Spectrum management strategy

Ofcom's approach to and priorities for spectrum management over the next ten years

Consultation

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Section 1

Executive summary

Spectrum is a valuable resource and securing its optimal use is key to delivering significant benefits for UK citizens and consumers

1.1 Radio spectrum is a major asset to the UK, serving as a critical input to a wide range of services including mobile communications, television and radio broadcasting services, emergency services communications, air travel and many more. Through these services, spectrum use delivers substantive benefits to citizens and consumers.

1.2 Two acts of Parliament[1] give Ofcom responsibility for managing UK spectrum while allowing for Government to direct us on how to carry out our spectrum functions. In this document, we discuss our proposed strategy to fulfil our spectrum management functions over the next ten years.

1.3 The purpose of this consultation is to:

- outline our approach to spectrum management, taking into account our experience over the past ten years; and
- explain our initial views on the future developments in spectrum use that could indicate the need for priority action by us over the next ten years. Whilst these developments are inherently uncertain, we believe it is important to take a long-term perspective given the long timescales often required to enable changes in spectrum use.

1.4 Ofcom's first strategic review of spectrum management took place in 2005[2]. Over the last eight years we have largely completed the work programme we set out then. This included a number of major initiatives, culminating recently with the completion of Digital Switchover, the 4G auction of spectrum at 800 MHz and 2.6 GHz and the liberalisation of mobile licences.

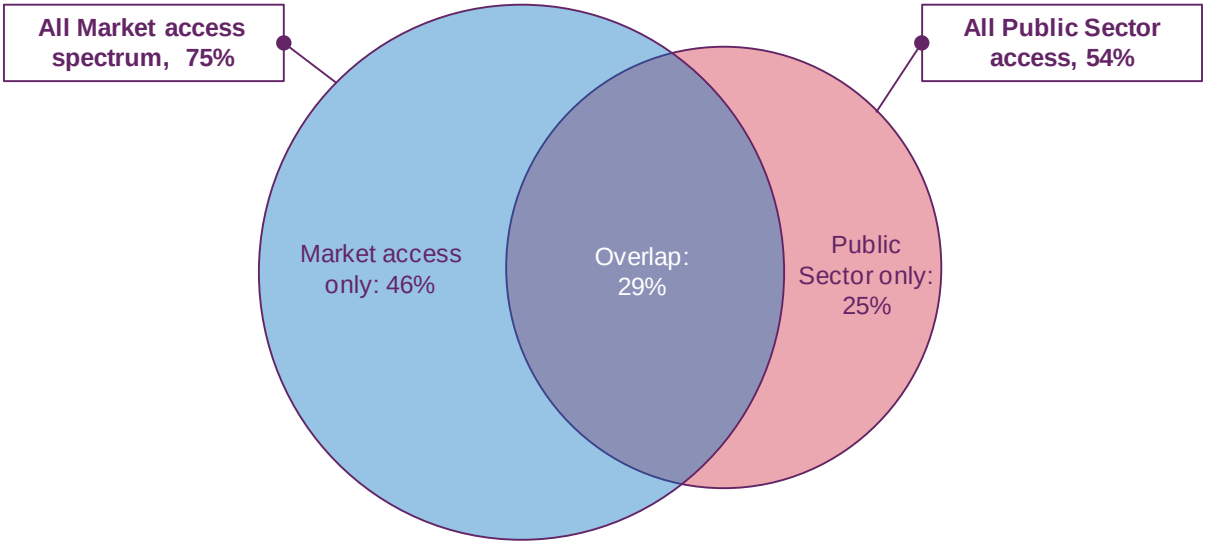
1.5 Looking forward, a number of important trends that could have a significant impact on spectrum use are emerging, including mobile broadband growth, the emergence of new uses such as machine-to-machine (M2M) communications and increasingly sophisticated techniques for sharing spectrum.

1.6 Therefore, we believe now is the right time to review our spectrum management strategy and consider major priorities for our work over the next 10 years.

1.7 Securing the best use of spectrum is a key element of the Government's broader economic and social policies. As illustrated below, three quarters of spectrum is available to the market and just over half of it is accessed by public sector users (with a significant number of bands having some form of shared access).[3]

[1] The Communications Act 2003 and the Wireless Telegraphy Act 2006
[2] Spectrum Framework Review, 2005: http://stakeholders.ofcom.org.uk/consultations/sfr/
[3] 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. This methodology is discussed further in Section 2.

Figure 1 - Illustration of market access and public sector access to UK spectrum



1.8 As announced in the recent *Connectivity, Content and Consumers* paper,[4] Government plans to develop a UK Spectrum Strategy that will cover all UK spectrum (including both market access and public sector access) and set out the key changes to spectrum that will be necessary over the next 10 to 15 years. Government expects this strategy to be published in early 2014.

1.9 Our spectrum management strategy will be an important contribution to the overarching UK Spectrum Strategy and we will continue to work closely with Government in the coming months to support them in this process.

Combining market mechanisms and regulatory action to deliver optimal spectrum use

1.10 In order to deliver optimal spectrum use, we rely on market mechanisms where possible and effective, but also take regulatory action where necessary.

1.11 Once the conditions required for the use of market mechanisms are in place, they are generally considered the most effective method of allocating scarce resources to ensure they are used efficiently. Ofcom has acted as a pioneer in developing a spectrum management approach that recognises the importance of market mechanisms and this approach has been widely adopted in Europe and elsewhere.

1.12 Our market-led approach to spectrum management was articulated in the 2005 Spectrum Framework Review. In it, we set a series of objectives around the introduction and extension of market mechanisms, including:

- auctions as a means to assign new spectrum access rights for large blocks of spectrum: our release programme has culminated with the 4G auction at 800 MHz and 2.6 GHz;
- spectrum pricing to create incentives for users to make efficient use of spectrum: we have extended spectrum pricing to most major licence classes;

4 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/225783/Connectivity_Content_and_Consumers_2013.pdf

- spectrum trading and leasing as the means for spectrum access rights that are already assigned to change hands: 84% of relevant spectrum is now tradable; and

- greater licence flexibility ('liberalisation') as a principle to enable change of use, wherever possible, without recourse to Ofcom to vary the technical licence conditions: since 2005 we have introduced high flexibility in licences equating to 21% of spectrum. This includes the liberalisation of mobile licensees which allowed the deployment of 3G and 4G technologies in all mobile bands and changes to business radio licensing.

1.13 In this document we build on this approach, reflecting that there can be an important and complementary role for us to play in addressing situations where market mechanisms alone are unlikely to deliver the greatest value to society from spectrum use.

1.14 As illustrated by our experience over the past 10 years, these situations often arise when major changes in spectrum use are contemplated. This is because, typically, major changes of use involve one or more of the following factors:

- Changes to international agreements: decisions taken by international institutions can be key enablers of major changes of use, in particular where internationally harmonised spectrum use enables economies of scale and where new high power uses need to be coordinated across borders to avoid harmful interference. Ofcom (in close collaboration with Government) is responsible for negotiating in relevant international institutions on behalf of the UK.

- Clearance and mitigation of co-existence challenges: a major change of use will normally involve clearance of incumbent users, and changes to the interference environment that could have negative effects on users of adjacent spectrum. These processes can be complex, making it hard for the market to reach a coordinated solution. In these cases proactive regulatory action can be required to address these challenges or support the market in delivering appropriate solutions. For example, we played a major role in assessing potential coexistence issues between new 4G services in the 800 MHz band with Digital Terrestrial Television reception. We then facilitated the formation of the industry body at800 to help the small number of DTT viewers that might suffer from interference.

- Implications for competition in relevant markets: changes to spectrum use can have important competition effects which can impact on the longer-term efficiency of spectrum use. Regulation may be required to prevent the concentration of key spectrum assets. 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 purchase in the 4G auction of spectrum at 800 MHz and 2.6 GHz.

1.15 In addition to overcoming barriers to market forces, regulatory action can also be required to deliver wider duties and the citizen interest when these are relevant to spectrum decisions. For example, we believe that DTT is currently the most appropriate method of meeting the objective of delivering universal free-to-air access to Public Service Broadcasting channels and therefore we take this into account when making decisions that have the potential to affect DTT.

1.16 When representing the UK (under Direction from Government) in international institutions, we may also need to consider issues which go beyond our duties. In particular, we may need to reflect Government's wider public policy objectives.

Future competing spectrum requirements are likely to raise significant challenges

1.17 There are likely to be significant challenges for spectrum management over the next 10 years. These will be related to the following broad trends:

- growing competing demands for key spectrum bands will lead to increasingly difficult choices associated with changing spectrum use, especially at lower frequencies; technology developments and the search for larger bandwidth will also drive some demand for higher frequencies;

- strong expansion in low power, localised uses, driven by the proliferation of internet-enabled wireless devices, machine-to-machine (M2M) and machine-to-people (M2P) applications; this will increase the role of spectrum sharing and the significance of technical and regulatory innovations to enable this; and

- the dynamism and intensity of spectrum use is likely to increase; this will make radio equipment performance an important factor for managing the risks of interference.

1.18 Demand for mobile and wireless data could increase significantly in the future. Over the past few years, the volume of data carried over mobile networks has increased materially. Looking forward, under a mid-level growth scenario, demand for data generated by wireless and mobile devices in 2030 could be 80 times higher than in 2012.[5] But beyond growing demand for capacity, there may also be an increasing expectation of ubiquitous coverage. Mobile services already deliver significant economic value and mobile broadband growth could increase this further, sustaining innovation and making an expanding range of new high value mobile services available to consumers.[6]

1.19 At the same time, spectrum requirements for other services are also likely to grow or, at the very least, remain stable.

- The resilience of linear TV viewing and trends towards higher definition transmissions are likely to influence demand for television broadcasting capacity on both digital terrestrial and satellite platforms.

- Programme Making and Special Events (PMSE) demand for spectrum is likely to continue to be driven by the increasing complexity of live events production and the move to higher definition camera capture, whilst the supply available for PMSE use may reduce with the prospect of future changes of spectrum use e.g. at 700 MHz and 3.4 GHz.

- Emerging M2M and M2P applications may also create demand for new types of wireless communications requirements. They are likely to be best served through a range of different solutions, including the use of public mobile infrastructure in some cases or the use of spectrum on a licence-exempt basis in others or,

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

[6] Following the 4G auction of spectrum at 800 MHz and 2.6 GHz we estimated that the value that 4G services could provide to consumers over the following 10 years could be in excess of £20bn.

indeed, through their own dedicated networks as when supporting more efficient operation of critical national infrastructure.

- Mobile broadband developments are also likely to involve growing capacity requirements in areas beyond consumer communications, opening up opportunities for new data-rich applications for the provision of Emergency Services (ES) or business radio applications.

1.20 These trends point towards a significant increase in competing demands for key spectrum bands, potentially raising the prospect of the need for important trade-offs amongst different sources of consumer and citizen benefits. It is likely that a combination of different solutions will be required to address future demand for spectrum. Many of these are likely to be developed and implemented by spectrum users, equipment manufacturers and standards bodies, although Ofcom could also have a role in enabling and facilitating these solutions. These will include:

- **Using better technologies to carry more information over a given amount of spectrum**. These will include new transmission technologies (e.g. LTE and emerging 5G standards in wireless broadband which could enable improvements in spectrum efficiency[7]; or greater use of digital technologies for wireless microphones and business radio applications) and new content compression standards (e.g. High Efficiency Video Coding in TV broadcasting).

- **Developing devices that minimise and are robust to interference**. As the intensity of spectrum use increases in future, technology standards that minimise out-of-band emissions by transmitting wireless devices and improved selectivity of receiving devices will also become increasingly important in managing co-existence issues when re-purposing spectrum.

- **Improving the way in which the same spectrum is used locally** so that each user can exploit it more. New means of achieving efficient spectrum use will include small cells deployments in mobile broadband, and improved operational practices in the deployment of devices, e.g. in PMSE.

- **Changing the use of given spectrum resources to more valuable uses** and **new ways to allow different uses to share the same spectrum resources**, including opportunities presented by new technical developments around dynamic spectrum access. In this context, Government's plans to release 500 MHz of public sector spectrum holdings to commercial uses will constitute a key source of supply both for dedicated and shared use of spectrum.

1.21 The international dimension of spectrum management remains critical, as it determines economies of scales from harmonisation and standardisation, and enables the coordination of high power uses across borders. We will continue to take an active role in the work of international institutions at both European and global levels and to coordinate closely with other National Regulatory Authorities.

[7] Future improvements in mobile broadband technology standards could increase spectrum efficiency up to 10 times between 2012 and 2030. See: http://www.ofcom.org.uk/static/uhf/real-wireless-report.pdf

In this consultation we propose seven key priority areas for Ofcom's spectrum activities over the next ten years

1.22 We have analysed future developments in major sectoral uses of spectrum to identify future trends in demand or supply of spectrum and assess the extent to which anticipated changes may require regulatory attention. Our analysis followed these key steps:

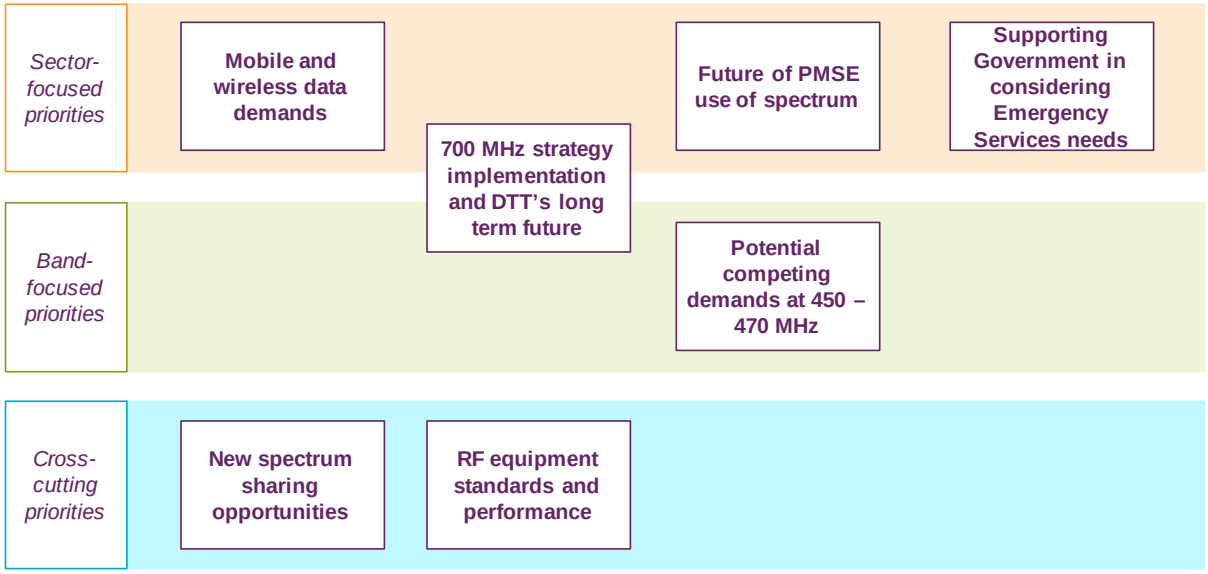
- we categorised the main sectoral uses of spectrum and looked at how they access spectrum today;
- we considered trends that could affect spectrum demand and supply for each of these uses over the next 10 years. We graded these future changes according to whether they could have a significant impact on consumer and citizen interests, and the urgency with which we might need to consider action;
- we then 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
- finally, we 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.

1.23 Our initial analysis of future developments suggests seven potential priorities for spectrum regulation over the next 10 years. These are illustrated below, according to whether they relate to challenges emerging in particular sectoral uses of spectrum (sector-focused priorities); specific bands under pressure from competing sectoral demands (band-focused priorities); or issues that could have particular relevance to a variety of sectoral uses and spectrum bands (cross-cutting priorities). There are, of course, significant interactions between these priority areas.

1.24 Here below, and in the rest of this document, we are drawing attention mainly to those areas that we think will raise significant challenges requiring a particularly strong focus for regulatory effort. Other bands and sectors (such as radio broadcasting, space and fixed wireless services) will also remain important and require ongoing regulatory attention with specific action being merited at times.

1.25 Our initial thinking on what these priority areas would encompass is summarised in the paragraphs below and discussed further in Section 6 of this document. Most probably, other issues and areas for attention that we are unable to foresee at this stage will arise over time. Therefore, we will need to keep our strategy and priorities under review.

Figure 2- Proposed priority areas



1.26 **Considering mobile and wireless data demands**: demand for capacity and expectations around ubiquitous coverage for wireless data networks could grow significantly over the next 10-20 years and there could be significant additional benefits for UK citizens and consumers associated with this. Considering the most appropriate response to growing demands for mobile and wireless data capacity and coverage will require us to consider a wide set of issues, including:

- contributing to international decisions on mobile broadband harmonisation for a wide range of spectrum bands, including engagement on the preparation for Agenda Item 1.1 at the 2015 World Radio Conference;
- supporting the Government's Public Sector Spectrum Release programme, and, in particular, delivering the release of spectrum at 2.3 and 3.4 GHz on behalf of the Ministry of Defence;
- developing a long term perspective on the value of further re-purposing spectrum to enable mobile and wireless data use, including the costs and benefits associated with such repurposing[8];
- understanding what steps we may need to take to facilitate this re-purposing to mobile and wireless data use (where this is justified);
- ensuring the effectiveness of the recently introduced coverage obligation on 4G spectrum at 800 MHz in extending indoor premises coverage to 98%;
- exploring options to support improvements in the geographical coverage of mobile and wireless voice and data networks in areas beyond population premises, including road and rail networks; andfacilitating any future role for spectrum sharing and licence-exemption in addressing growing mobile and wireless data demands. In particular we will contribute to international work on the proposed expansion of the 5 GHz band and support increased usage of WiFi and new forms of dynamic spectrum access for new small cell deployments.

[8] In particular, we will need to assess, in line with our duties, the value associated with increasing spectrum available to mobile and wireless data vis a vis the value associated with alternative uses, as well as the costs and disruption potentially associated with displacing incumbent spectrum users.

1.27 **Implementing our strategy for the 700 MHz band and considering DTT's longer-term future**: our UHF Strategy statement set out our objectives for enabling a potential change of use of the 700 MHz band to wireless broadband and the associated requirement for a re-planning of DTT in a way that secures the ongoing delivery of the benefits it provides. Whilst these potential changes are unlikely to take place before 2018, we are undertaking a number of activities to ensure they can be implemented with minimum disruption.[9] We have also initiated wider thinking on the longer-term future of DTT. This is because the implementation of future decisions on changes to DTT licences and transmission infrastructure are likely to influence outcomes beyond the potential timescales of the prospective change of use at 700 MHz.

1.28 **Considering the future of PMSE use of spectrum**: recent and future potential re-purposing of additional spectrum for mobile broadband is reducing the quantity, and changing the geographical pattern, of spectrum that PMSE applications (such as wireless cameras and wireless microphones) have access to. We are currently working with PMSE stakeholders to improve our understanding of their current and future spectrum demands, the impact of proposed spectrum re-purposing for mobile broadband and the scope for alternative spectrum supply options. We anticipate beginning to consult formally with stakeholders in Q4 2013.

1.29 **Considering potential competing demands for the 450-470 MHz band**: the configuration of this band is heavily fragmented between a number of different uses. In the past we have considered initiatives to re-organise and rationalise the use of this band, but then decided against action because of the cost and disruption to existing users that such a change would involve. Now, however, there are a number of new developments that mean it may be appropriate to reconsider the configuration of band. First, potential changes to technologies used in this band in other European countries may cause increasing levels of incoming interference. This might make the current UK configuration of this band (which does not align with the European harmonised band plan) unsustainable over the long term. Second, the long term potential for LTE use of the band means it could play a role in sustaining near ubiquitous mobile coverage. Our proposed future work in this area, therefore, will assess the potential impact of these developments and examine the case for a potential reconfiguration of this band.

1.30 **Supporting Government in its consideration of the future wireless communication needs of Emergency Services (ES)**: Emergency Services providers in the UK and throughout the world are currently considering their potential needs for a new generation of broadband communications. In the UK the existing contractual arrangements to deliver critical voice applications for the Emergency Service are coming to an end between 2016 and 2020. As a result, the UK is considering the future provision of both voice and broadband ES applications. Decisions on whether and how emergency services will require changes to the wireless communications services they use is a matter for Government, and we note the ongoing activities of the Emergency Services Mobile Communications Programme to address the future communications requirements of mainland UK ES. As Government progresses with this work, we anticipate that our support may be required, particularly in matters that relate specifically to spectrum availability and the potential for network sharing.

[9] http://stakeholders.ofcom.org.uk/binaries/consultations/700mhz-cfi/summary/UHF_SI_call_for_inputs.pdf

1.31 **Facilitating new spectrum sharing opportunities**: new technical and regulatory developments are expanding the range of uses for which shared spectrum access could be viable. At the same time, as part of its Public Sector Spectrum Release programme, Government, and in particular the Ministry of Defence, is looking to release spectrum for commercial purposes on a shared basis, both geographical and time based sharing. Spectrum sharing opportunities are likely, therefore, to become increasingly important as competing spectrum requirements grow and options for re-purposing spectrum diminish. We plan to support these developments by: progressing our work on TV White Spaces; considering new opportunities for shared access in new spectrum bands, as noted in our recently published consultation on spectrum sharing for mobile and wireless data[10]; assessing whether new regulatory tools are required and what form they may need to take; working to support Government as it considers the opportunities for it to share spectrum on a greater scale and in a more dynamic manner; and setting and reviewing over time co-existence parameters designed to balance the need to avoid harmful interference to incumbent services with the benefits associated with the provision of new and improved wireless applications.

1.32 **Supporting the improvement of radio equipment performance**: the growth of competing demands for spectrum and prospects for greater levels of spectrum sharing will continue to increase the intensity with which spectrum is used. This will drive the need to optimise, as far as possible, every component in a radio system. In this context, 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 become even more important to address new potential co-existence issues. We note that the proposals to replace the current EU Radio and Telecommunications Telecom Equipment (R&TTE) Directive represent a key opportunity to achieve this. In future, we will consider whether Ofcom should seek to contribute more to the work of standardisation bodies and the development of international regulations on radio equipment.

1.33 We also note that the Government's Public Sector Spectrum Release (PSSR) programme will be critical to the success of a number of the priorities we have identified. The potential of the PSSR programme is also illustrated by the significant proportion of spectrum that is used by Government bodies. Our support to this programme is a critical component of the mobile and wireless data priority as a potential source of new spectrum supply. The PSSR is also expected to be an important component in the identification of opportunities to share spectrum more dynamically and intensively within our spectrum sharing priority. It may also have a role in both the Emergency Services future needs and in considering the competing demands for the 450 – 470 MHz band given relevant public sector spectrum holdings in both cases.

1.34 There is a large programme of work that we expect to undertake in supporting Government to achieve its release target, which will directly contribute to the achievement of our priorities. This is most recently demonstrated by MoD's release of spectrum at 2.3 and 3.4 GHz to Ofcom for conduct the sale process as well as the work on co-existence with civil users. Given, however, the extent to which this work contributes directly to several of our proposed priorities, we have not identified it as a specific priority in its own right.

[10] http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-sharing/summary/Spectrum_Sharing.pdf

1.35 In Table 1 on page 13 we outline an indicative work programme relating to each of these proposed priority areas over the coming years. 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; in addition, other issues and areas for attention will most probably arise over time and we will need to keep our strategy and priorities under review.

Our licensing and enforcement activities will continue to remain central to ensuring optimal spectrum use

1.36 In addition to these priorities we will also continue with a large programme of work related to the authorisation and enforcement of spectrum use. It is illegal for anyone, apart from Crown bodies[11], to use spectrum[12] in the UK without first being authorised to do by Ofcom, either by holding a Wireless Telegraphy Act licence or under the terms of a specific licence exemption.

1.37 A central part of Ofcom's activities is concerned with managing, maintaining and developing the licence products and general authorisation regimes. This involves significant, ongoing policy effort to reflect technical and market developments that might require, for example: adaptation of channel plans to accommodate new channel widths; adjustments to assignment and coordination tools to deal with new technologies; and changes to technical co-existence parameters, or to the regulatory framework, that influence the way that different services can share spectrum access.

1.38 We also have a large programme of work associated with our enforcement activities. The main activities can be categorised as: proactive intervention, in relation to illegal broadcasting, otherwise known as pirate radio; market surveillance and enforcement, in relation to products made available illegally in UK; and reactive enforcement, where we investigate complaints from spectrum users of interference.

In future, we also propose to track an expanded set of key metrics to monitor of how spectrum use changes over time

1.39 Monitoring changes in spectrum use to track the effects of our spectrum management initiatives will continue to remain important. Relevant metrics for taking this forward include the quantities of spectrum that are available for market access and those managed and used by the public sector (Crown bodies). Within spectrum for market access, we will also track how much spectrum is managed by us and how much is released in large blocks to licensees (e.g. through auctions). Across these categories we also intend to monitor quantities of spectrum that are tradable, liberalised, internationally harmonised, and shared across more than one use.

1.40 In addition, we consider that targeted studies to measure how intensive the actual use of specific spectrum bands is could become increasingly relevant to inform future spectrum regulation initiatives. In particular, specific utilisation measurements could provide relevant evidence to assess levels of demand for uncoordinated bands that are available for licence-exempt uses and to screen candidate bands for new sharing opportunities.

[11] 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.
[12] It is unlawful to establish or use a wireless telegraphy station, or install or use wireless telegraphy apparatus.

