Appendix to spectrum management strategy

Future developments in major spectrum uses

Appendix to Consultation

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Contents

Section 1

Overview

A1.1 This Appendix to the *Spectrum Management Strategy: Ofcom's approach to and priorities for spectrum management over the next ten years*[1] sets out our perspective on potential future developments for major uses of spectrum in the UK. We refer to the sub-sections of this Appendix as 'sector roadmaps'. These roadmaps inform our preliminary assessments of potential future developments in major uses of spectrum, and our proposals for future priority areas, in Sections 5 and 6 of the *Spectrum Management Strategy*. This Appendix contains more detailed analysis of sector-specific developments and is therefore being published as a separate document.

A1.2 Below we consider the following twelve major uses of spectrum:

- Wireless and Mobile Broadband;
- Digital Terrestrial Television;
- Licence-Exempt and Short-Range Devices;
- Programme Making and Special Events;
- Emergency Services Communications;
- Business Radio;
- Utilities;
- Space;
- Fixed Wireless Service – Fixed Links;
- Radio Broadcasting;
- Aeronautical and Maritime Communications; and
- Amateur Radio.

A1.3 This list is non-exhaustive and there are also some overlaps between the topics discussed in some sectors. Most notably the wireless broadband section includes discussion of indoor use and backhaul services, which overlaps significantly with the sections on licence-exempt use and short-range devices, and the fixed wireless service, respectively. The roadmaps examine future requirements at a sub-class level where necessary, given significant variations in requirements within the same categories (e.g. Emergency Services Communications is divided into broadband applications and critical voice applications, as shown in Figure 1).

A1.4 The roadmaps are each divided into four sections:

- introduction;

[1] See: http://stakeholders.ofcom.org.uk/consultations/spectrum-management-strategy.

- potential sectoral challenges;
- potential mitigations; and
- international factors.

A1.5 **Introduction.** The introductions set out the key characteristics of each sector including, where appropriate, indicative illustrations of the bands currently used in the UK, quantitative estimates of their private value and qualitative descriptions of their wider social value. We have not sought to come to a definitive view on the value generated by each sector, and we cite a range of third-party estimates where possible in order to give a sense of the potential significance of future changes in spectrum use by that sector. We have restricted our consideration to two main sources for these estimates, in order to ensure methodological consistency and to allow for high-level comparisons between sectors.[2]

A1.6 **Potential sectoral challenges.** The next section considers the likely development of future trends potentially affecting the demand for spectrum from the sector over the next ten years and beyond. These are examined alongside any potential changes in spectrum supply over the same period. The roadmaps consider these developments together, in order to assess the likelihood of what we call 'sectoral challenges' emerging in the short, medium and longer term.

- *Demand trends.* The changing spectrum requirements of a sector could be driven by increasing demand from end users, a downstream sector, or the public sector.
- *Potential changes in supply.* Potential changes in the supply of spectrum to a sector could emerge from decisions to re-purpose spectrum at a national level, or international allocations and harmonisation measures. Changes in supply could also emerge from the re-purposing of spectrum used by Crown bodies as part of the Government's plans for the release of public sector spectrum.
- *Significance of changing spectrum requirements and potential urgency of enabling action by Ofcom.* The roadmaps identify the sectoral challenges which may emerge from these demand trends and potential changes in supply. We assess the potential significance of changing spectrum requirements in each sector, in terms of the impact that these might have on citizens and consumers. We also set out initial views on the extent to which action by us may be required to support optimal spectrum use, and the potential urgency of any such enabling action.

A1.7 **Potential mitigations.** The roadmaps also consider mitigation action that could be taken by licensees and the industry to address these changing spectrum requirements and the extent to which Ofcom can, and should, look to influence or facilitate this. Potential mitigations are described in four broad categories:

[2] *Impact of Radio Spectrum on the UK Economy and Factors Influencing Future Spectrum Demand*, Analysys Mason, November 2012, https://www.gov.uk/government/publications/impact-of-radio-spectrum-on-the-uk-economy-and-factors-influencing-future-spectrum-demand; and *Valuing the use of spectrum in the EU: an independent assessment for the GSMA*, Plum Consulting, 2013, http://plumconsulting.co.uk/pdfs/Plum_June2013_Economic_Value_of_spectrum_use_in_Europe.pdf.

- *Technology and receiver standards.* The potential development of improved network designs, transmitter and receiver technologies and standards that enable more technically efficient use of spectrum;

- *Implementation and coordination of spectrum usage*. The potential for users to improve the efficiency of their use of spectrum, given their existing use of technology, the spectrum made available for the use and the licensing regime;

- *Spectrum re-purposing*. Opportunities for recycling of spectrum from an alternative use, whether market-led or regulator-led; and

- *Spectrum sharing*. Opportunities to for sharing with other uses in ways that do not materially affect the rights of incumbent users.

These mitigations will have different degrees of relevance to different sectors.

A1.8 **International factors.** This section addresses the key international factors that could be relevant to future sectoral developments and, in particular, could influence the applicability of the potential mitigation action described above.

A1.9 The amateur radio section, however, does not follow this structure, as 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 we have provided a high-level discussion of the use of spectrum by the sector and of its specific requirements.

A1.10 Figure 1 below summarises the results of the analysis undertaken in the roadmaps, to facilitate comparisons between sectors at a high level and to assist us in defining the priority areas on which we will need to focus our action in the short, medium and longer term.

Figure 1: Summary of sector roadmaps

Spectrum uses		Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Wireless Broadband	*Coverage*	R	A	✓	✓✓	✓✓	✓	◕
	Capacity	R	R	✓✓	✓✓✓	✓✓✓	✓✓	◕
	Indoor	A	R	✓✓	✓✓	✓✓	✓✓✓	◕
	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	✓	✓	✗	✗	◕
Amateur Radio		*Our analysis of the amateur radio sector is a high-level discussion which does not fit into the structure of this table, as 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.*						

Significance and urgency of sectoral trends

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

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

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

Relevance of strategic levers

✓✓✓ = very high relevance

✓ = moderate relevance

✗ = no relevance

International factors

◕ = more important

◔ = less important

Section 2

Wireless and Mobile Broadband

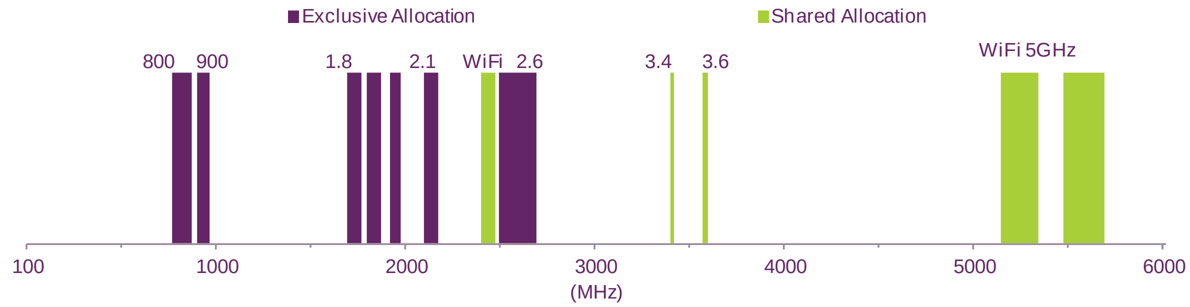
Introduction

Spectrum uses		Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Wireless Broadband	*Coverage*	R	A	✓	✓✓	✓✓	✓	◕
	Capacity	R	R	✓✓	✓✓✓	✓✓✓	✓✓	◕
	Indoor	A	R	✓✓	✓✓	✓✓	✓✓✓	◕
	Backhaul	G	G	✓	✓✓	✓	✓✓	◑

A2.1 For the purposes of this Appendix, we define wireless broadband services as those delivered through cellular mobile networks (e.g. through 3G, LTE[3] and LTE-A[4] technologies), as well as fixed broadband extensions through Wi-Fi, as these are increasingly used by mobile data users to 'offload' traffic generated by handheld devices onto fixed networks.

A2.2 In the UK, spectrum for cellular-based mobile networks is used on a dedicated basis by Mobile Network Operators (MNOs). In contrast, Wi-Fi bands are used on a licence-exempt basis, and shared amongst an unlimited number of users. Figure 2 below gives an indicative illustration of bands currently used for the provision of wireless broadband in the UK, including a breakdown by exclusive use and shared use.

Figure 2: Indicative illustration of bands currently used by the sector in the UK



A2.3 The use of spectrum to provide wireless broadband generates very high private value. In a report for the Department of Business, Innovation and Skills (BIS) and the Department of Culture, Media and Sport (DCMS), Analysys Mason estimates that cellular mobile had a consumer surplus of £24-28bn and a producer surplus of almost £6bn in 2011.[5] In 2006, Europe Economics estimated a total consumer surplus of £19.0 billion from the consumption of mobile services in the UK (by both

[3] Long-Term Evolution.
[4] LTE-Advanced.
[5] *Impact of Radio Spectrum on the UK Economy and Factors Influencing Future Spectrum Demand*, Analysys Mason, November 2012, https://www.gov.uk/government/publications/impact-of-radio-spectrum-on-the-uk-economy-and-factors-influencing-future-spectrum-demand.

private and business consumers).[6] The sector also contributes wider social value, in terms of the benefits to citizens of social inclusion and the increased availability of services, particularly in rural areas (e.g. via the coverage obligations that we set out as conditions of buying one lot of the spectrum auctioned in 2012). It may also have a future role in supporting informed democracy, e.g. as part of the communications between political parties and the electorate, or potentially in aiding voter registration, locating nearby polling stations, etc.[7]

A2.4 Another key characteristic of this sector is that international decisions have a strong influence, chiefly because global harmonisation is crucial to providing the economies of scale needed for handset and chip-set manufacturers in this sector. Common bands provide the additional benefit of enabling devices to roam between countries.

A2.5 Growth in demand for wireless data and the benefits this provides to consumers are likely to be the main drivers of change in spectrum use over the next ten years. This is discussed at greater length below, in relation to four key areas of the wireless broadband sector: coverage, capacity, indoor use and backhaul requirements. This Appendix also considers licence-exempt use as a whole, including Wi-Fi, in a separate section. The section on the fixed wireless service also covers mobile backhaul in greater detail.

Potential sectoral challenges

Spectrum uses		Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Wireless Broadband	*Coverage*	R	A	✓	✓✓	✓✓	✓	◕
	Capacity	R	R	✓✓	✓✓✓	✓✓✓	✓✓	◕
	Indoor	A	R	✓✓	✓✓	✓✓	✓✓✓	◕
	Backhaul	G	G	✓	✓✓	✓	✓✓	◑

Demand trends

A2.6 **Coverage.** The drivers of demand for spectrum to increase wireless broadband networks' coverage are likely to be associated with public policy objectives on rural broadband availability and mobile coverage. The commercial incentives to extend provision of mobile coverage and rural broadband availability are likely to remain limited by the challenging economics associated with network rollouts in areas with low population densities. The propagation characteristics of low frequency spectrum may however prove favourable to meeting public policy requirements to reach dispersed populations living in areas with challenging topography. However, the use of additional low frequency spectrum is not the only tool for extending coverage of mobile networks, nor is the use of mobile networks the only option for extending the coverage of rural broadband. In this context, in future, we may need to continue to focus on the capacity provided by wireless broadband networks within the context of the coverage they provide. For example, the coverage obligation included in one of the lots of the recent award of 800 MHz spectrum requires a speed of up to 2 Mbit/s. In future providing high-capacity mobile services to consumers may become

[6] *Economic Impact of the Use of Radio Spectrum in the UK*, Europe Economics, November 2006, http://stakeholders.ofcom.org.uk/binaries/research/spectrum-research/economic_impact.pdf.
[7] *Mobile Citizens, Mobile Consumers: Adapting regulation for a mobile, wireless world*, Ofcom, August 2008, http://stakeholders.ofcom.org.uk/binaries/consultations/msa08/summary/msa.pdf.

important as increasingly such services are seen by citizens and consumers as essential services.

A2.7 **Capacity.** The most significant factors in terms of capacity are the growth of demand for mobile data from end users, driven by the related trends of increasing adoption of data-enabled devices, and increasing usage of data-hungry applications. Our consumer research shows that, between Q1 2012 and Q1 2013, smartphone adoption grew from 39% to 51% of UK adults, and tablet adoption from 11% to 24%.[8] These trends are expected to continue over the long term, with the vast majority of mobile phones becoming smartphones, and multiple device ownership also common. The increasing sophistication of devices will mean that they support more data-hungry applications. Video traffic in particular is predicted to grow significantly (Cisco forecasts that two thirds of total global mobile data traffic will be video by 2017).[9] The combination of trends such as these looks likely to impact significantly on demand for wireless broadband capacity over the long term. Real Wireless developed a mid-range scenario which shows mobile data traffic could potentially grow to eighty times its current size by 2030.[10] An additional, but probably smaller increasing requirement could be associated with the growth in machine-to-machine (M2M) communications over the medium to long term. This is unlikely to place significant pressure on capacity, but could pose challenges to authentification systems, where millions of devices connect to the same network.

A2.8 **Indoor.** A significant proportion of the traffic generated by mobile devices is consumed inside a building or vehicle at present. The level of indoor use seems likely to rise, driven by trends such as the static use of data-enabled devices and increasing video traffic. The spectrum implications of this use will depend on the extent to which offloading mobile data from cellular networks onto fixed lines (e.g. via Wi-Fi) will meet mobile devices' data capacity requirements in future. Our current expectation is that both licensed and licence-exempt use of spectrum will contribute to meeting indoor demand in future.

A2.9 **Backhaul.** The more extensive use of fibre in terrestrial fixed networks is unlikely to substitute for mobile backhaul delivered over wireless fixed links, but rather act as a complement (see section on the fixed wireless service). New rural broadband macrocell deployments may also give rise to increasing backhaul requirements on a localised basis. As the deployment of small cells increases to meet growing capacity requirements in urban areas where there is dense usage, backhaul links are likely to be required in more locations, and the use of fixed wireless links may be preferable to MNOs. However, the impact of the rollout of fibre, increased opportunities for sharing, and the migration of fixed links to higher frequencies is expected to mitigate any increase in the spectrum requirements for mobile backhaul.

Potential changes in supply

A2.10 World Radio Conference 2015 (WRC-15) Agenda Item 1.1 (AI 1.1) will consider additional allocations to the mobile service and identifications for International

[8] *Communications Market Report 2013*, Ofcom, August 2013, http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr13/2013_UK_CMR.pdf.
[9] *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2012–2017*, Cisco, February 2013, http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf.
[10] *Techniques for Increasing the Capacity of Wireless Broadband Networks: UK, 2012–2030*, Real Wireless, April 2012, http://www.ofcom.org.uk/static/uhf/real-wireless-report.pdf.

Mobile Telecommunications (IMT). Although changes in spectrum use do not automatically follow from such allocations, the likelihood of internationally driven changes in supply coming out of this process is high and could have a significant impact over the following years. WRC-15 will also consider whether to allocate additional spectrum which could be used for Wi-Fi around 5 GHz. Future WRCs are likely to revisit these issues at regular intervals. In Europe, the Radio Spectrum Policy Programme (RSPP) also has a target to identify 1200 MHz for wireless broadband by 2015.

A2.11 Table 1 below sets out the state of play for spectrum bands that are likely to feature in forthcoming international discussions of wireless broadband.

Table 1: Spectrum bands likely to feature in future international discussions on wireless and mobile 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	
5350-5470 MHz/5725-5925 MHz	Yes	Yes	

A2.12 There is also currently technical standardisation work underway to define a variant of LTE for use in the 450 – 470 MHz band, and we understand some national administrations view the use of LTE, in this band, as a useful option to extend the reach of wireless broadband. However, it is currently unclear what level of international support there will be for enabling ES use of the 450 MHz band and specifically there is no consensus on the repurposing of this band for public wireless broadband use in Europe. In the UK there are, also, specific and major implications on incumbent users that would need careful consideration before such a change of use could be considered. (See section below on business radio for greater detail of these challenges.)

A2.13 Within the UK, the Public Sector Spectrum Release (PSSR) programme is expected to provide an important source of additional spectrum for commercial uses, including wireless broadband. Government has set a target of releasing 500 MHz of spectrum into civil use by 2020. As part of this, the Ministry of Defence (MoD) is planning to release 40 MHz of spectrum at 2.3 GHz and 150 MHz at 3.4 GHz to Ofcom for auction in the short term.[11]

Significance of changing spectrum requirements and potential urgency of enabling action by Ofcom

A2.14 **Coverage.** Public policy objectives for the widespread availability of services, particularly in relation to rural broadband and mobile coverage, might contribute, in future, to rationales for increasing the availability of low frequency spectrum for mobile broadband services. However, we expect that over the short to medium term mobile broadband coverage will increase as a result of the effects of the 4G coverage obligation (and the competitive pressure this has provided on other MNOs) and mobile infrastructure sharing arrangements. We also note that the potential future re-purposing of spectrum at 700 MHz could contribute to extending the coverage of high-capacity mobile services in hard-to-reach areas, for example, through the imposition of a coverage obligation. We will, however, need to be mindful of the costs that such additional coverage requirements would impose on network operators as well as the potential benefits to consumers and citizens. We also note that some national administrations are considering the potential use of 450-470 MHz for LTE (see section on business radio below).

A2.15 **Capacity.** There are likely to be potential benefits to making more spectrum available to increase capacity in the future. Decisions at WRC-15 on possible allocations to the mobile service and long lead times for changes in spectrum use mean that developing a strategy to address this issue is relatively urgent.

A2.16 **Indoor.** It is likely that indoor consumption of wireless data will increase substantially over the medium term, driven by adoption of connected devices including smartphones and tablets. However, the potential expansion of the 5 GHz Wi-Fi band may mitigate possible future contention in Wi-Fi bands. As above, decisions at WRC-15 on possible allocations to the mobile service and long lead times for changes in spectrum use imply a relatively high level of urgency for enabling action by Ofcom.

A2.17 **Backhaul.** The rising demand for mobile backhaul capacity is likely to be addressed through use of fibre backhaul links and migration of fixed wireless links to higher frequencies, enabling increased capacity and reducing congestion in the lower bands. Additional requirements, especially for non-line-of-sight backhaul, could potentially be addressed by new spectrum sharing arrangements.

A2.18 The questions related to capacity are the most urgent and have the greatest potential significance. However, we will need to conduct early investigation in each of these key areas, which are of course connected considerations.

[11] See: http://stakeholders.ofcom.org.uk/spectrum/public-sector-spectrum-release/?utm_source=updates&utm_medium=email&utm_campaign=mod-spectrum-release.

Potential mitigations

Spectrum uses		Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Wireless Broadband	*Coverage*	R	A	✓	✓✓	✓✓	✓	◕
	Capacity	R	R	✓✓	✓✓✓	✓✓✓	✓✓	◕
	Indoor	A	R	✓✓	✓✓	✓✓	✓✓✓	◕
	Backhaul	G	G	✓	✓✓	✓	✓✓	◑

Technology and receiver standards

A2.19 The most potentially significant technological developments for increasing capacity in the wireless broadband sector are ongoing improvements of network technologies such as LTE, LTE-A and future ‘5G’ technologies. The transition to improved technologies such as LTE can support capacity enhancements. Real Wireless estimates that these improvements could provide between three and ten times more mobile broadband capacity between 2012 and 2030.[12]

A2.20 Our service and technology neutral policy has facilitated the deployment of new transmission technologies, and we expect it will continue to do so as they emerge. All public wireless network licences now permit the use of 4G technology. In future, we expect that the implementation of these solutions will be led primarily by industry although we note that they will be heavily influenced by international trends in equipment standards. Action by Ofcom can have a positive impact on the future efficient deployment and use of new mobile technologies, primarily through our technology neutral policy on licence conditions.

Implementation and coordination of spectrum use

A2.21 The deployment by operators of additional macrocell sites would help improve coverage. There are however practical difficulties with the economic viability of extending coverage beyond certain limits because of the costs involved.

A2.22 The deployment of small cells is more likely to play a key role in increasing capacity in densely populated urban areas and supporting indoor use. By splitting the coverage of existing sites into smaller cells the number of mobile users sharing the capacity provided by each mobile transmitter is reduced, creating an effective increase in mobile capacity available to each user. Whilst small cells provide some cost advantages over macrocells, there are similar barriers, such as site identification, as well as additional requirements for backhaul. Action by Ofcom might facilitate opportunities for additional spectrum access (shared or dedicated) for small cells.

