ECC Report 310 on the receiver side.

parameters from better performing or more efficient equipment, this could create incentives for stakeholders to use better equipment in their services.

Increase the use of realistic deployment data, for example, station density or link length

7.64 Where we have data on existing deployments and use cases, we will aim to use this information in our contributions to international policy work – either in our analyses directly or as case studies, in order to minimise international studies relying on theoretical, but unlikely, worst case or generic scenarios. [56]

7.65 We already seek to identify mitigation factors for specific installations or as general inputs to national or international studies, for example, a wall built to provide shielding in some directions, an artificial pit, the use of filters etc. Our licensing tools already take these mitigations into account for a few stations, and we are therefore proposing to extend this practice where it makes sense to do so.

Seek to increase data availability

7.66 In order to base our analysis on realistic data, we need data to be available for our use, ideally in the public domain. We plan to continue to make as much of our own data available to others as possible. For some studies, we already do engage with stakeholders to produce data such as to investigate equipment performance. To promote, as far as possible, the continued and greater availability of data, we propose to engage standardisation bodies like ETSI and international bodies at ITU and CEPT study groups to encourage data that is already available to some stakeholders to be made publicly available, recognising that there will be limitations due to confidentiality. Furthermore, where data is not currently gathered, we propose to explore options for it to be collected.

Regularly review use of propagation models and associated data sets

7.67 Propagation models are mathematical models which predict the way radio waves will propagate between the radio transmitter and receiver. One of the uses of these models is to predict the level of interference created by a transmitter at a given location or over an area. Propagation models need various datasets to describe the physical environment between transmitter and receiver such as terrain, land use, and weather characteristics (rain characteristics, atmospheric temperature, etc.).

7.68 The accuracy of propagation models and associated datasets significantly impacts the outcome of coexistence studies. We recognise that models will never be perfectly accurate, and that a certain margin will always have to be applied to their predictions to account for this. The larger the uncertainty in the result of a particular scenario, the larger the margin added to ensure harmful interference is not caused to users. But these margins are often applied in a general way to all locations and scenarios, including those where it is not needed.

[56] We note that this information may not always be available, particularly when dealing with future services, so in these cases we will still need to make assumptions.

7.69 Propagation models can evolve over time in order to better model the underlying physical phenomena; to more accurately fit existing empirical measurements; or to factor in the impacts of weather changes as a result of climate change. Datasets should also be updated when more appropriate resolution information is available, or when there has been a significant change in the environment.

7.70 Updating propagation models in general or tuning them for particular UK-specific environments can require measurements and extensive scientific work which may take years. While this can be costly and complex, Ofcom has undertaken a number of such campaigns and has proposed improvements to a number of ITU-R propagation models as a result. We will continue to do this in order to improve the estimation of interference in our coexistence studies and those undertaken internationally. We propose to regularly review the way we use such models and datasets, both in our national co-existence analysis and in our international work.

7.71 In addition, some studies, particularly those in international bodies, are not meant to be location specific, and this often prompts the use of more generic propagation models. While we recognise the need to apply this methodology in some cases, we propose to incorporate the effects of the specific surroundings as much as possible by using specific example locations or case studies, where appropriate. In line with our proposal above to increase the availability of data, we also propose to make information about the existence of relevant datasets (e.g. terrain profiles and land use) more easily available to stakeholders who may want to carry out their own studies (subject to any relevant IP rights). For example, we might create an inventory of existing sources across CEPT countries.

Using authorisation tools to enable us to set technical conditions more realistically at a national level

7.72 Certain authorisation tools can allow technical conditions to be set more realistically. We are proposing to place greater emphasis on using different authorisation tools in order to reduce uncertainty where appropriate and allow more permissive conditions to be set. This may include consideration of different licensing regimes and automated spectrum management tools.

Reducing uncertainty about service deployment

7.73 When we set the technical parameters for authorising spectrum use in new frequencies, we generally set them conservatively in order to allow for uncertainties in the analysis or in the way systems may be deployed in practice.

7.74 We can, and already do, apply restrictions to how and where systems can be deployed to avoid certain worst-case scenarios (particular locations or use cases) that would cause interference. Typically, these kinds of deployment restrictions or coordination requirements are better suited to a licensing regime, compared to a licence-exempt regime, because the requirements can be more easily communicated to the relevant spectrum users (i.e. the licence-holders). This allows us to avoid those unlikely, but

possible, scenarios that might otherwise lead to unnecessary technical restrictions to equipment in all areas. We plan to continue setting such restrictions where appropriate.

7.75 Furthermore, we propose to consider the use of automated spectrum management tools to support these restrictions on an automatic basis without the requirement of user intervention. This could potentially allow us to implement restrictions whilst also licence exempting devices, for example the database could prohibit new users from accessing spectrum if there were too many users/devices already in that area.

Refining technical conditions over time

7.76 Automated spectrum management tools also have an advantage that they allow us to quickly and efficiently refine technical conditions as we gain more evidence about particular deployment scenarios or equipment performance over time. We could relax technical conditions at some future date – for example by allowing increases in transmit powers.

7.77 However, it may also be possible with some opportunistic uses to reduce our margins and allow more permissive technical conditions initially. If interference was worse than we modelled, then we could apply additional restrictions to technical parameters of existing and new deployments at a later stage to ensure other users were protected without overly constraining initial deployments. Therefore, where we do implement automated spectrum management tools, we will consider refining technical conditions over time to support increased sharing.

