



# PMSE Spectrum Review: Talkback, Audio Links and Telemetry & Telecommand

A review of the current landscape  
and future demands

Policy Investigation  
Document

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## Section 1

# Executive Summary

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 analysis presented in the report is part of our strategic review of spectrum access for PMSE. Under this strategic review we have already investigated the future spectrum requirements for two of the principal PMSE applications: wireless microphones (including personal monitors) in interleaved spectrum at 470 to 690 MHz; and wireless cameras at 2 GHz and above.

In this report we investigate the spectrum requirements for other PMSE applications which operate in the bands below 470 MHz and at 1.5 GHz. These are primarily audio applications but with a wide range of technical characteristics.

The objectives of this study were to:

- Understand if the current demand is being adequately met by the existing spectrum available in bands below 470 MHz and the 1.5 GHz band; and
- consider if any changes to the current spectrum availability (over the next five to six years) will have an impact on the ability to meet future demands.

Based on our analysis of current demand and trends, we have found that the current spectrum availability is sufficient to meet the recurring demands of the sector and anticipated growth over the next six years. However, there will continue to be a dependency on temporary access to loan spectrum<sup>1</sup> to satisfy the peak demands of some high profile events such as Formula 1 (F1) Grand Prix.

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.

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.

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<sup>1</sup> Spectrum not normally available to PMSE products which is available for assignment on request subject to coordination with other users of the band.

## Section 2

# Introduction

## 2.1 Purpose

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.

We recognise the importance of the PMSE sector and we were therefore concerned to ensure that sufficient spectrum is available so that these important services can continue to be supported.

This work is part of our strategic review of spectrum access for all PMSE applications. Under this strategic review we have already investigated the future spectrum requirements for two of the principal PMSE applications and published our findings:

- i) For wireless cameras at 2 GHz and above, we set out our analysis of supply and demand of PMSE spectrum in Chapter 8 of the PSSR award consultation<sup>2</sup> published on 19 February 2014. Subsequently, we published our strategy<sup>3</sup> for video PMSE applications on 28 October 2014; and
- ii) for wireless microphones (including personal monitors) in interleaved spectrum at 470 to 690 MHz we investigated the impact on PMSE of releasing spectrum at 700 MHz for new mobile services in Section 7 of our cost benefit analysis<sup>4</sup> published on 28 May 2014.

We now present our analysis of the spectrum requirements for other PMSE applications which operate in the bands below 470 MHz and at 1.5 GHz. These are primarily audio applications but with a wide range of technical characteristics.

## 2.2 Background

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;
- news and topical affairs;

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<sup>2</sup> Public Sector Spectrum Release (PSSR) : Technical coexistence issues for the 2.3 and 3.4 GHz award consultation (19 February 2014): <http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/summary/pssr.pdf>

<sup>3</sup> Programme Making and Special Events Strategy for video PMSE applications statement (28 October 2014): [http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/statement/Statement\\_on\\_camera\\_strategy.pdf](http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/statement/Statement_on_camera_strategy.pdf)

<sup>4</sup> Consultation on future use of the 700 MHz band Cost-benefit analysis of changing its use to mobile services (28 May 2014): <http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/summary/main.pdf>

- musical theatre; and
- rock and pop tours.

Examples of special events include:

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

PMSE applications enable wireless mobility for performers and facilitate 'closer to the action' coverage of sports, events and news.

Wireless cameras provide broadcast quality video feeds; wireless microphones provide high quality audio feeds of voice, musical instruments or background sounds for re-inforcement and/or for broadcast. In addition there is also a requirement for wireless 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, communication to performers is by personal In-Ear Monitor (IEM) whereas the communications requirements for the crew in stage shows are generally referred to as Intercoms. Spectrum requirements for IEMs and stage intercoms are generally within the band 470 to 694 MHz and have been considered in our earlier study.

Other vital wireless PMSE applications include:

- Remote control of broadcast equipment;
- remote monitoring of systems;
- broadcast quality audio links; and
- event enhancement services including audio description.

## **2.3 Scope**

The scope of this element of our work covers PMSE applications that operate in the VHF band at 48 – 215 MHz and UHF bands at 400 – 470 MHz and at 1.5 GHz. The principal PMSE applications within these bands are identified in Table 1.

**Table 1 - Overview of PMSE applications in Scope**

| <b>Application</b>                               | <b>Typical Channel Bandwidths (kHz)</b> | <b>Typical transmit power (W)</b> | <b>Typical Operating Frequency Ranges (MHz)</b> |
|--|---|-----------------------------------|---|
| Talkback   | 12.5                                    | 1 – 5                             | 60 – 470  |
| Telemetry & Telecommand<br><i>Camera Control</i> | Various<br><i>12.5 or 25</i>            | <= 1                              | 150 – 1632<br><i>400 – 470</i>                  |
| Audio Links                                      | <= 200                                  | 0.01 - 25                         | 47 - 1520                                       |
| ADS  | <= 200                                  | <= 25                             | 55 - 62   |

## 2.4 Objectives

The objectives of this study are to:

- Understand if the current demand is being adequately met by the existing spectrum available in bands below 470 MHz and in the 1.5 GHz band; and
- consider if any changes to the current spectrum availability over the next five to six years will have an impact on the ability to meet future demands.

## 2.5 Approach

In order to understand the existing use and the potential changing spectrum landscape for the services within the scope the work was broken down as follows:

Step 1: What is the current spectrum configuration?

PMSE services, frequency bands available, usage and configuration

### Section 3

To understand the current spectrum configuration;

Identify how the existing services are used;

Identify existing technologies and any potential known evolution;

Identifying the existing bands, channel availability, usage and associated configuration for each service.

Step 2: What is the current landscape?

Historical trends, demand profiles, spectrum loan requests, case studies

**Section 4**

To understand the existing demand and historical trends:

Evaluation of the current demand profiles considering annual licences, short-term and special events between 2002 and 2013;

Detailed analysis of the demand and usage during 2013;

Analysis of the volumes and types of spectrum loan requests actioned by Ofcom and (where possible) a discussion on the reasons the requests were made;

Review the hotspot venues and spectrum usage whilst considering a case study of the most demanding venue;

Step 3: What is the future landscape?

Spectrum access changes, forecast changes in demand, technology evolution

**Section 5**

To understand the potential changing spectrum landscape over next 5-6 years:

Identify key projects or initiatives where the spectrum landscape is potentially changing;

Where possible predict any potential trend of demand over the next 5-6 years and evaluating this against the spectrum supply.

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## Section 3

# Current Spectrum Use Landscape

## 3.1 Introduction

This section provides more details of the types of use, the technologies used and how the spectrum made available to PMSE supports a range of operational requirements. It will also identify the additional spectrum utilised by PMSE through temporary loans from other sectors.

## 3.2 Types of Operational Requirement

### Talkback

Voice quality channels providing the command, control and communication system essential to the coordination of the broadcast coverage of a sports or other event. Talkback channels are used to support different functions and can be duplex or simplex channels according to requirements.

At the heart of the production will be the Director. An open microphone in the production area relays the Director's instructions to the production crew such as camera operators and presenters. The open microphone also relays vital background production information from the Director's assistants in the production gallery such as timing of programme breaks and coordination of action replays. As the complexity of the production increases, the risk of confusion means that additional talkback channels are required. These often provide the means to relay individual instructions to a selected presenter or roving commentator.

The complexity of the Director's talkback requires continuous transmission from a base station to portable receivers. A dual frequency talkback channel enables the production team to reply on a press-to-talk basis where necessary and where feasible. Single frequency talkback channels are also used. Typical applications are continuous transmission of Director's talkback to a presenter or commentator (their broadcast microphone can be used to reply - when not live) or for press-to-talk communication between technical crew.

The overall number of channels required depends on the complexity of the production; basic coverage of a compact event by a single broadcaster, say for recorded highlights, may only require a few talkback channels. In contrast at complex events where there are multiple facets to the action, such as a major golf tournament, they may feature several live commentators and reporters. The demand for talkback channels is then much higher. Further, where there are multiple rights holders then each broadcaster will require their own talkback channels. Where the action is distributed over a wide area such as a road race or where the number of cameras becomes unworkable for a single Director, then the communications requirement becomes greater still.

Although talkback is a broadcasting term, there is a similar requirement in theatre and for other stage performance. Typical requirement is for the coordination of critical backstage operations such as scenery movements by the crew.

### Remote Monitoring and Control (Telemetry & Telecommand)

Essential for remote control of wireless cameras to match picture parameters such as colour and brightness with other cameras in a multi-camera production. Remote control links are also used to synchronise the trigger of complex displays such as fireworks.