A2.23 Offloading is likely to be an important means of meeting the requirements for growing indoor use. Wi-Fi and femtocells can be used to route indoor traffic onto fixed networks. The extent to which this can substitute for mobile network capacity is uncertain in the short term, but longer-term developments could enable Wi-Fi to seamlessly integrate with mobile networks. We support co-existence studies to determine whether extensions to Wi-Fi bands are desirable.

[12] *Techniques for Increasing the Capacity of Wireless Broadband Networks: UK, 2012–2030*, Real Wireless, April 2012, http://www.ofcom.org.uk/static/uhf/real-wireless-report.pdf.

Spectrum re-purposing

A2.24 It is expected that further spectrum will be allocated for mobile use at WRC-15. It is also anticipated that additional spectrum will be made available through the PSSR programme. It will, however, be necessary to weigh up the benefits of more spectrum for mobile use against the impact such re-purposing may have on other uses of spectrum. It will also be necessary to work proactively in international institutions to ensure international harmonisation is agreed in bands of most value for the UK, and also to provide advice and support to Government to enable it to focus on the bands of most value to society when releasing spectrum in its PSSR programme.

Spectrum sharing

A2.25 The pressure on capacity might be addressed in part through greater spectrum sharing, for example using geo-location access to locally underutilised bands for small cells and backhaul, and the development of TV White Spaces (TVWS). TVWS could enable long-range Wi-Fi-like services, to support indoor offloading, or deliver wide-area broadband. So far we have taken a lead on geo-location, while retaining a focus on protecting incumbent services, with scope for improvements in receiver standards.

A2.26 As part of PSSR, there is also the expectation of increased sharing of Crown spectrum with commercial users.

International factors

Spectrum uses		Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Wireless Broadband	*Coverage*	R	A	✓	✓✓	✓✓	✓	◕
	Capacity	R	R	✓✓	✓✓✓	✓✓✓	✓✓	◕
	Indoor	A	R	✓✓	✓✓	✓✓	✓✓✓	◕
	Backhaul	G	G	✓	✓✓	✓	✓✓	◑

A2.27 International harmonisation of spectrum used for mobile networks will remain central, given its role in facilitating economies of scale in the production of mobile components and devices, as well as the support of consumer benefits from international roaming. As such the importance of international factors in determining the use of spectrum for wireless broadband services cannot be overestimated.

A2.28 Of particular importance in this sector over the short to medium term will be discussions at WRC-15 on AI 1.1 and the RSPP target to identify 1200 MHz for wireless broadband by 2015. The role of European institutions in determining future use of spectrum for wireless broadband could also increase over the longer term.

Section 3

Digital Terrestrial Television

Introduction

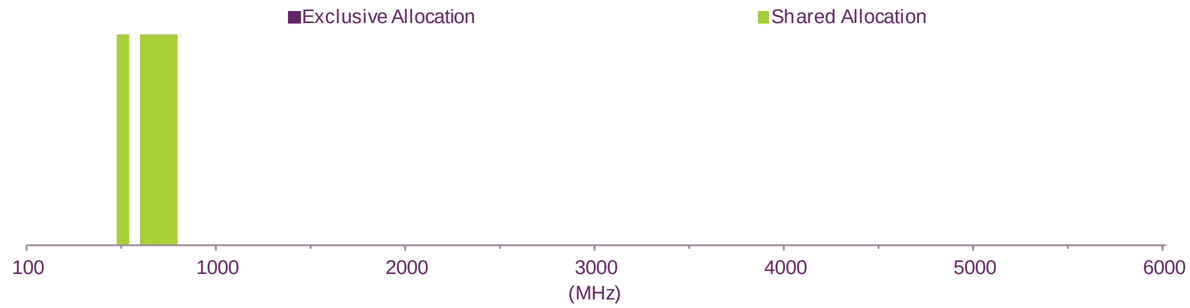
Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
TV Broadcasting – DTT	A	A	✓✓✓	✓✓	✓✓	✓	◕

A3.1 Digital terrestrial television (DTT) is an important means by which many UK TV households receive TV services, providing low-cost, near-universal access to free-to-air (FTA) TV broadcasting. In particular, it is a key platform for delivering public service broadcasting (PSB). Thus DTT delivers important benefits for UK citizens and consumers. We also have specific duties in relation to PSB that we need to consider when making policy decisions on their use of spectrum.

A3.2 The very high power nature of DTT transmissions requires substantial detailed technical planning and coordination with neighbouring administrations and so is managed through European agreements that can take many years to negotiate.

A3.3 Figure 3 below gives an indicative illustration of bands currently used for the provision of DTT. DTT accesses a frequency range of 256 MHz,[13] though other services access frequencies that remain locally unused by DTT (known as 'white space') on a secondary basis, including PMSE[14] uses.

Figure 3: Indicative illustration of bands currently used by the sector in the UK



A3.4 DTT provides substantial private and wider social value. Analysys Mason estimates that the consumer surplus of DTT in 2011 was between £4.2 and £5.3bn and that the producer surplus was £454m.[15] In a report for the GSM Association, Plum Consulting estimated the consumer surplus of DTT in the UK to be £3.6 billion.[16]

[13] This excludes the award of 550-606 MHz to Arqiva for the establishment of temporary DTT multiplexes. This licence will run until 2026, but with a minimum duration to 31 December 2018, subject to revocation on 24 months' notice.
[14] Programme Making and Special Events.
[15] *Impact of Radio Spectrum on the UK Economy and Factors Influencing Future Spectrum Demand*, Analysys Mason, November 2012, https://www.gov.uk/government/publications/impact-of-radio-spectrum-on-the-uk-economy-and-factors-influencing-future-spectrum-demand.
[16] *Valuing the use of spectrum in the EU: an independent assessment for the GSMA*, Plum Consulting, 2013, http://plumconsulting.co.uk/pdfs/Plum_June2013_Economic_Value_of_spectrum_use_in_Europe.pdf.

DTT also delivers significant wider social value as a means of delivering FTA PSB and, through this, contributing to the PSB objectives of informing and improving our understanding of the world, reflecting our cultural identity and stimulating our cultural interests.

Potential sectoral challenges

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
TV Broadcasting – DTT	A	A	✓✓✓	✓✓	✓✓	✓	◕

Demand trends

A3.5 Linear television viewing has remained relatively stable in recent years while growth in the average time spent watching time-shifted viewing has slowed.[17] This suggests that linear TV is likely to remain an important means by which audiences will watch TV.

A3.6 In future, television platforms are likely to make more use of high definition (HD) broadcasting. This is likely to influence capacity requirements for DTT, as well as other TV distribution platforms. HD channels require more bandwidth than standard definition (SD) services and may therefore increase the spectrum requirements of DTT. However, DVB-T2[18] and MPEG-4[19] standards could improve the spectral efficiency of DTT broadcasting.

A3.7 Some broadcasters and content distributors are developing ultra high definition (UHD) TV propositions, which offer a picture standard of at least four times the spatial resolution of existing HD services and make possible increased frame rates for enhanced motion portrayal. These technologies are unlikely to penetrate the market on a great scale in the short term. However, for a given source encoding standard, UHD is likely to require at least four times more bandwidth than HD. While new, more efficient codec standards like HEVC[20] can mitigate the additional bandwidth requirements of UHD, the technical and commercial viability of UHD broadcasting on DTT is likely to be uncertain for the foreseeable future.

A3.8 Over recent years consumers have grown used to watching video on demand (VoD) services using their internet connections. The recent widespread implementation of more efficient IP[21] distribution technologies (including multicasting) and improvements in broadband connection speeds have enabled the widespread distribution of linear TV channels as well as VoD, both ‘over the top’ (OTT), or through ‘managed’ services completely controlled by Internet Service Providers (ISPs).

A3.9 As domestic broadband connections become faster and more consumers take up superfast broadband, internet protocol television (IPTV) is likely to become an increasingly important distribution platform in the UK. However, it is unclear whether IPTV could deliver near-universal availability for FTA linear TV, as DTT does. In

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[17] *Communications Market Report 2013*, Ofcom, August 2013, http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr13/2013_UK_CMR.pdf.
[18] Digital Video Broadcasting - Second Generation Terrestrial.
[19] Motion Picture Experts Group Layer-4 Video.
[20] High Efficiency Video Coding.
[21] Internet Protocol.

particular, the potential lack of universal availability and take-up of broadband services that are capable of sustaining the delivery of linear television suggest that IPTV is more likely to be a complement, as opposed to a substitute, for other broadcast technologies over the next decade.

Potential changes in supply

A3.10 Our *UHF*[22] *Strategy Statement* set out a possible path for DTT to migrate out of the 700 MHz band after 2018, and use spectrum from about 470 to 694 MHz.[23] This possibility is as a consequence of the proposal, to be considered at WRC-15, to harmonise the 700 MHz band globally for mobile and broadcasting uses on a co-primary basis. Further international discussions on the allocations of the bands currently used for DTT are likely to take place in the context of future WRCs. This could, over the very long term, raise the potential prospect for further changes to the frequencies used by DTT.

A3.11 Ahead of any required regional replan of DTT to clear the 700 MHz band, we have licensed two 'interim' DTT multiplexes in the 600 MHz band. The interim multiplexes will use DVB-T2 and MPEG-4 technologies to broadcast additional channels, including services in HD.

Significance of changing spectrum requirements and potential urgency of enabling action by Ofcom

A3.12 The prospect of a replan of DTT to enable clearance of the 700 MHz band and the possibility that higher definition broadcasting will become more important on all television platforms are both important challenges for the DTT sector. In Figure 1 we rank the significance and urgency of such challenges as amber, or medium. This is because, whilst these possible developments could have very significant implications, we have already initiated a wide-ranging programme of work to ensure that the implementation of our UHF strategy addresses the challenges of a future DTT spectrum replan in a way that secures the ongoing delivery of benefits associated with DTT with minimum disruption for citizens and consumers.

Potential mitigations

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
TV Broadcasting – DTT	A	A	✓✓✓	✓✓	✓✓	✓	◕

Technology and receiver standards

A3.13 DVB-T2 and MPEG-4 are technical standards that can deliver transmission and compression efficiencies of up to 50 per cent respectively compared to legacy standards. These technologies can offer benefits including increasing the number of channels available per multiplex, improving subjective picture quality and/or allowing the transmission of services in HD. However, the installed base of compatible consumer equipment is likely to affect the viability of a (partial or full)

[22] Ultra High Frequency, in relation to UHF bands IV and V (470 to 862 MHz).
[23] *Securing long-term benefits from scarce low frequency spectrum – UHF Strategy Statement*, Ofcom, November 2012, http://stakeholders.ofcom.org.uk/binaries/consultations/uhf-strategy/statement/UHF_statement.pdf.

transition to greater use of these technology standards. The launch of new interim multiplexes using MPEG4 and DVB-T2 at 600 MHz could encourage consumer take-up of TVs compatible with these technologies.

A3.14 HEVC is a recently standardised ‘next generation’ video encoding technology that can deliver bandwidth efficiencies greater than that of MPEG-4, making it a potential successor technology standard to DVB-T2 and MPEG-4. HEVC offers up to approximately 70 per cent more efficient compression than the legacy MPEG-2 standard and could potentially ease any HD/UHD upgrade path for DTT.

A3.15 Stricter, coordinated common TV receiver standards could reduce potential co-existence problems arising from the re-purposing of DTT spectrum or in the sharing of white space in DTT spectrum in future. Such standards could introduce more stringent RF[24] performance targets (such as selectivity) for receivers. This would enable more efficient use of spectrum, with non-DTT services potentially able to operate with fewer constraints. We are engaging in various areas of work, including a review of the European Directive on radio equipment (the R&TTE Directive) and the European harmonised standards that specify test methods and limits for the conformity of DTT receivers. We consider Ofcom’s engagement with the issue of receiver standards in more detail in Section 5 of the main consultation document.

Implementation and coordination of spectrum usage

A3.16 As for other users of spectrum, in principle, applying administered incentive pricing (AIP) is likely to incentivise users of DTT spectrum to use spectrum as efficiently as possible by reflecting the opportunity cost of the scarce spectrum resources they use. At present, however, as we discussed in our recent statement on AIP for broadcasting,[25] as a result of a unique set of circumstances on decisions to be made on the future use of this spectrum we consider it inappropriate to introduce AIP for spectrum used for DTT at least until we have materially progressed our plans for future use of the UHF spectrum. We intend spectrum charges for DTT broadcasting to be adjusted to AIP, based on the true opportunity cost of the spectrum at that time, and therefore expect AIP to be in place by around 2020.

Spectrum re-purposing

A3.17 We have recently awarded the 550-606 MHz band to Arqiva for the delivery of additional DTT multiplexes using DVB-T2 and MPEG-4 technologies during the interim period before a potential future DTT replan (to enable re-purposing of the 700 MHz band for mobile use). This decision is consistent with our UHF Strategy objectives, preserving the opportunity to use spectrum in this range to re-accommodate existing DTT multiplexes when, and if, 700 MHz clearance takes place.

A3.18 Adopting single frequency network (SFN) DTT transmitter network configurations at a regional level could potentially reduce the amount of spectrum that DTT requires to maintain the platform’s population coverage. In addition, switching to national SFN topology could offer benefits if applied to national non-regionalised DTT services. A need to replan the DTT network could potentially offer an opportunity for SFNs after 2018. However, the adoption of regional or national SFNs would have significant implications for consumers, existing aerial installations, network costs

[24] Radio Frequency.
[25] *Spectrum pricing for terrestrial broadcasting*, Ofcom, July 2013, http://stakeholders.ofcom.org.uk/binaries/consultations/aip13/statement/statement.pdf.

and coverage, and would also present significant international coordination challenges. Any such change would require regulatory agreement before it could proceed and would need to be managed by Ofcom. As such, for the purposes of this discussion, we consider it is a form of re-purposing spectrum rather than a user-led action. The DTT Frequency Planning Project is currently developing technical scenarios, including possible network configurations for a replanned DTT network, under our chairmanship.

Spectrum sharing

A3.19 We anticipate that other services will continue to access spectrum that remains locally unutilised by DTT multiplexes (i.e. 'geographically interleaved spectrum'). These include PMSE applications, which already access these bands, and new uses that are expected to make use of these frequencies in the near future, such as local TV multiplexes and new devices making use of white-space technology.

A3.20 In future, it is possible that technological advances will enable new forms of spectrum sharing between DTT and other uses. In particular, international discussions around increasing mobile broadband requirements have raised the question of whether, in future, spectrum in the 470-790 MHz range could be used for the converged delivery of both broadcasting and mobile data services. The Radio Spectrum Policy Group (RSPG) has noted this long-term prospect in its recently published Opinion on Wireless Broadband.[26] We also note that the recently established European Conference of Postal and Telecommunications Administrations (CEPT) study group on the technical background to future options for the UHF band is likely to analyse these possibilities further.[27] However, this form of network convergence is as yet only a possibility and is unlikely to have an impact in the timescales relevant for this document.

International factors

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
TV Broadcasting – DTT	A	A	✓✓✓	✓✓	✓✓	✓	◕

A3.21 WRC-15 is expected to decide upon the co-primary allocation of the 700 MHz band with mobile, as anticipated at WRC-12 and considered in our UHF Strategy. We anticipate however that the implementation of a change of use at 700 MHz is likely to be complex and require significant preparatory work. For this reason we have initiated a wide-ranging programme of work to ensure that these changes take place with minimum disruption for citizens and consumers.[28]

A3.22 It is likely that new generations of common international DTT transmission or video encoding standards will continue to emerge (in the past they have done so roughly every seven years). If a significant number of countries were to choose to transition

[26] *RSPG Opinion on Strategic Challenges Facing Europe in Addressing the Growing Spectrum Demand for Wireless Broadband*, RSPG, June 2013, https://circabc.europa.eu/d/a/workspace/SpacesStore/c7597ba6-f00b-44e8-b54d-f6f5d069b097/RSPG13-521_RSPG%20Opinion_on_WBB.pdf.
[27] See http://www.cept.org/ecc/ecc-announces-long-term-vision-on-uhf-frequency-band.
[28] *Future use of the 700 MHz band – Implementing Ofcom's UHF Strategy*, Ofcom, April 2013, http://stakeholders.ofcom.org.uk/binaries/consultations/700mhz-cfi/summary/UHF_SI_call_for_inputs.pdf.

from the original MPEG-2 and DVB-T standards to HEVC and DVB-T2, and receivers do not support all the coding and modulation schemes in common use, then the resulting fragmentation of the international market for DTT receivers could have an impact on the economies of scale that are available to manufacturers. This could affect the retail prices and choice of TVs available to consumers.

A3.23 International standards and regulation, as well as global market factors, are likely to heavily influence the future RF performance of DTT TVs (and, in particular, their robustness to in-band and out-of band interference). Thus they could also have a strong influence on future opportunities for shared access to UHF frequencies by DTT and other services.

A3.24 In the context of future WRCs, further international discussions on the allocations of the bands currently used for DTT are likely to take place. This could, over the very long term, raise the potential prospect for further changes to the frequencies that DTT uses.

Section 4

Licence-Exempt and Short-Range Devices

Introduction

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Licence Exempt and SRDs	Ⓐ	Ⓐ	✓✓	✓	✓	✓✓✓	◕

A4.1 Licence-exempt (LE) use of spectrum refers to uses that do not require individual licensing, but rather are licensed through a single set of rules with which the operation of a device must comply. So long as equipment is deployed in the bands included in the exemption regulations, in the manner described, anyone can use such devices with no need to coordinate their use. Short Range Device (SRD) is a term applied to various radio devices designed to operate on an LE basis over short ranges and at low power levels. These include devices such as alarms, telemetry and telecommand devices, radio microphones and anti-theft devices.

A4.2 Devices that access spectrum on an LE basis also underpin a wide variety of localised radio network applications, including near field communications (NFC) such as radio frequency identification (RFID), personal area networks (PAN) carried over technologies such as Bluetooth or ZigBee, and local area networks (LAN) carried over technologies including Wi-Fi.

A4.3 Licence exemption lowers the barriers to using spectrum for users of compliant devices. Where manufacturers can produce LE devices on a harmonised and standardised basis, economies of scale lower equipment costs, supporting the deployment of compliant wireless infrastructure at limited incremental cost. However, as LE devices are not centrally managed, they can only operate on the premise that they do not cause harmful interference to other spectrum users.

A4.4 CEPT Report 14,[29] the RSPG Opinion on the collective use of spectrum[30] and our Licence Exemption Framework Review[31] set out the present European and UK approaches to LE SRDs.

A4.5 Linked to growing demand for wireless data, consumer uptake of devices such as smartphones, tablets and laptops is contributing to strongly increasing use of Wi-Fi connectivity. Real Wireless has modelled a mid-range scenario that shows mobile

[29] *CEPT Report 14*, CEPT, July 2006, http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP014.PDF.

[30] *RSPG Opinion on Aspects of European Approach to 'Collective Use of Spectrum'*, RSPG, November 2008, http://rspg.ec.europa.eu/_documents/documents/meeting/rspg17/rspg08244_finalopinion_collectiveuse.pdf.

