Spectrum management strategy

Ofcom's strategic direction and priorities for managing spectrum over the next 10 years

Statement

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Contents

About this document:

This document sets out Ofcom's new spectrum management strategy which establishes the strategic approach and priorities for managing radio spectrum for the next decade.

The strategic approach relies on market mechanisms where possible and effective and on regulatory action where necessary. It also places specific emphasis on: exploring opportunities for spectrum sharing; managing the co-existence of different services and promoting technology improvements that minimise interference; providing more information on how spectrum is used in the UK; and leading the debate on key international spectrum issues.

The priorities are: future mobile data demand, the future of the 700MHz band and free-to-view TV, Public Sector Spectrum Release, Programme Making and Special Events, Machine-to-Machine applications and the Emergency Services.

Section 1

Executive summary

This document sets out Ofcom's Spectrum Management Strategy for the next 10 years

1.1 Radio spectrum is a major asset to the UK, providing a critical input to a wide range of services including mobile communications, television and radio broadcasting services, emergency services and aeronautical communications and many more. By enabling this array of applications, spectrum use delivers substantial benefits to citizens and consumers.

1.2 Two acts of Parliament[1] give Ofcom responsibility for managing UK spectrum. Because our decisions have significant long term impacts on spectrum use, it is important that we take a strategic approach to managing this valuable resource. It is also important that we help stakeholders plan their own spectrum use by providing guidance on the nature of regulatory action we expect to take over the coming 10 years.

1.3 This summary of Ofcom's Spectrum Management Strategy begins with the context within which this strategy has been developed. It then draws attention to those aspects of our spectrum management approach on which we expect to place greater emphasis, before identifying the six sector-focused priorities which we expect to be a particular focus for regulatory action over the coming 10 years. The strategy is summarised "on a page" in Table 1. The development of this strategy reflects input provided by stakeholders' responses to the consultation we published in October 2013. It also represents a significant contribution to the government's overarching UK Spectrum Strategy[2].

[1] The Communications Act 2003 and the Wireless Telegraphy Act 2006. These Acts also include provisions for the UK Government to direct us in the execution of our spectrum functions under certain conditions.

[2] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287994/UK_Spectrum_Strategy_FINAL.pdf

Table 1 - Ofcom's Spectrum Management Strategy illustrated on a page

Key spectrum duty	**To secure optimal use of spectrum in the UK i.e. the use that delivers the greatest value to UK citizens and consumers**		
The context for future spectrum management	Requirements for wireless service are likely to increase for many spectrum uses. This will lead to **growing competing demands** for key spectrum resources	Adopting **technologies that enable more efficient use** of spectrum will be crucial, but the there will still be increased pressures on spectrum, especially in concentrated geographical locations	As there is no unused spectrum across many frequencies, the growth in competing spectrum demands will need to be addressed by a mix of **spectrum re-purposing** to higher value uses and greater use of **spectrum sharing**
Our strategy	We will continue to **combine the use of market mechanisms possible and effective and regulatory action where necessary**. When we do take action we seek to retain flexibility in order to create options, rather than dictate solutions We will place a growing emphasis on four aspects of how we manage spectrum: • Exploring **new forms of spectrum sharing** and extending **sharing across new bands** • Maintaining our increased focus on understanding the **coexistence challenges** associated with changes in spectrum use • Promoting **improvements in radio performance standards** to reduce future coexistence issues • Increasing the quantity and quality of **information on spectrum use** we make available We will also **continue to play a leading role in international spectrum debates** where this is most relevant to good outcomes in the UK		
Our priority areas	**Addressing future mobile data demands, the importance of mobile coverage and the availability of new mobile services**	**Implementing our strategy for the 700 MHz band and considering the evolution of Free-to-View TV**	**Supporting the Government's Public Sector Spectrum Release (PSSR) Programme**
	Addressing the challenges around future PMSE spectrum use	**Enabling growth and innovation in M2M/IoT applications**	**Supporting Government in its consideration of the future wireless communication needs of Emergency Services**

Growing and competing demands for spectrum will require a mix of spectrum re-purposing and increased sharing

1.4 The expanding requirements for wireless services across many sectors provide a backdrop to our review of spectrum management strategy. Significant growth is likely to occur in a number of important sectors including in mobile data over both public and private networks and in M2M / Internet of Things (IoT) applications. But the demands are also likely to grow, or at least be sustained, in most other sectors that deliver important benefits to citizens and consumers, though they will probably not grow to the same extent as for mobile data. Examples include Programme Making and Special Events, Business Radio and Utilities, Satellite services and Digital Terrestrial Television.

1.5 Technology improvements will go some way to meeting these increased demands by enabling more information to be carried over a given amount of spectrum. These will include new transmission technologies (e.g. LTE and emerging 5G standards in mobile broadband which could enable improvements in spectrum efficiency; or greater use of digital technologies for wireless microphones and business radio applications) and new content compression standards (e.g. High Efficiency Video Coding (HEVC) in TV broadcasting). Spectrum will also be used more intensively through increased frequency re-use, for example using low power, small cells.

1.6 Technological advance also enables services to be provided using ever higher frequencies making larger segments of the spectrum usable. For example, fixed wireless services, which support the delivery of many other end-user applications, are now beginning to use spectrum above 60 GHz, after a historic focus on bands below 18 GHz, and commercial satellite services that historically used spectrum below 12GHz have now expanded their use into 28GHz. This effect could also extend the range of the “sweet spot”, where demand for spectrum is greatest, up to perhaps 6GHz, providing some level of mitigation for forecast increases in demand.

1.7 However, we expect that the net effect of growing demands and changes in technology will still lead to increased pressures on access to spectrum in some specific frequency ranges. These demands will also be most acute in concentrated geographical locations of high population density where spectrum use is already intense.

1.8 There is no unused spectrum available for new release for a wide range of bands. Pressures on spectrum access will continue to be particularly intense in the 300 MHz to 3 GHz range, which is attractive to many current spectrum uses because of its propagation characteristics. In the longer term, demands for higher frequency spectrum are likely to grow as larger bandwidths are required to meet increasing capacity requirements and as technology evolves to enable higher frequencies to be used economically.

1.9 We therefore expect to see:

- a continuing emphasis on **re-purposing the use of some spectrum bands** as an important means of addressing changing spectrum needs. At the same time frictions between the long timescales often required to enable change of use and the fast pace of technology developments are likely to persist.

- an increase **in shared access to spectrum amongst different uses** as the opportunities to clear spectrum (particularly on a nationwide basis) become ever

more challenging and as technical and regulatory developments, such as dynamic shared access, enable more efficient re-use of spectrum where and when it is really needed.

Our strategy will combine the use of market mechanisms and regulatory action to drive these changes

1.10 Our key objective when managing spectrum is to deliver its optimal use, meaning the use that delivers the greatest value to UK citizens and consumers. To do this, we will continue to rely on market mechanisms where possible and effective, but also take regulatory action where necessary.

1.11 Ofcom has acted as a pioneer in developing a spectrum management approach that recognises the value of market mechanisms. Market mechanisms are generally considered to be the most effective method of allocating scarce resources to ensure they are used efficiently once the conditions required for them to be effective are in place.

1.12 However, our experience over the past 10 years suggests that there can be an important and complementary role for us to play, particularly, when major changes in spectrum use are contemplated. In these cases there are a number of reasons why market mechanisms alone are unlikely to deliver a value enhancing change:

- Changes to international agreements: decisions agreed within international institutions can be key enablers of (or obstacles to) major changes of use. Ofcom (in close collaboration with the government) is responsible for negotiating in relevant international institutions on behalf of the UK.

- Constraints relating to coexistence between adjacent users: a change of use will normally involve changes to the interference environment that could have negative effects on users of adjacent spectrum. Resolving these issues can be complex, making it hard for the individual market players, who do not have access to regulatory levers, to coordinate and develop an appropriate solution

- Implications for competition in relevant markets: regulation may be required to prevent the concentration of key spectrum assets causing competition concerns in downstream markets. For example, we carried out an extensive competition assessment of the mobile market to decide whether to put in place caps on the spectrum that existing players in the market could win in the 4G auction of spectrum at 800 MHz and 2.6 GHz.

- Relevance of wider duties and the citizen interest: where spectrum use is instrumental to delivering the citizen interest regulatory action has an important role to play. For example, we believe that, at present, DTT is the most appropriate method of meeting the objective of delivering universal free-to-view access to Public Service Broadcasting channels and we take this into account when making decisions that have the potential to affect DTT.

1.13 Regulatory action inevitably requires us to take a view on the potential merits of changes to spectrum use, some of which may be some way in the future. Where doing so, we seek to retain flexibility where possible so that our decisions create opportunities for industry to exploit, rather than dictate particular solutions. This is of particular relevance in the context of enabling innovation and enabling the market to respond to disruptive technology developments.

This strategy will be supported by an increased emphasis on four areas of cross-cutting activity

1.14 We will give increased emphasis to the four areas of cross cutting activity outlined below.

We will pro-actively explore new forms of spectrum sharing and extend sharing across new bands

1.15 Sharing spectrum will become increasingly important and new technical and regulatory developments are expanding the range of uses for which shared spectrum access could be viable. In a separate document we are publishing today we discuss how we expect spectrum sharing to play an increasingly important role in meeting different types of mobile and wireless data demands.[3]

1.16 We will pro-actively explore how regulatory support for new forms of sharing could enable new spectrum uses without unduly constraining incumbent users. Work in this area will include: progressing our work on TV White Spaces to demonstrate the capability of the geo-location database approach and to enable deployments in UHF spectrum; working to support the government as it considers opportunities to share more of the spectrum it uses to provide its own services with commercial market users; carrying out a more extensive scan of bands which might have the potential to support spectrum sharing in future; and considering the potential for new forms of dynamic sharing (over and above the current geo-location database approach).

We will maintain our increased focus on the coexistence challenges associated with changes in spectrum use

1.17 The rising intensity of spectrum use is likely to increase the challenges of coexistence between different uses in the same band and in adjacent bands. This means that the implementation of our strategy is highly dependent on our ability to understand new coexistence challenges and make the appropriate decisions on how to manage them.

1.18 Stakeholders and licensees are often well placed to provide evidence on coexistence between different uses, as they have a detailed understanding of their own technology and spectrum usage. We will continue to look to stakeholders to provide evidence where appropriate, notably where they are seeking a change in way they want to use spectrum. However, we have an important role in providing assurance and, in certain circumstances, we need to carry out the appropriate analysis ourselves to inform decisions on coexistence issues. Accordingly, we have put significantly more effort into this area in recent years in support of major changes in spectrum access (such as the 800MHz and 2.6GHz, TV White Spaces uses and the forthcoming release of 2.3 and 3.4GHz).

1.19 We will continue to develop effective planning tools to assess coexistence challenges and to make greater use of empirical testing with commercially available devices where possible. This will enable us to improve the way in which the theoretical models we use to predict potential coexistence issues reflect situations in the real world. We will also continue to develop our theoretical modelling capability, an example of which is our on-going work to improve our DTT planning and coexistence tools in the UHF and VHF bands. We will also place more emphasis on the nature of

[3] http://stakeholders.ofcom.org.uk/consultations/spectrum-sharing/statement/

the adjacent service. This is important to ensure that the appropriate information required to implement necessary solutions is available such that existing services can be protected from harmful interference whilst the opportunities for new services to gain access to spectrum can be maximised.

We will promote improvements in RF performance standards to reduce coexistence issues in future, using a range of levers

1.20 We will also encourage improvements in the performance of all of the components of radio systems to the extent possible without imposing excessive costs. Improving the ability of transmitters to minimise out-of-band emissions and the ability of receivers to screen out radio signals transmitted in adjacent bands will enable greater intensity of use whilst limiting future coexistence issues.

1.21 Although much of the work on standards is rightly led by industry, there is a case for regulatory action to avert poor RF performance standards because the associated costs are often borne by other spectrum users. This may be of particular relevance in the case of mass market, consumer devices or equipment that supports safety of life applications where poor RF performance may place undesirable constraints on future changes in use. On the other hand, we recognise that the hurdle for regulatory intervention in any given case should be high. We also recognise that action will need to be taken on an international stage to be effective and we will pro-actively pursue this.

1.22 We intend to focus our activities by identifying areas where the risks from not taking early regulatory action on standards for new RF equipment are greatest. This will mean a focus on bands where we expect major changes in the RF environment and on cases where the incentives to optimise RF designs are miss-aligned due to market structure.

We will increase the quantity and quality of information on spectrum use we make available

1.23 In our consultation we provided high level metrics on spectrum access in the UK highlighting the proportion of UK spectrum that is authorised to market users, used by public sector bodies, and shared across market and public sector users. In December 2013 we published a companion paper to the consultation that provided more granular detail on how access to UK spectrum is provided to different sectors[4]. Today we are publishing on our website an interactive map[5] of spectrum bands showing how spectrum is authorised, for what uses and also for which licence products.

1.24 We will continue to build on this work to give stakeholders more, and better, information on how spectrum is used. One example of this is that, in line with our established policy, we plan shortly to publish more technical information on individual licences. Our key objective is to make it easier for stakeholders to plan changes in their own use and to engage more closely with, as well as challenge, Ofcom's spectrum management plans - for example by identifying new sharing opportunities so as to exploit spectrum more effectively. Increased information on existing use could also facilitate market led activity.

[4] http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/annexes/Spectrum_attribution_metrics.pdf
[5] www.ofcom.org.uk/static/spectrum/map.html

1.25 We will also assess the case for targeted ad-hoc utilisation measurement campaigns to understand better how intensely specific bands are used by specific uses. This could help us address potential instances of congestion and identify opportunities for shared spectrum access.

We will take a leading role in key international spectrum fora, influencing outcomes in line with UK interests

1.26 International cooperation on spectrum management will remain critical to securing increased benefits from spectrum use in the UK. This is because the decisions taken internationally can provide the opportunity for equipment and device manufacturers to exploit economies of scale from harmonisation and standardisation, and also enable the coordination of high power uses across borders.

1.27 We will continue to take an active role in ensuring that international decisions taken at the European and global level are consistent with securing benefits for UK citizens and consumers. We will do so by:

- engaging proactively across international regulatory institutions, building and maintaining relationships and influence so as to enable us to promote and protect UK interests;
- complementing our work in the international groups which deal with the more technical aspects of spectrum regulation with a strong focus on engagement with European policy fora[6] which will continue to be a dominant influence on our spectrum policy;
- taking a leading role in areas which are of greatest significance for specific spectrum policy initiatives in UK;
- increasing our focus outside of Europe to engage with global developments that influence the technology trends that have implications for our spectrum policy; and
- continuing to engage with stakeholders in developing our policy on international regulatory issues.

We have six sector-focused priority areas, which will feature alongside other projects and programmatic activities

1.28 We will continue to consider the evolving needs of all spectrum users and to devote significant effort to supporting these. However, we have identified six sector-focused priority areas that will require particular regulatory attention over the coming 10 years. These sector-focused priorities have resulted from our analysis of future developments in spectrum demand and supply across 12 sectors of use of spectrum[7]

[6]These include the Radio Spectrum Committee (RSC) and the Radio Spectrum Policy Group (RSPG). The RSC plays a key role in ensuring that spectrum is made available according to harmonised technical conditions across the whole of the EU, while the RSPG advises the Commission on strategic issues relating to spectrum management.

[7] See in particular the appendix on future trends in major sector uses of spectrum that we published alongside our consultation document in October 2013: http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-

as set out in our consultation, taking account of feedback from stakeholder responses.