At motor racing, telemetry links provide real-time monitoring of a car's systems for analysis by competitors and to enhance broadcast coverage through on-screen graphics. Telemetry links also carry GPS derived geolocation information of competitors for use with on-screen graphics to enhance coverage of sports events such as cycling and other road races.

Other telemetry applications include relay of geolocation information from an airborne PMSE platform to guide auto-steering antenna systems.

### Audio Links

Temporary point-to-point links for broadcast quality audio. Typical applications include live reporting in national or local radio and for wireless audio feed to remote loudspeaker stack at a music event.

### Audio Distribution Systems (ADS)

Localised broadcast at a venue or event audience to provide enhancements such as relay of referee's microphone at Rugby Union matches or services such as audio description for the visually impaired.

## **3.3 Current Technologies**

### **Talkback & Simplex Handsets**

These systems generally use analogue FM technology as in the private mobile radio (PMR) sector and operate in a 12.5 kHz channel bandwidth. Occasionally 25 kHz channel bandwidths may be required where audio quality is critical. Digital technology is now on the increase and can either accommodate two transmissions within 2 x 6.25 kHz channels (Frequency Division Multiple Access (FDMA)) or within a single 12.5 kHz channel (Time Division Multiple Access (TDMA)).

### **Telemetry & Telecommand**

These systems generally use analogue frequency modulation (FM) technology and for camera control operate in a channel bandwidth of 12.5 kHz or 25 kHz and typically control up to three cameras.

There are other applications that use specific data transmissions and the equipment used here tends to be more bespoke and designed specifically.

### **Audio Links**

These systems generally use analogue FM technology and operate in a channel bandwidth of 50 kHz to 200 kHz and can be mono or stereo.

## ADS

These systems use analogue FM technology and operate in a channel bandwidth of up to 50 kHz.

### 3.4 Frequency Bands

The spectrum available for the services in scope of this report are summarised here. More detail of the frequency bands can be found in Annex 1.

#### Talkback

The sub-bands available are as follows:

**Table 2 Talkback bands available**

| Sub-Band      | Bandwidth | Number of Channels        |
|---------------|-----------|---------------------------|
| 457 / 467 MHz | 12.5 kHz  | 18 Duplex                 |
| 455 / 468 MHz | 12.5 kHz  | 23 Duplex<br>& 1 Simplex  |
| 446 / 467 MHz | 12.5 kHz  | 20 Duplex                 |
| 447 MHz       | 12.5 kHz  | 16 Simplex                |
| 462 / 469 MHz | 12.5 kHz  | 20 Duplex<br>& 11 Simplex |

#### Audio Links

These are for fixed point to point type use and are generally used to connect studios to a transmit site, or a remote studio to the main studio.

**Table 3 Audio Link bands available**

| Sub-Band      | Bandwidth      | Number of Channels    |
|---------------|----------------|-----------------------|
| 48 – 52 MHz   | Mono 50 kHz    | 5                     |
|               | Stereo 200 kHz | 2                     |
| 199.7 MHz     | Stereo 200 kHz | 1                     |
| 440 – 470 MHz | Mono 50 kHz    | Dependent on location |
| 1.5 GHz       | Up to 200 kHz  | 2                     |

#### Camera Control

Used to remotely adjust the picture attributes of one (or more) wireless camera's so that they can be matched with other cameras.

**Table 4 Camera control bands available**

| Sub-Band    | Bandwidth | Number of Channels |
|-------------|-----------|--------------------|
| VHF 181 MHz | 12.5 kHz  | Up to 5            |
| UHF 462 MHz | 12.5 kHz  | Up to 4            |
| UHF 473 MHz | 12.5 kHz  | Up to 3            |

Occasionally, additional channels are utilised for camera control from the frequency ranges that are designated for talkback.

### Audio Distribution (ADS)

Localised broadcast at a venue or event audience to provide enhancements such as relay of referee's microphone at Rugby Union matches or services such as audio description for the visually impaired.

**Table 5 ADS bands available**

| Sub-Band          | Bandwidth | Number of Channels |
|-------------------|-----------|--------------------|
| 60.75 – 62.75 MHz | 50 kHz    | Up to 4            |

## 3.5 Spectrum Loans

This is spectrum that is not normally available to PMSE products but is available for assignment on request subject to coordination with other users of the band. On occasions due to either the equipment constraints or in some cases due to the scale of the requirements (when considering major special events such as the Commonwealth Games 2014) there is a need to source additional spectrum outside of the standard set of channels available to PMSE. The most popular spectrum bands for Talkback and Audio Link applications tend to be in the following spectrum bands.

**Table 6 - Popular Loan Frequency Ranges**

| Frequency Range       | Typical PMSE Use   |
|-----------------------|--|
| 137-177 MHz (VHF)     | Mobile Comms, Airborne/Wide-Area Comms                                     |
| 400 – 425 MHz (UHF-1) | Talkback<br>Simplex Handsets<br>Trunked radio systems for event management |
| 425-470 MHz (UHF)     | Simplex Handset Comms, Talkback Duplex, Camera Control                     |

Due to the dependency to have access to supplementary spectrum there is a need to understand the future availability of this spectrum on a continuing basis. This report reviews and details the current position of future access to this spectrum in section 5.

## Section 4

# Demand Analysis

## 4.1 Introduction

This section investigates the current spectrum demand from the various service types and how the demand has changed over the last ten years. There will then be a more detailed analysis of the demand based on looking at where the highest concentration of use is located, looking at so-called 'hotspot venues'. There will then be an investigation into the amount of additional out of band spectrum that was utilised.

All data utilised in this study has been extracted from the PMSE licensing database.

In order to be transparent in the analysis of the data and in order to be able to reproduce or undertake further investigation of this report the following assumptions have been made whilst analysing the licensing data.

**Table 7 - Table of Assumptions with Regard to the Data Analysis**

| Assumption Reference | Assumption or Statement of Use   |
|----------------------|--|
| 1                    | Using PMSE Service types: Programme Links are considered as Audio Links  |
| 2                    | Narrow band talkback was considered as 12.5 and 25 kHz channel bandwidths. There were a small number of examples where the bandwidth was between 25 and 75 kHz. These were also considered as Talkback where likely multiple channels were made available. |
| 3                    | Using PMSE assignment types: Data assignments are considered as telemetry & telecommand.   |
| 4                    | ADS was considered as part of Audio Links general category.  |
| 5                    | Duplex frequencies are considered as two assignments.  |

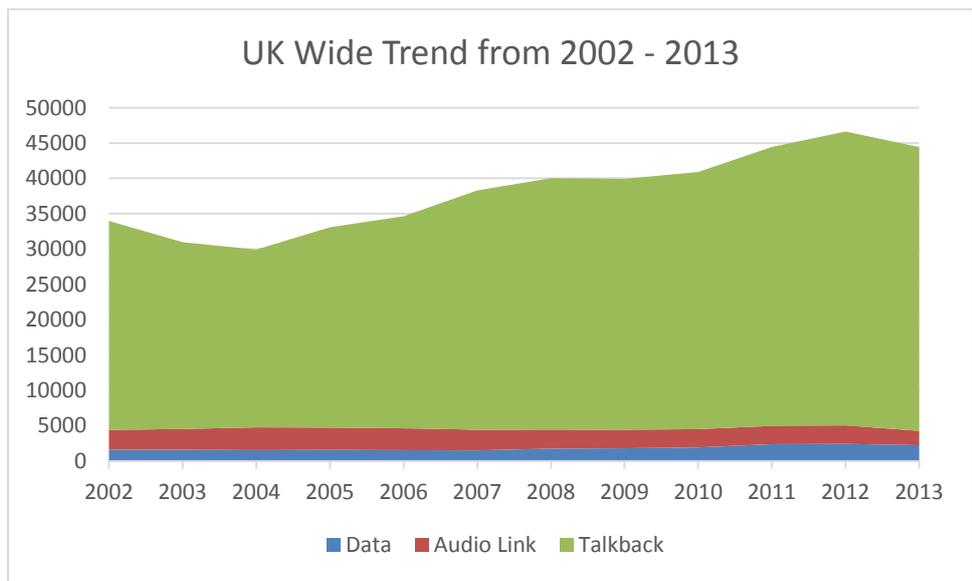
## 4.2 Historic Trends

In order to understand how the spectrum demand has changed we have examined the trend over the last ten years.