Encourage users to be more resilient to interference

7.78 On a number of occasions in recent years when we have tried to introduce new spectrum users, it has become apparent that the existing systems (in either the same band, or adjacent band) could suffer interference from new users, which could have been avoided if the existing systems had better interference rejection capabilities. For example, when introducing mobile at 2.6 GHz we had to undertake a radar remediation programme to ensure that the existing radars above 2.7 GHz would not suffer interference.

7.79 Systems are built and deployed with only a certain resilience to interference for several reasons, including costs and users' assumptions around the level of interference from their neighbours. The overarching factor is likely to be that the benefits of improved interference resilience do not necessarily accrue to the party who incurs the cost, at least in the short term. Nonetheless, greater interference resilience does provide much wider benefits by facilitating greater sharing of spectrum and the introduction of future services.

7.80 Normally, consumers, and some other types of users, such as businesses, don't have access to information on interference rejection capabilities when buying off-the-shelf equipment, and most would be unlikely to understand or take this into account if presented with it. As such, there is no pressure from them on manufacturers to improve interference resilience.

7.81 We note that in specific cases, when consumer information and equipment labelling are introduced for other reasons (that have an obvious relevance to, and understanding by,

consumers) they can sometimes also encourage more resilient systems. For example, the Digital Tick mark [57] for broadcast TV equipment was used to inform consumers about suitable equipment for use after 'digital switchover' (the move from analogue to digital transmissions for terrestrial TV). So, although consumers did not consciously think about choosing products with the tick because of their interference rejection capabilities, it did have that additional benefit. However, we think this is unlikely to be a general solution.

7.82 Therefore, as set out above (paragraphs 7.40-7.44), we plan to continue our programme of work to improve receiver performance, including prioritising consumer mass market equipment.

7.83 In addition, as noted in Section 5, we are proposing to publish a Spectrum Roadmap, which will be updated periodically. This will indicate potential future changes in spectrum use, and provide greater information and incentives for equipment manufacturers to take account of possible future changes in their spectrum neighbours.

7.84 Our proposals to further encourage the use of more interference resilient systems are set out below.

Make the technical details of our interference assessment more accessible

7.85 As we discuss in Section 5, accessible, good quality information about spectrum allows spectrum users to easily plan changes in their own use and engage more closely with Ofcom's spectrum management. Therefore, we want to make sure that spectrum users can access all the relevant information they need.

7.86 For bands and services requiring channel assignment (e.g. fixed links or business radio), Ofcom publishes a Technical Frequency Assignment Criteria (TFAC) manual detailing the procedure we follow, including all relevant assumptions.

7.87 We also publish technical details for almost all other services and bands, however they are not always in one single place. We therefore propose to make sure that the details of our interference assessment are accessible to all interested spectrum users in a clear, accessible way. We will consider the most appropriate methods to do this alongside our other proposals on 'spectrum information' (see paragraphs 5.40-5.43).

7.88 Publishing these assumptions will not guarantee protection against interference at any specific level. However, we consider that this will help stakeholders to make informed choices by providing them with additional, clear information (e.g. on the receiver characteristics we would normally expect and the protection criteria we assume). For example, if the interference rejection capabilities of a user's equipment do not meet our published parameters, they may suffer a higher risk of interference and could experience poorer performance. On the other hand, if a user chooses to deploy better interference

[57] The digital tick covered consumer electronics products (TVs, recorders, set top boxes etc) for the digital switchover and has now been superseded by the Freeview branding licence agreement that requires manufacturers to meet certain standards set out in the D book if they want to use the logo on their products. The D-Book provides DTT requirements for interoperability (i.e. how DTT services are transmitted and received).

rejection capabilities than the published parameters, they could end up with higher performance. [58]

We would not generally expect to take action as a result of poor receiver/system performance

7.89 In general, we expect professional spectrum users and equipment manufacturers to manage the risk of suffering interference in adjacent bands as a result of their own equipment performance, even when new adjacent band users are added later. One of the ways these users can protect themselves is by ensuring that their receivers are sufficiently selective and filter out any unwanted signals from the neighbouring band.

7.90 Ofcom has occasionally intervened to protect users with poor receiver selectivity as a result of wider policy considerations. In particular, as discussed above, consumers buying off the shelf equipment are not generally able to ensure that the equipment they use is robust to interference and so our work on improving standards (see paragraphs 7.40-7.4 above) has a focus on protecting consumers from poor performing equipment.

7.91 However, when we assess to what extent (if any) we should protect existing services by placing additional restrictions on new services, or by imposing further mitigations on services in adjacent bands, we would normally consider whether these existing services could be reasonably expected to use equipment with sufficiently selective receivers.

Pricing to incentivise better interference rejection capabilities, where appropriate

7.92 We are proposing to offer tiered levels of protection in spectrum licences, where appropriate. This could create an incentive for users to adopt better interference rejection capabilities. If a user was faced with the choice of paying for greater protection, or making changes to their system and/or receiver, they may decide to opt for the latter.

7.93 Our specific proposal for differential protection pricing for spectrum users is outlined in paragraphs 7.98-7.99 below.