[31] *Licence Exemption Framework Review: A consultation on the framework for managing spectrum used by licence-exempt devices*, Ofcom, April 2007, http://stakeholders.ofcom.org.uk/binaries/consultations/lefr/summary/lefr.pdf.

data traffic growing to potentially eighty times its current size by 2030[32] (the mobile broadband section of this Appendix explores the trends, such as consumer uptake of smartphones and tablets, that are likely to drive these changes in the long term). Wi-Fi is likely to remain well-placed to provide additional mobile data capacity to meet end user needs indoors, for example in the home.[33]

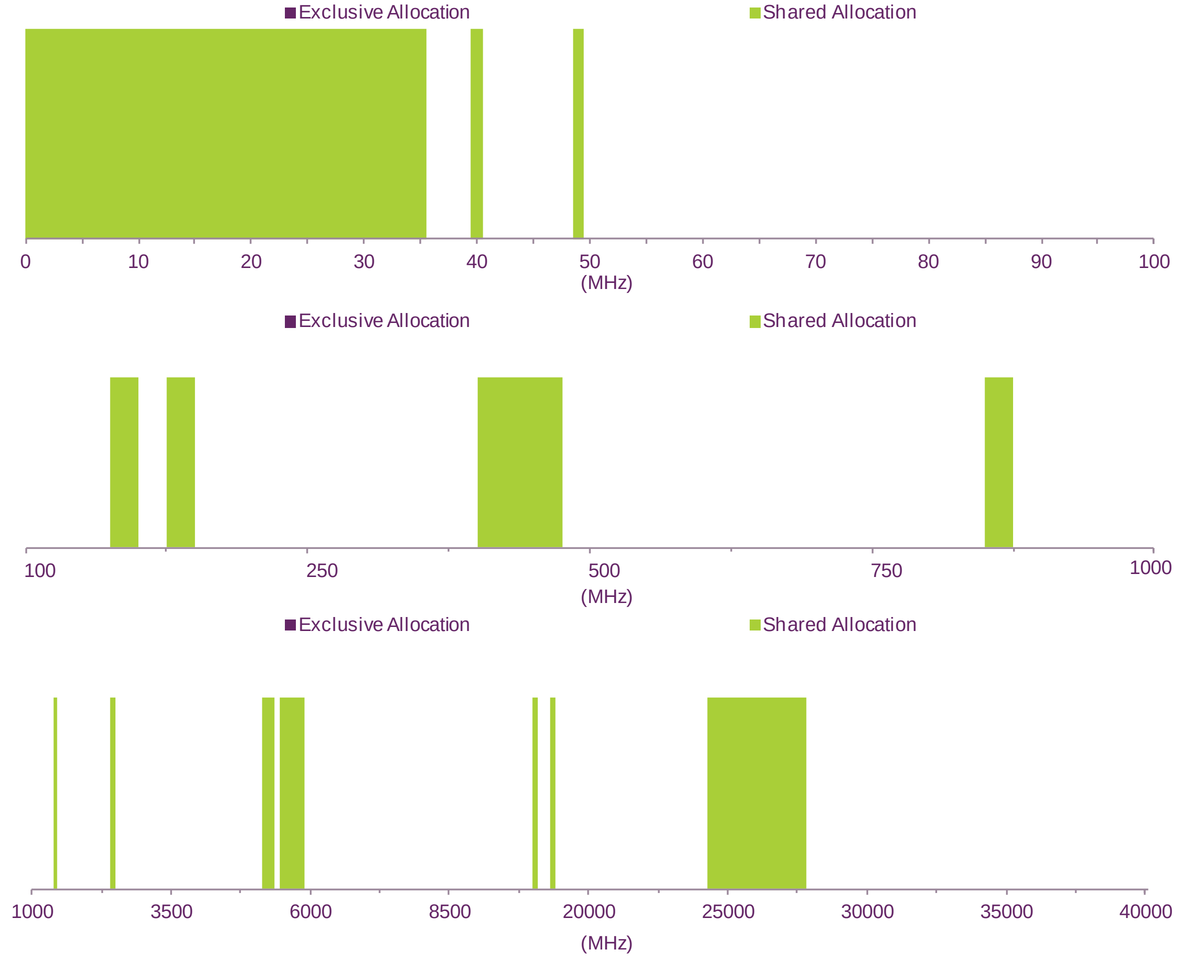
A4.6 Furthermore, Wi-Fi is increasingly important to MNOs as they expand mobile data capacity outdoors. MNOs are deploying heterogeneous networks that use Wi-Fi-enabled outdoor small cells and the metro Wi-Fi networks of fixed network operators to offload data from macro networks and meet local requirements for mobile data capacity.

A4.7 Growing use of LE machine-to-machine (M2M) applications in sectors including healthcare, utilities and transport are also likely to increase these sectors' spectrum requirements in future.

A4.8 A range of frequencies with varying propagation characteristics are allocated to LE use. We anticipate that user needs will change within all allocations to LE uses, including the 2.4 GHz and 5 GHz bands. The UK allocates the 2.4 GHz and 5 GHz bands to mixed uses of primary services and an underlay of LE apparatus, including WLAN.[34] Figure 4 below gives an indicative illustration of the spectrum used by LE transmitters (up to 40 GHz).

[32] Real Wireless, *Techniques for Increasing the Capacity of Wireless Broadband Networks: UK, 2012–2030*, April 2012, http://www.ofcom.org.uk/static/uhf/real-wireless-report.pdf.
[33] See *Study on the future UK spectrum demand for terrestrial mobile broadband applications*, Real Wireless, June 2013, http://stakeholders.ofcom.org.uk/binaries/consultations/cfi-mobile-bb/annexes/RW_report.pdf for further information on the UK's likely future use of LE requirements.
[34] Wireless Local Area Network.

Figure 4: Indicative illustration of bands currently used by the sector in the UK



Potential sectoral challenges

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Licence Exempt and SRDs	A	A	✓✓	✓	✓	✓✓✓	◕

Demand trends

A4.9 As we discussed in our recent consultation on spectrum sharing for mobile data,[35] a monitoring study that we have commissioned suggests that spectrum in the 2.4 GHz band, currently accessed by the majority of Wi-Fi devices, is heavily used. End users and operators in downstream sectors, including MNOs and fixed broadband operators, are increasingly using Wi-Fi spectrum at 2.4 GHz and 5 GHz and are likely to continue to do so, at least in the short term. This could result in contention and diminished quality of service indoors by 2020.[36] Outdoors, while congestion

[35] *The future role of spectrum sharing for mobile and wireless data services – Licensed sharing, Wi-Fi, and dynamic spectrum access*, Ofcom, August 2013, http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-sharing/summary/Spectrum_Sharing.pdf.
[36] See: http://stakeholders.ofcom.org.uk/binaries/consultations/cfi-mobile-bb/annexes/RW_appendices.pdf.

within Wi-Fi bands is not a widespread problem today, the uncoordinated deployment of Wi-Fi hotspots and the heightened risk of interference means that Wi-Fi's ability to meet end user data requirements may decline over time.

A4.10 Spectrum standards are evolving to deliver faster speeds in response to the proliferation of superfast fixed broadband connections. New standards such as IEEE802.11ac require higher bandwidth channels to provide faster bit rates, reducing the number of channels available to devices and increasing the risk of interference. Emerging Wi-Fi Direct-enabled devices, which communicate directly over separate channels to deliver very high bit rates or high quality multimedia data, may use higher bandwidth modes than Wi-Fi devices that communicate via a wireless access point.

A4.11 Cisco estimates that M2M traffic will grow at a CAGR[37] of 89% between 2012 and 2017.[38] Some future M2M applications that rely on low power transmissions over short distances could be well-suited to using spectrum on a licence-exempt basis. Growth in M2M communications could therefore strongly increase the number of devices using LE applications, although the small bandwidths typically used may not substantially increase spectrum requirements.

Potential changes in supply

A4.12 As it is the devices themselves, and not the spectrum they use, that are licence-exempt, it is very difficult to compare the demand and 'supply' of spectrum for LE use. In addition, with the notable exception of mobile uses such as Wi-Fi, LE uses are not typically identified as allocations in the ITU Radio Regulations (RR). Spectrum can be made available for licensed use as well as LE use, whilst some spectrum may be primarily used by LE devices or primarily used on a dedicated basis for licensed use. In this section, we therefore discuss specific changes to allocations that will impact the likely availability of spectrum for Wi-Fi uses, as well as opportunities that may be available to extend LE use to other bands.

A4.13 The EC is proposing to mandate CEPT to develop harmonised technical conditions for the 5350-5470 MHz and 5725-5925 MHz frequency bands ('RLAN[39] extension bands') in the EU for the provision of wireless broadband services with wireless access systems, including radio local area networks (WAS/RLANs). We currently expect this work to continue for several years and for the final deliverable to take into account the outcomes of decisions that will be taken at WRC-15.

A4.14 WRC-15 will consider whether to allocate an additional 195 MHz of 5 GHz spectrum, as well as 150 MHz in the same band currently available in UK for light licensed applications, to the 5 GHz LE band. Doing so would increase the spectrum available for Wi-Fi by approximately 60%.

A4.15 We are currently supporting co-existence studies relating to the use of the 5 GHz band and whether it is possible to extend the current 5GHz Wi-Fi allocation while ensuring due protection of its current users. This study will complement the work

[37] Compound Annual Growth Rate.
[38] *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2012–2017*, Cisco, February 2013, http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf.
[39] Radio Local Area Network.

that the EC has mandated from CEPT. We will also assess whether further studies are required.

A4.16 In addition, we have recently decided that we will make two (unpaired) unutilised bands, 870-876 MHz and 915-921 MHz available for use by LE RFID devices and other SRDs. This decision is subject to CEPT's development of harmonised technical measures that include sufficient technical constraints to permit the efficient use of the spectrum.[40] The release is technology neutral and applications that may use it include home automation and sub-metering, smart meter, smart grid, metropolitan mesh machine networks, surveillance alarms, fire/smoke alarms, intruder alarms, social alarms, automotive active safety, automotive diagnostic data exchange, automotive freight protection, automotive environmental and safety systems, and assistive listening services.

A4.17 As we continue to consider opportunities for greater sharing of spectrum, including the extension of geo-location services to additional spectrum bands, it is likely that the role for licence-exempt devices will grow. We also expect to continue to look for opportunities to licence exempt devices where doing so will increase the efficient use of spectrum.

Significance of changing spectrum requirements and potential urgency of enabling action by Ofcom

A4.18 Wider adoption and use of Wi-Fi-based equipment for the consumption of indoor and outdoor local wireless data services, and the prospect for a significant proliferation of M2M applications, both highlight the possibility that the number of devices reusing spectrum resources locally on an LE basis will increase significantly in future. There are many potential benefits and opportunities for innovation associated with such LE spectrum use and it is important to ensure that these are not unduly constrained.

Potential mitigations

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Licence Exempt and SRDs	A	A	✓✓	✓	✓	✓✓✓	◕

Technology and receiver standards

A4.19 Improvements to Wi-Fi equipment, such as beamforming and smart antennas (which focus the spatial distribution of transmissions), could reduce contention in relevant bands, particularly outdoors. Devices that only operate over limited distances, but require wide bandwidths, could operate in the allocation for wideband data transmission systems at 57-66 GHz.

A4.20 Improved interworking across cellular and Wi-Fi networks via network discovery and selection functions can realise greater spectral efficiency in end user devices like smartphones.

[40] *Statement on 870-876 MHz and 915-921 MHz – Update and Way Forward*, Ofcom, June 2013, http://stakeholders.ofcom.org.uk/binaries/consultations/870-915/statement/statement.pdf.

Implementation and coordination of spectrum usage

A4.21 There are opportunities for manufacturers and network operators to provide Wi-Fi-enabled devices in 5 GHz band in future, if congestion becomes an issue in the 2.4 GHz band. There are also opportunities for manufacturers of more generic SRDs operating over very short ranges to migrate into the 57-64 GHz band.

A4.22 The emergence of new dynamic spectrum access (DSA) techniques could also sustain, in future, new types of coordination amongst licence-exempt or light licensed devices. DSA refers to approaches that allow a middle ground between pure licensed and licence-exempt uses, overcoming some of the constraints of licence exemption, but maintaining the flexibility of shared spectrum access.

A4.23 DSA approaches may be well-suited to the needs of applications that would otherwise adopt a licence-exempt approach but require a higher quality of service than can be achieved through licence exemption. As we discussed in the spectrum sharing for mobile consultation,[41] applications of DSA may include the operation of outdoor small cells, to increase mobile broadband capacity in dense demand areas, and emerging M2M applications, such as intelligent transport or smart cities.

Spectrum re-purposing

A4.24 LE use does not typically require exclusive allocations, but rather shares spectrum already in use by other services. As such the role of re-purposing spectrum has to date been minimal in providing access to additional spectrum for LE devices.

A4.25 With the proliferation of demand for Wi-Fi type services to support anticipated increases in demand for mobile data, we may need, however, to reconsider whether dedicated access to additional spectrum bands is always required.

Spectrum sharing

A4.26 As we discussed in our recent consultation on spectrum sharing for mobile broadband, new approaches to shared spectrum access could be important to securing the benefit and innovation opportunities associated with growth in the adoption and use of Wi-Fi for localised (indoor and outdoor) wireless broadband services, and prospects for a wide range of innovative M2M applications.

A4.27 DSA techniques could deliver improved coordination between Wi-Fi access points, while intelligent traffic management could mitigate the risk of congestion within the Wi-Fi bands. New DSA techniques could also feature in the development of future wireless technology standards, including 5G.

A4.28 Equally, geo-location database techniques and cognitive sensing could help meet the spectrum and performance requirements of M2M applications. However, international agreements about the application of spectrum sharing techniques are required to ensure their interoperability and provide economies of scale to manufacturers.

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[41] *The future role of spectrum sharing for mobile and wireless data services – Licensed sharing, Wi-Fi, and dynamic spectrum access*, Ofcom, August 2013, http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-sharing/summary/Spectrum_Sharing.pdf.

International factors

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Licence Exempt and SRDs	A	A	✓✓	✓	✓	✓✓✓	◕

A4.29 The importance of securing economies of scale in the mass market production and diffusion of LE devices underlines how international standards and harmonisation can have a substantial influence on the success of current and future applications based on LE spectrum access.

A4.30 As discussed above, the EC is also proposing to mandate CEPT to develop harmonised technical conditions. We expect this work is likely to continue over the next few years, with a final delivery under the mandate likely to take into account future decisions at WRC-15 .

A4.31 The EC has mandated CEPT to continually develop harmonisation measures for SRDs.[42] We will continue to contribute within CEPT to the development of these harmonisation measures, in particular, for the 5350-5470 MHz and 5725-5925 MHz RLAN extension bands for wireless broadband services in the EU .

[42] 2006/771/EC: Commission Decision of 9 November 2006 on harmonisation of the radio spectrum for use by short-range devices (notified under document number C(2006) 5304), http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32006D0771%2801%29:EN:NOT.

Section 5

Programme Making and Special Events

Introduction

Spectrum uses		Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
PMSE	*Wireless microphones*	A	A	✓✓	✓	×	✓	◑
	Wireless cameras	R	R	✓✓	×	×	✓✓	◑

A5.1 Programme Making and Special Events (PMSE) describes a range of wireless services, primarily wireless microphones, wireless cameras and temporary fixed video links, used in the production of content for film and television, including news gathering, sports events and outside broadcasts. It also includes services used to support events such as live concerts, theatre, and religious, cultural and educational activities. There is a large concentration of users in London, although peak spectrum demand occurs at a variety of locations, depending on the nature of particular events.

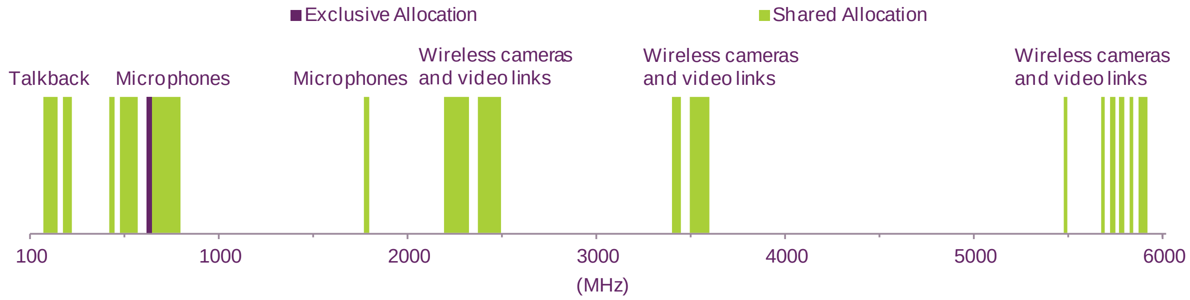
A5.2 The economic value generated by the sector's use of spectrum is difficult to establish due to this diverse range of users. The use of spectrum by the PMSE community is an important component of the activity of the creative industries. The PMSE sector also contributes to the delivery of significant wider social value as it supports the delivery of cultural and educational activities, as well as events of national interest.

A5.3 The majority of PMSE use of spectrum is on a localised geographic basis and on a time-limited (temporary) basis. There are significant, but time- and geography-limited, PMSE requirements associated with major events, e.g. at Silverstone for the two weeks of a British Grand Prix. Demand in these areas and at these times can be very high but demand is highly concentrated around specific locations and times compared to most other uses of spectrum.

A5.4 PMSE has access to spectrum from 48 MHz to 48 GHz in a number of sub-bands almost entirely on a shared basis. Apart from the band 606-614 MHz (TV channel 38) no spectrum is exclusively made available to PMSE. Wireless microphones and in-ear-monitors (IEMs) use sub-2 GHz spectrum; the 2-4 GHz range is the preferred band for wireless cameras and is also used for video links, including airborne links; the 5 GHz band is available to PMSE for wireless cameras and video links but is lightly used due to the risk of interference from licence-exempt wireless LAN[43] and fixed broadband radio systems. Figure 5 below gives an indicative illustration of bands currently available for the provision of PMSE within the range 100 MHz to 6 GHz. In total this roughly amounts to 1000 MHz of available spectrum, of which the vast majority is shared with other primary services. Additional spectrum is available for wireless cameras and video links at 7 GHz and for video links at 10 GHz, 12 GHz, 24 GHz and 48 GHz (1300 MHz additional spectrum in all), but these higher frequency bands do not provide the same utility to PMSE as sub-6 GHz spectrum.

[43] Local Area Network.

Figure 5: Indicative illustration of bands currently used by the sector in the UK



A5.5 For broadcasting and live events, the quality of service requirements and current technologies in use mean that there is low tolerance of interference, especially with wireless audio and video applications. The PMSE sector therefore requires access to spectrum in which the probability of interference from other services is low, including the 'noise floor', and therefore it is not suitable to share in all environments.

Potential sectoral challenges

Spectrum uses		Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
PMSE	*Wireless microphones*	A	A	✓✓	✓	×	✓	◑
	Wireless cameras	R	R	✓✓	×	×	✓✓	◑

Demand trends

A5.6 There has been a marked increase in the number of assignments licensed over the last ten years or so, reflecting, in the main, a rise in production values, with a variety of shows exploiting wireless technology on a greater scale than previously. A number of venues (and public places) do not allow trailing cables, making wireless equipment a necessity in many cases. As more PMSE devices are added PMSE users' spectrum requirements also increase to ensure a low probability of interference and a high quality of service.

A5.7 For wireless microphones and IEMs, theatre and live music events are a regular source of demand. There are also major events, including music concerts, festivals, sports and political events, which create large spikes in demand, albeit at specific locations and for short periods of time. These trends and those set out above will create increasing demand from the entertainment sectors for spectrum for wireless microphones and IEMs in the short to medium term.

A5.8 For video, programme makers are increasingly using more wireless cameras to improve their coverage, in terms of the camera angles available to viewers, especially at major sporting events, which creates a corresponding increase in spectrum demand. With increasing numbers of cameras there is also greater use of other equipment such as wireless telemetry devices for camera control. These trends and those set out above will create increasing demand from broadcasters and production companies for capacity for wireless cameras in the short to medium term.

A5.9 In addition, demands for increasing quality of content capture such as HD and UHD may potentially lead to larger bandwidth channels in the medium term in order to support the increased data rates. While increasing production quality demands may require larger bandwidth channels, more efficient video compression coding techniques could mitigate the impact that this trend will have on spectrum demand, as discussed below.

Potential changes in supply

A5.10 The 800 MHz/2.6 GHz award has reduced the spectrum available for PMSE, with the clearance of the former band affecting users of wireless microphones and IEMs and the latter users of wireless cameras. The potential re-purposing of the 700 MHz band for mobile use after 2018 would further reduce spectrum sharing opportunities for wireless microphones and IEMs, although DTT use of the 600 MHz band will allow for spectrum to continue to be accessed by PMSE equipment on an interleaved basis. Under PSSR, the MoD is seeking to release spectrum which it currently shares with wireless cameras and fixed video links. These developments at the international and national level are likely to place pressure on the spectrum available for PMSE use in the short to medium term, potentially affecting the ability of the sector to meet the requirements of large-scale, peak-demand events.

A5.11 At present PMSE users have shared access to the UHF spectrum with, and are required to protect, the DTT service. The introduction of White Space Devices (WSDs)[44] into the interleaved spectrum being progressed currently is on the basis that WSDs will not cause harmful interference to PMSE or DTT.

