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FINAL REPORT FOR THE SPECTRUM POLICY FORUM

UK SPECTRUM USAGE AND DEMAND

SECOND EDITION

Prepared by Analysys Mason for the UK Spectrum Policy Forum

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Contents

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About this report

This report has built on contributions received from many individuals and companies within the Spectrum Policy Forum (SPF), during a series of workshops conducted during 2018.

The report makes no attempt to cover every sector of spectrum use but covers the main sectors critical to businesses, citizens and consumers in the UK market (including business radio, utilities, Emergency Services, fixed wireless systems, satellite services, public mobile, digital terrestrial television and programme making and special events). The SPF notes there are developments in spectrum use in other sectors not extensively covered in this report (e.g. short-range devices (SRD), transport and medical services).

Analysys Mason's thanks go the following organisations who have provide contributions included in this report – Joint Radio Company, Federation of Communication Services, Digital Television Group (DTG) PMSE Group, Digital UK, Ofcom, Home Office, Global Suppliers Association, Avanti and members of the SPF Steering Board (see below).

About the UK Spectrum Policy Forum

Launched at the request of Government, the UK Spectrum Policy Forum is the industry sounding board to Government and Ofcom on future spectrum management and regulatory policy with a view to maximising the benefits of spectrum for the UK. The Forum is open to all organisations with an interest in using spectrum and already has over 150-member organisations. A Steering Board performs the important function of ensuring the proper prioritisation and resourcing of our work.

The current members of the Steering Board are:

- Airbus Defence and Space
- Avanti
- BT
- Department for Culture Media & Sport
- Digital UK
- Huawei
- Inmarsat
- Ofcom
- Plum Consulting
- QinetiQ
- Qualcomm
- Real Wireless
- Sky
- Telefonica
- Vodafone.

About techUK

techUK facilitates the UK Spectrum Policy Forum. It represents the companies and technologies that are defining today the world we will live in tomorrow. More than 900 companies are members of techUK. Collectively they employ approximately 800 000 people, about half of all technology sector jobs in the UK. These companies range from leading FTSE 100 companies to new innovative start-ups.

About Analysys Mason

Analysys Mason is a trusted adviser on telecoms, media and technology. We work with our clients, including operators, regulators and end users, to:

- design winning strategies that deliver measurable results
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With around 245 staff in 16 offices worldwide, we are respected internationally for our exceptional quality of work, independence and flexibility in responding to client needs. For over 30 years we have been helping clients in more than 110 countries to maximise their opportunities. For further information see www.analysysmason.com.

1 Summary of key points

The SPF's workshops during 2018 have aimed to identify significant trends in spectrum use and their impact on future spectrum demand. The intention is that these can be used as inputs to future UK spectrum policy, as well as to facilitate a joined-up view across industry on sector needs.

Since the SPF produced its previous report on spectrum demand in 2015[1], there has been growing demand for spectrum in the mobile sector to accommodate new fifth generation (5G) services, which will exploit new technology and operate in higher frequency bands. Higher frequency bands for 5G will be considered globally at the ITU World Radiocommunication Conference in 2019 (WRC-19). There is also growing demand for wider channel widths for fixed wireless systems to increase capacity (e.g. for wireless backhaul). Some current bands used by fixed wireless systems are now under consideration for 5G. Options to enable 5G use within bands currently allocated for fixed and/or fixed satellite use include transitioning of existing services, and/or geographic sharing.

A key challenge for the satellite industry is that bands used by the satellite sector are increasingly being sub-divided for different space and terrestrial uses and hence the industry is seeking to improve access to existing allocations, such as in Ka-band. The ITU World Radiocommunication Conference in 2023 (WRC-23) is expected to consider the results of studies on future use of the UHF spectrum 470–960MHz band, and to consider possible policy actions (e.g. whether changes to existing allocations are needed). This spectrum is important for mobile services as well as for digital terrestrial television (DTT) and programme making and special events (PMSE). The broadcast industry expects that continued access to UHF spectrum for DTT is needed until at least 2030, also confirmed in Ofcom's 'Public service broadcasting in the digital age' publication from March 2018.

A summary of the key points is as follows.

Public mobile

Ofcom is encouraged to progress with award of 5G spectrum in the UK including 3.6–3.8GHz, 700MHz and 26GHz	Ofcom's auction of spectrum in the 3.4–3.6GHz band, which was concluded in early 2018 has provided the four nationwide mobile operators with 5G-suitable spectrum for initial 5G launch. It is expected that additional frequency bands for 5G use will be made available by Ofcom over the next 1–2 years – this includes spectrum in the 3.6–3.8GHz band, in 700MHz and in millimetre-wave bands, principally 26GHz. The SPF's discussions are supportive of Ofcom's continued preparations for making this bands available for 5G use. The SPF notes that clearer intentions on award of licences in the 26GHz band would be helpful to avoid the UK falling behind other markets on award of millimetre-wave spectrum.

1 https://www.real-wireless.com/calculating-the-future-uk-spectrum-usage-and-demand/

Demand for 5G spectrum could come from neutral host providers or enterprises, as well as from nationwide network operators

With the possibility of 5G driving new business models – including potential demand for bespoke coverage and services in specific locations – there might be demand for novel approaches to licensing some spectrum, to enable localised use, and possible shared access between multiple providers. Cluster 2 of the SPF has been considering innovation in licensing approaches and a recent workshop considered tiered licensing approaches, enterprise networking requirements and spectrum-sharing models for 5G as well as considering the benefits of more traditional licensing schemes[2]. There could also be demand for spectrum for new types of mobile deployment – neutral host service providers, for example. Ofcom will need to consider how the economic benefits derived from use of the spectrum can be maximised and which schemes are most suitable to different frequency bands.

Studies are on-going into feasibility of sharing between 5G and existing fixed and fixed satellite services and the results of these studies will be important inputs to confirm UK licensing approaches

Studies into co-existence of 5G with existing fixed and fixed satellite uses in several bands under consideration for 5G (3.8–4.2GHz, 26GHz and 28GHz) are on-going with the relevant CEPT and ITU-R working groups. Options to enable 5G use within bands currently allocated for fixed and/or fixed satellite use include transitioning of existing services, and/or geographic sharing. Studies are suggesting that it would not be feasible to implement co-frequency, co-coverage between 5G and existing fixed, and fixed satellite services. The SPF notes that Ofcom is studying alternative options and the SPF would be keen to contribute to this on-going work.

The mobile industry is supportive of the 24.25–27.5GHz and 37.0–43.5GHz bands being identified for IMT/5G use at WRC-19, and also supports further consideration of IMT use in the ranges 45.5–50.2GHz and 50.4–54.6GHz

An important milestone for the mobile industry is the ITU World Radiocommunication Conference in 2019 (WRC-19), which will address studies currently being conducted within ITU-R study groups on new spectrum bands for 5G ('International Mobile Telecommunications' as defined by the ITU) under WRC-19 agenda item 1.13. Mobile industry views are in support of the 24.25–27.5GHz and 37.0–43.5GHz frequency ranges being identified for IMT/5G use at WRC-19. The mobile industry also supports further consideration for IMT use in the ranges 45.5–50.2GHz and 50.4–54.6GHz (noting that the 47.2–48.2GHz band is being envisaged for 5G use in the USA, which may stimulate demand in other regions). Other bands supported

2 https://www.techuk.org/insights/meeting-notes/item/13932-uk-spf-cluster-2-innovation-licensing-rural-enterprise

include 66–71GHz, which Ofcom has already identified as a possible band for 5G use in the UK in its 5G strategy.

BR, utilities and emergency services

There is growing use of mission-critical data in the BR sector alongside voice traffic. Although LTE technology is being developed to provide enterprise services, there will continue to be demand for BR spectrum in the UK, with BR systems having successfully met niche business demands to date

There continues to be strong demand for BR services in the UK within the frequencies allocated in the VHF and UHF bands. Although mission-critical *voice* traffic is the dominant BR service, there are expectations of mission-critical *data* traffic becoming more widespread in future. The SPF notes that increasing functionality of cellular networks might mean that enterprise and business traffic traditionally carried over BR systems could be carried over 4G or, in future, 5G mobile networks. BR users will tend to choose the services and technologies that best meet their user needs. However, it would appear that BR systems, having successfully met niche business demands to date, will continue to be in demand in the UK market in future, even if some users might also use mobile networks alongside this (as is the case today).

There is a question as to whether additional dedicated spectrum for use by critical infrastructure/utility might be needed, possibly in the 400MHz band; the SPF understands Ofcom is considering this

There is an issue concerning how critical infrastructure (e.g. for utilities use) might be delivered in future. Currently, utilities use BR-type spectrum in several bands, including VHF and UHF. The JRC's presentation to the SPF highlighted examples from other European countries where dedicated 400 and/or 450MHz spectrum is being used to provide critical utility services. There is a question as to whether there is a need for similar dedicated spectrum for 'critical infrastructure' in the UK.

In discussion, the SPF noted that licence-exempt spectrum is available for M2M and IoT use in the 800MHz. However, the 400MHz band is potentially of interest due to the potentially favourable operating conditions within a licensed 400MHz environment. Hence, if dedicated spectrum is needed for utility and/or critical infrastructure use, the properties of the 400MHz band are particularly favourable. This is partly due to the propagation characteristics of this band for reaching locations that are difficult to cover, but also because utility companies already use frequencies in the 400–470MHz band for telemetry, meaning that they have an existing network of transmission sites, and equipment, that would be compatible with a 400MHz network grid.

There is a need to find spectrum for emergency services' direct-mode communications	There is need for spectrum to be identified to support LTE-based direct-mode operation for the emergency services. The SPF understands that a preferred option for this might be in the 700MHz band (e.g. centre gap spectrum).

DTT and PMSE

There is continued demand for linear TV viewing and expectation that continued access to UHF spectrum for DTT is needed until at least 2030	Traditional linear TV viewing via DTT has declined less rapidly than might have been expected. Development of hybrid platforms such as Freeview Play offers consumers the possibility to select a mix of linear, catch-up and on-demand services best fitting their household requirements, which is proving popular. The broadcast industry expects that continued access to UHF spectrum for DTT is needed until at least 2030, which is confirmed in Ofcom's 'Public service broadcasting in the digital age' publication from March 2018.
While many in industry are preparing for increasing TV and radio consumption over IP, there remain coverage and pricing challenges associated with distributing linear broadcast content via mobile and fibre networks	Developments in mobile and full-fibre connectivity, as partly determined by UK Government policy, are relevant to the future of DTT. The BBC has indicated that it expects all-IP distribution to happen in future, but key challenges remain in using mobile and/or fibre networks. Challenges include coverage (noting that DTT coverage for PSB MUX reaches 98.5% of UK homes, whereas mobile coverage into buildings is variable, depending on network configuration and frequencies use), and data pricing (noting that 'unlimited' access to IP bandwidth will be needed for linear broadcasting).
Studies on future use of the 470–960MHz band are needed for WRC-23	Resolution 235 'resolves' to invite the WRC in 2023 to consider the results of studies on future use of the 470–960MHz band, and to consider possible policy actions (e.g. whether changes to existing allocations are needed). There has been limited work to date within the ITU-R to address this resolution – one industry participant has proposed a new ITU-R report (termed 'IMT-TV-600') however this has not been progressed to date.

700MHz clearance will reduce useable UHF spectrum for audio PMSE, whilst demand continues to grow. Any further reduction in DTT interleaved spectrum availability will cause significant issues for PMSE users

The 700MHz clearance project will reduce the useable spectrum for audio PMSE. This reduction is unlikely to be offset by increases in efficiency from digital equipment use in the short term, given the time needed by the industry to migrate to digital use. There is also a likelihood of increased demand for spectrum for 'bigger and better' shows, and demand for higher resolution in PMSE. Any further reduction in DTT interleaved spectrum availability would severely impact the PMSE audio sector and would cause significant difficulties for the UK creative industries.

Whilst appreciating Ofcom's initiative on making available spectrum in 960–1164MHz for audio PMSE use, economic feasibility of using this spectrum is still in question

Whilst the PMSE industry broadly appreciates Ofcom's initiative in proposing to make the 960–1164MHz available for audio PMSE use, greater certainty on availability is needed to ensure that equipment will become available within reasonable timeframes, and at reasonable cost. At present, there appear to be risks of delay to this spectrum being economically feasible, whilst compatibility issues are further investigated, and until equipment becomes available. Based on SPF discussions, it is noted that National Air Traffic Services (NATS) opposes use of the spectrum for PMSE. Further consideration would be helpful on whether access to existing European harmonised bands for PMSE can be improved in the UK, especially where there is good supply of equipment to use the spectrum, but the bandwidth is not available in the UK (e.g. the VHF channels, not available due to current DAB use).

Fixed and space services

Fixed wireless and satellite spectrum bands are increasingly being considered for other uses, including 5G and HAPS, whilst there is demand for wider channel widths for fixed link use

A key trend recognised by the industry and by Ofcom is that fixed wireless and satellite spectrum is increasingly being considered for other uses, including 5G as well as alternative delivery platforms such as HAPS. At the same time, there is demand for wider channel widths to be available for fixed-link use to increase capacity of links, meaning that consideration of possible new bands for fixed-link use (e.g. W and D bands) is needed. The SPF is supportive of Ofcom's initiatives in this regard and supports Ofcom's action to update the spectrum management approach in the 57–71GHz band.