Ensure an efficient balance between the level of interference protection given to one service and the flexibility for others to transmit

7.94 Some spectrum users prefer access to relatively 'quiet' spectrum, benefiting from a high degree of protection of interference from others, as this can boost the performance and reliability of their service. Such a boost may not always be noticeable by the final consumer, but it may, for example, enable an operator to serve more customers without compromising quality, to offer higher data rates, or to provide a more reliable service. [59]

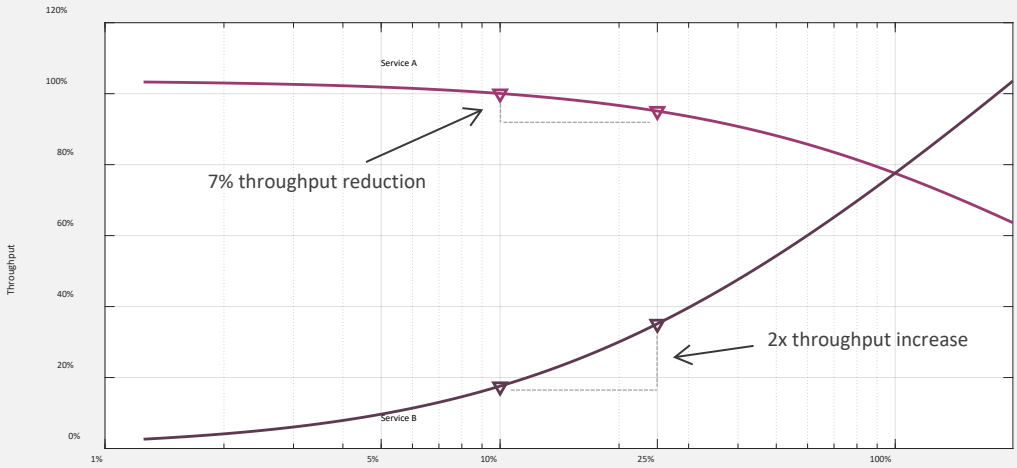
[58] In some cases, it will be more appropriate for Ofcom to technically assign power, frequency and other licence parameters based on the performance requested by licensees (e.g. a certain data rate or availability) and on the assumptions in the relevant TFAC. This approach, currently used for services like fixed links and business radio, can potentially create similar incentives for licensees to use equipment that is more resilient to interference.

[59] In contrast, some scientific services, such as radio astronomy and passive Earth observation from satellites, need very quiet spectrum in order to operate properly. For this reason, there are internationally recognized bands where all emissions are prohibited (see **5.340** in the Radio Regulations).

7.95 However, this comes at a cost to other services, as providing users with a very quiet environment to optimise their performance can hinder the introduction of new users and services in-band or in adjacent bands. In addition, the cost to other services, in terms of how much they are restricted, can be larger than the boost to performance of the service in quiet spectrum. In these cases, a different balance of interference between different services could lead to greater spectrum efficiency and greater benefits overall to consumers in terms of the services provided. We illustrate this through an example in Figure 7 below.

Figure 7: How the balance between interference protection and flexibility to transmit can affect spectrum efficiency

Below we illustrate how sometimes a small change in the balance between two services (the level of interference protection given to one service versus the flexibility for another to transmit) can lead to greater spectrum efficiency.



Protection threshold for service A (increase in unwanted power at the receiver)

In this example service A suffers interference from service B and sets a protection threshold in terms of increase in unwanted power at the receiver. Service B transmits with as much power as allowed without breaching this protection threshold.

Our starting point is that the unwanted power received by service A shall not increase by more than 10%. The throughput of service A under this assumption is shown as 100% in the graph and all other throughputs are compared to that. We can see that the throughput of service B in this case would be less than 20% of that of service A.

If we increase A's protection threshold from 10% to 25%, then its throughput does not fall much, only by 7%, but the throughput of B doubles. This is a significant increase in spectrum efficiency.

7.96 We set out our proposals to ensure an appropriate balance between users sharing bands in the following paragraphs.

Introduce tiered protection pricing for spectrum users, where appropriate

7.97 As noted under 'spectrum pricing' above, where there is excess demand in a band, we consider that we will typically achieve the optimal use of spectrum by setting licence fees at a level that reflects the opportunity cost of spectrum.

7.98 We propose to consider introducing the concept of tiered levels of protection into our spectrum licences, where appropriate. We do this to some extent today with grants of Recognised Spectrum Access where applicants can request different levels of protection. In bands where there is excess demand and we set the fee reflecting the opportunity cost, we would assess on a band-by-band basis whether we should introduce the tiered levels of protection. Charging a higher fee for more protection could incentivise users to only claim the protection level they need, and may therefore lead to spectrum efficiencies. Similar incentives may be possible in bands where we currently price using cost-based fees but as these are bands where there is no excess demand, our current assessment is that there would be little overall benefit in applying these different levels.

Require a greater level of evidence-based analysis from stakeholders when defining protection requirements

7.99 Stakeholders often have an incentive to ask for conservative criteria to protect their own services. Changing these criteria once they have been set or become widely adopted can be very difficult. As spectrum demand keeps rising, in the future we will need to ensure that these protection criteria are set in a way that facilitates optimal use of spectrum, including sharing, in order to ensure that this demand for spectrum can be met.

7.100 We are looking at how bands may already have a higher level of noise than is often assumed when stakeholders request protection levels. Some level of degradation to spectrum quality; reduced service coverage areas in polluted environments; poorer quality of service; and an adverse effect on battery life of handsets may exist anyway. Basing protection levels on thermal noise without taking this into account may be overly cautious and other services could be disproportionately restricted for no benefit to the first service if this increased noise floor is not taken into account when considering protection requirements.

7.101 Where protection criteria are being discussed for new services to share, we will seek to ensure that the proposed protection criteria do not have a detrimental impact on potential sharing in the band, including by challenging any protection criteria we think would not fairly balance the needs of different sets of users.

Question 8: Do you agree that it is important to encourage spectrum users to be 'good neighbours' to ensure more efficient use of the spectrum? Do you agree with our proposals to:

a) increase realism in coexistence analysis at a national and international level?

b) encourage spectrum users to be more resilient to interference?

c) ensure an efficient balance between the level of interference protection given to one service and the flexibility for others to transmit?

Do you have any comments on which of these will be the most important?