1.41 We invite all interested stakeholders to respond to this consultation by 11 December 2013.

Table 1 - Indicative work programme in support of our proposed priority areas

Priority area	Issues that Ofcom is already considering	Issues that are likely to become relevant over the next 3-5 years	Issues potentially relevant over the longer term
Mobile and wireless data demands	• Preparations for WRC-15 (esp AI 1.1) and other ongoing international engagement • Developing a long term perspective on demand and supply options • Undertaking the auction of the spectrum vacated by MoD at 2.3 and 3.4 GHz • 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 opened by international decisions • Developing and implementing a consistent approach to assessing and enabling use of additional spectrum for mobile and wireless data • Supporting Government in future releases, particularly sharing opportunities, as part of the PSSR programme • 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 demand
700 MHz strategy implementation and DTT's long term future	• International engagement on 700 MHz harmonisation and coordination discussions • Initial CBA on 700 MHz re-purposing and associated changes • Explore opportunities to reduce and avoid future disruption • Initiate thinking on role of DTT and free-to-view TV post 700 MHz re-purposing	• Final decision on 700 MHz repurposing • 700 MHz award design • Understand and begin implementation of regulatory steps required to enable transition • Consider issues around costs of transition	• Enabling action and regulatory support to 700 MHz clearance and award
Future of PMSE spectrum access	• Understanding current and future PMSE demand and the feasibility of different supply options • Considering the future role of new PMSE equipment technologies • International engagement on initiatives over PMSE harmonisation in Europe and within ITU work	• Reviewing our approach to PMSE spectrum management • Assessing the impact of planned spectrum changes on PMSE	• Considering the potential relevance of cognitive technologies to PMSE applications
Supporting Government in considering future ES communications needs	• Understanding the extent of Ofcom advice required by Government • Representing UK interests in International spectrum PPDR spectrum harmonisation negotiations	• Providing advice as requested by Government on potential availability of spectrum and costs • Providing support to Government, if required, on the planning and implementation of any required transition between spectrum bands	• Ongoing advisory role to Government in Emergency Services use of spectrum through PSSPG and UKSSC
Potential competing demands at 450 – 470 MHz	• Audit of current use by private mobile radio users • Assessment of potential role of spread spectrum techniques to enable greater sharing in UHF II and other business radio bands	• Technical risk assessment of current UK band planning arrangements in light of developments in Europe; • Assessment of benefits of a replan of the band to align with the European band plan • Considering benefits and costs associated with potential change of use of this band to wireless broadband (LTE)	• Assessment of migration and other supply options for Business Radio uses in the event of replan and / or repurposing of this band
New spectrum sharing opportunities	• Progressing our work on enabling sharing through geo-location databases in TV White Spaces • Progressing our work considering the role of licence exempt devices in delivering mobile wireless broadband and the regulatory implications • Identifying suitable spectrum for shared access for R&D purposes • Assisting MoD on making additional spectrum available through sharing	• Assessing the opportunities for greater market-led spectrum sharing including understanding any existing barriers to this occurring • Identifying new frequency bands that could be made available for shared access through a geo-location approach • Considering the case for new regulatory tools to support new applications making use of innovative techniques for sharing spectrum • Contributing to international discussion around the future use of spectrum bands on a shared basis	• Considering prospects for cognitive technologies and implications for spectrum management
RF equipment standards and performance	• Contributing to the R&TTE Directive revision process • Monitoring activities by European and other International standardisation bodies	• Considering the case for more active regulatory involvement on standardisation activities	• Prospects for cognitive spectrum access and potential easing of interference management

Section 2

Introduction and purpose

Spectrum is a key asset to the UK and Ofcom has specific duties and powers related to its management

2.1 Radio spectrum is a major asset to the UK. A recent study undertaken for Government indicated that it contributes over £50bn to the economy each year.[13] Radio communications underlie many aspects of our lives and are critical to areas such as air travel, Emergency Services, mobile broadband, sound 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 European common regulatory framework for electronic communications,[14] in particular the Framework Directive and the Authorisation Directive, sets the broad framework for how spectrum use should be authorised and managed in UK and aims to harmonise the regulation of electronic communications networks and services throughout the European Union. The UK's responsibilities for spectrum management under these Directives are given effect in UK law through two Acts of Parliament:

- The Communications Act 2003 (the "2003 Act"); and
- The Wireless Telegraphy Act 2006 (the "WT Act").

2.3 These Acts confer on Ofcom specific duties and powers in respect of spectrum (and the other sectors we regulate).

2.4 The 2003 and WT Acts set out a broad range of duties and powers, as well as a wide range of factors that we need to consider when making decisions on how to exercise our powers. Of particular relevance to the exercise of our spectrum functions, the 2003 Act sets out 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. It also requires us to secure in the carrying out of our functions the optimal use for wireless telegraphy of the electro-magnetic spectrum. The WT Act also includes specific duties which we must have regard to when carrying out our radio spectrum functions.

2.5 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 it is used to produce the maximum benefits (or value) for society. We intend the benefits from efficient use to include those enjoyed by providers and consumers of services as well as the wider social benefits, or the indirect benefits, of services provided using spectrum.

2.6 In addition to our spectrum related duties, we have a wide range of other duties that can be, impacted by, or delivered through, spectrum decisions. These include,

[13] https://www.gov.uk/government/publications/impact-of-radio-spectrum-on-the-uk-economy-and-factors-influencing-future-spectrum-demand

[14] The Common Regulatory Framework comprises the Framework Directive (Directive 2002/21/EC), the Authorisation Directive (Directive 2002/20/EC), the Access Directive (Directive 2002/19/EC), the Universal Service Directive (Directive 2002/22/EC) and the Directive on privacy and electronic communications (Directive 2002/58/EC), as amended by the Better Regulation Directive (Directive 2009/140/EC), www.ec.europa.eu/information_society/policy/ecomm/doc/140framework.pdf.

amongst others, promoting competition, securing the availability throughout the UK of a wide range of communications services and of a wide range of TV and radio services of high quality.

2.7 The Acts specifically recognise that on occasion we will need to exercise our discretion in terms of the weight we give to different considerations in making spectrum policy decisions. As such we exercise a considerable degree of discretion in terms of the activities we undertake and the specific decisions that we take. The Acts also provide for Government to direct us to act where it has a specific view on how we should discharge our duties and exercise our powers, including in relation to our spectrum functions.

2.8 In addition to our functions under the common regulatory framework, we have also been directed by Government to represent UK interests in negotiations within the main spectrum related international institutions, including the International Telecommunications Union (ITU), the European Conference of Postal and Telecommunications Administrations (CEPT), and spectrum committees of the European Union.[15]

2.9 Given the broad discretion we have in deciding how best to fulfil our spectrum duties, it is important that we take a strategic approach to managing this scarce and valuable resource. We also consider that it is important that our spectrum management strategy takes account of a forward looking perspective on long-term developments in major uses of spectrum. This is because communications markets and services for which radio spectrum is an important input continue to evolve, and enabling major changes in how spectrum is used often involves long timescales.

We authorise the use of all UK spectrum with the exception of that used by Crown bodies

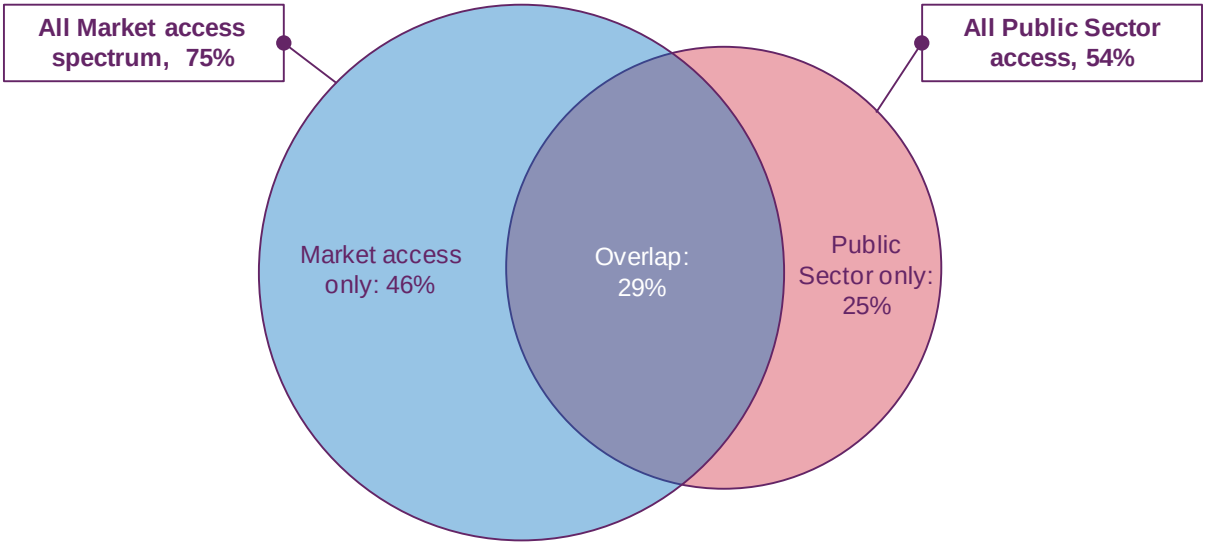
2.10 Ofcom is responsible for authorising the use of all spectrum with the exception of use by Crown bodies. There is no general legal definition of a Crown body but central government departments reporting to ministers such as the Ministry of Defence, Home Office and Department for Transport are generally considered to be Crown bodies.

2.11 As we illustrate in Figure 3 there is market access to around 75% of weighted spectrum[16] whilst Crown users have access to 54%. There is a significant proportion of spectrum to which both have access on a shared basis (29%).

[15] We discuss the role of these bodies in greater detail at paragraph 3.60

[16] We have considered spectrum frequencies between 87.5 MHz and 80 GHz. We have applied a linear weighting for spectrum up to 1 GHz so that 10 MHz of bandwidth at 100 MHz is given the same weight as 10 MHz of bandwidth at 1 GHz. Above 1 GHz, however, we have applied a logarithmic scale, so that the same weight is given to 10 MHz of bandwidth at 1 GHz as is given to 100 MHz of bandwidth at 10 GHz as is given to 800 MHz of bandwidth at 80 GHz. The use of a logarithmic scale above 1 GHz avoids the significance of bands at, or near, the UHF frequency range being swamped by the weight that would otherwise attach to the much higher frequency ranges. We used a similar weighting approach as part of our work on the Spectrum Framework Review in 2005 with the exception that the 2005 work applied a logarithmic scale across all frequency ranges, including spectrum below 1 GHz. We have adjusted this approach below 1 GHz in our current work to avoid giving a disproportionate weight to low frequency spectrum (e.g. a logarithmic scale below 1 GHz would attach ten times as much weight to 20 MHz of bandwidth at 100 MHz as to 2 x 9 MHz of bandwidth at 900 MHz). As we progress our work on these estimates in future, we may decide to make further changes to our methodology.

Figure 3 - Illustration of Market access and Crown spectrum



2.12 The manner in which Ofcom authorises market access to spectrum can be divided into one of three broad approaches:

- through a set of licence products for individual assignments or channels ("Ofcom band managed");
- through licences for large blocks of spectrum which give the licensee wide scope for exploitation of the spectrum ("block assigned"); or
- through licence exemption.

2.13 The UK spectrum map in Figure 4 on page 19 provides further detail on the proportions of weighted spectrum falling under each of the different modes of spectrum access discussed in Table 2 and their overlaps. The illustrations and figures we report here are indicative and based on our analysis of the UK FAT (Frequency Allocation Table)[17] and the UK PFA (UK Plan for Frequency Authorisation).[18]

[17] 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/)

[18] 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

Table 2 - Spectrum attribution categories

Spectrum attribution category	Explanation and indicative proportion of total weighted spectrum in this category in 2013	Major uses in this category
Ofcom band-managed	This refers to bands where we issue licences on the basis of the individual assignments within the band, often on a first come first served basis, and in many cases through detailed technical coordination. Circa 53% of all weighted spectrum falls under this category	*This includes DTT broadcasting, Business Radio, Fixed Links, PMSE and Satellite Permanent Earth Station and VSAT bands.*
Public Sector (Crown)	This is spectrum managed and used by Crown bodies under the terms of the Frequency Allocation Table[19]. Circa 53% of all weighted spectrum falls under this category	*The majority of Crown spectrum is used and managed by the Ministry of Defence. Other users include Home Office, the Department of Transport[20], the Department for Health, the Department for Communities and Local Government and the Emergency Services.*
Licence exempt (LE)	This is spectrum that is available for use by licence exempt devices. Circa 27% of all weighted spectrum falls under this category	*Licence exempt uses include WiFi, Bluetooth, RFID and a vast range of other Short Range Devices (SRDs).*
Block-assigned	This refers to bands where licensees manage their own deployments within the band (or act as a band manager for third party access) with a high degree of flexibility. In general these bands have been assigned via auction. Circa 12% of all weighted spectrum falls under this category	*This includes all bands that have been auctioned, together with long standing assignments such as the 900 MHz and1800 MHz licences used by mobile operators.*
Other	This includes other uses of spectrum which do not require licensing, but still need to be considered in our technical planning. These relate to both public sector and commercial users. Given the complexities in analysing sharing arrangements between "Other" uses and all the remaining categories, we only report the amount of spectrum that falls exclusively under this category. This is circa 2% of total weighted spectrum and roughly half of this falls in each of the two "market access" and "public sector access" categories we use in Figure 3.	*Radioastronomy and Met Office use including Earth Exploration Satellite Services (EESS), Receive only Earth Stations (ROES) for EESS.*

[19] This category includes spectrum used exclusively by Crown bodies and spectrum managed by Crown bodies (e.g. the MOD and the CAA), but where specific provisions allow Ofcom to mange civil uses within the same band(s). These bands have UK2 or UK4 allocation provisions associated with them and civil access is allocated typically under a UK4.xx provision. There are also cases where bands managed by Ofcom, which have a UK1 provision associated with them, also have specific provisions for shared Crown uses. Specific footnotes are used in these cases often Crown access is often limited to specific radiocommunication services http://stakeholders.ofcom.org.uk/binaries/spectrum/spectrum-policy-area/spectrum-management/ukfat2010.pdf

[20] In this category we also include Aeronautical spectrum coordinated between the Civil Aviation Authority and the Ministry of Defence.

2.14 In Figure 4 below, we illustrate the indicative proportions of total weighted spectrum that fall under each type of overlap across these categories.[21] These figures are provisional and subject to revision in light of further work. However, they illustrate a number of important features of spectrum access:

- Of the market access to spectrum that is authorised through licences (65%), the Ofcom band managed segment (53%) is significantly larger than the block assigned bands (12%)

- The high proportions of spectrum that is accessed by Crown users (53%), although a significant proportion of this access is shared;

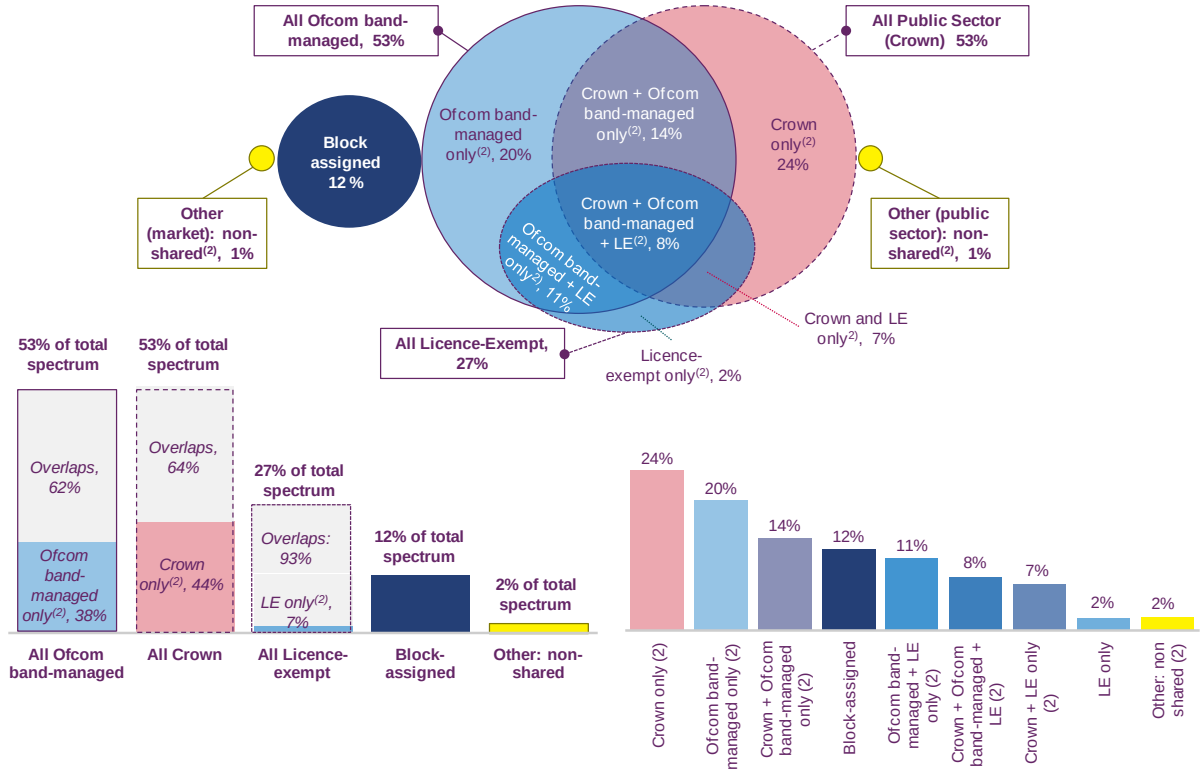
- Although 27% of the spectrum can be accessed by licence exempt devices, the vast majority of this is in bands where this access is shared with licensed users or with Crown users;

- The high proportion of spectrum access that is shared between one or more of the above modes of spectrum access (40% of the total shown in Figure 4, noting that this number does not include sharing with the "other" category which would increase the % shared). In particular, more than half of Crown spectrum is shared with uses authorised by us, both Ofcom coordinated and licence-exempt. "Market access" uses that access significant portions of Crown spectrum on a shared basis include Programme Making and Special Events, business radio and Amateur users.

2.15 It is also worth noting that the overlaps between these different modes of spectrum access under-represent the extent to which spectrum is shared across different uses. In fact, significant amounts of sharing exist within the same category and these are not reflected in these illustrations. For example, fixed links and satellite users share some spectrum bands within Ofcom-coordinated bands. The same applies to DTT broadcasting and PMSE (with new white-space devices also due to access the same spectrum resources from 2014). Also, bands that are illustrated below as "Crown-only" include frequencies that are shared between the Ministry of Defence and other public sector users.

[21] As we discuss above, for "other" uses we only report an estimated proportion of total spectrum that falls exclusively under this category. As we do not report estimates for how the "other" category overlaps with the remaining categories, the figures quoted in Figure 3 for spectrum proportions falling exclusively under public sector (Crown), Ofcom band-managed and LE categories *could be over-estimates* and should therefore be treated with caution.

Figure 4 - Indicative UK spectrum map for 2013



Please note:

(1) The Venn diagram at the top is illustrative and not to scale. It illustrates how the spectrum attribution categories we have identified in Table 2 overlap. The indicative figures quoted are a proportion of total weighted spectrum. With reference to Figure 3, "Market access" is the sum of Ofcom band-managed, Block-assigned, Licence-exempt and "Other (market) "spectrum. "Public Sector access" in Figure 3 is the sum of "Public sector (Crown)" and "Other (public sector)" in this Figure. Note also that, although not shown in this diagram, a small amount of Block-assigned spectrum overlaps with Crown (MoD) and LE spectrum.

(2) Figures for all sub-categories formed by the overlaps amongst the categories discussed in Table 2 are indicative and should be treated with caution. In particular, figures for "Crown only", "Ofcom band-managed only" and "LE only" are likely to be *over-estimates* as we are not reporting overlaps between "Other" and these categories.

(3) In the diagram on the bottom left, the main bars illustrate the proportion of total weighted spectrum falling under each of the main categories discussed in Table 2. Within each bar, we quote the split between spectrum falling exclusively under each category and overlapping with other categories. Figures quoted inside each bar are proportions of the total size of each bar. For example, 38% of all Ofcom band-managed spectrum falls exclusively in this category; this equates to 20% of total weighted spectrum.

(4) In the diagram on the bottom right, the size of each bar represents the proportion of total weighted spectrum falling under each sub-category formed by the overlaps amongst the categories discussed in Table 2. As noted above, all these figures are indicative and should be treated with caution.

2.16 Our proposed forward looking strategy in this document relates directly to most of these categories of spectrum. The main exception is bands that are exclusively used by Crown bodies (shown in pink in the charts above), although in some cases, we do and will provide advice to Government on those bands.

2.17 The considerable level of overlap amongst these categories, and between Public Sector and Market access in particular, illustrates the importance of ensuring consistency in how spectrum is used and managed across all types of UK spectrum. As we discuss further below, Government has announced plans to undertake an overarching UK Spectrum Strategy. The spectrum management strategy we discuss in this document will be an important contribution to this.

The main purpose of this document is to consult on our proposed strategy on how to fulfil our spectrum duties

2.18 We have considered carefully what our strategy should be to best achieve our relevant statutory duties over the coming years. Having done so, we are now publishing this *Spectrum management strategy consultation* setting out:

- the approach we propose to take to managing UK spectrum; and
- our proposals for the priority areas of our work over the next ten years.

2.19 In this consultation document we share our initial views on future developments in spectrum use (as they relate to technology, market and regulatory trends) that our strategy will need to take into account. We also discuss how our approach to managing spectrum has been refined in light of our experience.

2.20 We invite stakeholders to contribute their views on these important subjects to ensure that our strategy reflects a comprehensive assessment of relevant factors that are likely to impact spectrum use over the next 10 years. Ofcom aims to be consultative, transparent and proportionate in everything that it does and we remain committed to our consultation principles, which are laid out in Annex 2 of this document.

2.21 In establishing this spectrum management strategy we are not looking to forecast the future, but highlight potential developments that might raise the need for regulatory action in support of optimal spectrum use. Many trends in spectrum use may have little or no bearing on the need for us to act, whereas others may have a significant impact on the work we may need to do. It is likely that future spectrum use will not develop entirely as we currently expect. Some variations will not affect our strategy, whilst others may have a significant impact and result in a re-evaluation of our priorities. Ofcom will therefore continue to monitor market developments on an ongoing basis so that we are able to adjust our strategic approach to spectrum management should this be necessary.

This document will also contribute to Government plans for an overarching UK Spectrum Strategy

2.22 Given its importance to the UK, securing the best use of radio spectrum is a key element of the UK Government's broader policies on the economy and society.

2.23 The Government recently announced, in the *Connectivity, Content and Consumers* paper,[22] plans to develop an overarching UK Spectrum Strategy that will cover all UK spectrum (including both market access and public sector access) and set out the key changes to spectrum use that will be necessary over the next 10 to 15 years. Government expects this strategy to be published in early 2014.

2.24 This Ofcom consultation will be an important contribution to the overarching UK Spectrum Strategy and we will continue to work closely with Government in the coming months in support of this process.

22 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/225783/Connectivity_Content_and_Consumers_2013.pdf

This consultation builds on the Spectrum Framework Review and its Implementation Plan of 2005

2.25 This consultation document builds on the strategy Ofcom laid out in its 2005 *Spectrum Framework Review* (SFR) statement.[23] It adapts our approach to radio spectrum management in light of the progress we have made since we published the SFR, our experiences in implementing this approach, and as a result of our analysis of the potential future development of the communications market.

2.26 The SFR set out a vision for spectrum management in support of a market-led approach:

- Spectrum should be free of technology and usage constraints as far as possible. Policy constraints should only be used where they can be justified;
- It should be simple and transparent for licence holders to change the ownership and use of spectrum; and
- Rights of spectrum users should be clearly defined and users should feel comfortable that they will not be changed without good cause.

2.27 The SFR also noted that, inevitably, there would be circumstances in which we could not fully achieve this vision. In these cases we said that we would explain why we departed from it.

2.28 Following the publication of the SFR, we set a series of objectives to guide the implementation of this market-based approach. These included:

- awarding newly available spectrum through market mechanisms, e.g. by auction, minimising technology and usage restrictions;
- liberalising existing licences as far as possible, by removing unnecessary restrictions;
- extending trading to all appropriate licence classes;
- supporting the public sector in releasing under-used spectrum to the market; and
- extending spectrum pricing to all appropriate licence classes.

2.29 In the following section we describe how we delivered against these objectives through the progress we have made in major initiatives undertaken over the past eight years. We also consider the outcomes of these initiatives and whether, given hindsight, we would address these in a similar manner in future. We also consider whether the intended outcomes might have been more effectively achieved through different approaches.

[23] http://stakeholders.ofcom.org.uk/binaries/consultations/sfr/statement/sfr_statement

Ofcom has undertaken a range of initiatives and achieved much for consumers and citizens since the publication of the SFR

2.30 Since we published the SFR in 2005 a wide range of spectrum initiatives have delivered significant benefits to consumers and citizens. The following table summarises the main outcomes of these initiatives.