Bands used by the satellite sector are increasingly being sub-divided for different uses, causing increased complexity and risk of interference. Unlike fixed wireless systems, it is not possible to re-deploy satellite services in higher bands

A key challenge for the satellite industry is that bands used by the satellite sector are increasingly being sub-divided for different space and terrestrial uses, causing increased complexity in the planning and co-ordination between systems, and giving rise to increased risk of interference. Whereas technological advances might allow fixed wireless services to use higher frequency bands in the immediate future, it is not possible to re-deploy satellite services in higher bands due to propagation limitations as well as the bespoke nature of satellite constellations (being designed to operate in specific bands).

Specific concerns of the satellite industry are on preserving satellite access to the Ka-band where increased use of mixed GSO and non-GSO satellite is being accommodated

The key goal for the satellite sector for the upcoming WRC-19 is to retain and to improve access to existing satellite bands. With the Ku satellite band already congested with heavy incumbent satellite use, and growing pressure on C-band capacity resulting from increasing use of this band for mobile services, there is strong concern from the satellite industry that existing satellite access to Ka-band should be preserved, and improved, to accommodate mixed GSO and non-GSO satellite needs in this band. Any reduction in availability of Ka-band spectrum would severely affect the satellite sector. A specific concern is new uses of the spectrum around 28GHz, which has been earmarked for 5G use in some markets outside of Europe, although not part of the ITU-R studies in the context of agenda item 1.13. The view of the satellite industry is that satellite use must be fully protected if WRC-19 takes any actions on new uses of this band.

2 Introduction

This draft report has been prepared by Analysys Mason on behalf of the UK Spectrum Policy Forum (SPF). The report summarises the outcome of the SPF's discussions within its Cluster 1 group during 2018 regarding trends in spectrum use, and implications for future spectrum demand and for UK spectrum policy.

Cluster 1 of the SPF is concerned with current and future spectrum needs, with the goal of building a 'joined-up' understanding of UK spectrum use across different sectors.

The SPF commissioned Analysys Mason to produce this report to provide a summary of the discussions within Cluster 1 during 2018. The report builds on an earlier report published by the SPF in 2015 on spectrum demand, prepared by Real Wireless[3]. As with the previous report, this report has been produced for publication by the SPF, to inform:

- UK Government and Ofcom involved in spectrum policy
- UK spectrum users, to foster a joined-up understanding of spectrum use and needs
- other work in the SPF, relating to spectrum access mechanisms, impact of spectrum and future World Radiocommunications Conference (WRC) agenda items.

2.1 Scope and approach

The scope of work was to assess trends in use of wireless connectivity and demand for spectrum across several sectors of UK spectrum use, and specifically covering:

- public mobile networks
- business radio (BR), utility networks and emergency services
- fixed and fixed satellite services
- terrestrial television broadcasting, and programme making and special events (PMSE).

The approach taken has been to invite representatives from each of the sectors to give presentations and participate in discussions within a series of workshops organised within Cluster 1 of the SPF during 2018. Analysys Mason then used this material, along with its own sources where needed, to produce a draft final report. Members of the SPF Steering Board then reviewed this draft final report and Analysys Mason has incorporated comments from the review into this version for publication.

3 https://www.real-wireless.com/calculating-the-future-uk-spectrum-usage-and-demand/

2.2 Structure of document

The remainder of this document is laid out as follows:

- Sections 3 to 6 provides details of the specific spectrum need of each sector who have contributed to this report

The report includes several annexes:

- Annex A lists abbreviations used in the report
- Annex B lists references to published documents referred to in this report.

3 Public mobile

This section of the report discusses trends in use of spectrum for existing public mobile networks, as well as spectrum demand for evolution to the next generation (5G) of radio access networks. Although mobile networks are currently used predominantly for consumer broadband services, the 5G era is likely to herald a much more diverse array of uses and services.

The structure of the public mobile market in the UK was extensively discussed in the previous SPF report on spectrum demand. The following section includes an update on public mobile spectrum usage since the previous report, and considers trends in demand and spectrum requirements, including for 5G.

3.1 Scope of the sector

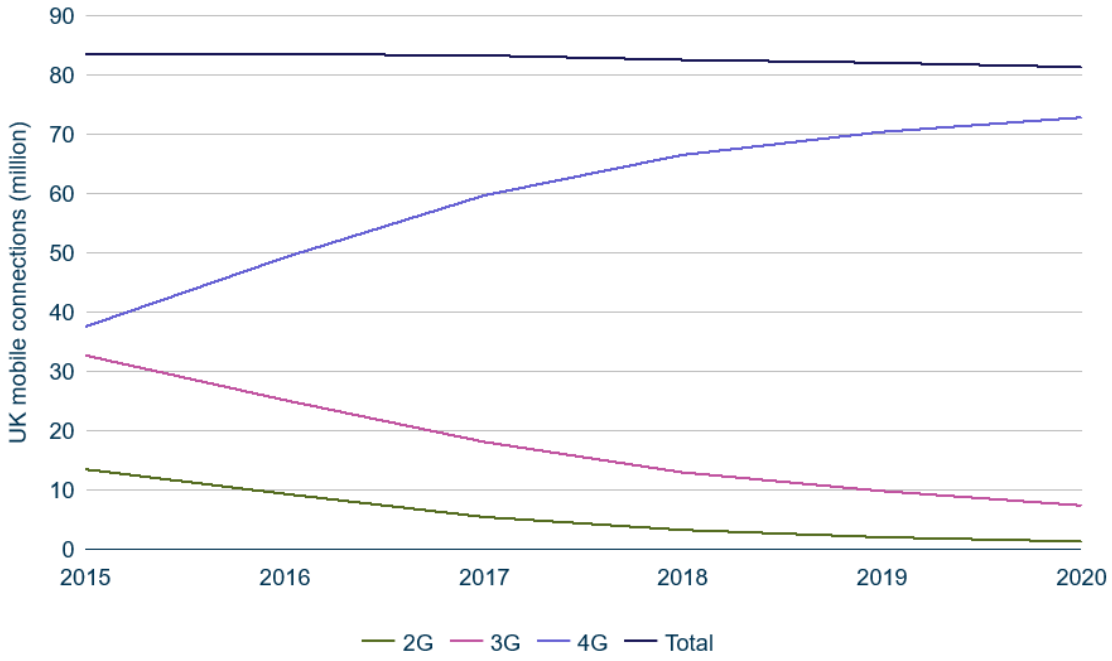
Public mobile or cellular mobile networks are operated in the UK by Vodafone, Telefónica (marketing its services under the O_2 brand), EE (part of the BT Group) and Hutchison 3G (which markets its services under the 3 brand).

The mobile systems currently in use include second-generation (2G, the digital system using GSM technology), third-generation (3G, using WCDMA and HSPA technology) and fourth-generation (4G, using LTE, and LTE-A) technology. 4G is now widely adopted in the UK and operators have 're-farmed' parts of their 2G and 3G assignments, for 4G use.

Vodafone, O_2 and EE operate 2G, 3G and 4G mobile networks, whereas 3 operates 3G and 4G mobile networks only.

Mobile networks have experienced rapid evolution in terms of data rates and use of data services in recent years, in line with user demands. The number of 2G and 3G connections in the UK market has declined as 4G use has increased, and forecasts suggest this decline will continue steadily between now and 2020.

Figure 3.1: UK mobile connections, and growth in 4G connections [Source: Analysys Mason, 2018]



As user demand evolves, future mobile networks will need to have greater capacity, scalability and flexibility in to cater for new demand. They will need not only to be able to support increased volumes of traffic with reduced latency but also a range of new applications, including artificial intelligence (AI), autonomous control, virtual and augmented reality. In anticipation of these developing requirements, the next generation of mobile technology – 5G – is now being planned, with global discussion ongoing, and implementation in the UK likely to be from 2019 onwards. 5G is expected to bring significant advances in mobile data speeds and network performance, as well as supporting a range of new uses and business models. 5G trends are further discussed in the next section.

The current mobile technologies (2G, 3G and 4G) operate over spectrum that is licensed to the operators for use and taken from frequency bands at 800MHz, 900MHz, 1400MHz, 1800MHz, 2300MHz and 2600MHz. Network coverage using the bands below 1GHz (i.e. 800MHz and 900MHz bands currently) is the most widespread and accessible of the different bands used for mobile services in the UK, resulting from the favourable propagation characteristics of these frequencies both for wide-area coverage, and for in-building penetration. However, the capacity available at higher frequencies, combined with the new generation of mobile technology being specified for 5G deployment, will enable operators to push data rates significantly higher than is currently achievable, and to drive improved levels of service and the improved reliability needed for industrial and consumer use of mobile networks in future.

3.2 Sector trends

In parallel with completing 4G roll-out – including building new sites to extend coverage into more rural areas[4] – the mobile industry is actively preparing for 5G roll-out. EE has publicly stated that it will launch 5G services in 2019, and ahead of 5G launch, the operator is improving the speed of its 4G network by re-farming 3G spectrum (in the 2.1GHz band) for 4G use[5].

The Government has stated an ambition for the UK to be a leading 5G nation and is focussed on putting foundations and policies in place to support the delivery of maximum socio-economic benefit from 5G, and to realise the potential from 5G technology for innovation. The UK Government support for 5G is wide-ranging and includes the 5G Testbeds and Trials Programme, urban and rural connected communities, for which Government funding has/will be made available[6]. In addition to this, many UK university research departments, vendors and operators are working collaboratively, including with market verticals, to test 5G technology and operating environments.

5G combines a new radio interface (NR) using a wider range of spectrum bands and more densely deployed cells, and new virtualised architecture for mobile core networks.

Ofcom's auction of spectrum in the 3.4–3.6GHz band, which was concluded in early 2018[7][8], has provided the four nationwide mobile operators with 5G-suitable spectrum for initial 5G launch.

It is expected that additional frequency bands for 5G use will be made available by Ofcom over the next 1-2 years – this includes spectrum in the 3.6–3.8GHz band, in 700MHz and in millimetre-wave bands, principally 26GHz, in line with Ofcom's 5G strategy and the European 5G Action Plan (5GAP). Other spectrum bands are also under study for mobile use, possibly on a shared basis with existing services, such as in the 3.8–4.2GHz band. Ofcom has not confirmed its approach to licensing of 3.6–3.8GHz, 3.8–4.2GHz and 26GHz spectrum for 5G, but has consulted on possible obligations regarding mobile coverage that would be attached to licences offered in the 700MHz band. With the possibility of 5G driving new business models – including potential demand for bespoke coverage and services in specific locations – there might be demand for novel approaches to licensing some 5G spectrum, to enable localised use, and possible shared access between multiple providers. Cluster 2 of the SPF has been considering innovation in licensing approaches and a recent workshop considered tiered licensing approaches, enterprise networking requirements and spectrum sharing models for 5G[9]. There could also be demand for spectrum for new types of mobile deployment – neutral host service providers, for example.

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4 For example, see https://www.ispreview.co.uk/index.php/2018/07/scotland-hand-25m-4g-mobile-infill-contract-to-whp-telecoms.html

5 http://www.mobilenewscwp.co.uk/2018/09/24/ee-to-convert-3g-spectrum-into-4g-in-preparation-for-5g-launch/

6 The Urban Connected Communities (UCC) plans were announced by the Government in 2018, see https://www.gov.uk/government/case-studies/urban-connected-communities. A separate programme for rural communities is anticipated.

7 https://www.ofcom.org.uk/__data/assets/pdf_file/0030/81579/info-memorandum.pdf

8 https://www.ofcom.org.uk/about-ofcom/latest/media/media-releases/2018/results-auction-mobile-airwaves

9 https://www.techuk.org/insights/meeting-notes/item/13932-uk-spf-cluster-2-innovation-licensing-rural-enterprise

The UK Government has also identified improving mobile coverage as a key priority in the 'Future Telecoms Infrastructure Review' (FTIR), published by DCMS in July 2018. As indicated in the FTIR, the Government has committed to extending mobile coverage to 95% of the UK's geography by 2022. There might be spectrum implications arising from extending mobile coverage beyond current geographic, premises and other specific coverage (e.g. along major roads, and/or railways). The SPF notes Ofcom has assessed several options for including coverage obligations in the award of 700MHz spectrum. A recent publication from Ofcom refers to several other cost-reduction measures for improving coverage, including public subsidy for covering total not-spots, rural wholesale access/roaming, infrastructure sharing and easing of deployment/planning barriers[10].

3.3 Demand for spectrum

A presentation from the Global Suppliers Association (GSA) to the SPF suggests that the following frequencies will be the key bands for early 5G-NR deployment (noting that countries may make different parts of these bands available based on market demand and current uses):

- 3300–4200MHz (3.3–4.2GHz)
- 4400MHz–5GHz (4.4–5GHz)
- 24.25–27.5GHz
- 26.5–29.5GHz
- 37.0–43.5GHz.

