New Spectrum for Audio PMSE

Consultation

Publication date: 23 October 2015

Closing Date for Responses: 18 December 2015

About this document

The Programme Making and Special Events (PMSE) sector relies on radio spectrum for wireless applications that are used in the production and staging of a wide range of live and broadcast entertainment events.

The planned release of the 700 MHz band for mobile services will reduce the amount of spectrum available for audio PMSE use – such as wireless microphones and in-ear monitors.

Ofcom intends to mitigate the effect of this reduction in spectrum access, with a focus on finding appropriate, alternative spectrum for PMSE users.

Today's consultation looks at a technical sharing analysis of the 960-1164 MHz and 1525-1559 MHz bands, and a proposal to allow access to spectrum in the 960-1164 MHz band. Audio PMSE users would share access to this band with aeronautical radio navigation services.

The document also sets out an assessment of spectrum demand and supply for audio links, talkback, telemetry and telecommand.

We invite stakeholders to comment on our provisional conclusions.

The closing date for responses is 18 December 2015.

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Section 1

Executive Summary

We propose to make new spectrum available for audio PMSE

1.1 This document sets out our proposals for ensuring that users of wireless audio PMSE equipment such as talkback, wireless microphones and in-ear monitors (IEMs) in the Program Making and Special Events (PMSE) sector continue to have access to sufficient spectrum to support their activities.

1.2 We have assessed the impact of future spectrum supply and demand on audio PMSE considering future growth in use and reduction in spectrum availability.

1.3 For telemetry and telecommand, audio links and talkback our analysis shows there is minimal growth in demand with no changes in spectrum supply. Therefore, for these applications the current arrangements are sufficient and we do not need to implement any changes.

1.4 However, some PMSE applications, specifically microphones and in ear monitors (IEM) used at live music, theatre and TV events, will be impacted by a reduction in the amount of spectrum available given the withdrawal of access to the 700 MHz band (694 – 790 MHz) as a result of our decision to release the band for mobile wireless broadband use and an identified increase in spectrum use by PMSE.

1.5 In order to try to mitigate this loss of spectrum it is possible for the PMSE sector to make some changes to improve the efficiency of their spectrum use. However, we recognise that in many cases of peak spectrum demand these actions (eg better planning and using new more spectrally efficient technologies) alone may not be sufficient to meet the requirement. We have, therefore, following a detailed analysis of alternative spectrum sharing options, identified a viable candidate band for low power audio PMSE applications.

1.6 Our proposal is to make the 960 – 1164 MHz band available to the PMSE sector for low power (an EIRP of less than 17 dBm/200 kHz) wireless microphones and in ear monitors. Access would be on a coordinated basis with aeronautical navigation and communication systems, similar to the current arrangement in the TV broadcasting band where PMSE shares with digital terrestrial television.

1.7 We believe this band offers long term stability for the sector. The nature of its current allocation is extremely unlikely to change meaning that the risk of competition for access is likewise low. Current use is generally the same internationally affording the potential for a harmonised approach to sharing with PMSE.

1.8 We invite comments on our provisional conclusions by 18 December 2015.

Section 2

Introduction

Purpose

2.1 The Programme Making and Special Events (PMSE) sector requires access to spectrum to support a variety of wireless applications that are integral to the production and staging of live entertainment and for broadcast coverage of sporting and other events. The concerts and performances which rely on audio PMSE devices make an important contribution to the creative economy and cultural life of the UK.

2.2 In 2013 we initiated a strategic review of the PMSE sector with the aim of ensuring it continues to have access to sufficient spectrum to deliver these benefits. Important issues for the review were the impact of the likely on-going increase in PMSE use and anticipated reductions in spectrum availability due to the planned repurposing of bands currently used by PMSE. The work programme was outlined in our 2013/14 annual plan[1] as a strategic priority

2.3 Our initial work addressed the spectrum requirement for video PMSE applications (wireless cameras, video links etc.) and concluded with a Statement on 28 October 2014[2] detailing our strategy for video PMSE.

2.4 In this document we examine the spectrum requirements for audio PMSE applications such as wireless microphones, in-ear monitors (IEMs) and talkback communications. In particular, we have looked at the impact of the planned change of use of the 700 MHz band as confirmed in our "Decision to make the 700 MHz band available for mobile data" published in November 2014[3]. We set out our analysis of the options considered to address the future spectrum requirements of audio PMSE applications and assess the likely impact on the users of those applications.

2.5 We are seeking the views of stakeholders on this analysis and our proposal to allow audio PMSE access to the 960-1164 MHz band on a coordinated basis sharing with aeronautical radio navigation services.

2.6 The closing date for the consultation is 18 December 2015.

Background

Audio PMSE involves a diverse set of activities and applications

2.7 Within the PMSE sector, examples of a production include:

- Television and radio coverage of day-to-day sports such as horse racing, football, rugby, motor racing, golf, cricket
- Entertainment programmes such as Great British Bake Off, X Factor, Big Brother

[1] See link: http://www.ofcom.org.uk/files/2013/03/annplan1314.pdf
[2] See link: http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/statement/Statement_on_camera_strategy.pdf
[4] See link: http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/statement/700-mhz-statement.pdf

- News and topical affairs
- Musical theatre
- Rock and pop tours

2.8 Examples of special events include:

- Music festivals such as Glastonbury and V Festival
- Annual sporting events such as: F1 Grand Prix, Wimbledon, The Open Championship, FA Cup Final
- Exceptional events such as: The London 2012 Olympic & Paralympic Games; The Glasgow Commonwealth Games 2014

2.9 Audio PMSE applications enable wireless mobility for performers and presenters to support dynamic, creative and engaging entertainment. They also facilitate 'closer to the action' coverage of sports, events and news.

2.10 Wireless microphones provide high quality audio feeds of voice, musical instruments or background sounds for live performance and/or for broadcast.

2.11 There is also a requirement for wireless audio communications between the director, the production crew, presenters and performers. In broadcasting, these communications requirements are generally referred to as Talkback. In live music and theatre, performers may require a personal IEM as an alternative to stage monitors and the communications requirements for the stage crew are generally referred to as Intercom.

2.12 Other wireless PMSE applications include:

- Remote control of broadcast equipment
- Remote monitoring of systems
- Broadcast quality audio links
- Event enhancement services including audio description

2.13 A musical stage production will often need more than 50 channels for microphones, IEMs and intercom. Live concerts may require up to around 80 channels of audio and large festivals such as Glastonbury and the V Festival have very high demand for multiple artists across multiple stages with a peak demand of around 100 channels. Major TV productions such as the X Factor and Children in Need also require around 100 channels.

Audio PMSE faces challenges in its access to spectrum

2.14 The requirements of many PMSE users are growing as the number and complexity of productions increase.

2.15 PMSE users typically access spectrum on a shared rather than exclusive basis. Low power, short range PMSE applications have been able to successfully exploit sharing opportunities with other services such as digital terrestrial television broadcasting (DTT) and with military users. But opportunities to share spectrum reduce when bands are repurposed to new users that have a higher density of use such as wide-area mobile broadband.

The key spectrum to which audio PMSE has access is set to change

2.16 The 470-790 MHz band has been the preferred band for wireless microphones, IEMs and stage intercoms. PMSE access is on a geographically interleaved basis with DTT with the exception of Ch38 (606 to 614 MHz) which is currently available on an exclusive basis for PMSE.

2.17 Our decision to make the 700 MHz band available for mobile data[4] means PMSE will not be able to access the spectrum released for mobile services in the 694 – 790 MHz band. This reduces the amount of available spectrum by around 30% with some locations experiencing greater loss of access due to the re-plan of the DTT network[5] and consequential changes to the amount and configuration of available interleaved spectrum.

2.18 Our analysis[6] has concluded that, for the majority of events the spectrum supply following the reallocation of the 700 MHz band would be sufficient to meet the needs for wireless microphones, IEMs and stage intercoms.

2.19 However, for those events with the greatest spectrum demand, we anticipate there may be a shortfall in spectrum which would cause a significant negative impact to a broad range of audio PMSE users.

Addressing the challenge

2.20 Our analysis suggests that there is scope for PMSE users to improve the efficiency of their spectrum use. Potential improvements include:

- using existing equipment in a more efficient manner;
- planning centrally for large events;
- managing use more precisely on the ground; and
- adopting new technologies e.g. digital microphones.

2.21 But we recognise that in many cases of peak spectrum demand, efficiency improvements alone may not be sufficient to meet the requirement. We have, therefore, also carried out a detailed analysis of alternative spectrum sharing options, identifying a viable candidate band for low power audio PMSE applications.

2.22 Our proposal, as set out in Section 5, is to make the 960-1164 MHz band available to the PMSE sector for low power (an EIRP of less than 17 dBm/200 kHz) audio PMSE applications such as wireless microphones and in ear monitors. This would be on a coordinated basis with aeronautical navigation and communication systems; similar to the current arrangement in the TV broadcasting band where PMSE shares with digital terrestrial television.

[4] See link: http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/statement/700-mhz-statement.pdf
[5] DTT will also need to be cleared from the 700 MHz band to allow for new mobile broadband services meaning greater use of spectrum between 470 to 694 MHz for TV broadcasting.
[6] See Annex 11: http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/summary/main.pdf

Legal context

Ofcom's specific duties and powers related to spectrum management

2.23 The European Common Regulatory Framework for electronic communications[7] (in particular, the Framework Directive and the Authorisation Directive) sets the broad legal framework for how spectrum use should be authorised and managed in the UK and aims to harmonise the regulation of electronic communications networks and services throughout the European Union.

2.24 The UK's responsibilities for spectrum management under these Directives are given effect in UK law primarily through two Acts of Parliament which confer on Ofcom specific duties and powers in respect of spectrum (and the other sectors we regulate): the Communications Act 2003 (the '2003 Act') and the Wireless Telegraphy Act 2006 (the 'WT Act').