A5.12 The potential re-purposing of 700 MHz spectrum for mobile use could diminish the availability and vary the geographical pattern of spectrum available for wireless microphone and IEM users in the long term, while PSSR may affect the availability of spectrum for wireless cameras in the short term. In addition, activities within the EC to identify 1200 MHz of spectrum for mobile broadband, and within the ITU in relation to WRC AI 1.1 to study additional spectrum requirements for IMT, may have further implications for spectrum available for PMSE use. International factors are discussed further below.

A5.13 In the longer term, further developments in the delivery of DTT could affect PMSE users that access UHF spectrum on a secondary basis. For example, if DTT transmissions eventually moved to SFNs on a National basis (discussed in the section on DTT above) this might reduce the amount of UHF spectrum available for secondary uses on an interleaved basis.

Significance of changing spectrum requirements and potential urgency of enabling action by Ofcom

A5.14 The demand for spectrum for both audio and video PMSE applications is growing and the previous and potential future reductions in access to spectrum may affect the sector’s ability to meet users’ requirements with respect to production quality. However, historically PMSE users gained access to spectrum through sharing of spectrum where it was unused by the primary user. There has not, therefore, been a particular focus on the extent to which the spectrum made available to PMSE would be warranted based on its demand.

[44] WSDs make use of spectrum that is allocated to other services, on a primary basis, but which is unused in their locality, with access managed through a geo-location database.

A5.15 It is important, therefore, that we determine whether and, if so, the extent of any potential shortfall in spectrum availability in future could exist. The situation is most urgent with regard to wireless cameras.

Potential mitigations

Spectrum uses		Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
PMSE	*Wireless microphones*	A	A	✓✓	✓	×	✓	◕
	Wireless cameras	R	R	✓✓	×	×	✓✓	◕

Technology and receiver standards

A5.16 Recent technological developments in the audio PMSE sector have seen improvements in spectral efficiency. Analogue wireless microphone systems with improved RF performance allow the deployment of more links in a given amount of spectrum. These are high-end systems designed to meet the demands of large-scale, high-profile, professional users, so financial costs remain a significant barrier to universal adoption.

A5.17 The recent introduction of digital wireless microphones enables more efficient use of spectrum for events requiring a large number of microphone links. Bandwidth requirements for a single digital microphone are the same as for a single analogue microphone, i.e. 200 kHz as current audio coding and compression to reduce the required bandwidth introduces too much latency for live performances. However, digital systems are less susceptible to the effects of intermodulation, so multiple links can be accommodated in fewer 8 MHz TV channels than analogue systems. For example, a large theatrical production using 48 analogue microphones would occupy around 16 contiguous 8 MHz TV channels, or around 6-8 individual channels if there was adequate channel spacing and filtering; in contrast, 48 digital microphones could be deployed in 4 contiguous 8 MHz channels. As for the improved analogue systems mentioned above, the new digital systems are aimed at the higher end of the PMSE market so financial costs remain a significant barrier to universal adoption.

A5.18 The development of wireless cameras designed to operate at higher frequencies could have greater significance, given the current reduction in access to spectrum for PMSE. There is potential for greater use to be made of the higher bands to which the sector currently has access (e.g. 7.5 GHz). These cameras would be suitable for some applications such as portable cameras but current technology does not support high-speed applications such as onboard cameras for motor racing. Also higher frequencies cannot be used for non-line-of-sight applications. There is currently a lack of available equipment at higher frequencies in the UK, in part due to the lack of demand. The lack of demand is partly due to the higher cost of the equipment, but primarily it is because the equipment provides a solution for some, but not all of the uses, made by PMSE of 2-4 GHz.

A5.19 Another potentially important development regarding wireless cameras is more efficient encoding standards which would make it possible to fit higher bit rates, such as for HD or UHD video, into a narrower bandwidth channel than otherwise.

A5.20 The PMSE sector comprises a very diverse group of users. These include broadcasters and major events organisers, but also small theatres and music venues, charities, religious or local communities. Some of these users may have a limited ability to invest in new equipment. Uncertainties around potential future changes to the availability of spectrum for PMSE users may also affect PMSE manufacturers' and users' incentives to invest in new kit, as this is often compatible only with specific frequency ranges.

A5.21 Ofcom initiatives that could influence the extent to which new PMSE technologies could positively contribute towards meeting the sector's future requirements include: providing clarity on long-term spectrum availability, whilst taking into account ongoing work at both the EC and ITU level looking to identify harmonised spectrum options for PMSE; and engaging with manufacturers and stakeholders to promote the development and adoption of spectrally efficient equipment that is also more frequency agile or upgradeable.

Implementation and coordination of spectrum usage

A5.22 Users of PMSE equipment could review their customs and practices to identify possible improvements in their technical planning, particularly with regard to multiple devices at a single location. Early consideration will need to be given in the initial planning phase of an event to ensure that the way a production will use wireless equipment can be accommodated by the available spectrum.

Spectrum re-purposing

A5.23 As future requirements for these sectors are still being investigated, it is not yet clear whether spectrum re-purposing could be a relevant and feasible mitigation to potential future challenges.

Spectrum sharing

A5.24 Given the potential reductions in current opportunities for spectrum sharing noted above, our PMSE Spectrum Review (see Section 5 in the *Spectrum Management Strategy*) is looking at indentifying alternative spectrum sharing opportunities that could provide sustainable access to spectrum for PMSE use.

A5.25 Over the longer term, there is a possibility that cognitive technologies might enable better coordination and efficiency in spectrum use, if the successful implementation of geo-location and other dynamic spectrum access (DSA) techniques encourages innovation. In particular, we note that a German research project on cognitive PMSE is currently ongoing.[45] Although the current focus of geo-location and DSA approaches focuses mostly on wireless data and M2M applications, over the longer term the use of these techniques for PMSE applications might enable better spectral efficiency, or access on a secondary basis to other spectrum bands.

International factors

Spectrum uses		Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
PMSE	*Wireless microphones*	A	A	✓✓	✓	✗	✓	
	Wireless cameras	R	R	✓✓	✗	✗	✓✓	

[45] See: http://www.c-pmse.research-project.de/index.php/en/.

A5.26 The development of equipment that would allow for greater spectral efficiency would benefit from harmonisation of the bands used for PMSE (at least at a European level), in order to take advantage of economies of scale. This could be especially important for PMSE users with limited ability to invest in equipment. At present, PMSE equipment that is compatible with a large number of different bands tends to be relatively more expensive.

A5.27 At WRC-15, AI 1.1 and AI 1.2 are relevant to PMSE. AI 1.1 is looking to identify additional spectrum for mobile broadband and the list of frequencies being considered includes a number of bands which are currently available for PMSE. AI 1.2 is related to the 700 MHz band and invites the ITU-R to, *inter alia*, study the channelling arrangements for the mobile service, adapted to the frequency band below 790 MHz. AI 1.2 also includes a requirement to study "*solutions for accommodating applications ancillary to broadcasting*" (Services Ancillary to Broadcasting/Services Ancillary to Programme Making is the ITU term for PMSE). If AI 1.1 and AI 1.2 create momentum for further re-purposing of UHF spectrum to the mobile service this will significantly increase the constraints on wireless microphones over the long term.

A5.28 Within the EC, the RSPP sets out a number of policy objectives including finding appropriate spectrum for PMSE. The identification and implementation of new spectrum sharing opportunities in alternative bands at a European level could help facilitate a UK solution. The harmonisation of bands could also encourage investment by manufacturers and users.

A5.29 At the Radio Spectrum Committee (RSC) in July, the Commission presented a working document with next steps on harmonisation options for radio spectrum available for wireless microphones in the EU. It outlined the background and relevant considerations for a harmonisation measure regarding a sustainable availability of spectrum for audio PMSE. To define harmonisation measures on radio spectrum for audio PMSE equipment, the Commission requested Member States' views on a proposed framework:

- harmonisation measures without guaranteeing full interference free usage;
- provision of a minimum of available spectrum for audio PMSE usage; and
- benefits from a geo-location database for PMSE use.

Ofcom provided comments and sought further clarification to the proposals in the Commission working document.

Section 6

Emergency Services Communications

Introduction

Spectrum uses		Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Emergency Services Coms	*Broadband applications*	Ⓐ	Ⓐ	✓✓	×	✓✓	✓✓	◕
	Critical voice applications	Ⓐ	Ⓡ	✓	×	✓	✓	◑

A6.1 The Emergency Services (ES) use wireless communications to perform a range of activities. Determining future ES communications needs and procuring them are matters for Government. A multi-agency programme, the Emergency Services Mobile Communications Programme (ESMCP), has been initiated to address these issues across the UK. The Scottish Government has also initiated the Scottish Future Communications Programme (SFCP) to consider issues for Scotland. While led by Government, we anticipate that, because of the nature of the decisions that Government will take on ES communications services over the medium term, it may seek our advice on the availability and value of spectrum that could be needed to deliver these services. We may also have access to technical research and other spectrum-related information that could help inform Government's decision and that we will make available as appropriate. Therefore, in the following section we set out our understanding of the environment in which Government will make these decisions and what challenges there might be in meeting spectrum needs within this programme.

A6.2 This discussion should not be considered to reflect current Government thinking on ESMCP or SCFP. We expect that this issue will form an important aspect of the Government's planned overarching UK spectrum strategy, which it plans to publish in Q1 2014.

A6.3 The ES use spectrum to provide wireless communications for police, ambulance and fire services. These wireless communications support critical public safety services. The most important of these services is that for 'critical voice' applications. These include, for example, voice communications between control centres and police officers or deployments of fire tenders and crews. Critical voice applications require dependable geographic coverage across the UK, a resilient service and reliable penetration into buildings and transport networks.

A6.4 The ES currently use the dedicated TETRA[46] network, provided by Airwave Solutions Ltd,[47] for critical voice applications. TETRA provides the ES with voice and short data applications and specific functionalities including group call, direct mode, security and encryption features.

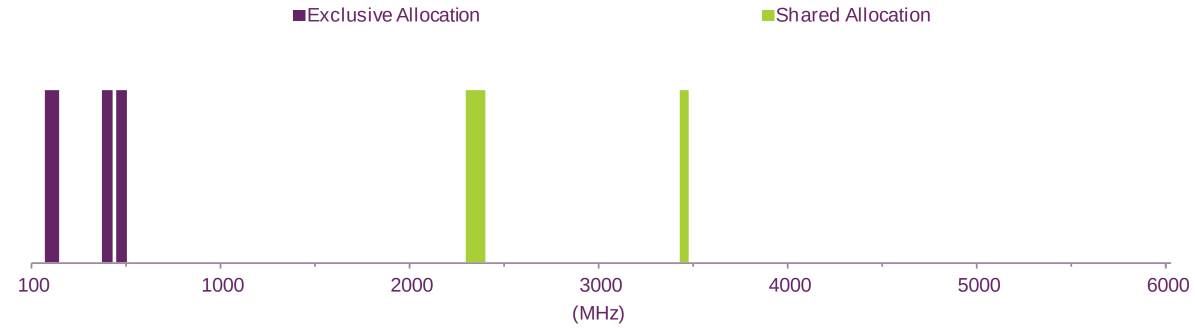
A6.5 The ES TETRA network currently uses 2x5 MHz across all of mainland Great Britain, supplemented by a further 2x2 MHz in Greater London provided by the Department of Health. Specifically, the bands that TETRA currently uses are:

46 Trans-European Trunked RAdio, or Terrestrial Trunked Radio.
47 Airwave provides services in Great Britain only: England, Scotland and Wales.

- 380-385 MHz paired with 390-395 MHz; and
- 410-412 MHz paired with 420-422 MHz.

A6.6 Further to the bands that the TETRA network uses to provide ES primary voice services, the ES also use additional spectrum including VHF[48] and UHF bands, and those above 1 GHz that they share with the military. These include 2310-2380 MHz and 3442-3475 MHz, bands which MoD has identified as candidates for release under PSSR (discussed further below).[49]

Figure 6: Indicative illustration of bands currently used by the sector in the UK



A6.7 Airwave also provides communications services over ES spectrum to a number of other organisations that provide support to 'blue light' services and are included on the 'Airwave sharers list' .[50] To be included on this list the organisation needs to be approved by Ofcom and to meet the criteria set out in the Ofcom guidance notes.

Potential sectoral challenges

Spectrum uses		Significance of potential changes	Urgency	Technology and receiver standards	Implementation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Emergency Services Coms	*Broadband applications*	A	A	✓✓	✗	✓✓	✓✓	◕
	Critical voice applications	A	R	✓	✗	✓	✓	◑

Demand trends

A6.8 In future, the ES will continue to require critical voice services with comprehensive geographical and in-building coverage, including services like group calls, direct mode, air-to-ground (A2G) transmissions and extensive air coverage.

A6.9 However, the expiry of the Airwave contracts provides an opportunity for Government to decide on changes to the types of wireless communication services provided for ES use and the way in which these are procured. The Home Office's contract with Airwave will expire at the end of 2020, although contracts with police forces and fire brigades begin to expire from 2016. The staggered expiry of Airwave contracts from 2016 raises the possibility that a replacement network running

[48] Very High Frequency.
[49] For a full list of ES bands, refer to UKFAT Annex I.
[50] Further information on Airwave Sharers is available at http://licensing.ofcom.org.uk/radiocommunication-licences/business-radio/guidance-for-licensees/airwave-emergency-services/airwave/.

alongside TETRA may require additional spectrum during a future transition, although alternative procurement solutions might be possible for Government.

A6.10 Developments in mobile broadband are creating opportunities for the delivery of data-rich applications over broadband. These may allow, for example, fire fighters to download detailed building plans, police to upload case reports including high quality pictures and video of crime scenes, or paramedics to upload videos or photos of injured patients. Longer-term opportunities may include the use of 3D video forensics and telehealth applications.

A6.11 Existing Public Protection and Disaster Relief (PPDR) communications systems such as TETRA 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 ES communications could be made available.

Potential changes in supply

A6.12 The MoD has identified a number of bands as candidates to help the Government meet its commitment to release 500 MHz of public sector spectrum by 2020. In some cases these bands contain public safety services. For example, they include two A2G video downlink bands used by the ES in the 2.3 GHz and 3.4 GHz military bands. The MoD and ES have worked in collaboration to move these applications into other MoD bands. They are also procuring more advanced equipment to improve the spectral efficiency of these services.

A6.13 Internationally, LTE is increasingly considered a suitable platform on which to provide broadband applications for the ES. The possible re-purposing of 700 MHz spectrum for mobile use might offer an opportunity for harmonised use of LTE networks to deliver the broadband services needed by the ES. Progress is also being made in international forums to develop the critical voice services for ES.

A6.14 There is also currently technical standardisation work underway to define a variant of LTE for use in the 450-470 MHz band, and we understand some national administrations, notably in South America, view the use of LTE, in this band, as a useful option to extend the reach of wireless broadband. In such a scenario, if spectrum at 450 MHz were to play a greater role in the provision of broadband to rural areas, investment in coverage might sustain the rationale for using this spectrum to provide the ES with broadband applications. However, it is currently unclear what level of international support there will be for enabling ES use of the 450 MHz band and specifically there is no consensus on the re-purposing of this band for public wireless broadband use in Europe. In the UK there are, also, specific and major implications on incumbent users that would need careful consideration before such a change of use could be considered. (The business radio section below provides greater detail on these challenges.)

Significance of changing spectrum requirements and potential urgency of enabling action by Ofcom

A6.15 The expiry of Airwave contracts from 2016 will pose challenges for securing the long-term delivery of ES critical voice services. As discussed above, this might have an impact on Government's spectrum requirements for ES, especially if they decide that they require spectrum for a replacement network running alongside TETRA during a future transition period.

A6.16 Future ambitions for new broadband applications could also pose very significant challenges for ES use of spectrum. Current PPDR networks do not have broadband capabilities. The suitability of using LTE-based networks at 700 or 450 MHz to meet future ES needs is the subject of an important debate both in the UK and in Europe.

A6.17 We recognise that addressing these matters is primarily for Government. We note that the ESMCP and the SFCP are currently considering how best to meet ES requirements over the long term. It is likely that Ofcom will contribute to Government's consideration of different solutions by providing expert advice, especially on spectrum access (including the opportunity cost of any specific use of spectrum).

A6.18 Although the challenges described above are unlikely to bring about changes to spectrum use before 2016, any action may require early consideration by Government of the costs and benefits of different options for delivering ES requirements.

Potential mitigations

Spectrum uses		Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Emergency Services Coms	*Broadband applications*	A	A	✓✓	×	✓✓	✓✓	◕
	Critical voice applications	A	R	✓	×	✓	✓	◑

Technology and receiver standards

A6.19 The TETRA Enhanced Data Service (TEDS) is the next generation of TETRA high-speed data service using different and higher RF channel bandwidths and data rates for flexible use of existing TETRA/PMR frequency bands. The TEDS standard 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). However, the data rates that wideband systems offer sit between those of narrowband and broadband systems. The technology is based on concatenating multiple narrowband TETRA channels and implies some re-engineering of the network infrastructure.

A6.20 In the US, Asia and Australia, LTE-based networks are being planned and deployed that provide ES broadband functionalities. The international adoption of LTE-based solutions for ES applications would create beneficial economies of scale. However, it is still unclear whether LTE solutions will meet the needs of critical voice services, including the specific private/secure network functionality and priority requirements of ES users that wider commercial providers of public services do not need.

Implementation and coordination of spectrum usage

A6.21 As Government is still investigating the future requirements for ES, it is not yet clear whether changes in the implementation and coordination of spectrum usage could be a relevant and feasible mitigation for potential future challenges.

Spectrum re-purposing

A6.22 As noted above, re-purposing of spectrum at 700 MHz or 450 MHz for mobile could provide an opportunity for Government to acquire spectrum to deploy new networks for broadband services for ES.

Spectrum sharing

A6.23 There are a number of ways in which, in principle, Government could consider ways of spectrum sharing to help enable the future delivery of ES communications services. For example, although the current approach used by Airwave involves using dedicated spectrum, it does provide access to other approved users through its sharers list. One suggested alternative might be to procure ES services spectrum or network infrastructure shared with other users. Current discussions internationally about the use of LTE technology for delivering PPDR applications means that the ES might potentially look to procure services from, for example, the commercial MNOs.

International factors

Spectrum uses		Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Emergency Services Coms	*Broadband applications*	A	A	✓✓	✗	✓✓	✓✓	◕
	Critical voice applications	A	R	✓	✗	✓	✓	◑

A6.24 3GPP, the standards body responsible for developing LTE technology, has stated its 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.

A6.25 Developments are being progressed in Europe for the use of LTE for broadband PPDR services. The UK is also keen to progress standards for critical voice services as well as broadband on a single LTE platform.

A6.26 The European Commission aims to harmonise EU Members' approaches to ES spectrum over time through CEPT processes. International engagement within this process will be important to ensure UK-specific interests are taken into account in any future decisions.

Section 7

Business Radio

Introduction

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Business Radio	A	A	✓✓	✗	✓	✓	◑

A7.1 The business radio sector provides robust private narrowband wireless communications for predominantly professional users, with the services and coverage tailored to specific requirements.[51] The typical use ranges from one-to-one 'walkie talkie' voice and short data services to dispatch or group call facilities for workgroups. There is a mix of private and public sector users, although usage by the latter has declined over the last ten years. The business user base is very large but fragmented, with many smaller users, and this trend has increased, since the introduction of greater technology and use neutrality in licensing. This dispersed user base is partially represented by a range of industry bodies.

A7.2 Professional Mobile Radio (PMR) supports a wide range of business uses, in particular where guaranteed availability is paramount and in some cases where negligible delays in setting up a transmission is of critical importance (e.g. a banksman instructing a tower crane driver to lower a load). The following is a sample of typical users: railway, tram, bus and traffic management operators; facilities management; airport support services; farms; finance; security; construction; manufacturing; pharmaceutical; petro-chemical; port operations; and Local Authorities, as well as taxis and private hire businesses. The utilities sector is a significant user of business radio spectrum; however, as the factors that will affect supply and demand trends in this sector include some, such as smart meters and a smart grid, which are less relevant to wider business radio users, they are considered separately in this Appendix (see section below on utilities).

A7.3 For most uses of business radio the communications requirement is for low latency essential voice communication, but the increased functionality of digital technology offers many additional applications, workstream management information and metrics.

A7.4 The most common technologies in use in the UK are:

- Traditional Frequency Modulation (FM), which is an analogue system;
- Digital Mobile Radio (DMR), which offers two voice or data channels within a 12.5 kHz channel; and
- Digital Private Mobile Radio (dPMR), which is similar to DMR, but provides single voice or data circuits within a 6.25 kHz channel.

