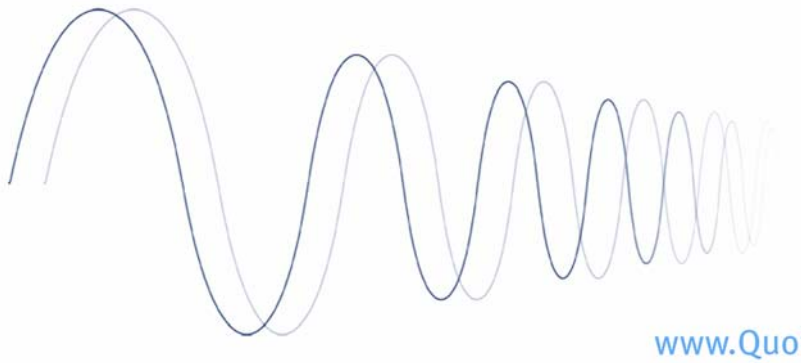
Quotient Associates

Supply and demand of spectrum for Programme Making and Special Events in the UK

Final report

Report to Ofcom, December 2006



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EXECUTIVE SUMMARY

In the UK, a total bandwidth of 2.7GHz of spectrum in frequency bands ranging from 50MHz to 48GHz is allocated for the use of Programme Making and Special Events (PMSE). The spectrum is harnessed by PMSE users to support a wide range of programme making and event hosting, ranging from TV and film production to newsgathering, staging concerts, plays and musicals, and other events including use in churches and at village fetes. The applications include wireless microphones, wireless cameras, point to point links to relay information to Outside Broadcast vehicles and studios and wireless voice communications to co-ordinate the event or production.

Some events are only for short periods in a specific location, and others, such as newsgathering, are required every day somewhere within a wide area. This complex mix of PMSE users and applications requires coordination to ensure that interference between assignments does not compromise quality of use. This task is undertaken by Joint Frequency Management Group (JFMG) Limited. JFMG is a UK-based private limited company, jointly owned by the ITV Network and Commercial Radio Companies Associates, who are contracted by Ofcom to exclusively co-ordinate PMSE frequency assignments, and to collect usage fees. Historically, these fees have been based on the recovery of administrative costs, and spectrum has been made available for PMSE by administrative assignment. The current contract with JFMG to manage spectrum for the purposes of PMSE ends on 30th September 2008.

In November 2003, Ofcom consulted on spectrum trading, and proposed its introduction into spectrum used for PMSE purposes and the possibility of multiple spectrum management organisations (SMOs) to create a competitive environment for access to programming spectrum.

In December 2005, the Independent Audit of Spectrum Holdings by Professor Martin Cave was published[1]. Its report recommended comprehensive application of Administered Incentive Pricing (AIP), where the AIP fee should reflect the opportunity cost of spectrum use. The report further advocates that public sector spectrum should be made tradable, and that public bodies should be able to gain financial benefit from commercial spectrum activity. Currently PMSE shares access to some MoD spectrum; adoption of Cave's recommendations would both increase the incentive for public bodies to share access to their spectrum holdings, and introduce competition for spectrum from alternative users who may also seek such access.

As well as the challenge of adapting to a market based spectrum management environment the PMSE sector faces a reduction in available spectrum since a substantial proportion of spectrum currently used for PMSE is to be released to the market by Ofcom. This consists of approximately 120MHz below 2GHz and over 500MHz above 2GHz. In addition, the demand for access to additional spectrum driven by innovative and more dynamic programme formats is anticipated to increase demand for spectrum used for PMSE purposes.

The purpose of this report is to provide Ofcom with an in-depth understanding of the role played by the PMSE sector, its use of spectrum, and how this can be expected to change in future.

[1] Report and supporting studies are available from http://www.spectrumaudit.org.uk/.

Current and future supply of spectrum for PMSE purposes

Currently, JFMG has access to spectrum in a total of 19[2] bands ranging from 50MHz to 48GHz. Almost half of this spectrum is shared on a secondary basis with either the MOD or with the terrestrial TV broadcasters. The frequencies below Bands IV & V (that is below 470MHz) are generally used for talkback and audio programme links whilst those at and above 2GHz are used for video programme links and wireless cameras. The band at 1.5GHz is used for digital audio programme links. The UHF TV bands, Bands IV & V and TV Channel 69, are used very largely for radio microphones, with some radio microphone usage in Band III as well.

Some of the current spectrum will become, or is at risk of becoming, unavailable for PMSE use over the next few years. The most notable change in spectrum will occur in the UHF TV band, where 14 out of 48 TV channels are expected to be released for other services after the switchover to digital TV, and in the 2.50 to 2.69GHz band which is due to be auctioned. The former band supports the vast majority of radio microphone usage, which itself accounts for almost 70% of all usage. With the switchover to all digital terrestrial TV taking place between 2008 and 2012, around 30% of this spectrum is expected to be released for new applications. Its loss could have a severe impact on many PMSE users. The latter band is extensively used by the PMSE community for wireless cameras but may become unavailable to PMSE users following its release on to the market.

Current demand for PMSE spectrum

Approximately 64,000 individual PMSE frequency assignments are made to around 1300 different organisations and individuals each year. The usage is skewed towards larger users. Just 50 of these account for 50% of all spectrum usage, with the BBC alone accounting for 13%.

The different PMSE activities can be divided into five broad categories of use.

Outside broadcasts – all situations in which temporary programme making facilities are established outside of a studio for the purpose of recording or broadcasting of any event other than a news event. The major users are broadcasters and production companies that produce outside broadcast content for the broadcasters.

Newsgathering – the temporary provision of programme making facilities away from the studio environment. The major users within this category are the large broadcasters such as the BBC, Independent Television News and BSkyB. The key difference is that news teams need to be able to respond to news events wherever and whenever they occur. Thus they need to be able to establish their facilities at short notice anywhere within their geographical area of operation.

Studio based programme making - studios are operated by both broadcasters (radio and TV) and independent production companies. In the studio environment, wireless helps avoid the use of cables and gives greater freedom of movement to presenters and other participants, allows greater flexibility in programming formats, and brings productivity gains. Studio based programme making can also include an element of outdoor work and this gives rise to requirements similar to those of Newsgathering.

Local entertainment and events – this includes theatres, concerts, touring shows, business events, and other public and private events. Theatres are the largest group within this category both in terms of the number of licensees and the amount of spectrum used.

[2] A further band at 1800MHz has been available for digital radio microphones. However, it is very little used and Ofcom now intends to release the band into the general market place.

Community uses - this covers all events whose end product is for use within the community. Typical examples include the use of radio microphones within places of worship, educational institutes, and amateur dramatics.

The reliance upon spectrum for the purposes of PMSE varies significantly between different user categories, and different applications are much more heavily used than others. Some assignments are local (confined to a specific location) and some are granted on an area basis or even nationally. The majority of assignments are local (92% in terms of assignment days) and most of these are indoor (80% of assignment days). There is also a strong bias towards metropolitan areas with 50% of all assignment days occurring in only 4 % of locations.

Radio microphones account for 64% of all assignment days. The main bands for this application are the UHF Bands IV & V and Channel 69 which together account for more than 70% of assignment days, illustrating the importance of these bands. Talkback has the second highest demand accounting for 25% of assignment days[3].

Future Demand for PMSE activities

Based on an assessment of the main drivers affecting demand for spectrum we have assessed growth for each category of use and application based upon the likelihood of increasing event size and an increase in the number of events as late adopters migrate to wireless technology.

Our predictions are based on a number of assumptions about future trends in consumption. The primary ones are that:

- A greater proportion of news will be covered live in future;
- Television viewing will be driven by increasing local news and content;
- The launch of HDTV will increase spectrum requirements for wireless cameras and video links;
- Production will become increasingly complex (with greater combined use of the different PMSE applications) especially for live events and outside broadcasting; and
- Local event and niche programming will increase, primarily based on the take-up of VoD through broadband TV.

Based on this we have estimated the growth in event size for each PMSE application and category of use up to 2014. In general, video links and data links are forecast to grow by up to 100%, radio microphones by 20 to 30%, with only modest growth for audio links and talkback.

The growth in the number of events is estimated by considering:

- The drivers for each of the relevant trends on growth, technology etc., by application and by category of use;
- Growth in number of users within the category of use (e.g. the number of theatres using radio microphones is expected to increase);
- The impact of changing the usage mix within each category of use (e.g. while usage of radio microphones may be going up for top commercial theatres, there will be an increasing number of smaller theatres using radio microphones and this may actually drive down the average across the category).

[3] The number of assignments and number of assignment days are measures of demand for spectrum use (see Section 4 for their definition).

This growth will be reflected in an increased number of events and wide area assignments. Based on the above considerations, we estimate growth of the number of events between 2004 and 2014 over the next 10 years will be between 55% and 65% depending upon the category of use.

Assessment of the balance of supply and demand

The objective of modelling PMSE spectrum assignments was to gain understanding of how use varies both temporarily and spatially in each of the spectrum bands used for PMSE. The supply and demand was compared in the years 2004 and 2014 for each band. In addition, the UHF Bands IV and V were evaluated under four alternative Digital Switchover (DSO) scenarios, with progressively more restrictive spectrum supply for PMSE.

Some of the bands are alternatives for each other in terms of functionality, and have been grouped together into six blocks of substitutable spectrum. For each block it was assumed that overload in one band (which may be due to forecast growth in usage or accommodating currently out of band assignments) can be migrated to other bands within the same block.