The historic trend of the applications included in the scope of this report can be seen in Figure 1. It shows that across the range of services that, whilst there has been a slow but steady increase in recent years, this appears to have reached a plateau and has begun to slightly decrease again. This means that between 2011 and 2013 the net rate of change has either been very small or static.

The number of assignments for 2012 show a larger increase but this would have been due to the London 2012 Olympic and Paralympic Games where there was a sharp increase.

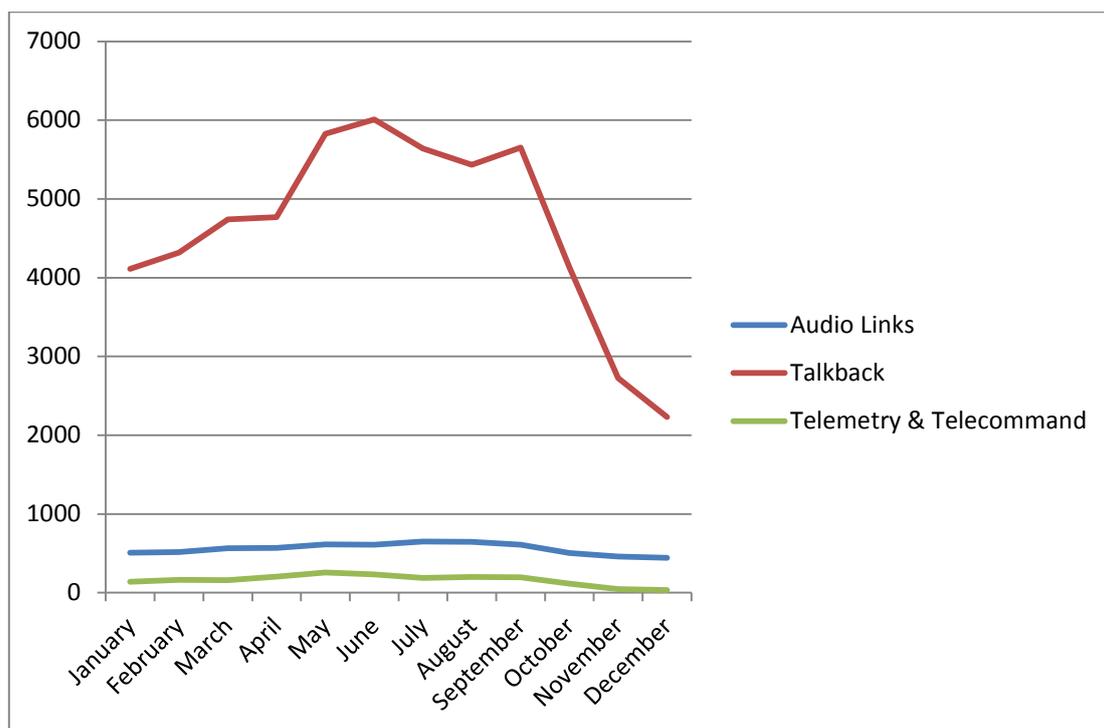
**Figure 1 - UK Wide Trend of PMSE Assignments**



This will be useful in considering the future demand forecasts and the impact analysis on the spectrum access landscape in order to ensure that any potential increase in spectrum demand can be accommodated. Although, it is worth pointing out that due to the nature of the use of these assignments are in many cases short-term and concentrated on specific areas any increase does not have a direct correlation with the intensity and demand of spectrum access. One of the ways that this can be fully investigated is to look at specific deployment examples and a case study which are covered in the next section.

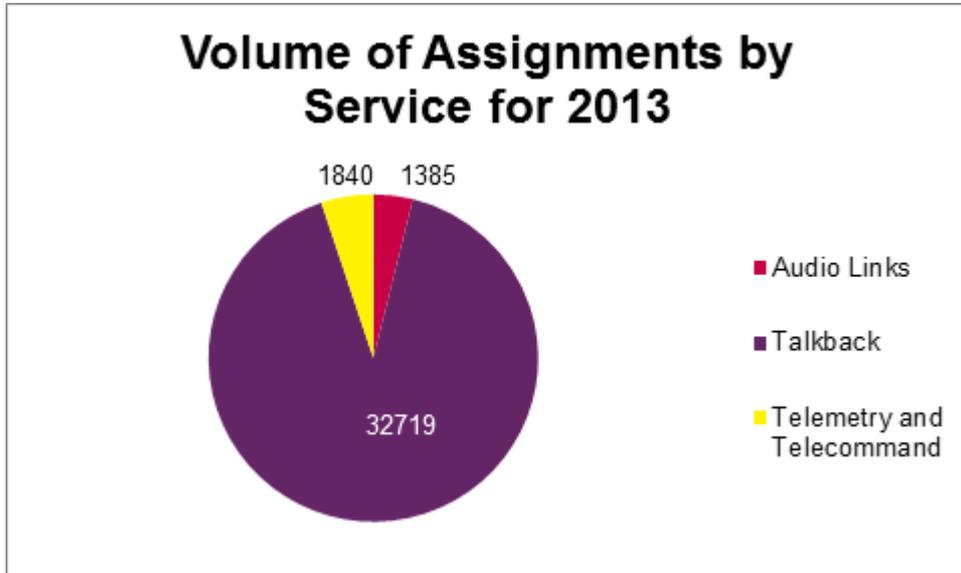
Another useful trend to investigate is how the demand varies over a calendar year. Figure 2 shows how the volumes of assignments changed every month throughout 2013.

**Figure 2 - Variation of demand month by month during 2013**



This is driven primarily by the high number of short-term temporary type use which follows the special event season and can be seen to peak between around May and September each year and can be clearly seen by the variation in the Talkback assignment volumes.

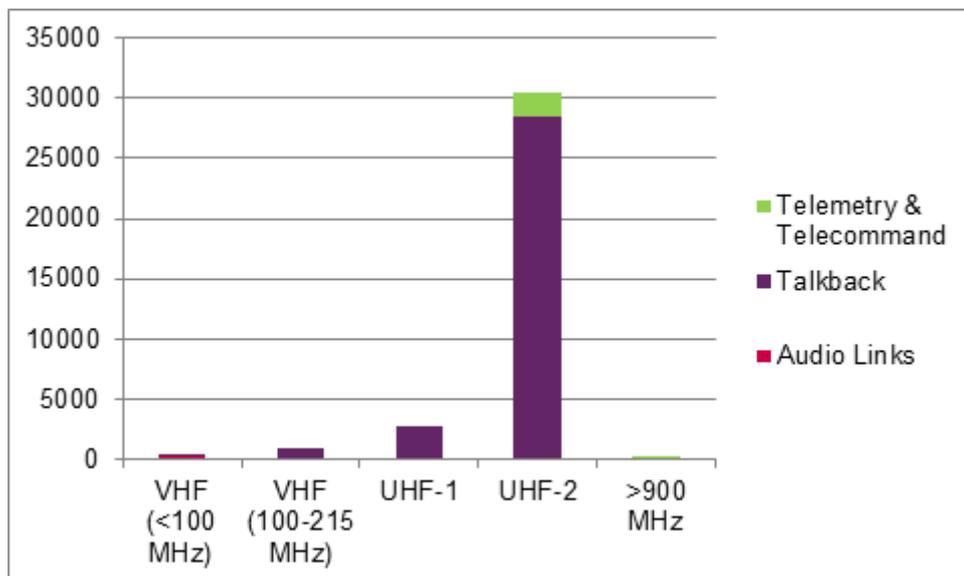
**Figure 3 - Breakdown of assignment volumes by service type for 2013**



From Figure 3 it can be clearly seen that the main volume of assignments are for talkback systems.

It is also useful to see which frequency bands are more heavily used for each of the applications and this can be seen in Figure 4.

**Figure 4 - Service type use by Frequency Band**



The majority of assignments are narrow band talkback and these are made in the UHF-2 frequency band (450 – 470 MHz). This highlights that due to the high dependence on access to the UHF-2 band that if there are any foreseen changes to the access arrangements to this band that these will have the largest impact.