Early 5G-NR equipment which supports the 28GHz and 3.4–3.8GHz bands is already available in 2018. Equipment that is fully 3GPP-compliant will be available in 2019 for these frequency bands. Network equipment and devices supporting other key 5G bands is expected to be available in due course, based on market demand and once licences are awarded.

The GSA's presentation highlights a desire for the mobile industry to have access to spectrum in a mix of 'low bands' (e.g. 700MHz), 'mid-bands' (e.g. 3.3–4.2GHz) and 'high bands' (above 24.25GHz):

- GSA envisages utilisation of low-band spectrum for 5G-NR for applications requiring extended range coverage. This includes certain Internet of Things (IoT) applications and to enhance existing consumer mobile broadband services coverage, as well as enabling services to deep indoor locations, and to reach rural and sparsely populated areas. There will also be a need to review regulatory conditions for 5G use of existing mobile bands below 2GHz (e.g. 800MHz, 900MHz, 1400MHz and 1800MHz), to ensure that operators are able to transition from current 2G/3G/4G to 5G use in these bands. Specifically, 5G (and advanced 4G) might use active antenna systems and hence licensing conditions should support this use.

- The 5G 'mid-band' spectrum – which in the UK is likely to be in the bands 3.4–3.6GHz (already assigned for 5G use), 3.6–3.8GHz (to be awarded) and 3.8–4.2GHz (under consideration by

10 https://www.ofcom.org.uk/__data/assets/pdf_file/0017/120455/advice-government-improving-mobile-coverage.pdf

Ofcom) – offers the potential for both capacity and coverage for mobile broadband services, including ultra-reliable services. The GSA's view is that 100MHz contiguous blocks will achieve the most efficient 5G-NR deployment for operators. These 100MHz contiguous blocks are not currently available in the mid-band spectrum assigned for 5G UK and achieving wider contiguous blocks will depend on subsequent awards e.g. in 3.6-3.8GHz (and possible re-positioning of blocks).

- 5G 'high-band' spectrum in the 26/28GHz and 40GHz bands could be suitable for several 5G-NR applications such as mobile broadband services in areas of high footfall, high-capacity connectivity along railways, and localised coverage (e.g. for enterprise and/or IoT use). The GSA's goal is that regulators should make available 1GHz of spectrum per 5G network in these bands.

An important milestone for the mobile industry is the ITU World Radiocommunication Conference in 2019 (WRC-19), which will address studies being conducted within ITU-R study groups currently on new spectrum bands for 5G ('International Mobile Telecommunications' as defined by the ITU) under WRC-19 agenda item 1.13. Mobile industry views are in support of the 24.25–27.5GHz and 37.0–43.5GHz frequency ranges being identified for IMT/5G use at WRC-19. The mobile industry also supports further consideration for IMT use in the ranges 45.5–50.2GHz and 50.4–54.6GHz (noting that the 47.2–48.2GHz band is being envisaged for 5G use in the USA, which may stimulate demand in other regions). Other bands supported include 66-71GHz, which Ofcom has already identified as a possible band for 5G use in the UK in its 5G strategy[11].

Although Ofcom is encouraging 5G trials in the 26GHz band in the UK, the approach to licensing of the 26GHz band for 5G has not yet been confirmed. This decision will depend, amongst other considerations, on future use of the 26GHz band in the UK for fixed links, which is the primary use currently. The 28GHz band – which will be used for 5G in the USA, and in South Korea – is licensed for fixed use in the UK, and for fixed satellite services (FSS). The SPF notes that clearer intention from Ofcom on award of licences in the 26GHz band would be helpful to avoid the UK falling behind other markets.

Studies into co-existence of 5G with existing fixed and fixed satellite uses in several bands under consideration for 5G (3.8–4.2GHz, 26GHz and 28GHz) are on-going with the relevant CEPT and ITU-R working groups[12]. Options to enable 5G use include transitioning of existing services, and/or geographical sharing, where feasible, based on frequency location of use.

Considerations relating to fixed and satellite service spectrum needs are discussed in Section 5.

The SPF notes that the GSA's view is that if users cannot be transitioned from bands such as 3.8–4.2GHz and 26GHz in a reasonable timeframe (e.g. within five years), there is an opportunity for geographical sharing between existing uses and 5G. In the 26GHz band for example, it is possible that localised 5G coverage could operate alongside existing fixed link use, depending on the density and distribution of the

11 https://www.ofcom.org.uk/__data/assets/pdf_file/0022/111883/enabling-5g-uk.pdf

12 See https://cept.org/ecc/groups/ecc/ecc-pt1/news/latest-news-from-ecc-pt160/

fixed link use, and on the characteristics of the 5G deployment (e.g. 5G small cells being lower-powered and therefore radiating over a smaller area than a 5G macro-cell, for example).

Ofcom has stated that it intends to consult on possible measures to enhance sharing between existing and new uses, including 5G, in the 3.8–4.2GHz band. Ofcom's statement suggests it is considering possible sharing based on site-by-site authorisation, or on a first-come, first-served basis. Similar measures could also be applied in the 26GHz band (e.g. the German regulator is understood to be proposing a site-by-site authorisation in 26GHz), however the possibility to acquire exclusive nationwide licences for 5G use in the 26GHz band would enable mobile operators to flexibly deploy infrastructure complementing their existing nationwide 4G infrastructures.

4 BR, utilities and emergency services

This section of the report discusses trends in spectrum use for professional BR systems. The uses of BR systems are diverse, covering a broad range of applications and services, often highly customised to the needs of an individual user, or vertical industry. Characteristics of BR systems include bespoke coverage, high reliability, guaranteed security and a need for instantaneous connection – including device-to-device/person-to-person connectivity. The SPF's previous spectrum demand report, published in 2015, discussed the BR sector in general, and the utility sector (a significant user of BR systems) in detail.

In this report, we provide an update on use of BR systems both in general terms, and specifically for the utility sector. We also discuss spectrum requirements for the emergency services, which is a sector that has traditionally relied on BR technology but is in transition to a public mobile network.

4.1 Scope of the sector

BR systems are used by a range of businesses and public bodies to provide resilient voice and data communications. Major BR users in the UK include airports, ports, transport, energy and utility companies, local authorities and emergency services.

BR systems have historically provided voice communications for users either from person to person (i.e. handheld radio to handheld radio) or from person to controller (i.e. handheld or vehicle radio back to a fixed control point) but are increasingly used for bespoke data networks. A key reason that business users might choose a BR rather than using public mobile services is cost structure: a BR user can own and operate the infrastructure such that, once installed, the only cost of the system is maintenance and system updates, rather than monthly usage charges. BR users have used public mobile networks alongside BR systems for some time, often for communication that is not mission-critical.

However, BR systems have also typically supported several unique characteristics and features that are not widely offered by public mobile networks, and this underpins the continued demand for individual BR systems, such as:

- ability to set up private point-to-multipoint (group) as well as point-to-point (individual) calls
- pre-emptive priority (e.g. this is a feature valued by 'blue-light'/emergency services users)
- once group calls are established, additional users can join the call, and there can also be restriction on the coverage of a group
- data networks which can be tailored to specific requirements of the users
- over-the-air security, in the form of air interface encryption, or end-to-end encryption.

Examples of BR users in the UK include:

- airports, which use BR systems for security, passenger management and airfield operations
- transport organisations such as bus companies, which use BR for driver safety, on-bus driver communications, as well as for location services and bus-stop updates
- shopping centres and retail outlets, where retail staff use BR for security and customer management
- gas, electricity and water utilities, who each make use of BR systems (voice and data) to monitor and control distribution networks and to enable communication between utility workers
- shipping ports, which use BR for operations, information, conveying of instructions and security.

The emergency services (police, fire and ambulance services) have also historically relied on BR systems. The emergency services originally used a variety of analogue BR systems but subsequently migrated to a national digital trunked radio network operated by Airwave, using TETRA technology. The nationwide Airwave network operates in spectrum from the Ministry of Defence (MOD) at 380–400MHz. Recently, the UK's Emergency Services Network (ESN) programme has planned a move to a commercial 4G (LTE) network for the emergency services. The programme is currently in the delivery phase, with network and device testing and assurance taking place. Users in the emergency services are scheduled to migrate to the EE network from 2019. This is further described in the section below.

4.2 Trends

BR

A presentation to the SPF from Federation of Communication Services (FCS) during 2018 suggested that:

- Voice is the dominant BR service today, representing 75% of 'over-the-air' traffic. The volume of voice traffic has grown by an estimated 15% over the past five years.

- Data – excluding machine-to-machine (M2M) communication – represents 15% of traffic but recent trends suggests significant growth in data traffic should be expected.

- M2M connectivity using BR systems accounts for the remaining 10% of traffic.

There will be a continued need in the BR sector for resilient communications. Resilient communication has several essential components, with location, physical security, power continuity, resilience to power surges/lightning, installation quality, equipment reliability and points of failure all being important, as well as the characteristics of the air interface protocol.

A key concern for BR users when considering adoption of new technologies, such as 4G and 5G, is ensuring the efficient and reliable provision of 'mission-critical' data. Users need to be convinced that the performance of new technologies – and networks delivering the services – meet the disparate BR user needs in terms of data rates, mobility, latency, coverage, battery life and security.

Utilities

As described in the previous SPF spectrum demand report, the infrastructure of the main utilities in the UK has undergone significant transformation in recent years, either to upgrade ageing infrastructure (e.g. water mains) or to improve efficiency and capacity and embrace new forms of energy (such as wind farms). Fundamental change to the way power is generated and distributed are having significant implications for supporting the grid. With increased use of onshore and offshore windfarms for example, there is a growing need for the grid to support two-way flow, to support a system of numerous, widely distributed microgeneration.

Key challenges being addressed in the energy industries include decarbonisation of heating, which will affect energy supply in several ways brought about by the need for improved energy efficiency, and greater demand, including generating electricity to support new technologies that the UK Government is actively promoting – such as electric cars.

Other consequences of the changing landscape of power transmission and distribution include:

- Phased closure of nuclear power stations, with some having closed already, and others scheduled for closure between now and 2025 (leaving one facility – at Sizewell – which will not be fully decommissioned until beyond 2025).
- Phasing out of coal power stations – there are eight remaining coal power stations in the UK, with a target for removal of coal power by 2025.
- Further deployment of wind farms – typically distributed across the UK, including in coastal areas, the number of operational wind farms reported to the SPF in 2018 by the Joint Radio Company (JRC) is now 989 and is forecast to increase
- Other forms of intermittent sources of renewable energy, such as photo-voltaic solar arrays, are emerging.
- Demand management and storage systems are being added.

The utility sector is increasingly relying on communications technology to actively monitor and control power and water infrastructures. Wireless technologies used includes telemetry systems, mission-critical voice (BR-type), supervisory control and data acquisition (SCADA) and M2M communication. Increasing intelligence is also being added into energy systems through for example smart grids to enable automatic responses in normal operations and reconfiguration during system emergencies. All these communication needs rely on use of highly customised wireless connectivity, due to the highly distributed nature of networks and grids, the need for flexibility and ubiquitous reach. The security, integrity and resilience of these networks are now major issues for government and regulators.

Utility network providers today make use of several spectrum bands, often using dedicated channels assigned within VHF and UHF bands designated by Ofcom for BR use. In the case of gas and

electricity, spectrum is coordinated by the JRC, which is a joint venture between National Grid and the Energy Networks Association[13]. There are similar but separate spectrum management arrangements for water companies organised through the Telecommunications Association of the UK Water Industry (TAUWI)[14]. The main spectrum used by the utilities currently was described in the SPF's previous report on spectrum demand – principally VHF 'mid-band' (around 140MHz and 148.5MHz), and UHF (around 456/461MHz and 457.50–485.50/463–464MHz[15]). The utilities also make widespread use of point-to-point fixed links for access to utilities core fibre networks and/or to provide resilient backhaul. Fixed link spectrum used by utility companies in the UK ranges from spectrum in the 1.5GHz band up to 58GHz.

As networks and grids become even more distributed with the increased reliance on renewable energy and demand management, the need for ubiquitous connectivity will increase by orders of magnitude, impacting the choice of wireless system used by utility companies, and the spectrum needed. This is further described in the following section.

Emergency services

The ESN is the new communications service being deployed to be used by police, fire and ambulance services in the UK to deliver secure and resilient voice and wireless data communications. The ESN will eventually replace the current Airwave service, although the Airwave network will continue to operate until migration to ESN has been completed. A recent announcement from the Home Office has clarified that ESN services can be used from next year (2019) as and when they become available (rather than waiting for full roll-out of the service). Hence, certain data services using the ESN will be available incrementally to police, fire and ambulance services from 2019[16].

4.3 Demand for spectrum

In terms of the demands for spectrum in the BR sector, we have found that there is likely to be a continued need for use of existing BR spectrum, with increasing use of mission-critical data, as well as voice, communications. In the utility sector there is a possible need for a solution to providing two-way wireless data services to manage the evolving grid infrastructure. For the emergency services, there is a need to resolve spectrum availability for direct-model (device-to-device) communications. These are further described below.