The results of the analysis for each block of substitutable bands are summarised below.

Block 1 Band I and Low Band	Analysis of Block 1 resulted in a fractional occupancy of just less than 100% in 2014. We do not believe there will be shortages of spectrum in Block 1 provided new PMSE equipment is appropriate for band availability in its area of intended use.
Block 2 High Band, VHF Band III (non-Radio Microphones) UHF 1 and UHF 2	All of the bands used in Block 2 needed out of band spectrum even to meet the 2004 demand, and exhibited peaks that exceeded a fractional occupancy of 100% for all demand and supply scenarios considered. Grouping the spectrum into a single block reduces the need to access out of band spectrum for some peak events, since the peak events rarely coincide in time and location. The peak fractional occupancy forecast for 2014 is 134% which corresponds to an additional spectrum requirement of 2.1MHz.
Block 3 VHF Band III (RM), UHF Bands IV & V and UHF Channel 69	The demand for spectrum in Block 3 is dominated by UHF Bands IV & V. The main PMSE uses in these bands are radio microphone applications which could also be accommodated to some extent by VHF Band III and UHF Channel 69. The areas of highest demand are major outdoor events such as Glastonbury, areas of restricted supply such as Newcastle, and locations having high indoor usage such as the major TV studios in Central London. The demand for PMSE is expected to increase substantially by 2014, and is forecast to outstrip supply based on current spectrum availability. However, the capacity of the retained interleaved channels may increase. Assuming that the supply and demand for VHF Band III, UHF Channel 69 and UHF Bands IV & V can be aggregated, we do not predict any shortage of spectrum in 2014, however demand approaches supply at Glastonbury, and in Newcastle and in Central London, demonstrating the geographic peaks in demand.
Block 4 1.5GHz	Block 4 has low levels of utilisation overall and the fractional occupancy is expected to only reach 33% in 2014.
Block 5 2, 3.5, 5, 7, 8	There will be substantial shortages of spectrum across the UK in the range 2 to 10GHz arising from increasing use of video links and digital transmission.

and 10GHz	Supply is expected to be around 1.2GHz in 2014, and access to a further 3.1GHz will be needed to fully satisfy forecast PMSE demand at Silverstone and in Greater London.
Block 6 11, 12, 24 and 48GHz	The analysis found no shortage of spectrum in this block. However, accommodating the 2014 demand is made possible by the availability of spectrum at 48GHz which constitutes approximately 38% of spectrum supply in the block. Use of the 48GHz band is likely to be less popular but there are few events for which this measure would be necessary.

Summary of the results of the balance of supply and demand for each block of substitutable spectrum

In summary, the analysis of supply and demand resulted in four main findings:

- To accommodate growth in talkback, audio links and data links, approximately 2MHz of additional spectrum is required between 100MHz and 470MHz;
- Growth in use of radio microphones could be accommodated within the retained interleaved DTT channels;
- To accommodate growth in video links and increasing use of digital cameras, approximately 3GHz of additional spectrum is required between 2GHz and 10GHz;
- Though peak use (at different large events) uses virtually all the spectrum in each band, in many bands a large amount of spectrum is unused in most parts of the country, for most of the time.

The value of PMSE spectrum

Three different economic value metrics were considered:

- Cost-effects: evaluation of the additional value to users of being able to use PMSE applications instead of the next best alternative;
- Value-effects: Using a case-study based approach, this metric considers the cost-effects (as above) in conjunction with improvements that PMSE applications add to the quality/value of the end products and services;
- Value to consumers and wider society: these aspects are considered only qualitatively.

On cost-effects: This is an approximation to the opportunity cost that existing users would face had they to use the next best alternative method of production instead of using spectrum designated for the purposes of PMSE. It is difficult to determine an accurate measure of the opportunity cost primarily because alternatives that maintain the same quality as the existing solutions often do not exist. However replacement with the best alternative method would cost as much as £70 to £75 per assignment for Newsgathering and Outside Broadcasts, but would result in a saving of £6 per assignment for radio microphones for Local entertainment and events. These measures are highly sensitive to the labour cost estimates required to replace wireless equivalents.

On value-effects: Value effects include the ability to provide added value to a brand through innovative and high quality programming (e.g. breaking news), providing coverage that would not otherwise be possible (e.g. F1 in-car shots), or by being able to charge a premium for the added value of an improved spectacle (e.g. a theatre event). The added value that spectrum provides depends critically upon the nature of the user and the context of use. For the majority of events the value-effect of wireless is a small fraction of the overall production cost – for others including high value cases where it is essential spectrum is an essential element of the production.

Value to consumers and wider society: We have found no reason why the consumer benefit from the use of spectrum for PMSE should generate any more consumer surplus or wider societal benefit than would be possible by other means. In most cases of spectrum use, only a marginal element of quality of the end-activity is at risk which is unlikely to have direct effects or externalities. Hence spectrum use by PMSE users does not lead to any significant economic surplus that would not be generated if spectrum were being used for purposes other than PMSE. We note, however, that the complexities of estimating consumer surplus here preclude a more quantitative analysis.

Contents

1 INTRODUCTION

This is the final report of a study for Ofcom, performed by Quotient Associates Limited in conjunction with Spectrum Strategy Consultants on the users, uses, and the supply and demand of spectrum used for programme making and special events (PMSE) in the UK, under Ofcom contract number C30201.

This report covers all aspects of the study. An Annex is used to document further details in a number of areas[4].

1.1 Programme making and special events in the UK

Programme making and special events (PMSE) describes a wide range of activities that use wireless primarily in support of programme making and broadcasting. Programme making here is broadly defined and includes the making of TV, film, radio, advertisement and corporate material through to the production of plays, concerts and shows of all sorts and sizes. PMSE activities supporting broadcasting include outside broadcasts of all types and newsgathering where temporary programme making facilities are required away from the studio. Also captured within this category is the use of radio at "events" such as fetes, carnivals, bingo sessions, and church services. Not surprisingly, the wireless equipment used also covers a wide range from short range radio microphones and wireless cameras through to links carrying programme material from remote sites back to broadcasting studios. The users range from the major broadcasters through schools to individuals.

A common feature of many PMSE activities is their temporary nature. Facilities are often required for just a few days at one location to cover a specific event. Some events, for example news events, are unpredictable but many are regular and scheduled. This temporary nature is reflected in the use of the spectrum with many frequencies being assigned to a specific user for a specific event for a specific period of time. At the same time, other frequencies are assigned to one user on an annual basis and some may be assigned for use by the same user across a region or even nationally.

Co-ordinating the use of frequencies between the different and varying users and uses is carried out by JFMG Limited. JFMG is a UK-based private limited company, jointly owned by the ITV Network and Commercial Radio Companies Associates. JFMG has been contracted since 1997 by Ofcom (and previously by the Radiocommunications Agency) to assign licenses, and to collect usage fees, for spectrum used for PMSE in the UK. Historically, these fees have been based on the recovery of administrative costs, and spectrum has been made available to JFMG through the offices of Ofcom (and previously the Radiocommunications Agency).

1.2 Future challenges

In November 2003, Ofcom consulted on spectrum trading, proposing its introduction into spectrum used for PMSE purposes and the possibility of multiple spectrum management organisations (SMOs) to create a competitive environment for access to programming spectrum, sometime in 2005. Subsequent to this consultation, in August 2004, Ofcom announced its decision to delay the introduction of trading for PMSE spectrum[5] until 2007. The purpose of the delay was to allow further assessment of alternative approaches to

[4] Supply and demand for spectrum for Programme Making and Special Events in the UK, Annexes A-H to the main report, Quotient and Spectrum, December 2006.

[5] For the purposes of this report we will define 'PMSE spectrum' as the list of spectrum defined in Ofcom's Frequency Register. It should be noted, however, that spectrum is not exclusively allocated for PMSE purposes, and that Ofcom's Spectrum Framework allows users to trade spectrum and apply for changes of use.

management of the spectrum, particularly considering how trading would operate with spectrum that is shared with other primary users, the potential adverse consequences of spectrum fragmentation with multiple SMOs, and the uncertainty over the future supply of spectrum. In the light of this decision, Ofcom's Statement on Spectrum Pricing in February 2005 announced its further decision against the early introduction of Administered Incentive Pricing to spectrum used by PMSE but raised fees by an average of 20% in April 2005. Fees were increased by a further 20% in 2006, with fees being weighted towards users of exclusive channels.

As well as the challenge of adapting to a market based spectrum management environment, the PMSE sector faces the forthcoming loss of access to a number of frequency bands. The biggest changes are in the 2GHz band (2.5 to 2.69GHz) and the UHF TV bands (470 to 862MHz). The former is extensively used by the PMSE community for wireless cameras but may become unavailable to PMSE users following its release on to the market[6]. The latter band supports the vast majority of radio microphone usage, which itself forms the largest part of PMSE usage. With the switchover to all digital terrestrial TV taking place between now and 2012, around 30% of this spectrum is expected to be released for new applications and its loss could have a severe impact on large shows and events which make heavy use of radio microphones.

The challenge for Ofcom is to develop a spectrum management approach, cognisant of the programme making sector's idiosyncratic use of spectrum, that can allow the programme making sector to secure access to spectrum, consistent with Ofcom's declared spectrum management policy.