8. Summary and next steps

8.1 This section summarises the continuing and proposed new actions (identified in the previous four section) that we consider will help achieve our spectrum vision in the future. It then brings together all of our proposals under three strategic themes and sets out next steps for the review.

Summary of continuing and proposed new actions to achieve our objectives

8.2 Sections 4-7 considered each of the four strategic spectrum management objectives that comprise our spectrum vision. We consider that 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. In addition, we have identified a range of proposals that we believe will put us in an even better position to address future challenges and opportunities.

8.3 Table 9 summarises our findings for each of our spectrum management objectives, covering:

- what we plan to continue to do, utilising our existing tools and approach, in order to achieve that objective; and
- the proposals we are making for new actions or updates to our strategy in order to achieve that objective. Where proposals are relevant to achieving more than one objective they appear in multiple rows.

Table 9: Summary of our continued work and proposals to address our spectrum management objectives

Objective	To achieve this objective	
	We will continue to	**We propose**
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	- **Licensing to fit local and national services**: Considering further options for localised spectrum access when authorising new access to spectrum. - **Supporting innovation in wireless technologies.** Includes 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	- **Licensing to fit local and national services** (as above) - **Supporting innovation in wireless technologies** (as above) - **Expanding 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	- **Supporting innovation in wireless technologies** (as above) - **Expanding our work to understand, assist and inform** (as above) - **Spectrum for pioneers:** Making more spectrum available for innovation before its long-term future use is certain - **Promoting 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
		- **Promoting spectrum sharing:** Building on existing work, promote greater spectrum sharing through encouraging:
		  ○ Increased realism in coexistence analysis at a national and international level
		  ○ Users to be more resilient to interference
		  ○ An efficient balance between the level of protection given to one service and the flexibility for others to transmit
		- All other proposals also contribute to this objective

Strategic themes

8.4 As discussed above, each of our proposals addresses one or more of our strategic spectrum management objectives. In addition, we have categorised our proposals into three strategic themes: **supporting wireless innovation, licensing to fit local and national services, and promoting spectrum sharing.**

8.5 A common theme to many of our proposals is further **supporting wireless innovation**. Innovation is a key enabler of the UK's wireless future and, as discussed in Section 6, can come from different levels in the value chain and different market players, from existing spectrum users (for example by deploying new technologies in bands they already use), or new entrants developing new technologies or applications. Much of our work already supports innovation and our proposals seek to make it even easier for different players to access spectrum and to further increase the flexibility of spectrum use. In turn this could support greater competition across all parts of the wireless supply chain.

Our proposals that further support innovation are:

- **Understand, assist and inform:** Expand our work to understand, assist and inform the growing range of organisations who could benefit from wireless technologies in the future.
- **Spectrum for pioneers:** 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.
- **Flexibility for new technology:** Reduce the barriers for smaller players to develop new wireless technologies and equipment, including by influencing the development of international recommendations and standards for equipment, so they have real flexibility for new technologies and applications.

8.6 Complementing proposals on innovation are our proposals on **licensing to fit local and national service**s. These reflect the growing diversity of spectrum users, particularly the fact that wireless services utilising mobile technology will be provided on a local basis as well as national basis.

8.7 More innovation and greater diversity of spectrum users will mean it's **even more important that a growing range of different users can share access to spectrum** effectively. This is necessary to enable new services to be introduced whilst protecting the benefits people already enjoy.

8.8 In addition, there is an opportunity to start with a fresh approach to spectrum sharing in much higher frequencies which are just starting to be used. This is important as it will encourage new spectrum users to make investments decisions, such as the equipment to be deployed, that are consistent with an increased level of sharing in the future. Even though these frequencies are relatively lightly used at present, history tells that demand for higher and higher frequencies only increases as technology advances over time.

8.9 In many cases greater spectrum sharing depends on a range of international decisions, recommendations and standards taken over period of years. Therefore, we would continue to use our strong position in international regulatory fora and work with other regulators to drive improvements internationally.

Next steps

8.10 We want to hear views from a wide range of people, businesses and organisations on the proposals we have identified. As well as the companies and organisations that normally engage with us and respond to our consultations, we are keen to get input from others who might be relatively new to spectrum and spectrum management.

8.11 Following the publication of this consultation we will hold a workshop on our proposals – details of which will be posted on our website. The consultation closes on 26 February 2021 and we expect to publish our conclusions in Q2 2021/22.

Question 9: Are there any other issues or potential future challenges that should be considered as part of this strategy?

Question 10: Do you agree that continued use of our existing spectrum management tools (as set out in sections 4-7) will be relevant and important for promoting our objectives in the future, in light of future trends?

Question 11: Is there anything else we should be considering doing, or doing differently, to promote our objectives?

A1. Responding to this consultation

How to respond

A1.1 Ofcom would like to receive views and comments on the issues raised in this document, by 5pm on 26 February 2021.

You can download a response form from https://www.ofcom.org.uk/consultations-and-statements/category-1/supporting-uk-wireless-future. You can return this by email or post to the address provided in the response form.

A1.2 If your response is a large file, or has supporting charts, tables or other data, please email it to spectrum.management.strategy@ofcom.org.uk, as an attachment in Microsoft Word format, together with the cover sheet.

A1.3 Responses may alternatively be posted to the address below, marked with the title of the consultation:

Spectrum Group
Ofcom
Riverside House
2A Southwark Bridge Road
London SE1 9HA

A1.4 We welcome responses in formats other than print, for example an audio recording or a British Sign Language video. To respond in BSL:

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

A1.5 We will publish a transcript of any audio or video responses we receive (unless your response is confidential).