2.25 Our principal duties under the 2003 Act are to further the interests of citizens and consumers, where appropriate by promoting competition. In doing so, we are also required (among other things) to secure the optimal use of spectrum.

2.26 In carrying out our spectrum functions, we have a duty under section 3 of the WT Act to have regard in particular to: (i) the extent to which the spectrum is available for use or further use for wireless telegraphy, (ii) the demand for use of that spectrum for wireless telegraphy and (iii) the demand that is likely to arise in future for the use of that spectrum for wireless telegraphy. We also have a duty to have regard, in particular, to the desirability of promoting: (i) the efficient management and use of the spectrum for wireless telegraphy, (ii) the economic and other benefits that may arise from the use of wireless telegraphy, (iii) the development of innovative services and (iv) competition in the provision of electronic communications services.

Our spectrum management strategy and the role of regulatory intervention

2.27 In exercising our discretion on how we can best fulfil our duties as they relate to spectrum, it is important that we take a strategic approach to managing this scarce and valuable resource. Ofcom's Spectrum Management Strategy statement[8] sets out our strategic approach, which is, in summary: to rely on market mechanisms where possible and effective, but also take regulatory action where necessary.

2.28 The authorisation of spectrum use in the UK is regulated through the application of the WT Act and licences granted under that legislation. These licences confer and define rights of use of spectrum, but generally do not provide exclusivity of use. For example, Ofcom introduced Ultra-Wide Band use in a range of bands including the 2.1 GHz band some years after the 2000 "3G auction", which had allocated rights to use spectrum in this band. Therefore, subject to not causing undue interference, new sharing uses may be allowed access to spectrum which has otherwise already been licensed for other use.

[7] The Common Regulatory Framework comprises the Framework Directive (Directive 2002/21/EC), the Authorisation Directive (Directive 2002/20/EC), the Access Directive (Directive 2002/19/EC), the Universal Service Directive (Directive 2002/22/EC) and the Directive on privacy and electronic communications (Directive 2002/58/EC), as amended by the Better Regulation Directive (Directive 2009/140/EC). See http://ec.europa.eu/digital-agenda/en/telecoms-rules.

[8] See http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/statement/statement.pdf

Impact assessment

2.29 Section 7 of the Communications Act 2003 (the "2003 Act") provides that where we are proposing to do anything for the purposes of or in connection with the carrying out of our functions, and it appears to us that the proposal is important, then we are required to carry out and publish an assessment of the likely impact of implementing the proposal, or a statement setting out our reasons for thinking that it is unnecessary to carry out such an assessment. Where we publish such an assessment, stakeholders must have an opportunity to make representations to us about the proposal to which the assessment relates.

2.30 The analysis presented in this document constitutes an impact assessment as defined in section 7 of the 2003 Act.

2.31 Impact assessments provide a valuable way of assessing different options for regulation and showing why the preferred option was chosen. They form part of best practice policy-making. As a matter of policy Ofcom is committed to carrying out impact assessments in relation to the great majority of our policy decisions. For further information about our approach to impact assessments, see the guidelines, "Better policy-making: Ofcom's approach to impact assessment", which are on our website.

Equality Impact Assessment

2.32 Ofcom is separately required by statute to assess the potential impact of all our functions, policies, projects and practices on race, disability and gender equality. Equality Impact Assessments (EIAs) also assist us in making sure that we are meeting our principal duty of furthering the interests of citizens and consumers regardless of their background or identity.

2.33 We do not consider that our proposals in respect to audio PMSE spectrum access are likely to have a particular impact on one group of stakeholders as opposed to another.

2.34 Additionally, we do not believe any aspect of the question of whether or not to allow access to alternative spectrum raises issues requiring separate EIAs in relation to race or gender equality or equality schemes under the Northern Ireland and Disability Equality Schemes.

The structure of this document

2.35 The remainder of this document is set out as follows:

- Section 3 explains our approach;
- Section 4 sets out our sharing analysis of the 960-1164 MHz and 1525-1599 MHz bands;
- annex 1 contains information on how to respond to this consultation;
- annex 2 contains Ofcom's consultation principles;
- annex 3 contains a consultation response cover sheet;
- annex 4 contains a list of consultation questions;

- annex 5 contains a review of spectrum for production communications;
- annex 6 contains information on the 960-1164 MHz band; and
- annex 7 contains information on the 1525-1599 MHz band.

Section 3

Our approach

Assessing the spectrum demands of audio PMSE

3.1 Our licensing records show a steady growth in both the number of events and the number of wireless channels used for audio PMSE, principally around events employing wireless microphones and IEMs.

3.2 We asked Cambridge Consultants to look at future technology evolution in the PMSE sector both in terms of production technologies likely to drive an increase in spectrum demand and PMSE technologies likely to help meet that demand.

3.3 As well as considering technology changes Cambridge Consultants also looked at how demand might increase due to trends in production such as bigger shows, more cameras and microphones etc.

3.4 For audio PMSE, their report[9] noted that there is:

- No demand for higher audio quality than is presently available because current sound quality is regarded as being as good as necessary;
- Steady but modest growth in number of channels per event; and
- A trend to provide an in-ear monitor and wireless microphone to each performer

3.5 Given our analysis of historical spectrum demand and the study by Cambridge Consultants it is clear that this demand for wireless microphones and IEMs will continue to increase steadily for the foreseeable future. However, for production communications (talkback, audio links and telemetry & telecommand applications), our analysis shows there is likely to be only marginal growth in the requirement for talkback and little or no growth in demand for the other applications.

We don't need to take action to meet spectrum demand for most production communications

3.6 Audio PMSE production communications applications including talkback, audio links and telemetry & telecommand primarily operate at UHF between 400 MHz and 470 MHz and at VHF between 48 MHz and 215 MHz. Talkback, and similar voice communications applications, makes up the majority of PMSE spectrum usage in these bands. The frequency band most heavily utilised is 450- 470 MHz which contains around 70 per cent of the frequency assignments.

3.7 We have assessed the likely future demand for PMSE applications in these bands considering trends in growth of PMSE use and adoption of new technologies. We have also examined the risk of a reduction in future spectrum availability for PMSE resulting from potential decisions to reallocate spectrum to other non-PMSE services.

[9] Cambridge Consultants, *Technology Evolution in the PMSE Sector*, p. 11. See link: http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/statement/cambridge-main-report.pdf

3.8 Our analysis, set out in Annex 5, focussed on the PMSE bands below 470 MHz and in the 1.5 GHz band but we recognised that PMSE often calls on spectrum "loans"(use of spectrum not designated for PMSE) from other sectors such as Business Radio, Emergency Services, Ministry of Defence and other government users. For example, we noted a large number of requests to loan spectrum from bands not designated for PMSE use in the range 137-173 MHz which is generally for international motor racing events. This is because there is little suitable PMSE spectrum available in the VHF band to meet these users' particular requirement.

3.9 Similarly, for peak demand events such as the Tour de France or Formula 1 Grand Prix, loan spectrum is vital to top-up the spectrum resource available for day-to-day PMSE use and to meet the particular needs of international competitors and broadcasters. So, in addition to those bands designated for day-to-day PMSE use we included these non-PMSE bands in our review of future spectrum availability.

3.10 We do not anticipate changes in spectrum supply affecting designated PMSE bands below 470 MHz and at 1.5 GHz. Similarly, we found no significant risks to the adequate future access to bands that are not designated for PMSE but are frequently used by PMSE.

Question 1: Do you agree with our assessment that minimal growth in demand and stability in spectrum supply means that we do not need to implement any changes to meet the ongoing spectrum requirements for talkback, audio links and telemetry and tele-command applications?

Clearing the 700 MHz band impacts spectrum available for wireless microphones, IEMs and stage intercoms

3.11 The 470-790 MHz band is currently the primary spectrum resource for low power audio PMSE devices such as wireless microphones and IEMs which geographically interleave with DTT broadcast frequencies.

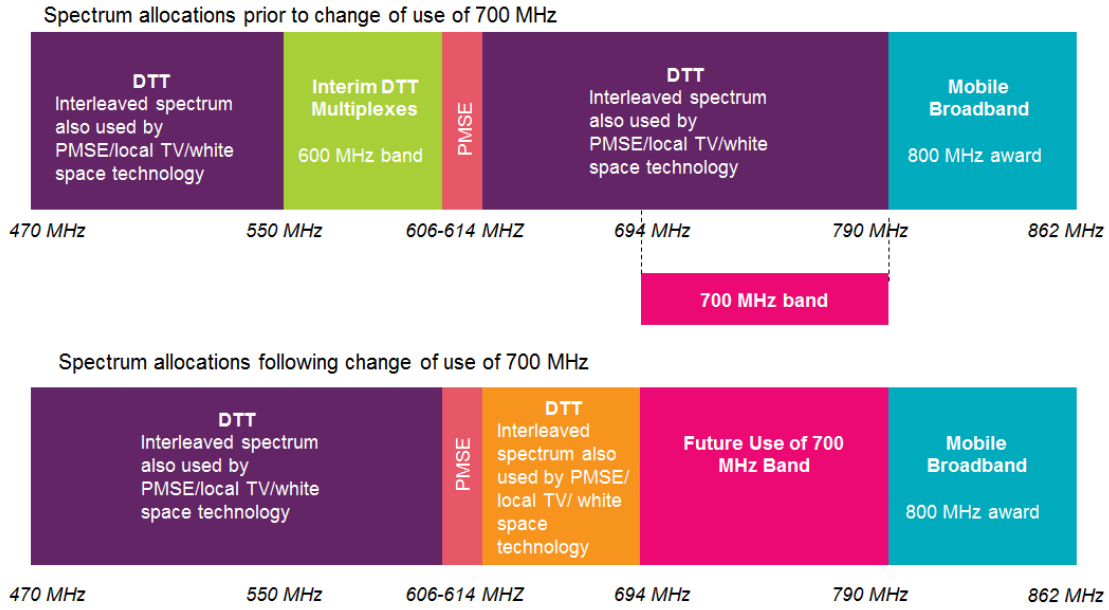
3.12 Our decision to make the 700 MHz band available for mobile data[10] means PMSE will not be able to access the spectrum released for mobile services between 694-790 MHz. This reduces the available spectrum by around 30% with some locations experiencing greater loss of access due to the re-plan of the DTT network[11] and consequential changes to the amount and configuration of available interleaved spectrum.