Table 3 - Outcomes associated with major past spectrum initiatives

Major spectrum initiatives	Ofcom's actions	Outcomes
Improved the efficiency of the use of spectrum allocated to terrestrial TV through Digital Switch Over (DSO)	Government mandated DSO leading to the release of UHF spectrum ("the Digital Dividend"). We put in place the licensing framework and monitored the process of transitioning from analogue to digital TV.	*DSO has increased choice for TV viewers, expanding the range of available terrestrial channels; preserved universal availability of PSB channels; and freed up spectrum for mobile broadband use.*
Re-purposed the Digital Dividend UHF spectrum align 800 MHz band with European harmonised band plan for 4G / LTE use	Defined the case for relocating existing DTT and PMSE use out of the 800MHz band and engaged with international bodies to secure the necessary agreements. We then delivered a major clearance programme over a 3 year period (ahead of original plan) to enable the deployment of 4G services in the awarded spectrum bands.	*Release of spectrum for mobile broadband will lead to coverage of 4G to 70% UK population by end 2013 and 98% of population indoors and at least 95% of population in each of the Nations by 2017.*
Released the 800MHz band, in combination with 2.6GHz band, to support new 4G mobile broadband market and deliver widespread coverage	We designed and carried out the combined auction which was structured to support a competitive market and which included a coverage obligation.	
Liberalised the licences made available for Mobile use	We removed technology-specific conditions from public mobile licences. This initially allowed 3G deployment at 900 MHz and, more recently, 4G at 1800 MHz and has now been extended to all public mobile licences.	*Mobile operators have exercised their choice of technologies to deliver enhanced and more efficient services to consumers.*

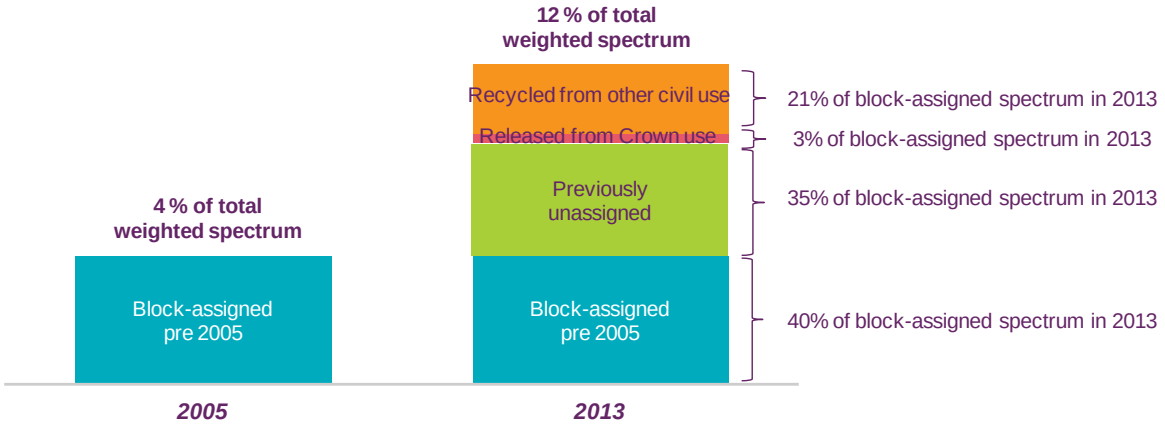
Extended liberalisation, trading and administered incentive pricing (AIP)	We extended trading to 84% of licensed spectrum and introduced leasing of spectrum. We simplified and provided greater flexibility to users of Business Radio licences. In addition, we have extended spectrum pricing (AIP) to most major licence classes (broadcasting remaining the most important class to which AIP is not yet applied).	*A range of spectrum users (notably in business radio, wireless access and mobile broadband sectors) have enjoyed greater flexibility in responding to new opportunities and changing requirements.* *Significant aspects of our strategic approach have contributed to European policy (e.g. the EU's WAPECs initiative developed technology neutral technical licence conditions for range of IMT bands).*
Brought unused spectrum into use and assigned through auctions	We have auctioned several significant spectrum bands in addition to the Combined Award of 800MHz and 2.6GHz, including 10-40 GHz, L-band, DECT guard band and 412 MHz and, most recently, have completed the award of interim use of the 600MHz band.	*The 10-40 GHz band is now widely used for mobile backhaul. L-band spectrum, although not yet in commercial use, has been championed by the new licensee as a credible candidate for harmonised mobile data downlink band.*
Provided spectrum management support to London 2012 Olympics and Paralympics	Ofcom sourced spectrum from the Crown holdings and WT Act Licensees and managed the spectrum required to deliver spectrum needs for 2012 Olympics and Paralympics.	*We contributed to successful 2012 Olympic and Paralympic Games by delivering the Government spectrum guarantee as well as other associated PMSE needs.*

Over the past eight years we have moved forward considerably in implementing a market-led approach to spectrum management

2.31 Over the past eight years we have moved a long way towards our objective of providing, as far as possible, an environment with minimal regulatory barriers to the operation of market forces.

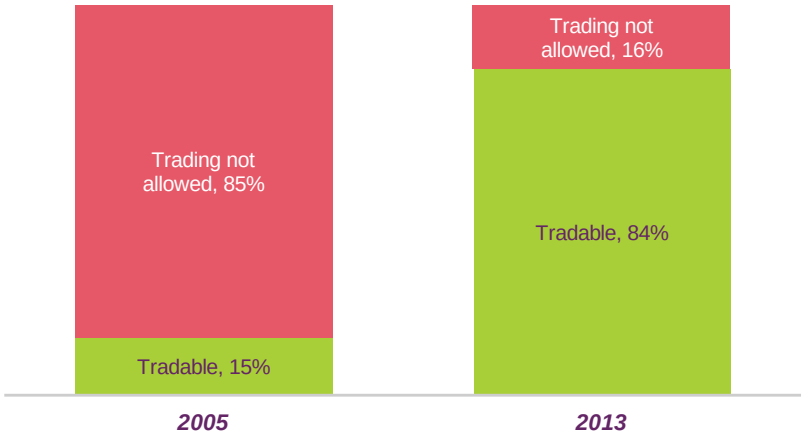
2.32 Our release programme has nearly tripled the proportion of block-assigned spectrum since 2005 and this has been achieved primarily through auctions. Over half of the spectrum that has been auctioned since 2005 was previously unassigned, whereas in other cases auctions have enabled bands that were already in use to be recycled to more valuable uses.

Figure 5 - Block-assigned spectrum in 2013



2.33 The majority of licence classes are now tradable and spectrum leasing has also been introduced, whereby, once granted the right to lease, licensees can transfer their rights to other users without regulatory oversight. Since 2005 trading has been extended to business radio, fixed links, public wireless network, maritime and Permanent Earth Station licences. As result, we estimate that, as of today, 84% of relevant[24] spectrum is tradable, up from 15 % in 2005.

Figure 6 - Proportion of relevant spectrum which is tradable, 2005 and 2013



2.34 We have, in general, removed unnecessary technology or usage constraints to the extent possible, given the need to define spectrum access rights that manage the interference environment. For example, we have changed the approach to management of business radio licences (a category which covers a very wide range of important users) so that users can gain access to a wider pool of spectrum resources without constraint on the type of use. Where licensees have come to us seeking greater flexibility we have varied licences (e.g. to allow mobile use in bands that were previously limited to fixed wireless broadband, to increase power limits in existing mobile licences, and to enable new fixed link technologies to be deployed).

2.35 We have also adopted a policy of technology neutrality towards auctioned licences such as the L band and 10 – 40 GHz auctions which are now used, or likely to be

[24] This excludes uses for which trading is not relevant. These are: Amateurs & Ships, Aeronautical, PMSE, Police and Fire, Licence Exempt, Science & Technology.

used in the near future, for purposes that were not prescribed at the time of the auction.

2.36 In cases where it is clear from market engagement that a band will be used for a particular purpose, such as mobile broadband in the case of the recent 4G auction, we have designed technical licence conditions that will support that use without developing more complex licence conditions that could also support other uses. However, as with all licences, we remain open to making changes in licence conditions in future, subject to the impact on adjacent users, if a new and more valuable use for the spectrum emerges over time.

2.37 Spectrum pricing has been extended to most licences that were granted through an administrative assignment. Although the responsibility of Government rather than Ofcom, spectrum pricing has been applied to a number of important Crown users of spectrum, notably MoD, and will be extended to others in 2015/16.

2.38 Because changes in the pattern of spectrum use can take many years, the significance of our market-led policies could appear limited thus far. However, a number of licensees have been able to change the services they provide and the technology they use with only limited oversight from the regulator.[25] There has been a modest, but meaningful, level of spectrum trades, a number of which have been important, and value-creating, for the parties concerned. Nevertheless, the characteristics of spectrum are not, in general, consistent with conditions required for liquid markets. Features like the heterogeneous nature of different spectrum bands and the sizeable investments required to exploit spectrum mean that spectrum trades are likely to remain relatively infrequent.

However, we have also learnt that timely regulatory action can be very important to securing benefits of spectrum use

2.39 When we reflect on how the most significant increases in the benefits of spectrum use that have come about, this has, by and large, been through action by us to facilitate and manage major changes in use (e.g. 800 MHz change of use from DTT to mobile use), rather than through spectrum trading and liberalisation. This is largely because of the following factors:

- the increasing importance of the international regulatory framework and our critical role in negotiating changes to this. 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 co-existence challenges that can arise in case of major change of use. This can form a major obstacle for markets to overcome, such as 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

[25] Although it has been appropriate, in some cases, to consult on the variation of technical licence conditions.

- 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.

2.40 However, even where these factors have been relevant, market mechanisms have still played an important role alongside regulatory intervention, notably through the use of auctions to assign the rights holders for the new use.

2.41 Reflecting on the vision for spectrum management set out in the SFR (see paragraph 2.26 above) we would add the qualification that enabling a significant change in spectrum use is not often a simple process; this is because of the potential impact on other users. It is also important to reflect not just on whether the outcomes have been desirable, but also on whether we achieved these in the most efficient and effective way. Assessments of co-existence can be challenging, often in the face of significant uncertainties, for example in the details of the transmission network and equipment that will be deployed or in the details of the receivers that may be affected. We have been more successful in understanding the scale and impact of coexistence challenges in some cases than in others. There is a need to guard against being overly conservative in assessing coexistence issues. There is also real benefit in considering, early on, what practical measurements we can undertake to inform the models we use so as to better reflect real-world experience.

It is now an appropriate time to review our spectrum management strategy

2.42 The SFR is now eight years old and we have gained significant experience of implementing the approach it set out. During this time we have also largely completed the work programme we set ourselves, which included a number of major activities, culminating recently in recently in the completion of the DSO, the 800 MHz and 2.6 GHz combined award and the liberalisation of the existing mobile licences. It is therefore an appropriate time to consider what the major priorities for our work over the next 10 years should be.

2.43 In addition, more than ever before there is a rapidly evolving demand for spectrum. As new, data-reliant technologies and services come to market and demand for capacity in public and private wireless networks increases, it is important that we consider the implications for future spectrum demand and supply and on what constitutes optimal spectrum use.

Structure of this document

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

- Section 3 introduces the key market, technology and international developments that have informed our strategic review. Spectrum demand and supply trends in key sectoral uses of spectrum are discussed in greater detail in the Appendix to this consultation[26].

- Section 4 discusses our approach to spectrum management. This builds on the 2005 Spectrum Framework Review and is informed by our experience of managing spectrum since then.

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

- Section 5 outlines the methodology and key findings for our analysis of future developments in major spectrum uses. This underpins the identification of our proposed priorities.

- In Section 6 we discuss in greater detail our proposals for our spectrum priority areas for the next 10 years. These indicate the key issues that we will need to consider within each of these priority areas to determine whether regulatory action is required and, if so, what form it should take.

- In Section 7 we outline our proposals for an extended set of metrics to track how spectrum use changes over time and our expectations for how these may change in future. We also briefly discuss how targeted measurements on spectrum utilisation could be relevant to informing future spectrum initiatives.

2.45 We invite stakeholders' comments on these proposals.

Section 3

Market and international context

3.1 In this section we outline:

- the importance of spectrum to the delivery of services that offer significant benefits to UK citizens and consumers;
- the key communications market and technology developments that could lead to significant change in spectrum demand and supply over the next 10 years. These developments are discussed in greater detail in the Appendix to this consultation and inform our proposals for future spectrum priorities set out in Section 6; and
- the continuing importance of international factors to regulating spectrum in the UK. We discuss our proposals for international activities in support of the delivery of our spectrum priorities in Section 6.

Spectrum use delivers significant citizen and consumer benefits

3.2 Radio spectrum serves as a critical input to a wide range of services through which it delivers highly significant benefits to citizens and consumers.[27] In the Annual Plan 2013/14 we discussed our general Ofcom strategy setting out the factors we consider crucial to delivering consumer and citizen benefits in light of our duties, including the importance of securing optimal use of spectrum.[28]

3.3 Different uses of spectrum deliver different types of consumer and citizen benefits. Regulating spectrum and optimising its use requires us to balance the delivery of these benefits. Below are some examples of how spectrum uses deliver different balances of consumer and citizen benefits.[29]

3.4 The benefits of spectrum use from communications services are most visible to consumers and citizens in the delivery of TV broadcasting and mobile communications:

- Digital Terrestrial Television (DTT) and Satellite TV provide significant value to consumers by delivering a variety of free-to-air and pay-TV broadcasting services and sustaining choice of digital TV channels and platforms. DTT also delivers important citizen benefits by delivering near-universal free-to-air (FTA) Public Service Broadcasting (PSB) and its associated social and cultural benefits.

[27] Citizens participate in the marketplace as well as in a range of social, cultural and political activities that are not the subject of commercial contracts. Consumers participate in the marketplace alone, buying or using goods and services. The roles of citizen and consumer are often intertwined; using media and communications services to participate in society usually involves having access to those services as a consumer. However, consumer goods can also be important tools for citizens. For example, mobile phones can also be used to enhance personal safety, promote social networking and enable participation in society by people with disabilities, such as those with hearing impairments being able to communicate using text messages.

[28] http://www.ofcom.org.uk/about/annual-reports-and-plans/annual-plans/annual-plan-2013-14/

[29] A broader discussion of different types of citizen and consumer benefits deriving from spectrum use is presented in the Appendix to this consultation: http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/annexes/appendix_spectrum_management.pdf

- Mobile communications services deliver significant benefits for consumers, sustaining choice and innovation in voice and data applications. Wireless broadband is the key growth area in the mobile sector and could, in future, deliver important additional consumer benefits. Wireless broadband is also important for citizens as widespread connectivity can encourage social inclusion and informed democracy.

3.5 But other types of important benefits associated with spectrum use are generated through services for industry or public sector users. For example:

- The use of spectrum for Emergency Services communications generates critical citizen benefits by contributing to the delivery of safety-of-life services.

- Spectrum use by utilities and transport providers for telemetry and other purposes is an input in the citizen benefits associated with the safe and efficient functioning of Critical National Infrastructure often underpinned by regulation.

- Spectrum use for wireless microphones and cameras in Programme Making and Special Events (PMSE) delivers private value by enabling elaborate productions, and serves also as an input in the delivery of citizen benefits through the creative sector.

- Earth exploration satellite services (EESS) gather sensing data and provide information for a wide range of scientific areas including climate change and environmental protection, disaster management and meteorology.

- The aeronautical and maritime sectors use spectrum for a range of applications including radar and navigation services. These sustain the delivery of important benefits to the trade and the tourism industry, as well as securing critical safety-of-life functions.

3.6 As consumer behaviour, market dynamics and technologies in the communications sector evolve, the actual and potential consumer and citizens benefits associated with existing and new spectrum uses are also 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.

The communications market continues to evolve rapidly and this could lead to significant change in spectrum demand and supply

3.7 While the precise nature of the future wireless communications market and its spectrum demand are uncertain, we have developed our view of their direction of travel and how they may affect our priorities over coming years. Our aim is not to forecast the future and to seek to directly deliver outcomes based on this forecast; rather, it is to ensure that we are conscious of any enabling action that we may need to take to ensure optimal spectrum use is secured over time.

3.8 Maintaining an informed perspective on future spectrum developments is particularly important in cases where securing additional benefits may require changes in spectrum use. This is because enabling regulatory action could be required well ahead of a future change of use to make sure this takes place in a way that delivers optimal use. The challenges associated with changing spectrum use include:

- The long timescales often involved: even though demand for spectrum can evolve rapidly, the infrastructure investments that are often required to enable new uses of spectrum mean that licensees require long licence lengths to be certain about the viability of their investments. Large installed bases of radio equipment will also limit the flexibility in enabling new spectrum uses within short timescales. In addition, the timescales normally associated with an internationally harmonised and coordinated change of use can be very long, sometimes in excess of 10 years.

- The potential relevance of co-existence issues: as new uses are introduced in a given spectrum range, this may cause interference with incumbent users in adjacent bands.

3.9 The timescales and complexities of changing spectrum use are in tension with the ongoing rapid development of communications markets, as underlying trends in infrastructure, content and devices facilitate greater choice of wireless services and platforms. This evolution is sustained by a virtuous cycle in which changing consumer demand encourages further technological and industrial developments, and, vice versa, new technical possibilities and service offerings stimulate growing demand.

There is growing demand in many sectors of spectrum users for some key spectrum resources

3.10 Different sectors of spectrum users are likely to pose new, competing demands for prime spectrum as they develop. New technologies and services entering the market are likely to increase demand for spectrum and raise challenges for how it is allocated. Below we consider examples of sectors where spectrum supply and demand could change significantly in future. The Appendix to this consultation[30] provides a broader assessment of future trends in spectrum supply and demand on a sector-by-sector basis.

Mobile and wireless data

3.11 Growing demand for mobile broadband capacity could drive the most significant changes in spectrum use over the next 10 years. Over the past few years, the volumes of data carried over mobile networks have materially increased. Looking forward, at a mid-range estimate, mobile data consumption could be as much as 80 times higher in 2030 than it was in 2012.[31] Whilst long term forecasts are inherently uncertain, they highlight potential developments that could have very important implications for future spectrum management.

3.12 More consumers own internet-enabled wireless devices and a greater proportion of them own more than one. Smartphone technologies have become more affordable to a larger proportion of the population in recent years. Ofcom research shows that UK households now have access to, on average, three different types of internet-enabled device.[32] Thus a growing proportion of the population requires data connectivity and typically the level of connectivity they require is growing. As the penetration of smartphones and tablets increases in future, the emergence of new types of data-

[30] http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/annexes/appendix_spectrum_management.pdf
[31] http://www.ofcom.org.uk/static/uhf/real-wireless-report.pdf
[32] http://stakeholders.ofcom.org.uk/market-data-research/market-data/communications-market-reports/cmr13/

capable devices (which could be linked, for example, to emerging trends around wearable technology) could sustain further increases in data capacity requirements over the long term.

3.13 The increased take-up of devices that can access different types of wireless IP-based networks has driven the use of over-the-top (OTT) services, sustaining the data demands of consumers. They increasingly access data-rich content like video 'on-the-go', further multiplying their demands for data capacity.

3.14 There may also be other sources of growing demand for spectrum as connectivity becomes more prevalent as a feature of previously unconnected devices. Industry is already introducing new machine-to-machine (M2M) applications, for example through smart metering, and there is significant scope for others in future. While the data demands of individual M2M applications are likely to be limited, public mobile networks might, in future, need to supply data services to a very large number of new devices using these applications.

3.15 Although growing demands for mobile broadband capacity are likely to remain concentrated in densely populated areas, end-users' expectations could also evolve towards an increasingly widespread and homogenous coverage of high-speed wireless data services. This may also imply that near-ubiquitous coverage, including the coverage of locations beyond commercial and residential premises, becomes increasingly important. This trend could be sustained by the emergence of M2M applications. For example we note that the delivery of benefits potentially associated with emerging M2M automotive application relying on public mobile networks would be dependent on coverage of the UK road network.

Digital Terrestrial Television

3.16 DTT is a primary means by which UK TV households receive TV services, the sole means of TV reception for over 40% of UK TV households[33] and used in many more households in combination with other TV platforms. Over recent years consumers have grown used to watching catch-up and video-on-demand (VoD) services over internet connections. However, linear television viewing has remained relatively stable and has even increased in recent years, despite the increasing range of content services available through IP-based distributions.

3.17 Over time, high definition (HD) may become a standard requirement for all TV broadcast platforms and Ultra High Definition (UHD)[34] programming is also likely to enter the market over the next few years. Higher definition channels require more bandwidth than standard definition services and while new codec standards like HEVC can help mitigate this demand, the technical and commercial viability of UHD broadcasting on DTT is likely to remain uncertain for the foreseeable future.

Incubation of innovation through licence-exempt devices

3.18 The nature of licence-exempt regimes is that the usually low powers permitted minimise the need for additional constraints to be imposed on the operation of

[33] http://stakeholders.ofcom.org.uk/binaries/research/tv-research/tv-data/dig-tv-updates/2012Q4.pdf

[34] Ultra High Definition television (also known as Ultra HD television or UHDTV) includes 4K UHD and 8K UHD. These are two digital video formats defined and approved by the International Telecommunication Union (ITU). 4K UHDTV (2160p) has a resolution of 3840 × 2160 pixels, four times the pixels of 1080p (or "Full") HDTV (i.e. 1920 × 1080). 8K UHDTV (4320p) has a resolution of 7680 × 4320 (33.2 megapixels), sixteen times the pixels of 1080p HDTV.

licence-exempt devices. This provides a wealth of opportunities for industry to innovate within these constraints and has resulted in some services that are now key to the delivery of high value services, including wireless broadband.

3.19 Linked to growing demand for wireless data, the consumer uptake of devices such as smartphones, tablets and laptops is contributing to a strong increase in the use of Wi-Fi based connectivity. As we discussed in our recent spectrum sharing for mobile and wireless data consultation,[35] a recent monitoring study we commissioned suggests that spectrum in the 2.4 GHz band, which is currently accessed by the majority of Wi-Fi devices, is used very heavily.

3.20 In future, Wi-Fi is likely to remain an important means of supplying wireless data capacity, especially as, as we discuss further below, mobile network operators (MNOs) deploy heterogeneous networks that use Wi-Fi enabled small cells and the metro Wi-Fi networks of fixed network operators to offload data from cellular networks and meet local requirements for mobile data capacity.

3.21 The prospects for significant growth of M2M and M2P applications in sectors including healthcare (e.g. wearable health monitors, or home sensors for telecare), utilities (e.g. in-home energy monitors linked to a smart grid supply to improve energy efficiency) and transport (e.g. intelligent parking guidance) could also contribute to a strong growth of devices making use of spectrum on a licence-exempt basis. Licence-exempt access for M2M/P may be particularly well suited to applications that will be relying on low power transmissions over short distances.

3.22 Other types of Short Range Devices (SRDs) access a variety of spectrum bands on a licence-exempt basis to deliver a wide range of localised applications, ranging from Radio Frequency Identification (RFID) to alarms, telemetry and telecommand devices. In many cases, international harmonisation plays a particularly important role in determining spectrum demand for SRDs applications, especially where these are implemented through low-cost devices relying on economies of scale.

3.23 We note that our recent decision to release spectrum at 870-876 and 915-921 MHz on a licence-exempt basis,[36] subject to further CEPT[37] progress on technical harmonisation measures, provides opportunities for the meeting demand for new SRD, RFID and M2M applications.

Emergency Services

3.24 Emergency Services in the UK, as elsewhere in the world, are currently considering what they will require from their next generation of communications technologies. Developments in mobile broadband and the ongoing deployment of LTE networks are creating opportunities for the delivery of enhanced, data-rich Public Protection and Disaster Relief (PPDR) applications.

3.25 For example, it may be desirable for fire fighters to be able to download detailed plans of buildings in order to better navigate through buildings. High speed broadband could enable police to upload high quality video or photos of scenes of crime or paramedics to upload video or photos of injuries to incident coordination centres.

[35] http://stakeholders.ofcom.org.uk/consultations/spectrum-sharing/
[36] http://stakeholders.ofcom.org.uk/consultations/870-915/statement/
[37] Conference of European Posts and Telecommunications Administrations.

3.26 Existing PPDR communications systems cannot deliver broadband communications. This is generating an important debate, both in the UK public sector and internationally, over whether, and how, additional spectrum capacity for Emergency Services communications should be made available.

Programme Making and Special Events

3.27 Programme Making and Special Events captures a range of wireless services used in the production of multi-media content and for live cultural events such as wireless cameras and wireless microphones. These are used to support such diverse activities as news gathering, sports events and outside broadcasts and events such as live concerts, theatre, religious, cultural and educational activities.

3.28 The PMSE sector relies heavily on spectrum access as a wider variety of live shows exploit wireless technology on a larger scale and with greater complexity than before. TV productions also pose growing requirements, using more video channels and wireless telemetry devices to improve coverage, particularly at sporting events, HD and UHD cameras are becoming more common.

3.29 PMSE users typically access spectrum on a secondary basis, for example by sharing with DTT or public sector users. The 800 MHz and 2.6 GHz awards have reduced the spectrum available for PMSE and potential future releases of additional spectrum to mobile broadband might pose additional challenges to PMSE users.

Business Radio

3.30 Business radio provides robust narrowband and wideband wireless communications for a wide and fragmented base of predominantly professional users from a range of sectors including utilities, facilities management and construction. Business radio applications access bands in the VHF and UHF range: the 450 MHz range is the most heavily used and congestion is reported in this band in the largest cities.

3.31 Business radio devices are migrating to digital technology. This enables more intensive use of spectrum, but also stimulates demand by supporting new data applications over the available narrowband channels. Although business radio users can and often do rely on public mobile networks for broadband data applications, some critical applications often require more resilient services with a higher quality of service than public networks can offer.

Space Services

3.32 Space services is terminology used to encompass a range of services key amongst these being:

- satellite direct to home TV;
- satellite direct to home broadband;
- other fixed satellite services, including infrastructure links and VSAT[38] services;
- mobile satellite services;

[38] Very small aperture terminals, using small dishes fixed on the ground,

- earth exploration satellite services (EESS) – where satellites are used to research the physical characteristics of Earth; and

- radioastronomy – where radio signals generated by bodies in space such as stars and quasars are monitored for research.

3.33 Satellite TV capacity requirements may grow with the ongoing platform transition to HD and the potential provision of UHD services over the medium and long term.

3.34 The development of residential broadband propositions based on satellite delivery could place increasing demands on available spectrum, notably around 28 GHz, if satellite broadband becomes a more important means of delivering fast broadband services in rural areas as well as on aeroplanes and ships.

3.35 Increasing interest in, and funding for, research into issues such as climate change is leading to more frequent launches of new EESS and meteorological satellites which are seeking to capture larger amounts of data. This is likely to lead to increasing capacity requirements both for earth observation itself and to enable this observation data to be delivered from the satellites to earth stations.

Wireless backhaul and fixed links

3.36 Fixed links are an essential input to a wide variety of consumer and business services, including, predominantly, backhaul for mobile networks, as well as distribution of TV material from studio to transmitter site and connecting nodes within public, private and corporate networks (e.g. local authorities, utilities, financial services, etc). Demand from the predominant application, mobile backhaul, is currently undergoing fundamental change as mobile network architectures evolve.

3.37 MNOs are increasingly complementing their use of fixed links with investment in fibre networks for high capacity links. Fibre provision is viewed as a complement rather than a substitute for wireless solutions and fixed links are likely to continue to play a significant role in a variety of situations, including difficult terrains and remote areas where fibre links are prohibitively expensive to install.

3.38 MNOs are also increasingly merging their infrastructure and implementing sharing agreements, reducing the number of macrocells deployed and the overall total of fixed links required, but increasing capacity requirements along the consolidated routes.

3.39 The expected deployment of large numbers of localised, high capacity, macro and small cells in 4G networks is forecasted by stakeholders to generate a significant increase in demand for millimetre wave spectrum at high frequencies above 60 GHz. The superior bandwidth available in these bands will drive greatly increased use of these bands to serve high capacity demand.

3.40 In addition, MNOs' deployment of small cells could increase substantially to provide additional capacity in congested urban areas, with wireless fixed links likely to be an important backhaul solution, alongside other options including the use of mesh networks. This may involve growing demand for quasi-line-of-sight and non-line-of-sight backhaul links for which sub-6 GHz spectrum may be particularly desirable.

The development and use of more efficient technologies and new means of achieving efficient re-use of spectrum resources will ease spectrum demand pressures in some cases

3.41 The supply of more spectrally efficient technologies will be an important means of moderating demand for spectrum in future. As the processing power of consumer devices continues to increase consistent with the predictions of Moore's Law, opportunities arise for the implementation of improved compression, coding and modulation techniques to achieve such efficiencies.