1.3 Project objectives

The objective of this project is to provide Ofcom with an in-depth understanding of the role played by the PMSE sector, its use of spectrum and how this can be expected to change in future, and what options there are to secure the future supply of spectrum in an economically efficient manner. Specifically, Ofcom requested an assessment of the following four areas:

1. Current and future PMSE uses and users of spectrum;
2. Current and future demand for spectrum for PMSE purposes;
3. Current and future supply of spectrum for PMSE purposes;
4. Current and future value of spectrum for PMSE purposes.

1.4 This report

This report is organised as follows:

Chapter 2: What constitutes Programme Making and Special Events?

- This chapter provides an understanding of the whole of the PMSE sector: Who uses it, what for and how.

Chapter 3: PMSE spectrum and licensing

- This chapter introduces the spectrum available for PMSE activities, describes the role of JFMG and presents some initial analysis of licensing data.

[6] Of course PMSE users could purchase spectrum at auction or negotiate use with the eventual purchasers.

Chapter 4: PMSE users and usage of spectrum

- This chapter provides a breakdown of the users and their use of the spectrum, and a quantitative analysis of their spectrum usage.

Chapter 5: The value chain

- The objective here is to identify how PMSE users fit into the overall production process within which they operate, and to understand the value that they add.

Chapter 6: Emerging trends and market predictions

- This chapter considers the future developments of the PMSE sector and how this will impact on the industry's future requirements for spectrum.

Chapter 7: Modelling spectrum supply and demand

- This chapter outlines the methodology used to assess the balance of supply and demand, and the format of the results.

Chapter 8: Balance of supply and demand for spectrum

- This chapter summarises the main findings of our analysis of the supply and demand for PMSE spectrum. It indicates where and when additional spectrum may be required.

Chapter 9: Use and usage of interleaved spectrum

- This chapter summarises the main findings of our analysis for bands affected by the switchover to digital terrestrial TV.

Chapter 10: Economic assessment

- This chapter provides quantitative estimates of the value of PMSE spectrum for a number of representative situations.

Chapter 11: Summary

- Chapter 11 summarises the results and conclusions from the whole project.

1.5 Consultation with users

In order to improve our understanding of the current and anticipated use of spectrum for PMSE, we sought input from the many different commercial and non-commercial users of PMSE applications, from vendors and industry bodies. We would like to express our thanks to them all.

JFMG provided access to their database of all assignments in the year 2004/5, and allowed access to their GIS system in order to enable us to identify frequency availability on a location specific basis for different applications and clarified details on assignments issued. We are particularly grateful to Paul Gill and Philip Harris, who facilitated access to JFMG's data, and who tirelessly responded helpfully and courteously to our many queries and requests for information.

To gain an understanding of the use of PMSE at large events, BBC Resources and the Royal and Ancient Golf Club provided access to the 2005 British Open in St. Andrews. Particular thanks are due to Richard Kemp and Nick Buckley of BBC Resources who facilitated this, allowing a better understanding of the practical realities of staging a large event to be gained. In addition, we should like to thank BBC Research and Development who made available to us the results of their analysis of post-DSO interleaved spectrum availability.

2 WHAT CONSTITUTES PROGRAMME MAKING AND SPECIAL EVENTS?

The objective of this and the following chapter is to provide the reader with an overall appreciation of the PMSE sector and to establish the context within which the more detailed subsequent analysis can be understood. This chapter covers the major uses of PMSE spectrum. The next identifies the spectrum normally available for PMSE activities, and the process by which spectrum use is co-ordinated and users are assigned frequencies. First, we summarise the purposes for which PMSE spectrum is formally authorised.

2.1 Authorised use of PMSE spectrum

JFMG Limited is authorised to license users to operate wireless equipment for PMSE activities. The activities permitted under these licences are:

- For theatres, concert halls and the production of TV or radio programmes:
  - Any radio usage directly involved in the production or control of the programme material;
- For public or private events whether broadcast or not (events include sports, education, music, theatre, religious services, retailing, and so on):
  - Radio microphones, communications exclusively for the use of participants, and wireless links to loudspeakers, video screens, and public address systems.

The permitted uses cover a very wide range of events from TV coverage of a major sporting event, such as an international golf tournament, to the use of a single radio microphone at a village fete.

2.2 Categories of PMSE use

To provide an understanding of the various ways in which PMSE spectrum is used, and to aid some of the later analysis, we have categorised use into five categories. These have been selected to group similar usage patterns although, given the variety of PMSE applications, there is inevitably some blurring of the boundaries. They are:

- Newsgathering;
- Outside broadcasts;
- Studio based programme making;
- Local entertainment and events;
- Community uses.

2.2.1 Newsgathering

Radio and TV news reporters need to be able to respond rapidly to breaking news, to go to any location (within their territory) at any time, and to provide live reports back to their news broadcasting studios. An illustration of the wireless facilities required in the case of a TV news team is shown in Figure 2.1.

A control vehicle is parked close to the news event of interest. The TV reporter uses a radio microphone, and the cameraman a radio camera, to provide reports back to the control vehicle. The producer within the control vehicle communicates with the reporter and camera man (and other on-site production staff) via a separate one or two way wireless link, referred to as talkback, so that he can control their actions.

Depending on the event being covered, more than one radio microphone and camera may be used. Where aerial coverage of a news event is required, an airborne camera and reporter can be linked back to the control vehicle by other wireless links.

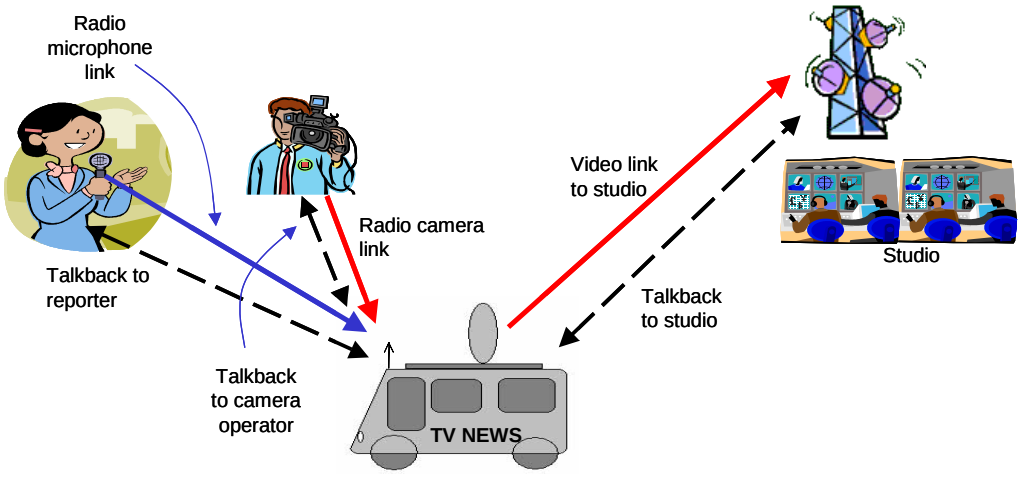

Figure 2.1: An example of the use of wireless in support of TV newsgathering.

The vehicle is connected back to the studio via two temporary links. A video link carries the programme material (combined video and audio) and a talkback link provides two way voice communications between the vehicle and the studio to enable coordination between the studio staff and the newsgathering team.

In the case of a radio reporter, the set up could be as simple as a single reporter using a radio microphone and talkback to the control vehicle, which in turn would have an audio link (for the programme material) and a duplex talkback link to the studio, with no need for any other personnel. With the development of high quality, portable digital radio cameras, a potential development is the use of two man TV news teams (a reporter and camera man) linking back to the studio in a similar way.

Because news teams need to go anywhere at anytime, and because several news organisations may cover the same event, the larger organisations are often assigned a unique frequency (or sometimes frequencies) over their area of operation on a long term basis[7].

Hence, we can summarise the key characteristics of newsgathering as:

- Newsgathering (both TV and radio) is performed locally, regionally and nationally;
- Users are typically either commercial or public broadcasters;
- Usage is both indoor and outdoor and use is often "live";
- Assignments are typically long term (usually on one year, renewable terms) and often for a wide area (local, regional or national) as the location of breaking news is unpredictable;
- Although the number of frequencies used by a news team is relatively small, a major news event will attract all the major news gatherers as well as more local news organisations. Thus there is the need to provide frequencies for multiple teams who will converge on the same location from time to time.

[7] Licences will be for one year at a time but would typically be renewable. It should be noted that assignment of frequencies for such wide area use (either national or regional), or for airborne use, precludes the re-use of that frequency within a wide geographic space.

The advantages of wireless

The use of wireless greatly facilitates the gathering of news, particularly live news. Radio microphones, wireless cameras and talkback give the reporter greater flexibility to report from the most appropriate location. The alternative of laying out cables takes time, can be a hazard to others in the area, and in some locations is not possible or is prohibited.

Wireless links are often the only means available for connection back to the studio. Satellite links can, and are, used as an alternative but are expensive and can be blocked by buildings. In a few regularly used locations, such as the High Courts in London, pre-wired interconnection points have been installed.

The examples of a single radio reporter and a two man TV news team given above illustrate the potential for productivity gains to be realised through the use of wireless.

2.2.2 Outside Broadcasts

We use the category Outside Broadcasts (OB) to refer to the temporary provision of programme making facilities at any event outside of a studio other than news events. A major use is to provide coverage of sporting events, but the broadcasting of air shows, indoor and outdoor concerts, and exhibitions, for example, all involve OB. The majority of such events are broadcast live.