3.13 Figure 1 shows how spectrum availability will change in the 470-790 MHz band following the award of the 700 MHz band. The full configuration of available spectrum post award will not be known for all locations until the final DTT transmission plan is agreed.

[10] See link: http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/statement/700-mhz-statement.pdf

[11] DTT will also need to be cleared from the 700 MHz band to allow for new mobile broadband services meaning greater use of spectrum between 470 to 694 MHz for TV broadcasting.

Figure 1: Spectrum allocations 470 – 862 MHz (UHF Bands IV and V)



3.14 Our analysis of the impact of this reduction in spectrum availability is set out in our consultation on the future use of the 700 MHz band published in May 2014[12]. In order to assess the impact the loss of the 700 MHz band would have on PMSE we took the following steps:

- We estimated how much spectrum would be available for PMSE across the country if we made the 700 MHz band available for mobile by assuming an indicative TV broadcasting plan and applying the same rationale for deriving spectrum availability and quality as we currently do; and
- We identified a sample of events with a high demand for spectrum at a variety of locations across the UK using licensing data and engagement with stakeholders.

3.15 We sought to re-plan these events against the expected future spectrum configuration (based on the indicative DTT plan) in that location. We assessed any shortfall in satisfied requirements qualitatively and graded the impact on a five point scale, ranging from minimal (no impact on the production of the event) to critical (even with action taken the event would not be viable in any recognisable form).

3.16 In summary we found that for the majority of events, the spectrum supply following the reallocation of the 700 MHz band would be sufficient (93% of events require fewer than 24 audio channels which could be accommodated in 24 MHz). However, for peak demand events the reduced spectrum available would not accommodate current usage levels of a range of audio PMSE applications. It noted that:

- There is a class of very high PMSE demand events, representing around 10 to 20 sporting, theatre and live music events a year for which the supply of interleaved spectrum following change of use of the 700 MHz band would not be adequate;

[12] http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/summary/main.pdf

- There is a larger set of events – representing a majority of those cases studied – for which, in order for the supply of spectrum to be adequate, significant changes to equipment and working practices would be needed; and

- The availability of interleaved spectrum varies greatly by region. There is a risk that this variation could lead to certain locations becoming unattractive for hosting high PMSE demand events.

3.17 Our analysis concluded that without measures to mitigate the effects of the loss of access to the 700 MHz spectrum audio PMSE, particularly microphones and IEMs, may face a shortfall in the amount of spectrum available to support its activities.

What can be done to mitigate the impact?

3.18 To support the spectrum needs for wireless microphones and IEMs, we have identified two options for mitigating actions to enable events to meet their production requirements. These are:

- making more efficient use of remaining existing spectrum resource by audio PMSE, including the adoption of more efficient technology; and

- opening an additional allocation of shared spectrum for audio PMSE.

3.19 In addition to the actions outlined above the European Commission has mandated EU Member States to make available the 800 MHz and 1800 MHz duplex gaps under its PMSE Implementing Decision 2014/641/EU. The Decision instructs Member States to make available the bands 823-832 MHz and 1785-1805 MHz for wireless audio PMSE equipment and therefore provides long-term certainty of access to this spectrum. We made this spectrum available in March 2015 and PMSE users are encouraged to make full use of these bands to help offset the loss of access to the 700 MHz band.

Make more efficient use of remaining interleaved spectrum

3.20 In our 700 MHz consultation we noted considerable variation in the spectral efficiency achieved between PMSE deployments.[13] This suggests there is scope for PMSE users to improve the efficiency of their spectrum use.

3.21 We have identified a number of actions that audio PMSE users could take in light of the reduction in available spectrum following the loss of the 700 MHz band. These include using:

- existing equipment in a more efficient manner, including planning centrally for large events and closely managing operational use on-site; and

- new technologies e.g. digital microphones.

3.22 With regard to closer operational management on-site, we found from interviews with stakeholders, that there is a diversity of practice in the level of on-site coordination performed and that not all equipment licensed for an event is required to be in use at all times. There is an opportunity to improve assignment density at high

[13] Paragraph 7.26, *Consultation on future use of the 700 MHz band: Cost-benefit analysis of changing its use to mobile services*. See link: http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/summary/main.pdf

demand events given improved temporal coordination, though this requires greater planning and operational overhead.

3.23 Improved working practices can be supplemented by the adoption of new technologies that will enable existing spectrum resources to be used more efficiently. This might involve a greater inventory of equipment operating over more frequency ranges and moving to digitally modulated systems that, when compared to analogue, will go towards mitigating future demand for some PMSE use cases.

3.24 Analogue equipment is already improving. Digital microphones are also now in use, but IEMs remain analogue due to latency issues. It is important to note that digital/analogue mixed environments, (e.g. digital microphones with analogue IEMs) reduce the benefits that digital equipment offers in a spectrum plan.[14]

3.25 The report by Cambridge Consultants on technology evolution in the PMSE sector notes that wireless microphones and IEM equipment is now available that can use spectrum around two and a half times as efficiently as current practice for analogue transmission and three times as efficiently for digital transmission (up to eight times in restricted cases).[15] Presently, this performance is offered only by top of the range equipment, but it could reasonably be expected to be available at lower cost in the next five years.

3.26 However, we think improvements that come from increased efficiency will be less significant at larger events. These events tend to be the most socially and culturally important and tend to have the greatest economic benefits so typically already use the best equipment and personnel to produce the show.

3.27 Although important, we believe increased efficiency would not fully address the impact of the loss of access to the 700 MHz band for audio PMSE.

Secure access to alternative spectrum

3.28 In assessing likely candidate bands we identified criteria to determine whether spectrum is both viable for and meets the needs of the sector. Importantly, this includes long term stability in terms of access and the possibility of harmonisation internationally. We recognize the importance of both these issues to the sector when considering the development of new equipment.

3.29 In Table 1 we define those criteria.

[14] Page 66 and 69 *Consultation on future use of the 700 MHz band: Cost-benefit analysis of changing its use to mobile services*.
http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/summary/main.pdf
[15] Cambridge Consultants, *Technology Evolution in the PMSE Sector*, p. 3. See link:
http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/statement/cambridge-main-report.pdf

Table 1 Selection criteria for new candidate spectrum opportunities for audio PMSE

Criteria	Rationale
Not already allocated to mobile	Due to the typical pattern of spectrum use and deployment by mobile networks, sharing with such networks would be challenging. On this basis, we did not consider a sharing scenario with mobile services in our analysis.
Not already identified as a candidate mobile band and unlikely to be so in the medium to long term	Any spectrum identified as a candidate mobile band is at risk of reallocation at some future time. While reallocation may be many years away, the associated uncertainty around long term access undermines incentives to invest in new equipment.
The existing use the same in other major markets	This would provide the opportunity for PMSE use to be adopted in other territories where existing use is the same as the UK, leading to economies of scale for manufacturers, both in terms of equipment production and of distribution.
Provides a substantial block of contiguous spectrum (ie a range of spectrum that could be realistically accommodated in the tuning range of equipment)	We consider that a fragmented spectrum supply would not be viable for PMSE users.
Below 2 GHz	The current industry consensus is that higher frequencies are inappropriate for PMSE applications due to their propagation characteristics.

3.30 We examined several frequency bands, which most closely satisfied these criteria, to determine their theoretical suitability for sharing with audio PMSE. Our initial analysis of the suitability of these bands is detailed in Tables 2, 3 and 4 below.

Table 2 Assessment of the 960-1350 MHz band's suitability for audio PMSE

Band	Current use	Suitable for PMSE use
960-1164 MHz	Aeronautical – Distance Measuring Equipment (DME) and Joint Tactical Information Distribution System (JTIDS) assignments.	Yes, subject to successful co-existence analysis.
1164-1214 MHz	Aeronautical – DME and JTDIS and radionavigation satellite service (RNSS) devices	No. Ubiquitous use of RNSS receiving devices (e.g. GPS terminals) makes sharing in this band not viable.
1215-1300 MHz	Aeronautical – RNSS devices and military and civil radar	No. Incompatibility with the ubiquitous use of RNSS receiving devices and difficulty of sharing with wide-bandwidth radar systems makes this band unsuitable.

1300-1350 MHz	Civil and military radars	No. The difficulty of sharing with radar systems which have stringent protection criteria and operate at high powers makes this band unsuitable for PMSE use.