13 https://www.jrc.co.uk/

14 https://tauwi.co.uk/

15 See page 26 of https://www.real-wireless.com/calculating-the-future-uk-spectrum-usage-and-demand/

16 https://www.gov.uk/government/news/new-strategic-direction-for-the-emergency-services-network-esn

BR

According to the FCS presentation to the SPF, the key future trends in BR use, driving a need for continued access to suitable spectrum, are as follows:

- continued strong reliance on resilient voice communications, although with more modest growth in voice traffic compared to the past five years
- strong growth in resilient 'mission-critical' data communications
- increased demand in rural areas for several uses (e.g. security for lone working where there is no broadband connection, etc.)
- more sophisticated range of services (e.g. including video).

In terms of the spectrum needed, BR use in the UK is distributed across several frequency bands in the VHF and UHF portions of the radio spectrum. Some spectrum is shared, such as the 'UHF1' band, 425.00625–449.49375MHz, which is shared with the MOD. There are different licence products or classes available, which Ofcom coordinates[17]. This flexibility in licence product and spectrum used will continue to be important for BR users as data usage increases.

In terms of the technologies used, BR users have typically adopted technologies appropriate to their business needs – originally this was analogue BR systems (e.g. analogue private mobile radio, or MPT1327 trunked radio), with use of digital solutions (such as digital mobile radio, or DMR and dPMR) becoming more widespread in recent years. It is noted that new features of 4G cellular technology (Long Term Evolution, or LTE) include BR-type functionality (including provision for group calling, and peer-to-peer /device-to-device connectivity). The emergency services are likely to be the first major group of traditional BR users to use LTE technology, with the migration of 'blue-light' communications to the ESN, which will use EE's 4G network. This is further discussed in Section 3.2.

Utilities

According to a presentation delivered to the SPF by the JRC in 2018, the main frequency bands where demand exists for utility networks are in the VHF and UHF portions of spectrum, along with use of fixed links and satellite communications within bands designated for those uses.

The JRC spectrum needs are broadly in line with similar utility companies across Europe, who have co-ordinated their views on wireless system needs and spectrum requirements within several harmonised bands. These spectrum requirements are now emerging globally as all countries address challenges of sustainable, secure and affordable energy supplies. UK energy utilities requirements, rooted in these common needs, are adapted as follows:

- Licensed VHF spectrum (50–200MHz), particularly needed for resilient voice communications and distribution automation in rural and remote areas. The bandwidth needed here is around

17 https://www.ofcom.org.uk/__data/assets/pdf_file/0023/59432/ofw164.pdf

2×1MHz – this requirement is being met in the UK in the BR mid-band frequency channels, around 150MHz.

- Licensed UHF spectrum (in the 400MHz range), which is needed for SCADA applications, automation, smart grids and smart meters. This is considered by the JRC and European utility companies as being its 'anchor band' and the desired bandwidth is 2×3MHz. This bandwidth is currently not available in the UK – although Ofcom as indicated that it is monitoring developments in this area (further discussed below).

- Licence-exempt spectrum in the 870–870MHz band, for smart meters and mesh networks – this is available in the UK.

- Spectrum in the L-band (around 1400MHz) for more intensive smart grid, security and point-to-multipoint applications – spectrum in the 1350–1375MHz range may be suitable and could become available in the UK.

- Fixed-link spectrum in several licensed bands, to provide access to utilities' core fibre networks and/or resilient backhaul – this is being met in the UK within licensed fixed link spectrum (see Section 5.3 of this report).

- A need for satellite communications, to complement terrestrial communications in certain cases.

As noted above, the key area where the JRC identifies that spectrum needs are not being met in the UK is in relation to access to block of frequencies in the 400MHz band, for SCADA, automation, smart grids and smart meters. According to the JRC's presentation to the SPF, there is a strong desire for access to a dedicated block of frequencies in this range, both to align with systems operating in other European countries, and to enable the JRC's current wireless systems to be expanded to meet future grid requirements, as described above. In response, the SPF understands that Ofcom has indicated to the JRC that it is not convinced of the need for dedicated spectrum, since there are other options for meeting the utility spectrum needs (including use of licence-exempt spectrum, and/or use of public mobile networks, as well as continued use of spectrum within the VHF and UHF channels already assigned by Ofcom for JRC use).

The utilities stress that there is no currently available spectrum in the 400MHz region to support licensed data systems requiring channel sizes greater than 12.5kHz, such as:

- Conventional point-to-multipoint systems using channel bandwidths from 25kHz to 200kHz in conformity to ETSI 300 113.

- Tetra networks using 25kHz bandwidth equipment.

- CDMA systems used by several European utilities with 1.25MHz channel bandwidths.

- Private LTE systems using 200kHz, 1.4MHz and 3MHz channelisation.

- WiMax-type systems conforming to the IEEE802.16s specification in channel bandwidths from 25kHz to 200kHz.

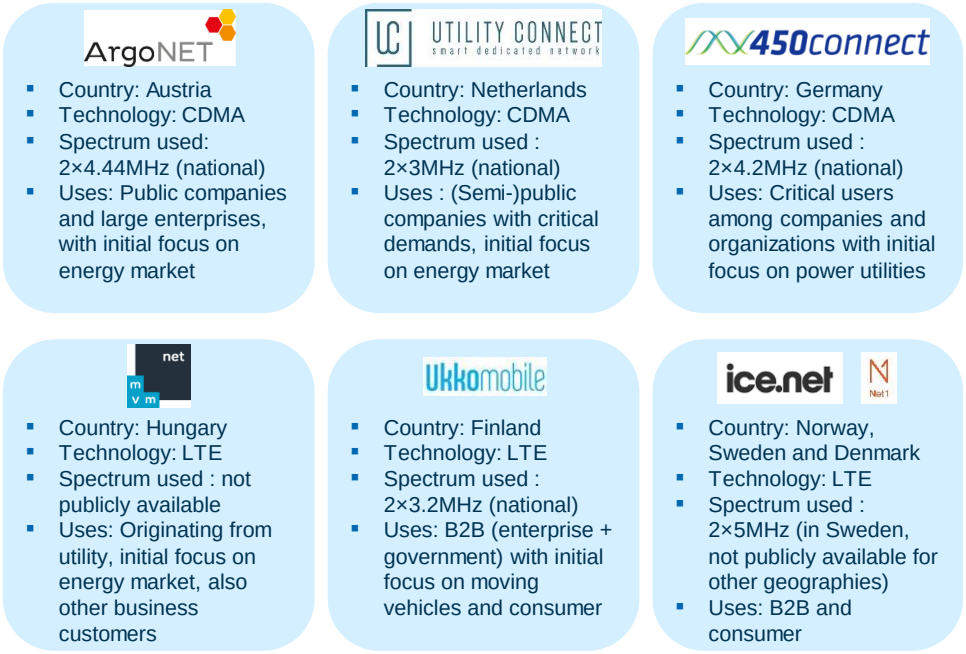
Ofcom has indicated that it is keeping the matter under review.

In discussion within the SPF, members noted there are alternative delivery models for meeting the communications requirements for critical national infrastructures and/or utility services, with differing spectrum implications. These implications are more fully described in the previous SPF report on spectrum demand – namely whether spectrum should be dedicated or shared (e.g. licence-exempt), and whether public mobile networks (e.g. 4G and/or, in future, 5G) can be used to deliver connectivity for critical infrastructure such as utility networks. As noted elsewhere in this report, the ESN will be delivered by EE using its nationwide LTE network in the 800MHz and 1800MHz bands. However, although EE's network coverage is being expanded to meet the geographical coverage needed for core ESN services, the JRC's view is that coverage requirements for utility use do not match well with the ESN requirements – with the utility coverage requirements being further distributed into remote locations, including coastal areas, where mobile network coverage is typically less reliable. It is also unlikely that the ESN will meet the emerging power supply resilience requirements for utility telecoms networks.

The JRC's view that there is a continued rationale for utilities needing 'private' networks (with dedicated spectrum) – such as in relation to data security, as well as the bespoke coverage and resilience requirements – is being embraced in other markets.

The JRC's presentation to the SPF highlighted examples from other European countries of where 400 and/or 450MHz spectrum is being used to provide critical utility services. This include networks that have been designed to meet utility needs but are not exclusively used by them (i.e. there are other user groups also sharing the same network). These examples are shown below.

Figure 4.1: Utility networks in the 400/450MHz bands in Europe [Source: JRC, Analysys Mason, based on several published sources, 2018][18]



The SPF did not reach conclusion on the matter of how future critical infrastructure connectivity (including for utilities) could/should be delivered in the UK, noting that the matter is under discussion with Government, and that the decision ultimately depends on cost-benefit analysis of different options. It was noted that although support for energy policy objectives has been the main driver for growth in the utility telecoms networks over the last ten years, data security and telecoms resilience are now much higher priorities than previously.

The SPF noted that, if dedicated spectrum is needed, the properties of the 400MHz band are particularly favourable for utility and other critical infrastructure use[19]. This is partly due to the favourable propagation characteristics of this band for reaching locations that are difficult to serve, but also because utility companies already use frequencies in the 400–470MHz band for telemetry, meaning that they have transmission sites and equipment already installed that are compatible with a 400MHz network grid.

The SPF noted that alternative substitutable spectrum could include in a VHF band, or spectrum in the 450–470MHz range, or licence-exempt spectrum around 870–880MHz.

18 Sources: https://www.rtr.at/en/tk/Spektrum450MHz, https://www.internetconsultatie.nl/pamr/document/3437, https://www.rijksoverheid.nl/documenten/publicaties/2017/07/03/toekomst-pamr-in-de-450-470-mhz-band, https://www.lvm.fi/documents/20181/755163/Summary+of+decision.pdf/78ab1722-eed6-4c77-b2da-7903a8192394?version=1.0 and http://pts.se/globalassets/startpage/bransch/radio/spektrumstrategi-och-inriktningsplan/inriktningsplan-spektrumhantering-180328.pdf

19 It is assumed that existing utility sites can be used in a 400MHz network, and that these sites might already be connected using dedicated transmission/backhaul (using fibre and/or microwave point-to-point links). This would mean that a 400MHz network could be deployed to provide high levels of geographic coverage with few sites and less resilience upgrades needed than would be needed if using a higher frequency band, or if using a public mobile network.

From the JRC's perspective, spectrum options above 1GHz are likely to be less relevant due to the nature of the uses being considered although it is noted that the utilities do also need bands above 1GHz for backhaul purposes (e.g. a critical national infrastructure using 400MHz spectrum might also use microwave or millimetre-wave spectrum for wireless transmission/backhaul).

Emergency services

A key objective of the ESN was to make efficient use of spectrum, whilst providing the future communications services needed by the emergency services. The ESN is principally being provided by EE using its public mobile (4G) network – with prioritised access for emergency services where needed. There are residual spectrum needs for the emergency services, which according to a presentation from the Home Office to the SPF, fall in three areas:

- air-to-ground overlay network
- coverage extension gateway
- direct device to device communications – in 3GPP specifications, known as 'proximity services' ('ProSe').

The Home Office has considered several options for air-to-ground communications (which refers to wireless connectivity used in police helicopters and air ambulances to communicate with emergency services teams on the ground), including satellite, use of the ESN network itself, an LTE-overlay network, and continued use of the current TETRA-based air-to-ground service. The most likely option is an LTE overlay network, which would allow air-to-ground communication via multi-band LTE handsets capable of using both the frequencies of the overlay network, and the ESN network on the ground. There is intention for the lower part of the 2.3GHz band – under MOD ownership – to be used, and a sharing agreement is to be put in place between the Home Office and the MOD to facilitate this. The Home Office has recently published a prior information notice for provision of air-to-ground solutions[20].

The coverage extension gateway refers to relay connectivity provided by vehicles between ESN devices and the EE network, as a means of extending coverage. Like the air-to-ground service, several options have been considered for this including use of in-band spectrum (i.e. the same spectrum EE is using in the ESN network) and use of a dedicated block. Since the dedicated spectrum will potentially enable better quality of service (e.g. due to less co-channel interference) it has been decided to use EE's 1.9GHz unpaired spectrum (not used within the EE nationwide 3G/4G service) for the gateway.

Spectrum for the emergency services device-to-device communications has yet to be confirmed. As with the other requirements above, this spectrum must be compatible with LTE technology (i.e. supported in LTE devices) to avoid the need for a separate, proprietary device being needed. Several options have been considered including use of the 450–470MHz band (e.g. within the channels formerly used by the Home Office for analogue BR in this band), 700MHz (e.g. in the 'centre gap'

20 https://ted.europa.eu/TED/notice/udl?uri=TED:NOTICE:394619-2018:TEXT:EN:HTML&src=0

between the paired blocks that Ofcom will auction in the 700MHz award) and 2.3GHz. Both the 450–470MHz and 2.3GHz options have several disadvantages. The SPF understands that the preference of the Home Office is use of the 700MHz band although this is subject to on-going discussion with Ofcom.

In addition to the ESN spectrum requirements, the SPF understands that spectrum to support other emergency service applications needs to be retained. This includes:

- spectrum used by the Airwave service, including direct mode operation, until the Airwave network is switched off
- airborne data-links
- fire-ground communications
- spectrum for surveillance, fixed links and speed radar.