The wireless facilities required to support an outside broadcasting event (see Figure 2.2) are similar to those for newsgathering. In the case of a large event such as a golf tournament, however, there are two key differences. Firstly, there will be a larger number of cameras, presenters and production staff requiring more frequencies for the radio cameras, microphones and talkback links. Secondly, where the event takes place over a large area, additional video and audio wireless links may be needed to connect distant cameras and radio microphones back to the OB control vehicle, and these links may be relayed over intermediate (remote) transceiver sites. These video and audio links may provide connection to fixed or mobile (or portable) equipment. For example a wireless camera may roam in the vicinity of a local golf buggy, which relays the video signal via a directional antenna to a (distant) remote receiver point connected to the OB control vehicle.

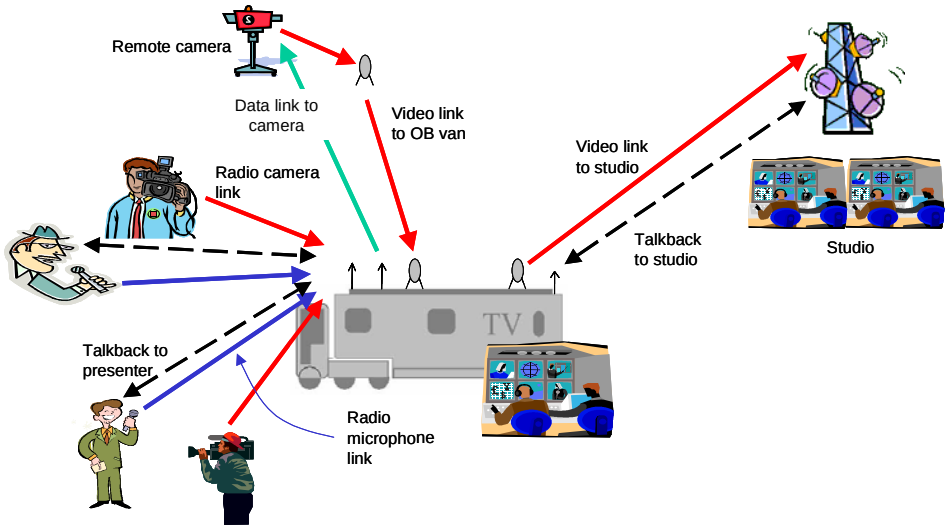

Figure 2.2 An example of the use of wireless at an outside broadcasting event.

For a large event, OB control vehicles can assemble different programmes (e.g. national and international programme streams) using different combinations of input sources and these different programme outputs can be sent to different studios for subsequent transmission using fibre, fixed microwave or satellite links. Locally, video tapes of the different sources will be archived and/or used to assemble other programme content that can be combined with the live data.

OB events may also make use of data links. These are most commonly used to enable remote control of cameras from the control vehicle but can be used to control any other piece of programme making equipment. For example, these data links are used to control wireless cameras to ensure consistent colour balance between the different video sources used to make the overall programme.

In addition, in-ear monitors (IEMs) may be used by some presenters. IEMs are earpieces connected to miniature receivers which enable a presenter to monitor an audio connection. Unlike talkback, IEMs are wide bandwidth devices providing high quality audio. Because of its lower audio quality, the use of talkback can become very tiring over a period of time. As a result, there is an increasing use of IEMs by presenters and others as an alternative to talkback, and IEMs are now being used at outside broadcasting events. As with radio microphones, they are restricted to low transmit powers and short distance operation.

Note that, depending upon the practicalities of the situation, fixed cameras and microphones may well be connected to the control vehicle by cable. For example, the majority of camera positions and the presenter's position at a regularly used stadium would usually be cabled with a radio camera and microphone used for perhaps one roving presenter. Similarly, in the case of an outside radio broadcast from a concert hall, the majority of microphones would usually be connected to the control vehicle by cable with PMSE frequencies used only for one radio microphone and talkback (to enable the presenter to move about the building). In both cases, a video (or audio) link would carry the programme material back to the studio in parallel with a talkback link. Some care must be taken in combining digital and analogue sources, since the digital encoding introduces a delay.

Note also that the venue itself may use PMSE frequencies for the production and control of its output. In the case of a concert hall, radio microphones and talkback are likely to be used. For our purposes, however, this usage is not considered as outside broadcasting but is included in the Local entertainment and events category described below.

At a large event there can be a number of broadcasters, each requiring several PMSE frequencies. To ensure that all the equipment can be operated without causing or suffering interference the selection of frequencies has to be properly planned, and this is currently undertaken by JFMG planning staff. As OB events are scheduled the planning can be done in advance and frequencies are assigned to the users just for the duration[8] and location of the event.

Hence, we can summarise the key characteristics of outside broadcasting as:

- Used by larger TV and radio networks (such as Sky sports or Talk Sports) and by commercial production companies (including BBC Resources);
- End users are typically either commercial or public broadcasters, though intermediate independent production companies can be responsible for coverage at the OB event;
- Typical usage is outdoor and use is typically "live";

[8] Including time for the setting up and testing of equipment.

- Use of the wireless equipment is typically short term and local to the event location – thus demand is predictable and scheduled;
- The largest events will be attended by numerous broadcast and production companies.

The advantages of wireless

The need for and benefit from wireless at outside broadcasting events varies with the type of event. In many cases it both greatly facilitates the production and enhances the viewing experience. Wireless enables the use of:

- Roving presenters and on-the-scene interviews;
- Mobile camera shots (tracking cyclists or providing the view from a racing car cockpit for example);
- Camera positions that would otherwise be impractical (due to the path or length of cabling required).

In addition, it can increase productivity through a reduction in set up time, such as rigging wired equipment, and minimises hazards associated with cable runs in public places.

For small events, wireless links are often the only means available for connection back to the studio. Satellite links can, and are, used as an alternative but can be expensive for long duration events. Fibre and wired links are installed for larger events, such as the Open Golf tournament.

2.2.3 Studio based programme making

Although production in a TV studio takes place at the same location, radio microphones, talkback and, to a lesser extent, wireless cameras are widely used. Because the studios are in regular use, frequencies will often be licensed on a long term basis and at a low power commensurate with the short distances involved. Large studio complexes are some of the biggest users of radio microphones and some use shielded buildings in order to maximise the number of frequencies available to them.

In addition, in-ear monitors (IEMs) may be used by some performers. IEMs are used by performers to monitor an audio stream, often their own voice or instrument. Because of their higher audio quality, IEMs are also used by presenters and others as an alternative to talkback, and IEMs are increasingly being seen in studios. As with radio microphones, they are restricted to low transmit powers and short distance operation.

Studio based programmes can also include an element of outdoor work and this gives rise to requirements similar to those of newsgathering. Thus this category of use also includes higher power talkback and programme links.

Studios are operated by both broadcasters and independent production companies. Video production companies and, to a lesser extent, film studios also make use of radio microphones, wireless cameras and talkback.

The advantages of wireless

The main drivers for the use of wireless devices in a studio are:

- Flexibility – it allows greater freedom of movement to presenters, actors and participants;
- Productivity – radio microphones reduce the need for boom microphones and therefore for boom operators, and enable faster set up between different scenes. The instant

communication with production staff possible with talkback can enable further productivity gains;

- Safety – with fewer cables required, health and safety issues are simplified.

Hence, we can summarise the key characteristics of studio based programming as:

- Used by commercial and public broadcasters, by independent TV, sound and video production companies;
- Usage can be indoors or outdoors;
- Use can be for both live and pre-recorded productions;
- Assignments are a mix of long and short term but typically restricted to specific sites, and demand is predictable;
- The larger studio operators are able to plan their use of frequencies, within a set of frequencies assigned by JFMG.

2.2.4 Local entertainment and events

This category covers theatres, concerts, touring shows, and public and private events which use PMSE radio frequencies, but excludes events whose output is for use within the community.

Theatres are the largest group within this category both in terms of the number of licensees and the amount of spectrum used. In a typical theatre production radio microphones will be used to pick up the performers' voices, and talkback will be used for communication and coordination between production staff. In addition, in-ear monitors may be used by some of the performers. By way of an example, performers in a rock band would use IEMs to listen to a specific subset of the instruments (often their own) being played.

Theatres and rock concerts can use a large number of radio microphones and IEMs each of which requires a separate frequency. Because the equipment is operated in close proximity, careful planning of the assignments is needed to avoid mutual interference. This is carried out by JFMG in conjunction with either the equipment provider or the end user.

Many of the other events falling into this category will be small and use just one or a small number of radio microphones. Some events, particularly outdoor events, will use audio or video links to loudspeakers or video displays.

Events within this category will be scheduled in advance and PMSE licences are therefore issued for the duration and location of the event. The duration can be short (a school sports day for example) or long (such as a long running theatre production).

Touring shows present an additional challenge. These shows have the same requirement for wireless at each venue on the tour but the frequencies available, particularly for radio microphones and IEMs, will vary with location, and so equipment used at one venue will not necessarily be retunable to suit. For small events, the same radio microphones can be operated on a limited set of frequencies available across the UK[9]. A number of these frequencies are operated on a shared basis and with these there is no guarantee that

[9] These frequencies in Band III and in the UHF TV bands IV & V are available across the whole of the UK for indoor and outdoor use with the exception of some frequencies which are not available in Northern Ireland. Both exclusive and shared frequencies are available, see Chapter 3 for a discussion of available spectrum and shared licences. The frequencies are shared by all appropriately licensed users thus there is some risk that a user will suffer interference from another user. However, it will often be possible to switch to another clear frequency.

another user will not occupy the same frequency and cause interference. Professional users prefer to use frequencies that they are confident will be reserved for their exclusive use during the performance.