A1.6 We do not need a paper copy of your response as well as an electronic version. We will acknowledge receipt if your response is submitted via the online web form, but not otherwise.

A1.7 You do not have to answer all the questions in the consultation if you do not have a view; a short response on just one point is fine. We also welcome joint responses.

A1.8 It would be helpful if your response could include direct answers to the questions asked in the consultation document. The questions are listed at Annex 4. It would also help if you could explain why you hold your views, and what you think the effect of Ofcom's proposals would be.

A1.9 If you want to discuss the issues and questions raised in this consultation, please contact Kirsty Logan on 020 7981 3095, or by email to spectrum.management.strategy@ofcom.org.uk.

Confidentiality

A1.10 Consultations are more effective if we publish the responses before the consultation period closes. In particular, this can help people and organisations with limited resources or familiarity with the issues to respond in a more informed way. So, in the interests of transparency and good regulatory practice, and because we believe it is important that everyone who is interested in an issue can see other respondents' views, we usually publish all responses on the Ofcom website as soon as we receive them.

A1.11 If you think your response should be kept confidential, please specify which part(s) this applies to, and explain why. Please send any confidential sections as a separate annex. If you want your name, address, other contact details or job title to remain confidential, please provide them only in the cover sheet, so that we don't have to edit your response.

A1.12 If someone asks us to keep part or all of a response confidential, we will treat this request seriously and try to respect it. But sometimes we will need to publish all responses, including those that are marked as confidential, in order to meet legal obligations.

A1.13 Please also note that copyright and all other intellectual property in responses will be assumed to be licensed to Ofcom to use. Ofcom's intellectual property rights are explained further in our Terms of Use.

Next steps

A1.14 Following this consultation period, Ofcom plans to publish a statement in Q2 2021/22.

A1.15 If you wish, you can register to receive mail updates alerting you to new Ofcom publications.

Ofcom's consultation processes

A1.16 Ofcom aims to make responding to a consultation as easy as possible. For more information, please see our consultation principles in Annex 2.

A1.17 If you have any comments or suggestions on how we manage our consultations, please email us at consult@ofcom.org.uk. We particularly welcome ideas on how Ofcom could more effectively seek the views of groups or individuals, such as small businesses and residential consumers, who are less likely to give their opinions through a formal consultation.

A1.18 If you would like to discuss these issues, or Ofcom's consultation processes more generally, please contact the corporation secretary:

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

A2. Ofcom's consultation principles

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

Before the consultation

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

During the consultation

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

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

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

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

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

After the consultation

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

A3. Consultation coversheet

BASIC DETAILS

Consultation title:

To (Ofcom contact):

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

CONFIDENTIALITY

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

Nothing ☐

Name/contact details/job title ☐

Whole response ☐

Organisation ☐

Part of the response ☐

If there is no separate annex, which parts? _____

_____

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

DECLARATION

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

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

Name Signed (if hard copy)

A4. Consultation questions

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

Question 1: Do you have comments on the overall approach to the review?

Question 2: Have we captured the major trends that are likely to impact spectrum management over the next ten years?

Question 3: Could any of the future technologies we have identified in Annex 6, or any others, have disruptive implications for how spectrum is managed in the future? When might those implications emerge?

Question 4: Do you agree that there is likely to be greater demand for local access to spectrum in the future? Do you agree with our proposal to consider further options for localised spectrum access when authorising new access to spectrum?

Question 5: Do you agree with the actual and perceived barriers identified for innovation in new wireless technologies, and our proposed ways of tackling those?

Question 6: Do you agree with Ofcom's proposals to improve our outreach and reporting activities, and spectrum information tools?

a) Are there additional ways that Ofcom could better engage with existing and future users and providers of wireless communications?

b) Please explain any specific areas where you believe more or better provision of information could provide value to stakeholders

Question 7: Do you agree that it is important to make more spectrum available for innovation before its long-term use is certain? Do you have any comments about our proposed approach to doing this?

Question 8: Do you agree that it is important to encourage spectrum users to be 'good neighbours' to ensure more efficient use of the spectrum? Do you agree with our proposals to:

a) increase realism in coexistence analysis at a national and international level?

b) encourage spectrum users to be more resilient to interference?

c) ensure an efficient balance between the level of interference protection given to one service and the flexibility for others to transmit?

Do you have any comments on which of these will be the most important?

Question 9: Are there any other issues or potential future challenges that should be considered as part of this strategy?

Question 10: Do you agree that continued use of our existing spectrum management tools (as set out in sections 4-7) will be relevant and important for promoting our objectives in the future, in light of future trends?

Question 11: Is there anything else we should be considering doing, or doing differently, to promote our objectives?

A5. Legal framework

A5.1 Ofcom's statutory powers and duties in relation to spectrum management are set out primarily in the Communications Act 2003 (the **"2003 Act"**) and the Wireless Telegraphy Act 2006 (the **"WT Act"**).

Duties under the Communications Act 2003

A5.2 Our principal duties under the 2003 Act, when carrying out our functions and exercising our powers, are to further the interests of citizens and consumers, where appropriate by promoting competition. In doing so, we are also required (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.

A5.3 We must also have regard to: (i) the desirability of promoting competition in relevant markets; (ii) the desirability of encouraging investment and innovation in relevant markets; (iii) the different needs and interests, so far as the use of the electro-magnetic spectrum for wireless telegraphy is concerned, of all persons who may wish to make use of it; and (iv) the different interests of persons in the different parts of the United Kingdom, of the different ethnic communities within the United Kingdom and of persons living in rural and in urban areas.

A5.4 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. Section 4 of the 2003 Act requires Ofcom to act in accordance with the six Community requirements, which give effect to the requirements of Article 8 of the Framework Directive.