5 Fixed and space sectors

This section of the report discusses trends in spectrum use for fixed and satellite services. The space sector was discussed in some depth in the previous SPF report on spectrum demand[21], although the fixed sector (e.g. point-to-point fixed links) was not described.

In this report, in the following section, we provide an update on fixed-link spectrum trends, and consider trends in demand within the space sector.

5.1 Scope of the sectors

Fixed and satellite services are used for a variety of telecommunications and broadcasting purposes, principally deployed for backhaul, resilience, rural connectivity (e.g. satellite) and for distribution of multimedia and/or broadcast content (e.g. via a satellite network). Two major satellite providers – Inmarsat, and Avanti – are headquartered in the UK. There is also extensive use made of fixed links – also called microwave links – by telecommunications operators, utility companies, emergency services, the oil and gas sector, transport and local authorities, amongst other users.

Fixed and satellite services make use of several frequencies that are typically in the higher portions of radio spectrum, including some bands in the millimetre-wave region that are under study for 5G use, as described in Section 3.3:

- **Fixed links** are terrestrial wireless links that are deployed either in a fixed point-to-point or point-to-multipoint configuration, and used to provide 'backhaul' connections (e.g. connections between base stations and the core network in a public mobile network), or to provide long-distance, fixed wireless connectivity for the distribution of telephone, internet and broadband traffic from fixed core networks either to customer premises or between fixed points (as an alternative to using fibre or cable).

- **Satellite services**, like fixed links, may be used to provide long-haul connectivity or backhaul for the distribution of voice, internet and broadband traffic, as well as satellite voice or satellite broadband services and satellite broadcasting, direct to end users.

The major users of microwave fixed-link services are fixed and mobile telecoms operators. The market is thus relatively concentrated, with the strongest demand coming from mobile operators, which use fixed links for backhaul purposes within 2G, 3G and 4G networks. More recent demand for fixed link spectrum also comes from the financial trading sector where there is a need for high-frequency, ultra-reliable transactions in financial districts of the UK, which are increasingly being delivered wirelessly, according to Ofcom research. 5G might drive further demand from mobile operators for fixed, and satellite services, such as to provide backhaul connectivity for small cells,

21 See page 57 of https://www.real-wireless.com/calculating-the-future-uk-spectrum-usage-and-demand/

or to support 5G coverage in rural areas. Avanti is working with mobile operator EE currently to provide resilient backhaul connectivity in EE's 4G network for the UK ESN, for example[22].

5.2 Trends

Although fibre connectivity is now widely available in the UK, use of fixed links and satellite services are still beneficial in several situations – for example, to connect over difficult terrain, or to provide resilient backhaul. Wireless links also typically provide a more rapid form of deployment and so can provide an interim solution until a fibre link is available.

A key trend that has been recognised elsewhere in this report (e.g. Section 3.3) is that fixed wireless and satellite spectrum is increasingly being considered for other uses, including 5G as well as alternative delivery platforms such as 'high altitude platforms' (HAPS)[23]. At the same time, there is demand for wider channel widths to be available for fixed-link use, to provide higher-capacity links. Other relevant trends include technological developments (e.g. technological advances in fixed wireless technology to use the 60GHz band and, in future, 92GHz and 130GHz bands) and increased use of 'block assigned' spectrum for fixed links[24].

To inform its five-year plan on the spectrum used for fixed links, Ofcom undertook an extensive review of spectrum used by fixed wireless services in 2016[25], resulting in a consultation document on proposed next steps, published in December 2017[26], and a statement published in July 2018[27]. A key message from the review and consultation was an increased focus on use of higher millimetre-wave bands for fixed links to deliver very high capacity. Specific interest currently is around use of the 60GHz band and there is continued growth in use of the 70–80GHz bands. Other higher bands that fixed-link equipment suppliers are currently focussing on for future use include W-band (92–114.5GHz) and D-band (130–174.8GHz).

In the satellite sector, there is growth in planned and operational satellite networks and systems. Portions of the radio spectrum that are important for satellite use are 1500MHz (used by Inmarsat, as well as for Global Positioning Systems, or GPS), S-band (around 2GHz – licensed to Inmarsat in Europe), the C-band (spanning 3.4–7.025GHz and widely used globally for fixed satellite television and data services, including broadcasting), Ku-band (10.7–14.5GHz, which as similar uses as the C-band) and Ka-band (17.3–30GHz, used for higher capacity services including two-way broadband services, such as the Avanti service)[28]. In the Ka-band, used by Avanti, there are over 2350

22 https://www.avantiplc.com/wp-content/uploads/2016/12/EE-Carrier-Services-08.12.16.pdf

23 Previous SPF discussion on market demand for HAPS in the UK is summarised here https://www.slideshare.net/TechUK/uk-spf-cluster-1-haps-workshop-summary-080617

24 This refers to several bands that have been assigned via auctions by Ofcom for self-managed use e.g. 28GHz and 32GHz, which have been assigned to MNOs, BT and other telecoms providers for use in specific geographic areas (without links needing to be individually coordinated by Ofcom).

25 https://www.ofcom.org.uk/consultations-and-statements/category-1/call-for-inputs-fixed-wireless-spectrum-strategy

26 https://www.ofcom.org.uk/__data/assets/pdf_file/0027/108594/Fixed-Wireless-Spectrum-Strategy.pdf

27 Https://www.ofcom.org.uk/__data/assets/pdf_file/0017/115631/statement-fixed-wireless-spectrum-strategy.pdf

28 See https://esoa.net/spectrum/satellite-spectrum.asp

geostationary orbit (GSO) and non-geostationary orbit (non-GSO) services being deployed globally (according to ITU-R filings), with over 750 non-GSO systems in planning. Mixing of GSO and non-GSO satellite systems in the same band is increasingly common, with consequential coordination requirements. Demand for use of Q/V band (37.5–51.4GHz) is also growing. This band is of interest for services to user terminals (including mobile) and could also be attractive for aircraft communications. Plans include NGSO systems where link budgets allow[29], and also GSO systems for aircraft 'Earth Stations in Motion' (ESIM) terminals.

A key challenge for the satellite industry is that bands used by the satellite sector are increasingly being sub-divided for different space and terrestrial uses, causing increased complexity in the planning and co-ordination between systems, and giving rise to increased risk of interference. Unlike for fixed wireless services where technological advances might make use of higher-frequency bands practical in the immediate future, it is not possible to re-deploy satellite services in higher bands due to propagation limitations as well as the bespoke nature of satellite constellations (being designed to operate in specific bands).

5.3 Demands for spectrum

SPF discussions both in the context of producing this report, and in previous workshops, have highlighted continued demand for fixed and space services in the UK market. In the fixed-link market, provision of rural connectivity has been a recent focus (driven by Government ambitions for ubiquitous fixed and mobile connectivity) as well as densification and expansion of mobile networks, with consequential requirements for backhaul. In the satellite market, there is also growth in broadband connectivity in rural areas and increasing demand for resilience, for which satellite services are ideally suited.

In terms of the demand for fixed-link spectrum, Ofcom concluded from its consultation on trends in the UK market that:

- There is a continued requirement by users for spectrum below 20GHz for fixed links requiring longer links in both suburban and rural areas, as well as for applications where an increase in capacity would be required on longer routes.
- Higher capacity provision is a key trend in urban areas, with increasing demand for bands such as 60GHz and 70–80GHz as well as more use of block-assigned spectrum (e.g. 28GHz, 32GHz).
- There is a greater take-up of the 60GHz band for point-to-multipoint and mesh topologies (e.g. within WiGig-type deployments), and continued demand for spectrum in the 70–80GHz band.
- There is a need to consider use of higher bands for fixed links in future (e.g. 92GHz and 130GHz) to meet future capacity requirements.

[29] Link budget data in ITU-R WP4A shows feasibility of Q/V user terminals

In terms of immediate actions that Ofcom is taking to meet demand for fixed-link spectrum, the July 2018 statement confirms:

- The 1492–1517MHz band is being closed to new fixed links from January 2019, in line with changing European use of this band (which has been identified for use by downlink-only mobile services). Ofcom is envisaging that links that currently use this band could use alternative spectrum within the 6GHz band (e.g. within small channels in the 6GHz guard bands/centre gaps).

- The 3.6–3.8GHz band is closed to new fixed links (ahead of planned award of spectrum for mobile/5G use) and the 3.8–4.2GHz band is also being considered for increased sharing (with 5G), although still open for fixed-link use.

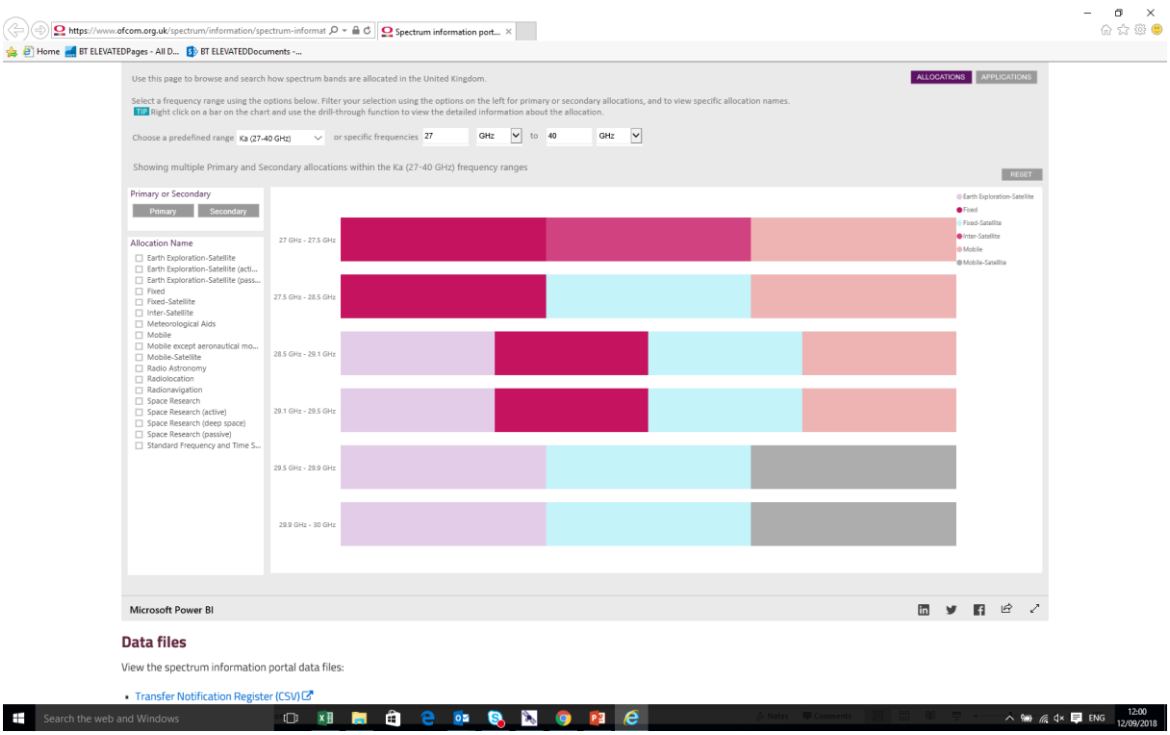
- The 26GHz band is still open for fixed-link use however Ofcom has stated '*applicants for fixed wireless licences in the 26GHz band are advised to take note that this band has been identified by the European Radio Spectrum Policy Group (RSPG) as the pioneer band in Europe (and wider) for 5G'*.

- 57–71GHz: regulatory changes being made to enable new fixed outdoor use cases on a licence-exempt basis (including changing the previous self-coordinated, light-licensed approach for 60–64GHz to a licence-exempt approach, enabling a single authorisation approach across 57–71GHz).

- 70/80GHz: continue with availability of this band for fixed links, and consider enhanced access to meet market demand (e.g. to reduce the current 250MHz separation between the coordinated and self-coordinated blocks, to increase the amount of useable spectrum).

In relation to satellite spectrum, a presentation to the SPF from Avanti highlighted that the key goal for the satellite sector for the upcoming World Radiocommunication Conference in 2019 (WRC-19) is to retain and to improve access to existing satellite bands. There is one agenda item for consideration at WRC-19 (9.1.9) that is considering spectrum needs and possible allocation for space use in the 51.4–52.4GHz band). In terms of improving access, a key challenge faced by the satellite industry is to work within the increasingly fragmented and congested band plans brought about by increased use of bands for different satellite and terrestrial uses.

Figure 5.1: Ka-band allocations [Source: Ofcom spectrum information system, Avanti, 2018]



There are also requirements for new forms of operation such as 'earth stations on moving platforms', and earth stations in motion, with implications for frequency coordination within the bands in question (which are in portions of the Ka-band).

With the Ku satellite band already congested with heavy incumbent satellite use, and growing pressure on C-band capacity resulting from increasing use of this band for mobile services, there is strong concern from the satellite industry that existing satellite access to Ka-band should be preserved, and improved, to accommodate mixed GSO and non-GSO satellite needs in this band. Any reduction in availability of Ka-band spectrum would severely impact the satellite sector. A specific concern is new uses of the spectrum around 28GHz, which has been earmarked for 5G use in some markets outside of Europe, although not part of the ITU-R studies in the context of agenda item 1.13. The view of the satellite industry is that satellite use must be fully protected if WRC-19 takes any actions on new uses of this band.