1.29 These priorities relate to:

- **addressing future mobile data demands, recognising the importance of improving mobile coverage and availability of new mobile services;**
- **implementing our strategy for the 700 MHz band and considering the evolution of free-to-view TV;**
- **supporting the government's Public Sector Spectrum Release (PSSR) programme;**
- **addressing challenges around future Programme Making and Special Events (PMSE) spectrum use;**
- **enabling growth and innovation in the Machine–to-Machine (M2M) / Internet of Things (IoT) applications; and**
- **supporting the government in its consideration of the future wireless communication needs of Emergency Services.**

1.30 These priorities are discussed in greater detail in section 5 of this document and we outline, in **Table 2** below the key issues we will be considering as we progress work in these areas. Given the inherent uncertainty of future developments, we have a clearer idea of the focus for our efforts in the short to medium term (three to five years from now) than in the longer term.

1.31 In addition, there will be many other issues of material significance to specific sectors (such as business radio, space and science, radio broadcasting and fixed links) which will require on-going regulatory attention and specific regulatory action at times over the next 10 years.

strategy/annexes/appendix_spectrum_management.pdf . We will be updating this document later in the year once we have all inputs to this from stakeholders

Table 2 - Work programme in support of our priority areas

Priority area	Issues that Ofcom is already considering	Issues that are likely to become relevant within the next 5 years	Issues potentially relevant over the longer term
Mobile data, mobile coverage and availability of new mobile services	• Preparations for WRC-15 (especially AI 1.1) and other ongoing international engagement • Developing a long term perspective on demand and supply options • Assessing the potential role of licence exempt and sharing approaches and implications for the supply balance • Monitoring progress in mobile coverage and networks' performance	• Considering harmonisation opportunities for UK spectrum use opened by international decisions • Applying our approach to assessing and enabling use of additional spectrum for mobile data as relevant • Exploring options for the further extension of geographical coverage of mobile voice and data services	• 5G technology evolution: consideration of new equipment standards and potential impact on spectrum requirements
700 MHz strategy implementation and the future of free-to-view TV	• International engagement on 700 MHz harmonisation and coordination discussions • Initial Cost Benefit Assessment on 700 MHz re-purposing for consultation • Explore opportunities to reduce and avoid future disruption of DTT platform • Engage with industry on role of DTT and the future of free-to-view TV • Participating in international discussions on the longer term future of spectrum at 470-694 MHz	• Final decision on 700 MHz repurposing If appropriate thereafter: • 700 MHz award design if relevant • Work with interested parties to prepare for changes and to monitor progress • Develop detailed plans, set up delivery structures and implement regulatory steps required to enable transition • Monitor developments in market and regulatory developments including TV distribution technologies and implications for the long term role of DTT	• Enabling action and regulatory support to 700 MHz clearance and award, if appropriate
Supporting the PSSR programme	• Undertaking the auction of the spectrum vacated by MoD at 2.3 and 3.4 GHz • Supporting the government on sharing opportunities	• Supporting the government's considerations of mechanisms to secure efficient use of spectrum by public bodies • Leveraging our experience on spectrum sharing into Public Sector spectrum • Moving towards unified information on spectrum usage and frequencies available for shared access across civil and crown holdings	• Supporting the government in future releases
Future of PMSE spectrum access	• Understanding current and future PMSE demand and the feasibility of different supply options, including access to alternative bands • Considering the future role of new PMSE equipment technologies • International engagement on initiatives over PMSE harmonisation in Europe	• Reviewing our approach to PMSE spectrum management • Assessing the impact of planned spectrum changes on PMSE and implementing mitigating actions	• Considering the potential relevance of new technologies to PMSE applications
Enabling growth and innovation in Machine-to-Machine (M2M) / Internet of Things (IoT) applications	• Improving our understanding of how M2M/IoT requirements will vary across applications and sectors • Enabling access by LE SRDs to the 870/915 MHz band and considering the case for light licensing regime for devices requiring higher transmission powers and duty cycles • Progressing our work on TVWS	• Understanding how the emergence of new technical standards could influence the evolution towards horizontal platforms for the Internet of Things and impact on requirements	• Considering prospects for DSA techniques enabling self-managed access to spectrum to M2M / IoT devices requiring quality-of-service assurance
Supporting the government in considering future ES communications needs	• Providing advice on existing licensing and spectrum environment of bands used by Emergency Services • Giving technical advice about mobile networks meeting ES needs • Representing UK interests in International PPDR spectrum harmonisation negotiations	• Providing advice as requested by the government on potential availability of spectrum and costs • Providing support to the government, if required, on the planning and implementation of any required transition between spectrum bands	• Ongoing advisory role to the government in Emergency Services use of spectrum through PSSPG and UKSSC

We will work closely with the government within its overarching UK Spectrum Strategy

1.32 The scope of this spectrum management strategy is determined by Ofcom's role as the body that authorises spectrum use, which at present we do in relation to around 75% of total spectrum access. Our spectrum management strategy is also a significant component of the overarching UK Spectrum Strategy that the government has recently set out.[8] This covers all spectrum, including that used and managed by government departments and other public sector agencies independently of Ofcom.[9] It will remain important for us and the government to continue working effectively together. This will include ongoing support to the government on changes to public sector spectrum access whether these relate to spectrum release or to new access requirements. This work recognises that uses such as those relating to defence, public safety and transport applications deliver significant social value and that it remains important that they do so by using spectrum efficiently.

We will monitor the effects of our strategy and keep it under review

1.33 We will track the effects of our strategic approach and priority work by monitoring how key aggregate metrics of spectrum use change over time. This will include tracking the proportion of spectrum that is used by the public sector and accessed by the market, the amount of spectrum managed in blocks by licensees following releases by both Ofcom and the public sector and the amount of spectrum authorised through licence exemptions. It will also include new metrics to track how much spectrum is shared in different ways e.g. geographic and / or dynamic sharing.

1.34 More broadly, we will continue to monitor changing spectrum demands and to keep this strategy under review accordingly. As consumer behaviour, markets and technologies continue to evolve our strategic direction and priorities are likely to require adjustments and changes to how we manage spectrum and, therefore, allocate our efforts and resources.

[8] https://www.gov.uk/government/publications/spectrum-strategy

[9] Ofcom is responsible for authorising all spectrum use with the exception of that by Crown bodies which is accessed under Crown immunity. 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.

Section 2

Introduction and purpose

This document discusses Ofcom's Spectrum Management Strategy for the next 10 years

2.1 Radio spectrum is a major asset to the UK. A recent study undertaken for the government indicated that it contributes over £50bn to the economy each year.[10] The services that use radio communications underlie many aspects of our lives and are critical to areas such as air travel, Emergency Services, mobile broadband, radio and television broadcasting, defence, and the management of utilities. As such, how spectrum is managed and made available for use is of critical importance.

2.2 The purpose of this document is to provide a concise discussion of our strategy for managing spectrum over the next 10 years.

2.3 This statement follows a consultation we published in October 2013[11] and reflects input provided by stakeholders in their responses to that consultation. We draw attention, later in this section, to a number of the main points from stakeholders that we have taken on board, although the rest of this statement is written without explicit reference to these. We include a separate annex which provides a summary of the points raised in stakeholder responses to the consultation and our reactions to those.[12]

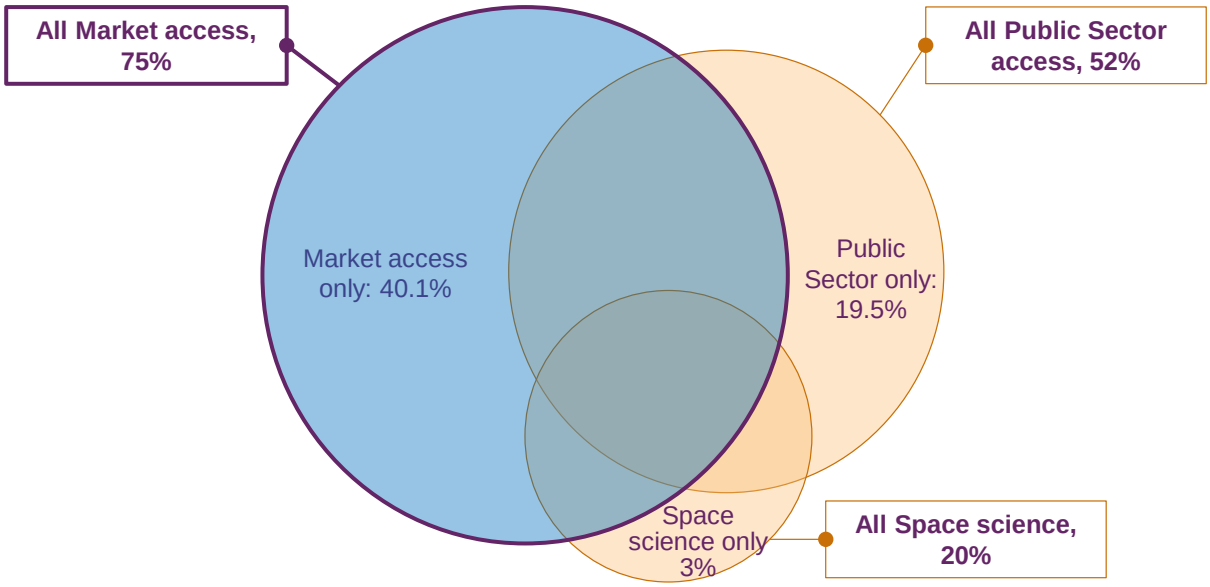
Scope of this spectrum management strategy

2.4 Two acts of Parliament[13] give Ofcom responsibility for managing UK spectrum, although they also provide for the government to direct us in execution of our spectrum functions. [14] Under our statutory duties and powers, Ofcom is responsible for authorising all uses of spectrum with the exception of use by Crown bodies, which are typically central government departments.[15] At present, Ofcom authorises use in 75% of the spectrum bands as illustrated in figure 1 below[16], although a significant proportion of spectrum bands is also used and managed by Crown bodies, primarily

[10] https://www.gov.uk/government/publications/impact-of-radio-spectrum-on-the-uk-economy-and-factors-influencing-future-spectrum-demand
[11] http://stakeholders.ofcom.org.uk/consultations/spectrum-management-strategy/
[12] http://stakeholders.ofcom.org.uk/consultations/spectrum-management-strategy/statement/annex.pdf
[13] The Communications Act 2003 and the Wireless Telegraphy Act 2006
[14] This requires the Direction to be authorised by Parliament except in specific circumstances (e.g. relating to the interests of national security, public safety and public health or in the interests of relations with other governments or to secure compliance with international obligations)
[15] 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 Treasury are generally considered to be Crown bodies.
[16] Figure 1 illustrates our estimates with reference to all spectrum between 87.5 MHz and 80 GHz. Spectrum bands above 1 GHz have been weighted so that 10 MHz at 1 GHz have the same weight as 100 MHz at 10 GHz.

the Ministry of Defence (this spectrum is often referred to as "public sector spectrum").[17]

Figure 1- Market access, Space science[18] and public sector access to UK spectrum



2.5 Ofcom's duties and powers to authorise spectrum use cover all frequency bands. Similarly, Crown bodies that are accessing spectrum under Crown immunity are not restricted as to which spectrum bands they can access. Clearly, however, it would not make sense for Ofcom to authorise (non-Crown) users in a way that took no account of existing Crown users - nor would it make sense for Crown users to access particular spectrum bands without taking account of (non-Crown) users that have already been authorised by Ofcom - as to do so would risk harmful interference to the detriment of all sides. Coordination is required, both at a policy level in terms of broad allocation of spectrum bands to different uses and, at a more operational level, where specific uses could cause interference to, or suffer interference from, other users that are in-band and / or in adjacent bands.

2.6 In light of this need for coordination, one of the functions of the UK Frequency Allocation Table (UKFAT) is that it records a de facto, mutual understanding between Ofcom and the government over which bands are deemed to be allocated for non-Crown use (where use is authorised by Ofcom) and which bands are deemed to be allocated to Crown users (the UKFAT also identifies bands which are deemed to be allocated to both civil and crown use, although the more detailed basis on which this shared access takes place is not recorded in the UKFAT).[19] The UKFAT does not have legal force but both Ofcom and the government make decisions that reflect this de facto, mutual understanding on band allocation between Crown and non-Crown use.

2.7 This strategy focuses on the spectrum functions and duties for which Ofcom is responsible. In practice, therefore, it focuses on the 75% of the spectrum bands in

[17] See http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/annexes/Spectrum_attribution_metrics.pdf for further details

[18] Market uses are those authorised by Ofcom. Space science uses are not typically authorised as they are receive-only or use spectrum in outer space and so have been identified separately. Use of spectrum for Space science is funded by Government

[19] The UKFAT performs a number of other functions, such as recording the type of service for which is band is allocated – see footnote 39 in Section 4 for more details

which we authorise spectrum use (although, as explained later, we expect this proportion to increase with the government's Public Sector Spectrum Release programme) and on the authorisation of non-Crown use of spectrum. It does not, except where explicitly stated (for example in relation to the Emergency Services) consider Crown use of spectrum, such as those relating to defence, even though these represent important, and socially valuable, uses of spectrum.

2.8 Our principal duty is to further the interests of citizens in relation to communications matters and of consumers in relevant markets, where appropriate by promoting competition. As explained further in Section 4, we are required to secure the optimal use for wireless telegraphy of the electro-magnetic spectrum amongst other duties. This is of particular relevance when undertaking our spectrum functions. Legislation gives us broad discretion in deciding how best to fulfil our spectrum duties. Because our decisions have significant long term impacts on spectrum use, it is important that we take a strategic approach to managing this valuable resource.

Securing optimal use of spectrum in the UK will require effective coordination between Ofcom and the government

2.9 Where is has been necessary to do so, Ofcom and the government have worked together in making a number of major spectrum decisions. Examples include: the clearance of 800 MHz that required Ofcom and the government to agree the case for a change of use, the government to fund the clearance and Ofcom to manage the clearance process including managing the allocation of clearance funds.

2.10 The increasing contribution and importance of spectrum to the economy, and to the delivery of the other public policy priorities, lies behind the government's creation of an overarching UK spectrum strategy. [20] Covering both spectrum managed by Ofcom and public sector spectrum, the government's document sets out a 13 point action plan to achieve the government's vision of doubling the contribution of spectrum to the UK economy from £50bn a year to £100bn a year.

2.11 Alongside the UK Spectrum Strategy, the government also published an update to its Public Sector Release (PSSR) Programme[21] in which it has confirmed its commitment to the release 500 MHz of Public sector spectrum for private sector (non-Crown) uses. Sharing of spectrum of between the Public sector and other uses forms an important aspect of this programme.

2.12 While we do not have a duty to promote economic growth, our duty to secure the optimal use of spectrum gives us a critical role in making sure that spectrum is available for the mix of uses which generates the greatest total value for citizens and consumers, including both private and wider social value. This spectrum management strategy will therefore be an important contribution to the government's overarching UK Spectrum Strategy.

2.13 We will continue to work with the government to ensure that we can secure the best use of spectrum for the UK. Indeed, the need to do so reflects the increasing *interaction* between spectrum managed by Ofcom and the public sector spectrum for a variety of reasons:

[20] https://www.gov.uk/government/publications/spectrum-strategy
[21] Ibid.

- Public sector spectrum releases, or sharing arrangements for new uses of spectrum, can have a significant impact on existing authorised users in adjacent bands. Similarly, changes in spectrum access for market users can impact on public sector uses. Decisions on such changes of use, therefore, need to be co-ordinated.