A5.5 In summary, the Community requirements are requirements: a) to promote competition in communications markets; b) to ensure that Ofcom contributes to the development of the European internal market; [60] c) to promote the interests of all European Union citizens; [61] d) to act in a manner which, so far as practicable, is technology neutral; e) to encourage, to the extent Ofcom considers it appropriate, the provision of network access and service interoperability for the purposes of securing efficiency and sustainable competition in communications markets and the maximum benefit for the customers of communications network and services providers; and f) to encourage such compliance with certain international standards as is necessary for facilitating service interoperability and securing freedom of choice for the customers of communications providers.

[60] After the implementation period following the UK exit from the EU, this requirement will no longer apply. See section 4(4) of the 2003 Act and paragraph 3 of Schedule 1 to the Electronic Communications and Wireless Telegraphy (Amendment etc.) (EU Exit) Regulations 2019/246.

[61] After the implementation period following the UK exit from the EU, this requirement will become a requirement to promote the interests of "all members of the public in the United Kingdom". See paragraph 3 of Schedule 1 to the Electronic Communications and Wireless Telegraphy (Amendment etc.) (EU Exit) Regulations 2019/246.

Duties under the Wireless Telegraphy Act 2006

A5.6 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.

A5.7 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

A5.8 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. [62]

A5.9 A wireless telegraphy licence may be granted subject to such terms, provisions and limitations as Ofcom think fit (WT Act, s. 9(7)). However, this power is subject to certain constraints. In particular:

a) in line with Article 6 of the Authorisation Directive, section 9(1A) of the WT Act provides that the terms, provisions and limitations of a licence for the use of spectrum for the provision of an electronic communications network or service must fall within Part B of the annex to the Authorisation Directive; [63]

b) 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

c) 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)).

[62] Section 8 of the WT Act.
[63] After the implementation period following the UK exit from the EU, this constraint will no longer apply. See paragraph 45(3) of Schedule 1 to the Electronic Communications and Wireless Telegraphy (Amendment etc.) (EU Exit) Regulations 2019/246.

Spectrum fees

A5.10 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

A5.11 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.

A5.12 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).

The Wireless Telegraphy Act Register

A5.13 Section 31 of the WT Act permits Ofcom to make regulations to establish and maintain relevant information in a register. Ofcom has made the Register Regulations [64] and established the Wireless Telegraphy Act Register, which provides information about who is licensed to operate services in specific frequencies or geographical areas. [65] The register supports the spectrum transfer process by providing basic information about allocated spectrum to the market.

[64] The Wireless Telegraphy (Register) Regulations 2012, as amended.
[65] 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

The European Electronic Communications Code

A5.14 On 12 October 2020, the UK Government (DCMS) laid down in Parliament a draft statutory instrument for implementing the European Electronic Communications Code Directive (2018/1972/EU) (the "**Draft EECC Regulations**").[66] At the time of writing, the final regulations have not yet been published on the www.legislation.gov.uk website. The amendments to the WT Act set out in the Draft EECC Regulations include the following changes (which according to the Draft EECC Regulations would enter into force on 21 December 2020):

a) adding consideration of effective spectrum sharing arrangements to the relevant conditions for making licence exemption regulations under section 8;[67]

b) an amendment to section 9 so as to clarify Ofcom's powers to attach conditions to a spectrum licence requiring the licence holder to enter into a wholesale roaming access agreement;[68]

c) amendments to the bidding process for a spectrum licence in section 14 which would require Ofcom to consider if a specified level of use requirement would promote the optimal use of spectrum when designing competitive awards;[69]

d) requiring Ofcom to allow the leasing or transfer of all spectrum licences, and the transfer of all grants of recognised spectrum access. These requirements would be subject to limitations and would not apply where, for example, the licence is granted free of charge, or the duration of the licence does not exceed 12 months;[70] and

e) amendments to section 31 which would allow information relating to spectrum leasing to be included within the wireless telegraphy register.[71]

[66] The Electronic Communications and Wireless Telegraphy (Amendment) (European Electronic Communications Code and EU Exit) Regulations 2020", in draft form; see https://www.legislation.gov.uk/ukdsi/2020/9780348213089/contents
[67] Paragraph 81(3) in Part 3 of Schedule 1 to the Draft EECC Regulations.
[68] Paragraph 83(3) and (4) in Part 3 of Schedule 1 to the Draft EECC Regulations.
[69] Paragraph 84 in Part 3 of Schedule 1 to the Draft EECC Regulations.
[70] Paragraph 86 in Part 3 of Schedule 1 to the Draft EECC Regulations.
[71] Paragraph 87 in Part 3 of Schedule 1 to the Draft EECC Regulations.

A6. Potential implications of future technologies for spectrum management

Introduction

A6.1 There are a number of emerging technologies that are cited by their proponents to have potential applications in many different areas. The uses and benefits of these technologies, such as Artificial Intelligence and Blockchain could be considered for spectrum management. We set out below a brief overview of some of these technologies and the potential areas where they might be relevant to spectrum management. We first consider technologies that might affect how we manage spectrum as well as technologies that are likely to need to be managed differently or in a higher frequency range in the future.

A6.2 In addition, as part of our wider technology horizon scanning programme, we recently issued a call for inputs on future technology that could affect any of the sectors we regulate.

A6.3 In general, we consider that the benefit of the technologies that may affect spectrum management is quite uncertain at present and particularly within the ten-year time frame of our spectrum strategy. Nevertheless, alongside our technology discovery programme, we will continue to monitor technological developments that may affect our approach to spectrum management where appropriate.