Table 3 Assessment of the 1427-1517 MHz band's suitability for audio PMSE

Band	Current use	Suitable for PMSE use
1427-1452 MHz	Lightly used at present; managed by the MOD and identified as a candidate for sharing with commercial users	No. The band is being proposed by CEPT for consideration as a candidate band for IMT at the World Radio Conference. Therefore the long-term availability of this band for PMSE and the potential for international harmonisation are both uncertain.
1452-1492 MHz	The band from 1452-1492 MHz was awarded to Qualcomm via auction by Ofcom in 2006 Following a variation to support Supplementary Downlink (SDL), the spectrum was traded in October 2015: - 1452-1472 MHz to Vodafone - 1472-1492 MHz to Three	No. The CEPT ECC Decision (Decision (13)03) was adopted in November 2013 harmonises the band for mobile/fixed communications networks supplemental downlinks. The band has been identified as a high priority band in Ofcom's Mobile Data Strategy. Therefore the long-term availability of this band for PMSE, and the potential for international harmonisation, is very doubtful.
1492-1517 MHz	Used extensively in the UK for private fixed links and also under consideration for International Mobile Telecommunications (IMT)	No. The band is being proposed by CEPT for consideration as a candidate band for IMT at the World Radio Conference (up to 1518 MHz). Therefore the long-term availability of this band for PMSE and the potential for international harmonisation are both uncertain.

Table 4 Assessment of the 1525-1710 MHz band's suitability for audio PMSE

Band	Current use	Suitable for PMSE use
1525-1559 MHz	Used by the mobile-satellite service (MSS) for downlinks from satellites to user terminals	There would appear to be some scope for sharing with PMSE.
1559-1610 MHz	Main RNSS band used by GPS, Galileo and other systems.	No. Incompatibility with the ubiquitous use of radionavigation-satellite receiving devices makes this band unsuitable for PMSE use.
1610-1626.5 MHz	Aeronautical RNSS, mobile-satellite service (Earth-to-space) and radio astronomy.	No. Limited size of the band, priority given to aeronautical use and difficulty in sharing appear to rule this band out for

		PMSE.
1625.5-1660 MHz	Earth-to-space link of MSS	No. Sharing with MSS uplinks could be feasible, but international harmonisation would prove challenging.
1660-1710 MHz	Radio astronomy and meteorological satellite service	No. There are six radio astronomy sites in this band that require significant separation distances, along with use of the 1677- 1685 MHz band by the Home Office.

Two bands were shortlisted for detailed co-existence testing

3.31 We concluded that the following bands were good potential candidates for sharing spectrum with audio PMSE:

- 960-1164 MHz sharing with the aeronautical navigation systems Distance Measuring Equipment (DME) and Secondary Surveillance Radar (SSR) and the military communications system Joint Tactical Information Distribution System (JTIDS); and
- 1525-1559 MHz sharing with the Mobile Satellite Service (MSS).

3.32 In the next section we set out our co-existence analysis of these two candidate bands with audio PMSE use. We also explore the type of sharing arrangements that would be necessary and the implications of this for spectrum availability.

Section 4

Analysis of the 960-1164 MHz and 1525-1559 MHz bands

Summary

4.1 Our assessment of the sharing potential for each band is based on both theoretical analysis and practical study. The results of this work indicate that both bands are viable candidates for accommodating low power audio PMSE devices. As the nature of incumbent use is different between the bands, the nature of sharing arrangements will also differ:

- 960-1164 MHz – sharing would be geographically interleaved with DME in order to protect both the ground DME beacon receiver and the airborne interrogator receiver. On a national basis the channels allocated to SSR, ± 10 MHz, would not be made available to PMSE. Of the 164 MHz available our analysis (of four locations) indicates between 50 MHz and 117 MHz of spectrum depending on location and offsetting the PMSE carrier frequency within the DME channel.

- 1525-1559 MHz – by including the band 1517-1525 MHz already allocated to PMSE this would provide 42 MHz of spectrum UK wide. However, where possible and necessary some small 'notches' could be considered to provide enhanced protection to certain satellite channels, for example the Maritime Safety Information broadcast channel which forms part of SafetyNET. It would also be necessary to have a geographical exclusion zone around the Cospas-Sarsat fixed receive location at Combe Martin, Devon. This site receives a relayed distress signal from a satellite in the band 1544-1545 MHz.

4.2 Due to the broad range of activities and use cases of audio PMSE it is difficult to quantify an amount of spectrum being absolutely sufficient to meet all use cases. However, in identifying our spectrum options we have qualitatively assessed the effect 42 MHz from the MSS band would have against our study cases (as presented in the 700 MHz cost benefit analysis published in May 2014) as this represents the worst case scenario of spectrum availability from our analysis of both bands. Within this assessment we made some assumptions about equipment performance and deployment and concluded that for the majority of use cases in the study the additional spectrum would fully mitigate the impact of the loss of the 700 MHz band.

4.3 Given that the amount of spectrum available in the aeronautical band is greater than 42 MHz in any location our assessment is that this band would also fully mitigate all peak demand cases.

960-1164 MHz band

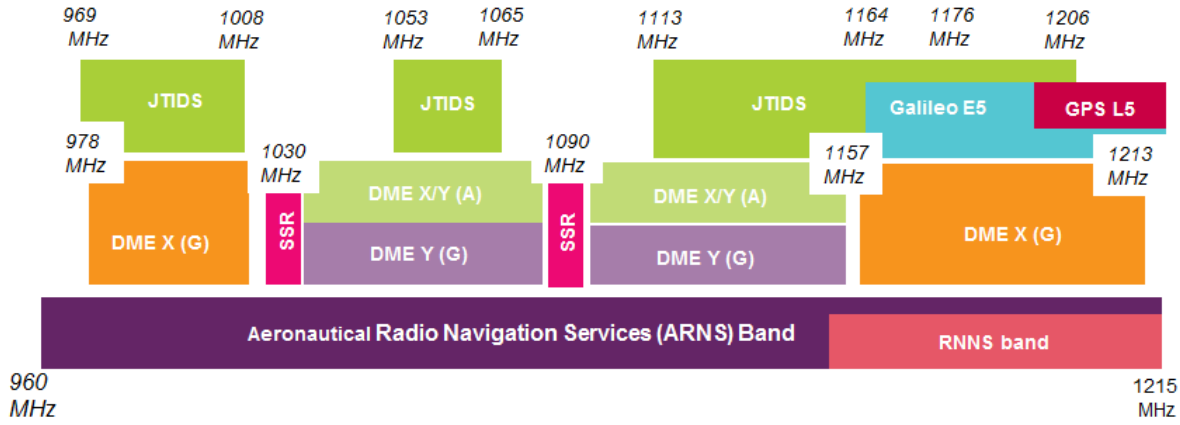
Current use

4.4 The band 960-1215 MHz is allocated to the Aeronautical Radio Navigation Service with the Radio Navigation Satellite Service sharing above 1164 MHz on a co-primary

basis. The allocation applies to each of the ITU Regions[16]. This means that any workable sharing arrangement in the UK could be adopted in other countries depending on their specific local conditions. Given the ubiquitous nature of satellite navigation receivers, e.g. GPS, PMSE sharing in the 1164-1215 MHz band is not viable, so we restrict our assessment to the band 960-1164 MHz

4.5 Figure 2 below outlines the current allocations and services in the band. In addition to the services outlined below it is expected that L-Band Digital Aeronautical Communication System (LDACS) will be introduced within the next few years.

Figure 2 – Allocations and services operating in the 960-1215 MHz band in the UK



4.6 The three main applications currently operating in the band are Distance Measuring Equipment (DME), Secondary Surveillance Radar (SSR) and the Joint Tactical Information Distribution System (JTIDS). Tactical Air Navigation (TACAN) is a navigation system used by military aircraft which provides the user with a distance and bearing from a ground station. It was agreed by the Ministry of Defence that this system is sufficiently similar to DME and does not need to be treated separately. Therefore we do not refer to TACAN further and apply the results and conclusions for DME to TACAN.

4.7 DME is identified as the main system for consideration of sharing with PMSE. DME is an interrogator-transponder system used by an aircraft (interrogator) to determine its distance from a ground station (transponder). It measures the slant-range distance of an aircraft from its destination by sending and receiving pulse pairs and timing the propagation delay of the radio signals. This system facilitates three primary types of navigation.

- En route –DME beacons are often paired with a VHF Omnidirectional Rangefinder (VOR) beacon, which allows the aircraft to know the beacon's bearing as well as the slant range provided by DME.

- Terminal DME – terminal DME beacons are generally paired with an Instrument Landing System; the ILS will provide precision lateral and vertical guidance to an aircraft approaching and landing on a runway, whilst the DME will give range to the threshold point of the runway.

[16] Region 1 comprises Europe, Africa, the Middle East west of the Persian Gulf including Iraq, the former Soviet Union and Mongolia. Region 2 covers the Americas, Greenland and some of the eastern Pacific Islands. Region 3 contains most of non-former-Soviet-Union Asia, east of and including Iran, and most of Oceania

- DME/DME – the Flight Management Systems on larger modern aircraft are able to track up to five DMEs at any one time; even in the absence of bearing information, this allows the triangulation of the aircraft's position. This is commonly referred to as 'scanning DME'.

4.8 Each DME beacon has a Designated Operational Coverage (DOC) area, which is given in terms of range (which may vary with bearing) and altitude. Within this area the signal level from the ground beacon must meet the field strength requirement laid down by the International Civil Aviation Organisation.

4.9 SSR is an active radar system used in air-traffic control. A highly-directional rotating antenna transmits an interrogation pulse train at 1030 MHz, and, upon receiving a reply pulse train from an aircraft's transponder at 1090 MHz, calculates the aircraft's slant range from the delay in the reply and its bearing from the orientation of the antenna at the time of interrogation. It also supports other aeronautical services such as the aircraft Traffic Collision Avoidance System (TCAS) and the Automatic Dependent Surveillance – Broadcast (ADS–B) which periodically broadcasts an aircraft's position enabling it to be tracked. The reply pulse train (in the most basic case) contains either the aircraft's pressure altitude or identification code. This protocol has been much extended to allow for the aircraft to be able to supply more data about its position, altitude and intent.