6 Broadcasting, and programme making and special events

6.1 Scope of the sectors

Digital terrestrial television

Television and radio programming can be broadcast in several ways – via terrestrial radio transmitters, via satellite, via cable networks, via managed broadband networks, and over the internet (also known as 'over the top', or OTT). With the SPF's focus being primarily on radio spectrum, we focus in this section on digital terrestrial television (DTT), which is one of the significant users of UHF (470–694MHz) spectrum in the UK.

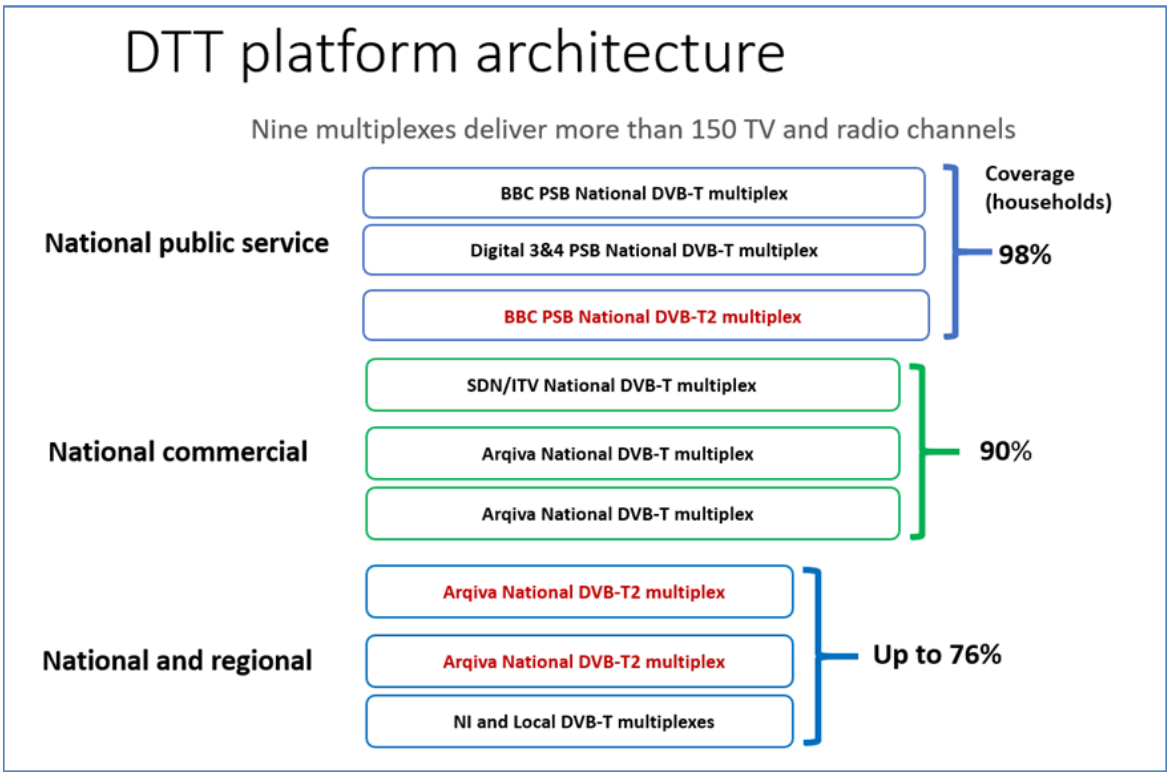
It is noted that digital radio in the UK also uses radio spectrum, in the VHF portion (202.0–230MHz), broadcasting alongside AM and FM analogue radio broadcasting. We have not considered this use in detail within the SPF discussions. Hence, the remainder of this section relates to spectrum used by DTT.

The digital switchover of terrestrial TV broadcasting was completed in the UK in 2012, when analogue TV broadcasting services were discontinued. Since this time, the nationwide DTT platform has grown in terms of the number of channels broadcast and the type of distribution – standard definition (SD) or high definition (HD) – being used.

The network currently comprises nine multiplexes (MUX), broadcast from 80 main transmitter sites across the UK and around 1000 smaller 'relay' sites which ensure universal coverage of public service channels. Three of the national MUX carry public service channels and are broadcast from all sites. A further three 'commercial' multiplexes are broadcast from 80 main transmitter sites which serve around 90% of UK homes. There are a further two 'interim' MUX broadcasting a mix of SD and HD channels (reaching around three quarters of homes) and one local television MUX. DTT is currently watched in 20 million households in the UK, and 98.5% of homes are within PSB coverage, according the latest research published by Digital UK[30]. The DTT platform architecture is illustrated below.

[30] http://www.digitaluk.co.uk/operations/about_dtt

Figure 6.1: DTT platform architecture [Source: Digital UK, 2018]



DTT channels are broadcast by the following organisations:

- the BBC
- commercial public service broadcasters (PSBs) – ITV, Channel 4 and Five
- regional PSB variants (e.g. in Scotland, Wales and Northern Ireland)
- other commercial broadcasters (of which is the largest is UKTV, jointly owned by BBC Studios and Discovery, Inc.).

The UK DTT service is known as 'Freeview', and is operated by Digital UK and DTV Services Limited – joint venture companies owned by the BBC, ITV, Channel 4 and Arqiva. Sky is also a shareholder in DTV Services Ltd. Development of Freeview is led by Digital UK[31] with DTV Services focused on consumer marketing and brand licensing. Digital UK is responsible for development of Freeview Play, which brings together terrestrial TV, catch-up and on-demand content in next-generation televisions and boxes from manufacturers such as Panasonic, LG, Toshiba and Sony.

Programme making and special events

Programme making and special events (PMSE) refers to a range of wireless audio and video technologies used to support the creative industries in production of entertainment, sporting events,

31 http://www.digitaluk.co.uk/about_digital_uk/management_team

news gathering, broadcast programme production and live events (including theatre, concerts, conferences etc.).

Types of PMSE equipment in use in the UK include[32]:

- audio distribution equipment, such as in-ear monitors, wireless microphones, talkback etc.
- temporary and permanent point-to-point links
- video distribution equipment, such as cordless cameras
- telemetry equipment, for remote control of cameras etc.

PMSE services are used by the large UK broadcasters to support their production services, with wireless equipment providing flexibility for audio-visual capture for both live broadcasts and for recordings. There is also a broad range of smaller independent PMSE equipment users – including sports clubs, schools, sports organisers, social clubs, theatres and churches – making use of wireless microphones and other audio equipment (e.g. in-ear monitors) at venues across the UK.

The frequencies used by PMSE equipment span a wide portion of the radio spectrum. PMSE has historically used discrete spectrum blocks on a secondary basis, shared with other primary users.[33] Several of the frequency bands used for video PMSE in the UK are shared with government users, primarily the military. Most audio PMSE use has historically been in UHF spectrum, shared with broadcasting services. Licences for PMSE use are typically location-specific, and frequencies are co-ordinated geographically to coordinate with other PMSE use, and to avoid interference with any designated primary services. Many PMSE frequency assignments are time-limited (e.g. an assignment lasting two or three weeks, covering a sports event). However, larger users such as broadcasters will usually hold annual licences to cover continual PMSE use within national broadcasting studios for live show production as well as for out-of-studio news, sports and entertainment content gathering and other outside broadcast events.

The frequencies used for PMSE are in two ranges, with short- and longer-range audio and data applications taking place in bands below 2GHz and video transmission, including terrestrial and airborne use, taking place in bands from 2GHz upwards. Usage can be characterised in summary form as follows:

Figure 6.2: PMSE spectrum and its uses in the UK [Source: Analysys Mason, 2018]

Frequencies	PMSE uses
40MHz to 2GHz	Wireless microphones, in-ear monitors, audio links, remote control data links – mostly operating in UHF spectrum shared with DTT (470–606MHz and 614–694MHz34) although there is some VHF use (e.g. 139MHz, 140MHz, 148MHz, 181MHz, 189MHz. Talkback

32 https://www.ofcom.org.uk/__data/assets/pdf_file/0017/10781/ir2038.pdf

33 The ITU Radio Regulations allocate spectrum on either a primary or a secondary basis. Primary services are afforded protection from interference, whereas secondary services operate on a non-interference, non-protected basis, i.e. they should not interfere with primary users and they cannot claim protection from interference from other licensed transmissions.

34 https://www.ofcom.org.uk/__data/assets/pdf_file/0017/10781/ir2038.pdf

Frequencies	PMSE uses
	equipment can also use the 'DECT' spectrum (1800–1900MHz), which is available for use on a licence-exempt basis
2GHz to 48GHz	Wireless cameras and video links (point-to-point and point-to-multipoint), including airborne (e.g. wireless cameras deployed in helicopters for aerial shots). Wireless cameras have traditionally operated at frequencies of 2–4GHz in the UK, although use of higher frequencies such as 7.5GHz is becoming more commonplace. Outside broadcast links operate in bands from 2–24.5GHz. There is also a band from 48–48.4GHz

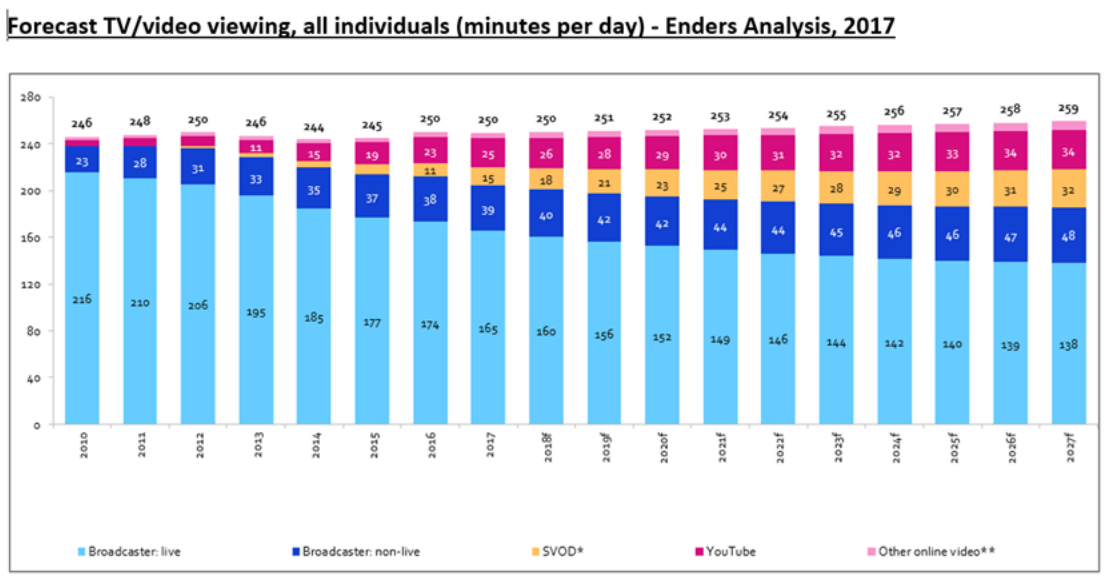
6.2 Trends

Digital television

As described in a presentation from Digital UK to the SPF during 2018, the digital television industry is entering an era of disruption, with strong competition to all major television platforms from internet players (e.g. Facebook, Amazon, Netflix and Google). Despite this, the DTT platform is still seeing growth in its viewing base, whereas other platforms have tended to see a decline.

Viewing habits are also changing, with an increasing portion of viewing being accessed via catch-up and on-demand services, at the expense of traditional linear TV. However, the pace of change is slower than some have suggested and while take-up of services such as Netflix has grown fast in recent years, overtaking the number of traditional pay subscribers, the overall proportion of viewing via these services remains modest – less than 10% of the total. Forecasts generally indicate that traditional linear TV will still account for most daily viewing in the late 2020s.

Figure 6.3: Forecast TV/video viewing (minutes per day) [Source: Enders Analysis, 2017]



With this continuing demand for traditional linear TV viewing, the UK Government and EU policy makers are planning for DTT's continued access to UHF spectrum until at least 2030. Recent statements in this regard are shown below.

Figure 6.4: UK and EU policy positions on DTT [Source: Digital UK, Ofcom, 2018][35][36]

Due to changes to mobile allocations and harmonisation of 700MHz spectrum for mobile broadband use at a European level, a 700MHz clearance project is under way: the objective is to re-plan the UK's DTT network to vacate spectrum from 694–790MHz ('the 700MHz band'). This clearance is also resulting in reduced spectrum availability for PMSE, as discussed below. The 700MHz clearance requires re-planning of the DTT network to use 30% less spectrum. From a practical perspective, clearance requires re-engineering of around 1000 transmission sites (including main transmitters and relays). The new network plan makes increased use of single frequency networks (SFN) compared to the traditional multi-frequency network (MFN) used in the initial stages of DTT use. This improves frequency re-use but causes a reduction in 'interleaved' spectrum that is available for PMSE use (as discussed below). The new network configuration will result in up to 20 million households across the UK needing to re-tune their TV sets. The total cost of the clearance project has been estimated at GBP600 million.