Larger shows will anyway need more frequencies than can be made available in this way. Many users therefore need to use different frequencies[10] in different parts of the UK, and need to apply for different licenses in each venue included in the tour.

Hence, we can summarise the key characteristics of the category Local entertainment and events as:

- This category encompasses a broad range of activities including theatres (which is the predominant user of spectrum in this category), concerts, business events, charity shows etc. Within this use, we have also included events organised by local councils, governmental organisations and businesses and other small scale (commercial) users;
- Users are typically commercial but comparatively more cost conscious than previous categories;
- Typical usage is indoor with a mix of long and short term assignments;
- Almost all usage is localised to specific sites;
- Demand is predictable.

The advantages of wireless

The benefits of using wireless at events in this category are essentially the same as for studio based production, namely greater flexibility in production, reduced health and safety issues, and increased productivity. The format of some of the large modern musical shows would simply not be possible without the use of radio microphones and IEMs.

2.2.5 Community uses

This category covers all events whose end product is for use within the community. This is the most diverse category considered. Typical examples include the use of radio microphones within places of worship, educational institutes, and amateur dramatics. Hospital radios use audio links to transmit the hospital radio programme between buildings within a single hospital, or between hospitals sharing the same hospital radio[11].

Typically, events within this category will be small in scale and the majority will use only radio microphones. The events will also often be indoors or well separated from other PMSE licensees. The use of shared radio microphone frequencies is therefore often appropriate for these events.

Hence, we can summarise the key characteristics of community use as:

- The scale of use is likely to be small (i.e. only a few wireless devices deployed);
- Almost all usage is localised and largely indoors;
- Demand is predictable;
- There is a mix of long and short term assignments;
- Users are typically non-commercial and highly cost conscious;

[10] Modern radio microphones are retunable over a wide frequency range so different equipments are not always required for each venue although different licences will be.

[11] Note that, despite their name, hospital radios usually do not broadcast directly to patients using radio. The programme is distributed within a hospital building by wire.

- Typically events are planned and run by non-professional users.

The advantages of wireless

The benefits of using wireless at events in this category are similar to the above, with the exception being that community users do not typically sell their output but provide services directly to their "audience" (unlike, say, a TV production company). These community users benefit from greater flexibility, and users have cited the presentation benefits of wireless delivery (for example a religious service can be spoken gently but amplified to be heard at all parts of the location of worship). Productivity benefits are a lower priority for these users, since they are not profit driven.

2.3 PMSE applications

From the foregoing it can be seen that four underlying types of wireless use are made of PMSE spectrum. These are reflected, as the "equipment type" in JFMG licences and are pertinent to some of the later analysis where we refer to them as PMSE applications. We therefore summarise them here.

Radio microphones and In-ear monitors

Radio microphones are either handheld or body worn. They transmit high quality audio to a nearby receiver and operate at low transmit powers of 10 to 50mW.

In-ear monitors are body worn miniature receivers with earpieces used for personal monitoring of a sound track. The associated transmitters are restricted to the same power levels as radio microphones. In some cases they are used instead of talkback.

Radio microphones and in-ear monitors are both classified as equipment type radio microphones within the JFMG licensing process.

Programme links

Programme links are point to point[12] links that carry either audio or video signals. They may be used within the locale of an event (e.g. to carry a presenter's audio signal back to an OB vehicle) or to carry signals over longer distances from an event back to a studio or suitable receiving point.

Programme links can be portable (carried by a person) or mobile (carried on a vehicle) or airborne (carried in an aircraft).

Note that radio microphones operating above 50mW are classified as audio links, and that all wireless cameras are also classified as video links.

Talkback

Talkback refers to any voice communication used to relay instructions amongst those involved in the production of programme material or an event. It can be one-way or two-way, and may be restricted to the site of an event or it can provide a communications link between an OB activity and a studio.

Data links

Data links are point to point links used to control any equipment related to programme making and special event activities. They are frequently used to give remote control of wireless cameras, and typically operate within the area of an event.

[12] Note although the communication is point to point, directional or non-directional antenna may be used depending upon the circumstances.

3 PMSE SPECTRUM AND LICENSING

The purpose of this chapter is to provide an overview of the spectrum used for PMSE, its licensing, and trends in the level of PMSE activity. A comprehensive survey of current PMSE spectrum, restrictions on its use, and potential future changes are presented in Annex C.

3.1 PMSE spectrum

The spectrum normally available to JFMG for assignment for PMSE activities is spread over a total of 19[13] different bands. The approximate[14] bandwidth available in each band is illustrated in Figure 3.1.

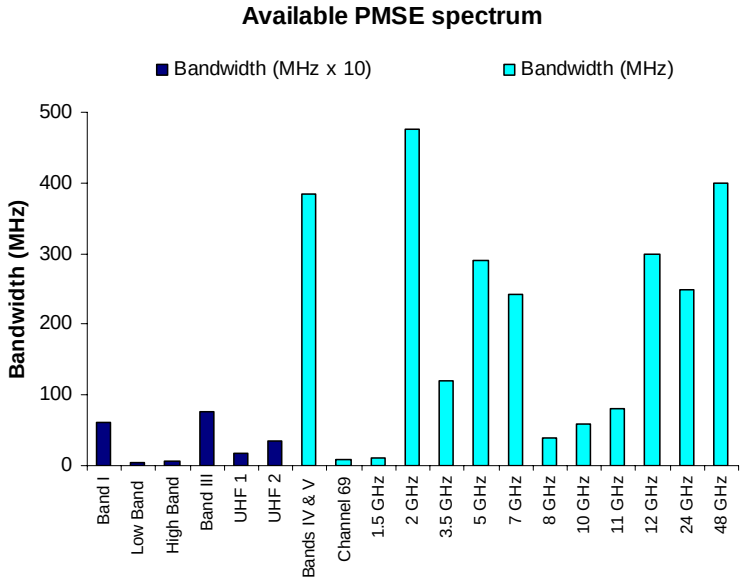

Figure 3.1: Spectrum available for assignment to PMSE activities. Note that the bandwidth shown is expanded by 10 for bands up to UHF 2.

The frequencies below Bands IV & V are generally used for talkback and audio programme links whilst those at and above 2GHz are used for video programme links and wireless cameras. The band at 1.5GHz is used for digital audio programme links. The UHF TV bands, Bands IV & V and TV Channel 69[15], are used very largely for radio microphones, with some radio microphone usage in Band III as well. The distribution of PMSE applications across the bands is illustrated in Figure 3.2.

[13] The band 1785 to 1800MHz has been available for digital radio microphones for some years but has remained unused. It is now expected to be released on to the market and has therefore been excluded in this analysis.

[14] In reality the actual bandwidth available varies on a regional basis. These figures identify the general spectrum available. Actual regional variation is taken into account in our detailed modelling of supply and demand.

[15] Channel 69 is treated separately from the remainder of the UHF TV spectrum because no TV broadcasting takes place within this channel in the UK and the conditions under which PMSE operations takes place are, as a result, significantly different to those in the remainder of the TV spectrum.

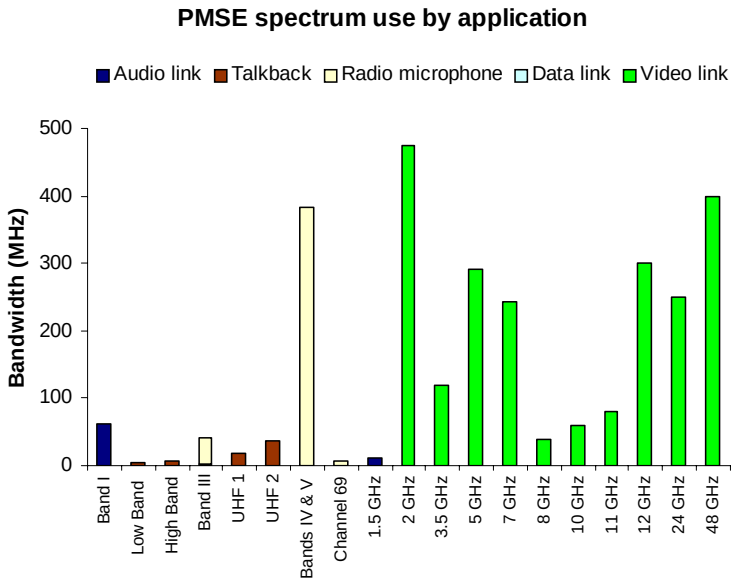

Figure 3.2: The distribution of PMSE applications across the different PMSE bands. Note that only the major application is shown for each band and that wireless cameras are included under Video links. The bandwidth scale is the same as for Figure 3.1.

The itinerant and temporary nature of many PMSE activities means that it has often been possible to share spectrum with other users, particular with the Ministry of Defence and with TV use in Bands IV & V. In the case of MOD spectrum, sharing is on a geographic basis and the exclusion zones have been designed so that relatively high power PMSE equipment (typically up to 25W) can be used in the permitted areas. As a general rule, restrictions apply more to the rural than to metropolitan areas.