[51] We consider the utilities separately below because their use of spectrum is distinct from that of other business radio users.

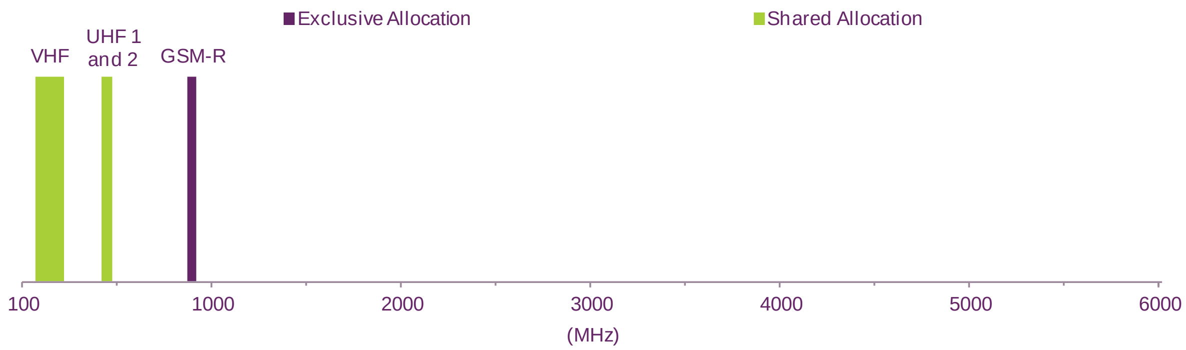
A7.5 All three of these technologies have either a direct terminal-to-terminal configuration or can be part of a trunked system with further options to facilitate shared infrastructure between a number of users requiring coverage in the same area.

A7.6 Business radio has access to around 84 MHz of spectrum. The most suitable bands for different users are determined by a combination of physical properties (such as antenna size, noise environment, coverage and building penetration), harmonised use and power requirements. Demand is stronger in the high VHF and UHF bands than in the low and mid VHF bands. Business radio spectrum is heavily utilised in major cities and it is becoming increasingly difficult to make new assignments in these areas, especially in the most popular frequency ranges.

A7.7 The transport sector's use of spectrum is largely uncoordinated as private rail, bus, tram and traffic management operators establish their own systems within business radio bands. A major exception to the uncoordinated spectrum use by the transport sector is the GSM-R[52] national network, which enables communication between train drivers and signallers. This network uses harmonised spectrum throughout Europe, allowing trains to use it across the continent. In areas where GSM-R does not provide geographic coverage across the entirety of train routes, trains are fitted with both GSM-R and the older cab secure radio.

A7.8 Figure 7 below gives an indicative illustration of the bands currently used in the 100 MHz to 6 GHz range. There are further allocations below this, which are generally less popular.

Figure 7: Indicative illustration of bands currently used by the sector in the UK



A7.9 Business radio is generally used as a business tool to facilitate commercial activities. However, it often supports business-critical functions and mandated regulatory conditions, and there are also potential gains in production efficiency resulting from the use of PMR. The wider social value of business radio is likely to be less relevant than its private value, although there are some indirect benefits associated with specific uses.

Potential sectoral challenges

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Business Radio	A	A	✓✓	×	✓	✓	◑

[52] Global System for Mobile Communication – Railway.

Demand trends

A7.10 Adoption of PMR devices is steadily increasing, although the UK market is mature, having developed since the first licence was granted in 1947. However, M2M applications are increasing, and users with a requirement for highly resilient services are returning to PMR because public networks do not meet quality of service standards for mission-critical applications. These trends may lead to growing requirements for spectrum from the business radio sector.

A7.11 Over the past few years there has been a market-led migration from analogue to digital technologies. Industry estimates of the digital market share are 30-40%. Base station systems are now equipped with smart switching arrangements that enable the radio terminals to be linked via the internet, or most likely a Virtual Private Network (VPN), to effectively give wide area linking to a number of private business radio islands. These base stations have developed to enable analogue to digital translation so that a company can migrate in stages to digital technology and maintain business continuity. However, any spectrum efficiency benefits are usually offset by demand for the extra applications a digital system can provide.

A7.12 Business radio users are beginning to consider data-rich applications, using efficient transmission signalling protocols to transmit data over narrowband channels. There is some demand for wide- and broadband data, which is currently met by using commercial public mobile networks, but this is unlikely to justify ad hoc infrastructure and spectrum access exclusive to business radio users (different rationales may however apply to utilities users – see separate section below). There is however potential for this trend to increase the spectrum requirements of the sector over the longer term.

A7.13 Another trend is for PMR users to switch to commercial networks instead, driven by the cost of equipment, coverage issues and attractive features of these networks, reducing demand for PMR-dedicated spectrum. However, this is likely to be balanced out (or at least slightly reduced) by new users coming to or returning to PMR, driven by commercial networks not providing a tailored low latency service to meet their needs (e.g. indoor coverage/instant voice calls) or due to service cost considerations.

A7.14 The development of the new High Speed 2 (HS2) rail network could also be a source of new demand for spectrum, both for signalling and to deliver public wireless services to train passengers. We expect HS2’s requirements to be become better defined over the next few years.

Potential changes in supply

A7.15 There are competing demands for access to the 450-470 MHz frequency range from, amongst others, business radio, the utilities, transportation and Emergency Services. There is also currently technical standardisation work underway to define a variant of LTE for use in the 450-470 MHz band and we understand some national administrations view the use of LTE in this band as a useful option to extend the reach of wireless broadband. However, there is no consensus on the re-purposing of this band for public wireless broadband use in Europe. In such a scenario it could also be considered as an option for broadband applications for the Emergency Services.

A7.16 The spectrum is, however, currently very heavily used in the UK to provide business radio and other services and any change of use of the 450-470 MHz range is likely to prove very costly and highly disruptive to incumbent business radio users. This issue is discussed further in the sections above on wireless and mobile broadband and Emergency Services communications.

A7.17 On the other hand, the need for changes to how the band is planned for business radio use might arise regardless of whether a change of use is contemplated in the UK. For historic reasons the UK band plan is the reverse of that agreed in Europe (reversing bands for uplink and downlink) and this has implications for the extent to which this band can be used in the UK free from interference. Changes in the way this spectrum will be used in future in Europe could increase interference challenges further.

A7.18 It is, however, worth noting that we have looked at the possibility of reversing the UK band in the past and have decided against this as it was deemed to be too disruptive and costly to be justified. However, if use of this band for wireless broadband in neighbouring countries (either through CDMA[53] or LTE systems) were to intensify significantly over the coming years, the increased risk of interference to UK users might strengthen the rationale for a band replan.

A7.19 Transport networks may seek to acquire more spectrum in future, through the ITU and European processes. Coordination of communications services and their safety and resilience are likely to remain priorities for the sector.

Significance of changing spectrum requirements and potential urgency of enabling action by Ofcom

A7.20 As noted above, parts of the spectrum available to business radio users are already heavily utilised in urban areas, and there are moderate upward pressures on the demand for spectrum. Prospects for an increase in the competing demands at 450-470 MHz, the potential for an increase of international interference, as well as the substantial complexities associated with any potential re-organisation of this band, imply that the business radio sector could pose important spectrum challenges over the medium to long term. We consider that an early investigation of the risks associated with these potential future changes is likely to be required.

Potential mitigations

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Business Radio	Ⓐ	Ⓐ	✓✓	×	✓	✓	◑

Technology and receiver standards

A7.21 As noted above, there has been a market-led migration from analogue to digital systems in recent years. There are clear benefits in terms of spectral efficiency, as digital systems use half the bandwidth of analogue (i.e. 6.25 kHz instead of 12.5 kHz). However, users are tending to exploit this extra capacity to improve operations and introduce additional applications, so the efficiency benefits are realised by existing users rather than being available for additional users.

[53] Code-Division Multiple Access.

A7.22 A longer-term option may be to employ emerging technologies. As an example we are currently scoping a research project to assess if a spreading code assigned spread spectrum technology could provide low latency PMR functionality. This type of technology presents a small rise in the RF noise floor and may be able to co-exist with existing users and hence facilitate the migration to a flexible digital solution. We are also investigating if any other technical solutions may optimise the use of this spectrum.

A7.23 More efficient compression standards could also be developed, although we are not aware of any such plans to develop such techniques at the moment. Our ability to influence such a development is limited.

Implementation and coordination of spectrum usage

A7.24 As future requirements for this sector are still being investigated, it is not yet clear whether changes to the way business radio users' manage their use of spectrum could be a relevant and feasible mitigation to potential future challenges.

Spectrum re-purposing

A7.25 Reorganisation of the 450 MHz band could provide an opportunity to speed up digitisation and ensure better international coordination. The difficulties of implementing such a reorganisation have been discussed above.

A7.26 There could potentially be opportunities for additional spectrum or increased sharing for the business radio sector arising from PSSR. However, this is uncertain at present.

Spectrum sharing

A7.27 With the collaboration of the MoD, we could look to assess the feasibility of extending coordination of military and civil use, and increasing opportunities for sharing, and will consider this as we work with Government on progressing sharing as part of PSSR.

A7.28 There are also more radical approaches which could be explored, such as using spread spectrum technologies to improve spectrum utilisation. An assigned spreading code is expected to minimise the conflict with other independent spread spectrum assignments and hence reduce the error rate. All digital technologies utilise methods to recover from limited errors and where this type of technology is in use it has proven to make efficient use of the spectrum resource.

A7.29 Over the long term, cognitive technologies might also enable better coordination and efficiency in spectrum use, but there is no real prospect of this appearing in business radio equipment in the short to medium term.

A7.30 We are also examining our assignment algorithm and policy options for improving the level of sharing amongst PMR users, as distinct from sharing between different sectors. This work follows on from our recent study that considered alternatives and enhancements to our propagation and planning algorithm together with the benefits of using Lidar surface terrain data.

International factors

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Business Radio	A	A	✓✓	✗	✓	✓	◑

A7.31 As a legacy of its early adoption of PMR, the UK is now exposed to a higher risk of interference from neighbouring countries, with many new digital technologies operating on incompatible channel plans in Europe. This situation also constrains the potential for additional efficiencies from new technologies within the UHF bands.

A7.32 The problem could only be fully rectified by undertaking a costly and disruptive replanning exercise. However, improved cross-border coordination with countries whose business radio bands are configured differently would improve spectrum availability in coastal areas in the South East of England, the Channel Islands, the North Sea and Northern Ireland.

Section 8

Utilities

Introduction

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Utilities	A	G	✓	✓	✓	×	◑

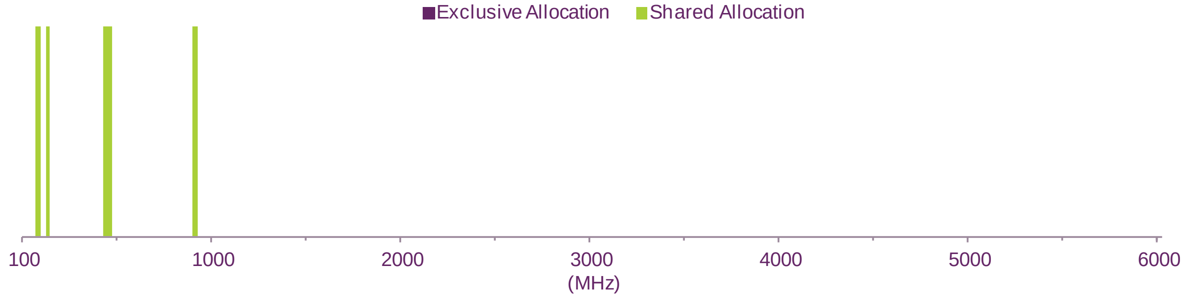
A8.1 The utilities sector is a major user of business radio spectrum. However, as there are some significant changes anticipated in this sector's use of spectrum that will affect demand and supply trends, such as smart meters and a smart grid, which are less relevant to wider business radio users, they are considered separately in this Appendix.

A8.2 Currently, the water industry uses spectrum to maintain efficiency by, for example, detecting faults among remote pumps, valves and waste management systems. Energy providers make extensive use of scanning telemetry and in places the sector's communications latency must be kept below 20mS for switching high power grid loads. Energy providers must also be able to use radio communication without mains power in the event of black starts. It is expected that there will soon be a need for a refresh of technology deployed in these networks that could also have a significant impact on its future use of spectrum.

A8.3 In addition, utility providers on the Airwave Sharers list can access Airwave's TETRA network for public safety voice and narrowband communications. The spectrum that the utilities sector uses includes Ofcom-managed and industry-managed bands. Utilities stakeholders with Area Defined licences provide communications services to the wider industry and in some cases the sector leases spectrum to third parties.

A8.4 Figure 8 gives an indicative illustration of the bands that the utilities sector uses between 100 MHz and 6 GHz. It does not cover the 55.75-68 MHz band used by water providers and 68.08125-87.49375 MHz bands used by water and other utilities providers.

Figure 8: Indicative illustration of bands currently used by the sector in the UK



A8.5 In common with much of the business radio sector, the utilities have developed and expanded their use of spectrum over many years. The spectrum that they have been assigned has not always been available in a contiguous block or even, in some cases, within the same band. Contiguous spectrum offers the user greater flexibility, allowing them to make use of different technologies and plan re-use patterns when all sites are under their control.

A8.6 Spectrum used by the utilities often requires very low latency to support safety-critical applications, particularly control systems for the National Grid.

A8.7 Spectrum use in the utilities sector has significant private value as it is often needed to meet mandatory regulatory conditions designed to ensure that the citizen benefits of Critical National Infrastructure (CNI) are delivered by commercial operators that are responsible for providing and maintaining this infrastructure.

Potential sectoral challenges

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Utilities	A	G	✓	✓	✓	✗	◑

Demand trends

A8.8 The utilities sector has indicated that it wishes to collect more data and use it to manage its networks and services using more data-rich communications services. In many instances its existing communications equipment will not support this.

A8.9 The utilities sector is also looking at providing smart metering, although it is currently anticipated that these requirements will be provided using spectrum held by the successful bidders for this initiative.

A8.10 The utilities sector's requirements are likely to change significantly as it seeks to introduce smart meters and a smart grid with control and communication needs. The Joint Radio Company, a joint venture operated by the National Grid and Energy Networks Association, has suggested to us that operating the smart grid would require an additional 2x3 MHz. Utilities are evaluating how they might transition from SCADA[54] applications to technologies such as multiple-input multiple-output (MIMO) antennas to manage networks, or a smart grid, more effectively, though these could pose significant demands on bandwidth availability.

A8.11 We are aware that sector regulators are imposing new efficiency requirements on the utilities sector. We wish to ensure that these requirements take account of the opportunity cost of spectrum when making decisions that might affect their use of spectrum. Once the sectors' requirements become clearer we will consider how to engage with other regulators on this issue.

Potential changes in supply

A8.12 Any consideration of a potential future re-allocation of the 450 MHz band to public wireless broadband, and/or potentially for the provision of PPDR applications, would require consideration of how the needs of the utilities sector could be met. Any solution would need to provide the very low latency communications required by this sector.

[54] Supervisory Control and Data Acquisition.

A8.13 The unpaired 870-876 MHz and 915-921 MHz bands, which we have recently decided to make available to LE uses, could be used to facilitate in-home communication between smart meters and utility providers, as could other bands allocated to LE uses, such as 2.4 GHz.

Significance of changing spectrum requirements and potential urgency of enabling action by Ofcom

A8.14 As users of both general business radio licences, and shared users of the Airwave TETRA network, it is important to note that utilities providers may also be affected by the key developments we discussed in the sector roadmap for Emergency Services communications, above.

Potential mitigations

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Utilities	A	G	✓	✓	✓	✗	◑

Technology and receiver standards

A8.15 It is relatively early in the development of the technology that supports a smart grid but the industry is currently considering technology options for its delivery. This will be critical in determining spectrum needs.

Implementation and coordination of spectrum usage

A8.16 The development of a smart grid will require considerable ongoing coordination between individual utilities companies. This will minimise the spectrum requirements and maximise the benefits the sector gains from its implementation.

Spectrum re-purposing

A8.17 The potential reconfiguration of the band 450-470 MHz that is currently used by the sector may present opportunities to increase the spectrum made available to it, although this is heavily dependent on the nature of any potential changes in the use of the band.

Spectrum sharing

A8.18 The Airwave Sharers list already permits a large number of utilities providers to use the ES critical voice service, emphasising the importance to these sectors of coordinating their requirements with those of the Emergency Services. We anticipate that consideration of future models of spectrum access (including shared networks approaches) for the delivery of future ES applications may also be relevant to meeting some of the needs of the utilities. However, we note that coordinating ES and utilities communications could be done at switch level (i.e. on the terrestrial fixed network) via separate wireless access networks, rather than over core ES spectrum.

A8.19 It is unlikely that sharing will provide an opportunity to meet the new demands of smart grids.

International factors

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Utilities	A	G	✓	✓	✓	✗	◑

A8.20 The EU Joint Research Centre (JRC) is proposing that the WRC adopt harmonisation of utilities spectrum on a future WRC agenda. This could help efforts to defragment utilities spectrum. We plan to engage with CEPT and the ITU in coming years in considering the benefits of such an approach.

Section 9

Space

Introduction

Spectrum uses		Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Space	*End user services*	G	G	×	✓	×	✓	◕
	Infrastructure links	G	G	×	×	×	✓✓	◕
	Science active	G	G	×	✓	×	×	◕

A9.1 Space services provide a diverse set of commercial and scientific services using a number of bands between 0.1 and 300 GHz.

A9.2 Space services can be divided into the following categories:

- **Fixed Satellite Services (FSS).** These provide business or home broadband connectivity, as well as communications for public bodies including the Emergency Services for public disaster relief and during natural catastrophes. In recent years there has been increased interest and investment in high-speed broadband communication to and from mobile platforms (e.g. ESOMPs,[55] ESV,[56] and aeronautical) for the provision of services to end users via specialised equipment installed on board ships, aeroplanes, trains and other vehicles. FSS is also used to provide consumers and businesses with VSAT[57] services, using small dishes fixed on the ground. In addition, FSS covers the feeder links to and from the satellites (as distinct from the end customer service links) and the tracking/telecontrol/telemetry connectivity for the satellites themselves. Commercial services can also delivered where the satellite forms part of a wider network (e.g. trunk telephony connectivity).These services are provided using satellites located in a geo-stationary orbit (GSO) around the Earth (where the speed of the satellite in orbit exactly matches that of the rotation of the Earth, so it appears stationary in the sky when viewed from Earth and provides a constant coverage area).

- **Broadcast Satellite Services (BSS)**. These provide direct-to-home (DTH) TV and radio services, as well as other interactive services (e.g. for gaming). These services also use GSO satellites.

- **Mobile Satellite Services (MSS).** These provide communications (data, voice and facsimile) to end users on the move, mainly at sea, in the air and in remote areas where terrestrial mobile networks do not reach, such as in rural/desert/polar regions. For example, MSS provides safety, distress and emergency communications inland (e.g. for the Emergency Services), in the air (AMS(R)S[58] under ICAO[59] auspices) and at sea (GMDSS[60] under IMO[61]

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[55] Earth Stations on Mobile Platforms.
[56] Earth Stations on Vessels.
[57] Very Small Aperture Terminals.
[58] Aeronautical Mobile Satellite (Route) Service.
[59] International Civil Aviation Organisation.
[60] Global Maritime Distress and Safety System.

auspices). It is also used for public disaster relief and during natural catastrophes. As these services are mobile by nature they can be provided by both GSO satellites or by non-GSO satellite systems.[62] From the Earth's surface, satellites in non-GSO appear as moving in the sky and their coverage area changes as they rotate around the Earth. As such, to provide constant coverage of any particular geographic area it is necessary to have a certain number of satellites (a constellation) in place so that, as one satellite moves out of sight, another appears.

- **Radionavigation and Global Positioning Systems (GPS and Galileo).** These are global satellite systems used to provide positioning information for a variety of navigation and positioning services on and around the Earth. These services are provided using an MEO[63] constellation of non-GSO satellites (at an altitude of approximately 20,000 km).

- **Space science radio services.** These include:

  - *Earth Exploration Science Service (EESS) and Earth Observation*: the use of satellites to study the Earth's physical characteristics (e.g. sea levels, the ozone layer), climate change and long-term weather patterns, natural hazards (e.g. flooding, hurricanes, tsunamis), agriculture (e.g. drought, crop distribution), security monitoring and for other purposes.