To manage the reduction in spectrum availability, whilst also ensuring enough capacity is maintained to accommodate the nine MUXes currently operating, there has been a continued improvement in spectrum efficiency in the DTT network. This has been enabled through migration to newer DVB-T2 modulation and coding formats as well as increased use of more spectrally efficient SFNs.

Figure 6.5: Improvement in DTT spectrum efficiency [Source: Digital UK, 2018]

Year	No. of MUXes	No. of services	Spectrum used (MHz)	Bandwidth deployed (MHz)	MHz per service	Efficiency increase from 1998
1996	Analogue	5	470–854	368	73.6	
1998	6	24	470–854	368	15.3	*1.0

35 In Ofcom's view 'Mobile demand (for UHF spectrum) has substantially diminished as investments in 5G require spectrum at higher frequencies'

36 https://www.ofcom.org.uk/__data/assets/pdf_file/0026/111896/Public-service-broadcasting-in-the-digital-age.pdf

Year	No. of MUXes	No. of services	Spectrum used (MHz)	Bandwidth deployed (MHz)	MHz per service	Efficiency increase from 1998
2002	6	32	470–854	368	10.5	*1.4
2012	6	48	470–790	312	6.5	*2.4
2017	9	89	470–790	312	3.5	*4.4
2020	7 or 9[37]	83	470–694	224	2.7	*5.7

Hybrid platform development has also been a key trend in the DTT sector in recent years. Freeview Play brings together terrestrial TV, catch-up and on-demand services, providing fully integrated DTT and broadband delivery, brought about through use of the 'Hbb-TV 2.0' standard. Most major broadcast manufacturers are now making Freeview Play TVs and boxes, and there has been rapid consumer adoption. The latest figures provided to SPF from Digital UK is that 3.5 million products have been sold. Freeview Play is also driving take-up of connected TVs, and of DVB-T2.

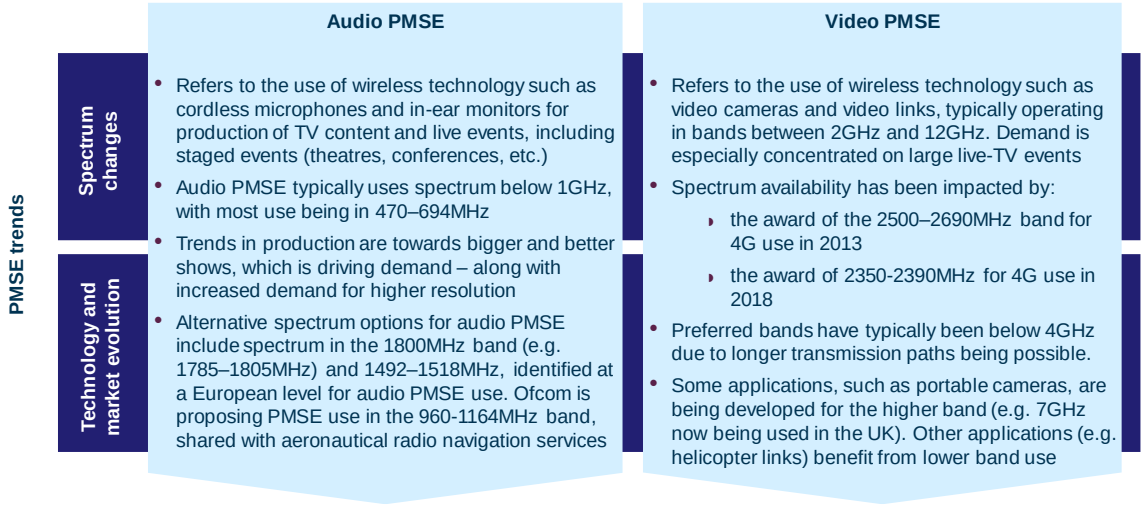
PMSE

The spectrum available for PMSE has been affected over the past five years by re-planning of several bands to make available spectrum for mobile use – including in 700MHz, 800MHz, 2.3GHz and 2.6GHz, all of which have been used for PMSE applications prior to the award of mobile licences.

Alongside this reduction in spectrum, there has been a trend towards production of larger live shows – which has increased demand for PMSE.

These trends are summarised below.

Figure 6.6: Trends in PMSE use and spectrum availability [Source: Analysys Mason, 2018]



Since the SPF's previous spectrum usage and demand report was published in 2015, the main changes to PMSE spectrum availability have been (a) clearance of the 700MHz band, reducing

37 Interim MUX licensed to 2020 with possible extension

spectrum available for audio PMSE, and (b) auction of 40MHz in the 2.3GHz band, reducing spectrum available for video PMSE.

One of the main applications of audio PMSE is wireless microphones. These have traditionally used 'interleaved' UHF spectrum between the frequencies used by DTT in specific locations[38]. The amount of UHF spectrum available for PMSE has reduced as the spectrum used for DTT has been reduced, to reflect increasing 4G spectrum demand. Some wireless microphone systems use VHF spectrum although the UHF band is more widely used.

The 800MHz band was auctioned for mobile use by Ofcom in 2013 as part of the UK 4G auction and so has been unavailable for PMSE use since that time. The allocation of 700MHz spectrum for mobile use has resulted in further migration of digital TV and PMSE from the 700MHz band, as described in the DTT section above. The impact of the 700MHz clearance is that, from 2020 onwards, DTT and PMSE will use frequencies from 470–703MHz[39], rather than 470–790MHz. The 700MHz clearance programme has been accelerated with an intention to release spectrum for mobile use by May 2020.

To date, most wireless microphone systems have used analogue technology, although digital PMSE equipment is now being introduced. Digital equipment is considerably more spectrally efficient than analogue; typically, only one analogue PMSE channel can be accommodated per 1MHz of spectrum, whereas digital equivalents can fit two to eight channels per 1MHz. Digital equipment is more linear, and less susceptible to reverse intermodulation distortion of the transmitter, allowing for denser channel packing utilising adjacent channels (which most analogue equipment cannot do). Increased adoption of digital equipment, whilst beneficial from a spectrum efficiency perspective, depends on PMSE users and manufacturers overcoming several other performance impacts – such as latency, battery life, cost, reduced range and audio codec artefacts, amongst others.

There is a wide variation in the density of PMSE use across the UK:

- church halls and conferences typically need 1–10 channels per location/venue
- large theatres, outside broadcasts, TV studios and film productions use up to 200 channels in a given location. Larger users also have complex RF and audio routing systems, affecting the frequencies that their systems can use.

Licensing of PMSE equipment is undertaken by Ofcom, with frequencies being tightly controlled and coordinated. At present, spectrum from 470–790MHz is available for indoor audio PMSE use – outdoor PMSE has frequency/location restrictions to protect DTT service areas – though as noted above, the available frequency range will reduce once DTT is cleared from the 700MHz band

38 Interleaved spectrum is available in different quantifies in different areas of the UK arising from the MFN configuration used by the terrestrial TV network in the UK, meaning that frequencies used in one geographical area are not re-used in neighbouring areas to avoid interference. These frequencies can be re-used by lower-power systems (such as wireless microphones) on a co-ordinated basis without interfering with TV signals and vice versa.

39 694–703MHz PMSE spectrum is likely to be of lower quality than 470–694MHz due to interference from new mobile services above 703MHz.

The number of protected DTT MUX varies on a geographical basis across the UK, ranging from three to nine[40], which directly limit the frequency availability for PMSE. Additionally, nearby 'unprotected' DTT transmitters (including relays and broadcasts from neighbouring countries) act as noise that particularly affects outdoor PMSE operation.

6.3 Demand for spectrum

DTT

As described above, linear TV viewing via DTT has declined less rapidly than might have been expected given the increasing competition from internet providers offering on-demand services. Development of hybrid platforms such as Freeview Play is also improving the outlook for DTT by offering consumers the possibility of a mix of linear, catch-up and on-demand services best fitting their household requirements (so-called 'skinny bundling'). This also allows the broadcast industry to cater for audience patterns shifting at different speeds (e.g. greater relevance of on-demand services for younger audiences, relative to linear TV viewing for older audiences). The broadcast industry expects that the DTT platform is likely to remain in use until at least 2030, which is confirmed in Ofcom's 'Public service broadcasting in the digital age' publication from March 2018.

Developments in mobile and fibre connectivity, as partly determined by UK Government policy, are relevant to the future of DTT:

- The possibility of using mobile technology to deliver television services directly to mobile devices is appealing, given the rise in TV viewing (catch-up and on-demand especially) via mobile devices.

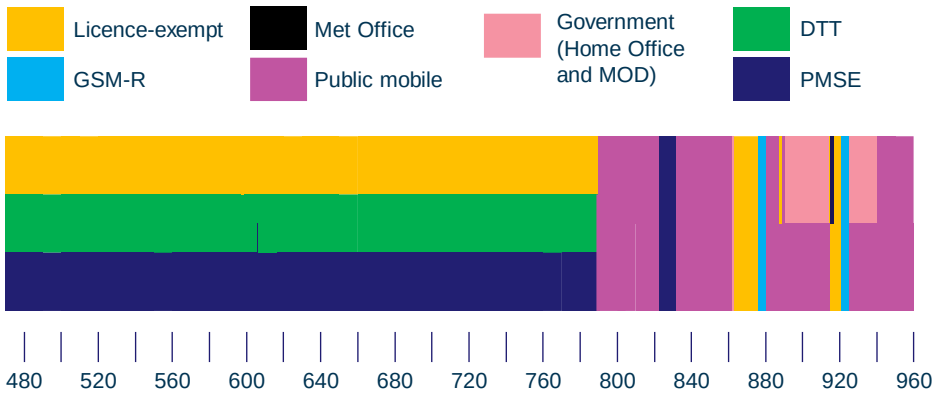
- The intervention of UK Government to fund 'full fibre' connectivity in the UK will potentially result in most UK homes having fast broadband connection – which could be used to deliver TV services into the home.

The BBC has stated publicly that it considers the distribution of linear media (TV, and radio) will migrate to IP-based infrastructure in future. However, the transition will be complex and remains subject to several technology, market and regulatory uncertainties, which will influence future distribution choices, and timing. Whilst there will be several benefits of IP distribution, there are also many challenges. Key challenges identified in SPF discussion (over and above those relating to the future use of UHF spectrum) included achieving the coverage needed for TV and radio distribution: neither fibre nor mobile currently offer potential for distribution to the same proportion of households as DTT currently provides (although satellite distribution does approach the same population availability as DTT); there is also a question over broadband (and mobile) data tariffs (with a need for 'unlimited' access to allow for viewing of live TV in the way that the DTT platform currently provides).

40 The nationwide DTT network in the UK currently comprises three PSB MUX, three commercial MUX, two commercial HD MUX and a local television MUX, together using between 24 to 72MHz of spectrum.

In relation to spectrum, the SPF notes that the ITU World Radiocommunication Conference (WRC) in 2015 agreed Resolution 235[41], to review the use of spectrum and future needs across the 470–960MHz band. These frequencies span the current UHF broadcasting spectrum, several mobile bands, military, short-range device (SRD) and railway communications (GSM-R) uses in the UK, as shown below.

Figure 6.7: Current use of spectrum 470–960MHz [Source: Analysys Mason based on Ofcom's website, 2018]



Resolution 235 invites the WRC in 2023 to consider the results of studies on future use of the 470–960MHz band, and to consider possible policy actions (e.g. whether changes to existing allocations are needed). In relation to possible future allocations in 470–960MHz, the SPF notes:

- The auction of 600MHz spectrum in the USA resulted in a new mobile band being added to 3GPP specifications: 663–698MHz (mobile transmit)/617–652MHz (base transmit). This band can only be used in countries where there is a footnote in the ITU Radio Regulations identifying the band 470–698MHz, or parts of it, for use by International Mobile Telecommunications (IMT) – currently this only applies to a few markets in ITU Region 2 and 3 (with Region 1 decisions being tied to Resolution 235, not to be considered until WRC-23).

- There has been limited work to date within the ITU-R to address Resolution 235 – one industry participant has proposed a new ITU-R report (termed 'IMT-TV-600') however this has not been progressed to date. The SPF commissioned research in 2018 into the practicality, feasibility and implications of defragmenting the parts of the UHF band used by public mobile systems in 694-960MHz, concluding that the overall capacity gains would be small compared to the gains promised by future mobile technology developments, such as 5G, and the use of higher frequency bands[42].

- Ofcom's 'public service broadcasting in the digital age' publication from March 2018 states that Ofcom expects DTT operation to continue in UHF spectrum for at least the next ten years (to

41 https://www.itu.int/dms_pub/itu-r/oth/0c/0a/R0C0A00000C0029PDFE.pdf

42 http://www.techuk.org/insights/reports/item/13599-spf-report-uhf-band-694-960mhz

2030) – this is in line with market indications that linear TV will continue to dominate viewing for some years yet.

- Ofcom has also updated its view on future demand for UHF spectrum for mobile which it believes to have 'substantially diminished'[43] as the focus moves to higher frequencies better suited to the high data rates of future networks such as 5G.