3.42 The extent to which new technologies improving spectrum efficiency are adopted and the extent to which they contribute to moderating spectrum demand will be led largely by the action of market players. Ofcom is committed to creating a regulatory environment which is conducive to realising their potential and the resultant benefits for citizens and consumers.

3.43 Relevant technical developments that could increase spectrum efficiency in future include the following factors.

- In mobile broadband, Long-Term Evolution (LTE), LTE-Advanced (LTE-A) and other ongoing improvements in transmission technology could provide between 3 and 10 times more mobile broadband capacity between 2012 and 2030.[39] The increasing use of heterogeneous network architectures is also increasingly relevant to meeting growing mobile capacity needs, for example by incorporating small cell technology into network topologies and offloading data onto fixed networks via Wi-Fi hotspots in areas of high demand. Passpoint and Wi-Fi Hotspot 2.0 standards are also making it easier for mobile users to roam between Wi-Fi and cellular networks.

- Emerging DTT standards DVB-T2 and MPEG-4 can deliver transmission and compression 30-50% more efficiently than legacy standards. Their impact could be to allow more services per multiplex and improve the reception quality of DTT. However, slow consumer take-up of compatible receivers could dampen their practical impact. HEVC is the next generation video encoding standard that can enable further spectrum efficiencies on DTT, DTH (Direct to Home) and IPTV (Internet Protocol TV). HEVC offers up to approximately 70% more efficient compression than the legacy MPEG-2 standard. However capacity constraints and large existing receiver bases may restrict the speed at which DTT and DTH adopt HEVC.

- In PMSE, the use of digital microphones could lead to better coordination of an increased number of wireless devices[40] in contiguous spectrum allocations. Until recently the challenge of meeting the limitations of latency and battery life have limited the introduction of digital microphones. Recent developments have made a significant step in overcoming these challenges but the financial cost of these systems is a barrier to universal adoption. The development of wireless cameras designed to operate at the higher frequencies currently used for fixed video links could alleviate some congestion, though there is reluctance to invest in this

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

[40] A study undertaken on behalf of Ofcom suggested that in certain environments up to 15 wireless microphones could operate in a single 8MHz channel, irrespective of whether they are analogue or digital. However, the study observed that digital microphones were less likely to suffer from the effects of intermodulation products, caused when devices operate in close proximity to each other. See http://stakeholders.ofcom.org.uk/binaries/research/technology-research/sewm/finalreport.pdf.

equipment. Additional mitigations could come from the use of the improved compression standards described above, as well as improved practices in the deployment and coordination of PMSE equipment in major events.

- Small beam satellites can increase frequency re-use and, hence, the delivery of higher bandwidth residential broadband services, potentially sustaining growing demand for these services over time.

Spectrum recycling to uses with higher value will remain an important objective and the release of public sector spectrum is likely to be a key source of spectrum supply in future

3.44 Re-purposing spectrum to facilitate optimal use of spectrum is likely to remain an important solution to changing spectrum needs over the next 10 years.

3.45 As we discuss further in Section 4, the complexities associated with spectrum re-purposing mean that, in some circumstances, regulatory intervention could be required to further the optimal use of spectrum. This is therefore likely to remain an important area of focus for Ofcom's spectrum activities over the coming years.

3.46 Technical research we commissioned[41] indicates that additional spectrum is likely to be an essential part of the mix of techniques required to address the expected growth in mobile capacity demand, together with the use of better mobile transmission technologies and the efficiencies that heterogeneous networks enable.

3.47 The release of public sector holdings will make a significant contribution to future spectrum availability for mobile broadband. The Government plans to release 500 MHz of public sector spectrum into civil use by 2020. This will begin in 2015/16 with the release by Ofcom of around 200 MHz of spectrum previously used by the Ministry of Defence (MoD) in the 2.3 GHz and 3.4 GHz spectrum bands.

3.48 While some public sector spectrum will be released to meet growing demand from commercial services, the supply is limited. In order to ensure that we can enable what we consider to be the optimal use of spectrum in future, it will be important to take a coordinated approach across civil and public sector holdings. Government is leading on this issue through its plans for an overarching UK Spectrum Strategy to be published in early 2014.

3.49 In our UHF Strategy statement[42], we established that one of the key potential sources of re-purposed spectrum for mobile services is a possible replan of DTT from 700 MHz and its release for mobile usage, while using the 600 MHz band for DTT. We will also assess other candidate bands for mobile use so as to influence international decisions on harmonisation.

3.50 Future UK spectrum re-purposing is likely to be strongly influenced by international harmonisation initiatives and by cross border coordination of high power uses (notably for DTT in the UHF band). The importance of harmonisation is discussed further below and in Section 6.

[41] http://stakeholders.ofcom.org.uk/binaries/consultations/cfi-mobile-bb/annexes/RW_report.pdf
[42] http://stakeholders.ofcom.org.uk/consultations/uhf-strategy/statement/

Technology advancements could bring new forms of spectrum sharing into effect

3.51 As new competing demands for spectrum emerge, spectrum sharing is likely to become more relevant in addressing new sources of spectrum demand and could offer further opportunities to enable innovation.

3.52 There are already many examples of successful spectrum sharing, including through coordination between different spectrum user sectors. For example fixed links and satellite communications users share spectrum and PMSE users share Crown spectrum.

3.53 In addition to the existing spectrum sharing arrangements, new types of sharing are emerging due to advances in technology that have the potential to enable effective interference management between incumbent users and new sharers. Where re-purposing of spectrum is not feasible, sharing may still offer opportunities to utilise spectrum more intensively and more efficiently.

3.54 'White space' frequencies are those that are not being used by existing licensees at all times or at all locations. A white space device (WSD) can make efficient use of these frequencies, provided that the risk of harmful interference to the licensed users of the spectrum can be managed appropriately. 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.

3.55 We have been investigating the prospects for access to white spaces in the UHF TV band (also known as TV white spaces) since 2007. Our latest step towards enabling the use of TV white spaces was our recent consultation on TVWS coexistence.[43] WSDs promise to deliver innovative, low power and localised data applications.

3.56 Further technology advances could open up future opportunities for more sophisticated forms of sharing across a wide set of applications. These include:

- improvements in robust transmission and reception protocols that would enable wireless devices accessing shared spectrum resources to tolerate greater interference;
- the evolution of radio frequency components capable of operating over wider frequency bands. As components become less frequency-specific, devices would be able to exploit underutilised spectrum available over a wider sets of frequency ranges;
- the emergence of smart antennas and the evolution of 'beamforming' techniques that could allow devices to better manage interference by focusing the spatial distribution of wireless transmissions;
- the growing use of software-defined radios, software solutions and general-purpose computing processors to implement radio transmissions functions traditionally associated with specific hardware components. Software-defined radios can provide significant cost advantages in the production of low power devices by replicating transmission techniques that are normally associated with higher cost and higher power devices;

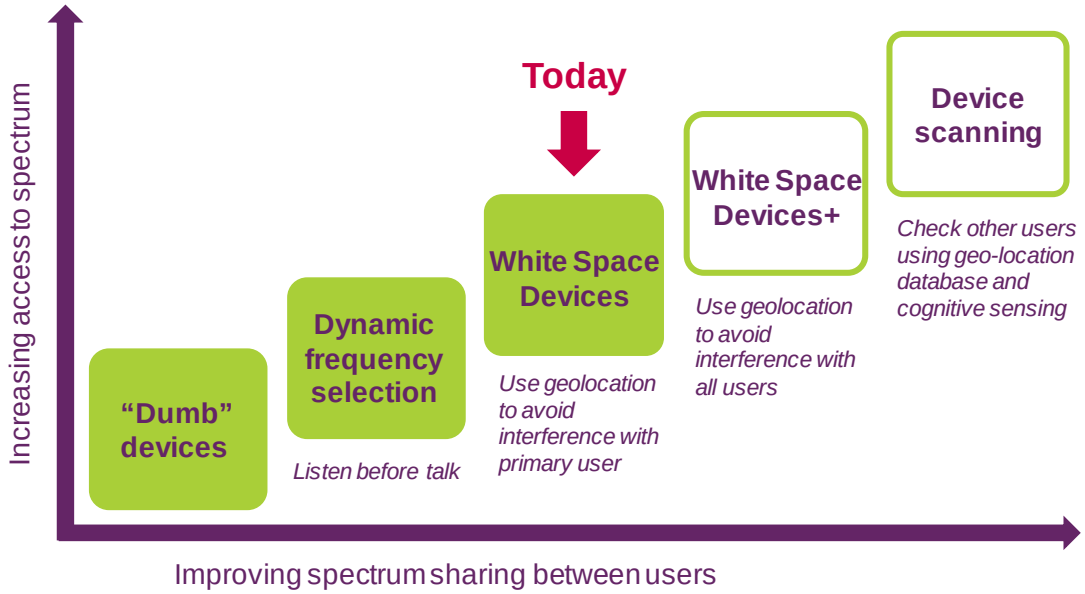
[43] http://stakeholders.ofcom.org.uk/consultations/white-space-coexistence/

- the development of carrier aggregation techniques, through which devices can dynamically combine small bands of spectrum into a single, virtual broadband pipe;

- increasingly sophisticated white-space devices and geo-location databases, with functionalities extending towards more active spectrum management (see Figure 7). For example, it will be possible to reflect devices' (or users') quality of service requirements through tailored assignment and management approaches. This could facilitate a 'tiered approach' to sharing, with access to spectrum and protection from interference optimised for each device or user type; and

- the development of 'sensing' techniques, through which devices can independently detect and access available unused spectrum without the need to communicate with a database. Technical barriers to implementing cost-effective spectrum sensing in consumer equipment may mean that sensing can only become viable in the longer term.

Figure 7 - Potential roadmap for the evolution of wireless devices accessing shared spectrum resources



As the use of key spectrum bands intensifies, the interference environment is likely to become more challenging

3.57 In future, the management of interference is likely to become more challenging as a result of two broad trends we discussed above.

3.58 Future spectrum re-purposing activities, and especially those associated with new high power uses like wireless broadband, could raise new co-existence challenges, as devices associated with incumbent uses may suffer from increased transmission powers in adjacent bands. In this context, technology standards that minimise out-of-band emissions by transmitting wireless devices and improved selectivity of receiving devices will become increasingly important in preventing and managing new co-existence issues. More broadly, effective interference management will require a shift

towards considering transmitters and receivers as components of the same radio systems, rather than as discrete elements.

3.59 At the same time, new forms of shared access to bands with incumbent users may cause an increase in the 'noise floor' or background level of interference that all users will be subject to, as well as new in-band emissions. It will therefore be important to balance the risk of interference to devices associated with incumbent uses, and the costs associated with potential measures to improve their robustness to in-band interference, with the potential benefits associated with innovative uses enabled by shared access to spectrum.

The international dimension of spectrum management remains highly relevant to optimal spectrum use in the UK

3.60 Ofcom represents the interests of the UK[44] in the international institutions responsible for developing the international regulatory framework.

3.61 As we discuss further below, spectrum decisions taken in European and international bodies have a substantial influence on achieving optimal spectrum use in the UK. On the other hand, this is balanced by the persistence of important factors underpinning national differences in how spectrum is used and managed. Some of these are:

- Nation-specific requirements for particular applications. These will include cases where national objectives require particular spectrum uses, e.g. to support the Critical National Infrastructure or military operations.

- Legacy uses and equipment. Opportunities for new spectrum uses and the disruption associated with potential future spectrum re-purposing will vary across different countries depending on the type and scale of incumbent uses.

- Different conditions influencing the interference environment. For example, different densities of spectrum use in different countries (which may be associated with population densities) may require different approaches to managing the interference environment.

3.62 The international regulatory framework is determined through negotiations by national administrations in a variety of institutions. The key international institutions include:

- The International Telecommunication Union (ITU) is 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) 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. The current European framework places considerable emphasis on spectrum activities, most notably through the

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

Framework Directive, Authorisation Directive and Radio Spectrum Policy Programme.

3.63 Most spectrum bands are subject to some form of international constraint. The decisions of international institutions that have the greatest impact on spectrum use in the UK fall under three broad categories.

- **Harmonisation** agreements make spectrum available for particular services on an international basis. Harmonisation decisions may or may not be binding, but can influence spectrum demand by changing stakeholders' expectations of how spectrum will be used in future. Harmonisation also unlocks economies of scale by signalling to manufacturers that they should consider developing wireless equipment that is compatible with the harmonised frequencies and setting expectations that there will be a growing number of countries that will make use of these frequencies for a specific type of service. As devices for wireless communications are increasingly developed and marketed in globalised markets, economies of scale can become a central consideration in determining the potential benefits for UK citizens and consumers deriving from spectrum use.

- **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 the geographies of a number of administrations, and for other high power uses such as broadcasting.

- **International technology standards** can have a strong influence over UK spectrum use. With harmonisation agreements, standardisation decisions support economies of scale in globalised wireless devices markets, and cross-border interoperability. Wireless transmissions standards can also have a strong influence on the extent to which enabling a new use of spectrum could give rise to co-existence issues with pre-existing services. Trends towards increased intensity of use of prime spectrum resources will mean that the importance of equipment standards in securing effective interference management is likely to rise. Many technology standards are developed and agreed in specialised international bodies, including the European Telecommunications Standards Institute (ETSI) and the 3rd Generation Partnership Project (3GPP).

3.64 Recent developments have also highlighted two key broader trends within the international regulatory framework:

- Growing economic powers are increasingly influential within international institutions. Countries such as China, India, Brazil and South Africa are deploying more resources and playing a more active role in organisations such as the ITU. Regional interests, such as the African ITU members, are also becoming better coordinated and more vocal in support of shared interests. At WRC-12, for example, the African region worked concertedly towards its desired outcomes relating to the 700 MHz band.

- Spectrum management is increasingly the subject of political interest. This reflects its growing importance to economies and to societies. Whereas, in the

past, spectrum management decisions were more often made on purely technical grounds, public policy objectives are now increasingly significant. For example, the European Commission's spectrum objectives correlate closely with their wider policy goals, such as extending broadband coverage.

3.65 As the critical role that spectrum plays in the achievement of key policy objectives has become clearer, so the European Commission's interest in spectrum matters has increased. In particular, the Radio Spectrum Committee (RSC) which is chaired by the Commission plays a key role in ensuring that spectrum is made available according to harmonised technical conditions across the whole of the EU, while the Radio Spectrum Policy Group (RSPG) advises the Commission on strategic issues relating to spectrum management.

3.66 More recently the Commission has brought forward proposals that would see it play a more active role in a range of spectrum issues, including an oversight role in relation to spectrum awards. These proposals will be discussed over the coming months as the proposals are considered by the European Parliament and Council. Ofcom will actively engage in this process, both in our own capacity and through Government which will lead negotiations on behalf of the UK at the Council. In addition we will contribute to discussion in RSPG and to ongoing debate in other international bodies.

3.67 All these developments underline how international cooperation on spectrum management, especially at the European level, will remain critical to securing the delivery of benefits from spectrum use in the UK. In key recent spectrum initiatives, including our work on the700 MHz band,[45] we have emphasised the need to take an internationally coordinated approach to decisions relating to future spectrum use in order to promote economies of scale and interoperability, as well as to ensure efficient use of spectrum. In future, we will continue to take an active role towards ensuring coordination with other National Regulatory Authorities, as well as contributing to the work of international institutions at both European and global levels.

Question 1: Have we captured all the major trends that are likely to impact spectrum use over the next ten years in this section and the separate Appendix on sectoral developments? Are there other market, technology or international developments that could lead to significant changes in spectrum demand and supply over the next 10 years?

[45] See http://stakeholders.ofcom.org.uk/spectrum/uhf700mhz/consultations-statements/

Section 4

Our approach to spectrum management

4.1 In this section we summarise our approach to spectrum management. This builds on the approach we described in our *Spectrum Framework Review*[46] (SFR) in 2005 and is informed by our experience of managing spectrum since that time. In particular, we explain:

- the range of duties that we consider when making spectrum policy decisions, including those which go beyond the aim of promoting efficient spectrum use;
- the three strategic objectives around which our spectrum management activities are focussed; and
- why it might sometimes require a combination of market forces and regulatory action to deliver a major change in use.

We have a wide range of duties to consider when making spectrum policy decisions and need to carefully balance these duties

4.2 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. Among other duties, we are required to secure, in the carrying out of our functions, the optimal use for wireless telegraphy of the electro-magnetic spectrum, which is of particular relevance when undertaking our spectrum functions.

4.3 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 is used to produce the maximum benefits (or value) for society. These benefits are not just private sector benefits, but also include the benefits of public sector use. These benefits include those enjoyed by providers and consumers of services as well as the wider social benefits, or the indirect benefits, of services provided using spectrum[47].

4.4 Alongside our principal duty and 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[48]) that are relevant to, and impact our spectrum decisions. These include:

- Promoting competition: changes to spectrum use can have important competition effects and regulation may be required to prevent the concentration of key spectrum assets. For example, we carried out an extensive competition assessment of the mobile market to decide whether to put in place caps on the

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

[47] 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 (and as required under our duty to conduct an Impact Assessment including an Equality Assessment). 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, but we would also need to consider whether this outcome would be optimal.

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

spectrum that existing players in the market could purchase in the 4G auction of spectrum at 800 MHz and 2.6 GHz. Promoting competition also highlights the need to consider the impact of our decisions over time. In particular, securing adequate competition over the long term may lead to decisions on efficient spectrum allocations different from cases where only short term effects are considered[49].

- Securing the availability throughout the UK of a wide range of electronic communications services: spectrum can be a relevant input to delivering this. For example, in the case of the recent 4G spectrum auction at 800 MHz and 2.6 GHz, we decided that imposing a coverage obligation on one spectrum lot would support the delivery of wider social benefits from widespread mobile broadband coverage. Achieving the delivery of these wider benefits is consistent with our duty to secure optimal spectrum use and is further justified by our duty to secure wide availability of services.

- 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 that spectrum use for Digital Terrestrial Television is currently the most appropriate method of meeting the objective of delivering universal free-to-air access to PSB channels and therefore we shape our spectrum policy decisions accordingly when making decisions that have the potential to impact DTT.

4.5 When taking decisions on spectrum matters we consider all relevant duties, alongside those that are directly related to our spectrum functions. However, the remainder of this section focuses primarily on the way that we manage spectrum resources so as to promote spectrum efficiency. We view spectrum as a scarce and valuable input to the delivery of a huge range of services so that efficient allocation and use of spectrum resources plays a key role in securing citizen and consumer benefits.

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

4.6 Our spectrum-specific activities – of which there are many – can be thought of as addressing one of the 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 future value and benefits from the use of spectrum; and

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

[49] For example, it may appear efficient to permit a single company to have access to a large block of spectrum because it is able to derive more value from its use than other firms. However, this could provide the company with market power in a downstream market. Firms with market power may restrict output and increase prices thus reducing the efficient use of spectrum over the long term compared to a situation where adequate competition in the downstream market was assured. This may, therefore, involve an allocation of spectrum that may not appear efficient when only considered in the short term, but is efficient over the longer term.

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

ii) 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

4.7 It is illegal for anyone, apart from the Crown, to use spectrum[50] 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 every user to be authorised that a central part of Ofcom's activities is concerned with managing, maintaining and developing the operation of the licensing and general authorisation regime.

4.8 There is a significant distinction between different modes of spectrum access via:

- A set of licence products that provide access to Ofcom band managed spectrum: this is where we coordinate the individual assignment of frequencies within the band often on a first come first served basis: where we need to undertake technical coordination of individual transmitters before making assignments; where we make narrow channels available on a UK wide (or more limited area) basis; or where devices are low power, but cannot be made licence-exempt, and are available on request under "light licence" products.

- Block-assigned, in particular spectrum bands that provide dedicated access: many of these block assignments have been awarded via auction to one or more users under bespoke licences which give these licensees significant flexibility in the way that they manage the band concerned (almost always this is for their own use, but they could also provide spectrum access to third parties as a commercial band manager). This category also includes some long standing assignments such as the 900MHz and 1800MHz mobile network licences.

- Regulations that authorise licence exempt use by devices that meet defined technical parameters.

4.9 The amount of spectrum that is made available through our Ofcom licence products is very substantial, covering 53% of the spectrum between 87.5 MHz and 80GHz (see Figure 4 in section 2). There are several hundred thousand 'live' licences with over 30,000 new licences issued annually by the Ofcom licensing centre. We continue to make changes that improve the efficiency of our licensing processes and this could include an expanded role for e-licensing over the coming years.

4.10 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;

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

- 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[51].

4.11 The maintenance and development of licence products – and the creation of new licence products – also involves significant, ongoing policy effort to accommodate technical and market developments that might require adaptation of channel plans to accommodate new channel widths, adjustments to assignment and coordination tools to deal with new technologies, changes to technical coexistence parameters, or to the regulatory framework, that influence the way that different services can share spectrum access, etc. A significant amount of this work takes place in (upwards of 50) international regulatory groups, notably in CEPT and ITU-R, that progress, amongst other things, the technical analysis that is needed to underpin regulatory policy in these areas, and to which Ofcom is often a key contributor.

4.12 Typically a spectrum fee is charged for our licence products based on Administered Incentive Pricing (AIP). AIP fee levels are set to reflect the opportunity cost[52] of the spectrum used. This provides an incentive for licensees to use the spectrum efficiently (or where the use made of the spectrum is lower than its opportunity cost, to return the spectrum for use by others).

4.13 The release of new block-assigned spectrum has been, and continues to be, a major focus of Ofcom policy work, from the identification of opportunities for new release through to the design and delivery of auctions which assign the associated licences.

4.14 On occasion, the terms of these licences are varied, usually following a request by the licensee and a public consultation process. The issues raised by such licence variations can represent significant policy initiatives in their own right (e.g. extensions to the licence term, or changes in technical conditions to enable a change in the way the spectrum can be used).

Enhance and maintain the value of spectrum

4.15 The authorisation of spectrum use in the UK (via any of the above spectrum access modes) 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 legal constraint on specifically how we use spectrum in UK[53] – and this is observable in the fact that not all spectrum use is harmonised across Europe. However, international harmonisation

[51] 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

[52] Opportunity cost is the value of alternative spectrum use forgone by society due to the current spectrum use.

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

is a very major factor that influences the prospective value that can be derived from a given spectrum band for the reasons explained in 3.64 above. Indeed, the value of a band may increase by orders of magnitude as the result of a successful harmonisation initiative.

4.16 It can take many years, and very considerable effort, by a large number of parties in the various international regulatory arenas, to achieve agreement on new harmonisation decisions. Given that the future economic value is potentially huge, the work that we do in this area represents a significant component of our activities – and the contribution of our work towards enhancing the potential future value of spectrum use in UK makes this an important strategic objective of our activities.

4.17 The most significant value driver in this context relates to the economies of scale in equipment markets and, for portable devices, the ability for user devices to roam between countries. This is most visible in mass consumer devices such as mobile phones and many short range devices from Wi-Fi to car key fobs; but equivalent considerations apply to most sectors.

4.18 The most visible harmonisation measures are those which relate the service allocations at either a European or global level (eg. designating a particular band as "IMT"). But there is a wide range of associated activities including the development of band plans for how services use a harmonised band and, separately, the technical coexistence parameters that effect the basis on which different services can either share spectrum or operate in adjacent spectrum.

4.19 There is, however, a 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 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 (net) detrimental to the efficient use of spectrum.

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

4.20 There is no vacant spectrum available for new release across a wide range of bands, particularly in those bands in and around the UHF 'sweet spot' from 300 MHz to 3 GHz. Where the latent demand for spectrum access cannot readily be met by new auctions of unused spectrum (or where current congestion means that applications for a licence 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.

4.21 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 ongoing 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.

4.22 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 so as to enable recycling of spectrum from one user to another; and

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

4.23 We have significantly extended the scope of trading, with an increase from 15% to 84% over the past eight years in the amount of relevant spectrum for which trading is permitted.

4.24 Meanwhile, our approach to release new spectrum blocks through auction, together with the liberalisation of existing mobile licences and the overhaul of business radio licensing, means that around a fifth of the licensed spectrum now has a relatively high degree of flexibility. The corollary of this, of course, is that four fifths of the licensed spectrum remains more tightly constrained, largely through the need to undertake technical coordination between different licensed users.

4.25 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 TV to DTT and the subsequent clearance programme in the 800 MHz band are obvious examples where Ofcom, working with Government, has done just this.

4.26 Given the importance of these issues, the remainder of this section discusses the respective roles of market mechanisms and regulatory action in enabling change, noting that these can often work in combination when applied to different components of the overall change process.

A combination of market mechanisms and regulatory action is sometimes needed to deliver optimal spectrum use

Creating the environment for market forces to promote efficient use

4.27 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. Once the conditions required for the use of market mechanisms are in place, they are generally considered to be the most effective method of allocating scarce resources. 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.

4.28 Ofcom has been a pioneer of a spectrum management approach that recognises the importance of market mechanisms and many aspects of this approach have been widely adopted in Europe and elsewhere. The above sections have already referred to the range of market-based tools available to us and to spectrum users, notably the use of:

- auctions as a means to assign new spectrum access rights for large blocks of spectrum;

- spectrum pricing to create incentives for users to make efficient use of spectrum;

- spectrum trading and leasing as the means for spectrum access rights that are already assigned to change hands; and

- greater licence flexibility ('liberalisation') as a principle to enable change of use, wherever possible, without recourse to Ofcom to vary the technical licence conditions.

4.29 The following policy principles continue to underpin our market-based approach to spectrum management (see Annex 5).

- 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

- Users should be able to transfer their rights to use spectrum simply and quickly unless we have strong grounds for concerns about competition effects

Role of regulatory action in changes of use

4.30 Despite a 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. For example:

- information asymmetries, coordination failures, or transactions costs, all of which impose a barrier to market mechanisms delivering efficient outcomes;

- market power issues, which can also lead to inefficient outcomes over time due to the loss of competition and its associated benefits; and

- indirect costs or benefits (i.e. externalities) which are not necessarily reflected in the decisions made on the basis of market forces and thus result in outcomes that do not reflect the full social value of some uses.

4.31 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 appropriate regulatory response, between the benefits of addressing a market failure and the costs direct regulatory action and risks of regulatory failure.