4.10 JTIDS is a military air-to-ground and air-to-air communication system used by NATO nations and its allies. JTIDS is one of the family of radio equipment implementing what is called Link16. This is a network that provides communications by allocating a period of time for a user to transmit its messages. The data to be transmitted during a specific time slot is encrypted and encoded as a series of pulses. Each pulse is transmitted at a specific time within the time slot. Transmissions are therefore distributed across available time slots using time division multiplexing. Each transmitted pulse is allocated to frequencies in a pattern known only to the members of the network and spread across multiple frequencies.

Opportunities for PMSE

4.11 The DME band is divided into 1 MHz channels across the band (126 channels for interrogation and 126 channels for reply). Channels are assigned in order to minimise the risk of interference to adjacent DME coverage areas. This is analogous to DTT planning where different neighbouring broadcast transmissions are planned to avoid mutual interference.

4.12 Interleaving of large coverage areas suggests it may be possible to achieve geographical sharing with low-power PMSE in a similar way to how PMSE currently interleaves with DTT.

4.13 Given the use of the SSR for safety critical roles in both the aircraft to aircraft Technical Collision Avoidance System (TCAS) and ground based ATC and surveillance systems, we do not believe geographically interleaved sharing is viable. Consequently our analysis identifies the frequency separation necessary to protect this service

4.14 This band is internationally harmonised for DME. Thus, there is potential for other countries to adopt this sharing option for PMSE and thereby help to generate further economies of scale for the PMSE sector.

Challenges

4.15 Although geographical sharing in the band is analogous to sharing with DTT the situation is more complex. There is a requirement to protect both ground and airborne receivers with the latter operating anywhere in the defined coverage area. There is also the need to consider interference into PMSE from both the ground beacon transmitter and, more importantly, the airborne transmitter. In any given location multiple coverage areas overlap and it is necessary to consider the protection requirements and interference potential (to PMSE) for each DME channel in use. However, although more complex than current arrangements for use of interleaved spectrum in the 470-790 MHz band we believe we can develop practical coordination and licensing arrangements to facilitate sharing.

4.16 The nature of the technology used by JTIDS i.e. a spread-spectrum signal, and the sensitivity of its operational deployment suggests technical sharing is not possible even on a coordinated basis. However, the use of JTIDS is typically in remote areas and above 10,000 feet, therefore away from areas where PMSE use is likely. In addition, the Frequency Clearance Agreement between the CAA and MOD limits the use of JTIDS in the presence of civil aviation and these areas also align closely with those of high PMSE demand. Therefore the use of JTIDS does not constrain spectrum availability where it is needed for PMSE.

Practical testing

4.17 The report from JCSys Ltd details the approach and conclusions of the practical analysis and is provided in Annex 6. The purpose of this work was to establish the co-existence criteria which would enable PMSE to operate on an interleaved basis with aeronautical systems. The testing looked at the impact of PMSE interference into the aeronautical systems in the band and from those systems into PMSE. The testing addressed both co-channel and adjacent channel compatibility and provides interference thresholds on PMSE for these scenarios.

4.18 The Frequency Clearance Agreement between the CAA and MOD defines the level of JTIDS activity that allows DME to continue to operate within its performance requirement. This agreed JTIDS signal environment, the full pulse environment, was included when determining the threshold of interference from PMSE into DME.

4.19 For DME ground beacons and airborne interrogators three commonly-used systems were tested for co- and adjacent-channel susceptibility to interference. Ground beacons were tested against the performance requirement to maintain a beacon reply efficiency of 70% and interrogators were tested in terms of both their ability to acquire a stable lock from a DME beacon (the Acquire Stable Operating Point test - ASOP), and their ability to maintain that lock (the Break Stable Operating Point test - BSOP).

4.20 As mentioned above we had already concluded that co-channel sharing with SSR is not viable. However, it was important to understand the susceptibility of SSR to adjacent channel operations and therefore the testing looked at determining the adjacent channel thresholds and required frequency offsets to ensure no impact from PMSE.

4.21 JCSys Ltd also carried out an assessment of the impact from DME and JTIDS into PMSE. The methodology employed was the same as that used to determine audio quality in the presence of white space device interference with the test equipment configured for interference from aeronautical systems.

Test conclusions

4.22 The recommendations provided by JCSys Ltd present a range of interference and frequency offset limits to ensure aeronautical systems are not affected by low power audio PMSE transmissions. We have universally adopted all recommendations in the report to define co-existence arrangements between PMSE and other uses of the band, for example PMSE should not operate within ±10MHz of the SSR channels at 1030 MHz and 1090 MHz. Where there are differences in measurements across equipment, for example when comparing the results for the three DME ground beacons, we have used the most stringent value, effectively developing an envelope of compatibility based on the lowest thresholds. We have then used these limits in deriving spectrum availability for PMSE.

4.23 For interference into PMSE from DME, primarily airborne interrogator transmissions, results show that operation is possible especially outside the operational area of the DME. Greater rejection of DME signals is possible by offsetting the PMSE channel with a 25 dB reduction in DME interference if the PMSE channel is offset by 300 kHz.

4.24 Our assessment of the impact of DME on PMSE and the resulting spectrum availability is based on an assumption of how DME is used, specifically that aircraft do not regularly transmit on DME channels outside the designated coverage area.

4.25 JTIDS is a potential threat to PMSE due to the waveform used and the spread-spectrum nature of the JTIDS signal. The report shows that a C/I of -10 dB to -24 dB is required to protect PMSE which suggests that for the typical airborne transmit power protection distances of the order of kilometres may be required to protect outdoor PMSE use with indoor. However, the use of JTIDS is typically above 10,000 feet and away from areas where PMSE use is concentrated so the risk of any interference is very low and will be transient in nature given the signal characteristics and the nature of use i.e. aircraft flying in training areas rather than a fixed installation.

4.26 The L-Band Digital Aeronautical Communication System (LDACS) link is being considered as part of the European Union Single European Sky programme and if adopted it is expected in the band, possibly by 2021/2022. The system is a based on a cell architecture interleaving with DME. The deployment of LDACS would likely reduce the amount of spectrum available but we have not been able to assess this in detail as there is little information on likely deployment scenarios or channel assignments.

4.27 There has also been some discussion on the introduction of Unmanned Airborne Systems in the band. A new work item has been raised in ETSI to develop a Technical Reference Document on frequencies for professional UAS in Europe but there are no details at this time. Work is underway by the Radio Technical Commission for Aeronautics in the USA to define minimum operational performance standards for Unmanned Aircraft Systems using this band amongst others and is intended to be published in May next year. It is too early to know what the outlook for this system would be.

Coexistence modelling

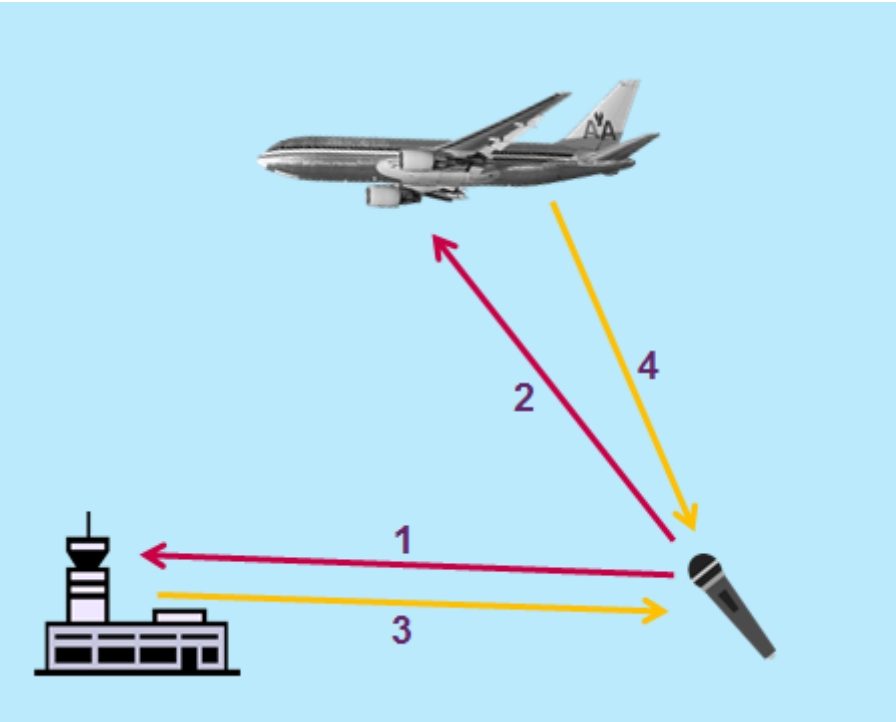
4.28 In order to determine a picture of spectrum availability in this band for PMSE we have carried out propagation analysis using the thresholds and recommendations derived from the practical studies. This includes the protection of DME and SSR and the effect of interference from aeronautical systems into PMSE. We have taken a

conservative approach by adopting the most stringent limits from all of the testing to derive an envelope of thresholds which captures the most limiting value for all frequency offsets.

4.29 This analysis considers four protection scenarios, see Figure 3:

1. Protecting ground transponder receiver from PMSE
2. Protecting airborne interrogator receiver from PMSE
3. Protecting PMSE receiver from DME transponder
4. Protecting PMSE receiver from DME airborne interrogator

Figure 3 – DME/PMSE interfering paths considered



4.30 A different modelling approach is used for each scenario. For Scenario 1 (protection of ground transponder receiver from PMSE) the location of the DME receiver is known and we have used a path specific propagation model using the relevant elements of ITU-R Recommendation P.452 in conjunction with a terrain model. In addition we accounted for the effects of clutter and buildings at the PMSE end only as DME ground transponders are sited free of clutter.