- The expected increase in spectrum sharing between public sector and market users could be enabled by leveraging the experience and tools that Ofcom has developed into the public sector. For example, the geo-location database approach we are working to enable in the UHF TV band could be relevant to enable Dynamic Spectrum Access for commercial uses in Public sector spectrum.

- There can be strong synergies where some parts of a spectrum band are managed by Ofcom and other parts by Crown bodies (for example, in the 450-470 MHz band, about two thirds of spectrum is managed by Ofcom and one third by the Home Office). A strategy to change the way the band is used is may be sub-optimal if it does not consider the band as a whole.

- Delivering a government public policy objective could depend on access to spectrum managed by Ofcom. For example, the future delivery of broadband applications for the Emergency Services could require access to mobile spectrum awarded by Ofcom.

- UK positions for international negotiations need to take into account the government's public policy objectives and public sector use of spectrum as well as market uses of spectrum.

2.14 Managing spectrum for major events often requires coordination across public sector and private users as well. For example, the MoD supported the 2012 London Olympics spectrum plan through the provision of over 2000 Defence frequencies to manage the Games and to provide additional spectrum capacity for the broadcasters. The MoD is already engaged with the planning team responsible for the Commonwealth Games in Glasgow this year to provide similar spectrum support. The MoD also shares spectrum with PMSE users on a day-to-day basis, supporting, for example major sporting events (such as the Olympics, Premier League football matches, F1 Grand Prix) and other national events such as Royal weddings and State funerals.

2.15 We will continue to work with the government as both our spectrum management strategy and the government's UK Spectrum Strategy evolve over time to meet the changing demands.

Our Spectrum management strategy reflects stakeholder responses to the consultation we published in October 2013

2.16 On 2nd October we published a consultation document on our Spectrum Management Strategy. Alongside this we published an Appendix of sector roadmaps[22] that provided our view of the likely trends in supply and demand for all of the sectors for which we authorise spectrum use.

[22] http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/annexes/appendix_spectrum_management.pdf

2.17 We received a significant volume of comments relevant to this Appendix through stakeholder responses to the consultation. Stakeholders have also indicated they will provide further relevant input over the coming months. This includes, in particular, work that the Spectrum Policy Forum is undertaking across a range of sectors, which they initiated as part of their engagement with the government's UK Spectrum Strategy. We will publish an update to our Appendix on sector roadmaps when we have been able to gather and consider this additional stakeholder input.

2.18 We received 44 responses to our consultation, of which 6 were confidential. Non-confidential responses are available on our website at http://stakeholders.ofcom.org.uk/consultations/spectrum-management-strategy/?showResponses=true. We received comments that represented the views of all of the sectors that we identified in our sector roadmaps.

2.19 Most respondents broadly agreed with us on many of the general issues, such as our high-level spectrum management principles (although many reemphasised the importance of taking the wider social value of spectrum use into account), our methodology for analysing market developments and the key challenges for spectrum management over the next 10 years. Respondents also emphasised the specific requirements of their sector. But while respondents generally agreed with the priorities we have identified, views diverged about how we should be taking these forward and on the likely outcome of decisions.

2.20 Having considered the many comments and suggestions made by stakeholders we have made changes to our priorities. In particular we have developed a more focused priority list that is limited to those aspects of our work that will be targeted to addressing specific spectrum challenges caused by changes in spectrum demand.

2.21 We have identified two specific elements of work, previously identified under the mobile data priority, that we agree with respondents should be priorities in their own right. The two additional priorities are:

- enabling innovation in machine-to- machine (M2M) / Internet of Things (IoT) [23] applications. We agree with stakeholders that M2M/ IoT developments could deliver significant benefits through innovation across a variety of fields, as well as having potential implications for spectrum demand across different bands and types of spectrum access;

- supporting the Public Sector Spectrum Release (PSSR) Programme. We agree with stakeholders that the scale and potential relevance of this programme to the future supply of spectrum for different uses is such that this area should warrant priority attention in its own right.

2.22 We discuss these areas, together with other priorities, in Section 5 of this document.

2.23 We have removed our work on competing demands for the 450-470 MHz band work from the list of priorities discussed in Section 5. This change reflects the limited interest expressed by stakeholders in the prospect of using this band for LTE for public mobile networks in the long term, which reduces the prospect of us needing to consider the case for a significant programme of work to enable this change of use.

[23] There is no universally agreed definition of the Internet of Things or Machine-to-Machine applications. However, in general both terms are used for communications that involve communication with at least one machine. In this document we, therefore refer to M2M/IoT to incorporate all applications that provide communications where this is not solely between people

However, this band remains an important area for attention with the scope of our work likely to focus on changing requirements of incumbent users and potential increases in interference from the continent.

2.24 We have also repositioned two topics that we identified in our consultation as cross-cutting priorities - spectrum sharing and RF performance standards. We discuss these in Section 4 of our statement as aspects of our strategy to which we will give a new or increased emphasis, differentiating them from other priorities (discussed in Section 5) which are defined around specific challenges raised by sector trends in spectrum demand and supply.

2.25 We have also sought to provide more clarity on our approach to two issues that raised significant stakeholder comments and concerns. These are:

- how we take into account the wider social value of spectrum use; in Section 4 we provide specific additional explanation of both why our duties require that we take social value into account and also how we do this in practice; and

- how we will manage the risk of harmful interference to existing users associated with greater levels of sharing and repurposing of spectrum (including public sector spectrum); in Section 4 we explain that we will maintain our increased focus on ensuring that potential coexistence challenges, including those from greater levels of sharing, are appropriately managed.

2.26 Finally, stakeholders were supportive of our work on spectrum attribution metrics and felt that the additional information would be useful. However, they expressed concern about how we might look to use these metrics in future. In particular, they advised caution about their use as “measures of success” or “KPIs”.

2.27 As we discuss further in Section 4, we intend to build on these metrics to monitor how spectrum use changes over time as part of wider work on spectrum information. Our key objective in this area is to provide more and better information on spectrum use to stakeholders so to make it easier for them to plan their use and engage with spectrum regulatory processes.

2.28 We will also monitor some of the high level attribution metrics we introduced in the consultation to track how spectrum use changes over time as a result of our future work and other relevant initiatives by the government. However, we will not consider these metrics as targets in their own right. We discuss this further in Section 6 of this document.

Structure of this document

2.29 In the rest of this document we cover the following topics:

- Section 3 describes the key developments that are likely to shape the context for spectrum management over the next 10 years.

- Section 4 outlines our strategy for spectrum management, highlighting specific aspects to which we will give a new or increased emphasis in response to the likely challenges for managing spectrum in future. The themes we discuss in this section will be relevant to many aspects of Ofcom’s spectrum work over the next 10 years, including our priorities, other major projects and our more programmatic activities. Where relevant, we also outline specific actions we expect to take in relation to each of these themes.

- Section 5 discusses our key priorities for the next 10 years. These result from the review of future developments discussed in our consultation document and the contributions made by stakeholders in their responses. In discussing these priorities, we also outline our likely next steps in each of these areas. Both the list of priorities and likely next steps are subject to on-going review and could change as a result of new developments that might require regulatory action.

- Section 6 discusses how we will monitor the effects of our strategy and keep it under review. This will include tracking some of the high level metrics on spectrum use introduced in our consultation, as well as continuing to monitor changing spectrum demands and responding to developments in consultation with stakeholders.

2.30 In addition to this main document, we are also publishing an Annex in which we address the main points raised by stakeholders in their consultation responses. This is available here: http://stakeholders.ofcom.org.uk/consultations/spectrum-management-strategy/statement/annex.pdf

Section 3

Future spectrum management context

3.1 In this section we discuss key developments that are likely to be relevant to the way in which we manage spectrum in the UK over the next 10 years. These include trends in the key sectors relying on access to spectrum authorised by Ofcom as an input in their services and applications, technical developments that could influence how spectrum is accessed and managed in future and the implications of growing, competing demands on spectrum management.

3.2 Whilst future developments in spectrum use are inherently uncertain, it is important for us to maintain an informed perspective on their direction of travel. As consumer behaviour, market dynamics and technologies in the communications sector evolve, the consumer and citizens benefits associated with existing and new spectrum uses are likely to change. This implies that the balance of spectrum uses that leads to optimal use, and thereby furthers the interests of citizens and consumers, will vary over time. Moreover, where regulatory action is required to enable major changes in use, it may, in some cases, need to begin many years in advance of the change themselves.

Demand for many spectrum uses is likely to grow, sustaining the need to adopt more spectrally efficient technologies

3.3 Over the next ten years, evolving requirements for wireless services across many sectors will place new pressures on spectrum use. At the same time, new technologies will enable spectrum to be used more efficiently, helping to mitigate the impact of new demands in many cases. The development and use of more efficient technologies will be largely led by industry. Ofcom is committed to ensuring a regulatory environment that is conducive to the development of technical innovation that realises the potential of new spectrally efficient technologies

3.4 Below we summarise key developments across the main sector uses of spectrum, excluding Crown uses. In Section 5, we discuss how some of these developments raise challenges that are expected to require priority regulatory action by Ofcom, driven by the potential impact that changing requirements could have on benefits for citizens and consumers in future and the amount of resource that will be needed to facilitate them.

Mobile data

3.5 Growing demand for mobile data will have important implications for the management of spectrum over the next decade. A greater proportion of the population can now afford, and choose to buy, internet-enabled wireless devices such as smart phones and tablets. Thus a growing proportion of the population uses mobile data services, and each user tends to consume more data. The rising popularity of over-the-top services, including on-demand video, is likely to sustain mobile data consumption over time. These trends could see the volume of data consumed over mobile networks grow by many orders of magnitude; recent analysis for Ofcom suggested a central estimate of demand in 2030 might be of 80 times the 2012 level,[24] although projections of this growth rate are subject to high levels of uncertainty. Moreover,

[24] http://www.ofcom.org.uk/static/uhf/real-wireless-report.pdf

demand will be highly concentrated in urban, hot-spot locations, placing even greater pressure on spectrum access at these locations. As the consumption of mobile data grows, consumer expectations around widespread data coverage are also likely to increase.

3.6 Technological developments will moderate pressures on spectrum from growing mobile data demands. The roll-out of LTE enables more information to be sent over a given amount of spectrum than 3G and future moves to LTE-Advanced will increase this further. The deployment by mobile network operators of heterogeneous networks, which incorporate small cell technologies into network topologies and offload data onto fixed networks, will also play an important role in meeting growing mobile data demand.

3.7 Over the next 10 years mobile technologies will evolve towards 5G. Today, there are different visions for the defining characteristics of 5G. These include the need to provide ever increasing data rates, the ability to cater for different applications, including M2M/IoT, the flexibility to access spectrum where and when needed in a dynamic way, the ability to combine the provision of very high network capacity in dense population areas with ubiquitous coverage, and reliability for specific applications that will require them. Depending on future technology trajectories, 5G spectrum use and requirements could differ significantly from that of 3G and 4G technologies.

M2M / Internet of Things (IoT)

3.8 The number of machine-to-machine (M2M) devices using wireless communications with little or no human interaction, is expected to grow significantly over the next decade, driven by a range of new applications in many fields, including energy, transport, health and the environment. As more and more devices become internet enabled, there will be greater opportunities for application developers to make devices used in different fields and for different purposes talk to one another. This could lead to significant developments for the Internet of Things, in which network effects could mean that the value provided by individual applications increases as more and more applications and devices emerge and connect to each other.

3.9 Data demands from M2M / IoT applications are likely to vary significantly across different applications. This means that a variety of different combinations of technologies, spectrum bands and types of spectrum access (e.g. licensed or licence exempt) could be relevant to sustaining growth and innovation in these fields. Although it is unlikely that the data demands from M2M / IoT will be as great as those for devices like smartphones and tablets, strong growth in the number of connections and transactions could have implications for spectrum demand and service coverage.

3.10 The Utilities sector currently uses M2M applications to manage a variety of critical operations and it is expected that this will continue and increase.

DTT

3.11 DTT remains one of the primary means by which UK TV households receive TV services. It is the sole means of TV reception for over 40% of UK TV households and is used by many more in combination with other TV platforms. Levels of linear television viewing are remaining stable despite consumers accessing more catch-up and video-on-demand services through the internet. This is likely to sustain the relevance of DTT for many years.

3.12 Over time, there may be a shift toward higher video quality over all TV broadcast platforms in the coming years as High Definition (HD) and even Ultra High Definition (UHD) programming becomes increasingly available, requiring greater capacity. However, use of new standards such as DVB-T2 and MPEG-4 could mitigate capacity requirements by allowing for more information to be carried over the same amount of spectrum. Going forward the adoption of HEVC will improve the efficiency of video compression further.

PMSE

3.13 Programme Making and Special Events (PMSE) refers to wireless services used in the production of multi-media content and live events such as wireless cameras and microphones. These support a range of activities including news gathering, sports events, live concerts, films, theatre, religious, cultural and educational activities. The growing scale and complexity of many professional productions means that spectrum requirements for some users are likely to increase. On the other hand, the spectrum available to PMSE is reducing. PMSE users typically access spectrum on a secondary basis. But opportunities to share spectrum reduce when bands are re-purposed to new users that do not allow secondary uses (such as wide-area mobile broadband). The recent 4G award at 800 MHz and 2.6 GHz has reduced the spectrum available to PMSE and further future anticipated changes could pose additional challenges.

3.14 The introduction of digital technologies and more efficient analogue systems might help in allowing PMSE users to use spectrum more efficiently. There is also scope for greater planning and coordination by users, especially where multiple devices are concentrated at a single location for a particular event.

Business Radio and Utilities

3.15 Business radio provides narrowband and wideband communications for applications that in many cases are of critical importance to a large variety of end users, ranging from utilities and transport operators, to hospitals, care homes, industrial sites and taxi firms. The evolving needs of many business radio and utility users are likely to increase pressures on the spectrum available to them. Data-rich wideband applications will be increasingly important for many other business radio users.

3.16 Many of the existing and future uses of the Utilities sector will be more intelligent and sophisticated M2M applications and are likely to have the same characteristics as these applications.

3.17 Many of the communication devices used by these industries are migrating to digital technology, enabling more intensive use of spectrum and stimulating demand by supporting new data applications. Business radio users also currently often rely on public mobile networks to provide broadband functionality.

Emergency Services (ES)

3.18 Emergency Services are considering what they will require from next generation communications technologies. New data-rich Public Protection and Disaster Relief (PPDR) applications could, for example, allow fire-fighters to download building plans or police officers to upload high-definition photographs and videos to a central database. PPDR systems cannot currently deliver these services. An international debate has emerged on whether the Emergency Services should access additional spectrum to take advantage of new broadband-enabled applications. The

government has setup the Emergency Services Mobile Communications Programme (ESMCP) to consider how to meet future communication requirements for the Emergency Services in Great Britain.

Satellite

3.19 A range of commercial satellite-based services rely on spectrum including:

- satellite direct to home TV;
- satellite direct to home broadband;
- other fixed satellite services including infrastructure links and VSAT services; and
- mobile satellite services.

3.20 The move towards HD TV and potentially UHD services may increase Satellite TV capacity requirements. Residential broadband propositions based on satellite delivery could also become more popular in future, potentially placing greater demands on Ka-band spectrum on a dedicated basis (if sufficient demand emerges). The availability of terrestrial networks has reduced the need for fixed satellite services providing trunk telephone connectivity – though such services remain important to provide mobile networks in rural areas and international backbone internet in countries outside the UK. Infrastructure links today typically support news gathering or high quality video links for delivering TV content.