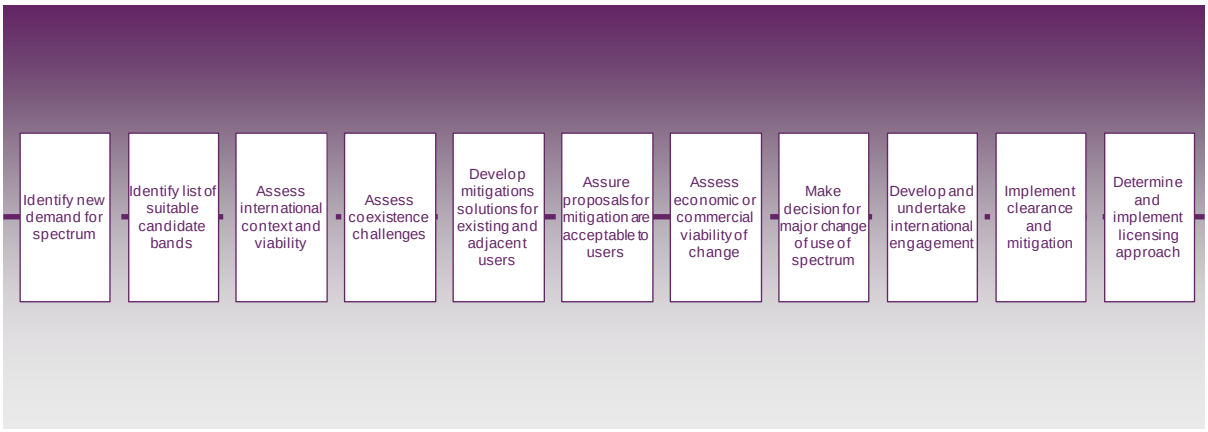
4.32 Market mechanisms have seemed to work well in assigning, and enabling changes to the ownership of, spectrum access rights, and also in enabling changes of use which can be accommodated within those spectrum access rights. However, we have had a greater role to play in cases where there has been a major change of spectrum use.

4.33 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, e.g. adding a primary allocation for terrestrial mobile to one for broadcasting; involve a change in the way the spectrum is managed, e.g. a change

from a Ofcom band managed spectrum for services such as PMSE[54] to a dedicated use such as public mobile networks; or have a significant impact on adjacent users arising from a requirement to change technical licence conditions.

4.34 Given the extent of the impact on other users of a major change of use there are a number of steps that are typically required before such changes of use can occur as shown in Figure 8. The figure is illustrative only. Not all of these steps may be necessary, depending on the specific circumstances of the change of use. These steps are also likely to be iterative as high level plans and business cases are refined over time. The balance between which of the steps would be best undertaken by Ofcom or by market participants is also likely to be heavily dependent on the specific circumstances of the change of use.

Figure 8 - Steps required for major changes of use



4.35 In general, we would expect users of spectrum to have a better understanding of the value of their current use and potential future use than the regulator. In some cases licensees seeking to change their use may also be better placed to agree, through commercial negotiation, on the costs that a change of use will impose on other users. As such we would look to the market, in the first instance, to determine whether and when a change of use should occur.

4.36 However, for a major change of use to occur it is necessary for all of the (relevant) steps to be completed successfully. If any required step in this process fails then the change cannot take place.

4.37 There are steps in the process where there is often a material risk of market failure given the different interest groups involved. This can make it challenging for the market to drive major changes of use. There are also some steps in the process that only we can undertake. There are two areas in particular which may require significant regulatory involvement relating to the need to:

- change international regulations if this is a pre-requisite to enable the new use; and
- in some circumstances, carry out a major programme to clear existing users out of a band and/or mitigate impacts on users in adjacent bands.

[54] For the purposes of the international regulatory framework, PMSE is considered a ‘mobile’ service.

Major changes in use requiring a level of harmonisation require us to act

4.38 In some cases there may be a significant increase in value associated with a prospective new spectrum use, but the ability to exploit the spectrum in this way is contingent on changes to the international regulatory environment, including new harmonisation decisions. These might relate to: decisions made in European Commissions Radio Spectrum Committee and in the various CEPT bodies that undertake much of the underpinning technical regulatory work; or to changes in the ITU Radio Regulations (ITU RR) which are negotiated at World Radio Conferences every 3-4 years; or to bi-lateral or multi-lateral coordination agreements with our international neighbours.

4.39 This is particularly relevant where the prospective new use involves changes to higher power uses of spectrum which have the greatest likelihood of causing interference to other countries; where global harmonisation is necessary for economies of scale; or where the nature of the services requires a greater degree of international coordination.[55]

4.40 Industry will often identify opportunities and create the momentum for changes in the international regulatory environment which is in keeping with a market-led approach. Stakeholders also play an important role in providing evidence to inform our engagement with other national administrations in the relevant international regulatory bodies.

4.41 However, Ofcom represents, and negotiates on behalf of, the UK on spectrum matters in these international institutions. We are responsible for negotiating on behalf of the UK at the World Radio Conferences with guidance from Government and working closely with stakeholders. We also have to consider whether changes proposed by one industry sector or interest group are in the interest of spectrum users overall, taking account of the impact of the proposed change on others. As such, we have a critical facilitating role regardless of whether the subsequent change of use itself is delivered in a process managed by stakeholders or by Ofcom.

Spectrum clearance and mitigation of co-existence challenges can be difficult for markets to achieve in some circumstances

4.42 There may still be circumstances where, to secure the efficient use of spectrum, we need to go beyond just facilitating of a major change of use and to coordinate and manage key aspects of the change of use.

4.43 Major changes of use often mean that existing users may have to relocate out of a frequency band. In addition, where the prospective new use of the band has materially different characteristics, notably higher transmit powers or greater density of use, there is potential for this to result in harmful interference into existing users in adjacent spectrum (and these impacts could extend beyond the nearest neighbour in both geography and frequency).

4.44 In some circumstances we would expect the individual users (and potential users) to be able to negotiate and make the determination themselves as to whether it made commercial sense to change the use, taking account of any costs associated with moving existing users and mitigating co-existence challenges. This should be possible where the number of users impacted is relatively small and sufficient

[55] Such as satellite, aeronautical and maritime uses.

information is available for users to identity others whom might be impacted and the likely size of the challenge associated with any mitigation.

4.45 However, where there are large numbers of users impacted, either in the band itself or in adjacent bands, there could be considerable transactions costs and coordination challenges for prospective new users in seeking to drive the change through commercial negotiation. These costs might be so high, or introduce so much risk, as to make it impractical to drive the change through commercial negotiation. In comparison, where there is a strong case for the change in use we are able to revoke the existing licences (with certain safeguards). This may mitigate some of these costs and risks. As such there are occasions where we might be best placed to undertake the clearance of existing users.

4.46 We note also that a market led approach is not generally appropriate with respect to licence-exempt users: amongst other challenges, individual users are very hard, if not impossible, to identify and there may be millions of devices already in use.

4.47 Indeed, our recent experience is that major changes of spectrum use can result in a scale and complexity of co-existence challenges that make it unlikely that markets can overcome these challenges on their own. In some circumstances, therefore, we may need to take a more active approach to the assessment and managing of co-existence issues and of clearance.

4.48 Our experience indicates this is most likely where:

- there are large numbers of impacted users, so coordination is either complex or the transaction costs could be high;
- the co-existence challenges are complex (and therefore difficult/costly to coordinate) as a result of many different uses being impacted or where the services are critical and existing users need to have our assurance on the mitigation solutions proposed (e.g. safety of life services);
- where the services impacted play a role in the delivery of our wider duties and therefore we have a more direct interest in assuring their continued operation to specific quality of service levels (e.g. DTT); or
- the information needed to carry out the co-existence work is not available to potential users or only partial information is available (e.g. where it is Crown use).

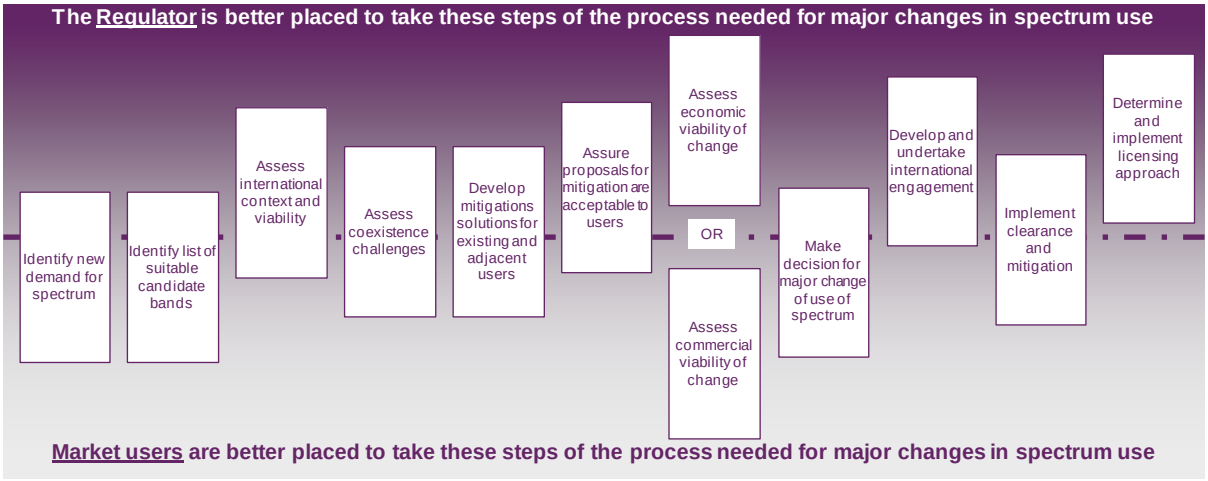
4.49 We emphasise, however, that Ofcom should not be the instigator of clearance activities where this can be driven by market forces. The benefit of allowing market forces to determine whether, and when, a change takes place is that much more important when it is hard for us to assess the real value of spectrum to different users.

Both market mechanisms and regulatory action have a role to play in major changes of use

4.50 An important observation from the above discussion is that 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. Figure 9, below, provides an illustration of which steps might typically be more market-led (positioned towards the lower half of the diagram) and which might typically be more regulator-led (positioned towards the upper half of the diagram). 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.

Figure 9 - The balance between market-led and regulator-led steps required for major changes of use



Ownership of clearance decisions is the key determinant of balance

4.51 The most significant factor in shaping the balance of activity is the ownership of decisions in respect of any clearance of existing users:

- under the more market-led approach the parties seeking access for a new use will buy out existing users and take responsibility for mitigation of co-existence challenges through commercial negotiation based on their view of the commercial viability of the change; but even where this happens, regulatory engagement may still be required if there is a dependency on changes to the international regulatory position for the band or where the new licensee needs their licence to be varied to authorise the new use; while

- under the more regulator-led approach, the decisions on clearance, and the implementation of the clearance programme, are owned by the a combination of Government and Ofcom (with decisions on funding the costs of clearance ahead of an award being owned by Government); but in these cases, the new spectrum access rights will usually be assigned through an auction (a regulatory process that uses market forces to assign new rights).

4.52 In the first case the decisions will be made by the prospective new licensees on the basis of their commercial business case. In the second, the case for intervention will be based on an economic cost benefit analysis of the proposed change. The nature and scope of the decision making process will clearly be quite different in each case. But, in either case, it is necessary to understand whether the costs the new use imposes on existing users in the band itself, and on users in adjacent bands, outweigh the benefits of such a change. In the case of a decision that may have an impact on, or be a mechanism to deliver, any of our wider duties, we will also need to take account of these wider duties.

Auction type can allow for increased role of the market in clearing spectrum

4.53 Where Ofcom leads the clearance process, the assignment of new spectrum rights is usually made using the market based approach of auctions. To date we have typically undertaken 'forward' auctions of cleared spectrum. In these auctions, a pre-determined, cleared quantity of spectrum is offered for sale. Bidders compete to buy the spectrum in the auction. This reflects the separation of the clearance and award processes. However, there may be circumstances in the future in which other types of auction could be used that allow market processes to play a role in clearance as well:

- In an overlay auction new spectrum access rights can be awarded in spectrum where existing users remain in place: with the winning bidder(s) obtaining access to the unused spectrum in the band and also the exclusive right to buy the spectrum rights of the incumbent users. The rights of the existing users can be enduring – or they might be time-limited (e.g. with a long back-stop date to give them time to relocate out of the band). Decisions on the timing and extent to which existing users move out of the band are then driven by commercial negotiations between the new licensee and the existing users. This could be of particular help in circumstances in which geographical sharing between the new and existing users is possible, so that decisions can be driven on a location specific basis where there is a significant gain from a trade of spectrum access rights (with existing users continuing to operate in places that are less valuable to the new user).

- An incentive auction incorporates sellers as well as buyers into a process to determine the allocation of spectrum resources and thus includes aspects of the decision on clearance within the auction process.[56] Just as buyers submit bids in a standard forward auction, existing users of spectrum submit 'offers' or 'asks' for the price at which they are willing to relinquish their holding. It may be possible to design such auctions in order to permit buyers and sellers to determine whether, when and how much spectrum should be changed to the new use.

4.54 At present, we do not consider that we have the necessary powers to conduct incentive auctions. In particular we do not have the power to retain the receipts of an auction and make these (or a proportion of these) available to participants in the auction. However, Government in its recent Strategy Paper on Communications indicated that it intends to provide us with the power to do so.[57]

4.55 A significant difference between overlay auctions and incentive auctions relates to risk that the bidders carry in relation to clearance (both the costs of clearance and the certainty of existing users exiting the band). In the overlay auction, the successful bidders acquire the new access rights before knowing whether they will be able subsequently to reach commercial agreements to buy out existing users; this might be appropriate where the ability to use the new rights is only partially constrained by existing users, where the business case to buy out existing users varies by location

[56] Auctions with both buyers and sellers are often given a number of names, including 'double' or 'two-sided' auctions or just a 'market' or 'exchange' mechanism.

[57] " .. will give spectrum licensees the right incentives to surrender all or part of their rights to spectrum for other uses where it is no longer needed or is being under-used, by giving Ofcom the power to run auctions where some of the proceeds are shared with the licensees that have surrendered their spectrum rights." See p.19 of https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/225783/Connectivity_Content_and_Consumers_2013.pdf.

and when it is likely to evolve over time as business conditions change. If, on the other hand, the ability to make any meaningful use of the new rights is dependent on buying out (at least some) existing users, then an incentive auction – in which existing users commit in advance to vacate spectrum - could mitigate the risk for successful bidders that they would not be able to conclude a subsequent deal to buy out the existing users.

4.56 A significant difference between a conventional forward auction and an overlay auction is that the clearance process can begin, and potentially complete, ahead of the auction itself. In some circumstances, this may advance the date at which the spectrum is available for new use which could generate significant economic benefit.

4.57 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.

Question 2: Do you have any comments on this summary of our approach to spectrum management and on the principles discussed in Annex 5?

Section 5

Future spectrum challenges

In this section we discuss our preliminary findings around future trends in spectrum demand and supply

5.1 The prospect of significant change in the future demand and supply of spectrum means it is important to maintain a long-term perspective on what might constitute optimal spectrum use in future, and whether regulatory action might be required to support it.

5.2 Our aim in developing such a perspective is not to forecast the future and seek to engineer outcomes based on this forecast; rather it is to ensure that we are conscious of any enabling action that we may need to undertake, for example in our international engagement, and to help us identify any potential market failures that might inhibit an otherwise efficient change of use from occurring.

5.3 In this section, we outline a summary of our preliminary assessment of future developments in the key sectors that use spectrum, aimed at identifying areas in which future changes in spectrum demand and supply are likely to require our attention. This assessment draws on the market context set out in Section 3 and is discussed further in the Appendix to this consultation.[58]

Our preliminary analysis suggests a set of key challenges related to future changes in demand and supply of spectrum resources

5.4 The developments we have looked as part of our preliminary assessment suggest a set of key challenges related to future developments in spectrum demand and supply.

5.5 **Growing competing demands on key spectrum bands:** spectrum demand is increasing across a wide range of sectoral uses, leading to more intense competition for scarce spectrum in some bands. Developments around broadband enabled data applications are fuelling capacity requirements primarily in public mobile networks, but also in a series of sector-specific applications including emergency services communications, business radio and utilities. Capacity requirements for TV broadcast transmissions and content production are also increasing with the move towards higher definition video capture.

5.6 **Strong expansion in low power, localised uses**: as handheld and other personal wireless devices proliferate, growing data capacity requirements are also likely to be increasingly focused in areas of high population density. This provides opportunities for greater spectrum efficiency through local re-use of spectrum. Public mobile networks are likely to evolve towards greater use of small cell technology. Prospects for new types of machine-to-machine applications could lead to new types of device connectivity, with short range, low power transmissions likely to be prevalent in personal devices. The implications for the balance of requirements between licensed and licence-exempt use of spectrum are not yet clear however.

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

5.7 **Fewer opportunities for low frequency spectrum re-purposing**: opportunities for re-purposing spectrum at low frequencies are likely to become increasingly limited and pose increasingly challenging trade-offs. Over the past 10 years a significant amount of spectrum below 3 GHz has been re-purposed through the TV digital switchover (which has freed up the 800 MHz band for wireless broadband use) and the transition of fixed wireless services to higher frequencies (freeing up spectrum at 1.4, 2 and 2.6 GHz). Over the next 10 years the main opportunities for recycling spectrum to higher value uses in these frequency ranges potentially exist in the 700 MHz band as well as the spectrum identified for release by Government at 2.3 and 3.4 GHz.

5.8 **Transition to more intensive use of higher frequencies**: linked to the two points above, there is likely to be an increasing shift, for some data applications, towards the exploitation of higher frequency spectrum. Trends towards more localised high capacity requirements and the deployment of small cells may make spectrum above 3 GHz increasingly suitable for supplementing public mobile network capacity. The growth in mobile backhaul capacity requirements may continue to sustain the move of fixed wireless services to higher frequencies. Developments in satellite technology are also making the use of higher frequency links possible for new high capacity applications. Ongoing research and development in 5G technologies suggest that in the very long term mobile connectivity could make use of high frequency spectrum above 20 GHz.

5.9 **Growing relevance of spectrum sharing techniques**: the growth in competing spectrum demands, the limitations and costs associated with re-purposing spectrum to new dedicated uses, and the predicted expansion of requirements for low power localised uses are trends that, taken together, point towards the growing importance of enabling shared spectrum access to locally underutilised resources to achieve efficient use of spectrum. Technology advances enabling effective interference management between incumbent users and new sharers could open up significant future opportunities for new types of shared spectrum access.

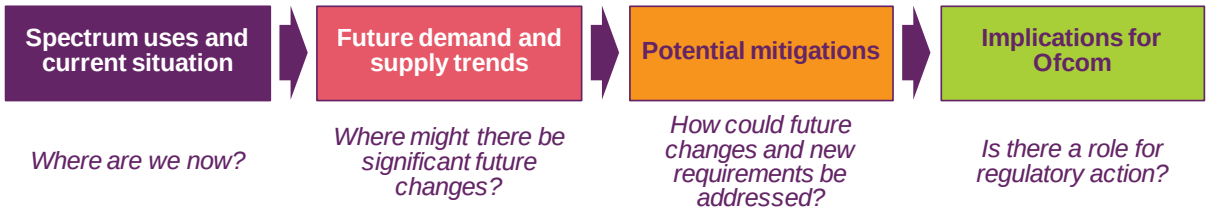
5.10 **Growing intensity of spectrum use and importance of radio equipment performance:** the potential for future spectrum re-purposing for intensive uses, such as wireless broadband, and the potential for new forms of shared spectrum access, are likely to increase 'noise floor' levels, as well as create new types of in-band and out-of-band emissions. In this context, interference management may require a growing focus on ensuring better performance of radio equipment, so to minimise risks around out-of-band and in-band emissions whilst preserving the benefits potentially associated with more intensive spectrum use.

Our preliminary assessment is primarily based on a sector-by-sector analysis of future spectrum developments

5.11 We have analysed future developments in a series of key sectoral uses of spectrum to identify future changes in demand or supply of spectrum that could, in future, require us to consider action. Our preliminary analysis followed the steps discussed here below and illustrated in Figure 10 (a fuller discussion is presented in the Appendix to this consultation).[59]

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

Figure 10 - Framework to analyse future developments in spectrum uses



5.12 **Categorisation and main features of major spectrum uses**: we have defined twelve broad sectors of spectrum uses primarily informed by licence class. These macro-categories are not fully exhaustive, but are intended to capture the main spectrum uses. In some cases, we needed to further divide these macro-categories into subgroups, given the significant variations in the characteristics of spectrum usage and future trends. For each of these uses we have reviewed current spectrum made available for the use, and key sectoral factors that may be of relevance to spectrum policy considerations.[60]

5.13 **Trends affecting future spectrum demand and supply**: we have considered market, technology, regulatory and, where appropriate, public policy trends to understand the extent to which demand and supply of spectrum resources may cause significant changes in future spectrum use. On the demand side, we have looked at how potential changes in end-user and industry demand are likely to influence demand for spectrum from the private sector. We have also looked at circumstances in which spectrum policy may play a role in our meeting future demands related to our wider duties (such as those around PSB availability) and public sector demands that may be relevant to future advice we provide to Government (such as in the case of the Emergency Services). On the supply side, we have considered future changes in spectrum use caused by potential spectrum releases (in particular by the public sector) and potential future changes in international allocations and harmonisations.[61]

5.14 We then scored these future changes according to their:

- **significance**, i.e. the extent to which future changes in spectrum demand and supply could cause considerable impacts on consumers and citizens, as well as the extent to which there may be a role for regulation in addressing such future potential impacts;

- **urgency**, i.e. the extent to which action (by spectrum users, industry or ourselves) is urgently required to respond to these future changes, also by considering dependencies with other developments (e.g. in international institutions or in other sectors competing for the same spectrum resources).

[60] This included the characteristics of private and wider social value that tends to be associated with services delivered through spectrum use, the extent to which dispersed spectrum users could face coordination challenges, the relevance of international vs UK-specific trends in determining spectrum requirements.

[61] Whilst often not binding on national decisions on how spectrum is used, expected changes in international allocations can be a strong driver for actual change in spectrum use, as demand for newly allocated uses increases as a result of the economies of scale harmonisation delivers. A relevant example is the expected co-primary allocation of the 700 MHz band for mobile broadband and broadcast services to be ratified at the World Radio Conference in 2015.

5.15 These preliminary scorings are illustrated below and discussed further in the Appendix to this consultation.[62]

Figure 11 - Preliminary assessment of potential sectoral challenges due to future trends is spectrum demand and supply

Spectrum uses		Significance of potential changes	Urgency
Mobile and wireless data	*Coverage*	R	A
	Capacity	R	R
	Indoor	A	R
	Wireless backhaul	G	G
TV Broadcasting – DTT		A	A
Licence Exempt and SRDs		A	A
PMSE	*Wireless microphones*	A	A
	Wireless cameras	R	R
Emergency Services	*Broadband applications*	A	A
	Critical voice	A	R
Business Radio		A	A
Utilities		A	G
Space	*End user services*	G	G
	Infrastructure links	G	G
	Science active	G	G
Fixed Wireless Service – Fixed Links		G	G
Radio Broadcasting		G	G
Aeronautical and Maritime		G	G

Legend

R = Severe impact / high urgency – likely to require priority strategic work

A = Moderate impact / urgency – likely to require early investigation

G = relatively minor impact / no urgency – likely watching brief or programmatic work

5.16 As illustrated in Figure 11, our preliminary assessment suggests that there are likely to be significant changes in spectrum use in six of the main sectors we have analysed: Mobile and wireless data, Digital Terrestrial Television, LE devices and SRDs, Programme Making and Special Events, Emergency Services and Business Radio and Utilities.

5.17 **Potential Mitigations:** in considering the implications for the pressure on spectrum access, we have then looked at four broad types of mitigation action that might be taken by users, industry and ourselves:

- the availability and use of new or improved equipment and receiver **technologies** enabling greater efficiency of spectrum use;
- other factors influencing spectrum efficiency that are related to how **spectrum users implement and coordinate spectrum access**. In this broad category we

[62] http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/annexes/appendix_spectrum_management.pdf. Please also note that, whilst not reported here, the Appendix includes a discussion of the Amateur Radio sector, which, however, does not follow the structure reported in this and the next table. Several of the factors that we consider in the other sectors are less relevant to this sector given the unique nature and range of amateur radio use. Instead in the Appendix we provide a high-level discussion of the use of spectrum by the sector and of its specific requirements.

have included, for example, changing mobile network topologies (i.e. greater use of small cells enabling localised spectrum re-use);

- the role of **re-purposing spectrum to a new use**, and in particular the extent to which enabling re-purposing of spectrum could be an effective solution to increasing requirements within a particular category of use; and

- the role of **spectrum sharing**, i.e. opportunities for sectoral users to access other spectrum resources on a shared basis in ways that do not impinge on the rights of incumbent users.

5.18 In examining the role of these types of solutions we have also considered the potential influence and relevance of international factors (e.g. decisions on allocations and harmonisation, standardisation of new technologies, and relevance of globalised markets and economies of scale).

5.19 The results of our preliminary analysis of the relevance of each the above potential types of mitigation to the challenges posed by future developments in spectrum are illustrated in Figure 12.

Figure 12 - Relevance of different types of mitigation to the challenges posed by future developments in spectrum demand and supply across key sectoral uses

Spectrum uses		Significance of potential changes	Urgency	Technology and receiver standards	Implementation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Mobile and wireless data	*Coverage*	R	A	✓	✓✓	✓✓	✓	◕
	Capacity	R	R	✓✓	✓✓✓	✓✓✓	✓✓	◕
	Indoor	A	R	✓✓	✓✓	✓✓	✓✓✓	◕
	Wireless backhaul	G	G	✓	✓✓	✓	✓✓	◑
TV Broadcasting – DTT		A	A	✓✓✓	✓✓	✓✓	✓	◕
Licence Exempt and SRDs		A	A	✓✓	✓	✓	✓✓✓	◕
PMSE	*Wireless microphones*	A	A	✓✓	✓	×	✓	◕
	Wireless cameras	R	R	✓✓	×	×	✓✓	◕
Emergency Services Coms	*Broadband applications*	A	A	✓✓	×	✓✓	✓✓	◕
	Critical voice applications	A	R	✓	×	✓	✓	◑
Business Radio		A	A	✓✓	×	✓	✓	◑
Utilities		A	G	✓	✓	✓	×	◑
Space	*End user services*	G	G	✓✓	✓	×	×	◕
	Infrastructure links	G	G	×	×	×	✓✓	◕
	Science active	G	G	×	✓	×	×	◕
Fixed Wireless Service – Fixed Links		G	G	✓	✓	×	✓✓	◑
Radio Broadcasting		G	G	✓✓	✓	×	×	◔
Aeronautical and Maritime Coms		G	G	✓	✓	×	×	◕

5.20 **Implications for Ofcom:** although we have a preference for market forces to drive mitigation actions and deliver solutions to the challenges suggested above, we recognise that this will not always possible or effective. We have therefore considered the implications of these challenges for the role that Ofcom might need to play. This is reflected in the preliminary analysis of priorities summarised below and described in more detail in section 6.