4.31 However, for the airborne path in Scenario 2 we have used the general path propagation model ITU-R Recommendation P.528 (IF77) without any adjustments for terrain or clutter. We have assumed that the DME airborne receiver can be located anywhere within the DOC of the transponder. The DOC is usually defined as a cylinder of airspace in terms of distance and height e.g. 100 Nautical miles, 50,000 feet. The approach we have taken is to protect the airborne DME from zero feet to the maximum altitude specified at all ranges. We believe this is a conservative approach as it does not consider the radio horizon. This means the PMSE transmitter and DME receiver have no separation distance so results are extreme worst case. We are reviewing this approach with the CAA to include consideration of the radio horizon. Were such an approach acceptable then this would introduce a physical

separation distance between the PMSE transmitter and DME receiver, for example at 100 NM the radio horizon infers approximately 5,000 feet vertical separation.

4.32 In order to provide an indication of spectrum availability for PMSE in this band we have performed analyses at the following four venues:

- Seven Dials, London.
- Glastonbury, Somerset.
- Media City, Salford.
- Scottish Exhibition & Conference Centre, Glasgow (SECC).

4.33 PMSE emissions were modelled as 50 mW radiated considering several simultaneous emissions within a channel to help account for non-linear effects at the aeronautical equipment.

4.34 Coexistence is mostly constrained by the airborne DME which may be operating in a very large airspace volume within the DOC meaning the airborne receiver could be hundreds of kilometres from a ground transponder. The constraint on spectrum availability is from both the requirement for PMSE to protect DME and the potential interference from airborne transmissions into PMSE.

4.35 Interference to PMSE from DME can be mitigated by offsetting the PMSE carrier frequency but still remaining within the DME channel. However, this may limit the number of PMSE channels that could use the DME channel but this would depend on local conditions and PMSE equipment deployment.

4.36 Considering neighbouring countries, the number of overlapping designated operational coverage areas is densest in the south east UK which limits the potential for PMSE in this area. Consideration of the radio horizon may reduce the number of coverage areas to be considered especially for the adjacent channel cases. This could increase the amount of spectrum available for PMSE and we are working with the CAA to evaluate this.

4.37 The results for the four locations (without consideration of the radio horizon) show that the available spectrum in terms of 1 MHz channels between 960 – 1164 MHz are as given in Table 5. Within this assessment we have also considered adjacent services and excluded the DME channels at the boundaries of the band, i.e. 1 MHz channels centred at 960.5 MHz and 1163.5 MHz.

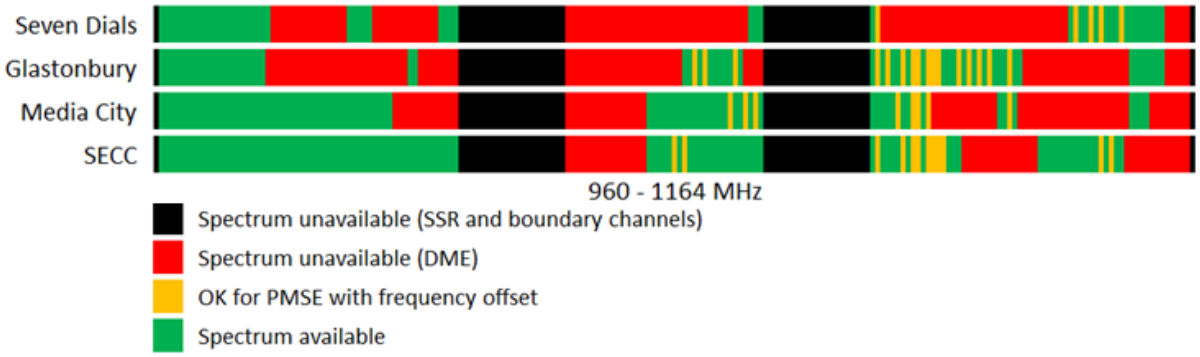
Table 5 – Number of 1 MHz channels available to PMSE across the 960-1164 MHz band

	Seven Dials	Glastonbury	Media City	SECC
Channels with no frequency offset required	50	56	81	105
Additional channels gained with frequency offset	5	16	8	12

4.38 The results are specific to the conventional PMSE technologies tested but provide an indication of availability. As with PMSE sharing with DTT, the amount and configuration of available spectrum will change depending on the specific location.

4.39 Figure 4 gives an indication of the arrangement of available spectrum in the four specific locations studied.

Figure 4 – arrangement of available spectrum across the 960-1164 MHz band



Provisional conclusion

4.40 The 960-1164 MHz band meets all our criteria for identifying an alternative sharing option to mitigate the loss of the 700 MHz band. The band is harmonised for aeronautical use across all three ITU Regions which could allow for the development of further economies of scale for PMSE manufacturers if other administrations adopted the band for low power PMSE.

4.41 Our analysis shows there is sufficient spectrum available on a geographically interleaved basis that would fully mitigate the loss of the 700 MHz band. However, it is highlighted that the band is used by safety critical radio navigation aids so sharing would need to be on a coordinated basis in spectrum identified as available at particular locations. This coordinated access matches the framework we currently use for access to spectrum in the DTT band i.e. location, frequency and duration specific. Initially spectrum availability would be derived for named venues but would develop over time to cover more locations.

4.42 Future developments in the band will see the introduction of LDACS, possibly as early as 2021/2022, which could reduce the amount of spectrum available for PMSE. Our estimate is this will be of the order of 10 MHz which would still allow sufficient spectrum to mitigate the loss of the 700 MHz band. Beyond this there are no further changes expected in any timescale over which we can be confident. It is also noted that changes to spectrum use or allocations in the aeronautical sector are relatively slow, often taking many years of development before any decisions are made so it is reasonable to assume that as there is nothing currently on the horizon we are confident that further changes beyond those identified for LDACS will be many years off.

1525-1559 MHz band

Current use

4.43 The band 1518-1559 MHz is primarily allocated to the Mobile Satellite Service across all three ITU Regions so, as for the aeronautical band, any potential sharing solution could be adopted by other administrations if local conditions allow. In the UK PMSE has access to the band 1517-1525 MHz (for high power audio and data links which could also be used for low power audio PMSE) therefore our study only considers the range 1525-1559 MHz. The band is for the space to Earth component of the satellite communications link with the Earth to space component in the 1.6 GHz band. Applications include land, aeronautical and maritime communication services which include safety-related applications which require particular consideration.

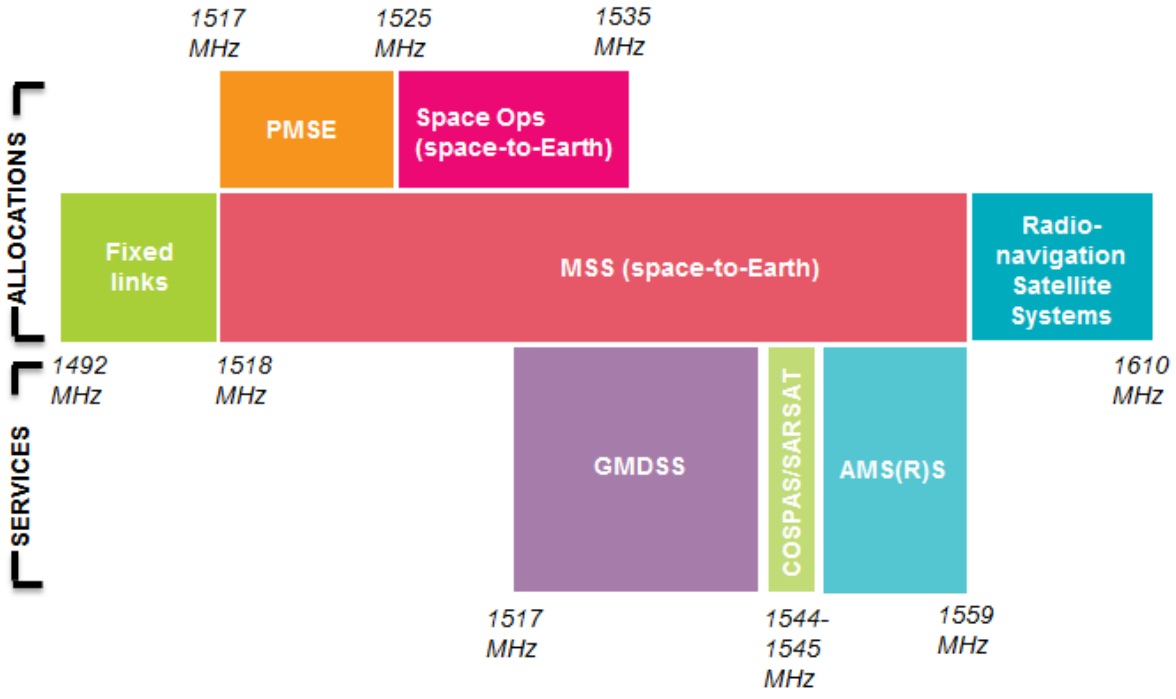
4.44 In the range 1530-1544 MHz, priority is given to accommodating the distress, urgency and safety communications of the Global Maritime Distress and Safety System (GMDSS) under footnote 5.353A of the ITU Radio Regulations.

4.45 The range 1544-1545 MHz is used as a downlink to a fixed satellite receiver at Combe Martin in North Devon for the COSPAS/SARSAT search and rescue system.

4.46 In the range 1545-1559 MHz, priority is given to accommodating the downlink of the Aeronautical Mobile Satellite (Route) Service (AMS(R)S) under footnote 5.357A of the ITU Radio Regulations providing communications for the safety and regularity of flight.

4.47 Figure 5 provides an overview of the allocations in the 1518-1559 MHz band.

Figure 5 – Allocations and services in and around the 1525-1559 band



4.48 While there is no restriction of where a mobile satellite Earth station (ES) may operate the primary application is to provide connectivity for voice and data applications in remote areas not served by terrestrial fixed (either wired or wireless)

and mobile networks or where these networks have been compromised, for example because of natural disasters. Typical use includes providing remote communications to ships and aircraft and remote workers in the oil and gas industry.