  - *Radioastronomy*: research relating to astrophysics and cosmology, typically the study of celestial bodies such as pulsars, the formation of new stars, the properties of interstellar gases and plasmas, solar activity and microwave background radiation, the study of invisible mass and energy, and the expansion of the Universe.

  - *Space exploration and space operations*: where communications are needed between space facilities on Earth and spacecraft in outer space or on other celestial bodies as well as space-to-space communications.

A9.3 Commercial telecom satellite services do not typically compete directly with terrestrial services because their services can be expensive to provide to end users. Instead, providers tend to operate them in markets based, for example, on geography (where terrestrial services may be unavailable for technical or economic reasons). As a result, to justify investment in requisite infrastructure, commercial satellite services rely on the ability of satellites to provide services over a wide multi-national coverage area. As such, regional and global spectrum harmonisation is vital to the sustainability of the sector. In addition, the economies of scale afforded by the global harmonisation of frequency bands are needed for end user terminal costs to be economically viable.

A9.4 The market for satellite services is, therefore, international in nature and satellite operators compete for services regionally and globally. Satellite industries tend to be quite heavily concentrated in certain countries, historically the US, UK, France, Russia and China, while the industry has grown more recently in the Netherlands, Germany, Italy, India and Brazil. In many countries where there is a large satellite

[61] International Maritime Organisation.
[62] Non-GSO (NGSO) constellations of satellites sit at a lower altitude than GSO satellites. High Elliptical Orbit (HEO) constellations of satellites, which have a high eccentricity elliptical orbit, are also able to provide MSS.
[63] Medium Earth Orbit.

industry, particularly where it is deemed to be of national strategic importance for other sectors such as defence, industrial policy supports the satellite sector and this is taken into account in the development of relevant UK policy and international negotiating positions.

A9.5 However, the market for commercial satellite telecoms services (both fixed and mobile) is not very large in UK and Europe (with the exception of broadcast satellite services) when compared to those in other regions, due to the extensive nature of terrestrial networks.

A9.6 Most EESS satellite constellations are in non-GSO orbits and so move above the surface of the Earth collecting data from different parts of the world. As such they rely on global harmonisation of the frequencies they use. Most EESS missions also rely on international collaboration (between space agencies and the scientific community) and shared infrastructure to gather and analyse the data collected. Most activity in the space science sector is publicly funded, in particular the UK Government invests heavily in the space programmes of the European Space Agency, as well as NASA's international programmes and those of other national space agencies.

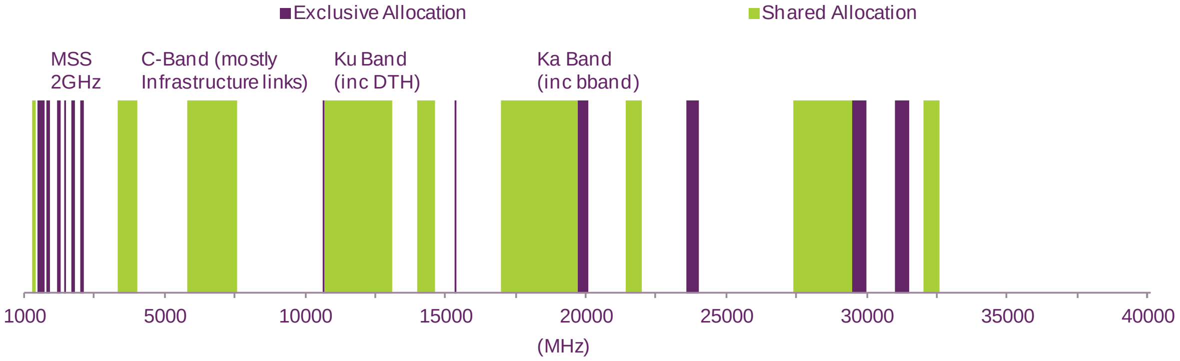
A9.7 Many space science services monitor specific aspects of the Earth's surface and atmosphere, as well as extraterrestrial radiation. The physical properties of some frequency bands often dictate which spectrum bands EESS can use (except for control services and to enable the delivery of data from the satellites to Earth) and it is not possible to relocate these to alternative spectrum bands. Decisions to re-purpose such spectrum in the UK can also affect other countries' use of this spectrum. EESS is divided between active services, which transmit and receive signals, and passive services, which operate a receive mode only (without making any transmissions).

A9.8 The situation is similar for radioastronomy services, which use frequencies dictated by the specific resonating frequencies of molecules found in celestial bodies and outer space and the Doppler Effect (caused by the relative movement of the celestial bodies with the Earth and the expansion of the Universe). Furthermore, as radioastronomy services are purely passive, decisions to re-purpose such spectrum for active uses, without exclusion zones to protect radioastronomy sites, would cause the cessation of these services in the UK.

A9.9 Passive space services are highly susceptible to interference, including interference due to out-of-band emissions from adjacent band services, because of the extremely weak signals they receive on Earth or in space near the Earth. Radio interference to passive bands can thus result in unpredictable and disruptive noise, which is inherently difficult to separate and filter out. Numerical forecast models can ingest such noise in turn, causing unreliable and incorrect measurements. UK science and research depends on access to spectrum nationally and globally that is sufficiently clear from interference to allow reliable and accurate observation. EESS and radio astronomy are therefore often allocated on an exclusive basis and do not share with other active services. They may further require equipment deployed in adjacent bands, which uses band rejection filtering to prevent interference into these bands. Even where EESS could use alternative spectrum bands, the nature of much of the research based on data collected by EESS relies on the availability of directly comparable data in order to understand long-term trends, which would further complicate any proposed change in a frequency band.

A9.10 Figure below gives an indicative illustration of bands currently used by the science and space sector (between 1 and 40 GHz). Bands below 1 GHz and above 40 GHz are not illustrated here, though they are used by, and relevant to, the sector.

Figure 9: Indicative illustration of bands currently used by the sector in the UK



A9.11 The majority of satellite users of the illustrated spectrum are FSS and BSS. The MSS bands and Radionavigation bands are located between 1 GHz and 2 GHz.

A9.12 Satellite services in the C band (4/6 GHz) and Ku band (11/14 GHz) share spectrum with fixed links. Small dish Earth stations, such as VSATs, are allowed to operate on an unprotected and non-interfering basis. Large dish permanent Earth stations (PES) instead operate here on a coordinated basis. The C and Ku bands are traditionally FSS bands and are therefore used extensively for the deployment of satellites; satellite operators have reported that these bands are highly congested, affecting the placement of new satellites in orbit, and that they require additional spectrum (see WRC-15 AI 1.6). Services have opened in the Ka band (18/28 GHz) in recent years, both as a response to this congestion and as satellite technology has evolved to enable this.

A9.13 Spectrum used by space technologies is of high private value both to the space industries and those that use their services. It is also of wider social value, primarily because of its importance to space sciences and for the provision of global positioning. Satellites can also contribute to the wider public policy goals of delivering rural broadband and PPDR.

Potential sectoral challenges

Spectrum uses		Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Space	*End user services*	G	G	✗	✓	✗	✓	◕
	Infrastructure links	G	G	✗	✗	✗	✓✓	◕
	Science active	G	G	✗	✓	✗	✗	◕

Demand trends

A9.14 For the purposes of this assessment, the categories of space service described above have been regrouped into three broad types based on the services delivered to end users:

- **End user services.** These are commercial and non-commercial services delivered directly over a satellite to the end users. Examples include MSS (land, aeronautical and maritime), DTH TV, multimedia, broadband services, PPDR, emergency and navigation.

- **Infrastructure services**. The main component in this category relates to feeder links between the satellites and their gateway earth stations. It also includes any commercial services delivered over the satellite which form part of a wider network; examples include services providing backhaul for mobile networks in rural areas, international backbone internet and trunk telephony connectivity. However, it should be noted that there is relatively little use of this latter type of infrastructure service in the UK, and it is decreasing, given the availability and quality of terrestrial networks.

- **Active space science services**. These are services that provide data for scientific research through the active use of spectrum, similar to the use of sonar and radar to determine the physical properties of objects.

A9.15 As the passive uses of EESS are largely dictated by the physical properties of certain frequency bands, and because these are already allocated and protected from active services in the radio regulations, we do not anticipate any significant additional demand for spectrum for such uses (passive EESS). In the following discussions therefore we restrict our discussion to the active uses of EESS.

A9.16 Satellite services that deliver residential broadband have recently been launched in the UK. There is a possibility that in future the uptake of residential broadband and other multimedia services over satellite (using the Ku and Ka bands) could increase significantly and would alter the requirements of end user services in the short and medium term. The ubiquity required by such services (i.e. the ability to be able sell the service anywhere in the UK without the need to coordinate) may place greater demand for spectrum available on a dedicated basis at Ka band (if demand emerges), rather than on a shared basis with fixed links. In addition, the Ka band is likely to be used for provision of broadband services to aircraft and ships through ESOMPs.

A9.17 In addition, demand for spectrum for DTH TV could grow in future with the development of HD and UHD TV services over the long term. Such a trend would be likely to change requirements for spectrum for downlink broadcast and their feeder links. However, it is also possible that more advanced video compression technologies and smaller beam technologies could be developed to increase the spectral efficiency of HD and UHD TV.

A9.18 Satellite launches for new EESS and meteorological services are taking place more frequently, in part reflecting the increasing focus of governments on climate change. However, the extent to which spectrum will be available to meet the needs of new satellites depends on the extent to which older satellites continue to use spectrum. Sensing and data downlinks using feeder link bands are, however, likely to require additional spectrum before 2020.

A9.19 The EESS sector is, however, already expressing its desire for an additional 600 MHz of spectrum for synthetic aperture radar (SAR) for observation missions at around 8-10 GHz, and 45-60 MHz spectrum for EESS uplink (TT&C) around 7.2GHz, at the next WRC (AI 1.12 and 1.13 address this).

A9.20 We are also supporting a proposal for additional satellite spectrum at around 7-8 GHz under WRC-15 Agenda Item 1.9.1.

A9.21 Ka band, and the Q and V bands (40-50 GHz), could be candidates to provide spectrum for data downlink to the new generation of EESS and meteorological satellites, which will offer high resolution scientific and operational data.

A9.22 The Met Office is planning to expand its wind profiling radar network in future, but coordination at 1290 MHz may become more difficult when new international positioning systems come into use, such as Galileo and Compass.

A9.23 With the likelihood of future missions to outer space and to other celestial bodies such as Mars and the Moon, spectrum requirements for deep space missions could grow after 2020. Such missions will require wide bandwidths and be located at frequencies above 5 GHz.

A9.24 In the longer term, EESS and meteorological satellite services can be expected to seek to use bands up to 1000 GHz, beyond the current scope of the ITU Radio Regulations (RR).

A9.25 BSS operators have the potential to use the 22 GHz band to deliver HD and UHD services, following WRC-12 proposals concerning 21.4-22.0 GHz.

Potential changes in supply

A9.26 The 2 GHz MSS band[64] has not been brought into commercial use to date, although several satellite operators in Europe and the US have launched satellites to do so. Operators in the US failed to find a market for their services and have now been bought by pay TV operator DISH. In Europe, the European Commission managed a process to determine the rights to use the spectrum on a pan-European basis. Two operators, Solaris and Inmarsat, were authorised as a result of this process on condition that they met a set of commitments on the date and extent of launch of the service. Solaris has launched a satellite while Inmarsat has not yet launched a satellite in this band. An enforcement regime is in place which enables Ofcom to take enforcement action where Ofcom finds that an operator has failed to comply with one or more of the common conditions set out in their authorisation.

A9.27 Satellite links at 3.6-4.2 GHz are currently being used by FSS earth stations of differing sizes and providing different applications (for example VSATs and PESs). These are the legacy bands for FSS systems and are of interest for consideration of an allocation to mobile use at WRC-15 as they are globally harmonised. The impact on commercial satellites of such a mobile allocation, including potential share use between terrestrial mobile and fixed satellite services, has not yet been fully assessed.

Significance of changing spectrum requirements and potential urgency of enabling action by Ofcom

A9.28 We consider the spectrum access that is available for end user services looks broadly sufficient, even though pressure on Ka band[65] spectrum is mounting. Market requirements are generally stable or addressable today, though significant changes in future, e.g. as a result of a significant uptake in rural broadband and mobile platforms over satellite, could pose challenges in future.

[64] 1980-2010 MHz and 2170-2200 MHz.
[65] Downlink frequencies at 17.7-19.7 GHz and uplink at 27.5-29.5 GHz.

A9.29 However, we note because of reported congestion in the Ku band, WRC-15 is considering whether an additional 2x250 MHz of additional spectrum should be made available to these services.

A9.30 The spectrum requirements for infrastructure links are likely to remain stable. However, the possibility of a mobile allocation within the 3.6-4.2 GHz range could result in parts of this band being shared (or conceivably re-purposed) in Europe.

A9.31 The frequency coordination of scientific applications with other services may pose spectrum management problems in the future, made more urgent by heavy public investment in scientific programmes (for example via the UK Space Agency). Accordingly, we monitor the sector's requirements. Spectrum requirements and decisions on what spectrum should be used need be taken into account in early stages of mission planning, requiring coordination between Government agencies, funding bodies and ourselves so that we can advise on the availability of appropriate spectrum and its opportunity cost.

Potential mitigations

Spectrum uses		Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Space	*End user services*	G	G	×	✓	×	✓	◕
	Infrastructure links	G	G	×	×	×	✓✓	◕
	Science active	G	G	×	✓	×	×	◕

Technology and receiver standards

A9.32 For broadcasting TV services, HEVC, the next generation video encoding standard, could enable very significant spectrum efficiencies. It is likely to be deployed to deliver UHD services on DTH. However, improvements in video compression techniques may not fully offset the possible future spectrum requirements of DTH downlink and feeder uplinks.

A9.33 The development of very high frequency Q and V band satellites (at 30-50 GHz) may allow broadcast (and possibly also generic FSS/MSS) feeder links to move out of the C, Ku and Ka bands. However, given the technological challenges to be overcome, this is likely to only affect spectrum supply and demand in the long term (after 2020).

A9.34 Small beam satellites, which are enabled by moving to higher frequencies and by the development of larger antenna, can enable the re-use and delivery of higher bandwidth residential services. This could have the potential to sustain greater use of the Ka band by home broadband and broadcasting services without the need for additional spectrum allocations.

Implementation and coordination of spectrum usage

A9.35 Some commercial satellite services operators have a choice in the spectrum that they use: for example, congestion in the C and Ku bands is already pushing all satellite operators to use the Ka band 17.3-20.2 GHz (downlink) and 27.5-30 GHz (uplink) for end user and business-to-business services.

Spectrum re-purposing

A9.36 If demand for broadband services over satellite develops in such a manner that requires ubiquity (i.e. the ability to be able to sell the service anywhere in the UK without the need to coordinate) this may place a greater demand for spectrum available on a dedicated basis at Ka band.

Spectrum sharing

A9.37 Spectrum sharing is not generally possible for services that are delivered to end users, as such services need to be available ubiquitously and so cannot be individually coordinated. They might, in some cases, however, be managed through geographical separation with satellite end user services being made available, for example, in rural areas, and other services being made available in dense urban areas; this has been suggested for the 18 GHz used by fixed links, for example.

A9.38 Infrastructure services (i.e. satellite feeder links) already share spectrum with fixed links on a technically coordinated basis. They also share with mobile broadband services in the 3.6 GHz band through a process of geographical coordination. Feeder links are placed in FSS bands, which are also used for smaller and mobile, fixed or transportable user applications. This means that when the spectrum becomes congested (as it is in Ku band) other frequencies may need to be found. However, feeder links do require extremely high availability and it is difficult to move feeder links to higher frequencies due to physical (higher rain fade) and technological impediments.

A9.39 Radioastronomy services already share spectrum with terrestrial services in a number of bands, on a technically coordinated basis. However, radioastronomy cannot share with other satellite services, especially in their downlink bands; uplink bands can be shared on a similar coordinated basis.

A9.40 It is also not possible for cognitive devices to detect the existence of satellite (downlink) signals due to their very low power and so sharing downlinks with such services is not possible. Sharing with satellite uplinks presents a different problem in that interference from such devices will be aggregated at the satellite given its wide beam and is likely to cause harmful interference.

International factors

Spectrum uses		Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Space	*End user services*	G	G	×	✓	×	✓	◕
	Infrastructure links	G	G	×	×	×	✓✓	◕
	Science active	G	G	×	✓	×	×	◕

A9.41 Satellites rely on international coordination in a number of ways (e.g. by service offerings, by investment, by commercial reach and by company structure) and therefore the international context for spectrum and public policy is very important to the sector. In particular, in addition to the use of spectrum, satellite operators need access to orbital slots around the GSO arc to provide the coverage they need. Orbital slots, like spectrum, are a scarce resource and access to these is managed internationally by the ITU and through bilateral and multilateral agreements by national administrations.

A9.42 Radioastronomy and EESS rely heavily on the international agreements and provisions in the RR for their protection from other radio services.

Section 10

Fixed Wireless Service – Fixed Links

Introduction

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Fixed Wireless Service – Fixed Links	G	G	✓	✓	✗	✓✓	◑

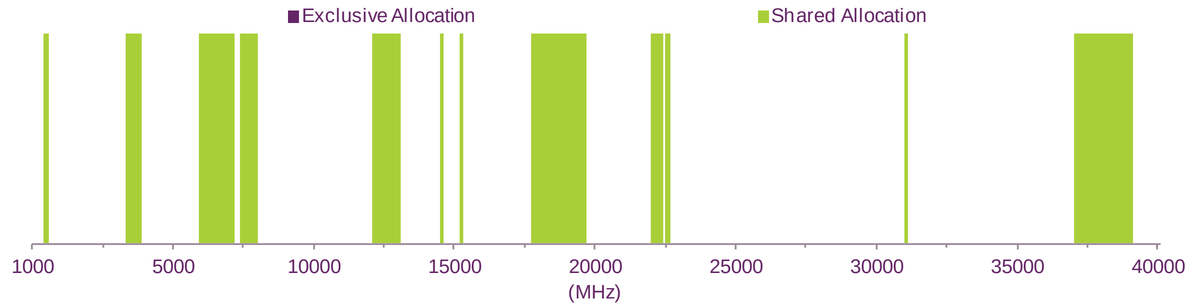
A10.1 Fixed links are an essential input to a wide variety of consumer and business services, including, predominantly, backhaul for mobile networks, as well as distribution of TV material from studio to transmitter site and connecting nodes within public, private and corporate networks (e.g. local authorities, utilities, safety services, etc).

A10.2 Spectrum used for fixed links is shared with a number of other services including, most significantly, the fixed satellite service. The important role played by fixed links in providing backhaul for next generation mobile networks means that the sector contributes significant value to the UK economy. Analaysys Mason estimated that terrestrial fixed-link services generated a consumer surplus of £3.3bn in 2011.[66] At the level of the EU27, Plum Consulting estimated that the sector had a total economic value of €27.8 billion in 2013.[67]

A10.3 Fixed links uses spectrum in a wide variety of bands from 1.4 GHz to 86 GHz. Much of this (especially in the higher frequencies) is currently light licensed or licence-exempt, and blocks previously allocated to fixed links (totalling ~5.9GHz BW) in bands between 10 GHz and 40 GHz were auctioned in 2008. Around 12 GHz of spectrum is managed by Ofcom on a link by link/centrally coordinated basis, of which around 80% is being used to provide backhaul for mobile access networks and fixed networks. There are currently around 33,000 links centrally managed and coordinated by Ofcom across the UK. Figure 10 below gives an indicative illustration of the bands currently used by the fixed wireless service between 1 GHz and 40 GHz which are managed by Ofcom. Additional spectrum is available/used by the fixed wireless service in the 52 GHz, 55 GHz, 60 GHz, 65 GHz, 70 GHz and 80 GHz bands.

[66] *Impact of Radio Spectrum on the UK Economy and Factors Influencing Future Spectrum Demand*, Analysys Mason, November 2012, https://www.gov.uk/government/publications/impact-of-radio-spectrum-on-the-uk-economy-and-factors-influencing-future-spectrum-demand.
[67] *Valuing the Use of Spectrum in the EU*, Plum Consulting, April 2013, http://plumconsulting.co.uk/pdfs/Plum_June2013_Economic_Value_of_spectrum_use_in_Europe.pdf.