Science use

3.21 Science use of spectrum is dominated by Space use for scientific research – for example, Earth Exploration Satellite services (EES) and radioastronomy – as well as for meteorological services (weather forecasting etc.). Growing interest in research into issues such as climate change is leading to more frequent launches of EES and meteorological satellites. Space science use of spectrum includes both passive and active uses and the use of spectrum at higher frequencies (beyond 275 GHz) for these purposes is increasing.

3.22 Terrestrially science uses of spectrum also contribute to scientific research in the fields of meteorology and climatology. These uses include meteorological radar, radiosondes and radiometers.

Fixed links and wireless backhaul

3.23 Fixed links are essential for a variety of services including, predominantly, backhaul for mobile networks, but also distribution of TV material from studio to transmitter site and connecting nodes within public, private and corporate networks.

3.24 Demand from mobile backhaul is changing as network architectures evolve:

- MNOs use fixed links and fibre as complements. Fixed links remain important, especially for reaching more remote areas where fibre may be prohibitively expensive to install or in cases where rights of access to install fibre are problematic in urban areas.

- MNOs are merging and sharing their infrastructure, reducing the number of fixed links required to macrocells but increasing capacity requirements along consolidated routes.

- An increase in the deployment of localised, high capacity 4G cells could raise demand for millimetre wave spectrum at frequencies above 60 GHz.

- Wireless fixed links could be an important backhaul solution for small cells deployed by MNOs to meet the need for extra capacity in urban areas.

Radio broadcasting

3.25 On average, around 90% of UK adults listen to the radio each week[25]. Over the past 5 years, the number of people who tune in has remained consistent though listening hours have declined slightly, with more prominent declines in younger demographics[26].

3.26 The government is working with industry towards a digital radio switchover and it has set a series of benchmarks to refer to in order to set a switchover date. These include:

- 50% of all radio listening is via digital platforms; and

- national Digital Audio Broadcasting (DAB) coverage is comparable to FM, and local DAB reaches 90% of the population and all major cities

3.27 As of December 2013, the digital share of all radio listening stood at 36.1%.[27] While the BBC national digital coverage is comparable to FM coverage, the national commercial digital multiplex is estimated to cover 89.5% of homes and aggregate coverage by local DAB multiplexes reaches 71.7% of households.[28] Achieving the conditions for a digital switchover is therefore likely to require some time.

Aeronautical and maritime

3.28 Aeronautical applications of spectrum include communications between the ground and aircraft, ground-based navigation aids, ground-based radars and airborne systems such as altimeters and weather radar. Maritime radio, amongst other uses, provides for the safety of people and vessels at sea. It enables communication between coast stations, port/harbour authorities and vessels, on-board navigation aids and radar and the automatic tracking of ships at sea. These uses are inherently global in nature and this is reflected in the extent to which the international regulatory regime influences the use of spectrum by the sector. Ofcom and specialist regulators (the Civil Aviation Authority and the Maritime and Coastguard Agency) represent the UK interests in international institutions and collaborate on spectrum use in the UK.

3.29 In both sectors there is likely to be an increase in data-based communications systems for both voice and data over the medium to long term. These increased demands could be mitigated to some degree by a shift to using more spectrally efficient digital equipment by aeronautical and maritime users.

[25] http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr13/2013_UK_CMR.pdf
[26] http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr13/UK_3.pdf
[27] http://www.rajar.co.uk/docs/2013_12/RAJAR%20Q4%202013%20Chart%202%20-%20All%20Digital%20Radio%20listening%20-%20clean.pdf
[28] http://stakeholders.ofcom.org.uk/binaries/research/radio-research/drr-13/2013_DRR.pdf

Amateur and Amateur satellite

3.30 Amateur radio is the use of spectrum for non-commercial communication (including radio hobbyists), training and experimental purposes. Amateur satellite services use space stations or satellites for the same purposes. Amateur radio can foster technical innovation in fields such as telecoms, broadcasting and aerospace, playing a part in the development of new radio technologies.

3.31 Users must pass an exam to receive a licence, which obliges them to avoid causing interference with other wireless radio services. The total number of amateur licences has increased by 10% in the past three years.[29]

3.32 Citizen's Band radio is licence exempt, short-range radio communication between individuals which may be used for some business services.

Addressing the growth in competing demands for spectrum will require a mix of spectrum re-purposing and sharing

3.33 The adoption of more efficient technologies will go some way to meeting these increased demands by enabling more information to be carried over a given amount of spectrum.

3.34 Technological advance also enables services to be provided using ever higher frequencies making larger segments of the spectrum usable. For example, fixed wireless services, which support the delivery of many other end-user applications, are now beginning to use spectrum above 60 GHz, after a historic focus on bands below 18 GHz, and commercial satellite services that historically used spectrum below 12 GHz have now expanded their use into 28 GHz. This effect could also extend the range of the "sweet spot", where demand for spectrum is greatest, up to perhaps 6 GHz, providing some level of mitigation for forecast increases in demand.

3.35 However, we expect the net effect of demand and technology trends will still lead to increased pressures on access to spectrum in some specific frequency ranges. Competing demands will not be uniform, but they will vary significantly both across:

- **frequencies** - spectrum is heterogeneous and different frequencies are suited to different applications. The availability of equipment capable of operating in specific frequency ranges also has a significant influence on spectrum demand. In the short to medium term, pressures on spectrum access will continue to be particularly intense in the 300 MHz to 3 GHz range, which is attractive to many uses because of its propagation characteristics. In the longer term, competing demands for higher frequency spectrum are likely to increase as larger bandwidths are required to meet increasing capacity requirements and as technology evolves to enable this higher frequency use; and

- **locations** - the geographical distribution of users is a key determinant of spectrum demand, In future, growing requirements will be most acute in areas of high population density, where spectrum use is already most intense.

3.36 There is no unused spectrum available for new release across a wide range of bands. We therefore expect to see:

[29] http://licensing.ofcom.org.uk/radiocommunication-licences/amateur-radio/guidance-for-licensees/monthly-stats/

- a continuing emphasis on **changing the use of given spectrum bands to more valuable uses.** Re-purposing spectrum to facilitate its optimal use is likely to remain an important means of addressing changing spectrum needs over the next 10 years. Future UK spectrum re-purposing is likely to be heavily influenced by international harmonisation initiatives and by cross border coordination of high power uses (notably for DTT in the UHF band); and

- an increase **in shared access to spectrum amongst different uses.** This will become more important as the opportunities to clear spectrum (particularly on a nationwide basis) become ever more challenging and as technical and regulatory developments enable more efficient re-use of spectrum where and when it is needed.

Section 4

Our strategic approach and direction in managing spectrum

4.1 In this section we summarise our strategic approach to spectrum management. This builds on the approach in Ofcom's *Spectrum Framework Review*[30] (SFR) of 2005 and is informed by our experience of managing spectrum since that time, also taking account of the nature of new challenges that we anticipate.

4.2 In particular we outline:

- the range of duties that we consider when making spectrum policy decisions, including those which go beyond the aim of securing efficient spectrum use;
- the three strategic objectives around which our spectrum management activities are focussed; and
- why we need to combine market forces and regulatory action to secure the optimal use of spectrum.

4.3 We also highlight specific aspects of our strategic approach where we intend to place a new or increased emphasis as a result of the challenges that we expect to face. In particular we highlight a greater emphasis on:

- exploring proactively the opportunities for increased spectrum sharing;
- maintaining an increased focus on the appropriate assessment of potential coexistence challenges;
- promoting improvements in radio frequency (RF) performance of transmitters and receivers to reduce future coexistence challenges and enable greater intensity of spectrum use; and
- improving the quality and quantity of information we make available on spectrum use.

4.4 Finally, we discuss the continued importance of the international dimension of spectrum management and the need for us to take a leading in role in international discussions that are of greatest relevance to decisions in the UK.

Ofcom has specific duties related to spectrum in the UK as well as a wide range of other duties that need to be carefully balanced

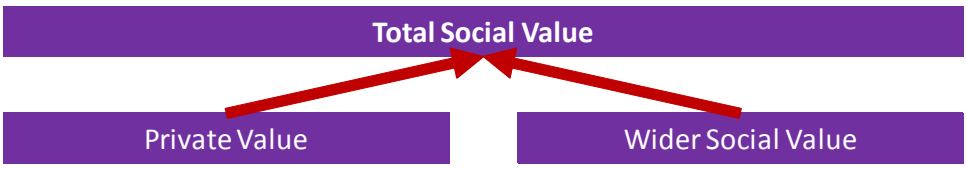
4.5 Ofcom's principal duty, in carrying out its functions, is to further the interests of citizens in relation to communications matters and of consumers in relevant markets, where appropriate by promoting competition. We are required, amongst other things, to secure the optimal use for wireless telegraphy of the electro-magnetic spectrum. This is of particular relevance when carrying out our spectrum functions.

[30] http://stakeholders.ofcom.org.uk/consultations/sfr/

4.6 We consider that, in general, the optimal use of spectrum is most likely to be secured for society if spectrum is used efficiently, that is if it delivers the maximum benefits (or value) for society.[31] The total value to society from spectrum use derives from two broad sources of value, namely, private value and wider social value as depicted in Figure 2 below.

4.7 The private value of spectrum use is the value (for the consumer and service provider) generated as a direct result of the use that is made of it. The wider social value of spectrum use is the value (for others) that is generated indirectly, or as a by-product of the use that is made of it.

Figure 2: Components of value to society from spectrum use



4.8 When considering the benefits (or value) of spectrum use, therefore, we consider all sources of value, whether or not these can be monetised (i.e. can be captured in the price that is paid for the service provided). These additional sources of value include the indirect benefits ("wider social value") that society derives from the use of spectrum (e.g. as a result of increased social cohesion, or the plurality of the media). Whilst putting a value on the indirect value of spectrum use can be challenging it is still possible for robust decisions to be reached on the basis of a qualitative assessment of the relative wider social value of services.

4.9 A specific example is where we carried out significant analysis in the Digital Dividend Review (DDR) to test the hypothesis that terrestrial TV services generated a significant increment in wider social benefits compared to potential alternative uses of cleared DDR spectrum. This analysis included the use of complex consumer research methodologies to understand the relative wider social values citizens placed on a variety of potential future uses of the DDR spectrum. Whilst we identified specific sources of wider social value deriving from alternative uses, including DTT, we found that these were not sufficient to alter the ranking of these services based on private value alone.

4.10 Alongside our principal duty (to further the interests of citizens in relation to communications matters and of consumers in relevant markets, where appropriate by promoting competition) and our duty for securing optimal use of spectrum, we have a wide range of other duties (set out in the Communications Act 2003 and the Wireless Telegraphy Act 2006[32]) that are relevant to, and impact on, our spectrum decisions. These include:

[31] There are, however, circumstances in which the efficient use of spectrum may not secure the optimal use of spectrum. In particular, we need to consider the interests of particular groups in society, as set out in our general duties. Put simply, if efficient use can only be secured at a significant cost to a particular group of citizens or consumers, then securing that increase might be efficient overall, but we would also need to consider whether this outcome would result in optimal use in all the circumstances.

[32] See in particular sections 3 and 4 of the Communications Act 2003 and section 3 of the Wireless Telegraphy Act 2006.

- *Encouraging the availability and use of high speed data transfer services throughout the UK,* spectrum can be a relevant input to delivering this.

- *Securing the availability throughout the UK of a wide range of electronic communications services,* again spectrum can be a relevant input to delivering this.

- *Securing the availability throughout the UK of TV and radio services of high quality and wide appeal, and duties relating to fulfilling the purposes of public service broadcasting in the UK,* we believe the use of spectrum for DTT is currently the most appropriate way of meeting this objective and shape our spectrum policy accordingly.

4.11 When taking decisions on spectrum matters we consider all relevant duties.

In seeking to secure efficient use of spectrum our activities focus on three strategic objectives

4.12 Our spectrum-specific activities – of which there are many – can be thought of as addressing one of three objectives, each of which contribute in different ways to the efficient use of spectrum:

- provide and maintain efficient and effective spectrum access in UK;

- enhance and maintain the potential future value of spectrum use; and

- enable recycling of spectrum from lower to higher value uses and users. This objective can be further divided into:

  - creating the right environment for market forces to drive spectrum recycling and re-purposing; and

  - taking regulatory action where necessary to overcome barriers to the ability of market forces to deliver a value enhancing change in use or user.

Provide and maintain efficient and effective spectrum access in UK

4.13 It is illegal for anyone, apart from the Crown, to use spectrum[33] in the UK without first being authorised to do by Ofcom, either by holding a WT Act licence to use spectrum or under the terms of a specific licence exemption. The terms of the licence or licence exempt authorisation will set out the specific technical (and other) conditions that the user must abide by, including the frequencies authorised, the power limits, etc. It follows from this requirement for Ofcom's authorisation that a central part of our activities is concerned with the creation of new authorisations and the management, maintenance and development of the licensing and general authorisation regime.

4.14 New authorisations in respect of significant blocks of spectrum that are unused, or which will be vacated by current users in a defined timescale, are generally assigned through auction. Where smaller amounts of unused spectrum become available it may be more appropriate to use administrative allocation tools (e.g. first come first served) or make the spectrum available for access under one of the existing Ofcom licenced products. Where the most valuable uses are expected to be for licence

[33] It is unlawful to establish or use a wireless telegraphy station, or install or use wireless telegraphy apparatus.

exempt applications, as with the recent release of the 870 / 915 MHz bands, then a regulatory decision is required to make the appropriate allocation and accompanying regulations. The creation of a new spectrum authorisation is often a major exercise in its own right.

4.15 Meanwhile, the maintenance and development of existing licence products in bands that are managed by Ofcom – and the creation of new licence products – involves significant, on-going policy effort to reflect technology changes and market developments.

4.16 We also have a large programme of work associated with our enforcement activities which include

- proactive intervention, with our current priorities focusing on illegal broadcast, otherwise known as pirate radio stations;
- market surveillance and enforcement in relation to products made available illegally in UK with our principal targets being jammers (equipment specifically designed to hinder or prevent the legal operation of licensed services that include mobile phones and satellite navigation, e.g. GPS) and mobile phone repeaters; and
- reactive enforcement, where we investigate complaints from spectrum users of interference.[34]

Enhance and maintain the potential future value of spectrum use

4.17 The authorisation of spectrum use in the UK takes place against a backdrop of international agreements on the allocation of spectrum bands to different radio communications services, together with a range of associated technical and regulatory provisions (both at European and ITU levels). For the most part, these international allocations do not place a specific legal constraint on how we use spectrum in the UK [35] – and this is observable in the fact that not all spectrum use is harmonised across Europe. However, international harmonisation can be a major factor influencing the potential future value that can be derived from the use of a given spectrum band (indeed, the value of the use of a band may increase many times over as the result of a successful harmonisation initiative). Accordingly, a key objective for us is to increase the potential future value of spectrum use through our work in support of international harmonisation (where we tend to favour non-mandatory, non-exclusive harmonisation so as to enable industry-led changes whilst reducing the risks of regulatory failure that can arise from mandatory, exclusive harmonisation).