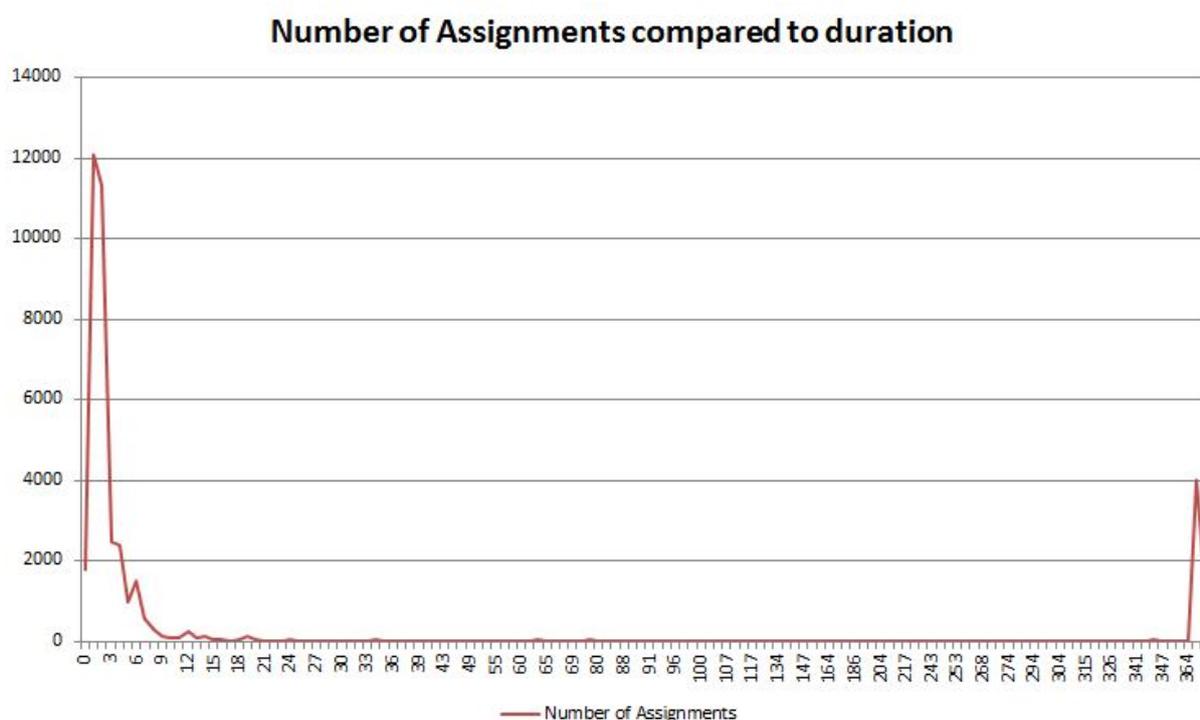
### 4.3 Annual Licences

There are some requirements that are needed on an ongoing basis to support certain types of applications and these are facilitated through annual licences. A large proportion of these annual licences are predominantly covering fixed applications. These include theatres, football stadiums, concert arenas and broadcast studios and sets.

The following graph (figure 5) is an attempt to show the ratio of short-term temporary assignments (shown as the peak on the left of the graph) to annual ongoing assignments (shown on the right). The horizontal axis shows the duration of the assignment. The reason for the small numbers of fluctuations between around 12 and 351 days is most likely because of the pro-rata element of any changes that have been made to an annual licence or assignment.

Figure 5 below shows the number of assignments against the duration in days and it can be seen that the short-term use (typically up to around 3-4 days) is around 12,000 assignments which is three times the number of annual assignments.

Figure 5 - Shows the ratio of Short-term temporary use versus Annual Use



### 4.4 Hotspot Venues

It was indicated earlier in the report, that whilst it is useful to look at the historical trends in the overall numbers of assignments (i.e. through the entire UK) a way of identifying a more accurate view of the trend is to investigate how the hotspot areas have changed over the last ten years.

There are two potential ways in which to identify the “hotspot” areas and these are:

- **Notice of Variation ID (NoV):** This is using the NoV as an identification of a special event or area for which a set of assignments are required across each of the service types. This method is useful to identify a set of events where the time periods tend to

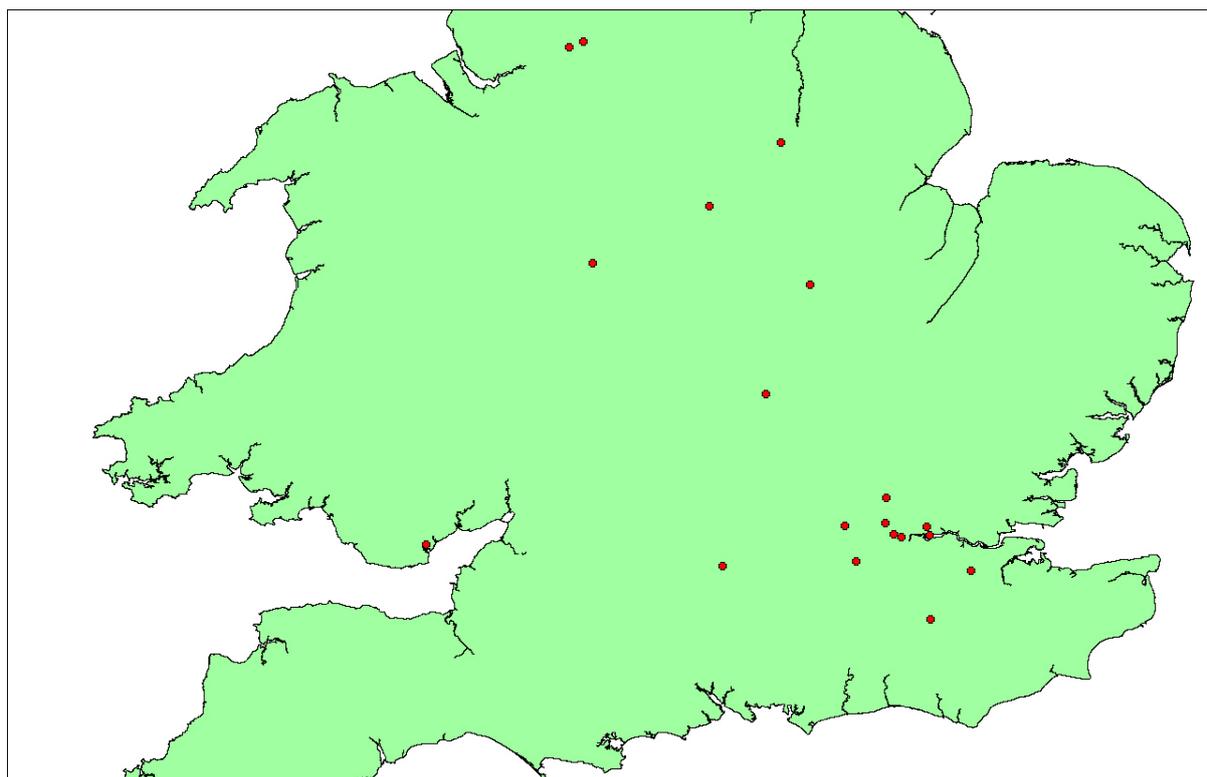
be aligned. The disadvantage with this method is that in some cases there are multiple NoVs that are used for each event so there is a difficulty in identifying if there are additional NoVs that would need to also be considered, also some NoVs have multiple locations in them, in some cases covering a large area of the UK. So this could result in much lower volumes of assignments in some cases and much higher in others; the other method is to use;

- **NGR/Location:** This method is to use the geographic location or venue as the basis of identifying the highest intensity areas of use. This also has the benefit of ensuring that the majority of assignments at a given location are identified. The disadvantage with this method is that in many cases there are locations/venues with high volumes of assignments but these may be split out over multiple time periods meaning the resultant intensity is much lower.

Considering both these methods they both add value in identifying the hotspot areas but must be used with caution and some manual assessments have to be made. It is therefore very challenging to produce a single map showing the hotspot areas and how it has changed over the last ten years.

Figure 6 below shows the locations of the top hotspot areas between 2002 and 2013 using the NGR/Location method and considering the volumes of assignments by location.

**Figure 6 - Top Hotspot Venues from 2002 to 2013**



Annex 2 contains the full breakdown of assignment volumes at each of the hotspot locations identified.

## Spectrum Loan Requests

The number of loan requests for supplementary spectrum is also an indicator of the busiest venues. The majority of the requests are to support the extensive requirements for talkback in UHF-2 (450-470 MHz - which is a highly popular band) and also VHF (around 130-180 MHz – where there is little dedicated PMSE spectrum available). Examples of the types of event having the greatest demand for loan spectrum in 2013 are shown in Table 4.

**Table 8 – Spectrum loans for 2013**

| Venue                      | Date | Requested | Cleared |
|----------------------------|------|-----------|---------|
| Motor racing (Silverstone) | Jun  | 271       | 271     |
| Motor racing               | May  | 130       | 112     |
| Motoring festival          | Jul  | 47        | 28      |
| Motor racing               | Oct  | 20        | 18      |

It can be seen that motor racing events generate the greatest requirement for spectrum loans. Of these, it is the F1 Grand Prix at Silverstone that has the highest overall loan spectrum requirements. Fortunately, due to its more remote location it is possible to find available spectrum. It is therefore useful to look at Silverstone as a special case to see how the demand has changed over the last ten years.