Figure 10: Indicative illustration of bands currently used by the sector in the UK



A10.4 The propagation characteristics of this range of bands vary widely. The lower frequencies generally support longer hops than higher bands, and some bands exhibit very specific physical characteristics which may have a strong influence on their value to certain types of use (e.g. 60 GHz with its high oxygen absorption characteristics being suitable for short, high-capacity links). The value of a band is also highly dependent on the international regulatory framework and the level of standardisation of equipment for each band, and as a consequence some bands are much more popular than others.

A10.5 In terms of current use, the majority of fixed links in the UK are used to provide backhaul for mobile networks and are licensed to MNOs and fixed network operators. As a result, over 90% of all links that we license are held by eight companies. The remaining 10% of individual fixed link licences are spread across more than 300 other licensees, the majority of whom hold only a few licences each. These licensees use fixed links for a variety of applications including broadcast distribution, utilities networks, public safety communications networks, broadband, industry and universities networks, and CCTV[68] by Local Authorities.

Potential sectoral challenges

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Fixed Wireless Service – Fixed Links	G	G	✓	✓	×	✓✓	◑

Demand trends

A10.6 Demand from the predominant application, backhaul for mobile networks, is currently undergoing fundamental change as networks, network architectures and businesses evolve. It is widely expected that mobile broadband traffic will increase significantly in future and that this rapid increase will give rise to a requirement for suitable backhaul architectures and an increase in spectrum use.

A10.7 MNOs, which have made extensive use of fixed links for backhaul, have also adopted strategies of investing in fibre networks for high-capacity links. Fibre provision is viewed as a complement rather than a substitute for wireless solutions, with fibre mainly used in the core of the network and wireless for access and aggregation point links. For difficult terrains and remote areas where fibre links are prohibitively expensive to install, fixed links also plays a significant role, for example in meeting the coverage obligation attached to one lot of the spectrum recently

[68] Closed Circuit Television.

auctioned to one MNO for 4G services. Upgrades may be necessary to address the increase in backhaul capacity requirements if mobile data consumption grows at the rate forecast (see the section on wireless and mobile broadband above). Wireless backhaul provision is therefore expected to continue to be a major requirement, with demand for spectrum from this source increasing over the short to medium term.

A10.8 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. However, the capacity of each fixed link, and the associated bandwidth requirement, are likely to grow significantly along the consolidated routes, increasing demand for spectrum bands that can support wider channels (which generally means higher frequencies), and impacting on overall spectrum consumption on specific routes. The effect is to concentrate the combined traffic from the different networks along a smaller number of specific routes, which will reduce the extent to which frequencies can be re-used, and potentially increase the demand for spectrum along the highest capacity routes in the short to medium term.

A10.9 In addition, MNOs' deployment of small cells will potentially increase substantially to provide additional capacity in urban areas, with wireless fixed links likely to be a key backhaul solution. There will be a requirement, linked to microcell applications, for quasi-line-of-sight and non-line-of-sight microwave backhaul, for which sub-6 GHz spectrum is particularly desirable (although the propagation characteristics of some higher frequency bands and technology developments may also make them suitable).

A10.10 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 above 60 GHz.[69] The superior bandwidth available in these bands will drive greatly increased use of these bands to serve high-capacity demand. Many stakeholders also believe that rapid deployment of backhaul from small urban cells will require fixed link spectrum rather than fibre, focusing on bands which offer high capacity over relatively short hops. This migration to higher frequency bands is likely to relieve some of the pressure on the more congested lower bands in the short term.

A10.11 The public sector has generated significant savings for some applications (e.g. CCTV) by using wireless links over leased lines. Although Local Authorities currently only make up a small proportion of fixed link usage, these organisations could contribute to spectrum demand if they were to adopt wireless links on a more widespread basis, over the medium to long term.

A10.12 As we discussed in a section above, the Emergency Services are currently considering how to meet their future communications requirements. Future changes to ES communications networks could impact on the demand for backhaul capacity and fixed link spectrum.

A10.13 The financial services industry has shown a preference for microwave links over fibre for some specific applications, primarily 'High Frequency' trading, due to the lower latency properties of the former (approximately one third faster than optical waves in fibre). There has recently been a significant increase in demand from these users, and low latency is also a key factor in the delivery of other services

[69] *Spectrum Review – Update on Key Messages and Next Steps: A review of the management of the spectrum currently used for point to point fixed links other services that share this spectrum*, Ofcom, December 2012, http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-review/update.pdf.

(e.g. cloud computing). If this trend continues there will be increasing requirements for low latency links across a number of bands, with the 6 GHz band, due to its propagation characteristics, being particularly popular for cross-channel link connections.

Potential changes in supply

A10.14 AI 1.1 at WRC-15 will consider additional allocations to the mobile service, which could potentially put pressure on lower frequency bands used by fixed links. The likelihood of this is high, as the propagation characteristics of these bands make them attractive for mobile use.

A10.15 Access to the bands shared between fixed links and satellite Permanent Earth Stations (PESs) is already a matter of significant interest for operators of satellite earth stations with requests for more dedicated or enhanced spectrum access for satellite services. There could be an impact on fixed links if there is an enlarged role for satellite services in the provision of rural broadband, possibly in the shared 18 GHz band.

A10.16 Our E band Review (71-76 GHz and 81-86 GHz) is currently consulting on a change to the licensing approach at these frequencies, with the aim of creating the right environment to facilitate the rollout of backhaul services to support 4G mobile networks.[70]

A10.17 In addition to reviewing the 70/80GHz band, and given the increasing interest now emerging in the higher mmWave bands, we also plan to look into the bands above 80 GHz (e.g. around 92 GHz and above) that may be suitable for future fixed wireless applications.

Significance of changing spectrum requirements and potential urgency of enabling action by Ofcom

A10.18 The main challenges for this sector are increased demand for mobile backhaul in the short term, and pressures on supply from the possible re-purposing of spectrum for mobile data, with potential congestion in the bands between 1 GHz and 7.5 GHz. However, a recent review of the bands used by the fixed wireless service concluded that spectrum availability will not constrain the estimated demands of fixed links users above 20 GHz, due to intensive frequency reuse and the expansion in use of bands above 60 GHz (e.g. the 70/80 GHz band).[71] The other significant factor is that the mobile operators have access to the 10-40GHz bands which were auctioned in 2008 which has significantly increased the supply of spectrum and which are being increasingly used for their backhaul operations.

Potential mitigations

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Fixed Wireless Service – Fixed Links	G	G	✓	✓	✗	✓✓	◑

[70] *Review of the Spectrum Management Approach in the 71-76 GHz and 81-86 GHz Bands*, Ofcom, August 2013, http://stakeholders.ofcom.org.uk/consultations/70-80ghz-review/.
[71] *Frequency Band Review for Fixed Wireless Service*, Aegis, November 2011, http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-review/annexes/report.pdf.

Technology and receiver standards

A10.19 There are a number of technological developments which could mitigate the impact of rising demand for spectrum from the fixed wireless service, through both improving spectral efficiency and addressing increasing technical planning requirements. These include:

- higher order modulation techniques, to increase data capacity and improve transmission efficiency on existing fixed links;
- greater use of high performance antennas, which increase the packing density of fixed links; and
- improved network topologies, to more effectively route or aggregate traffic.

A10.20 These technological developments are likely to be industry-led, although there is a role for us in incentivising spectral efficiency, primarily through spectrum pricing.

Implementation and coordination of spectrum usage

A10.21 We are planning a review of fixed links fees, which are already subject to AIP, and work on this will get underway later this financial year. We will look at this time to see whether there is a need, or scope, to better focus the incentives users are given in the choices they make when using fixed links through the fees algorithms.

Spectrum re-purposing

A10.22 Fixed links have access to 12GHz that is Ofcom band managed under coordinated licence products and a further 6GHz that is available in block-assigned spectrum. There are no proposals to re-purpose spectrum in order to increase supply for fixed links although we are considering the potential future use of bands above 90 MHz.

Spectrum sharing

A10.23 If there is an increased role for the satellite service in the provision of rural broadband, leading to increased congestion in the 17.7-19.7 GHz range currently shared with fixed links, then further possibilities for sharing may need to be explored. These would be likely to include: geographic sharing; frequency segmentation; and dynamic channel allocation techniques. However, it is at present unclear how effective these different techniques would be in relieving further congestion, should any arise.

A10.24 It may also be necessary to develop more advanced sharing solutions between fixed links and wireless broadband (e.g. LTE applications), including more advanced propagation modelling, e.g. in the 3.6 - 4.2 GHz band, if it is identified for wireless broadband.

International factors

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Fixed Wireless Service – Fixed Links	G	G	✓	✓	×	✓✓	◑

A10.25 The frequency allocations and the associated international technical/regulatory conditions for fixed links are governed by the Radio Regulations. Bands are also often ‘soft’ harmonised via international channel plans and standards are designed and implemented to facilitate regional and global markets, providing the economies of scale needed for equipment costs to be economically viable. As the Fixed Service (FS) covers such a wide range of bands there are always numerous international issues on WRC agendas that can have either a direct or indirect impact on the FS spectrum and how it is used. Allocations to the terrestrial fixed services are often shared with satellite services and the technical/regulatory provisions for the two services need to managed carefully at the international level, as the two services evolve, in order to avoid international interference between the services.

A10.26 WRC-15 AI 1.1 will consider additional allocations of spectrum for mobile broadband. A number of the bands being considered for the mobile service within the ITU are currently used by fixed links, which, if identified and re-purposed for mobile broadband based services will place additional pressure on the spectrum used for backhaul. In the longer term there will continue to be interest from competing applications, including both terrestrial and satellite-based services, in gaining access to fixed link bands. We will therefore remain fully engaged in the relevant international discussions leading up to and beyond WRC-15.

A10.27 In more general terms, the sector benefits from the development of internationally harmonised channel plans and standardised equipment, which deliver economies of scale. Again, we play a role in supporting this through engagement in the relevant international committees.

Section 11

Radio Broadcasting

Introduction

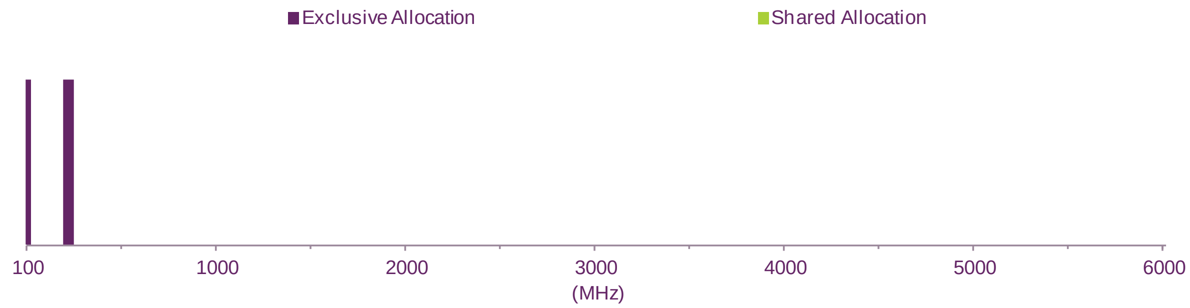
Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Radio Broadcasting	G	G	✓✓	✓	×	×	◔

A11.1 The radio broadcasting sector includes national, local and community radio stations, broadcast in analogue form on FM[72], and also AM[73] (medium wave and long wave), and in digital form on DAB[74]. The BBC operates national, regional and local services across the UK, often broadcasting the same content in both analogue and digital form. There are three national analogue commercial radio stations (Classic FM, and, on AM, talkSPORT and Absolute Radio), which are also broadcast on the DAB platform, over the Digital One multiplex. There has been some consolidation of the ownership of local commercial radio, leading to the development of quasi-national networks (e.g. Global Radio's Capital and Heart services), which share the same content between different areas, while also delivering local news. In addition, over 200 community radio licences have now been issued, providing small-scale and not-for-profit services to specific communities.

A11.2 In addition to internet streams, many linear radio services are simulcast on other digital broadcast platforms (DTT, cable and satellite), but the spectrum used by radio broadcasters on these alternative platforms is outside the scope of this section. Similarly, AM radio services are not considered in this section, as it is a mature market, with an established technology, which we do not expect to undergo significant changes.

A11.3 Roughly 39 MHz of spectrum is used by FM and DAB: 88 MHz to 108 MHz in VHF Band II (FM) and 210.88 MHz to 229.84 MHz in VHF Band III (DAB). There is high usage of these frequencies, which are assigned on an exclusive basis, the majority of which we manage. Figure 11 below gives an indicative illustration of the bands currently used by the sector.

Figure 11: Indicative illustration of bands currently used by the sector in the UK



[72] Frequency Modulation.
[73] Amplitude Modulation.
[74] Digital Audio Broadcasting.

A11.4 We regulate radio broadcast content and Wireless Telegraphy (WT) Act licensing for commercial radio (and WT Act licensing only in the case of the BBC's services), act as band manager in defining the individual assignment characteristics of transmitters, and contribute to policy formulation.

A11.5 The Government leads on many policy aspects and, in particular, on decision-making in relation to a possible future digital switchover, which is discussed further below.

A11.6 There are a large number of stakeholders that would be affected by any changes in broadcast radio spectrum use, with a substantial base of installed equipment, and the potential for high consumer costs if the technology underpinning the sector was changed.

A11.7 On average, 90.3% of the UK population listened to broadcast radio each week in the twelve months to the first quarter of 2013. This represents a year-on-year decrease of 0.9pp. However, radio broadcasting still has a very high reach across the UK.[75]

A11.8 The wider social value of the sector is considerable, with its extensive reach (including among vulnerable groups) fostering social inclusion and informed democracy at both the national and the local levels, particularly through the delivery of PSB services. Radio content remains free at the point of consumption.

Potential sectoral challenges

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Radio Broadcasting	G	G	✓✓	✓	×	×	◔

Demand trends

A11.9 The frequencies currently assigned to radio broadcasting are used heavily and in densely populated areas we are unable to accommodate all potential users of this spectrum. We manage demand through 'beauty contests', in which potential licensees compete with each other by proposing formats for radio stations which are judged against pre-existing criteria. As noted above, we have licensed over 200 community radio stations, and demand from this segment looks set to continue. However, the spectrum requirements of the sector as a whole are likely to remain stable.

A11.10 In the short term, the popularity of radio listening appears to be resilient, despite competition from newer media, such as internet radio and other online music services. However, internet radio and other online music services are growing in popularity, particularly among younger age groups (e.g. 77% of 16-24s cited online video as their preferred method of listening to music in 2013).[76] In the medium to long term, therefore, it seems likely that the rise of other platforms could lead to decreasing demand for spectrum from radio broadcasting. Many radio stations are

[75] *Communications Market Report 2013*, Ofcom, August 2013, http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr13/2013_UK_CMR.pdf.
[76] *Communications Market Report 2013*, Ofcom, August 2013, http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr13/2013_UK_CMR.pdf.

already preparing for this shift by significantly improving their online offerings with additional services. The increasing prevalence of mobile internet connections could help drive a more general shift to online radio broadcasting.

A11.11 As DAB take-up increases, and as the impact of consolidation in the local commercial radio sector continues to be felt,[77] there could be demand for additional commercial national stations, either instead of – or in addition to – the current quasi-national digital station networks. Separately, a second national commercial DAB multiplex, in addition to Digital One, could potentially be launched (spectrum was allocated and a licence for such a service was awarded in 2007, but it failed to launch due to commercial factors). Either of these scenarios could modestly increase the spectrum requirements of the sector, although the situation remains uncertain at present.

Potential changes in supply

A11.12 First published in 2010, the Government's Digital Radio Action Plan[78] has set out a number of criteria for determining whether to proceed to a full digital switchover for radio broadcasting, with a decision on the desirability of carrying out switchover to be taken by Government by the end of 2013. The conditions for switchover to take place include a target for radio listening via digital platforms to reach 50% of all radio listening, as well as minimum levels of coverage being achieved by DAB services. Digital listening currently stands at 34%, and consumer adoption of DAB is still increasing, but achieving a full transition to digital still presents significant challenges.[79]

A11.13 In the event of a full digital radio switchover, the freed-up FM spectrum could be reallocated to an increased number of smaller analogue stations, or potentially released for other uses such as WSDs or PMSE.

Significance of changing spectrum requirements and potential urgency of enabling action by Ofcom

A11.14 The overall picture for spectrum access by the radio broadcasting sector is stable, with significant changes likely only in the longer term, notwithstanding the possibility of a full digital radio switchover in the second half of this decade.

Potential mitigations

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Radio Broadcasting	G	G	✓✓	✓	×	×	◔

[77] In 2012, Global Radio acquired Guardian Media Group (GMG) Radio Holdings Ltd, now Real and Smooth Ltd (R&SL), increasing its share of analogue commercial radio licences from 24.2% to 27.5%. R&SL is currently required to operate separately from Global Radio. Bauer Radio is the second largest radio group, with 13.9% of commercial analogue radio licences.

[78] *Digital Radio Action Plan, Version 9*, DCMS, June 2013, https://www.gov.uk/government/publications/digital-radio-action-plan.

[79] *Communications Market Report 2013*, Ofcom, August 2013, http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr13/2013_UK_CMR.pdf.

Technology and receiver standards

A11.15 DAB+, a standard developed more recently than DAB, uses a more efficient audio coding standard and can provide benefits including additional services, improved audio quality or more robust error correction (enhancing coverage for a given transmitter power). DAB+ could also potentially reduce the spectrum requirements of radio broadcasting, but it would be likely to be unpopular to require consumers to make a second digital set upgrade via an enforced migration of all current services to DAB+, without a noticeable improvement in the service provided or over a long period of time. Nevertheless, there is the potential for a gradual migration of services to DAB+, subject to appropriate regulation, as the uptake of DAB radios with DAB+ capability increases.

A11.16 The emergence of software-defined radio techniques is enabling opportunities for small-scale DAB transmissions. Although DAB is traditionally associated with relatively large infrastructure costs and specialised transmission equipment operating at high powers, experimental solutions based on software-defined radio can enable low power DAB transmissions at significantly lower costs. These techniques might, in future, facilitate transitions to DAB for community or other small-scale radio stations.

A11.17 In the long term, a general shift to internet radio and other online audio services could reduce the demand for dedicated radio spectrum, which would have a bearing on capacity and possibly coverage. The trend is dependent on the availability, quality and pricing of mobile broadband, as well as the development of suitable receivers.

Implementation and coordination of spectrum usage

A11.18 Recently published research has demonstrated the feasibility of using new wireless techniques to transmit on DAB instead of FM, on a small scale and at a relatively low cost.[80] This could allow local and community radio stations, which might otherwise find the costs of migration to the digital platform prohibitive, to improve the efficiency of their spectrum usage, potentially without regulatory oversight.

Spectrum re-purposing

A11.19 As future requirements for this sector are still being investigated, it is not yet clear whether spectrum re-purposing could be a relevant and feasible mitigation to potential future challenges.

Spectrum sharing

A11.20 As future requirements for this sector are still being investigated, it is not yet clear whether spectrum sharing could be a relevant and feasible mitigation to potential future challenges.

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[80] *Small-Scale DAB: The potential for lower-cost transmitting stations in support of DAB rollout*, Ofcom, August 2013, http://stakeholders.ofcom.org.uk/binaries/research/radio-research/Software-DAB-Research.pdf.

International factors

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Radio Broadcasting	G	G	✓✓	✓	×	×	◔

A11.21 DAB+, DMB[81], DRM[82] and DRM+ are digital radio technologies used in other parts of the world that can be more spectrally efficient than DAB, or could potentially offer other advantages over DAB. DRM and DRM+ are not widely adopted technologies, in either transmission or availability of receivers. The UK's DAB market is comparatively small, meaning that substantial economies of scale for equipment manufacturers are difficult to achieve. However, steps towards a single European digital radio receiver standard (incorporating the ability to decode DAB, DAB+ and DMB transmissions) could lead to greater economies of scale, and potentially ease a future transition to more advanced radio transmission standards. In addition, DAB, DMB and DAB+ encoded services can all be transmitted within the same DAB multiplex. However, currently the majority of digital radio sets in the UK can only receive the original DAB standard, and a migration to alternative technologies is unlikely to be viable in the short to medium term. In addition, even though there is significant use of DAB in some countries (e.g. Denmark, Norway and Germany), no other administration has yet indicated any intention to switch off their FM services.