Mobile satellite networks consist of geostationary satellites providing coverage to defined areas of the Earth's surface, with a network providing almost global coverage, for example Inmarsat's I-4 satellites. In order for an Earth station to communicate it must have a clear view of the sky and the satellite orbiting 36000 km above the Equator. Therefore a disadvantage of MSS is the fact that the satellite link is susceptible to blocking by structural attenuation, particularly in urban areas and inside buildings.

Opportunities for PMSE

4.49 In the UK, high power PMSE[17] already shares with MSS in the band 1517-1525 MHz with no known cases of interference to MSS attributable to this use. In addition the 1525-1559 MHz band has been used to support non-operational spectrum use (test and development and equipment trials) as well as additional PMSE applications for some events, normally motor racing. Access to the 1525-1559 MHz band in addition to the 1517-1525 MHz already available would provide up to 42 MHz of spectrum for PMSE.

4.50 Our initial view for considering sharing in the band is that the respective geographical distribution and density of PMSE and MSS use means interference is unlikely. Our understanding is that the majority of MSS use is in remote areas, typically at sea and on aircraft operating or in remote land areas out of reach of alternative terrestrial communications. We have seen limited evidence of MSS use in areas where the PMSE requirement is greatest i.e. urban areas inside theatres, stadia and studios.

4.51 Our initial theoretical analysis suggested that protection distances of less than 1 km in the best case and 9 km in the worst case would be needed to protect MSS from PMSE. We also reviewed currently available studies, specifically ECC Report 121, which provides a range of required separation distances depending on various propagation modelling assumptions. Given the variance of results from studies we considered it useful to carry out practical compatibility measurements with commercially available satellite terminals to better understand the susceptibility to PMSE interference. The analysis is presented in Annex 7.

4.52 The band is internationally harmonised for MSS so there is potential for other countries to adopt this sharing option and thereby help to generate economies of scale for the PMSE sector. In addition, the adjacent band (1492-1518 MHz) is identified in ERC Recommendation 70-03 as a tuning range for wireless microphones and there is work within CEPT to extend this range to 1525 MHz, which may lead to development in equipment which could easily be adapted to operate above 1525 MHz.

Challenges

4.53 As receiving Earth stations in the band are mobile there remains the possibility that an MSS terminal could be coincident in location and time and on the same channel as a PMSE transmitter so there remains a risk that interference may occur. There is no way to fully mitigate this risk for all scenarios but our view is that a number of

[17] The technical licence conditions for PMSE in this band allow for a maximum ERP of 100 W although typically assignments are made at less than 10 W

factors would need to coincide and the risk of this happening is extremely low given the density and profile of use of the two services.

4.54 For maritime use of MSS the risk of harmful interference is also small given the location of MSS use. However, aeronautical use needs to be considered differently due to the potential for line of sight from the PMSE transmitter to the airborne receiver. However, this is largely mitigated by the MSS antenna being directional and mounted on top of the aircraft.

Practical testing

4.55 Two commercial devices were sourced that operate on the Inmarsat network; a BGAN data terminal (Broadband Global Area Network) which provides voice and data connectivity allowing users to access the internet, check emails etc, and GSPS (Global Satellite Phone Service) satellite phone which provides voice telephony and a variety of data capabilities, including SMS. Testing took place on co-channel and adjacent frequencies to determine to minimum operational level (MOL) and the resulting C/No degradation for each of the channels.

4.56 Inmarsat I-4 satellite allocates fixed channels within the Global and Wide Spot (Regional) beams so we were able to reliably test against these. However, in the Narrow Spot beams traffic channels are dynamically allocated but we were able to obtain a known traffic channel from Inmarsat for our tests.

4.57 The tests conducted investigated coexistence for PMSE equipment with a maximum output power of 100 mW (20 dBm). Values for the PMSE levels that cause interference to the global, regional and narrow beams for the BGAN and GSPS terminals were measured for both co-channel and adjacent channel interference.

Test conclusions

4.58 Our testing showed that the point of where the MSS receiver was unable to reliably operate within the global, regional and narrow beam channels is considerably higher than that assumed for theoretical studies. Even when including an additional 6 dB or 10 dB to allow for margin in the MSS link there is still a significant difference between what is assumed for theoretical studies and what we measured. For both BGAN and GSPS the testing indicated a ‘cliff edge’ effect of the MSS terminal with failure being brought on over a 1 dB step in all scenarios.

4.59 In the co-channel case for the BGAN global and regional beam channels the level at which interference occurred was below the performance characteristics and noise floor of the test equipment and are not consistent with the overall test methodology. Interference values have been derived as explained in section 3.2 of Annex 7 and are included for completeness only and should not be considered representative. For the adjacent channel measurements all tests were completed within the performance envelope of the equipment.

4.60 The interference thresholds recorded in test report are 1 dB below the point of failure. We have used these thresholds in our analysis on separation distances and have included an additional 6 dB margin.

Coexistence modelling

4.61 We have modelled the results from our practical analysis to assess the area over which PMSE has the potential to interfere with an MSS terminal based on the

measured values. However, this approach has not been considered for the global and regional beam channels used by BGAN as we were unable to measure these levels due to the limitation of the test equipment. However, as noted above our position is that co-channel use on these fixed channels (and any other identified fixed channels) could be avoided without significantly reducing spectrum availability for PMSE so we have not sought to resolve the co-channel measurements in these cases. There are two main scenarios to consider, firstly PMSE into land and maritime Earth stations and secondly PMSE into airborne Earth stations.

4.62 In the first scenario we have assessed the required separation distance using the propagation model ITU Recommendation P.1411. We believe this is the most appropriate path loss model as both the PMSE transmitter and MSS receiver are at low height and amongst clutter. For the airborne case we have calculated a general path loss using free space path loss for various aircraft heights and ground distances while considering the effect of antenna discrimination for a typical MSS receive antenna mounted on an aircraft.

4.63 The parameter values used in our assessment of required separation distance are given in Table 6.

Table 6 – Parameters assumed for deriving required separation distance of PMSE from MSS

	Hand held mic		**Body worn mic**	
PMSE EIRP (dBm)	10	13[1]	17	20[1]
Building loss (dB)	15	15	15	15
Body loss (dB)	6	6	11	11
Polar disc (dB)	3	3	3	3
Interference threshold GSPS (dBm)[2]	-111.29	-111.29	-111.29	-111.29
Interference threshold BGAN (dBm)[2]	-117.56	-117.56	-117.56	-117.56
Aero antenna gain (dBi)	-5	-5	-5	-5
Additional margin (dB)[3]	6	6	6	6

Note 1: Increase in maximum radiated power to mitigate additional propagation losses in the 1.5 GHz band when compared with the 470-790 MHz band
Note 2: Measured interference threshold bandwidth corrected to 200 kHz. This threshold is 1 dB below the MSS failure point
Note 3: Margin to provide MSS with additional link budget

4.64 Table 7 and 8 provide the required path loss and separation distances for each case noted above, i.e. GSPS and BGAN for PMSE use both indoor and outdoor.

Table 7 – Required path loss and separation distances for GSPS

	Hand held mic		Body worn mic	
PMSE EIRP (dBm)	10	13	17	20
Req'd path loss for GSPS (indoor mic)	103.29	106.29	105.29	108.29
Req'd separation distance (m)	63	68	65	77
Req'd path loss for GSPS (outdoor mic)	118.29	121.29	120.29	123.29
Req'd separation distance (m)	137	162	153	182

Table 8 – Required path loss and separation distances for BGAN

	Hand held mic		Body worn mic	
PMSE EIRP (dBm)	10	13	17	20
Req'd path loss for BGAN (indoor mic mic)	109.56	112.56	111.56	114.56
Req'd separation distance (m)	83	98	93	110
Req'd path loss for BGAN (outdoor mic)	124.56	127.56	126.56	129.56
Req'd separation distance (m)	196	233	220	261

4.65 For the airborne case we have derived a general path loss for a mechanically steered and phase array MSS antennas from information provided by an antenna manufacturer. Within the calculation we have assumed an antenna elevation angle of 20° to account for the satellite elevation in UK latitudes. These are provided in Table 9 and Table 10.

Table 9 – Path loss (dB) for mechanically steered MSS antenna

	Ground range (km)							
Height (m)	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1000	109.9	113.8	116.4	118.9	119.9	121.5	122.8	123.9
3000	119.1	118.1	119.4	120.9	121.8	123.3	123.8	124.9
10000	129.7	131.8	129.9	128.7	128.3	128.7	128.9	129.0

Table 10 – Path loss (dB) for phased array MSS antenna

	Ground range (km)							
Height (m)	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1000	110.92	114	116.6	118.6	120.2	121.6	122.8	123.9
3000	121.9	119.8	120.4	120.4	122.6	123.6	124.5	125.3
10000	143.8	136.6	133.1	131.3	130.6	130.3	130.3	130.4

4.66 Our understanding is that aeronautical MSS is typically used above 3000 m (10,000 feet). It can be seen that for heights greater than 3000 m the path loss for airborne MSS terminals exceeds that required to protect MSS from indoor PMSE use but is marginal, and in some cases insufficient, for outdoor PMSE transmissions.

Provisional conclusion

4.67 The MSS band meets all our criteria for identifying an alternative sharing option to mitigate the loss of the 700 MHz band. The band is harmonised for MSS use across all three ITU Regions which could allow for the development of further economies of scale for PMSE manufacturers if other administrations adopted the band for low power PMSE.