A presentation to the SPF from Real Wireless entitled 'Technology developments and the impact on future spectrum demand'[44] discusses LTE broadcast/eMBMS[45] technology developments to date, including the architecture updates in the latest 3GPP specifications (Release 14), such that:

- There is support for larger inter-site distances – with similarities to the current DVB-T/DVB-T2 site grid.
- There is the possibility of deploying a dedicated eMBMS carrier (rather than a carrier mixing eMBMS with mobile broadband traffic), possibly allowing for a dedicated 'broadcast' service to be developed.
- A receive-only mode in devices potentially enables free-to-air content broadcast over eMBMS.

Although LTE broadcast is a global standard, it is yet to be widely deployed. There are also similar initiatives within the IEEE802.11 working group that will consider broadcast service enhancements within an 802.11-based network. The conclusion from Real Wireless's presentation was that although technology migration is progressing, there are policy and market issues to be resolved. However, the possibility of convergence exists, and further development of hybrid models (Freeview Play-type) embracing eMBMS could in future provide broadcasting services to mobile and tablet devices, as well as to TVs.

PMSE

The implication of the 700MHz clearance is that the bandwidth available in the UHF band for DTT and for PMSE use is reduced by 96MHz, to a maximum of 216MHz (equivalent to 27 DTT channels). The UHF channels being re-allocated for mobile use cannot be shared with PMSE.

Taking account of the geographical sharing between DTT and PMSE, in areas where nine DTT MUX are operating, there will typically be up to 161MHz of interleaved spectrum available for outdoor PMSE use. In some areas, where DTT transmitters overlap, less than this will be available. On the other hand, additional interleaved spectrum is potentially available in locations where fewer than nine MUX operate, although this is not usually in urban areas. There is potentially more spectrum available for indoor PMSE use, as co-channel use between PMSE (indoors) and DTT

43 Public service broadcasting in the digital age, Ofcom, March 2018

44 http://www.techuk.org/insights/meeting-notes/item/13417-uk-spf-cluster-1-future-spectrum-demand-meeting-notes

45 Multimedia broadcast multicast service is the point-to-multipoint interface for 3GPP cellular networks, which can be used for multicasting

(outdoors) is sometimes possible, albeit with performance implications on the PMSE use. Usable spectrum in some locations might be further reduced due to increased interference (e.g. from neighbouring countries).

There is also a 9MHz guard band (between the mobile and DTT spectrum), which could be usable for PMSE, but would be subject to interference from mobile use.

Implications (especially for larger PMSE users) after 700MHz clearance are that:

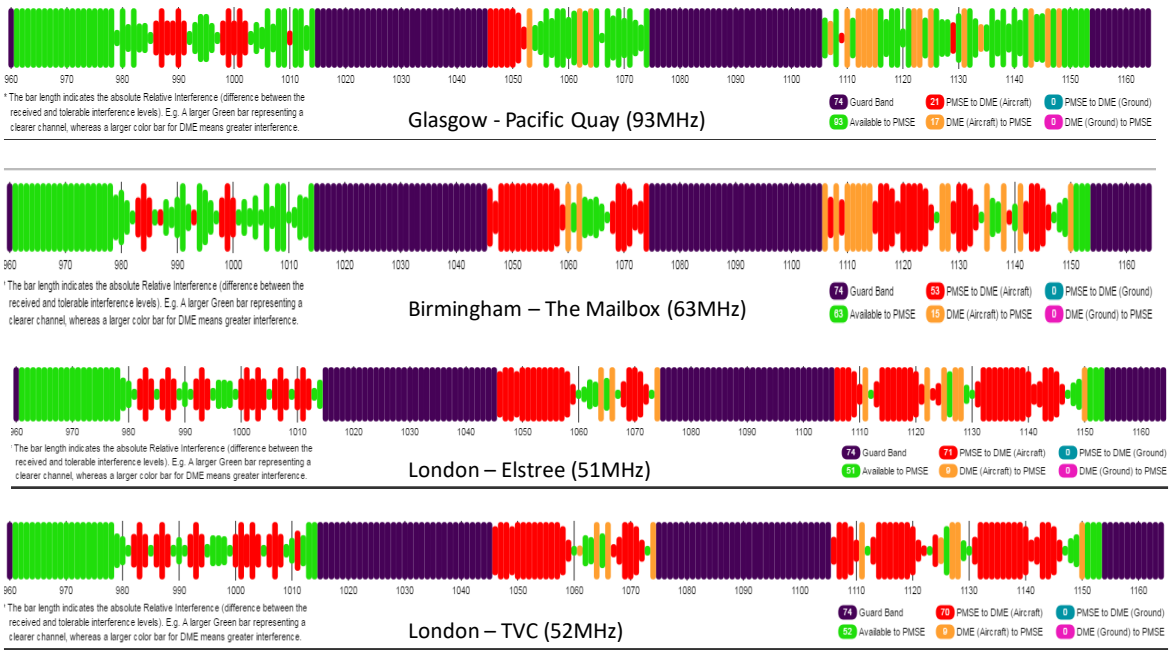
- More efficient equipment will be needed i.e. replacing analogue with digital equipment, requiring users to become comfortable with use of digital equipment to meet a given production's quality requirements.
- Re-engineering of reception equipment might be needed (e.g. filters, antennas, routing and monitoring systems).
- Alternative equipment could be used for talk-back e.g. in the DECT band (although noting that equipment in this band is typically more expensive, and operation is subject to licence-exempt operating conditions i.e. carrying a higher risk of interference).

The Government is funding a grant scheme, which Ofcom is administering, to provide funding to PMSE equipment owners to help with frequency migration. The funding being offered to eligible PMSE users is equivalent to the residual value of equipment operating in the 700MHz band that needs to be replaced at the time of clearance[46].

As a response to 700MHz clearance, Ofcom is has made available new spectrum for audio PMSE in the 960–1164MHz band, subject to non-interference to aeronautical use for radio navigation and communications. However, a present lack of European harmonisation of this spectrum means that equipment availability for the UK market is uncertain. The amount of spectrum available for PMSE use in the new band also varies by location and by equipment type, as shown below.

46 https://www.ofcom.org.uk/__data/assets/pdf_file/0021/100965/700mhz-band-pmse-funding.pdf

Figure 6.8: Typical 960–1164MHz availability for PMSE [Source: Analysys Mason, 2018]



There are potentially other bands suitable for audio PMSE use based on current European band plans[47], however several of these bands are subject to restrictions in the UK, as indicated below.

Figure 6.9: European spectrum allocations for audio PMSE use and UK availability [Source: CEPT ECC, 2016, DTG, Analysys Mason]

Band	UK availability/equipment availability
29.7–47MHz	Possibility of some bandwidth (8–9MHz) available/not used by MOD, but not currently available in Ofcom's PMSE licensing
174–216MHz	Limited authorisation currently in the UK (due to use by DAB) although reasonably well supported in PMSE equipment
470–703MHz	This is the UHF band, post-700MHz clearance – see above discussion. Well supported in PMSE equipment
823–832MHz	800MHz duplex gap – could be used for PMSE but not currently available as such in the UK
1350–1400MHz	Not authorised for PMSE use in the UK
1492–1518MHz	Not authorised for PMSE use in the UK
1518–1525MHz	Up to 7MHz might be available in the UK. Limited vendor support currently
1798–1805MHz	7MHz available in the UK (in accordance with EU Decision 2014/641/EU), but technical limitations apply
960–1164MHz	UK-only spectrum – not covered by European harmonisation. Limited vendor support currently but several manufacturers are thought to be investigating this band for future use

47 European Recommendation 25-10: "Frequency ranges for the use of terrestrial audio and video PMSE applications", last amended October 2016, see https://www.ecodocdb.dk/download/d3599aad-a5b6/Rec2510.pdf

In conclusion, in relation to PMSE spectrum demand, the SPF has noted that:

- Inputs to SPF from large PMSE users suggest those users require 175–200MHz of interleaved UHF spectrum for audio use; post-700MHz clearance, the UHF spectrum available for outdoor PMSE audio use will be reduced to 161MHz in many locations (e.g. in locations where nine DTT MUX are operating).

- There are also significant geographical variations to UHF spectrum availability, which the 700MHz clearance will exacerbate. Some spectrum may be unusable for certain PMSE applications.

- Larger PMSE users will need to re-engineer and replace existing systems e.g. move to digital equipment, re-engineer reception systems to support denser use in a smaller band, etc.[48]

- Whilst the industry broadly appreciates Ofcom's initiative in proposing to make 960–1164MHz available for audio PMSE use, greater certainty on availability is needed (not just in the UK, but in other European countries) to ensure that equipment will become available within reasonable timeframes, and at reasonable cost. At present, there appear to be risks of delay to this spectrum being economically feasible, whilst compatibility issues are further investigated, and until equipment becomes available. On compatibility, there is a concern that high levels of interference could arise to PMSE from the primary aeronautical use of this spectrum, which would affect several PMSE operations. Based on SPF discussions, it is noted that National Air Traffic Services (NATS) opposes use of this spectrum for PMSE.

- Any further reduction in DTT interleaved spectrum availability would severely affect the PMSE audio sector and would cause significant issues for the UK creative industries. This is particularly because alternative spectrum available in the UK is non-harmonised and/or of unknown quantity, as noted above. There will be benefit in keeping several of the bands identified in Figure 6.9 under review in case future availability for PMSE use can be improved, especially where there is good supply of equipment to use the spectrum, but the bandwidth is not currently available in the UK (e.g. the VHF channels are not available due to DAB use).

48 Subsequent to the SPF's discussions on UHF PMSE use it is noted that Ofcom has published details of a funding scheme to compensate for PMSE equipment replacement arising from 700MHz clearance

Annex A Abbreviations used in this report

Abbreviation	Description
AI	Artificial intelligence
AM	Amplitude modulation
B2B	Business-to-business
BR	Business radio
C-band	3.4–7.025GHz
CDMA	Code division multiple access
CEPT	European Conference of Postal and Telecommunications Administrations
D-band	130–174.8GHz
DCMS	Department for Digital, Culture, Media & Sport
DECT	Digital enhanced cordless telecommunications
DMR	Digital mobile radio
dPMR	Digital private mobile radio
DTG	Digital Television Group
DTT	Digital terrestrial television
DTV	Digital TV
eMBMS	Multimedia broadcast multicast service
ESIM	Earth Stations in Motion
ESN	Emergency Services Network
ESPG	European Radio Spectrum Policy Group
FCS	Federation of Communication Services
FM	Frequency modulation
FSS	Fixed satellite services
FTIR	Future Telecoms Infrastructure Review
GHz	Gigahertz
GPS	Global positioning systems
GSA	Global Suppliers Association
GSM	Global system for mobile communications
GSM-R	Global system for mobile communications – Railway
GSO	Geostationary orbit
HAPS	High altitude platforms
HD	High definition
HSPA	High speed packet access
IMT	International Mobile Telecommunications
IoT	Internet of Things
IP	Internet protocol
ITU	International Telecommunication Union

Abbreviation	Description
ITU-R	Radiocommunications sector of the International Telecommunication Union
JRC	Joint Radio Company
Ka-band	17.3–30GHz
Ku-band	10.7–14.5GHz
L-band	Around 1400MHz
LTE	Long Term Evolution
LTE-A	Long Term Evolution - Advanced
M2M	Machine-to-machine
MFN	Multi-frequency network
MHz	Megahertz
MOD	Ministry of Defence
MUX	Multiplex
NATS	National Air Traffic Services
NGSO/ non-GSO	Non-geostationary satellite orbit
NR	New radio
OTT	Over the top
PMSE	Programme making and special events
ProSe	Proximity services
PSB	Public service broadcaster
Q/V-band	37.5–51.4GHz
RF	Radio frequency
S-band	Around 2GHz
SCADA	Supervisory control and data acquisition
SD	Standard definition
SFN	Single frequency networks
SPF	Spectrum Policy Forum
SRD	Short-range devices
TAUWI	Telecommunications Association of the UK Water Industry
TETRA	Terrestrial trunked radio
UHF	Ultra-high frequency
VHF	Very high frequency
W-band	92–114.5GHz
WCDMA	Wideband code division multiple access
WiGig	Wireless gigabit
WRC	World Radiocommunication Conference
2G	Second generation of mobile communications technology
3G	Third generation of mobile communications technology
3GPP	3rd Generation Partnership Project
4G	Fourth generation of mobile communications technology
5G	Fifth generation of mobile communications technology
5GAP	5G Action Plan

Annex B References

This report has been produced to capture contributions made to several SPF workshops during 2018, as follows:

- Workshop 1 held on 26 April 2018: https://www.techuk.org/insights/meeting-notes/item/13122-meeting-notes-future-spectrum-demand
- Workshop 2 held on 28 June 2018: http://www.techuk.org/insights/meeting-notes/item/13417-uk-spf-cluster-1-future-spectrum-demand-meeting-notes
- Workshop 3 held on 24 September 2018: https://www.techuk.org/events/meeting/item/12795-spf-cluster-1-future-spectrum-demand-3