We have also developed a high level overview of current and future demand by frequency range

5.21 To complement the sector-based overview of future developments discussed in the Appendix to this consultation, we have also developed a preliminary overview of how, by looking at different frequency ranges, growing requirements are likely to lead to competing demands and potential changes in key spectrum bands. This is illustrated in Table 4 below.

5.22 This band view on the potential for changes in spectrum use illustrates that most of the above sector specific changes are closely interconnected, as different sectoral uses compete for spectrum access in the same frequency ranges.

Table 4 - Preliminary overview of key potential changes in spectrum use by frequency range

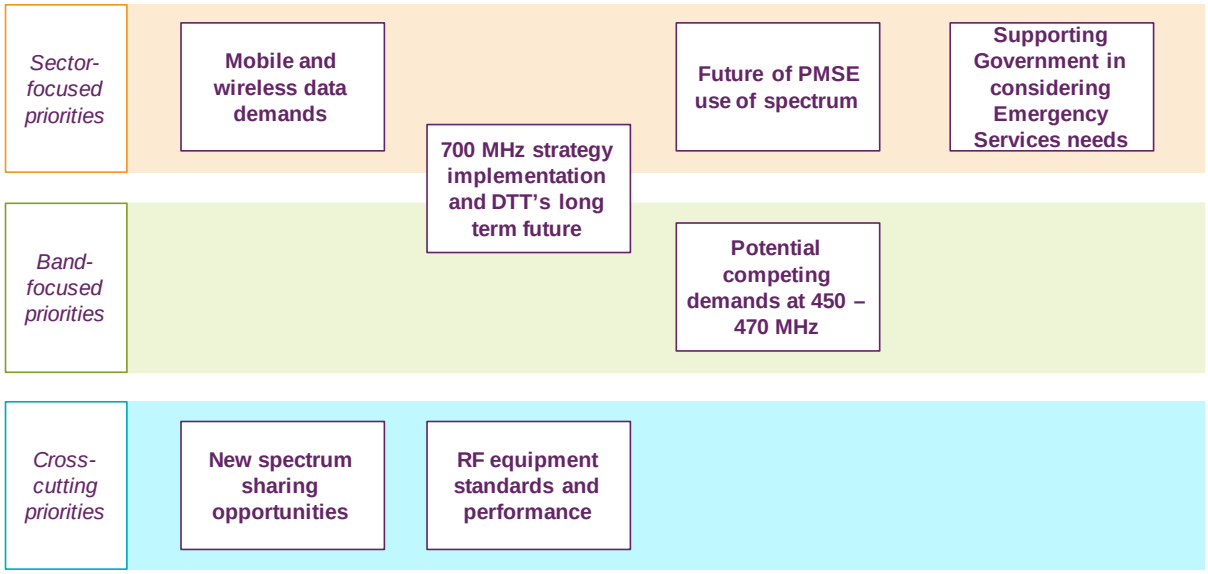
Frequency range	Current uses (selection)	Potential future changes	Overall prospects for changes in spectrum use
100 KHz – 300 MHz	• Ministry of Defence • Radio Broadcasting • Emergency Services communications (VHF) • Business radio • Various SRD bands • Utilities and transport bands • Aeronautical and Maritime allocations	• *Radio Digital Switchover (Government decision)* • *Shared access to spectrum used for radio broadcasting through geo-location approach*	**Low**
300 MHz – 470 MHz	• Ministry of Defence (incl RAF Fylingdales) • Emergency Services communications (TETRA) • Business radio (PMR) • PMSE (shared access for talkback audio links)	• *Potential re-organisation of existing users at 450-470 MHz (business radio, Emergency Services and other Home Office use, Utilities)*	**Medium**
470 MHz – 1 GHz	• Digital Terrestrial Television • PMSE (audio links, shared access with exception of 606-614 MHz) • Wireless broadband (800 and 900 MHz band) • Transport (including GSM-R) • Licence-exempt devices: SRDs including RFID • Mobile voice and data (900 MHz band)	• *Shared access to TVWS spectrum through geo-location approach* • *Potential re-purposing of spectrum at 700 MHz to wireless broadband* • *Reduced access for PMSE wireless microphones* • *Very long term prospects for further changes to the UHF TV band* • *Licence-exemption at 870 – 920 MHz for RFID and other SRD use*	**High**
1 GHz – 3 GHz	• Ministry of Defence • Fixed Wireless Services • L-band (1.4 GHz – awarded but currently unused) • Mobile Satellite Services (2GHz) • PMSE (shared access for wireless cameras and video links) • Emergency Services communications (shared access to MoD bands • Licence-exempt devices including WiFi (2.4 GHz) • Wireless broadband (1.8, 2.1 and 2.6 GHz) • Aeronautical and Maritime radars	• *1452-1492 MHz likely to be brought into use for wireless broadband* • *Potential for use of 2GHz MSS spectrum subject to EU enforcement proceedings* • *MoD planned release at 2.3 GHz, potentially for wireless broadband use* • *Reduced access for PMSE wireless cameras* • *Shared access opportunities of other MoD spectrum* • *Potential for re-purposing of spectrum at 2.7 - 2.9 GHz for wireless broadband use*	**High**
3 GHz – 6 GHz	• Ministry of Defence • Space services • 5 GHz WiFi band • PMSE (shared access for wireless cameras and video links) • Emergency Services communications (shared access to MoD bands • Aeronautical and Maritime allocations	• *MoD planned release at 3.4 GHz, potentially for wireless broadband use* • *Shared access opportunities of other MoD spectrum* • *Potential for shared access of spectrum at 3.6 – 4.2 GHz for wireless broadband use and NLoS small cell backhaul* • *Potential for expansion of licence-exempt WiFi use at 5GHz*	**High**
6 GHz – 18 GHz	• Ministry of Defence • Satellite services including satellite TV broadcasting • Fixed Wireless Services • Earth Exploration Satellite Services	• *Migration of MoD uses from lower bands being released* • *Potential migration of additional Fixed Wireless Services in case of in case of re-purposing / growing congestion of lower frequency bands* • *Potential for growing PMSE wireless cameras use (LoS applications)*	**Medium**
18 GHz – 55 GHz	• Satellite services including residential broadband and science • Fixed Wireless Services including mobile backhaul and CCTV	• *Potential migration of Space services in case of re-purposing / growing congestion of lower bands* • *Very long term potential for 5G use* • *Potential extension of satellite TV broadcasting use*	**Medium**
55 GHz – 300 GHz	• Fixed Wireless Services (E-band) • 60 WiFi and various SRD bands • Science services	• *Growing use of Fixed Wireless Services for mobile backhaul*	**Low**

These future trends suggest a set of priority areas for considering the role of regulatory action in addressing emerging challenges

5.23 Based on the sector-by-sector analysis and the overview of potential changes by frequency range, our preliminary analysis suggests that regulatory action could be particularly relevant to seven areas that present challenges for the future management of spectrum. In Figure 13 below we have categorised these according to whether they relate primarily to:

- particular sectoral uses of spectrum (sector-focused priorities);
- specific bands (band-focused priorities); or
- issues that could have particular relevance to a variety of sectoral uses and spectrum bands (cross-cutting priorities).

Figure 13 - Proposed priority areas



5.24 **Mobile and wireless data demands:** these are likely to grow significantly over the next 10-20 years and there could be significant additional benefits for UK citizens and consumers associated with this. Considering the most appropriate response to these growing demands is likely to involve a significant amount of regulatory activities, both in the UK and internationally.

5.25 **Implementing our strategy for the 700 MHz band and considering DTT's longer term future**: our UHF Strategy statement set out our objectives for enabling a potential change of use of the 700 MHz band to wireless broadband and the associated requirement for a re-planning of DTT in a way that secures the ongoing delivery of the benefits it provides. Whilst these potential changes are unlikely to take place before 2018, we are undertaking a number of activities to ensure they can be implemented with minimum disruption.[63] We have also initiated wider thinking on the longer-term future of DTT. This is because the implementation of future decisions on

[63] http://stakeholders.ofcom.org.uk/binaries/consultations/700mhz-cfi/summary/UHF_SI_call_for_inputs.pdf

changes to DTT licences and transmission infrastructure are likely to influence outcomes beyond the potential timescales of the prospective change of use at 700 MHz.

5.26 **Considering the future of PMSE use of spectrum**: recent and future potential re-purposing of additional spectrum for mobile broadband is reducing the quantity, and changing the geographical pattern, of spectrum that PMSE applications (such as wireless cameras and wireless microphones) have access to. These changes are raising the need for us and industry to consider current and future spectrum demands and the scope for different spectrum supply options as well as other potential mitigating action such as changes in user customs and practices.

5.27 **Considering potential competing demands for the 450-470 MHz band**: the configuration of this band is heavily fragmented between different uses. In the past we have considered initiatives to re-organise and rationalise the use of this band, but then decided against action because of the cost and disruption to existing users that such a change would involve. Now, however, there are a number of new developments that mean it may be appropriate to reconsider the configuration of band. First, potential changes to technologies used in this band in other European countries may cause increasing levels of interference. This might make the current UK configuration of this band (which does not align with the European harmonised band plan) unsustainable over the long term. Second, the potential for LTE use of the band means it could play a role in sustaining near ubiquitous mobile coverage. These issues are likely to raise the prospect of the need for important trade-offs that will require regulatory consideration in future.

5.28 **Supporting Government in its consideration of the future wireless communication needs of Emergency Services (ES)**: Emergency Services providers in the UK and throughout the world are currently considering their potential needs for a new generation of broadband communications. In the UK the existing contractual arrangements to deliver critical voice applications for the Emergency Service are coming to an end between 2016 and 2020. As a result, the UK is considering the future provision of both voice and broadband ES applications. Decisions on whether and how emergency services will require changes to the wireless communications services they use is a matter for Government, and we note the ongoing activities of the Emergency Services Mobile Communications Programme to address the future communications requirements of mainland UK ES. As Government progresses with this work, we anticipate that our advice may be required, particularly in matters that relate specifically to spectrum availability and the potential for network sharing.

5.29 **Facilitating new spectrum sharing opportunities**: new technical and regulatory developments are expanding the range of uses for which shared spectrum access could be viable. At the same time, as part of its Public Sector Spectrum Release (PSSR) programme, Government, and in particular MoD, is looking to release spectrum for commercial purposes on a shared basis, both geographical and time based sharing. Spectrum sharing opportunities are likely, therefore, to become increasingly important as competing spectrum requirements grow and options for re-purposing spectrum diminish. Therefore, we expect that supporting spectrum sharing developments will be an increasingly important part of our spectrum work in future.

5.30 **Supporting the improvement of radio equipment performance**: the growth of competing demands for spectrum and prospects for greater levels of spectrum sharing will continue to increase the intensity with which spectrum is used. This will drive the need to optimise, as far as possible, every component in a radio system. In

this context, 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 become even more important to address new potential co-existence issues. In future, we will consider whether Ofcom should seek to contribute more the work of standardisation bodies and the development of international regulations on radio equipment.

5.31 the Government's Public Sector Spectrum Release (PSSR) programme will be critical to the success of a number of the priorities we have identified. The potential of the PSSR programme is also illustrated by the significant proportion of spectrum that is used by Government bodies. Our support to this programme is a critical component of the mobile and wireless data priority as a potential source of new spectrum supply. This programme is also expected to play an important role in the identification of opportunities to share spectrum more dynamically and intensively within the spectrum sharing priority. It may also have a role in both the Emergency Services future needs and in considering the competing demands for the 450 – 470 MHz band given relevant Crown holdings in both cases.

5.32 As such there is a large programme of work that we expect to undertake in supporting Government to achieve its release target, which will directly contribute to the achievement of our priorities. This is most recently demonstrated by MoD's release of spectrum at 2.3 and 3.4 GHz to Ofcom for conduct the sale process as well as the work on co-existence with civil users. Given, however, the extent to which this work contributes directly to the identified priorities we have not identified it as a specific priority in its own right, but rather focused on the outcomes its delivery will enable us to facilitate.

5.33 In the following section we discuss all the areas identified in Figure 13 in greater detail.

Question 3: Do you think we have adopted the right approach to analysing future trends and developments that could raise the need for future regulatory action?

Question 4: What are your views on the results of our analysis of future developments summarised in this section and discussed in greater detail in the Appendix to this consultation? Please provide evidence in support of your views wherever possible

Section 6

Proposed priorities

6.1 In the sections below, we discuss our preliminary thinking on the rationale and the key issues that future Ofcom work may need to consider over the next 10 years in each of the priority areas indentified in Section 5.

6.2 As we outline how these spectrum challenges may 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.

6.3 In addition, it is important to note that the work programmes we outline below are indicative and our future activities could differ from these, as a result of stakeholders' input, the emergence of new issues over time, and the priorities we set for the use of our resource. In practice, we will need to keep our strategy and priorities under review over time.

6.4 We invite stakeholders to submit their comments and views in relation to these priority areas in response to this consultation.

Sector-focused priority areas

Considering mobile and wireless data demand

6.5 Demand for mobile and wireless data is likely to continue to increase significantly in future and could lead to important changes to how a number of key spectrum bands are used over the next 10 years. As demand for capacity generated by handheld devices increases, expectations of ubiquitous data coverage are also likely to become increasingly relevant.

6.6 Mobile broadband and the services and applications it sustains deliver significant benefits to UK citizens and consumers today. Mobile services already deliver significant economic value, and mobile broadband growth could increase this further, sustaining further innovation and making an expanding range of new high value mobile services available to consumers.[64] Sustaining mobile broadband growth, including the delivery of high-capacity services to rural areas, could also make a significant contribution to citizen benefits, contributing to digital inclusion and facilitating social participation. For these reasons we believe that considering the most appropriate enabling action to address the growing demand for mobile data could deliver significant future benefits to UK consumers and citizens in the future.[65]

6.7 Spectrum re-purposing is likely to be a key component of a mix of solutions that will be required to address growing wireless and mobile data demand. On the other hand any future spectrum re-purposing for mobile and wireless data use would only be

[64] Following the 4G auction of spectrum at 800 MHz and 2.6 GHz we estimated that the value that 4G services could provide to consumers over the following 10 years could be in excess of £20bn.
[65] However, where competing demands for spectrum resources arise, the mobile data benefits will need to be balanced as appropriate against benefits associated with competing uses.

justified where the incremental value associated with such re-purposing is greater than the value associated with alternative or incumbent spectrum uses. It may also be that the costs and disruption potentially associated with displacing incumbent spectrum users could severely affect the rationale for re-purposing specific spectrum bands to mobile broadband use. Such challenges are likely to be particularly relevant for frequency bands below 3 GHz.

6.8 It is likely that any future re-purposing of spectrum for mobile broadband will require specific regulatory action because of:

- the reliance on international decisions on changes to the international regulatory framework and on enabling harmonisation of spectrum; and
- the complexities that are often associated with managing major changes of use, and in particular those related to the transaction costs when the clearance of large numbers of incumbent users is required, and when seeking to manage the challenges of coexistence with large numbers of adjacent users and uses.

6.9 Our future activities in this area are likely to include:

- contributing to analysis supporting and influencing relevant international decisions, particularly those related to AI 1.1 at WRC-15;
- supporting Government's Public Sector Spectrum Release programme;
- developing a long-term UK perspective on future supply and demand options and monitoring ongoing developments;progressing our work on mobile coverage; and
- assessing the role of spectrum sharing and licence exemption in addressing growing mobile and wireless data requirements.

Contributing and influencing relevant International decisions on mobile broadband

6.10 Only bands that are internationally harmonised are likely to be economically viable for the delivery of mobile data services. International harmonisation is 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 offers consumers a widening of choice of mobile devices developed and sold in global markets that are compatible with the use of frequency bands used internationally.

6.11 International processes at both ITU and European levels will be very important in setting expectations around the use of additional bands for mobile services.

6.12 A key milestone will be the next ITU World Radio Conference, which is scheduled to take place in 2015. In particular, Agenda Item 1.1, which concerns the allocation of additional spectrum for wireless broadband applications. The ITU has set out a schedule of studies for bands considered in the preparatory work for WRC-15. In March 2013 we published a call for input[66] on the bands being considered as part of this preparation for WRC-15.

6.13 Within Europe, the Radio Spectrum Policy Programme (RSPP), which was agreed by the European Parliament and Council in April 2012, has already set out policy

[66] http://stakeholders.ofcom.org.uk/binaries/consultations/cfi-mobile-bb/summary/cfi-mobile-bb.pdf

objectives, seeking to identify at least 1200 MHz of spectrum for mobile broadband by 2015. The RSPG has recently delivered an Opinion on wireless broadband[67] that includes its assessment of which bands may be suitable for wireless broadband in future, along with an indication of the associated timeframes. This Opinion is expected to influence the European Commission's stance on the future of wireless data spectrum and may ultimately lead to the development of binding Commission Decisions to make spectrum available for wireless broadband in certain bands within the EU.

6.14 CEPT is also undertaking 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.

6.15 Table 5 below sets out the state of play for 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 likely to be considered in the preparatory work for WRC-15, and whether it is already allocated to mobile broadband services.

Table 5 - Spectrum bands likely to feature in future international discussions on mobile and wireless broadband

Band	Likely to be 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 to mobile satellite use but ongoing EU enforcement action	Yes	
2700-2900 MHz	Yes	No	
3600-3800 MHz	Yes	Yes	
3800-4200 MHz	Yes	Yes	

[67] 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

Supporting Government's Public Sector Spectrum Release programme

6.16 The release of public sector holdings is expected to make a significant contribution to future spectrum availability for mobile broadband. As part of this, the Ministry of Defence (MoD) has been advancing plans to vacate and enable the release of around 200 MHz of spectrum in the 2.3 GHz and 3.4 GHz spectrum bands.

6.17 Recently, the MoD announced its intention to release to Ofcom this spectrum for Ofcom to conduct the sale process.[68] To deliver this, we expect our work will include:

- progressing our ongoing analysis of potential co-existence challenges and developing appropriate mitigation strategies;
- assessing 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;
- considering policy and competition implications of the planned release on downstream service markets; and
- designing and conducting the award.

6.18 Our immediate next steps include publishing a document seeking expressions of interest from potential users of this spectrum.

6.19 The timing of this release will be subject to our ongoing analysis of all relevant issues, as well as any new issues raised by stakeholders in response to future consultations. Our intention is to conduct an auction of this spectrum in 2015/16.

Developing a long term UK perspective on demand and supply options and monitoring ongoing developments

6.20 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. 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 data, are properly accounted for and managed.

6.21 As an important first step we are developing a *mobile data strategy*. Its aim is to understand how we can enable long-term growth in mobile data benefits 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 work programme relating to mobile data spectrum. In doing this we are looking to the long term and beyond the tranche of

[68] https://www.gov.uk/government/news/ofcom-to-manage-release-of-mod-radio-spectrum

spectrum (including 700 MHz, 2.3 GHz and 3.4 GHz) already under detailed consideration.

6.22 We plan to publish a consultation later this year setting out our initial thinking on potential long-term priorities in relation to mobile and wireless data. This will include consideration of network and technology trends that could shape future demand for mobile spectrum, and the prospective bands for future mobile data use (taking account of the prospective demand for even larger channel sizes, the balance of high and low power cells and the evolution of heterogeneous networks amongst other factors). We expect the subsequent statement will act as an initial high level plan for our future programme of work on mobile data spectrum and for this to be reviewed periodically in order to take account of market and other developments.

Progressing our work on mobile coverage

6.23 The 4G coverage obligation imposed on the 800 MHz spectrum lot that was acquired by O2 requires the provision of indoor coverage to 98% of UK households (corresponding to about 99.5% outdoor coverage). 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, in fact, result in increased voice and data mobile coverage offered by operators other than O2.

6.24 In future there may be increasing expectations and potential demand for ubiquitous coverage of wireless data services, extending to geographies other than population premises. In particular, we note that the benefits potentially offered by new automotive M2M applications could be dependent on the provision of reliable mobile data coverage across the road network.[69] However, other types of infrastructure may also play a part in delivering widespread geographic availability of wireless data.

6.25 Over the next few years our work on mobile coverage will to include:

- continuing to monitor effective progress in UK premises coverage;
- considering ways to make sure information is available to consumers on coverage levels and the effective quality of experience offered by operators;
- exploring options to support improvements in geographical coverage of mobile voice and data services, including road and rail coverage; and
- considering the potential demand for near ubiquitous availability of mobile voice wireless data services, the role that public mobile networks might play in delivering this and whether any enabling action by us may be required.

Assessing the role of spectrum sharing and licence exemption in addressing growing wireless data requirements

6.26 Mobile data demands, although highly significant, are not going to be the only source of growing spectrum requirements in future. This is likely to lead to growing competing requirements for specific spectrum bands, and an increasing difficulty in

[69] These could include eCall, a new service endorsed by the European Commission providing automated calls to the nearest emergency centre in case of car crash (see http://ec.europa.eu/information_society/activities/esafety/ecall/index_en.htm),live traffic updates to navigation systems, or longer term prospects for intelligent traffic systems interacting with automated cars.

re-purposing spectrum into dedicated blocks of spectrum for mobile use. In this context, we believe that spectrum sharing and particularly licence exemption could make a growing contribution in the delivery of mobile capacity needs in future.

6.27 We have recently published a high level consultation on spectrum sharing for mobile and wireless data,[70] in which we noted how:

- Wi-Fi equipment, which uses shared spectrum in the 2.4 and 5 GHz bands on a licence-exempt basis, is likely to play an increasingly important role indoors by enabling a significant proportion of the demand for mobile data to be offloaded onto fixed broadband connections. However, a study recently conducted on our behalf[71] found that the current spectrum allocation for Wi-Fi at 2.4 and 5 GHz is likely to be under pressure by 2020, and that additional spectrum at 5 GHz could make a significant contribution to meeting expected demand. WRC-15 is expected to consider whether to allocate 195 MHz of additional spectrum and/or 150 MHz of light-licensed spectrum in the 5 GHz band to LE/SRD use, including Wi-Fi. Ofcom will set out its position on the extension of 5 GHz band within the CEPT and WRC working groups considering its harmonisation following the completion of a detailed study of coexistence in the 5 GHz band.

- The use of low power small cells (using licence-exempt devices) for mobile broadband may be suitable for deployment in areas of high demand to complement networks based on licensed mobile spectrum. This could be facilitated if spectrum bands were made available for shared use where they are currently primarily used outside of dense urban areas, such as some bands used by MoD. Such an approach has been announced in the US to enable spectrum sharing and small cell deployment in the 3.5 GHz band, where maritime radars are the primary user.[72]

6.28 As we progress our stakeholder engagement on these topics, we believe that activities around spectrum sharing will feature more prominently in our consideration of the issues we may need to act on when considering the mobile data challenge, but also, as we discuss further below in this Section, may also provide significant opportunities for meeting requirements for other services, beyond mobile broadband.In Table 6 below, we indicate our initial thinking on potential questions we will need to address and high level timescales related to our proposed mobile and wireless data priority area.

Table 6 - potential work programme in support of our proposed mobile data priority area

Issues that Ofcom is already considering	• Preparations for WRC-15 (esp AI 1.1) and other ongoing international engagement • Developing a long term perspective on demand and supply options • Undertaking the auction of the spectrum vacated by MoD at 2.3 and 3.4 GHz • Assessing the potential role of licence-exempt and sharing

[70] http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-sharing/summary/Spectrum_Sharing.pdf
[71] http://stakeholders.ofcom.org.uk/binaries/consultations/cfi-mobile-bb/annexes/RW_report.pdf
[72] http://www.fcc.gov/document/fcc-proposes-innovative-small-cell-use-35-ghz-band

	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 3-5 years	• Considering harmonisation opportunities opened by international decisions • Developing and implementing a consistent approach to assessing and enabling use of additional spectrum for mobile and wireless data • Supporting Government in future releases, particularly sharing opportunities, as part of the PSSR programme • 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

Question 5: Do you agree that a consideration of mobile and wireless data demands should feature as a priority area in our work programme for the next ten years? Have we captured all the major issues that we should consider within this area?

Spectrum access for Programme Making and Special Events is reducing, triggering the need for a review of the sector's long-term use of spectrum

6.29 Programme Making and Special Events 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.

6.30 PMSE has access to spectrum from 48 MHz to 48 GHz in a number of sub-bands almost entirely on a shared basis. For example, applications including wireless microphones, in-ear monitors and audio links access spectrum in the UHF TV bands (470 to 792 MHz) on a geographically interleaved basis with frequencies primarily used for DTT transmissions. Wireless cameras and video links generally access spectrum in a variety of bands above 2 GHz, sharing spectrum with different types of users, including MoD.

6.31 Recent and future spectrum releases for mobile broadband use have already reduced, and are likely to reduce further, the quantity of spectrum that remains available for PMSE and, in the case of UHF TV Bands, vary the geographical pattern of spectrum access. This is because wide-area mobile broadband networks do not, with current technology, allow for spectrum to be shared with another service.

6.32 The recent combined award of the 800 MHz and 2.6 GHz bands for mobile broadband use resulted in PMSE no longer having access to these frequencies for audio applications at 800 MHz and video applications at 2.6 GHz. The release of the 3.4 GHz band by MoD will reduce spectrum availability for wireless cameras and video links as PMSE currently has access to the band. MoD's release of the band 2350-2390 MHz will have an indirect impact on PMSE use as, whilst the band is not allocated for PMSE use, it does provide loan spectrum for peak demand events, e.g.

State occasions such as Royal weddings, and the London marathon. The potential future release of the 700 MHz band, as part of our UHF Strategy implementation programme, would further reduce spectrum availability for wireless microphones and in-ear monitors.

6.33 In order to understand PMSE users' future needs and the impact of the spectrum release programme on the PMSE sector we have initiated a project to review PMSE spectrum use and future needs, the PMSE spectrum review. This recognises that the demand for spectrum for both audio and video PMSE applications is growing and the previous and potential future reductions in access to spectrum is one factor that may affect the sector's ability to meet users' requirements of production quality. It also recognises that historically PMSE users gained access to spectrum through sharing of spectrum where it was unused by the Primary user and there has not, therefore, been a particular focus on the extent to which the spectrum made available to PMSE was warranted based on its demand.