### 4.5 Case Study: Silverstone Race Circuit

It could be considered that looking at Silverstone as a standalone case study will give an indication of how the spectrum landscape has changed over the last several years. Silverstone is located in Towcester in Northamptonshire.

Silverstone holds a large number of events throughout the calendar year and it can be seen that there is a large number of assignments required for many of them. The F1 Grand Prix is the event with the most PMSE audio assignments and usually takes place at the end of June each year. This event has the highest use out of all PMSE use throughout the UK.

**Table 9 - Top five events for assignments at Silverstone**

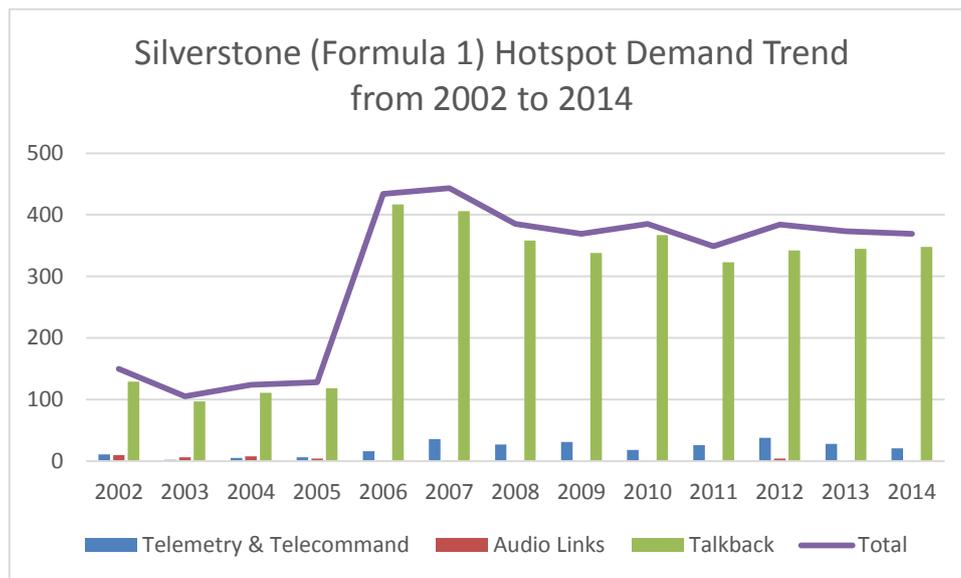
| <b>Event</b>           | <b>Date</b> | <b>Number of Assignments</b> | <b>Talkback</b> | <b>Data</b> | <b>Audio Links</b> |
|------------------------|-------------|------------------------------|-----------------|-------------|--------------------|
| Endurance Championship | Apr         | 247                          | 209             | 38          | -                  |
| F3/GT Championship     | May         | 34                           | 34              | -           | -                  |
| Endurance Series       | May         | 193                          | 193             | -           | -                  |
| F1 Grand Prix          | Jun/Jul     | 373                          | 345             | 28          | -                  |
| IGT & EF3              | Jul         | 42                           | 42              | -           | -                  |

From a detailed look at the amount of spectrum used for the F1 Grand Prix for 2013 there were 373 assignments, of which 271 assignments were in loan spectrum (a bandwidth of around 3.38 MHz). The detailed use per frequency band can be seen below in Table 10.

**Table 10 - F1 Grand Prix PMSE: Number of assignments per frequency band**

| <b>Service</b>          | <b>VHF &lt;100 MHz</b> | <b>VHF &gt;100 MHz</b> | <b>Total VHF</b> | <b>UHF 1</b> | <b>UHF 2</b> | <b>Total UHF</b> | <b>&gt;900 MHz</b> |
|-------------------------|------------------------|------------------------|------------------|--------------|--------------|------------------|--------------------|
| Audio Links             | -                      | -                      | -                | -            | -            | -                | -                  |
| Talkback                | -                      | 116                    | 116              | 12           | 217          | 229              | -                  |
| Telemetry & Telecommand | -                      | 1                      | 1                | -            | 2            | 2                | 25                 |
| <b>Total</b>            | <b>-</b>               | <b>117</b>             | <b>117</b>       | <b>12</b>    | <b>219</b>   | <b>231</b>       | <b>25</b>          |

**Figure 8 - Assignment demand for F1 Grand Prix at Silverstone from 2002 to 2014**



## 4.6 Summary of Analysis

|  |   |
|--|---|
| <p>Assignment Totals<br/>Steady increase in demand</p>   | <p>There has been a steady increase in the number of assignments made between 2002 and 2011. This peaked during 2012, which was more than likely related to the Olympic and Paralympic Games. The volumes following the Olympics have continued a steady increase.</p>        |
| <p>Assignment Variation across each Service<br/>Talkback makes up most of the volume</p>                             | <p>Talkback make up the majority of the assignments and therefore the trends described above are resultant from these. The data and audio link assignment volumes have remained static throughout the period from 2002 to 2013 with audio links showing a slight decline.</p> |
| <p>Assignment Totals variation across each Band<br/>UHF-2 is the highest in demand and is continuing to increase</p> | <p>From the analysis VHF is in a steady decline, UHF is a steady increase of around 3% per year. The assignments above 900 MHz do show an annual increase but the variation data is more unreliable with 2013 seeing a decline.</p>   |
| <p>Spectrum Loans<br/>Predominantly UHF-2 and VHF</p>  | <p>Most of the spectrum loans that are requested are when it is either for spectrum access where there is little dedicated PMSE spectrum available (e.g. VHF), a tuning range that is outside of PMSE spectrum or</p>   |

|   |   |
|---|---|
|   | where there are high-volumes at particular special events.  |
| Hotspot Venues<br>There are many areas where PMSE use is intensive  | There are a number of venues throughout the UK where there are more intensive use of PMSE audio services. Although, some of the geographical areas where there is intensive use have changed they have predominantly remained the same.   |
| Case Study: Silverstone<br>Currently the highest use of audio assignments in the UK but starting to decline | Silverstone has a high demand for PMSE audio use. The F1 Grand Prix event which occurs June/July each year has typically 370 assignments across all the bands with narrowband talkback in UHF-2 making up the largest use. It can be seen that the demand for spectrum has remained fairly constant with a slight decline in recent years but will be heavily dependent on the applications and technologies used year on year. It can also be seen that in 2006 there was a dramatic increase in the number of assignments from just over 100 to around 500. It is not clear what may have caused this change. |
| Ability to meet demand<br>Mostly, demand can be met from current spectrum available to PMSE                 | For the majority of scenarios demand can be met from the total PMSE spectrum currently available but with the exception of larger events where spectrum needs to be loaned.   |

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## Section 5

# Future Spectrum Landscape

## 5.1 Introduction

This section investigates if there are any changes to the spectrum availability that is currently utilised for PMSE audio applications that is likely to happen within the next five years or longer (if already known or planned for).

As for larger events and where primary PMSE spectrum is small or not available, requests for loan spectrum are made and hence a reliance on the availability of other key bands. These bands will also be investigated.

This section will begin looking at the key spectrum bands summarising any changes in availability and when it is likely to happen. The following section will then investigate what could be the typical scenarios and associated outcomes if and when these changes take place. Then this section will provide a summary of the technical evolution of equipment and potential services that could also have an impact on the ability of meeting the future PMSE spectrum requirements.