Bands IV & V are used for terrestrial TV transmissions and operation in these bands has to ensure that PMSE activities do not cause interference to domestic TV receivers. As a result PMSE activity here is very largely limited to very low power equipment, typically radio microphones transmitting at 50mW or less. In addition, the frequencies used have to be carefully managed to avoid interference in the frequencies used for TV broadcasting in the locality. In areas where relay stations are used to enhance TV reception, the areas over which a particular set of frequencies are usable can be as small as a few square kilometres. JFMG uses a detailed database to ensure that frequencies are only assigned where they can be used without risk of interference.

Channel 69 is the upper TV Channel within Bands IV & V but is not used for TV transmissions in the UK. As a result its use is not restricted geographically and it is used extensively for radio microphones, particularly by those who need UK-wide operation. For this reason it is shown separately from Bands IV & V in the figures here.

The two bands at 11 and 12GHz use the same bands as some direct broadcasting satellites. Although not used for these services at present in the UK, transmit power limits apply to protect such services in continental Europe. Figure 3.3 shows which of the frequency bands are available for PMSE use on a shared basis. Note that where use is shared with other users, PMSE use is usually on a secondary basis[16].

[16] This means that PMSE usage must not cause interference to the primary user and that the PMSE users must be prepared to accept interference from the primary user. In practice, the coordination is such that this sort of interference is rare. In the UHF 1 band, where the MOD is the primary user the MOD has nevertheless guaranteed not to cause interference to assignments.

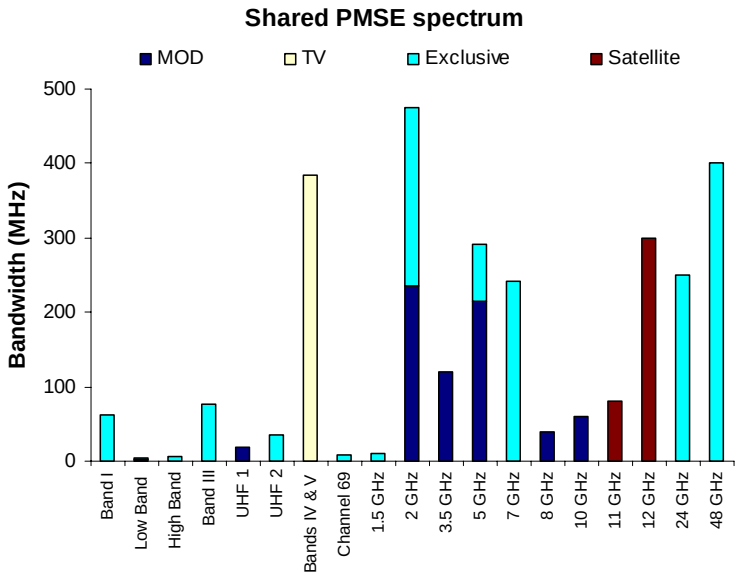

Figure 3.3: Bands shared with the Ministry of Defence or with terrestrial TV transmissions are shown. The remainder of the spectrum is used exclusively by PMSE users although account has to be taken of satellite services operating in continental Europe in the 11 and 12GHz bands. The bandwidth scale is the same as in Figure 3.1.

3.1.1 Other spectrum

Spectrum is available to PMSE users from two other sources. Firstly, in situations where the normal spectrum is insufficient, as can be the case at the largest outside broadcast events such as the Open Golf Championship, JFMG may temporarily be granted use of other spectrum. Such access is agreed through Ofcom (an indication of the level of usage is given in Figure 3.5).

Secondly, PMSE users can of course make use of the licence exempt frequencies. Some data links make use of the 2.4GHz band, and wireless video cameras can operate in either the 2.4 or 5.8GHz bands. DECT and PMR446 can be used for on-site voice communication, and there is some use of both for talkback. In addition, there are licence exempt bands for radio microphones at 173.7 – 175.1MHz and 862 – 865MHz, and for wireless video cameras at 1.394GHz.

3.2 Licensing use of PMSE spectrum

Co-ordinated assignment is required to protect primary users with whom PMSE users share spectrum and to help avoid interference from other users of PMSE equipment. The area over which some frequencies are available for use for PMSE activities (particularly in UHF Bands IV and V) can be as small as a few square kilometres, and vary according to the characteristics of equipment being used. Particular care has to be taken to ensure that only compatible assignments are made and JFMG makes use of a detailed geographical database for this purpose.

It is worth noting that in the case of radio microphones, a hire company may take out licences. Equipment can then be hired to individual users without the end user being required to obtain a licence although they must, of course, operate within the licence conditions.

The process of licensing PMSE users has to be, and is, sufficiently flexible to accommodate the variety of applications and situations encompassed by PMSE activities. Users may require frequencies for use indoors or out, at a fixed location or over a wide area (including national operations) and for periods of between 2 days and 1 year. Any of these attributes may change from day to day, or from one event to the next.

PMSE users can have equipment that may be co-ordinated with other users (using a standard licence), shared with other users (using a shared licence) or operate on a license-exempt basis. These are discussed below.

3.2.1 Standard Licences

The majority of assignments are made on a coordinated basis, that is JFMG select the frequency and operational parameters to ensure that the user will not cause, or suffer from, harmful interference. For these the user requires a Standard Licence which comes in 3 main parts:

- The Licence – which contains general licensing terms and conditions;
- Schedule One – which describes the terms and conditions of the spectrum use listed in Schedule Two;
- Schedule Two – which details characteristics of spectrum assignment (such as frequencies and bandwidth used, with technical characteristics, location or area of operation, times and dates, etc.).

To accommodate changes to any attributes in Schedule Two, including licensing of equipment for use at another event, JFMG issues a Notice of Variation (NoV) which identifies attributes of these new assignments.

The Licence lasts for a period of one or two years, but specific assignments are only available for use for the time period identified in Schedule Two or the NoV. Assignment durations are for up to one year, but the duration will typically vary according to the nature of use. Up to 48 hour licences are used for temporary assignments, or multiples of them, for long term outdoor, high power assignments. Fixed site licences are typically for long term, indoor, low power assignments. Therefore, in our analysis of spectrum use, we have used assignment data as the basis for determining demand for use of spectrum, since the number of licences has little relation to the demand for spectrum use.

Exceptions to these general conditions exist; for example, nationwide coverage of high power links is assigned annually to facilitate newsgathering. Also multiple frequencies can be assigned for use within a given TV channel (e.g. a long term block booking), even though all of the frequencies assigned cannot be used simultaneously. This provides operational flexibility and allows a user to choose compatible subsets of the assigned channels for use within a specific TV channel. In our analysis we treat area-based assignments differently from local assignments, and take account of block-booking effects to reduce the possibility of overstating demand for spectrum.

3.2.2 Shared licences

Because radio microphones operate at very low transmit powers they only interfere with each other when in close proximity. Many smaller users will use only one or two equipments, and are unlikely to find themselves operating close to another user. For these

users coordination is often unnecessary and JFMG has therefore designated 15 specific frequencies for shared use within Band III and 14 within Channel 69[17].

Shared licences have a duration of either one or two years and permit licence holders to use any number of radio microphones on any of the shared frequencies at any time and anywhere within the UK. Shared use provides the user with considerable flexibility but runs the risk that two users in close proximity may operate on the same frequency and cause each other interference. At larger events co-ordinated use is preferred by professional users either because the probability of such interference increases, or because their demand is greater than the small number of shared channels that can be used.

3.2.3 Licence exempt use

Licences are not required to operate radio microphones in a small range of frequencies in both VHF and UHF frequency bands. The UHF spectrum is in a 1.8MHz band in channel 70, which is not used for TV broadcasting in the UK and whose use will not be affected by digital switchover. As with the shared spectrum for radio microphones, this licence-exempt spectrum is available nationally, and users can be subject to interference from other users.

3.2.4 The level of activity within PMSE spectrum

Figure 3.4 shows the level of licensing activity by JFMG over last two complete years[18]. Licences for shared frequencies are shown for VHF frequencies (Band III) and UHF frequencies (Channel 69). All other frequency assignments are made under standard licences. It shows a small rise in the number of standard licences and a small fall in the number of shared licences.

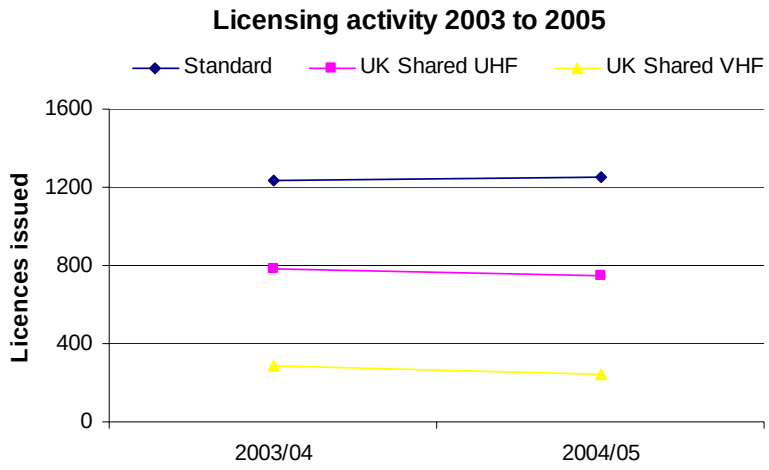

Figure 3.4: Licences issued during 2003/04 and 2004/05. Note that shared licences may be issued for one or two years. (These data were extracted from the Ofcom record of PMSE licences issued.)