4.18 There is, however, a potential downside to some international regulatory initiatives in that not all proposed changes are necessarily beneficial. For example, changes are sometimes proposed by specific interest groups that focus, quite naturally, on their own needs, but may not take adequate account of the impact on other spectrum

[34] As an example of the reactive work we undertake, in 2012 we received 74 interference complaints involving 79 pirate radio stations, 36 of which affected critical services. In the same year we conducted 431 operations against 99 of these pirate stations. We also responded to 96 interference reports affecting mobile phone networks. We also play a particularly vital role in the protection of services that are safety critical from interference, specifically aircraft communications and navigation systems, and the Emergency Services

[35] Although we must ensure that our international neighbours are able to use spectrum consistent with these allocations without suffering harmful interference.

users. Hence, another part of our role is to protect the value of existing spectrum use where the overall effect of a proposed change would likely be detrimental to the efficient use of spectrum.

Enable recycling of spectrum from lower to higher value uses and users

4.19 Where the latent demand for spectrum access cannot readily be met from unused spectrum (or where current congestion means that applications for a new licence under one of Ofcom's standard products have to be declined) the only way for new users to gain access is to recycle spectrum held by existing licensees – and the only way for new applications to gain access is to re-purpose the way in which spectrum is currently used. Enabling and, where relevant, actively facilitating this recycling / re-purposing is therefore a further core objective of our spectrum management activities.

4.20 The pressure for spectrum recycling / re-purposing – and the value that can be realised – comes from the fact that:

- existing licensees will have typically opted for the most useful spectrum available at the time of assignment when, in the case of spectrum users that have been in place for many years, there may well have been less competition for access to spectrum; and

- the on-going emergence of new business applications, often linked to new technology developments, drives the demand for new spectrum access, some of which may be of significantly higher value than current uses.

4.21 A key part of our activities has therefore been directed at improving the environment in which user-led spectrum recycling and re-purposing can take place by:

- removing barriers to the transfer of spectrum access rights through the extension of trading and leasing to enable recycling of spectrum from one user to another; and

- the provision of as much flexibility as possible in licence conditions ("liberalisation") to avoid unnecessary restrictions on the ability of a licensee to re-purpose its spectrum without it needing to seek a licence variation.

4.22 However, there are circumstances in which there appears to be a strong efficiency case for a change in spectrum use but where market forces are unable, or highly unlikely, to deliver this change on their own. In these circumstances Ofcom may be able to play a critical role in facilitating, or even driving, the change, through appropriate intervention. Digital Switch Over of analogue TV to DTT and the subsequent clearance programme in the 800 MHz band are obvious examples where Ofcom, working with the government, has done just this.

Our spectrum management approach combines market mechanisms and regulatory action to deliver optimal spectrum use

Creating the environment for market forces to promote efficient use

4.23 An important principle of our spectrum management strategy is to rely on market mechanisms where possible and effective to help deliver efficient spectrum allocation

and use. Ofcom has been a pioneer of a spectrum management approach that recognises the importance of market mechanisms.

4.24 Market mechanisms are generally considered to be the most effective method of allocating scarce resources to ensure they are used efficiently once the conditions required for them to be effective are in place. They enable the transfer of rights to scarce resources based on the value that users, and potential users, place on these resources. In the absence of market failures, those that value the resource the highest are most likely to deliver the greatest value from the use of spectrum.

4.25 Our market-based approach to spectrum management is underpinned by two policy principles:

- rights to use spectrum should be unambiguous, unlikely to be changed without good cause, and as flexible as possible whilst respecting the rights of others; and
- users should be able to transfer their rights to use spectrum simply and quickly unless we have strong grounds for concerns about competition effects.

4.26 We have a range of tools available to us and to spectrum users, that support our market-based approach notably the use of:

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

The need for regulatory action

4.27 Despite our preference for market mechanisms to drive change where possible and effective, we are not able to rely on market forces in all circumstances given the complex nature of spectrum interactions. Market failure can take a number of different forms, all of which impose impediments on market mechanisms delivering efficient outcomes and, in the face of which we may need to intervene to secure an optimal outcome. The major factors that have led to us taking regulatory action in the past include:

- the increasing importance of the international regulatory framework as a precursor for some changes in use, and our critical role in negotiating changes to this framework. This is particularly important for some sectors where the economies of scale needed can only be achieved through the regional and, increasingly, global harmonisation that is made possible through this framework;
- the scale and complexity of the coexistence challenges and their mitigation that can arise in case of major change of use. This can form a major obstacle for markets to overcome due to the co-ordination problems that can result, for example where there are many thousands of light-licensed users or potentially millions of licence exempt users (e.g. households receiving DTT transmissions);
- the often substantial timing benefits in initiating changes ahead of new licences being granted via an award process, as in the case of the 800 MHz and 2.6 GHz

award (noting that, under a fully market led approach, it is the new licensees who would have to negotiate and drive the change); and

- for changes that have specifically impacted on DTT, the nature, and extent, of the regulatory oversight that we give to the planning of DTT coverage, given its current importance in delivering the benefits of Public Service Broadcasting.

4.28 In addition, there may be circumstances where a potential use of spectrum creates wider social value which, by definition, cannot be reflected in pure market-led activity (although in such cases it is important that decisions take account of the opportunity cost of spectrum allocations that are designed to access this wider social value).

4.29 The diverse nature of market failures means that the potential regulatory responses to them are equally diverse. A balance needs to be struck in each case when considering the benefits of addressing a market failure through regulatory intervention compared to the risk of regulatory failure

4.30 Our experience has shown that market mechanisms have worked well in assigning, and enabling changes to the ownership of spectrum and also in enabling changes of use which can be accommodated within the existing spectrum access rights. However, we have had a greater role to play in cases where there has been a major change of spectrum use. In this context, we think of major changes as being those that require a change in the status of allocations for a band as understood within the international regulatory framework.

4.31 As discussed in more detail in our consultation document, a major change in use will often involve a combination of market-led and regulator-led activity at different points in the overall change process. Of course, the balance between regulator- and market-led activities is heavily dependent on the specific circumstances of the change of use, including the type and numbers of existing users, and potentially impacted adjacent users, as well as by the international context of the change of use.

4.32 In summary, we remain committed to the principle of enabling the market to drive change where possible and effective. Where we are not able to rely on market forces we are prepared to take the appropriate regulatory action. But in deciding on the nature of regulatory action, we will still look to maximise the role that market mechanisms can play in the process.

We will increase our emphasis on spectrum sharing, coexistence management, RF performance and provision of spectrum information

4.33 There are some specific aspects of our spectrum management approach to which we will give a new, or increased, emphasis as a result of the challenges that we expect to face and the lessons we have learned. We explain the nature and rationale for this enhanced emphasis in the following sub-sections; these sub-sections also identify a number of specific actions which we plan to take in each area.

We will explore and, where appropriate, implement new forms of spectrum sharing and extend sharing across new bands

4.34 There are already many examples of successful spectrum sharing today. For example fixed links and Permanent Earth station licensees share access to spectrum under a process of technical coordination that is managed by Ofcom and licensed

PMSE users share access to Crown spectrum. Different applications also share spectrum through a variety of licence exemption regimes which use low power in order to re-use spectrum without risk of harmful interference. These include short range applications such Wi-Fi, Bluetooth and equipment based on Zigbee standards.

4.35 As the potential to repurpose spectrum becomes more challenging we will explore the use of additional methods of sharing spectrum to meet increasing demand. We expect that this will play a particularly important role in meeting geographically focussed demand for mobile data services, such as to meet very high capacity demands in city and urban centres.

4.36 Greater spectrum sharing is being made possible, in part, by new techniques and more sophisticated technologies that enable more dynamic sharing between services. One relevant example is the access to white space being enabled through geo-location database technology.

4.37 'White space' refers to frequencies that are not being used by existing licensees at a specific time or location. Location-aware wireless devices assisted by 'geo-location' databases, providing information on white space availability and taking other existing licensed use into account (e.g. PMSE use) offer one new way of sharing spectrum.

4.38 Since 2007 we have been exploring opportunities to enable access to TV white-spaces (TVWS) in the UHF bands. The latest step in this process has been our work with stakeholders to implement pilot tests consisting of a number of trial deployments of white space devices and databases by stakeholders, and a programme of coexistence testing led by Ofcom. During 2014 Ofcom will complete the pilot and then, subject to the pilot confirming the feasibility of the policy, to move forward to permit white space devices access the UHF band on a commercial basis. Our plan is to publish our decisions on the implementation the framework for accessing TVWS in Autumn 2014 and then carry out the practical and legal implementation of this.

4.39 The completion of the TVWS work will be a key milestone in exploring whether this form of spectrum sharing, known as dynamic spectrum access (DSA), can be made to work in practice. This could lead to the wider application of DSA techniques to other spectrum bands.

4.40 The government's PSSR Programme is another important ongoing development that is likely to increase future sharing opportunities. Supporting the government in delivering on the objectives of this Programme has been identified as a specific priority in our work going forward and we describe in Section 5 the work we intend to progress under this priority. In its recent update to the programme, the government has re-iterated its commitment to supporting sharing opportunities and outlined its considerations of specific bands. Bands that the government is currently in the process of considering as potential sharing opportunities include spectrum at 1427-1452 MHz and the 4.8 – 4.9 GHz band.

4.41 We also plan to review the opportunities for increased levels of spectrum sharing in spectrum bands that are authorised by Ofcom. This will complement the above work on potential sharing opportunities in public sector spectrum bands.

4.42 Today we are also publishing a statement on spectrum sharing for mobile and wireless data.[36] In it, we highlight a series of key next steps we will take to encourage

[36] http://stakeholders.ofcom.org.uk/consultations/spectrum-sharing/statement/

wider use of spectrum sharing in the mobile broadband, Wi-Fi and Internet of Things sectors. These include:

- continuing to periodically monitor spectrum usage by Wi-Fi devices to provide an early warning of potential congestion;
- undertaking further work looking into the risk that a future extension of the 5GHz band for licence exempt Wi-Fi use could cause new co-existence issues with existing users, to inform our international activities;
- investigating further the feasibility of making new shared spectrum bands available for mobile broadband use, including the retained parts of the 2.3GHz spectrum band. To this end, we will work with the MoD and other government users to determine the feasibility of sharing of this band once current government use has been replanned. This work will be based on gaining a full understanding of the existing users' extensive requirements;
- investigating further the feasibility of making additional narrowband shared spectrum available below 1GHz to help meet the spectrum requirements for the emerging M2M/IoT sector;
- extending the application of the geolocation database approach beyond TV white spaces and consider enabling tiered spectrum access; and
- introducing a pilot of measures to pre-agree arrangements for research and development access for bands of particular interest for innovation. As part of this work we are investigating the feasibility and benefits of using an online system to manage such requests for access.

We will maintain our increased focus on the coexistence challenges associated with changes in spectrum use

4.43 As competing demands for spectrum continue to grow and spectrum is used more intensively we expect we will need to consider coexistence issues between different uses in the same band and in adjacent bands more frequently.

4.44 Our assessment of coexistence issues needs to balance carefully the benefits that could derive from new uses gaining access to spectrum with the need for existing services (that will have continued access to spectrum) to operate without suffering harmful interference. For example, if our assessment of coexistence is overly cautious this could reduce the benefits that consumers might otherwise have gained from the new uses by limiting (or denying) access to spectrum for these new uses or by placing onerous and costly constraints on them. Conversely if our assessment of coexistence is overly optimistic this could reduce the benefits that consumers already gain from the existing uses by permitting greater levels of interference than expected and degrading the services that are provided.

4.45 Whilst always important in principle, not all cases of potential coexistence issues will require the same level of investigation. Low risk and uncontroversial cases can usually be addressed adequately with the use of high level modelling, including that carried out within the CEPT by us and by other administrations. Other cases could need much more detailed work, with theoretical modelling complemented with ad-hoc empirical testing of commercially available equipment. Assessing coexistence issues can be a very time consuming and costly exercise, so it is important that our efforts are proportionate to the level of risk involved.

4.46 The extent to which we feel able to rely solely on theoretical modelling, or feel the need to explore testing of equipment in more realistic settings, will depend on factors such as:

- the likelihood of interference as indicated by the theoretical modelling;
- the potential impact of such interference on the existing services;
- the consumer and citizen benefits that the new service is likely to deliver; and
- the size of any loss to these benefits that might arise as a result of mitigation measures that theoretical modelling indicates may be needed.

4.47 Stakeholders and licensees are often well placed to provide evidence on coexistence between different uses as they have a detailed understanding of their technology and spectrum use. We will continue to take account of such evidence when considering coexistence issues and will look to stakeholders to provide evidence where appropriate, notably where they are seeking a change in way they want to use spectrum.

4.48 But evidence provided by stakeholders can sometimes be skewed as a result of commercial incentives, or it may be that the victim of potential interference is not well placed to assess the impact on their use (e.g. licence exempt use). In all cases we have a critical role in ensuring that the evidence provided is sufficiently comprehensive and accurate for making a decision to permit a change in use. Where it is not, we may have a role in providing independent evidence and analysis on which to base our decision.

4.49 In recent years we have put significantly more effort into this area in support of major changes in spectrum access (such as the 800MHz and 2.6GHz, TV White Spaces uses and the forthcoming release of 2.3 and 3.4GHz). Future areas that are likely to require our close involvement in examining coexistence issues will include the prospect of change of use at 700 MHz, and enabling new forms of spectrum sharing.

4.50 In future, we will maintain our increased focus on appropriately addressing coexistence issues. This will include:

- continuing to develop our theoretical modelling capability. For example we are exploring the potential to procure new DTT planning models and coexistence tools for the UHF and VHF bands.[37] In parallel, we will work closely with industry stakeholders to review the planning assumptions used in our present and future models. This will allow more accurate DTT coverage predictions, which will also be used as inputs into other computer simulation tools which are better able to predict, for example, coexistence with other services including mobile, white space devices and PMSE; and
- making greater use of empirical testing where complements to theoretical models are justified. Depending on the stage of development of relevant technologies we will use testing rigs at our facility at Baldock, or we will consider testing commercially available consumer equipment out in the field in a more “real world” environment.

[37] http://stakeholders.ofcom.org.uk/consultations/uhf-vhf-spectrum-planning/

4.51 As we continue to balance the needs of new and incumbent spectrum users, we will also place more emphasis on the nature of the adjacent services, the technology they deploy and their tolerance to interference. This is important for determining how to ensure appropriate levels of protection without taking overly cautious stances that would reduce potential access to spectrum for new valuable uses.

We will also promote improvements in RF performance standards to reduce coexistence issues in future, using a range of levers

4.52 Improving the ability of transmitters to minimise out-of-band emissions and the ability of receivers to screen out radio signals transmitted in adjacent bands will enable greater intensity of use whilst limiting the scale of future coexistence issues. Equipment standards therefore have an important role to play in enabling more intensive use of spectrum. Whilst much of the work on standards is rightly led by industry, there is a case for increased regulatory involvement, albeit of a limited and targeted nature, so as to reduce the risk of poorly performing equipment acting as a material constraint on more intensive spectrum use in future.

4.53 The case for regulatory action on radio frequency (RF) performance stems in part from the potential miss-alignment of incentives. Poor receiver selectivity, or modest out-of band transmission performance, might help to keep down equipment costs to the benefit of the relevant service providers or device users. But if these deployments constrain the way that in-band, or adjacent, spectrum can be used by others, then the associated opportunity cost of poor RF performance will fall on others.

4.54 Whilst receivers with poor selectivity do not have rights to protection in the face of changes in spectrum use around them, spectrum policy needs to take account of the realities of pre-existing deployments, particularly where equipment is deployed in large numbers (for example, consumer SRDs or DTT receivers) or in safety of life applications (e.g. air traffic radars, Cospas Sarsat) or in cases where mitigation is impractical once costly deployments have been made (e.g. satellites). In these circumstances, it may be more effective to reduce the risks of future coexistence challenges by securing better receiver performance before widespread deployments have taken place.