After looking at the potential changes to the availability of the PMSE spectrum and loan spectrum the following band review activities were identified:

|  |                                       |   |
|--|---------------------------------------|---|
| Business radio VHF Spectrum Release (143 to 169 MHz) | What is the band used for?            | Assignment of Business radio (primarily PMR), Maritime, Some PMSE and Amateur.  |
|  | Why was a review undertaken?          | 5.875 MHz of spectrum has been returned for Civil use throughout England, Wales and Northern Ireland from the Emergency Services and Police Service Northern Ireland (PSNI). Future strategic applications as they may arise. |
|  | What is the impact on Audio PMSE use? | Other competing demands for VHF spectrum may reduce spectrum available for PMSE. This is expected to be low risk as VHF use is in a slow decline.   |
| UHF 1 & 2 (425 to 470 MHz) Strategic Review          | What is the band used for?            | Assignment of Business radio (Primarily PMR), Amateur, Aeronautical, Licence exempt, PMSE and Maritime.   |
|  | Why is a review taking                | To address the issue of increasing demand and   |

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|  |   |
|--|---|
| <p>place?</p>                                | <p>congestion;</p> <p>Facilitating the introduction and managing the impact of new technologies; and;</p> <p>Mitigating the risk of continental interference.</p>   |
| <p>What is the impact on Audio PMSE use?</p> | <p>There are no plans at this time to restrict access to dedicated PMSE spectrum. In the future demand pressures on the band could make loan spectrum more difficult to coordinate access. For any future exceptional events such as the Olympics would require special plans to be put into place to secure additional access to spectrum.</p> <p>Longer term requirements for new use could constrain access by existing users. Any longer term decision to align with the CEPT band plan would require a comprehensive re-plan of existing access arrangements.</p> <p>Additional spectrum that is currently utilised on a short-term adhoc basis from the Emergency Services is up for potential release in 2020 which may see it returned for civil use or other (which could include an award).</p> |

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## 5.2 Spectrum Availability Changes

### Business radio VHF Spectrum Release (143 to 169 MHz)

Loans of VHF spectrum are frequently requested for PMSE use and this is mainly because there is very little spectrum allocated to PMSE on either a primary or secondary basis.

Where wider-area coverage is required there is likely to be a requirement to access VHF spectrum. A good example of high-demand is for the motor racing events where, for

example, Silverstone requires access to VHF spectrum to support various wireless applications ranging from GPS telemetry to instrument levels and voice communications.

As most of the VHF spectrum was originally borrowed from the Emergency Services on a temporary basis there is an interest in the future access arrangements to this spectrum that has now been returned to Ofcom for civil use. There is 5.875 MHz of spectrum that has been returned and is available throughout England, Wales and Northern Ireland.

A Call for Input (CFI)<sup>5</sup> was published requesting feedback on potential uses of this spectrum. A follow-up consultation<sup>6</sup> and statement<sup>7</sup> have now been published with the following conclusions:

- A need to maintain future flexibility in presence of meeting demand requirements as they arise;
- spectrum was made available as follows:
  - Business radio (first come-first served) available to the Technically Assigned and Area Defined licence products;
  - 250 kHz has been made exclusive to Maritime and Coastguard Agency;
  - Continued use to PMSE on a temporary basis subject to coordination with existing users;
  - Further Amateur use on a temporary basis between 146-147 MHz;
  - Availability of temporary access to spectrum until there is a demand from other users;
- the decisions will come into effect immediately; and
- if new applications / demand does arise (more likely in the longer term) which cannot currently be accommodated in the current Licensing framework the it may be decided to review the decisions made and then consult on alternative models of spectrum allocations, including availability of spectrum through an awards process.

### **Impact on PMSE Sector**

The outcome of this consultation is positive for the PMSE sector in that the spectrum will continue to be made available on a temporary basis as and when required.

The only risks associated with this ongoing arrangement is that firstly, annual business radio assignments will be made and over time there is a risk that this spectrum will become increasingly congested. This is low risk as the demand for spectrum in VHF is much lower than UHF and there is a slight migration from existing VHF services. Secondly, if there is a case (in the medium to longer term) to review the decision on access to this spectrum then this should then be reviewed at the appropriate time. As any potential reduction to access in VHF spectrum could have quite a significant (for larger events where loan spectrum is used) impact on the PMSE sector. In any future decisions that we make we would take account of PMSE use of the band.

The following spectrum detailed in table 11 has now been made available on a temporary basis to PMSE with an understanding that if there is a Business radio requirement then this

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<sup>5</sup> VHF Spectrum Release in the range 143 to 156 MHz – Call for Inputs (12 July 2012):

<http://stakeholders.ofcom.org.uk/binaries/consultations/call-for-input/summary/condoc.pdf>

<sup>6</sup> Responses to the Call for Input and Consultation on next steps of the release of spectrum within the frequency ranges 143 MHz to 169 MHz – Consultation (24 March 2014):

[http://stakeholders.ofcom.org.uk/binaries/consultations/vhf-143-169mhz/summary/VHF\\_consultation.pdf](http://stakeholders.ofcom.org.uk/binaries/consultations/vhf-143-169mhz/summary/VHF_consultation.pdf)

<sup>7</sup> Release of spectrum between 143 MHz to 169 MHz – Statement (10 October 2014):

[http://stakeholders.ofcom.org.uk/binaries/consultations/vhf-143-169mhz/statement/VHF\\_Release\\_statement.pdf](http://stakeholders.ofcom.org.uk/binaries/consultations/vhf-143-169mhz/statement/VHF_Release_statement.pdf)

takes precedence and there is also residual legacy Emergency Services use within the ranges.

**Table 11- Amount of PMSE spectrum allocated following the VHF Release Consultation**

| Start Frequency (MHz) | End Frequency (MHz) | Amount available minus legacy use (MHz) |
|-----------------------|---------------------|---|
| 152.3500              | 152.4750            | 0.125                                   |
| 155.0000              | 155.7375            | 0.600                                   |
| 168.3125              | 168.8375            | 0.465                                   |

### Strategic Review of UHF Spectrum at 420-470 MHz

Loans of UHF spectrum are requested for PMSE use and this is mainly because of the high demand spectrum requirements or specific equipment constraints that may arise at larger events.

The UHF bands include 420-450 MHz and 450-470 MHz, known as the UHF 1 and UHF 2 bands respectively. These frequency bands are extremely popular due to their desirable propagation characteristics.

The band is used by a wide range of parties covering a diverse set of services ranging from the RAF Fylingdales radar and the emergency services (ES), to civil users of business radio (BR) including transport, security and manufacturing industries, utilities, programme making and special events (PMSE), maritime and aeronautical sectors, amateurs and licence exempt (LE) use (including short range devices). BR is the most significant civil user of the 420-470 MHz band (of which professional private mobile radio (PMR) is the most common type of use).

The pattern of use of the 420-470 MHz band is particularly complex and its current configuration is not fully aligned with the relevant European configuration plan. There are indications of increasing demand from some existing users of the 420-470 MHz band, particularly in dense urban areas, and signs that new types of use also want to make use of these frequencies. In addition, the risk of interference is growing from wideband and narrowband technologies deployed by our continental neighbours (which can be exacerbated in some meteorological/atmospheric conditions).

Against this background, and having regard to our statutory duties, a strategic review of the band commenced earlier in 2014. A Call for Inputs<sup>8</sup> (CFI) has already been published (and now closed) which formed part of the initial phase of work in the strategic review.

In keeping with our duty to ensure efficient use of the spectrum, the strategic review seeks to understand whether the current approach to managing the band is able to meet the needs of current and future users. This is to be achieved in two ways:

- a) Improving the understanding of current and future use of the band, including competing demand for its use; and;

<sup>8</sup> Strategic Review of UHF Spectrum at 420-470 MHz (UHF Bands 1 and 2) Call for Inputs (4 December 2014): <http://stakeholders.ofcom.org.uk/binaries/consultations/420-470-mhz/summary/420-470-mhz.pdf>

- b) Gathering evidence to address the challenges brought about by competing demand and the bands' fragmentation and existing configuration, in order to support future decisions.

The next steps that are now underway on the review are as follows:

- Reviewing the responses to the CFI;
- understanding the extent of interference from the continent;
- monitoring growth in demand and congestion;
- understanding the potential for new use;
- investigate the opportunity for band reconfiguration (as well as alternative solutions for resolving growth in demand) – intervention options analysis; and
- publishing the outcomes of the analysis.

The proposal is to publish the outcomes of the analysis from the monitoring and data gathering activities set out in the work programme, along with a summary of key themes from responses to the CFI and any proposals following the analysis of intervention options before the end of 2015. At that time, we may also be in a better position to put forward options for future management of the band (if evidence indicates that action is needed).

More detail on the review and the configuration of the band can be found in the CFI publication.

### Impact on PMSE Sector

The impact on spectrum utilisation in this band on the PMSE sector at least in the short term is unlikely to change or have any real material impact. Over the longer term as new services require additional spectrum and with the review of access to the Emergency Services spectrum up for review in 2020 this is something that may potentially have an impact and should be monitored closer to the time. As part of the review the options and feasibility of a managed reconfiguration will be explored so that the potential implications are understood for all incumbents. The spectrum requirements of PMSE in this band will be taken into account in any developing strategy.

So in summary table 12 shows the risks to the PMSE sector for ongoing access to this band based on the outcomes of this review.