6.34 We plan to publish a Call for Inputs in Q4 2013/4 in which we expect to share our analysis to date. Issues that we plan to consider as part of the review will include:

- investigating how demand for PMSE services is likely to evolve over the long term, and the feasibility and sustainability of different supply options;
- an appreciation that PMSE users value security of tenure and therefore any future spectrum access options should look to offer a period of stability;
- the potential changes PMSE users can make to mitigate their future demand, including discussing with stakeholders:
    - whether and how PMSE users can improve the efficiency of their use of spectrum through the use of new PMSE equipment technologies;
    - whether and how PMSE users can further improve the efficiency of their use of spectrum through changes to their customs and practices to identify possible improvements such as in their technical planning, particularly with regard to multiple devices at a single location; and
- international engagement on initiatives over PMSE harmonisation in Europe and with the work of the ITU.

6.35 The PMSE spectrum review will also consider the approach to PMSE spectrum management, noting that proposals for PMSE band management were put on hold in 2010 in the light of our need to commit attention and resources to preparations for the Olympic Games.

6.36 In Table 7 below, we indicate our initial thinking on potential questions we will need to address and high level timescales related to our proposed PMSE priority area.

Table 7 - potential 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 • Considering the future role of new PMSE equipment technologies • International engagement on initiatives over PMSE harmonisation in Europe and within ITU work

Issues that are likely to become relevant over the next 3-5 years	• Reviewing our approach to PMSE spectrum management • Assessing the impact of planned spectrum changes on PMSE
Issues potentially relevant over the longer term	• Considering the potential relevance of cognitive technologies to PMSE applications

Question 6: Do you agree that the future of PMSE spectrum access should feature as a priority area in our work programme for the next ten years? Have we captured all the major issues that we should consider within this area?

Emergency Services future communications needs represent a key public policy challenge where we may be asked to support and inform Government decisions

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

6.38 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[73]. This provides robust and secure voice and narrowband data services, with tailored functionality such as group calling, nationwide roaming and direct mobile to mobile calls without network infrastructure support. 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.

6.39 Decisions on whether and how emergency services will require use of spectrum, and how that would be secured, will be a matter for Government. In particular, we note that Government has initiated a multi-agency programme, the Emergency Services Mobile Communications Programme (ESMCP) to address these issues UK-wide. The Scottish Government has also initiated the Scottish Future Communications Programme (SFCP) to consider issues for Scotland. While led by Government, we anticipate that there will be specific aspects of their decisions on which Government may ask for our advice.

6.40 The need to re-assess options for the long term provision of critical voice and narrowband applications is also increasing the relevance for UK 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[74] applications based on broadband communications.

6.41 In the US, spectrum has been assigned in the 700 MHz band for PPDR and networks are being planned and deployed based on LTE. International developments on the

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

[74] The terminology PPDR (Public Protection and Disaster Relief) is the equivalent used in Europe and elsewhere of the ESMCP and SFCP programmes in the UK. To note that Disaster Relief is catered for separately in the range 4 - 5GHz internationally.

harmonisation of the 700 MHz band for mobile broadband use raise the opportunity of adopting similar approaches of LTE-based solutions for the delivery of broadband ES communications on a global scale, which is likely to lead to economies of scale on equipment and incentives on manufacturers and service providers to meet the needs of the ES market.

6.42 Other spectrum options for LTE-based solutions for broadband ES communications that could potentially benefit from international harmonisation include the 450-470 MHz band. There is currently technical standardisation work underway to define a variant of LTE for use in the 450-470 MHz band, and we understand some countries view the use of LTE, in this band, as a useful option to extend the reach of wireless broadband. However, it is not yet clear whether this proposal will receive wide international support or whether a wide range of devices will use it. Whilst ES broadband networks in this frequency range could benefit from more effective coverage in remote and rural locations, as we discuss further below, re-purposing use of this band in the UK could pose serious challenges to UK incumbents.

6.43 The standards body responsible for developing LTE technology (3GPP) has a stated commitment to provide features and functionality required by ES critical voice applications and has a roadmap for its delivery. However, the timetable for this remains unclear.

6.44 A different technology evolution path is offered by the next generation TETRA standard. The TETRA Enhanced Data Service (TEDS) is designed to be compatible with TETRA Release 1 and to allow migration between the two variants. This technology is generally referred to as wideband (in relation to TETRA which is narrowband), but the data rates it offers are significantly lower than those potentially delivered by LTE.

6.45 There are a number of ways in which, in principle, one could envisage the needs of the ES (broadband or narrowband) being met. For example, the current approach used by Airwave involves using dedicated spectrum that is only used for this purpose, and this could continue. An alternative might be for PPDR services to be deployed using spectrum or network infrastructure that is shared with non-PPDR users.

6.46 The timetable associated with the Airwave expiration of licences for the provision of voice and narrowband services, the emerging demand for broadband ES functionalities, 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 Government.

6.47 Although the decision on how to meet the ES future communications needs is one for Government, we believe that Ofcom's expertise and advice could be useful to Government as it considers the long-term solutions for the provision of ES wireless communications. In particular, we believe Ofcom support could be valuable in the following areas.

- Assist Government in assessing the spectrum implications for different solutions for the long term provision of ES communications, both broadband and narrowband

- Represent UK interests in International institutions that are working towards harmonised approaches to spectrum for the delivery of ES communications.

Table 8 - potential work programme in support of our proposed emergency services priority area

Issues that Ofcom is already considering	• Understanding the extent of advice required by Government from Ofcom • Representing UK interests in International PPDR spectrum harmonisation negotiations
Issues that are likely to become relevant over the next 3-5 years	• Providing advice as requested by Government on potential availability of spectrum and costs • Providing support to 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 Government in Emergency Services use of spectrum through PSSPG and UKSSC

Band-focused priority areas

Implementing our UHF Strategy will require important work over a number of years, and wider consideration of DTT's long-term future will be increasingly relevant

6.48 Ofcom's UHF Strategy Statement, published in November 2012,[75] set out two objectives relating to the use of UHF bands IV and V, which cover the frequency range 470 - 862 MHz, namely: enabling the potential release of additional low frequency spectrum for mobile broadband use, to help meet the rapidly increasing demand for mobile data; and securing the ongoing delivery of the benefits provided by Digital Terrestrial Television (DTT).

6.49 We said that to achieve these objectives we would support the international process and conduct preparatory work to enable the release of the 700 MHz band harmonised for mobile use. We also said that, in the event that the 700 MHz band was to be released, we would seek to ensure that the 600 MHz band can be used for DTT and other services sharing spectrum with it on a geographic interleaved basis. We have now started a programme of work to prepare for implementation of our UHF strategy.

6.50 The 700 MHz band is currently used for DTT, and other services sharing spectrum with it, including PMSE. In the near future this spectrum is also expected to be used for Local TV and new applications based on white-space technology.

6.51 Any change of use of the 700 MHz band from broadcasting to mobile broadband services would need to be coordinated at an international level. Consequently, international developments will influence many aspects of the future of the 700 MHz band, including potentially the future use of the band, the earliest timing of any release and the exact DTT band plan adopted by the UK. The need for new international agreements makes it likely that none of these changes will start to take place until 2018 at the earliest.

[75] http://stakeholders.ofcom.org.uk/binaries/consultations/uhf-strategy/statement/UHF_statement.pdf

6.52 As explained in the UHF Strategy Statement, we anticipate that a release of the 700 MHz band at some future point in time is likely to create significant benefits for citizens and consumers. However, there may also be some disruption for consumers if, and when, a change of use of the band takes place.

6.53 As we discussed in our 2013 Call For Input on the future of the 700 MHz band,[76] the key strands of work we have identified to prepare for the implementation of the above strategy are:

- engaging in the various international forums with a view to securing an outcome that best serves the interests of UK citizens and consumers;
- undertaking an initial cost-benefit analysis to build on our position in the UHF Strategy Statement and inform other implementation decisions, and initiating work to identify the options for determining the timing of any release that maximises the benefits for citizens and consumers; and
- exploring opportunities for reducing, and potentially avoiding, costs and disruption, such as those related to the need to modify or bring forward the replacement of consumer equipment, as a result of a change in use of the 700 MHz band.

6.54 Should a decision be taken to change the use of the 700 MHz band then there will be a range of issues about how in practice this will be implemented. In advance of a decision Ofcom will begin consideration of implementation issues and will engage with Government as appropriate. Such issues include:

- the regulatory steps that would need to be taken for current users to cease using the 700 MHz band and for those services (primarily DTT and PMSE) to be given access, as appropriate, to frequencies in the spectrum remaining for that use, including the 600 MHz band;
- the approach to implementing any necessary changes to DTT transmission infrastructure, including roll-out planning;
- where the costs incurred in a transition process could fall and how those costs might be met, including whether any mitigating action would be required and how that could be managed; and
- the scope and structure of a potential future award of the 700 MHz band, including (in due course and if appropriate) auction design.

6.55 As we and stakeholders consider the implications of implementing changes to DTT to enable a release of the 700 MHz band, a wider debate over the longer-term role and future of DTT is emerging, looking beyond the timescales of any change of use at 700 MHz. For example, we note the ongoing work of the Future of Innovation in Television Technology (FITT) Taskforce coordinated by the Digital Television Group (DTG).[77]

6.56 As we stated in our UHF Strategy Statement, we believe that DTT is likely to remain an important platform for the delivery of PSB, as well as for TV services more generally in the 2020s. We also acknowledged that, over the very long term, and

[76] http://stakeholders.ofcom.org.uk/consultations/700mhz-cfi/
[77] http://www.dtg.org.uk/projects/fittt_latest.html

beyond the likely timescales for release of the 700 MHz band, there is a potential for the universal take-up of superfast broadband to enable IPTV services to provide a viable substitute for the linear broadcast TV service provided by the DTT platform, enabling a potential future DTT switch-off scenario. Other scenarios could include the use of hybrid platforms to deliver free-to-view services, leveraging both DTT and IPTV networks, or the use of non-pay TV satellite provision.

6.57 Whilst significant uncertainties remain over the long-term developments of TV distribution, we believe that it is important that decisions around implementing changes to DTT licences and transmission infrastructure are informed, as far as possible, by a long-term perspective on desirable outcomes for citizens and consumers in light of plausible future developments.

6.58 For this reason, we have initiated early thinking about the likely evolution of free-to-view TV and intend to work with stakeholders to develop a series of scenarios for the long-term future of DTT and free-to-view TV more generally.

6.59 In Table 9 below, we indicate our initial thinking on potential questions we will need to address and high level timescales related to our proposed UHF Strategy implementation and future of DTT priority area.

Table 9 - potential work programme in support of our proposed 700 MHz strategy implementation and future of DTT priority area

Issues that Ofcom is already considering	• International engagement on 700 MHz harmonisation and coordination discussions • Initial CBA on 700 MHz re-purposing and associated changes • Explore opportunities to reduce and avoid future disruption • Initiate thinking on role of DTT and free-to-view TV post 700 MHz re-purposing
Issues that are likely to become relevant over the next 3-5 years	• Final decision on 700 MHz re-purposing • 700 MHz award design • Understand and begin implementation of regulatory steps required to enable transition • Consider issues around costs of transition
Issues potentially relevant over the longer term	• Enabling action and regulatory support for 700 MHz clearance and award

Question 7: Do you agree that the implementation of our 700 MHz strategy and the longer term future of DTT should feature as a priority area in our work programme for the next ten years? Have we captured all the major issues that we should consider within this area?

Competing demands for spectrum in the 450-470 MHz band raise important trade-offs between existing and future potential benefits

6.60 Around one third of the capacity available in the 450 – 470 MHz band is heavily used by business radio users. Ofcom has over 25,000 business radio licences assignments in this spectrum that sustain 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. Other users of spectrum in this the frequency range include Emergency Services, Scanning Telemetry used by the utilities, PMSE “talk-back”, and licence-exempt devices.

6.61 For historic reasons the UK band plan is highly fragmented and is also in the reverse configuration (receive and transmit) compared to the agreed European band plan. We have considered the possibility of reconfiguring this band in the past, both to reverse the UK band plan and also rationalise the fragmented nature of its use, and have decided against this as it was considered to be too disruptive and costly to be justified.

6.62 However, new emerging developments mean it is now appropriate to reconsider the long-term configuration and use of this band.

- Potential changes to technologies used in this band in other European countries (either through CDMA or LTE systems) could increase the risk of incoming interference to UK users, strengthening the rationale for a band re-plan.

- Demand from utilities providers for spectrum in these frequencies could increase substantially in future as new smart grid applications and control systems are considered for implementation within the Critical National Infrastructure (CNI).

- Another set of potential competing demands over the longer term relate to future prospects for LTE use of this band. Technical standardisation work to define a variant of LTE for use in the 450 – 470 MHz band is currently underway in international bodies and we understand some countries view the use of LTE, in this band, as a useful option to extend the reach of wireless broadband, most notably Brazil. A potential long-term use of this band for LTE in the UK could prove beneficial to improving coverage of data services in remote and hard-to-reach areas, given the favourable propagation characteristics of these frequencies. However, any change of use of the 450 – 470 MHz is likely to prove very costly and highly disruptive to incumbent business radio users.

6.63 The prospect of increasing competing demands for spectrum resources in the 450 – 470 MHz frequency range, the risk of increasing international interference into existing services, and the complexity associated with any re-plan or change of use of such intensively utilised spectrum underpin our rationale for proposing work in this area as one of our spectrum priorities over the coming years. Our activities are likely to include:

- an ongoing audit of current usage of the band;

- a technical risk assessment of current UK band planning arrangements, particularly with reference to incoming interference from continental Europe;

- the considerations of benefits and costs associated with potential change of use of this band to LTE for the delivery of commercial mobile broadband services and/or PPDR communications, taking account of international developments; and

- as assessment of migration and other supply options for business radio uses in the event of replan and/or re-purposing of this band

6.64 In Table 10 below, we indicate our initial thinking on potential questions we will need to address and high level timescales related to our proposed UHF Band II priority area.

Table 10 - potential work programme in support of our priority area on competing demands for spectrum at 450 – 470 MHz

Issues that Ofcom is already considering	• Audit of current use by private mobile radio and other users • Assessment of potential role of spread spectrum techniques to enable greater sharing in UHF II and other business radio bands
Issues that are likely to become relevant over the next 3-5 years	• Technical risk assessment of current UK band planning arrangements in light of developments in Europe • Assessment of benefits of a replan of the band to align with the European band plan • Considering benefits and costs associated with potential change of use of this band to wireless broadband (LTE)
Issues potentially relevant over the longer term	• Assessment of migration and other supply options for Business Radio uses in the event of replan and / or re-purposing of this band

Question 8: Do you agree that a consideration of competing demands for spectrum at 450 - 470 MHz should feature as a priority area in our work programme for the next ten years? Have we captured all the major issues that we should consider within this area?

Cross-cutting priorities

6.65 Our preliminary analysis has also highlighted two wide-ranging themes that are likely to become increasingly important over the next 10 years across a variety of sectors and bands.

6.66 For this reason we envisage two priority spectrum work areas that have a cross-cutting nature to them. These relate to spectrum sharing and to technical standards and performance of radio equipment.

Spectrum sharing

6.67 Spectrum sharing has always been an important aspect of increasing the opportunity for gaining greater use of spectrum. As such already plays an important role in sustaining the delivery of important services, for example:

- PMSE applications tend to be based on the use of locally unutilised spectrum that is assigned on a primary basis to other uses and use by PMSE users is technically coordinated;
- The directional nature of terrestrial point-to-point fixed links and satellite permanent earth stations enables a coordinated re-use of the same spectrum between the two different uses; and

- Licence-exempt use permits large numbers of users to share spectrum with no coordination as they typically use only low power, which means there is a very low likelihood of interference between users (and, where this likelihood is higher, they use polite protocols such as listen before talk or low duty cycles to manage access, e.g. Wi-Fi).

6.68 As we discuss in greater detail in the Appendix to this consultation, future developments in spectrum usage suggest that competing requirements for a number of key spectrum bands are likely to increase. Whilst re-purposing spectrum from a lower to a higher value use would, in principle, improve the efficient use of spectrum, in practice changing spectrum use can be a lengthy, disruptive and costly process and there may not be alternate spectrum to which displaced users can relocate. Moreover, new users may be low power – or have a specific geographic focus – and so may not need dedicated spectrum access themselves. In these circumstances, spectrum sharing can play an important role in increasing the efficient use of spectrum whilst minimising the trade-offs and disruption associated with displacing incumbent uses.

6.69 As well as potentially avoiding the disruption associated with spectrum re-purposing, spectrum sharing can also enable opportunities to use licensed spectrum more efficiently. In theory, most types of licensed spectrum could be shared with other devices, provided that these do not cause harmful interference to licensed services (whether this is through a low power licence exempt approach or through a higher power, more cognitive licensed approach). In practice however, sharing opportunities are likely to be greater for licensed spectrum that remains unutilised in specific locations and/or at specific times.

6.70 New technological developments are expanding the range of uses for which shared spectrum access and licence exemption will be a viable option, and provide opportunities to permit devices operating under licence-exemption or 'light licensing' regimes at higher powers than we are able to authorise today. These approaches could also be extended to blocks of spectrum licensed for dedicated use, thus enabling licence-exempt (or 'light-licensed') devices to deliver new services through shared spectrum resources in a way that does not create harmful interference to incumbent users. This has the potential to make more efficient use of this spectrum than is possible today.

6.71 Ofcom is supportive of all developments of new mechanisms and technologies to increase opportunities to share spectrum. One example has been our support of the development of white-space devices. Other examples could include:

- An extension of geo-location approaches to frequencies other than TVWS: although our work on WSDs has so far focused on frequencies used on a primary basis for DTT, approaches based on geo-location databases could, in principle, be applicable to any frequency that is used for applications with specific geographical or temporal focus. Such bands may include parts of public sector holdings that remain underutilised, or radio broadcasting spectrum;[78]

[78] It is worth noting however two key constraints to the use of radio broadcasting spectrum by WSDs. The characteristics of these frequencies are such that applications would be limited by scarcity of capacity available and requirements for long aerials. In addition, Band II is allocated to broadcasting services on a single primary service. In order to use it for other types of services, e.g. WSDs, agreement from neighbouring countries may be required. This could limit the extent to which WSDs in this band are usable across the UK.

- The concept of licensed shared access (LSA): Ofcom supports work by the RSPG and other institutions on this broad concept for new forms of sharing of licensed spectrum, which might include tools through which a national regulatory authority mediates contract arrangements so that primary spectrum users can enable shared access by other users. In particular this might be a helpful mechanism for public sector holdings.

6.72 Other Dynamic Spectrum Access (DSA) methods and developments: DSA refers to approaches that are dynamic in nature and therefore are able to intelligently change their use of spectrum depending on a variety of factors. TVWS are an example of a DSA method. We can expect more sophisticated developments in this area such as cognitive sensing. DSA could enable operators to provide a variety of service levels to consumers through a licence exempt approach that today can only be provided through a licensed approach. The increasing sophistication of DSA technology would for example permit a service provider to use licence exempt devices whilst still also being able to offer higher levels of service to one community over another through the active management of their individual use of the spectrum. As we discussed in the spectrum sharing for mobile and wireless data consultation,[79] applications of DSA may include the operation of outdoor small cells, to increase mobile broadband capacity in dense demand areas, and emerging machine to machine (M2M) applications, such as intelligent transport or smart cities.

6.73 As part of the Government's PSSR programme, MoD in particular is looking at ways in which it can share spectrum more effectively with commercial users and as such this will form an important source of additional spectrum that new sharing technologies and techniques might be applied to. Given the specific nature of much of MoD's use, which is geographically and time bound within quite small limits, this could potentially offer a major opportunity for spectrum sharing in future.

6.74 Market-mechanisms could play a part in achieving optimal use of spectrum through the sharing of licensed spectrum, particularly where this is initiated by the incumbent licensee (perhaps through leasing arrangements to third parties managing this sharing).[80] It is possible that market forces could have the potential to provide the necessary incentives for incumbent licensees to pursue efficient use of their spectrum access holdings and make spare capacity available to those wishing to share. They also have the potential to ensure that any scarce capacity made available for sharing finds its way into the hands of the most valuable uses. However, it is not clear at present whether the business case for doing so will be attractive enough for most existing licensees to consider.

6.75 On the other hand, regulatory action may need to play an important role in enabling sharing so that it contributes to delivering optimal spectrum use.[81] In our work in the future on sharing we will need to carefully consider what the appropriate balance between market-led sharing and regulatory facilitated sharing will be.

6.76 Key areas for Ofcom to progress over the coming years will include:

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

[80] Innovative market mechanisms for managing the assignment process may include the development of spectrum exchanges that could match supply and demand across equivalent users in specific bands on a dynamic basis.

[81] It is important to note that any future enabling of shared access to bands already in use would not impinge on the rights of existing users. In particular, implementing new methods of sharing is not intended to impose costs on the incumbent users, who will continue to be able to expand their use of spectrum (whether in geographic terms or in terms the frequencies used) without reference to those who we may permit to share the spectrum.

- **Progressing our work on TV White spaces**: we expect to run a pilot of the operation of devices in TV white spaces this year. The objective of the pilot is to expedite deployment and to test the end-to-end interoperability between devices, white space databases and Ofcom services.

- **Identifying opportunities for shared access to new spectrum bands across civil and public sector spectrum** and taking the necessary steps to enable efficient use. In its recently published Information Economy Strategy,[82] Government asked us to investigate the creation of an automated online geo-location database aimed at providing on-demand, short term spectrum licences for research and development (R&D) into 5G and other advanced communication systems. Ofcom is also providing technical advice to the MoD on the potential for shared spectrum access at 1427 – 1452 MHz and 4.8 – 4.9 GHz. In addition, we will engage internationally with the CEPT as well as the Federal Communications Commission and stakeholders in Asia to determine which bands are most suitable for new sharing approaches including DSA.

- **Understanding whether new regulatory tools are required to enable and support spectrum sharing opportunities**. The RSPG is currently developing its conceptual approaches to LSA and recently issued a consultation on the topic[83]. CEPT has also initiated work on an LSA regulatory framework, seeking to apply LSA to the 2.3 GHz band to make it available for mobile broadband services.

- **Setting and reviewing coexistence parameters** as appropriate over time, in a way that balances effective interference management with supporting the operation of innovative devices and services

- **Continue to monitor and remain abreast of market and technical developments** towards supporting advanced sharing techniques.

Table 11 - potential work programme in support of our proposed spectrum sharing priority area

Issues that Ofcom is already considering	• Progressing our work on enabling sharing through geo-location databases in TV White Spaces • Progressing our work considering the role of licence exempt devices in delivering mobile wireless broadband and the regulatory implications • Identifying suitable spectrum for shared access for R&D purposes • Assisting MoD on making additional spectrum available through sharing
Issues that are likely to become relevant over the next 3-5 years	• Assessing the opportunities for greater market-led spectrum sharing including understanding any existing barriers to this occurring • Identifying new frequency bands that could be made available for shared access through a geo-location approach • Considering the case for new regulatory tools to support new

[82] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/206944/13-901-information-economy-strategy.pdf
[83] https://circabc.europa.eu/sd/d/dc44e39f-7fab-4cc2-8513-f6fce5c25c34/RSPG13-529rev1-Draft%20RSPG%20Opinion%20on%20LSA.pdf

	applications making use of innovative techniques for sharing spectrum • Contributing to international discussion around the future use of spectrum bands on a shared basis
Issues potentially relevant over the longer term	• Considering prospects for cognitive technologies and implications for spectrum management

Question 9: Do you agree that spectrum sharing should feature as a priority area in our work programme for the next ten years? Have we captured all the major issues that we should consider within this area?

Equipment standards and RF performance of transmitters and receivers

6.77 Trends towards an increasing scale and frequency with which spectrum may need to be re-purposed, and new forms of shared spectrum access (including more dynamic sharing) are likely to lead to greater intensity in spectrum use in future, and correspondingly a more challenging environment for co-existence between different users.

6.78 This context is likely to drive the need to optimise the performance of every component in radio systems. In particular, it is important to recognise the interdependence of transmitter and receiver equipment performance and their combined impact on spectrum use. The issues of emission performance and reception performance are often dealt with separately within the regulatory environment. This is evident in a situation like 4G coexistence with DTT for example, where 4G emission regulatory levels are covered by both NRA and ITU regulations, but transmit and receive equipment standards are managed through separate industry standards bodies. However, to determine the ability for wireless systems to co-exist and to make decisions which efficiently manage and use the radio spectrum it is crucial that both transmit and receive equipment performance is considered together and analysed as a complete system. Equally it is important that all the relevant parts of the regulatory regime work appropriately together to achieve the efficient outcome – involving Ofcom as an NRA specifying appropriate license conditions, but also through CEPT, ITU, ETSI and other standards-related organisations.

6.79 Given the timescales involved for standardisation it is important Ofcom takes a forward looking view in its engagement to ensure poor equipment performance decisions are not made now which result in sterilised opportunity to use spectrum efficiently at a future date.

6.80 As wireless communications equipment is increasingly produced and sold in globalised markets, international regulations and standardisation activities can represent the most effective factors in influencing RF equipment performance. International engagement is therefore likely to feature prominently in our potential future activities in this area.

6.81 Although new regulatory measures in both transmissions standards and receivers selectivity may increase the cost of equipment design and manufacture, the benefits

associated with new services that may be provided in contended spectrum resources, as a result of improved receiver performance could be significant.

6.82 In considering whether regulatory engagement in this area is appropriate, we will need to weigh the potential benefits that would arise from improving RF equipment performance and achieving more efficient use of spectrum, against the potential costs associated with regulatory burdens and the risks of unintended consequences.

6.83 Historically, the development of equipment standards has been led largely by industry. Although harmonised standards have the primary role of ensuring transmitter compatibility with other spectrum users, commercial interests have been successful in shifting the focus of harmonised standards to minimise the effects of interference between equipment deployed for the same use.[84]

6.84 Whilst this approach is understandable, it has resulted in situations where equipment has been standardised for harmonised spectrum bands that co-exists well with other similar equipment but creates major issues for co-existence with different types of uses. In some cases, however, better coordination between industry sectors developing equipment for use in adjacent bands could have been effective in minimising co-existence issues.

6.85 We note the role of the ITU, CEPT and ETSI in determining relevant regulations for the development of European telecommunications standards and we note that out-of-band emissions and potential co-existence issues are now more prominent in the agendas of these bodies.