These licensing statistics do not provide a reliable means of determining how heavily PMSE spectrum is used: Firstly, shared licences permit the licensed user to operate any number

[17] A number of other frequencies within Channel 69 are retained for coordinated assignments. Note, separate licences are issued for the shared frequencies in Band III and in TV Channel 69 (VHF and UHF shared licences respectively).
[18] JFMG's year runs from April 1st to March 31st.

of devices (i.e. radio microphones) and secondly, by means of a notice of variation, multiple assignments can be made under a single licence to the same user during the year. However, each time a frequency is assigned for use by a specific user, for a specific period, in a specific area it is registered as a separate assignment. Thus the number of assignments and the number of days for which they are active gives a better though still incomplete measure of spectrum usage[19].

Figure 3.5 gives the average number of assignment days per month (that is the number of assignments times the number of days for which they were active during the month). The historical records for Band III and for Channel 69 include an allowance for shared usage of radio microphones which is large and uncertain[20]. The associated activity has therefore been separated out. The results suggest that the overall level of activity in the PMSE spectrum excluding Band III and Channel 69 has risen slightly over the last few years. Channel 69 shows a significant increase and Band III a small increase. It is also notable that the number of assignments within Channel 69 is comparable with the total number across all other PMSE bands.

Also shown in this figure is the average number of assignment days per month which used frequencies outside the normal PMSE bands. The number is seen to be small relative to the use of regular PMSE spectrum although of course such assignments can be important to the provision of PMSE services at large events.

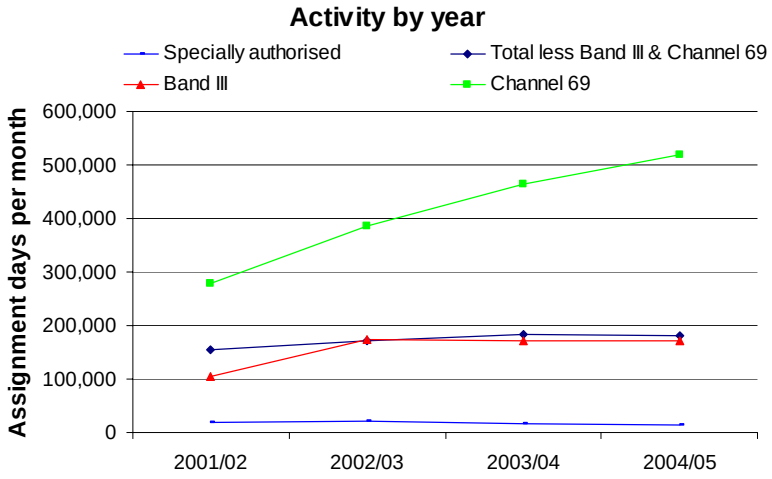

Figure 3.5: The average number of assignments days per month is shown for the four years 2001 to 2005. Specially authorised assignments refer to the use of frequencies outside of the normal PMSE bands and the level of activity has been multiplied by 100 for display purposes. (Figures extracted from the Ofcom record of PMSE spectrum usage.)

[19] The number of assignments times the number of days of use provides as indication of how heavily spectrum is used over a period of time. However, because the same frequency can be assigned multiple times in different locations, it is does not reveal how much spectrum is used at any one location and therefore it does not provide a measure of what proportion of the spectrum is actually used. The analysis of the balance of supply and demand for PMSE spectrum given later in this report addresses this issue by considering the use of spectrum by both time and location.

[20] This allowance assumes that each shared licence is equivalent to 15 / 14 assignments active for 365 days per year in Band III / Channel 69 respectively.

4 PMSE USERS AND USAGE OF SPECTRUM

The objective of this chapter is to provide insight into the users of PMSE spectrum and the characteristics of their usage of the spectrum. We therefore identify the number of users as well as the largest users, and present a quantified analysis of spectrum usage. Greater detail is provided in Annexes A and B. Whilst this chapter provides an overview of PMSE users and usage, Chapter 9 provides an analysis focussed on users and usage within the UHF TV bands.

The analysis is based on JFMG's database of frequency assignments for the 12 month period April 1st, 2004 to March 31st 2005. This database provides detailed information on every assignment made, including the user, the frequency, period and place of use, whether licensed for indoor or outdoor use, and the application (radio microphone, programme link, etc.). Note that the database only records successful applications and therefore only provides a measure of "realised" demand. We understand from JFMG that the number of applications that could not be accommodated is very small, amounting to a few tens of assignments at most out of a total of approximately 64,000. As previously noted, assignments to shared frequencies are not made and shared usage is not therefore included in any of the analysis given in this chapter.

In the following, PMSE use of the spectrum is defined in terms of *assignments, assignment days* and *occupancy*. These and other terms are defined in the adjacent text box. Note that although spectrum is available for PMSE use in the 24GHz band, no assignments were made here and it does not therefore appear in the following analysis.

Definition of terms

- *Assignments (also referred to as assignment requests or frequency assignments)*: each time an individual frequency is assigned to a user for a specific contiguous period of time, it is recorded in the JFMG database and referred to as an assignment. Note where a duplex channel is requested, two assignments are made (one for each of the two duplex frequencies). The number of assignments within a given area at any one time is a measure instantaneous demand;
- *Assignment days*: is the number of days within the financial year (April 1st 2004 to March 31st, 2005) for which an assignment was made. Assignment days therefore provide a measure of the amount of use made of the spectrum, or a particular part of the spectrum, by a user or group of users;
- *Long term assignments*: all assignments with a duration of greater than 300 days have been classified as long term (note: the analysis would have been substantially the same if we had used as few as 30 days as the cut off for the definition of long term);
- *Occupancy*: is the amount of spectrum (in MHz) assigned in a given area at a given time. It is obtained by summing the bandwidth of each different[21] frequency assignment;
- *Licences:* every user authorised by JFMG to use a PMSE frequency receives a licence. As noted earlier, a single licence may cover many frequency assignments, each being defined in a Notice of Variation.

The following analysis includes consideration of how spectrum usage is split between the different categories of use (as discussed in Chapter 2). It is important to note that some

[21] Where two or more assignments are made using the same frequency the corresponding users are in effect sharing the spectrum so the frequency is only counted once.

users span more than one category of use (e.g. broadcasters typically use spectrum for both newsgathering and studio programming). This categorisation was based on the primary business of the organisation listed as the license holder and on the purpose of the assignment as given in the database. The category "Others" encompasses the small number of organisations whose purpose was not identified.

4.1 Users of PMSE spectrum

During the year of interest 64,007 frequency assignments were made to over 1331 different users, with the users ranging from the major broadcasters to individual freelance sound engineers. The total usage of all PMSE spectrum, i.e. the total number of assignment days, was 3,224,025. As illustrated in Figure 4.1 the majority of spectrum usage is dominated by a relatively small number of large players with the largest 50 users (3.7% of the user base) contributing 50% of assignment days and 70% of assignments. The BBC alone accounts for almost 13% of total assignments and assignment days.

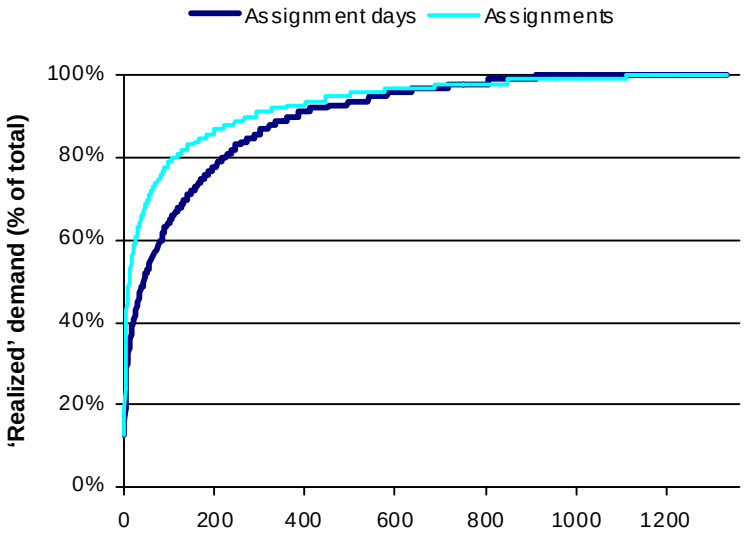

Figure 4.1: The cumulative sum of assignments and assignment days, as a percentage of the total, is plotted against the number of users ranked in order of size, showing that a small proportion of users account for the majority of use.

Table 4.1 gives the breakdown of activity between the different categories of use by both assignment days and assignments. The greatest use in terms of assignment days is not necessarily the same as the greatest use in terms of the number of assignments. For example, users operating at outside broadcasting events over the year will require different assignments to cover the different events but will only operate for a few days on each occasion resulting in many separate assignments but not many more assignment days. Conversely, a newsgathering organisation may use a small number of frequencies but they may be assigned on a yearly basis resulting in a large number of assignment days but a small number of assignments.

In the case of assignment days the largest category is Local entertainment and events (covering theatres, concerts, travelling shows and similar entertainment activities) followed by Studio based programme making. This reflects both the long term and static nature of their activities and the large amount of PMSE equipment that theatres and studios can require.

In terms of numbers of assignments, Outside broadcasts is the largest category even though its share of assignment days is very small. This reflects the itinerant nature of OB

operations and the need for new assignments at each event. The second largest category is Local entertainment and events and this reflects usage at travelling rock concerts, for example, which can use a large number of frequencies at each show but spend only a day or so at any one venue.