**Table 12 Potential risks to PMSE sector**

| Risk   | Likelihood  | Rank | Impact  | Rank   |
|--|---|------|---|--------|
| Ongoing Short-term access to the Emergency Services spectrum becomes contended with Business radio (PMR) | There is sufficient spectrum available in UHF-2 for both Business radio and PMSE use. This is primarily due to the fact that PMSE use is generally only required at larger special or major events which do | LOW  | If there is a significant contention then the ability to support the spectrum requirements for larger special or major events would be problematic. | MEDIUM |

| <b>Risk</b>   | <b>Likelihood</b>   | <b>Rank</b> | <b>Impact</b>   | <b>Rank</b> |
|---|---|-------------|---|-------------|
|   | not occur very often.   |             |   |             |
| Access to Business radio (PMR) spectrum becomes difficult in major conurbations.  | This is generally the case now. There is already increasing congestion in major conurbations (especially London) and the likelihood of access is already problematic.   | HIGH        | As there is no real change from the status quo this is unlikely to have any significant impact on spectrum access.  | LOW         |
| Access to Emergency Services Spectrum from 2020 may be significantly reduced or not available.                                | This is only likely to happen if the alternative solution for the existing users is not viable or does not meet their needs. This is difficult to forecast now but the likelihood of the procurement of any new system should meet the requirements if scoped appropriately | LOW         | If the spectrum availability is diminished then the ability to support the spectrum requirements for larger special or major events would be problematic. | MEDIUM      |
| Access to Emergency Services Spectrum from 2020 not available due to being used as parking channels for Band Re-configuration | It is difficult to see if band re-configuration will happen. The current analysis shows that there is not a requirement at present but this could change with increasing demand and roll out of new services in Europe. This should be kept under review.                   | LOW/MEDIUM  | If the spectrum availability is diminished then the ability to support the spectrum requirements for larger special or major events would be problematic. | MEDIUM      |

| <b>Risk</b>  | <b>Likelihood</b>   | <b>Rank</b> | <b>Impact</b>  | <b>Rank</b> |
|--|---|-------------|--|-------------|
| Band Re-configuration is required and undertaken                         | It is difficult to see if band re-configuration will happen. The current analysis shows that there is not a requirement at present but this could change with increasing demand and roll out of new services in Europe. This should be kept under review. | LOW         | This will impact fixed installations more due to the fact that these systems will need to be retuned and possible changes to filtering/hardware. With the flexibility of newer equipment through software programming it is not expected to be as high an impact as it was 10 years ago. | MEDIUM      |
| Interference from Europe due to roll out of new (e.g. LTE/CDMA) services | Whilst the likelihood of this is currently unknown until further investigations have been done. Any interference that is present is geographically limited to the coastal areas of the UK.  | LOW         | Due to geographical limitations of the potential interference and the current situation this is expected to be low risk but should not be underestimated and should be monitored.  | LOW/MEDIUM  |

### 5.3 Demand Forecast Analysis

If we are to look at the volumes of assignment across each of the key frequency ranges it is possible to estimate the growth for the next few years using the Compound Annual Growth Rate (CAGR) methodology. A point to note about this method is that it does not take into account where there have been annual variances in which the trend in the volumes have not been consistent from year to year. It is extremely difficult or near impossible to predict the annual variances so this methodology is the only appropriate method to use.

Based on the trend changes for each of the frequency bands from 2002 up to and including 2013 the following results are resultant.

**Table 13 - Numbers of PMSE Audio assignments from 2013 and projected through to 2018**

| Frequency Band      | Minimum | Maximum | CAGR   | 2013  | 2014* | 2015* | 2016* | 2017* | 2018* |
|---------------------|---------|---------|--------|-------|-------|-------|-------|-------|-------|
| VHF (<100 MHz)      | 446     | 912     | -5.79% | 446   | 420   | 395   | 372   | 350   | 329   |
| VHF (100-230 MHz)   | 885     | 1975    | -0.43% | 1087  | 1082  | 1077  | 1072  | 1067  | 1062  |
| UHF-1 (400-450 MHz) | 2153    | 3723    | +0.69% | 3184  | 3205  | 3227  | 3249  | 3271  | 3293  |
| UHF-2 (450-470 MHz) | 22720   | 37531   | +3.14% | 36982 | 38143 | 39340 | 40575 | 41849 | 43163 |
| >900 MHz            | 19      | 185     | +17.2% | 141   | 165   | 193   | 226   | 264   | 309   |

\* Estimated

## 5.4 Technology Evolution

### Migration from Analogue to Digital

In the mobile radio sector we are in a period of sustained growth in digital. This growth also includes the churn of legacy equipment. The increase in digital applications is also reflected in the number of digital applications being received by Ofcom for Business radio. From the PMSE Licensing and Assignment data it is difficult to identify the types of equipment being used whether it be analogue or digital but for the communications provided for infrastructure at larger recent events, such as the Commonwealth Games, we have seen evidence that digital equipment is being more readily used.

Typically, a base station should last around 15 to 20 years with the subscriber units (mobile terminals) lasting about 7 to 10 years. There is no evidence of a marked rate of change of equipment but rather a change to digital equipment after the operational life. It is to be noted that new digital equipment will offer more features with the potential for new software applications to be developed. It is expected that this offering is likely to dramatically increase the use of data applications and services over the next few years.

There are two types of digital mobile radio available on the market today in the UK, DMR (Digital Mobile Radio) and dPMR (Digital PMR). DMR operates using a standard 12.5 kHz channel but utilises a two-slot, time division multiple access (TDMA) system offering voice, data and a range of other features and applications. dPMR operates using a 6.25 kHz channel and because the emission mask is so tight, two 6.25 kHz dPMR signals can be used next to each other with a 12.5 kHz channel without resulting in any interference.

One key thing to highlight from the equipment point of view is that UHF digital equipment is readily available but the understanding currently is that VHF digital equipment availability is getting to market less quickly.

### **Increase in Data**

It is fast moving from a voice only world to a voice and data world. With the introduction of digital equipment this has opened the potential opportunity to introduce hosted facilities provided by third party applications. This is likely to result in a big impact on the spectrum management. Even if the data services are not currently used this is expected to increase. In terms of managing sharing, the growth of data traffic could be a significant issue for channel occupancy. This includes GPS and telemetry type applications.

## Section 6

# Conclusions

### Current Demands and Spectrum Landscape

There are many channels across multiple bands primarily 48 MHz to 215 MHz (VHF), 425 MHz to 470 MHz (UHF) and at 1.5 GHz.

These bands, for the majority of cases, meet the spectrum demands for the sector but there are exceptional circumstances where additional spectrum is sought. Examples of these cases include recent events such as the London 2012 Olympic and Paralympic Games, Glasgow 2014 Commonwealth Games and Tour de France 2014. For these events there is a requirement not only to secure additional spectrum to meet the sheer volumes but also to accommodate a wide range of equipment tuning ranges from different regions of the world.

There are also some 'hotspot' areas where spectrum is used intensively on a more regular basis either for specific events or on an annual basis. Examples of these include motor racing events (e.g. F1 Grand Prix at Silverstone) where additional spectrum is sought and also theatres in London which primarily use the existing PMSE allocations at 462 MHz and 469 MHz.

Where additional temporary use of spectrum is required this is generally sourced from other sectors under Ofcom's management or by request to other spectrum holders such as Scottish Government or the MoD.

Narrowband (communications quality) talkback makes up the majority of spectrum usage in VHF and UHF at around 80%. The overall trend of narrowband talkback assignments is slowly on the increase with Data, Audio links and Wide-band talkback remaining fairly steady. The frequency band most utilised is 450-470 MHz (known as UHF-2) which contains around 70% of the frequency assignments. It is therefore, the use of narrowband talkback in UHF-2 is the main area to focus on.

When investigating in more detail the use of UHF-2 it can be seen that the intensity of use for each channels varies considerably across the channel set highlighting that there are channels that are utilised extensively and others which are lightly used. This identifies that some of the channels could be used more aggressively than they currently are and there is still capacity in many areas.

Another frequency range of interest is 137-173 MHz (known as VHF-Mid and VHF-High bands). During the study it was highlighted that there were a large number of out of band requests for spectrum, generally for motor racing events that have been used. The primary reason for this is that there is little PMSE VHF spectrum available.

### Future Spectrum Demands and Landscape

Taking a detailed look at the demand forecast if this is based on the trends from previous years then the changes for the key bands are: VHF (100-215 MHz) is an annual decrease of around 0.5%; and; for UHF-2 (450-470 MHz) an annual increase of 3%. When looking at the location of the intensive use it is London and the surrounding areas where the increases are taking place.