Technologies that may affect how we manage spectrum

Artificial intelligence

Introduction to the technology

A6.4 Artificial intelligence (AI) is a term that applies to a range of different technologies that can be implemented to create intelligent agents able to perform autonomous functions. AI uses live or historical data and computational and mathematical logic in order to make a decision or take an action. Machine learning is a subset of AI, which allows a system to automatically "learn" by varying that logic based on experience from data without being explicitly programmed. In the case of spectrum management, the source data is likely to be some form of licensing database or spectrum monitoring / sensing data.

How this might be relevant to our approach to spectrum management

A6.5 Machine learning / AI has the potential for automating some of our spectrum management decisions to provide more efficient use of spectrum and a faster assignment of frequencies, possibly in a dynamic environment.

A6.6 Using information from spectrum monitoring about spectrum use and the specific environment that a user is within; detailed information about a user's requirements in

radio resources and time; and previous (learned) actions, might automate decisions on how to allocate further frequency assignments in a spectrum efficient manner. AI / machine learning technology would need to be coupled to some form of database for the management of spectrum allocations. We have discussed in sections 6 and 7 some of the benefits of using databases as part of automated spectrum management tools and we already make use of these for providing access to TV White Space spectrum.

A6.7 However, AI / machine learning will also require significantly enhanced spectrum monitoring capabilities within environments and devices themselves to allow characterisation of the environment and signal classification necessary as inputs to the system machine learning processes. This could drive significant cost into the equipment ecosystem. AI techniques may also have several other challenges related mainly to the complexity of the system management; the high level of processing and power requirements; the complexity of defining and improving the learning models; and the large amount of data involved. It may be possible in some circumstances to apply AI techniques in a distributed way in large scale systems, so that the databases could be decentralised reducing the exchanged data in the network.

Self-configuring networks

Introduction to the technology

A6.8 Self-optimising networks (SON) technology has been available for a number of years and is predominantly standardised within cellular networks in order to optimise network coverage and performance across an area. This is a form or machine learning where key parameters are adjusted (such as transmit power and antenna down-tilt) in order to maximise certain key performance indicators (KPIs).

A6.9 However, this concept can be taken further to consider the concept of self-healing networks – ones that adjust parameters to compensate when a particular network node is removed or fails. DARPA (Defense Advanced Research Projects Agency) has even taken the concept further to enable adaptive networking among diverse platforms. [72] This concept is a set of functions that automate the configuration, the optimisation, and the healing of multiple networks. Thus, the system self-organises all its functions across different networks or even among different elements of the same network. The main objective of the technology is the self-coordination and efficiency of the network, but it could also be useful in maximising the availability of shared spectrum.

A6.10 More functions are being developed to include end to end functions across all network parts. Techniques like artificial intelligence, spectrum sensing and automated spectrum management tools are key components of automation in a self-configuring network.

How this might be relevant to our approach to spectrum management

[72] DARPA, Dynamic Network Adaptation for Mission Optimization (DyNAMO)

A6.11 The self-configuring technique has the potential to create a fully autonomous network in all its functions including the spectrum management aspects. It could make more efficient use of available spectrum and lead to increases in the capacity in allocated spectrum bands. This would reduce the amount of spectrum required to meet a certain level of coverage and service quality, allowing alternative users or uses in the remaining spectrum.

A6.12 There may also be benefits in the way spectrum is made available as the networks themselves will self-configure to avoid interference between different uses without the need for complex coexistence analysis in advance.

A6.13 However, 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 for these techniques. Processing and power consumption could also be high and reliability uncertain at present.

Automated spectrum management tools

Introduction to the technology

A6.14 We already make use of databases to manage opportunistic spectrum access as part of our TV Whitespace approach. There are also a number of other benefits that we have highlighted in sections 6 and 7. Whilst the assignments of spectrum may be considered to be short term or temporary (as devices must check with the database every 15 minutes) they in practice vary less often.

A6.15 However, the concept of automating spectrum access with databases will be a key component of some of the AI/machine learning and self-configuring network concepts. This component may also have some benefits as a stand-alone technology. Reducing the assignment duration from 15 minutes down to near-real time would give the potential for these databases to schedule resources between different users or potentially even different services.

How this might be relevant to our approach to spectrum management

A6.16 Allowing automated spectrum management tools to schedule user resources could allow more efficient spectrum sharing. Frequency bands could more easily be shared between different types of user with a higher occupancy. Spectrum resources would be assigned on demand and released afterwards rather than being allocated but remaining unused for part of the time, thus increasing the number of users that can be served. The greater efficiency of spectrum use may mean that there is no excess demand in an area and spectrum access may still be able to be provided with more surety of access than opportunistic access of dynamic spectrum access databases today.

A6.17 There are however a number of downsides. With increased complexity, comes additional cost for developing and running the database itself and there may be additional development needed and associated cost in the devices themselves. The very short

duration spectrum assignments could also mean increased signalling and database management traffic on the network which would offset some of the efficiency benefits that could be achieved. Where there are multiple databases (to encourage competition in services) then this adds further complexity and network traffic in maintaining links between those databases.

Blockchain

Introduction to the technology

A6.18 Blockchain is a distributed digital ledger technology. It is considered an efficient technique to securely transmit data in decentralised systems where transaction security is important – transactions cannot be altered in a block without the consensus of the whole network.

A6.19 This technology has been considered by Ofcom in a collaborative project with industry to improve how UK telephone numbers are managed. [73] Trials of the proposals are ongoing, [74] and the approach is expected to make it quicker and easier for landline customers to move numbers between providers as well as reducing nuisance calls and fraud. Moreover, in that context, it could reduce regulatory and business costs and increase industry agility.