A11.22 The Regional Radiocommunication Conference 2006 (RRC-06) included planning of VHF Band III. Future UHF replanning could potentially lead to a need to revisit this area. The Federal Communications Commission (FCC) in the USA, for example, plans to use VHF Band III for TV. However, VHF replanning would be very costly, requiring a complete overhaul of the infrastructure currently in place, and upgrades of consumer receivers, and therefore it looks unlikely. In addition, revisiting RRC-06 would take a very long time to achieve – at least four years from a decision by the ITU.

[81] Digital Multimedia Broadcasting.
[82] Digital Radio Mondiale.

Section 12

Aeronautical and Maritime Communications

Introduction

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Aeronautical and Maritime Coms	G	G	✓	✓	×	×	◕

A12.1 In addition to radiotelephony, the aeronautical and maritime sectors use spectrum for a range of applications such as: radar, navigation, communications and safety related services. These sectors play a major role in the UK economy.

A12.2 Spectrum is a critical and regulated input to the aeronautical and maritime sectors, and much of its use of spectrum is mandated, e.g. to ensure safety of life in the delivery of these services. As such its value is primarily reflected in the private value of commercial airlines, airports and ports. However, there is also wider social value in the sectors' use of spectrum, e.g. through ensuring safety of life for people around airports and under flight paths.

A12.3 The most important characteristic to note about these sectors' use of spectrum is that they are inherently global in nature and require equipment to be able to be moved between countries whilst seamlessly continuing to operate, e.g. between different aircraft control centres. This requires all equipment both in airports and ports (as well as that on aircraft and ships) to work in common bands and to common equipment standards. This need is reflected in the international regulatory framework that regulates aeronautical and maritime communications. The other major characteristic of these sectors is the need for international safety regulation to ensure consistency of safety requirements across national administrations.

A12.4 The international nature of these sectors is reflected in the extent to which the international regulatory regime influences the use of spectrum by the sector. As a result we discuss this aspect of the sector in more detail below.

A12.5 For the civil aviation sector the international safety regulator is the International Civil Aviation Organisation (ICAO) and for the maritime sector it is the International Maritime Organisation (IMO). Both have a role in all aspects of the sector related to communications and safety and both liaise closely with the ITU. In the case of ICAO, they have responsibility for developing international operational and technical standards (e.g. SARPS[83]) that consider spectrum and non-spectrum aspects of aviation. Aviation is also subject to regulation by the European Commission.

A12.6 For the maritime sector, IMO plays a role in technical standardisation through IMO Radiocommunications Circulars and the requirements of the 1974 International Convention for the Safety of Life at Sea (SOLAS).

[83] Standards and Recommended Practices.

A12.7 In both sectors technical standardisation is linked to the published spectrum allocations in the ITU Radio Regulations (RR) and associated ITU Recommendations. These draw upon the international nature of their respective sectors with both sectors often enjoying exclusive allocations of spectrum due to the related safety considerations (i.e. reflected in the ITU RR).

A12.8 UK representation to the IMO is primarily led by the Maritime and Coastguard Agency (MCA), an agency of the Department for Transport. Ofcom's participation in IMO concentrates on consideration of spectrum requirements. Ofcom represents the UK in international institutions directly related to the use of spectrum and that are relevant to both sectors, including the ITU, ECC[84] and relevant Groups in the EU.

A12.9 At the UK national level, the Civil Aviation Authority (CAA) and the MCA are the specialist regulators for aviation and maritime respectively, with specific responsibility for safety regulation. In conjunction with DfT they implement international regulations and UK Government sector-related policy. Many of these policies draw upon the ICAO and IMO requirements that are based on the ITU spectrum allocations to the sectors. At a spectrum level, States may deviate from the international allocations, as long as other countries are not adversely affected. However, the global nature of the aviation and maritime sectors means that the scope for any State to act unilaterally is limited. This is particularly true of the UK, given our geographic proximity to so many other States.

A12.10 In the case of the aeronautical sector, the CAA also issues, on Ofcom's behalf, WT Act licences and is under a statutory duty from DfT[85] to act as band manager, which it does in coordination with the European Organisation for the Safety of Air Navigation (Eurocontrol) and to meet regulatory requirements set by the European Commission within Single European Sky legislation. Only Ofcom can set the licence conditions of use reflected in these WT Act licences. Eurocontrol is the European agency responsible for pan-European air traffic management in the upper airspace.

A12.11 In the case of the maritime sector, Ofcom is responsible for issuing WT Act licences and acts as band manager in making individual assignments, but we work closely with the MCA on international negotiations and on spectrum use more generally.

A12.12 In both sectors, our ability to change existing, or create new, aeronautical/maritime allocations is limited. This is because, in many cases, the core spectrum requirements are closely linked to sector-specific regulations. On the other hand, Ofcom can have an important role to play, especially where potential co-existence issues with other services might arise.

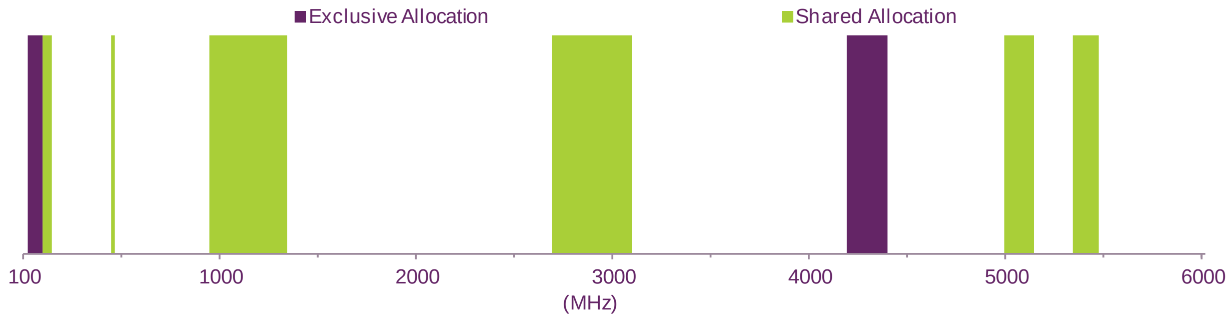
A12.13 The inherent global environment in which these sectors operate also affects the pace of change in technology, applications and the consequent use of spectrum. Due to the need to coordinate change regionally or even globally at the very detailed operational level, change generally takes longer than in other sectors. The maintenance of safety-of-life services is central to both sectors. This means there are more robust assessment approaches and a more conservative attitude to change, which also affects the pace of change.

A12.14 Figure 12 below gives an indicative illustration of the bands currently used by the sectors between 100 MHz and 6 GHz. There are further aeronautical and maritime

[84] Electronic Communications Committee.
[85] See: http://www.caa.co.uk/docs/7/DfT%20CAA%20Directions.pdf.

allocations throughout the spectrum below and above this range, e.g. at 9 GHz, 13 GHz and 15 GHz.

Figure 12: Indicative illustration of bands currently used by the sectors in the UK



Potential sectoral challenges

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Aeronautical and Maritime Coms	G	G	✓	✓	×	×	

Demand trends

A12.15 In both sectors there is likely to be an increase in data-based communications systems for both voice and data over the medium to long term. This additional demand is likely to be met from existing terrestrial allocations or existing and planned commercial satellite capacity that will not require additional allocations with a specific aeronautical or maritime designation.

A12.16 In the aeronautical sector, any increase in flight traffic may increase demand for spectrum in the short to medium term. Eurocontrol cites forecasts that air traffic levels will double by 2020, while noting that the rate of growth has slowed in recent years. In addition, Remotely Piloted Aerial Systems (RPAS) use is expected to increase significantly over the next decade, particularly in civilian applications. Existing aeronautical spectrum has been identified for use by RPAS, and there are ongoing international discussions looking at potential spectrum alternatives.

Potential changes in supply

A12.17 The Government, in its PSSR programme, has identified spectrum in the 2.7-2.9 GHz range, currently used for aeronautical and maritime radar, as a potential release for commercial uses. In addition, 2.7-2.9 GHz is among a number of bands being considered to provide additional spectrum for the mobile service at WRC-15, under AI 1.1. However, these potential releases will be subject to considering the potential effects on safety.

A12.18 Other Agenda Items at WRC-15 which are directly relevant to the aeronautical and maritime sectors, and may have a bearing on their supply of spectrum, are discussed below under international factors.

A12.19 A number of changes were agreed at WRC-12 to Appendix 18 of the RR. This is the list of internationally recognised VHF maritime channels (principally for the purpose of radiotelephony). These changes considered spectrum that was considered to be underutilised in its current use and identified a range of new and important maritime uses for this spectrum. These uses included future maritime digital technologies and Automatic Identification System (AIS) applications. These changes are due to be implemented by 2017, although individual States may opt out if doing so, as long as that does not adversely affect other States' use of the channels. Implementation of new digital technologies and AIS applications will be discussed, in parallel, in the IMO.

A12.20 In the maritime sector, new UHF onboard communications working has resulted in discussions internationally about making further allocations to enable greater use of this approach, but at this stage of the international discussions this is unlikely in the medium term.

Significance of changing spectrum requirements and potential urgency of enabling action by Ofcom

A12.21 As noted above, we do not participate directly in the work of ICAO and our role in IMO is limited and is through the UK MCAI; as a result we are not as close to developments in this sector as we are with many others. A report conducted by Aegis for Ofcom in 2007 concluded there was no prospect of a material shortage of spectrum for these sectors,[86] and none of the forecast developments seem likely to significantly alter that assessment.

A12.22 Based on this evidence we anticipate that the aeronautical and maritime sectors will remain broadly stable, in terms of the demand for and supply of spectrum, over the short, medium and long term. The pace of technological and regulatory change is slower than in other sectors. New sector-based applications under development are expected to be rolled out over an extended period and will largely be accommodated within existing spectrum allocations.

Potential mitigations

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Aeronautical and Maritime Coms	G	G	✓	✓	✗	✗	◕

Technology and receiver standards

A12.23 The shift to digital equipment in both sectors is expected to improve the spectral efficiency of these services but it is possible that these gains will be offset by a limited increase in demand from sources such as new communications systems, as discussed above. Also, as noted above, implementation normally takes longer in these sectors than in others (e.g. the ICAO has indicated a likely timeframe of 35 years for digitisation for the aeronautical sector).

A12.24 A more immediate issue is the move from 25 kHz to 8.33 kHz channel sizes in VHF band plans in Europe. Superficially, this should make more spectrum available, although this benefit will be delayed until ICAO rules on channel sizes are revised to mandate these smaller channel sizes. This will not be possible until all nation states confirm that they are able to comply with this change.

86 *Aeronautical and Maritime Spectrum Pricing*, Aegis, April 2007, http://stakeholders.ofcom.org.uk/binaries/research/spectrum-research/aipreport.pdf.

A12.25 The CAA has commissioned a study looking at how non-cooperative surveillance requirements can be met through emerging technologies, in order to future-proof surveillance, better mitigate the effects of wind farms, and potentially facilitate the release of spectrum. This work is led by the CAA and DfT; but, as it has important implications for spectrum use in the UK, we have an advisory role.

Implementation and coordination of spectrum usage

A12.26 In the aeronautical sector, in particular, the replanning or re-equipping of old radar with more efficient technology might provide an opportunity to reduce significantly the spectrum requirements for radar in the UK. The DfT and CAA would oversee any such initiative. As with many changes of spectrum use the process can be logistically difficult, time-consuming and costly. However, for example at 2.7-2.9 GHz, the benefits could be significant and outweigh these costs. Such a replan would also require testing and safety evaluation before implementation.

Spectrum re-purposing

A12.27 Spectrum re-purposing is not anticipated to be required to meet growing aeronautical and maritime demands.

Spectrum sharing

A12.28 Spectrum sharing is not anticipated to be required to meet growing aeronautical and maritime demands and presents some significant challenges in order to maintain the appropriate protection of safety-of-life spectrum.

International factors

Spectrum uses	Significance of potential changes	Urgency	Technology and receiver standards	Implement-ation and coordination	Spectrum re-purposing	Spectrum sharing	International factors
Aeronautical and Maritime Coms	G	G	✓	✓	✗	✗	◕

A12.29 Under direction from Government, we represent the UK in CEPT, ITU and at WRCs on issues relating to these sectors. In this regard we will continue to work closely with industry, the CAA and the MCA.

A12.30 In the short to medium term, international discussions that will be concluded at WRC-15 will address two Agenda Items directly related to the aviation sector (AI 1.5 and AI 1.17). AI 1.5 is to consider RPAS making use of frequency bands allocated to the fixed satellite service, in non-segregated airspace (which is a term that refers to areas outside any national aviation control/management). AI 1.17 is to consider spectrum allocations to support an application referred to as Wireless Avionics Intra-Communications (WAIC) (subject to approval by ICAO). The primary function of the WAIC application is the replacement of airplanes' wired infrastructure, which is used to control flight-related systems, with a wireless alternative, principally monitoring and telemetry. This is explained in the ITU report ITU-R M.2197.[87] The 2.7-2.9 GHz band is one of three bands currently being studied internationally for this application, the others being 4200-4400 MHz and 5350-5470 MHz.

[87] See: http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2197-2010-PDF-E.pdf.

A12.31 The discussion of the proposal to consider RPAS making use of frequency bands allocated to the fixed satellite service (AI 1.5) are ongoing and, whilst the final outcome is still to be finalised, there is not expected to be a material change at a UK national spectrum level. However, the 2.7-2.9 GHz band may require assessment and evaluation in the UK in the event of any potential release under PSSR, and where the band is identified, internationally, for WAIC.

A12.32 WRC-15 Agenda Items 1.15 (AI 1.15) and 1.16 (AI 1.16) are relevant to the maritime sector. AI 1.15 to consider spectrum demands for UHF onboard communication stations for the maritime mobile service. AI 1.16 is to consider additional allocations to enable new radiocommunication applications, including AIS technology, used for tracking vessels, maritime assets and hazards.

Section 13

Amateur Radio

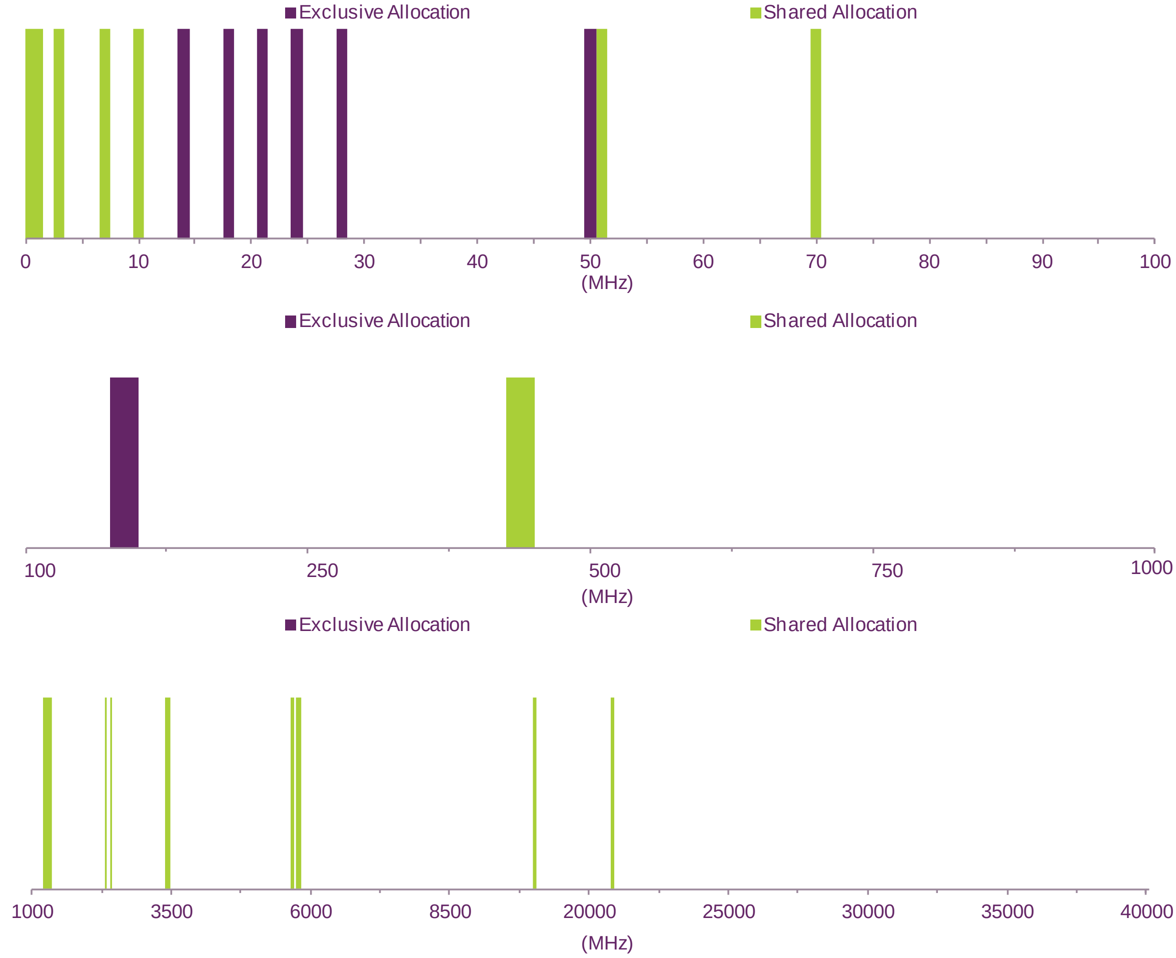
A13.1 This section does not follow the structure of those above, as many of the factors that we consider elsewhere are less applicable to the amateur radio sector. Instead this section provides a high-level overview of the sector.

A13.2 Amateur radio is the use of spectrum for non-commercial communication (including radio hobbyists), training and experimental purposes. Amateur satellite services use space stations or satellites for the same purposes. Amateur radio can foster technical innovation in fields such as telecoms, broadcasting and aerospace, playing a part in the development of new radio technologies.

A13.3 Most countries allocate internationally harmonised bands to amateur radio, often on a secondary basis, sharing with military use. The International Amateur Radio Union (IARU) coordinates amateur radio around the world, while national governments or National Regulatory Authorities (NRAs) licence radio amateurs based on applicants' understanding of the field. We issue several classes of Amateur Licenses, each recognising a particular degree of technical competence.

A13.4 At present, radio amateurs in the UK have access to 53 different bands from 135.7 kHz to 250 GHz, primarily sharing with other users on a secondary basis. These bands have various uses, depending on their propagation characteristics, and the range of bands available means that radio amateurs communicate across cities, regions, and continents, or across space using text, voice, images and data modes. Figure 13 below gives an indicative illustration of the bands currently used by the sector under 40 GHz.

Figure 13: Indicative illustration of bands currently used by the sector in the UK



A13.5 It is difficult to estimate the economic value of amateur radio, for example through its contribution to GDP, as its purpose is not to bring about financial returns but to promote innovation and skills. In 2006 we commissioned a study that estimated the non-commercial aviation, amateur radio and the citizens' bands to have a producer surplus of £114m and a consumer surplus of £10m (2006 prices).[88] A report published by the Radiocommunications Agency in 2001 estimated the consumer benefit of amateur radio licences to be £2.6m (2002 prices).[89] However, it is likely that amateur radio has additional wider social value from its role in promoting innovation and skills.

A13.6 Amateur radio also has wider social value as a means of emergency communication, a role recognised by the Civil Contingencies Secretariat within the Cabinet Office. The Radio Amateurs Emergency Network (RAYNET) often works with Local Authority emergency planning departments.

A13.7 The use of amateur radio to facilitate training and education in emerging digital technologies and software-defined radio in particular suggests that the number of radio amateurs may remain steady or increase in the long term.

[88] *Economic Impact of the use of radio spectrum in the UK*, Europe Economics, November 2006, http://stakeholders.ofcom.org.uk/binaries/research/spectrum-research/economic_impact.pdf.
[89] *The Economic Impact of Radio*, Radiocommunications Agency, February 2001, at http://www.ofcom.org.uk/static/archive/ra/topics/economic/eis-report.pdf.

A13.8 The requirements of other sectors of spectrum users may mean that radio amateurs may have reduced access to some spectrum bands that they currently use over the long term. Where this is a prospect we consult on the issue – and are currently doing so with respect to the 2.3 and 3.4 GHz bands that form part of the Government's PSSR programme.