Considering the changes in technology the move from analogue to digital type services is expected to increase over the next two to five years. Within the wider market sales of digital

equipment we expect some take-up of this digital technology within some types of compatible PMSE use. However, it is not yet clear if digital technology will be widely adopted for core applications such as Director’s talkback. Where digital technology is deployed this may result in the spectrum ultimately being utilised more efficiently with both TDMA (12.5 kHz channel bandwidth) and FDMA (6.25 kHz channel bandwidth) leading to a reduction in the demand requirement.

The following are the key conclusions from the study:

|                           |   |  |
|---------------------------|---|--|
| Current Spectrum Demand   | 1 | There has been a steady increase in assignments between 2002 and 2013 and this varies geographically.  |
|                           | 2 | Narrowband talkback makes up the majority of PMSE audio assignments.   |
|                           | 3 | UHF-2 is the most popular band which shows a steady increase of around 3%, with VHF bands showing a steady decline.  |
|                           | 4 | Most of the out of band clearances are from Business radio and Emergency Services where requests are predominantly VHF and UHF-2. These are for the major hotspot areas and for major special events.  |
|                           | 5 | Silverstone has the highest demand for frequency assignments every year for the Formula One Grand Prix.  |
| Future Spectrum Landscape | 6 | <p>Ongoing demand forecast:</p> <ul style="list-style-type: none"> <li>• Expected continued growth in narrowband talkback of around 3% per year;</li> <li>• UHF-2 (450-470 MHz) is the most popular band and this is expected to continue;</li> <li>• Demand for VHF (48 – 215 MHz) is expected to continue to decline based on trends;</li> <li>• Demand for other audio services expected to remain static or potentially decline;</li> </ul>                        |
|                           | 7 | <p>Spectrum Band Reviews:</p> <ul style="list-style-type: none"> <li>• VHF Spectrum Release: PMSE has an allocation of spectrum and unless there is a new strategic requirement for another service this should continue.</li> <li>• UHF 1&amp; 2 Review: There is potential for changes to this band and with competing demands from other sectors and with this being the most demanded band for audio PMSE the future of this band should be continually</li> </ul> |

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monitored.

9 Sales of digital equipment increasing.

- Digital equipment can potentially deliver efficiency gains of up to 100% although it is yet to be determined if this is achievable in PMSE applications;

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In summary, based on our analysis of current demand and trends, we have found that the current spectrum availability is sufficient to meet the recurring demands of the sector and anticipated growth over the next six years. However, 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 F1 Grand Prix.

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.

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.

## Annex 1

# PMSE Spectrum Allocations

This annex details the spectrum allocations for PMSE for each of the service types in scope of this review.

This is an extract from the UK Frequency Allocation Table 2013 (Footnote UK 27 – Annex H – Spectrum Available for Use in Programme Making and Special Events)

| Frequency                 | Comments & typical use   |
|---------------------------|--|
| 47.55 - 48.8 MHz          | Audio.   |
| 52.0 - 52.95 MHz          | Audio.   |
| 53.75 - 55.75 MHz         | Audio.   |
| 60.75 - 62.75 MHz         | Audio.   |
| 67.75 - 67.8375 MHz       | Audio.   |
| 69.15625 - 69.18125 MHz   | Audio.   |
| 74.68125 - 74.71875 MHz   | Audio.   |
| 75.2625 - 75.3 MHz        | Audio, airborne use permitted, restrictions apply.                                     |
| 76.80625 - 76.84375 MHz   | Audio.   |
| 78.18375 - 78.25875 MHz   | Audio.   |
| 82.65625 - 82.68125 MHz   | Audio.   |
| 86.66875 - 86.68125 MHz   | Audio, geographical restrictions apply.  |
| 86.80625 - 86.84375 MHz   | Audio, airborne use permitted, restrictions apply.                                     |
| 139.54375 - 139.55625 MHz | Audio, geographical restrictions apply.  |
| 139.56875 - 139.58125 MHz | Audio, geographical restrictions apply.  |
| 139.64375 - 139.66875 MHz | Audio, geographic restrictions apply.  |
| 140.9875 - 141.4875 MHz   | Audio, geographic restrictions apply. Airborne use permitted, restrictions             |
| 148.5625 - 148.5875 MHz   | Audio, geographic restrictions apply.  |
| 148.7125 - 148.7375 MHz   | Audio, geographic restrictions apply.  |
| 181.69375 - 181.80625 MHz | Audio Links and Data Links.  |
| 189.69375 - 189.80625 MHz | Audio Links and Data Links.  |
| 191.6 - 191.8 MHz         | Includes use by Links and wireless microphones.  |
| 199.6 - 200.2 MHz         | Includes use by fixed audio links. Restrictions apply.                                 |
| 425.3125 - 425.5625 MHz   | Audio, geographic restrictions apply.  |
| 427.7625 - 428.0125 MHz   | Audio, geographic restrictions apply.  |
| 442.2625 - 442.5125 MHz   | Audio, geographic restrictions apply.  |
| 446.425 - 447.5125 MHz    | Audio, power restrictions apply in certain geographic areas.                           |
| 454.9875 - 455.4625 MHz   | Audio, geographic restrictions apply. Some airborne use permitted, restrictions apply. |
| 457.25 - 457.475 MHz      | Audio, some airborne use permitted, restrictions apply.                                |
| 461.23125 - 461.25625 MHz | Audio, some airborne use permitted, restrictions apply.                                |
| 462.750 - 463.000 MHz     | Audio, Some airborne use permitted, restrictions apply. Some power restrictions apply. |
| 467.2625 - 469.8750 MHz   | Audio. Geographic restrictions apply. Some airborne use permitted, restrictions apply. |
| 1517 - 1525 MHz           | Audio and wireless microphones.  |

## Annex 2

# Hotspot Venues

Using the hotspot location method the table below shows the trend in PMSE audio frequency assignments from 2002 to 2013 for the most intensively used venues.

| Venue              | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|--------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| TV studios         | 560  | 600  | 609  | 587  | 637  | 677  | 588  | 513  | 442  | 502  | 305  | 245  |
| TV Studios         | 269  | 167  | 191  | 365  | 342  | 705  | 626  | 414  | 637  | 146  | 320  | 583  |
| Motor Race Circuit | 46   | 80   | 49   | 65   | 231  | 447  | 567  | 489  | 294  | 194  | 320  | 232  |
| Stadium            | 272  | 260  | 266  | 415  | 381  | 390  | 227  | 168  | 159  | 113  | 158  | 184  |
| Stadium            | 123  | 57   | 196  | 108  | 176  | 208  | 393  | 217  | 328  | 511  | 610  | 455  |
| Motor Race Circuit | 117  | 120  | 150  | 99   | 359  | 387  | 396  | 367  | 47   | 194  | 323  | 223  |
| Race Course        | 423  | 370  | 258  | 256  | 192  | 208  | 221  | 224  | 187  | 176  | 238  | 247  |
| Arena              | 2    | 9    | -    | -    | -    | 17   | 90   | 285  | 306  | 268  | 270  | 616  |
| Stadium            | 274  | 373  | 291  | 325  | 420  | 404  | 365  | 388  | 390  | 558  | 403  | 581  |
| Race Course        | 277  | 252  | 220  | 189  | 217  | 238  | 221  | 203  | 201  | 222  | 195  | 195  |
| Stadium            | -    | -    | -    | -    | -    | -    | -    | -    | --   | 10   | 442  | -    |
| Film Studios       | 68   | 111  | 185  | 206  | 295  | 317  | 335  | 529  | 335  | 370  | 308  | 396  |
| Motor Race Circuit | 8    | 111  | 238  | 264  | 267  | 252  | 130  | 127  | 111  | 91   | 78   | 93   |
| Arena              | 140  | 236  | 279  | 201  | 287  | 318  | 364  | 254  | 280  | 128  | 140  | 130  |
| Film Studios       | 442  | 51   | 69   | 78   | 146  | 158  | 281  | 129  | 161  | 315  | 230  | 233  |
| Silverstone        | 274  | 192  | 216  | 254  | 877  | 1272 | 1266 | 1006 | 1186 | 1198 | 1173 | 1172 |
| Race Course        | 340  | 237  | 164  | 140  | 120  | 99   | 142  | 146  | 130  | 133  | 145  | 166  |
| Stadium            | 5    | -    | 3    | -    | -    | 726  | 655  | 576  | 601  | 797  | 484  | 902  |
| Race Course        | 379  | 237  | 148  | 161  | 147  | 167  | 145  | 168  | 136  | 177  | 204  | 266  |