How this might be relevant to our approach to spectrum management

A6.20 Blockchain has the potential to bring new opportunities to spectrum assignments, providing a similar level of security to that in the fixed telecom numbering trial. The secure transaction feature could be used to support dynamic spectrum management databases that can be updated in near real-time with data collected by spectrum sensing techniques. It could be significant in allowing new models of spectrum access charges such as pay-per-use as bands are actively updated through spectrum sensing and updated in the blockchain. Blockchain may also be a component of self-configuring networks to secure the transactions, particularly when dealing with military networks.

A6.21 However, the technology has some limitations. It requires a 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 due to the requirement to update a transaction on every single blockchain node. The extent of this may depend on whether the database is a centralised or distributed model.

[73] How blockchain technology could help to manage UK telephone numbers, October 2018.
[74] Ofcom's Plan of Work 2020/21: September 2020 update on outputs and milestones, September 2020.

Technologies to be managed in the future

Spectrum in the 3000 GHz range and above

Introduction to the technology

A6.22 Ofcom's spectrum management functions under the Wireless Telegraphy Act 2006 (the "WT Act") concern the frequencies up to 3,000 GHz (3 THz) although the Secretary of State has the power to modify the definition of "wireless telegraphy" by substituting a different frequency for 3,000 Gigahertz. [75]

A6.23 Spectrum is currently only allocated to specific types of services up to 275 GHz. Spectrum between 300 GHz and 3000 GHz is known as Tremendously High Frequency ('THF'). Irrespective of the correct definition, applications in this range are also referred to as 'Terahertz technology' or 'in the Terahertz band' or the 'sub-millimetre band'.

A6.24 Visible light frequencies fall above 3000 GHz (3 THz), with Red light around 400 THz, Violet light around 700 THz to Ultraviolet light above 750 THz and as such are not directly regulated by Ofcom. However, emissions from surrounding components such as power supplies can cause interference to lower frequency spectrum users and this interference is regulated by Ofcom. Visible light communications (VLC) are being exploited for laser links between satellites and for a 'small cell' concept of providing coverage in a room using Light-Fidelity (LiFi) Technology, although this latter example is still being developed.

A6.25 Materials and other technology are developing that will support use of spectrum above 300 GHz. In the even longer term, electromagnetic spectrum above 3000 GHz may also be viable for radio applications.

How this might be relevant to our approach to spectrum management

A6.26 Technology progress will take time to enable manufacture of equipment that can use all the available spectrum up to 3000 GHz. The radio wave propagation characteristics in this spectrum range may facilitate high frequency re-use and spectrum efficiency but are likely to require complex radio systems and management. These technologies are also likely to have significant costs initially. However, with technology progression over the next 10 years and our desire to support innovation, 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.

6G technology

Introduction to the technology

A6.27 6G represents the sixth generation standard for mobile technology and is expected to follow the continued development of 5G technology over the next 10 years as it is

[75] See section 116(1) and (3) of the WT Act.

implemented, services are upgraded, and capabilities facilitated by use of additional frequency ranges as these become available for mobile use.

A6.28 The main themes emerging for 6G are in some cases an extension of 5G themes. They are for ubiquitous services which follow users everywhere seamlessly; more intelligence and adaptability within wireless connectivity; and even higher data rates and/or lower latency than available in 5G.

A6.29 Research and discussion on what may be included as part of 6G technology is currently ongoing. 6G is proposed to build and improve on existing technology (including some from 5G) but bringing them together within a single technology standard. 6G may therefore include technology capabilities such as: incorporating network core functions/interconnects at the edge of the network; increased security and authentication using block chain or quantum computing techniques; intelligent surfaces; Artificial Intelligence/quantum computing; and joint communication and radar modes that simultaneously sense objects/people using the same wireless network.

How this might be relevant to our approach to spectrum management

A6.30 As the key components of 6G become clearer, the impact on spectrum management will also become clearer. At the very least, we expect that 6G may require additional spectrum bands to be made available for mobile, likely at considerably higher frequencies.

A6.31 We will also need to consider whether our authorisation tools at that time remain appropriate for making spectrum available in more of a dynamic/intelligent environment to those services and applications that need it in real time. This type of spectrum management could build on our automatic database frequency allocation ability or require new approaches. 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.

A7. 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.

AIP Administered incentive pricing. A fee charged to users of the spectrum to encourage them to make economically efficient use of their spectrum.

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

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.

CEPT The European Conference of Postal and Telecommunications Administrations.

DARPA Defense Advanced Research Projects Agency. An agency within the US Department of Defense.

DCMS Department for Digital, Culture, Media and Sport.

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.

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

EHF Extremely High Frequency. Frequencies between 30 and 300 GHz.

ETSI European Telecommunications Standards Institute.

EU European Union.

FCC Federal Communications Commission (US).

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

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

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.

Li-Fi A wireless communication technology which uses light to transmit data between devices.

Machine Learning A subset of AI, which allows a system to automatically "learn" based on experience from data without being explicitly programmed.

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.

Ofcom The Office of Communications.

Open RAN Open RAN provides specifications for open, interoperable interfaces between the elements of a mobile Radio Access Network.

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.

RSA Recognised spectrum access. A method of recognising the use of radio spectrum by an operator which is not covered by a Wireless Telegraphy Act licence or licence exemption.

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

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.

TFAC Technical frequency assignment criteria.

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.

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

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

WRC World Radiocommunication Conference. World Radiocommunication Conference. An international conference organised by the ITU to review and revise radio regulations, held every three to four years.

WT Act Wireless Telegraphy Act 2006.