4.55 On the transmitter side of RF performance, we specify technical conditions in licences and interface regulations for licence exempt use. However, where equipment is based on harmonised standards, as is increasingly the case, it is often unrealistic for the UK, on its own, to depart from these standards because of the international scale of equipment markets.

4.56 The activity of standards bodies is driven primarily by manufactures and operators with direct commercial interests in the services that the standards support. Whilst standards, therefore, specifically take account of intra-system coexistence, they may not always optimise the standard for out of band transmissions with respect to adjacent users. Although most devices subsequently manufactured often perform much better than is required by the standard, it would be preferable for the standard to be set closer to achievable performance in the first place. While standards permit poorer performance, however, inevitably there are some manufacturers whose equipment is closer to, and at the limit of, the poorest performance permitted; anecdotally, this is often a consequence of practice rather than cost. This can lead to a situation where most equipment significantly out performs the standards but there is a long “tail” of equipment that performs much worse than the average. If standards reflected the levels of performance which manufacturers can achieve at a reasonable cost this would help to eliminate the tail of poor equipment and to give greater

confidence that standards can be used to reflect the real world experience of coexistence (this might also reduce the need for us to carry out testing to inform coexistence planning). In the case of SRDs, similar considerations apply with respect to the spectrum access protocols which can facilitate far more effective sharing.

4.57 Standards are set internationally, some at the European level (e.g. ETSI) and some at the global level (e.g. 3GPP or IEEE). Hence, our approach for addressing the issues on RF standards will be to work in partnership with our administrations in Europe and elsewhere to provide the appropriate level of targeted influence over the standards bodies. There are precedents for our more active involvement in standards development including our direct engagement with ETSI, notably to tighten the standards for SRDs in light of our experience of the coexistence issues in the band immediately adjacent to the new 800 MHz LTE band.

4.58 The new EU Radio Equipment Directive (RED) will cover receiver performance, unlike its predecessor the RTTE (Radio Transmitters and Telecoms Equipment) Directive it will replace. This will provide a new platform for action by regulators in Europe.

4.59 To help prioritise future activity, we will seek to identify those areas where the risks from not taking early action to discourage materially sub-optimal RF performance are greatest. We will focus on bands where material changes in use could take place over the next 10-15 years and on cases where the incentives to optimise RF designs may be weak due to market structure (for example, some types of mass market devices where there may be greatest scope for material consumer harm, or sub-optimal spectrum use, from poor quality devices gaining widespread deployment).

4.60 However we acknowledge the risks of regulatory failure in taking a more proactive approach. There are complex trade-offs between equipment costs, equipment performance and impacts on other spectrum users, all of which are subject to considerable uncertainty. Even a small percentage increase in device cost adds to significant sums when the size of the device market runs to many millions. The hurdle for regulatory action in this area will therefore be high. We expect our work in this area to lead to only a modest number of specific interventions.

4.61 We will also consider what we can do to help inform standards bodies about the types of coexistence environments they may need to consider in light of potential future changes in use and greater sharing with other specific services. This will include thinking on how best to create appropriate signals to industry without the need for direct regulatory action. This might be most feasible, for example, in cases where there is a degree of vertical control across the specified standards and the production of equipment. Other relevant approaches could include setting expectations on the generic RF environment within which we would expect equipment to be capable of operating.

4.62 We also recognise that, for some uses of spectrum, mandatory standards bodies may not exist. In such cases it will be important to liaise directly with manufacturers and relevant industry bodies to provide them with information on potential future coexistence environments they may need to consider as they develop new equipment. This is likely to be of particular importance for receive-only consumer equipment such as TVs.

We will increase the quantity and quality of information on spectrum use made available

4.63 Ofcom is committed to ensuring transparency in the spectrum regulatory process by making more and better information available on how spectrum is used in the UK. Our key objective is to make it easier for stakeholders to plan changes in their own use of spectrum and engage more closely with, as well as challenge, Ofcom's spectrum management plans – for example by identifying new sharing opportunities so as to exploit spectrum more effectively.

4.64 In our consultation on spectrum management strategy we provided high level metrics on spectrum access in the UK which highlighted the proportion of UK spectrum that is authorised for market uses, used by public sector bodies, or has shared across market and public sector uses. In December 2013 we published a companion paper[38] to the consultation that expanded on the metrics introduced in the consultation. This included information on how access to UK spectrum is provided to different sector uses.

4.65 Today, we are taking this work forward by publishing an interactive spectrum map, available on the Ofcom website together with its source data and a beta version of the UK FAT available online. This map reflects the information available in the UK FAT (Frequency Allocation Table)[39] and the UK PFA (UK Plan for Frequency Authorisation)[40] to provide a consolidated and more detailed picture of the use of spectrum. Stakeholders can interrogate the map, by frequency and by sector, with the information on band use by sector and by authorised product displayed both visually in a frequency map and in a table. This will provide a more detailed understanding of how spectrum is shared and by which specific product. This map is available here www.ofcom.org.uk/static/spectrum/map.html and the UK FAT is available here http://www.ofcom.org.uk/static/spectrum/fat.html.

4.66 In future we will take forward spectrum information activities in a variety of ways.

- In line with our existing policy we will continue to expand the information included in the Wireless Telegraphy Registers (WTR) to provide information on transmission parameters (including power and antenna characteristics) and include other non-tradable licences not currently displayed. This complies with the requirements placed on us under the Environmental Information Regulations 2004, further assists trading by making more information to the market and will enable stakeholders to plan and manage their own use of spectrum by better understanding the radio environment they are operating in.

- We aim to provide, in the longer term, information with regards to individual assignments by licence product by band and geography to better understand

[38] http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/annexes/Spectrum_attribution_metrics.pdf

[39] The UK FAT is issued by the National Frequency Planning Group on behalf of the Cabinet Official Committee on UK Spectrum Strategy. The UK FAT details the uses to which various frequency bands are put in the UK (referred to as 'allocations') and which bodies are responsible for planning and managing them, including making frequency assignments to individual users or installations at particular locations. It also shows the internationally agreed spectrum allocations of the International Telecommunication Union. http://stakeholders.ofcom.org.uk/spectrum/information/uk-fat/)

[40] The UK PFA provides details on the frequencies authorised by Ofcom. It includes a list of licences available through Ofcom and provides information on how they are allocated and whether or not they can be traded. The UK PFA is available at http://spectruminfo.ofcom.org.uk/spectrumInfo/ukpfa

intensity of use and inform our sharing approach with regards to identifying future opportunities for sharing access to spectrum

- We will continue to monitor the spectrum against the attribution metrics identified in the Spectrum Management Strategy consultation to track how spectrum use changes over time as a result of our spectrum management initiatives (see Section 6). As part of this we will, for example, seek to develop an expanded set of metrics on spectrum sharing, to reflect the different ways in which shared spectrum access can take place.

- As part of Ofcom's wider international work we will be contributing to the Spectrum Inventory project being run by the European Commission. The aim of which is to review current spectrum use and forecast potential future demand for spectrum.

- We will also consider the case for targeted measurements of how intensively spectrum is used by individual assignments of spectrum for specific frequency ranges and uses. This could help us address potential instances of congestion and identify opportunities for shared spectrum access. Over the next few months we will publish an exploratory study summarising recent developments in this area which we will use to inform our thinking of how new measurement and analysis techniques could be used to conduct spectrum utilisation exercises.

- We may also look to provide information on potential future demand.

- We will also work with the government to support them in their stated aim of developing a single source of information on spectrum managed by the public sector which clearly identifies what frequencies are in use at what geographic locations, and hence what frequencies might be available for use by others.[41]

We will take a leading role in key international spectrum fora, influencing outcomes in line with UK interests

4.67 Ofcom represents the interests of the UK[42] in the international institutions[43] responsible for developing the international regulatory framework on spectrum. We engage closely with the government to ensure that we understand and are able to take account of all UK interests and priorities in the development of UK positions

[41] Action point 4 of the UK Spectrum strategy: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287994/UK_Spectrum_Strategy_FINAL.pdf

[42] Ofcom is responsible for representing the UK in the main international institutions that deal with spectrum issues under a Ministerial Direction.

[43] 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 Radio Conferences (WRCs);
- The European Conference of Postal and Telecommunications Administrations (CEPT), which consists of 48 member countries, including all EU Member States. The CEPT undertakes technical analysis to facilitate spectrum harmonisation in Europe and is also responsible for developing European positions for WRCs
- The European Commission – whose involvement centres on a range of policy priorities relevant to European interests

4.68 Most spectrum bands are subject to some form of international agreement, making international co-ordination of spectrum use critical to securing the delivery of benefits from spectrum use in the UK. This is because the decisions taken in international institutions can enhance value that can be derived from spectrum use by providing the opportunity for economies of scale from harmonisation and standardisation, and also enable the coordination of high power uses across borders.[44]

4.69 We will continue to take an active role in ensuring that international decisions taken at the European and Global level are consistent with securing benefits for UK citizens and consumers. We will do so by:

- **maintaining our wide ranging engagement across international institutions, building and maintaining relationships and influence** so that we can promote efficient use of spectrum and protect UK interests, including in the more technical aspects of spectrum regulation. A significant amount of the work that defines the conditions for enabling new spectrum access, and to maintaining and developing licence products in the UK, takes place in (upwards of 50) international groups, notably within CEPT and ITU. These groups progress, amongst other things, the technical analysis that is needed to underpin regulatory policy in these areas and often determine the conditions under which spectrum is made available in the UK. As well as contributing extensively to the work of these groups, Ofcom also seeks out key roles, for example the chair of the ITU Joint Task Group which is overseeing the global preparations for the future allocation of spectrum for mobile broadband at the 2015 World Radio Conference (WRC-15);

- placing **a strong focus on engagement with European policy fora which will continue to be the most dominant influence on our spectrum policy**. This includes the Radio Spectrum Committee (RSC) which is chaired by the Commission and plays a key role in ensuring that spectrum is made available according to harmonised technical conditions across the whole of the EU; and the Radio Spectrum Policy Group (RSPG) which advises the Commission on strategic issues relating to spectrum management. We already have a key role in RSPG leading one of the major work items for 2014/15 on efficient awards and the harmonised use of spectrum for electronic communication services across Europe;

- **taking a leading role in areas which are of greatest significance for specific spectrum policy initiatives in UK**. Ofcom staff currently occupy a number of key roles, including the chair of the Joint Task Group overseeing the global preparations for the future allocation of spectrum for mobile broadband at the 2015 World Radio Conference (WRC-15), and vice-chair of the Conference Planning Group responsible for developing European positions for all agenda items to be discussed at WRC-15;

- **continuing to focus outside of Europe** to engage with global developments in other markets that could drive technology trends and have significant implications for international spectrum decisions, using this to inform our own spectrum

[44] Coordination agreements determine spectrum rights across borders, so as to avoid cross-border interference and ensure spectrally efficient delivery of services. Without cross-border coordination, UK spectrum use would be hampered by the need to accommodate existing interference coming in from other countries and to avoid increases in outgoing interference. The coordination of spectrum use across borders can be determined through bilateral and multilateral agreements between national administrations. This is particularly relevant for satellite spectrum use which, by its nature, extends across several geographic territories, and for other high power uses such as broadcasting.

management policy. Ofcom regularly engages with like-minded regulators from around the world (outside of Europe) and we keep this engagement under review to ensure it reflects emerging ideas and areas of influence (especially where it is shifting outside traditional ones). We will particularly look to continue our engagement with other non-European regional preparatory fora in the run-up to WRC-15.

4.70 We note that our work with international institutions will be an important element in delivering most of the priorities for the next 10 years that we set out next in Section 5.

Section 5

Our priorities for the next 10 years

Our priorities result from a wide-ranging review of sector developments

5.1 In the sections below, we discuss the rationale and key issues that future Ofcom work may need to consider over the next 10 years in each of the priority areas we have identified as a result of our strategic review.

5.2 These priorities result from a comprehensive review of future developments upon which we consulted stakeholders. As part of our review we have:

- categorised the main sectors of spectrum use and looked at how they access spectrum today;
- considered trends that could affect spectrum demand and supply for each of these uses over the next 10 years. We graded these future changes according to whether they could have a significant impact on consumer and citizen interests, and the urgency with which we might need to consider action;
- considered a range of mitigation actions that could be taken by licensees and the industry to address these changing spectrum requirements and the extent to which Ofcom can, and should, influence or facilitate these. These mitigation factors were categorised into: technology and receiver standards, implementation and coordination of spectrum use, spectrum re-purposing and spectrum sharing; and
- considered the implications of these developments in terms of whether they indicate the potential need for priority Ofcom work. In particular, whether action by Ofcom is likely to be required to address situations in which market forces are unlikely to deliver optimal spectrum use.

5.3 As we outline how these spectrum challenges will lead to Ofcom programmes of work, we indicate specific projects or activities that we have already initiated, as well as those that we are planning to begin over the next few years, and we also seek to provide an overview of key issues that may become relevant over the longer term. Given the inherent uncertainty of future developments, we have a clearer idea of the focus for our efforts in the short to medium term (three to five years from now) than in the longer term.

5.4 The six sector-focused priorities we discuss below will complement the work outlined in Section 4 which is less sector specific. Taken together, these will still represent only part of Ofcom's future work to deliver its spectrum management functions. There will be many other issues of material significance to specific sectors which will require on-going regulatory attention and specific regulatory action at times over the next 10 years.

5.5 Ofcom work on these additional issues will take place through other:

- **projects addressing specific regulatory issues within sectors that are not captured by the specific priorities above**: these will include, for example, our

review of competing demands and other issues for the 420-470 MHz band and on-going consideration of the changing needs of the satellite and space science community; and

- **programmatic activities**: we typically dedicate around 50% of our spectrum management resources to these activities. They include our work on the authorisation and enforcement of spectrum access and our technical work in the International working groups that feed into major decisions at World Radio Conferences and in Europe.

5.6 It is also important to note that the work programmes we outline below are indicative and our future activities could differ from these due to the emergence of new issues over time and in light of our resourcing considerations. In practice, we will need to constantly keep our priorities list under review.

5.7 The six priority areas, which we discuss in turn below, are as follows:

- addressing future mobile data demands, recognising the importance of improving mobile coverage and the availability of new mobile services;
- implementing our strategy for the 700 MHz band and considering the evolution of free-to-view TV;
- supporting the government's Public Sector Spectrum Release (PSSR) programme;
- addressing challenges around future Programme Making and Special Events (PMSE) spectrum use;
- enabling growth and innovation in the Internet of Things (IoT) applications; and
- supporting the government in its consideration of the future wireless communication needs of Emergency Services.

Addressing future mobile data demands, recognising the increasing importance of mobile coverage and the availability of new mobile services

5.8 Demand for mobile data is likely to continue to increase significantly in future. As demand for capacity generated by handheld devices increases, expectations of ubiquitous data coverage are also likely to become increasingly relevant.

5.9 There have been a range of predictions of future demand for mobile data, and we acknowledge that any long term forecasts in this sector will have a high degree of uncertainty. However, the potential scale of this challenge, the potential benefits that could be achieved by meeting it, and the long lead times normally associated with changing spectrum use, where appropriate, mean that maintaining a forward looking perspective on these issues is a priority for us.