6.86 Recently our involvement in the standardisation activities of these bodies has been more ad hoc and limited than in the past. In future, there may be a role for us in becoming more involved in coordinating standardisation activities, particularly in relation to highly contended bands, for example, where we foresee co-existence challenges that may become problematic. It may be, however, more effective for us to engage with other national administrations within CEPT in developing mandates to the standards bodies. In this way it should be possible to ensure these mandates specifically address inter-service co-existence, as well as self co-existence, and that the standards are returned by CEPT for revision if they don't sufficiently do this.

6.87 Protecting receivers from new sources of interference can raise significant challenges and impose material costs. A relevant example is the need of implementing measures to protect DTT receivers from the risk of interference from 4G mobile services at 800 MHz. Poor selectivity of some DTT receivers, i.e. their inability to filter effectively signals from adjacent bands, has contributed to these challenges.

6.88 In the European Union, the Radio and Telecommunications Terminal Equipment Directive (R&TTE Directive) has important implications for the co-existence and performance of radio communications equipment. The Department for Business, Innovation & Skills (BIS) recently carried out a public consultation on the European Commission's proposal to replace the R&TTE Directive with a new Directive on Radio Equipment. If adopted by the European Council and Parliament the Radio Equipment Directive will be binding on the UK. Ofcom has responded to the consultation as a primary public stakeholder and expert body in this area. We note the European Commission's proposals on Radio Equipment Directive, and remain

[84] For example, work by 3GPP on mobile technology standards has placed significant emphasis on minimising the interference effects between base stations.

concerned that the proposed scope only includes equipment capable of transmitting. This would mean that many receivers could only be regulated under the EMC Directive which we do not consider to be the most effective tool.

6.89 Receivers, being unable to cause interference to other spectrum users, typically have no technical limitations placed on their use. It may therefore be necessary to consider whether an expectation amongst users of a minimum receiver performance threshold should be developed, so that the costs associated with future changes of use can be minimised and greater benefits can be obtained for society as a whole. One method of doing this could be for a reference receiver to be noted with standards, albeit non-mandatory.

Table 12 - potential work programme in support of our proposed equipments standards and performance priority area

Issues that Ofcom is already considering	• Contributing to the R&TTE Directive revision process • Monitoring activities by European and other International standardisation bodies
Issues that are likely to become relevant over the next 3-5 years	• Considering the case for more active regulatory involvement on standardisation activities
Issues potentially relevant over the longer term	• Prospects for cognitive spectrum access and potential easing of interference management

Question 10: Do you agree that, in future, we should consider whether and how to play a greater role in supporting improvements to the performance of RF transmitters and receivers? What are your views on the potential future role for regulation in this area?

Question 11: Are there other issues or potential future challenges that you consider should feature as a priority in our work programme for the next ten years? Please provide evidence in support of your views wherever possible

Section 7

Improving how we monitor spectrum use

7.1 In this Section we discuss metrics that we could use to continue 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 that our future spectrum management initiatives have over time.
- Measurements on how spectrum is used can also be an important source to inform future spectrum management initiatives.

We propose to track a set of key metrics to monitor the effects of our spectrum management strategy

7.2 In Section 2 we present a set of indicative results for a *UK spectrum map*. This is based on a review of all spectrum bands between 87.5 MHz and 80 GHz aimed at developing a set of quantitative measures[85]. We refer to these as *spectrum attribution metrics.* They illustrate the proportions of weighted spectrum falling under different categories related to the nature of spectrum access.

7.3 The metrics discussed in Table 2 and illustrated in Figure 3 and Figure 4 are defined according to how access to spectrum is authorised and who is responsible for its management, i.e. whether it is:

- available for market access, or used by Crown bodies;
- band-managed by Ofcom or managed by licensees holding rights to the use of blocks of spectrum; or
- uncoordinated and available for licence-exempt devices.

7.4 Other relevant features of spectrum access can also be tracked through similar exercises, looking across these categories. For example, in Sections 2 and 4 we highlight trading and liberalisation as important features of a market-led approach to spectrum and discuss how our past initiatives have extended tradability and sought to minimise constraints imposed on spectrum users. In other parts of this document we discuss the potential benefits associated with international harmonisation of spectrum, as well as the developments that are likely to make shared spectrum access a feasible solution for an increased number of uses and spectrum bands in future.

7.5 We believe that tracking these, and potentially other, quantitative indicators related to the nature of spectrum access could be useful in future to represent the effects that our strategic approach to spectrum management has, in aggregate, on future changes to how spectrum is used.

[85] See footnote 16 for a brief discussion of our methodology.

7.6 In Table 13 below we outline a potential set of such metrics, and our expectations as to how they might change over the coming years in connection to initiatives related to our spectrum management strategy.

Table 13 - Potential future spectrum attribution metrics

Spectrum attribution metrics	How might this metric change in future?
Market access vs Public Sector access to spectrum	The Public Sector Spectrum Release programme could decrease the proportion of Public Sector access in future.
Ofcom band-managed vs Block-assigned spectrum	The quantity of Block-assigned spectrum could increase in future as a result of potential releases from Ofcom band-managed and Public Sector spectrum (through PSSR).
Spectrum available for Licence-exempt (LE) uses	TVWS implementation, any future initiatives to enable shared access on a licence-exempt basis, and the potential expansion of the 5GHz WiFi band could cause this indicator to increase in future.
Tradable spectrum	Tradability has already been introduced to the vast majority of licences for which trading is relevant.
Flexibility of use (liberalisation)	Any future spectrum recycling by Ofcom will consider how best to ensure flexibility of use for new licensees is as high as practical and appropriate.
Internationally harmonised spectrum	Future international decisions at ITU and EU levels are likely to increase the number of bands harmonised for specific uses, including mobile. Any future spectrum release for those uses will take into account the implications of such harmonisation opportunities for UK citizens and consumers.
Shared spectrum	We expect new types of sharing opportunities to emerge. This may enable shared access by new uses for bands that are already shared by two or more uses (e.g. WSD in spectrum shared by DTT and PMSE) and/or increase the number of bands that are accessed on a shared basis.

Question 12: Do you consider that tracking these metrics could be a useful way to help monitor the effects that our spectrum management strategy has on the nature of spectrum access and how this changes over time? Are there any other indicators that we should be seeking to track for these purposes?

Targeted studies on spectrum utilisation could also inform future spectrum management initiatives

7.7 These spectrum attribution metrics consider how spectrum use is authorised, licensed and managed, but not whether spectrum is actually used in practice, and if so, how intensively.

7.8 In principle, sets of measurements of the intensity of spectrum use across all bands could be desirable. Simplistically, a comprehensive perspective on spectrum utilisation could inform us and current and potential new spectrum users as to whether spectrum resources are under- or over-utilised.

7.9 However, spectrum utilisation measurements would not, by themselves, tell us whether spectrum is used efficiently. This is because spectrum utilisation levels do not necessarily relate to value of spectrum use. High utilisation levels may, in some cases, indicate inefficient transmissions or low network quality. On the other hand, low utilisation levels may still indicate efficient spectrum use, depending on the nature and type of use.[86]

7.10 In addition, there could be a number of significant practical challenges associated with comprehensive measurement campaigns. The resource costs could be considerable, and we would need to assess whether these would be proportionate to the benefits they could provide.

7.11 However, more targeted measurement campaigns do have the potential to inform spectrum regulation initiatives in relation to specific bands and, when designed to answer specific questions, can be carried out in a way that is resource efficient.

7.12 This is illustrated by a recent study on the utilisation of Wi-Fi spectrum at 2.4 and 5 GHz[87] that we published alongside our spectrum sharing for mobile and wireless data consultation.[88] This study was designed to combine measures of Wi-Fi spectrum use (including a representative sample by the time of day, location at which measurements are taken, frequency and bandwidth, etc) with measures of quality (e.g. signal thresholds and network or link quality, i.e. how much of the data received is useful, application data, rather than errors or signalling traffic).

7.13 Future spectrum management initiatives that might benefit from exercises to monitor spectrum utilisation could include:

- Assessing effective levels of demand for licence-exempt spectrum: as illustrated in our Wi-Fi measurement study, whilst technical conditions for licence-exempt devices are designed to minimise interference issues between devices, a strong uptake of LE devices can lead to instances of very heavy utilisation and congestion that can impact on the quality of service experienced by users. As prospects for the proliferation of M2M applications arise, monitoring effective levels of usage of LE bands is likely to become increasingly important in future

[86] Many spectrum uses will only utilise spectrum at specific points in time and in specific locations. There are also passive spectrum uses that do not use signal transmissions at all – but are still highly valuable for scientific purposes.
[87] http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2013/key-licence-exempt-bands/
[88] http://stakeholders.ofcom.org.uk/consultations/spectrum-sharing/

- Understanding whether current sharing and coexistence arrangements could work more effectively: current arrangements for shared access to the same spectrum resources, or access to adjacent bands, are often managed through parameters defined through modelling based approaches incorporating a number of assumptions. Practical measurements based on real-world experience could inform the extent to which such assumptions may be adjusted to enable a better exploitation of scarce spectrum.

- Considering new opportunities for shared spectrum access: utilisation measurements could play a part in informing whether candidate bands for new types of sharing arrangements should be investigated further, gathering information on the extent of use in specific spectrum bands in practice. This could also play a role in cases where in future, Crown bodies might consider allowing shared access for civil uses to some of the bands they manage.

Question 13: Do you consider that targeted spectrum utilisation measurements could be useful in informing future spectrum management initiatives? What type of specific uses or bands could be the subject of future measurement studies, and why? Please provide evidence in support of your views wherever possible

Annex 1

Responding to this consultation

How to respond

A1.1 Ofcom invites written views and comments on the issues raised in this document, to be made **by 5pm on 11 December 2013**.

A1.2 Ofcom strongly prefers to receive responses using the online web form at http://stakeholders.ofcom.org.uk/consultations/spectrum-management-strategy/howtorespond/ , as this helps us to process the responses quickly and efficiently. We would also be grateful if you could assist us by completing a response cover sheet (see Annex 3), to indicate whether or not there are confidentiality issues. This response coversheet is incorporated into the online web form questionnaire.

A1.3 For larger consultation responses - particularly those with supporting charts, tables or other data - please email spectrum.management.strategy@ofcom.org.uk attaching your response in Microsoft Word format, together with a consultation response coversheet.

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

Alison Esslemont
3rd Floor
Spectrum Policy Group
Riverside House
2A Southwark Bridge Road
London SE1 9HA

A1.5 Note that we do not need a hard copy in addition to an electronic version. Ofcom will acknowledge receipt of responses if they are submitted using the online web form but not otherwise.

A1.6 It would be helpful if your response could include direct answers to the questions asked in this document, which are listed together at Annex X. It would also help if you can explain why you hold your views and how Ofcom's proposals would impact on you.

Further information

A1.7 If you want to discuss the issues and questions raised in this consultation, or need advice on the appropriate form of response, please contact Alison Esslemont on 020 7981 3147 or Marco Marini on 020 7783 4656.

Confidentiality

A1.8 We believe it is important for everyone interested in an issue to see the views expressed by consultation respondents. We will therefore usually publish all responses on our website, www.ofcom.org.uk, ideally on receipt. If you think your response should be kept confidential, can you please specify what part or whether

all of your response should be kept confidential, and specify why. Please also place such parts in a separate annex.

A1.9 If someone asks us to keep part or all of a response confidential, we will treat this request seriously and will try to respect this. But sometimes we will need to publish all responses, including those that are marked as confidential, in order to meet legal obligations.

A1.10 Please also note that copyright and all other intellectual property in responses will be assumed to be licensed to Ofcom to use. Ofcom's approach on intellectual property rights is explained further on its website at http://www.ofcom.org.uk/about/accoun/disclaimer/

Next steps

A1.11 Following the end of the consultation period, Ofcom intends to publish a statement in the first quarter of 2014.

A1.12 Please note that you can register to receive free mail Updates alerting you to the publications of relevant Ofcom documents. For more details please see: http://www.ofcom.org.uk/static/subscribe/select_list.htm

Ofcom's consultation processes

A1.13 Ofcom seeks to ensure that responding to a consultation is easy as possible. For more information please see our consultation principles in Annex 2.

A1.14 If you have any comments or suggestions on how Ofcom conducts its consultations, please call our consultation helpdesk on 020 7981 3003 or e-mail us at consult@ofcom.org.uk . We would particularly welcome thoughts on how Ofcom could more effectively seek the views of those groups or individuals, such as small businesses or particular types of residential consumers, who are less likely to give their opinions through a formal consultation.

A1.15 If you would like to discuss these issues or Ofcom's consultation processes more generally you can alternatively contact Graham Howell, Secretary to the Corporation, who is Ofcom's consultation champion:

Graham Howell
Ofcom
Riverside House
2a Southwark Bridge Road
London SE1 9HA

Tel: 020 7981 3601

Email Graham.Howell@ofcom.org.uk

Annex 2

Ofcom's consultation principles

A2.1 Ofcom has published the following seven principles that it will follow for each public written consultation:

Before the consultation

A2.2 Where possible, we will hold informal talks with people and organisations before announcing a big consultation to find out whether we are thinking in the right direction. If we do not have enough time to do this, we will hold an open meeting to explain our proposals shortly after announcing the consultation.

During the consultation

A2.3 We will be clear about who we are consulting, why, on what questions and for how long.

A2.4 We will make the consultation document as short and simple as possible with a summary of no more than two pages. We will try to make it as easy as possible to give us a written response. If the consultation is complicated, we may provide a shortened Plain English Guide for smaller organisations or individuals who would otherwise not be able to spare the time to share their views.

A2.5 We will consult for up to 10 weeks depending on the potential impact of our proposals.

A2.6 A person within Ofcom will be in charge of making sure we follow our own guidelines and reach out to the largest number of people and organisations interested in the outcome of our decisions. Ofcom's 'Consultation Champion' will also be the main person to contact with views on the way we run our consultations.

A2.7 If we are not able to follow one of these principles, we will explain why.

After the consultation

A2.8 We think it is important for everyone interested in an issue to see the views of others during a consultation. We would usually publish all the responses we have received on our website. In our statement, we will give reasons for our decisions and will give an account of how the views of those concerned helped shape those decisions.

Annex 3

Consultation response cover sheet

A3.1 In the interests of transparency and good regulatory practice, we will publish all consultation responses in full on our website, www.ofcom.org.uk.

A3.2 We have produced a coversheet for responses (see below) and would be very grateful if you could send one with your response (this is incorporated into the online web form if you respond in this way). This will speed up our processing of responses, and help to maintain confidentiality where appropriate.

A3.3 The quality of consultation can be enhanced by publishing responses before the consultation period closes. In particular, this can help those individuals and organisations with limited resources or familiarity with the issues to respond in a more informed way. Therefore Ofcom would encourage respondents to complete their coversheet in a way that allows Ofcom to publish their responses upon receipt, rather than waiting until the consultation period has ended.

A3.4 We strongly prefer to receive responses via the online web form which incorporates the coversheet. If you are responding via email, post or fax you can download an electronic copy of this coversheet in Word or RTF format from the 'Consultations' section of our website at www.ofcom.org.uk/consult/.

A3.5 Please put any parts of your response you consider should be kept confidential in a separate annex to your response and include your reasons why this part of your response should not be published. This can include information such as your personal background and experience. If you want your name, address, other contact details, or job title to remain confidential, please provide them in your cover sheet only, so that we don't have to edit your response.

Cover sheet for response to an Ofcom consultation

BASIC DETAILS

Consultation title:

To (Ofcom contact):

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

CONFIDENTIALITY

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

Nothing ☐ Name/contact details/job title ☐

Whole response ☐ Organisation ☐

Part of the response ☐ If there is no separate annex, which parts?

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

DECLARATION

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

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

Name Signed (if hard copy)

Annex 4

Consultation question

Question 1: Have we captured all the major trends that are likely to impact spectrum use over the next ten years in this section and the separate Appendix on sectoral developments? Are there other market, technology or international developments that could lead to significant changes in spectrum demand and supply over the next 10 years?

Question 2: Do you have any comments on this summary of our approach to spectrum management and on the principles discussed in Annex 5?

Question 3: Do you think we have adopted the right approach to analysing future trends and developments that could raise the need for future regulatory action?

Question 4: What are your views on the results of our analysis of future developments summarised in this section and discussed in greater detail in the Appendix to this consultation? Please provide evidence in support of your views wherever possible

Question 5: Do you agree that a consideration of mobile and wireless data demands should feature as a priority area in our work programme for the next ten years? Have we captured all the major issues that we should consider within this area?

Question 6: Do you agree that the future of PMSE spectrum access should feature as a priority area in our work programme for the next ten years? Have we captured all the major issues that we should consider within this area?

Question 7: Do you agree that the implementation of our 700 MHz strategy and the longer term future of DTT should feature as a priority area in our work programme for the next ten years? Have we captured all the major issues that we should consider within this area?

Question 8: Do you agree that a consideration of competing demands for spectrum at 450 - 470 MHz should feature as a priority area in our work programme for the next ten years? Have we captured all the major issues that we should consider within this area?

Question 9: Do you agree that spectrum sharing should feature as a priority area in our work programme for the next ten years? Have we captured all the major issues that we should consider within this area?

Question 10: Do you agree that, in future, we should consider whether and how to play a greater role in supporting improvements to the performance of RF transmitters and receivers? What are your views on the potential future role for regulation in this area?

Question 11: Are there other issues or potential future challenges that you consider should feature as a priority in our work programme for the next ten years? Please provide evidence in support of your views wherever possible

Question 12: Do you consider that tracking these metrics could be a useful way to help monitor the effects that our spectrum management strategy has on the nature of spectrum access and how this changes over time? Are there any other indicators that we should be seeking to track for these purposes?

Question 13: Do you consider that targeted spectrum utilisation measurements could be useful in informing future spectrum management initiatives? What type of specific uses or bands could be the subject of future measurement studies, and why? Please provide evidence in support of your views wherever possible

Annex 5

Principles for our market-based approach to spectrum management

A5.1 In this annex we summarise the main policy principles that underpin our market-based approach to spectrum management, together with some qualifications to their practical implementation.

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

A5.2 An important feature of adopting market mechanisms to allocate scarce resources is the definition of rights that are to be bought and sold. We are responsible for defining the rights to use spectrum, typically through issuing individual licences. These limit the number of users who can use specific frequencies in specific geographies (and time).

A5.3 It is important that these rights are clear, unambiguous and that users can expect that they will not be changed without sound spectrum management reasons. It is also important that the rights that are defined are constrained only to the extent needed to protect others' rights, so that over time the use made of spectrum can change as more efficient uses evolve.

A5.4 We define these rights primarily through a combination of limits on the power levels (and for licensed products in the spectrum we band manage other relevant technical parameters) of individual transmitters and, in the case of large, block-assigned bands, block edge masks.[89]. However, these cannot be completely service and technology neutral in the sense that these technical conditions cannot enable any use (i.e. there will always be uses that cannot fit within the envelope defined by power level, bandwidth, etc). As such, there is a limit to the flexibility that can be included in the licence conditions.

A5.5 In the absence of a mechanism to characterise spectrum rights in a truly technology and service neutral way, we rely on our stated commitment to look favourably on requests to vary the technical licence conditions where:

- doing so would not adversely impact other existing users; or
- those users that would be affected by the change have agreed to the change through separate arrangements with the party wishing to change its use.

A5.6 One of the implications of the principle of not changing rights to use spectrum without good reason is that we do not take away spectrum access rights if they are not currently actively used, even if the spectrum lies idle for some considerable time. In particular, we have not included 'use it or lose it' clauses in our licences. Such clauses could introduce uncertainty for licensees which could undermine investment incentives. There are also a number of legitimate reasons why a licensee might not be using their spectrum at any specific time without this leading

[89] Block edge masks define the extent of interference permitted into adjacent frequencies.

to inefficient use of spectrum over the longer term, e.g. in circumstances in which technology and equipment standards may need to be developed to enable the anticipated use that may subsequently increase the value of the spectrum. There may also be significant challenges to enforcement.

A5.7 In general, individuals and firms are best placed to understand the future value they can generate from spectrum under these circumstances and whether greater value is likely to be generated by the use of the spectrum today or at some point in the future. If a higher value user wishes to acquire the spectrum from the current licensee both parties have an incentive to trade. If we were concerned that the reason for retaining spectrum unused was to deter or prevent other competitors (or potential competitors) from gaining access to the spectrum then we could consider whether to take action, including under our competition powers. In many cases we also retain the ability to revoke a licence on spectrum management grounds, subject to giving appropriate notice to the licensee.

Users should be able to transfer their rights to use spectrum simply and quickly unless we have strong grounds for concerns about competition effects

A5.8 Another important feature of a market-based approach is that users and potential users of spectrum can buy and sell these rights. We will, therefore, continue to make all new licences tradable unless there are specific reasons why this is not possible or appropriate.[90] We will also continue to extend leasing to licences on request for relevant licence classes. Leasing provides a mechanism for users to permit others to use their spectrum without the need to inform us, or gain our permission.[91] Leasing also enables time-limited use of spectrum which can improve the utilisation of spectrum where a licensee does not use all of the spectrum it holds all of the time but does not wish to trade the rights permanently.

A5.9 It should be recognised, however, that spectrum is not a commodity and is not fully substitutable. Different frequencies have different physical characteristics that make them more suitable for one type of application over another. For example, lower frequencies tend to travel further, be less susceptible to rain attenuation and penetrate buildings better compared to higher frequencies. Higher frequencies may need line of sight (i.e. antennae need to be visible to each other) but provide larger bandwidths and therefore support high capacity uses.

A5.10 However, even for bands that are very close together in frequency the use that can be made of each band can be very different for a variety of reasons:

- *International constraints.* The need for certain equipment to have the same spectrum and interoperable equipment available for use in exactly the same way in all countries of the world (e.g. for services that inherently involve movement between nations such as aeronautical and maritime uses) means that some spectrum can only be used by these services.

- *International harmonisation and availability of equipment.* The existence of international harmonisation agreements can create economies of scale needed

[90] For example Amateur licences where the right to use spectrum includes a condition that the user has personal certificate of competency which cannot be transferred.
[91] The obligation to meet the technical conditions on the use of the spectrum remains with the licensee, who is responsible for the use made by the lessee.

for equipment manufacture, particularly where it is supported by technical standards. Where harmonisation exists, this and the availability of equipment, therefore, typically drives how the spectrum is used.

- *Licensing restrictions.* Restrictions are imposed on how spectrum may be used and are needed to manage the risk of interference between users. These restrictions often need to be quite onerous, particularly to avoid harmful interference between different types of use, which might have very different power levels and receiver sensitivities. Most frequency bands that are heavily contested already have incumbent users, or close neighbours, with existing licences and associated conditions. Spectrum bands, which in other respects have very similar properties, might therefore have very different conditions attached in order to protect adjacent users. This constrains the potential uses of the spectrum.

A5.11 For the majority of licences we place no restrictions on how spectrum is traded and to whom it is traded.

A5.12 For example, trades can be full or partial, are unconstrained by geography, frequency or time, and can be concurrent trades (i.e. the rights and obligations become held by both parties).

A5.13 However, for some licences, where we have good grounds to believe trading could have a material impact on competition in downstream markets, we may include a specific competition assessment clause. This clause enables us to hold off processing a request to trade until we have carried out a competition assessment, if we deem necessary. It also enables us to withhold permission to trade based on the outcome of this competition assessment. We have so far only applied this condition to a small number of licences used to provide mobile services.

Users should be incentivised to use spectrum efficiently through spectrum pricing based on the opportunity cost their use imposes on others

A5.14 Administered Incentive Pricing (AIP) is a form of spectrum pricing that acts as a proxy for market prices for scarce spectrum that has typically been assigned administratively.[92] It promotes efficient use by ensuring that users consider the opportunity cost[93] imposed on society by their use and therefore take this into account in their business and investment decisions, just as they do for other resources that they employ, and so have incentives to use it efficiently in the provision of downstream services.

A5.15 Where licences have been made tradable, licensees should face the opportunity cost of their use in the form of the value that they could realise through the sale of the licence. AIP is used primarily for spectrum bands which are made available by Ofcom under one of our standard licence products or for larger blocks of spectrum that have been assigned by an award process other than an auction.

A5.16 For spectrum that has been assigned by auction, we do not charge spectrum fees for the initial term. At the end of this initial term, usually between 15 to 20 years, it is

[92] That is, in general, assigned on a 'first come first served' basis or by comparative selection ('beauty contest').
[93] Opportunity cost is the value of alternative spectrum use forgone by society due to the current spectrum use.

probable that the circumstances that existed when the spectrum was auctioned will have changed. As such, the current holder may not remain the most efficient user – or have the incentives to continue using the spectrum in the most efficient way. Making the licences tradable should, in principle, result in the rights holder reflecting the opportunity cost of the spectrum use in their usage decisions. However, there may be a number of reasons in practice why this might not be so, as we set out in our *Strategic Review of Spectrum Pricing*,[94] and AIP can still be a useful tool in promoting efficient use in these cases. Trading can, of course, still take place when spectrum charges apply to the licence being traded.

In general auctions are the best method of making the initial assignment of blocks of spectrum

A5.17 In general, a well-designed auction is the best way of assigning spectrum access rights that enable use of a block of spectrum primarily for dedicated use.[95] This is because the successful bidders in an auction are likely to be those that can generate most value though its subsequent use and so support the objective of securing efficient spectrum use.

A5.18 In certain circumstances, auctions can also be an effective way to ensure the most efficient provider is awarded spectrum for the delivery of specific public policy objectives, e.g. where we include coverage obligations in a licence.

Spectrum should be released as soon as possible

A5.19 In most cases, the release of spectrum as soon as possible will enable the benefits of its use to be generated quickly and can also stimulate innovation and promote the identification of harmonised use(s) of the spectrum more quickly. However, in certain cases where harmonisation work is underway, or is in prospect, it might be prudent to delay the release of spectrum until it is clear what the outcome of the potential harmonisation is likely to be. This is because to ensure an efficient outcome of an auction it is important that participants are armed with sufficient information to have a clear understanding of their own likely future value and that all potential users of the spectrum take part. Given the impact harmonisation measures can have on the value derived from spectrum use, therefore, there may be some potential users of the spectrum who may believe they have insufficient information to take part.

A5.20 In addition, given the significant resource costs and time often required to release spectrum bands we also have to prioritise our resources in a way that may defer the release of some unused, or under-used, spectrum that is of lower value.

[94] http://stakeholders.ofcom.org.uk/consultations/srsp/statement

[95] This is where a single or small number of users hold the rights to use all of the frequencies across a specific frequency band across a wide geography (most usually UK-wide) and manage the individual technical assignments necessary to co-ordinate their own use of the spectrum.