4.68 Access to the 1525-1559 MHz band in addition to the 1517-1525 MHz already available would provide up to 42 MHz of spectrum for PMSE. We have qualitatively assessed the effect this spectrum would have against our study cases (as presented in the 700 MHz cost benefit analysis published in May 2014). Within this assessment we made some assumptions about equipment performance and deployment and concluded that for the majority of use cases in the study the additional spectrum would fully mitigate the impact of the loss of the 700 MHz band.

4.69 For a subset of very high PMSE demand events the residual impact would be slight, i.e. some minor changes might be required to working practices but the overall assignment count would be satisfied.

4.70 Our analysis suggests that for the majority of compatibility scenarios the use of low power audio PMSE applications will not cause harmful interference into MSS. We accept that there is a risk of interference should an MSS terminal be in close proximity to a PMSE transmitter but given the small protection distances between terrestrial use of PMSE and MSS and the large separation distance between PMSE and airborne MSS the probability of this occurring is very low.

4.71 Our understanding is that there are certain fixed MSS channels allocated to particular satellite beams and MSS applications. While not necessary it is possible to avoid co-channel use with any fixed channels within beams covering the UK, for example broadcast control channels in the global or regional beams and the Maritime Safety Information broadcast channel as used by SafetyNET. It is not possible to avoid co-channel use with any dynamically assigned channels as these are unknown outside of the satellite operator but we consider the possibility of a particular traffic channel being allocated at the same time, in the same location and on the same frequency as a PMSE transmitter as being very low.

4.72 It is necessary to carefully consider the safety related MSS applications, specifically maritime and aeronautical use and Cospas-Sarsat. For maritime use the small separation distances derived and the relative locations of PMSE venues and ports means there is a very low probability of harmful interference into shipborne MSS, and only when the ship was in port – at sea there would be no potential for interference. For airborne use of MSS within the band prioritised for AMS(R)S it may be necessary to restrict PMSE use to indoor only.

4.73 The fixed receive site at Combe Martin can be protected via a geographical exclusion zone for the frequency 1544-1545 MHz but given its location in relation to any PMSE use this would not significantly limit PMSE.

4.74 Our long term view of the band has not revealed any expected developments or changes to utilisation of the band by spectrum users.

Question 2: Do you agree with our sharing analysis which concludes that audio PMSE (low power microphones and IEMs) could co-exist with incumbent services in the bands 960-1164 MHz and 1525-1559 MHz? If not please provide specific details/evidence to illustrate your view

Section 5

Proposal

We propose sharing in the aeronautical band

5.1 We have provisionally concluded that audio PMSE applications could co-exist with incumbent services in either of the two bands studied. Both bands comply with our criteria for finding a long term spectrum option for PMSE users.

5.2 However, of the two bands we consider that the 960-1164 MHz band is the most suitable for low power audio PMSE applications. The reasons for proposing this band are that it:

- provides a greater amount of accessible spectrum;
- is closer (in spectrum terms) to the current preferred band for PMSE at 470-790 MHz ; and
- the long term prospects for continuing access are extremely good. The nature of aeronautical use in this band means that it is extremely unlikely there would be any significant changes to the allocation, or services within, the band beyond those we have already identified i.e. LDACS.

5.3 In particular, the latter point above addresses the need for long term stability in any new band. Our preference for this band significantly reduces the risk of competition for spectrum access that could threaten PMSE access in the future.

Question 3: Do you have any comments on our proposal to allow low power audio PMSE applications (wireless microphones and IEMs) access to the 960-1164 MHz band?

How would it work?

5.4 Access would be granted on a licensed and geographically coordinated basis with aeronautical navigation and communication systems. This approach would be similar to the model currently used to facilitate access to interleaved UHF spectrum where PMSE shares with digital terrestrial television i.e coordinated access under specific licence conditions detailing frequency, location and date and time of use.

Next Steps

5.5 Subject to the outcome of this consultation, should we decide to proceed with the 960-1164 MHz band as proposed, we would expect to extend current PMSE licensing and coordination arrangements to incorporate the band. We will provide further information on this in due course.

5.6 We have already engaged with other European administrations and shared our thinking on alternative bands for audio PMSE. We will continue to advocate a harmonised approach and provide further advice and data as required. We will also work with the CAA in discussions with other aviation authorities as appropriate.

5.7 The 700 MHz clearance programme will allow mobile network operators to deliver mobile broadband using frequencies within the 694 – 790 MHz band. The objective is to enable the spectrum to be used nationwide for mobile services by the start of 2022, and possibly up to two years sooner. We are also exploring the possibility of releasing the 700 MHz band for mobile use on a region-by-region basis as we clear it of DTT uses. In principle, this means some parts of the UK may be clear of DTT in the 700 MHz range during the course of 2019.

5.8 As we explained in our Statement[18], decisions on any funding for PMSE users affected by the 700 MHz programme are a matter for Government and we will provide advice to Government in the coming months. We also intend to consult on a range of policy issues relating to the programme in the first quarter of next year.

[18] See link: http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/statement/700-mhz-statement.pdf

Annex 1

Responding to this consultation

How to respond

A1.1 Ofcom invites written views and comments on the issues raised in this document, to be made **by 5pm on 18 December 2015**.

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

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

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

Vaughan John
Floor 3
Sector policy
Riverside House
2A Southwark Bridge Road
London SE1 9HA

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

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

Further information

A1.7 If you want to discuss the issues and questions raised in this consultation, or need advice on the appropriate form of response, please contact Vaughan John on 020 7981 3093.

Confidentiality

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

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

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

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

Next steps

A1.11 Following the end of the consultation period, Ofcom intends to publish a statement in early 2016.

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

Ofcom's consultation processes

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

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

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

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

Tel: 020 7981 3601

Email Graham.Howell@ofcom.org.uk

Annex 2

Ofcom's consultation principles

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

Before the consultation

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

During the consultation

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

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

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

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

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

After the consultation

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

Annex 3

Consultation response cover sheet

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

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

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

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

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

Cover sheet for response to an Ofcom consultation

BASIC DETAILS

Consultation title:

To (Ofcom contact):

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

CONFIDENTIALITY

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

Nothing ☐

Whole response ☐

Part of the response ☐

Name/contact details/job title ☐

Organisation ☐

If there is no separate annex, which parts?

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

DECLARATION

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

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

Name

Signed (if hard copy)

Annex 4

Consultation question

A4.1 In this consultation we are seeking comments on three specific points. Firstly ask for comments on our assessment of spectrum demand and supply for audio links, talkback, telemetry and telecommand. Secondly we ask for comments on our sharing analysis in the bands 960-1164 MHz and 1525-1559 MHz and our conclusion that sharing is possible in both bands. If you disagree with our assessment please provide a detailed explanation supporting your response.

A4.2 Finally we are seeking comments on our proposal to allow low power audio PMSE applications in the 960-1164 MHz band only.

Question 1: Do you agree with our assessment that minimal growth in demand and stability in spectrum supply means that we do not need to implement any changes to meet the ongoing requirements for talkback, audio links and telemetry and tele-command applications?

Question 2: Do you agree with our sharing analysis which concludes that audio PMSE (low power microphones and IEMs) could co-exist with incumbent services in the bands 960-1164 MHz and 1525-1559 MHz? If not please provide specific details/evidence to illustrate your view.

Question 3: Do you have any comments on our proposal to allow low power audio PMSE applications (wireless microphones and IEMs) access to the 960-1164 MHz band?

Annex 5

Review of spectrum demand for talkback, audio links and telemetry & telecommand

A5.1 Based on our analysis of current demand and trends, we have found that the current spectrum availability is sufficient to meet the recurring demands for talkback, audio links and telemetry & telecommand and anticipated growth over the next six years. But there will continue to be a dependency on temporary access to loan spectrum to satisfy the peak demands of some high profile events such as Formula 1 (F1) Grand Prix.

A5.2 For any future exceptional events (similar to London 2012 Olympic and Paralympic Games, Glasgow 2014 Commonwealth Games and Tour de France 2014), it would be necessary to secure additional spectrum to meet the peak demand and to accommodate a wide range of equipment tuning ranges from different regions of the world.

A5.3 Over the next six years we do not anticipate any significant changes to current PMSE spectrum allocations below 470 MHz and at 1.5 GHz that are likely to result in reduced availability. Nor do we anticipate any significant issues in continuing to facilitate temporary access to spectrum outside of PMSE bands to satisfy peak demands of events such as F1 Grand Prix.

A5.4 The report detailing our analysis into spectrum requirements for talkback, audio links and telemetry and telecommand is included as a separate document – http://stakeholders.ofcom.org.uk/binaries/consultations/PMSE-audio-strategy/annexes/annex5.pdf

Annex 6

Report on the coexistence study between PMSE and aeronautical services

A6.1 The report details the test methodology and conclusions for the study to determine the compatibility of low power audio PMSE applications, specifically wireless microphones, with existing aeronautical communications, navigation and surveillance systems operating in the 960-1164 MHz frequency range.

A6.2 The report is presented as a separate document at http://stakeholders.ofcom.org.uk/binaries/consultations/PMSE-audio-strategy/annexes/annex6.pdf

Annex 7

Coexistence testing between wireless microphones and Mobile Satellite System receivers in the band 1525-1559 MHz

A7.1 The report details the test setup, methodology and results for assessing coexistence interference thresholds for Program Making and Special Events (PMSE) equipment into Mobile Satellite System (MSS) User Equipment (UE). The analysis only considers MSS services on the Inmarsat 4-F2, positioned in a geostationary orbit at 149.12º and elevation 26.03º.

A7.2 The UEs covered within this test plan are a BGAN (Broadband Global Area Network) data terminal and a GSPS (Global Satellite Phone Service) satellite telephone.

A7.3 The report is presented as a separate document at http://stakeholders.ofcom.org.uk/binaries/consultations/PMSE-audio-strategy/annexes/annex7.pdf