5.10 There are a range of potential solutions to meeting the mobile data challenge, including the use of more efficient technologies and greater use of small cells. However, additional spectrum is likely to be a one component of the relevant mix of future solutions. This spectrum could be made available through spectrum re-

purposing or spectrum sharing (e.g. where the use of the spectrum could be for off-loading data from mobile networks, including Wi-Fi off-loading).

5.11 Any future spectrum re-purposing for mobile data use could involve significant costs and disruption. We would expect to proceed with such repurposing only in cases where we considered that the incremental value of the new use was greater than the value associated with alternative or incumbent spectrum uses. If regulatory action is necessary to bring about such changes we would consider the case with reference to the full range of costs and benefits associated with change of spectrum use, as well as consideration of all our duties.

5.12 Spectrum sharing could, for example, be effective in providing the additional capacity requirements expected in city centres arising from the increasing density of use of these locations. We will carefully assess the potential for coexistence between different services to understand when sharing could be feasible.

5.13 Our work in this area will cover three key areas: contributing to international debate and decisions, maintaining a long term perspective on changing UK demand and options to address this, and progressing our work on mobile coverage. This is in addition to the work in the following two areas which have been identified as separate priorities in their own right and discussed below, but which are clearly relevant to mobile data:

- supporting the government in delivering its PSSR Programme and in particular the release of 2.3 GHz and 3.4 GHz by Ofcom; and
- implementing the 700 MHz strategy.

International engagement and WRC-15

5.14 Only bands that are internationally harmonised are likely to be economically viable for the delivery of mobile data services. International harmonisation is therefore essential to operators, handset and device component manufacturers as it delivers the economies of scale required for the development and production of network and consumer equipment. Harmonisation also acts as a signpost to manufacturers on which bands it is best to concentrate their development efforts and offers consumers a wider choice of mobile devices developed and sold in global markets that are compatible with the use of globally harmonised frequency bands.

5.15 International processes at both ITU and European levels will be very important in setting expectations around the use of additional bands for mobile services. A key milestone will be the next ITU World Radio Conference in 2015 (WRC-15) where two items on the WRC-15 agenda of particular relevance:

- Agenda item 1.1 looking at additional spectrum for mobile broadband applications; and
- Agenda item 1.2 looking specifically at 700 MHz

5.16 Within Europe, the Radio Spectrum Policy Programme (RSPP), which was agreed by the European Parliament and Council in April 2012, set out last year its policy objective of seeking to identify a total of at least 1200 MHz of spectrum[45] for mobile

[45] The 1200 MHz includes spectrum already identified and in use for mobile broadband applications (excluding Wi-Fi)

broadband by 2015. The RSPG has delivered an Opinion on wireless broadband[46] that includes its assessment of which bands may be suitable for wireless broadband in future, along with an indication of the associated timeframes.

5.17 CEPT is leading the European preparatory work for WRC-15. It is, in particular, coordinating technical studies of bands being considered as part of the work to develop European Common Proposals (ECPs) for each of the Agenda Items to be discussed at WRC-15. ECPs will form the basis of CEPT's negotiating position at WRC-15.

5.18 Ofcom is engaging, and will continue to engage, with these international processes with a view to securing the best interests for UK citizens and consumers. This includes ensuring that international decisions enable options to meet growth in mobile data demands in the UK should these be justified.

5.19 Table 3 below sets out the spectrum bands that are likely to feature in forthcoming international discussions of wireless broadband. The table indicates whether the RSPG Opinion is positive about the band's potential for wireless data use, whether the band is being considered in the preparatory work for WRC-15, and whether it is already allocated to mobile broadband services.

Table 3 - Spectrum bands likely to feature in future international discussions on mobile broadband

Band	Being considered as part of preparatory work for WRC-15?	Is the RSPG Opinion positive about its use for mobile broadband?	
694-790 MHz ('700 MHz')	Yes (agreed in principle at WRC-12)	Yes	*Already allocated to mobile broadband or under preparation*
1452-1492 MHz	Already allocated	Yes	
2300-2400 MHz	Already allocated	Yes	
3400-3600 MHz	Already allocated	Yes	
450-470 MHz	Already allocated	No	*Potential long term prospects under review for mobile broadband*
470-694 MHz	Yes	Yes (in the very long term)	
1375-1400 MHz/1427-1452 MHz	Yes	Yes	
1980-2010 MHz/2170-2200 MHz ('2 GHz MSS')	Assigned for mobile satellite use	Yes	
2700-2900 MHz	Yes	No	
3600-3800 MHz	Yes	Yes	
3800-4200 MHz	Yes	Yes	

[46] https://circabc.europa.eu/d/a/workspace/SpacesStore/c7597ba6-f00b-44e8-b54d-f6f5d069b097/RSPG13-521_RSPG%20Opinion_on_WBB.pdf

5350-5470 MHz/5725-5925 MHz	Yes	Yes

Maintaining a long term UK perspective on changing demand and supply options

5.20 Over the coming years, we will need to maintain an informed view of how demand for wireless data continues to evolve, and how international, market and technology changes affect mitigation options for increasing mobile data capacity if this emerges. This will be crucial not only to sustain the current increasing benefits associated with growing mobile data use, but also to ensure that any potential impacts on incumbent spectrum users, whose access to spectrum could be affected by accommodating more mobile use, are properly accounted for and managed.

5.21 We are developing a *mobile data strategy*[47] to help us understand how we can create options to address long-term growth in mobile data whilst taking account of other spectrum users. Two specific objectives are i) to inform the UK position in the important international debates on future mobile spectrum discussed above; and ii) to prioritise Ofcom's future spectrum work programme relating to mobile data. In doing this we are looking to the longer term and beyond the tranche of spectrum (including 700 MHz, 2.3 GHz and 3.4 GHz) already under detailed consideration.

5.22 As discussed above, the long term level of demand for mobile data is very uncertain and there is a range of ways that the capacity of networks can be improved in the future. At this stage we do not know how much additional spectrum it will be appropriate to make available for mobile data use in the long term. It is possible that only a small number of additional bands will be ultimately made available. However, we think it is important to undertake preparatory work to understand and, where appropriate, create the long term options for additional mobile data spectrum use.

5.23 Over time, we will keep the relative prioritisation of potential mobile bands under review. This will include monitoring market and international developments, as well as considering how evolving demand influences the relevant mix of supply options (including new technologies and changing network topologies), as well as monitoring overall level of demand to assess the need for additional spectrum.

5.24 One key development that is likely to affect spectrum demand for mobile data is the process of defining 5G technologies. Today, this is still at a very early stage and different visions, not necessarily compatible, exist for what 5G will stand for. But as prospects for 5G materialise there could be significant implications for spectrum demand. For example, whilst current mobile technologies rely on spectrum access below 6 GHz, in future 5G developments will mean that higher frequencies could be increasingly relevant to dense network infrastructures to provide very high capacity at high data rates in concentrated geographical locations, whilst lower frequency spectrum could continue to remain important to deliver widespread geographic coverage.

[47] We consulted on our draft Mobile Data Strategy in November 2013. We are now planning to publish a statement Q2 2014. In developing our work of mobile data strategy we will also take account of relevant points made in responses to the Spectrum Management Strategy consultation of October 2013.

Progressing our work on mobile coverage

5.25 The 4G coverage obligation imposed on the 800 MHz spectrum awarded to O2 requires the provision of indoor coverage to 98% of UK households (corresponding to an estimated 99.5% outdoor coverage) and 95% of the households in each nation. As a consequence of this, we expect that mobile coverage of UK premises will improve significantly. Competitive pressures and the effects of network sharing agreements could also increase the voice and data mobile coverage offered by operators other than O2.

5.26 However, consumer expectations on mobile voice and data coverage are likely to continue to increase over time and improvements driven by the 4G coverage obligations may not meet all relevant usage scenarios. These could relate to geographies other than those with population premises, locations deep inside buildings or within vehicles that are hard to reach with cellular signals. In addition, the poor reception performance of specific devices can affect the mobile quality of experience.

5.27 Over the next few years we will continue to investigate how to support improvements in the provision of mobile coverage and quality of experience of end users. This will include:

- monitoring compliance with, and enforcing, the 4G coverage obligation;
- exploring options to support further improvements in geographical coverage of mobile voice and data services, including road and rail coverage;
- working with third parties to provide better consumer information on coverage levels provided by operators, as well as additional information relevant to the quality of experience of mobile end-users, such as voice calls reliability and mobile data speeds; and
- conducting research on the role of device performance affecting the consumer mobile coverage experience and on the effectiveness of technical solutions to addressing instances of poor signals inside buildings or cars.
-

Table 4 - planned work programme in support of our mobile data priority area

Issues that Ofcom is already considering	• Preparations for WRC-15 (especially AI 1.1) and other ongoing international engagement • Developing a long term perspective on demand and supply options • Assessing the potential role of licence exempt and sharing approaches and implications for the supply balance • Monitoring progress in mobile coverage and networks' performance
Issues that are likely to become relevant over the next 5 years	• Considering harmonisation opportunities for UK spectrum use opened by international decisions • Applying our approach to assessing and enabling use of additional spectrum for mobile data as relevant

	• Exploring options for the further extension of geographical coverage of mobile voice and data services
Issues potentially relevant over the longer term	• 5G technology evolution: consideration of new equipment standards and potential impact on spectrum requirements

Considering the case for change of use at 700 MHz and the future of free-to-view TV

5.28 Ofcom's UHF Strategy Statement, published in November 2012, set out our dual objectives of enabling the release of spectrum in the 470-790 MHz band for mobile broadband whilst also securing the on-going delivery of the benefits provided by DTT.

5.29 This has led to a substantial programme of work under our UHF Strategy Implementation project. We published a Call for Inputs on the future of the 700 MHz band in April 2013. Since then we have been carrying out a cost benefit analysis testing the case for change of use of the 700 MHz band, assessing the implications of the potential change for citizens, consumers and all spectrum users concerned and investigating the costs and practicalities of implementing such a change.

5.30 We have been considering the potential changes to the frequency plan for national and local DTT, PMSE and TV WSDs and the associated changes for infrastructure and equipment and potential alternative spectrum requirements.

5.31 We are soon due to consult on the case for a change of use of the 700MHz band, as well as associated initial implementation approaches.

5.32 Should a decision be taken to go ahead, a wider programme of work would then start and continue over a number of years, in the UK and internationally, leading to use of the band by mobile services in the early 2020s. This would include:

- continuing with our efforts to promote future-proofing of consumer TV equipment;
- continuing to work with PMSE stakeholders to help them plan for changes to equipment and spectrum use;
- planning for and designing changes to DTT infrastructure in detail and working to agree a frequency plan with our international neighbours; and
- in due course, preparing consumer engagement and support campaigns.

5.33 As we consider the future of the 700 MHz band, we are also engaging with stakeholders on wider issues involving the longer-term future of DTT. As decisions on 700 MHz are made, it is important that these are in a wider context around long-term evolution of options for delivery of free-to-view TV.

5.34 As we set out in the UHF Strategy Statement, we remain of the view that DTT will remain an important platform for TV delivery at least until 2030. In particular, we do not expect other distribution platforms to substitute for DTT's role in providing free-to-view universal access to PSB content for the foreseeable future. However, the evolution of viewer preferences, the technical options available to meet those and the

dynamics of the wider TV distribution markets will mean that DTT's offer and role is unlikely to remain unchanged over time.

5.35 Two specific aspects are of particular importance to the potential future evolution of free-to-view services:

- The prospect of greater use of better transmission and encoding standards on the DTT platform. Our decision to enable interim use of 600 MHz spectrum for additional multiplexes using DVB-T2/MPEG-4 underlines our view that it is important to encourage adoption of these new technologies to enable more efficient use of spectrum. However, any future full or partial transition to new technology standards on the DTT platform should take into account both the benefits potentially associated with the delivery of new channels, including in high definition, and the costs, including, in particular, those associated to the potential for consumer disruption and the potential consumer costs associated with upgrading equipment.

- The likely growing role of IP delivery: many TV propositions based on broadband-enabled delivery are emerging in the UK market, and this trend is likely to continue as growing adoption of superfast broadband services improves the capabilities and reliability of IP-based TV delivery. But as the limitations in superfast broadband availability and take-up could persist over time, we believe that, in the medium –term, IPTV is likely to remain a complement to, rather than a substitute for, more traditional distribution platforms. However, IPTV complements could play an increasingly important role in increasing choice and functionality for DTT viewers, including through hybrid platform models.

5.36 Over the coming years we will continue to engage with industry on how a market-led evolution of the DTT platform can support its long term relevance in light of these trends. We intend to publish a discussion document on the future of free to view television and we plan to engage further with the industry on these important issues.

5.37 We also note growing international interest in potential future uses for the remainder of UHF spectrum that DTT will use in the event of a change of use at 700 MHz (470-694 MHz). Several discussions on the future of this frequency range are emerging, especially within Europe, through RSPG, CEPT, and further work sponsored by the European Commission. Our UHF Strategy forms the basis of our international position, reflecting our views around the continued importance of DTT for the foreseeable future. As we engage in these discussions we will need to balance different objectives, including securing the ongoing delivery of the benefits provided today by DTT, but also not precluding long term developments for the UK and for other countries in Europe and beyond.

Table 5 - planned work programme in support of our 700 MHz and the future of free-to-view TV priority area

Issues that Ofcom is already considering	• International engagement on 700 MHz harmonisation and coordination discussions • Initial Cost Benefit Assessment on 700 MHz re-purposing for consultation • Explore opportunities to reduce and avoid future disruption of DTT platform • Engage with industry on role of DTT and the future of free-to-view

	TV • Participating in international discussions on the longer term future of spectrum at 470-694 MHz
Issues that are likely to become relevant over the next 5 years	• Final decision on 700 MHz repurposing If appropriate thereafter: • 700 MHz award design if relevant • Work with interested parties to prepare for changes and to monitor progress • Develop detailed plans, set up delivery structures and implement regulatory steps required to enable transition • Monitor developments in market and regulatory developments including TV distribution technologies and implications for the long term role of DTT
Issues potentially relevant over the longer term	• Enabling action and regulatory support for 700 MHz clearance and award, if appropriate

Supporting the government's Public Sector Spectrum Release programme

5.38 The release of public sector holdings is expected to make a significant contribution to future spectrum availability for mobile data and other civil uses which, in turn, supports Ofcom's duty to secure the optimal use for wireless telegraphy of the electro-magnetic spectrum.

5.39 A first key milestone in the Public Sector Spectrum Release (PSSR) Programme will be the release of 40 MHz in the 2.3 GHz band (2350 – 2390 MHz), and 150 MHz in the 3.4 GHz band (from 3410 to 3600 MHz) by the Ministry of Defence (MoD)

5.40 In September 2013 the MoD announced its intention to release to Ofcom this spectrum in order for Ofcom to conduct the sale process.[48] Our work to deliver this sale has already started, and we have recently published a consultation on technical coexistence issues.[49]

5.41 The timing of the 2.3 and 3.4 GHz release will be subject to our on-going analysis, taking account of any new issues raised by stakeholders in response to future consultations. Our intention is to conduct an auction of this spectrum in 2015/16. Our work before then will include:

- progressing our on-going analysis of potential coexistence challenges and developing appropriate mitigation strategies;
- progressing the assessment of the impact on spectrum users who may need to be cleared to facilitate the release (e.g. PMSE, Emergency Services and Amateur users) and potential mitigating actions;

[48] https://www.gov.uk/government/news/ofcom-to-manage-release-of-mod-radio-spectrum
[49] http://stakeholders.ofcom.org.uk/consultations/pssr-2014/

- considering policy and competition implications of the planned release on downstream service markets; and

- designing and conducting the award.

5.42 More broadly, we will continue to support the government's PSSR programme. Traditional methods of sharing based on exclusion zones are highly relevant to public sector spectrum, because of the localised nature of some uses (such as where spectrum is used primarily for training activities in UK). However, we expect that DSA techniques will become more relevant to sharing by the public sector. We will, therefore, work with the government to examine how to leverage our experience in developing the geo-location database approach. We will also assess whether we need to develop new regulatory regimes to enable sharing between the government and commercial users, particularly where this is enabled by new technology.

5.43 This will include:

- considering opportunities for the release of other bands, both through releasing cleared spectrum blocks, and by enabling shared access by market users to spectrum retained for public sector use in specific geographies or at specific points in time;

- ensuring appropriate incentives to secure efficient use of spectrum by both public sector and civil users are in place. This will include supporting the government considerations of whether mechanisms to reflect the opportunity cost of spectrum used by the public sector are effective;

- leveraging our experience in white space devices and geo-location databases into the sharing opportunities identified by the public sector; and

- ensuring we have a regulatory regime that enables and encourages spectrum sharing between Public sector users and market users.

Table 6 - planned work programme in support of the government's PSSR programme

Issues that Ofcom is already considering	• Undertaking the auction of the spectrum vacated by MoD at 2.3 and 3.4 GHz • Supporting the government on sharing opportunities
Issues that are likely to become relevant over the next 5 years	• Supporting the government's considerations of mechanisms to secure efficient use of spectrum by public bodies • Leveraging our experience on spectrum sharing into Public Sector spectrum • Moving towards unified information on spectrum usage and frequencies available for shared access across civil and crown holdings
Issues potentially relevant over the longer term	• Supporting the government in future releases,

Considering future challenges and options for PMSE spectrum access

5.44 Programme Making and Special Events (PMSE) captures a range of wireless services used in the production of content for film and television, including news gathering, sports events and outside broadcasts and events such as live concerts, theatre, religious, cultural and educational activities. The primary applications can be divided into wireless video (e.g. radio cameras) and wireless audio (e.g. radio microphones, in-ear monitors and talkback). PMSE has access to spectrum from 48 MHz to 48 GHz in a number of sub-bands almost entirely on a shared basis.

5.45 The requirements of many professional PMSE users are growing as productions increase in number and become more complex. At the same time, the number of bands available for these users is decreasing. The award of the 800 MHz and 2.6 GHz bands for mobile broadband removed opportunities in these bands previously available for PMSE use and the future release of the 3.4 GHz band by the MOD and the potential release of the 700 MHz band would further reduce PMSE spectrum availability.

5.46 PMSE users play an important role in the UK's creative industries and provide wider economic, social and cultural benefits for citizens and consumers. Ofcom recognises that security of tenure within a set of spectrum frequencies would help to support this contribution. Such security would allow users to plan their long-term investment in new equipment more effectively.

5.47 In order to understand PMSE users' requirements and the impact of the spectrum release programme on the sector, we are carrying out a strategic review of PMSE spectrum use. Our on-going work is focusing on:

- The impact of the award of the 2.6 GHz band and the prospective award of the 2.3 and 3.4 GHz bands on the availability of spectrum for wireless cameras. To mitigate the negative effects of these changes, we are engaging with industry on our proposals to secure access to a core of 2 GHz spectrum for wireless cameras and to encourage greater use of 26 channels available for PMSE in the 7GHz band[50].

- The impact of the potential future release of the 700 MHz band on spectrum available on audio PMSE. As part of our UHF Strategy Implementation programme we will assess the role of potential mitigations that could be implemented over the short to medium term. These could include providing good notice of future spectrum availability and engaging with industry to promote more efficient working practices and to encourage coordinated planning of spectrum requirements by event organisers.

- The case and options available for alternative frequency bands, in light of long term security of tenure considerations. Any move would first require detailed coexistence studies to be carried out so incumbents are protected. Also, international momentum would prove very important to secure benefits from economies of scale in equipment production.

[50] http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/summary/pssr.pdf

5.48 Technological developments will shape PMSE spectrum use over the next ten years, potentially contributing to increased demand, but also enabling more efficient applications. As part of our PMSE priority work we will also examine the possible effects that the long term evolution of technology will have on the spectrum requirements of PMSE users.

5.49 Once we have refined our view on options to balance future PMSE spectrum demand and supply, we will also consider implications for our approach to licensing and the future management of the sector.

5.50 The issues affecting PMSE spectrum are not only relevant for the UK and we welcome work by the European Commission in this area. Our European engagement is focusing on establishing a strategic perspective on the challenges facing the sector, with a view of identifying sustainable, long term solutions. At the same time, we are also liaising directly with other national regulators and governments to develop a coordinated approach to these challenges.

Table 7 - planned work programme in support of our proposed PMSE priority area

Issues that Ofcom is already considering	• Understanding current and future PMSE demand and the feasibility of different supply options, including access to alternative bands • Considering the future role of new PMSE equipment technologies • International engagement on initiatives over PMSE harmonisation in Europe
Issues that are likely to become relevant over the next 5 years	• Reviewing our approach to PMSE spectrum management • Assessing the impact of planned spectrum changes on PMSE and implementing mitigating actions
Issues potentially relevant over the longer term	• Considering the potential relevance of new technologies to PMSE applications

Enabling growth and innovation in machine-to-machine (M2M) / Internet of Things (IoT) applications

5.51 Developments in machine-to-machine and the Internet of Things could have significant implications for the evolution of wireless communications over the next decade. By 2022 there could be over 350 million devices in the UK communicating wirelessly with little or no human interaction[51]. New M2M / IoT application could deliver significant benefits through innovation across a variety of fields, including: greater energy efficiency, better management of city infrastructures, greater building security and more regular flows of transport traffic.

5.52 The broad and highly heterogeneous nature of M2M / IoT applications suggests that different solutions could be required to meet the needs of different types of application. These could include delivery options that are already available (e.g. private networks, public cellular networks, Wi-Fi or other existing SRD solutions) as well as new solutions based on emerging technologies and new bands.

[51] http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2014/M2MSpectrum

5.53 Our long term objective in this area is to ensure that the spectrum access and authorisation regimes enable the delivery of the wide range of prospective benefits associated with innovation in these areas.

5.54 To support this objective, we have begun work to improve our understanding of current trends and potential future developments in M2M and the IoT. In particular, we are working to gain a better understanding of the characteristics of different application types and of the potential implications of these characteristics for the different types and amounts of spectrum access required.[52]

5.55 We are also taking a number of specific actions that will be relevant to supporting M2M / IoT developments.

- we are making available spectrum at 870 – 876 and 915 – 921 MHz for use by M2M devices transmitting over short ranges. Ofcom is one of the first countries in Europe to enable access to this band. We are also considering light licensing approaches for devices that more frequently transmit data at higher powers;
- our mobile data strategy has identified M2M as a new source of demand and recognises the role that mobile networks might play in meeting this;
- our on-going work on TVWS could provide opportunities for M2M devices capable of tuning into a wide range of frequencies. The future implementation of geo-location approaches to other spectrum bands will also provide further opportunities to lower barriers to spectrum access and encourage innovation;
- as part of our future work on sharing, we will investigate the feasibility of making additional narrowband shared spectrum available below 1 GHz to help meet the spectrum requirements for the emerging M2M / IoT; longer term, we will consider the role that new Dynamic Spectrum Access techniques could play in supporting applications with specific quality-of-service requirements through shared spectrum access.

Table 8 - planned work programme in support of our proposed M2M / IoT priority area

Issues that Ofcom is already considering	• Improving our understanding of how M2M/IoT requirements will vary across applications and sectors • Enabling access by LE SRDs to the 870/915 MHz band and considering the case for light licensing regime for devices requiring higher transmission powers and duty cycles • Progressing our work on TVWS
Issues that are likely to become relevant over the next 5 years	• Understanding how the emergence of new technical standards could influence the evolution towards horizontal platforms for the Internet of Things and impact on requirements

[52] A first step in this direction is represented by the report we commissioned from Aegis and Machina research analysing how the key characteristics of circa 150 M2M/ IoT applications could influence technology and spectrum requirements. http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2014/M2MSpectrum

Issues potentially relevant over the longer term	•	Considering prospects for DSA techniques enabling self-managed access to spectrum to M2M / IoT devices requiring quality-of-service assurance

Supporting the government in assessing the future wireless needs of the Emergency Services

5.56 The Emergency Services (ES) rely heavily on wireless communications to deliver their public policy objectives, which are of vital importance to UK citizens.

5.57 Critical voice communication services used by the police, fire and ambulance services in mainland UK are currently provided through a commercial contract by Airwave and based on the ETSI TETRA (TErrestrial Trunked RAdio) standard[53]. Airwave has a licence for spectrum to support these services which expires in 2020 at the same time as the national network service contract. However, contracts with individual emergency services entities will begin to expire from as early as 2016; this fragmentation reflects the regionalised nature of the rollout of the Airwave service.

5.58 Decisions on whether and how Emergency Services will require use of spectrum, and how that would be secured, will be a matter for the government. In particular, we note that the government has initiated a multi-agency programme, the Emergency Services Mobile Communications Programme (ESMCP) to address these issues in Great Britain. While led by the government, we anticipate that there will be specific aspects of their decisions on which the government may ask for our advice.

5.59 The need to re-assess options for the long term provision of critical voice and narrowband applications is also increasing the relevance for ES of the linked issue of potential future requirements for more advanced, broadband-enabled applications. Mobile broadband developments and the ongoing deployment of LTE networks are raising opportunities for the delivery of enhanced, data-rich PPDR[54] applications based on broadband communications networks.

5.60 In the US, spectrum has been assigned in the 700 MHz band for PPDR and networks are being planned and deployed based on LTE. LTE-based solutions for the delivery of broadband ES communications on a global scale are likely to lead to economies of scale in equipment and incentives on manufacturers and service providers to meet the needs of the ES market.

5.61 The timetable associated with the Airwave expiration of licences for the provision of voice and narrowband services, the emerging demand for broadband ES functionality, and the opportunities and uncertainties around future LTE developments raise an important and complex set of challenges on the future provision of ES wireless services for the Emergency Services themselves and for the government.

[53] Northern Ireland, The Channel Islands and The Isle of Man who also utilise TETRA will no doubt be following developments on mainland quite closely.

[54] The terminology PPDR (Public Protection and Disaster Relief) is the terminology used in Europe and elsewhere for services with equivalent aims to those being procured through ESMCP in the UK. To note that services to specifically address Disaster Relief activities are catered for separately in the range 4 - 5GHz internationally.

5.62 The Home Office has started the procurement process for its new Emergency Services Network, which includes the potential for PPDR services to be deployed using spectrum or network infrastructure that is shared with non-PPDR users.

5.63 Although the decision on how to meet the ES future communications needs is one for the government, we have been asked to provide advice to the government given Ofcom's specific expertise in spectrum. In particular, we are currently supporting the government by:

- providing information on the current licensing and spectrum environment of bands being used to provide a wide range of wireless services to the Emergency Services;
- advising on the coverage of the MNO networks and where these would need to be supplemented to meet ES needs; and
- representing UK interests in International institutions that are working towards harmonised approaches to spectrum for the delivery of ES communications. In particular, we are contributing to the work being taken forward in the CEPT and EU on potential harmonisation of spectrum for PPDR applications. Our objective in contributing to this debate is to retain as much flexibility in the use of spectrum as possible, whilst still permitting the benefits of harmonisation to be realised.

Table 9 - potential work programme in support of our proposed Emergency Services priority area

Issues that Ofcom is already considering	• Providing advice on existing licensing and spectrum environment of bands used by Emergency Services • Giving technical advice about mobile networks meeting ES needs; • Representing UK interests in International PPDR spectrum harmonisation negotiations
Issues that are likely to become relevant over the next 5 years	• Providing advice as requested by the government on potential availability of spectrum and costs • Providing support to the government, if required, on the planning and implementation of any required transition between spectrum bands
Issues potentially relevant over the longer term	• Ongoing advisory role to the government in Emergency Services use of spectrum through PSSPG and UKSSC

Section 6

Monitoring our strategy and keeping it under review

We will monitor the aggregate effects of our strategy by tracking how key high-level metrics on spectrum use change over time

6.1 In our consultation document we introduced the concept of spectrum attribution metrics to monitor how spectrum use changes over time. This is an important aspect of our strategy for two reasons:

- monitoring changes in spectrum use can help track the effects our future spectrum management initiatives have over time; and
- measurements on how spectrum is used can also be an important source to inform future spectrum management initiatives.

6.2 In future, we will monitor high-level metrics as a way of tracking whether changes in how UK spectrum as a whole is used are consistent with the expected effects of our strategy. However, we will not use these metrics as targets that drive our work.

6.3 In line with this approach we will monitor the following metrics:

- changes in market spectrum against public sector spectrum, both as a result of planned releases and sharing activities;
- changes in block assigned spectrum as a result of releases from both Ofcom licenced and Public Sector Spectrum;
- changes to spectrum authorised through licence exemptions; and
- changes to shared spectrum

6.4 In addition to the metrics above, our consultation considered how the proportion of tradable and liberalised licences has changed in the past. However, we do not expect this metric to change significantly in future. This is because we have already completed the tasks of making spectrum licences tradable where possible and of liberalising those classes of licences where appropriate (notably the business radio and mobile licences).

6.5 We will also consider using the more detailed attribution metrics (at sector level) introduced in the companion paper to our consultation published in December 2013 to support and improve our understanding of changes in the high level metrics.

6.6 In the table below we outline our expectations as to how these high level metrics are likely to change over the coming years. It is important to note, that as these measures are based on the totality of UK spectrum, future initiatives are likely to change monitored values by only few percentage points. This should not however detract from their potential significance for increasing benefits to UK citizens and consumers.

Table 10 - future expected changes in high-level spectrum metrics

Spectrum attribution metric	How might this metric change in future?
Market access vs public sector access to spectrum	The Public Sector Spectrum Release programme is expected to decrease the proportion of Public Sector access in future and increase the proportion of spectrum exclusively available to the market
Ofcom band-managed vs Block-assigned spectrum	The quantity of Block-Assigned spectrum could increase in future as a result of the Public Sector Spectrum Release programme, and other potential releases from Ofcom band-managed (700MHz) to Block Assigned spectrum
Spectrum available for Licence exempt (LE) uses	The implementation of TV White Spaces will affect the proportion of spectrum available for licence exempt uses. We will continue to work to identify new opportunities to extend the application of geo-location databases beyond TV White spaces.
Shared spectrum	Today 58% of the spectrum is already shared between two or more sectors. Increasing competing demand for spectrum will further increase the importance of sharing. Our approach is to encourage new forms of sharing, including in new bands, as detailed in section 4 of this document.

We will monitor changes in spectrum demands and keep our strategy under review

6.7 More broadly, we will continue to monitor changing spectrum demands and keep this strategy under review. As consumer behaviour, markets and technologies continue to evolve our strategic direction and priorities are likely to require adjustments and changes to how we allocate our efforts and resources. In particular, we expect that future disruptive technologies and new business models are likely to impact on how our priorities list changes over time

6.8 As circumstances require it, we will respond to new developments in consultation with stakeholders. We will also work closely with the government on the review of UK spectrum strategy from time to time, as signalled in its recent UK Spectrum Strategy document.