The split of PMSE activity between categories of use			
Category	Share of assignment days	Share of assignments	Percentage of users active in the category
Local entertainment and events	41%	32%	42%
Studio based programme making	30%	17%	25%
Newsgathering	15%	4%	4%
Community uses	9%	3%	24%
Outside broadcasts	4%	40%	10%
Other	2%	4%	12%

Table 4.1: The share of assignments and assignment days for each category of use. Note that the shares in the final column do not add to 100% because some users operate across more than one category.

4.1.1 The key users

The most significant user of PMSE spectrum is the BBC whether measured in terms of assignments or assignment days. The BBC excepted, the largest users in terms of assignment days are not necessarily the same as the largest users in terms of the number of assignments. Thus theatres and studios amongst the largest users in terms of assignment days, while outside broadcasting companies and equipment hirers amongst the largest users in terms of the number of assignments.

The largest users also differ between the different categories of use, and this is illustrated in Table 4.2.

The share of assignment days for the top 5 users in each category			
a) Local entertainment & events	22%	**b) Studio based programme making**	34%
c) Newsgathering	85%	**d) Community uses**	15%
e) Outside broadcasts	59%	**f) Other**	48%

Table 4.2: The total share in terms of spectrum usage (in assignment days) of the 5 largest users of PMSE spectrum are shown for each category of use.

It is noticeable that the share of assignment days contributed by the top five users varies significantly between the 6 categories. For example, the share of the top 5 users is close to 90% for Newsgathering. This, in part, is a reflection of the small number of users in this category (49) and the predominance of the BBC in this group. In contrast, the distribution is less skewed for Community uses and for Local entertainment and events, for which the combined shares of top 5 users are 15% and 22% respectively.

4.2 Characteristics of spectrum use

4.2.1 Wide area and local assignments

PMSE spectrum is used in two different ways. First, wide area assignments allow frequencies to be used across a defined geographic region. They are often long term assignments used for newsgathering or programme making. Second, local assignments are restricted to use in a specific location. They can be short term as for an OB event, or long term as for theatre or studio use. Thus spectrum usage across the country can be viewed as an underlying layer of wide area use, with peaks of localised use in specific locations. The amount of wide area and local spectrum assigned at any given location will depend both on the location and on time but two examples illustrate the situation.

In the first we consider the amount of spectrum assigned for use for use at Wimbledon during the tennis championships compared to the amount that is anyway assigned for use in the area on a wide area basis. In the second we consider the situation at St Andrews for the 2005 Open Golf Championship[22]. Note that here we are considering the total bandwidth of spectrum assigned[23]. As illustrated in Figure 4.2, large events such as these use approximately twice as much spectrum as is used locally for wide area assignments.

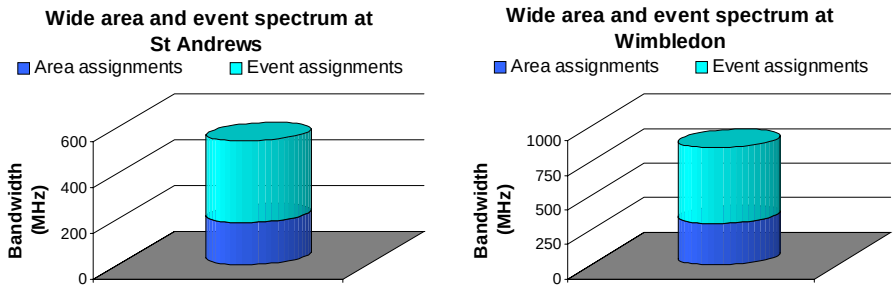

Figure 4.2: Comparison of the amount of spectrum (inMHz) assigned to the "event" and to wide area use at the Wimbledon tennis championship and at the Open Golf Championship.

Note, both of these are major events in the PMSE calendar and smaller events would be assigned less spectrum. Note, however, that the overall usage for wide area assignments amounts to only 8% of assignment days.

4.2.2 Variation with time and event

From the foregoing it is clear that spectrum occupancy is peaky in both time and location. Further evidence for this is given by the example in Figure 4.3 which shows how the numbers of frequencies in use within Cardiff varied during the 12 month period analysed here. The variation in the number of frequencies in use is distinct. Note, Cardiff provides a relatively simple example. A similar plot for the city of Manchester or London would show a more complex picture but with the same peaky characteristic.

[22] This event took place in July 2005 and so is not included in the 2004/05 database. However, JFMG provided a full list of assignments allowing this particular case to be analysed.

[23] Assignment days would not provide a true comparison given the short duration of event assignments. Comparing the number of assignments in each case would provide a better comparison but would ignore the bandwidth of the assignments made. Note, that this is the bandwidth occupied by the actual assignments, other spectrum precluded from use (due to intermodulation for example) has not been counted.

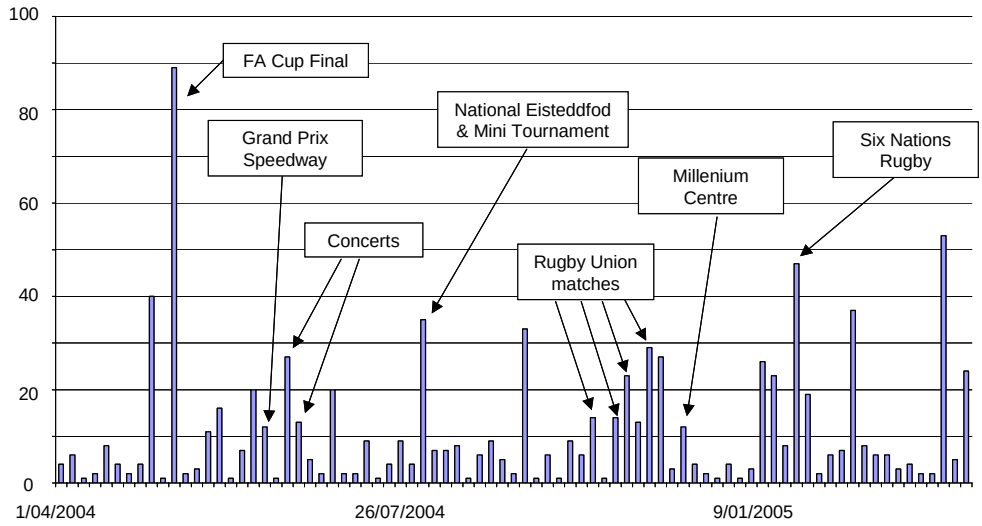

Figure 4.3: The number of active frequency assignments in Cardiff is shown across the 12 month period, 1st April 2004 to 31st March 2005. Some of the peaks were due to a single event, such as the FA Cup Final, others to a number of simultaneous events. Note that wide area and long term assignments have been excluded from this analysis.

We also expect different events to require more or fewer assignments depending upon their size and nature. The data in Figure 4.3 shows that the majority of events[24] use a small number of assignments, and that there are a relatively small number of large events. This is a general characteristic of PMSE usage as illustrated in Figure 4.4. These results show that approximately 64% of events require 5 or fewer assignments and that less than 1% use 50 or more assignments.

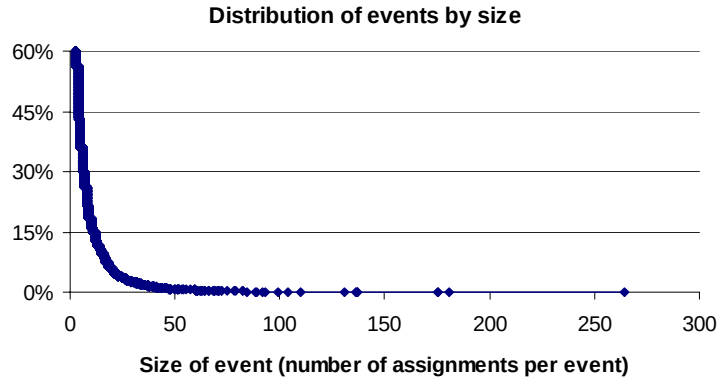

Figure 4.4: This plot shows the percentage of events that are larger than a given size (the x-axis) as determined by the number of frequencies assigned to the event. This analysis covered all site specific assignments during the year both indoor and outdoor.

Note that for the purposes of the analysis in Figure 4.4 an event is defined as a group of assignments used at the same location and finishing on the same date. Some large events may involve assignments at more than one location, and different PMSE users at the same

[24] By "event" here we mean any PMSE activity which takes place at the same location and over the same period of time. An event can be short term as in a sports event, or long term as in a theatrical production.

event sometimes cease their operations on different days. As a result, this analysis will under-estimate the number of large events by a small amount.

4.2.3 Geographic distribution

Many of the locations at which PMSE activities take place are situated within populated areas - sports stadiums, theatres, studios, concert venues, and smaller users such as churches and schools, for example. A smaller number, such as motor racing and golf matches take place in more rural settings. This is reflected in the overall geographic distribution of PMSE activity as illustrated in Figure 4.5.

The distribution shows particular concentrations of activity in the major metropolitan areas such as London, Birmingham, Manchester, Liverpool, Bristol and Cardiff. Although this example is for PMSE activity within bands 100 and 470MHz, a similar distribution is seen for all the other bands although the overall density of usage varies (see Annex B). An analysis of assignments shows that more than 50% of usage (assignment days) takes place at less than 3% of locations reflecting continual or repeated use at the same locations.

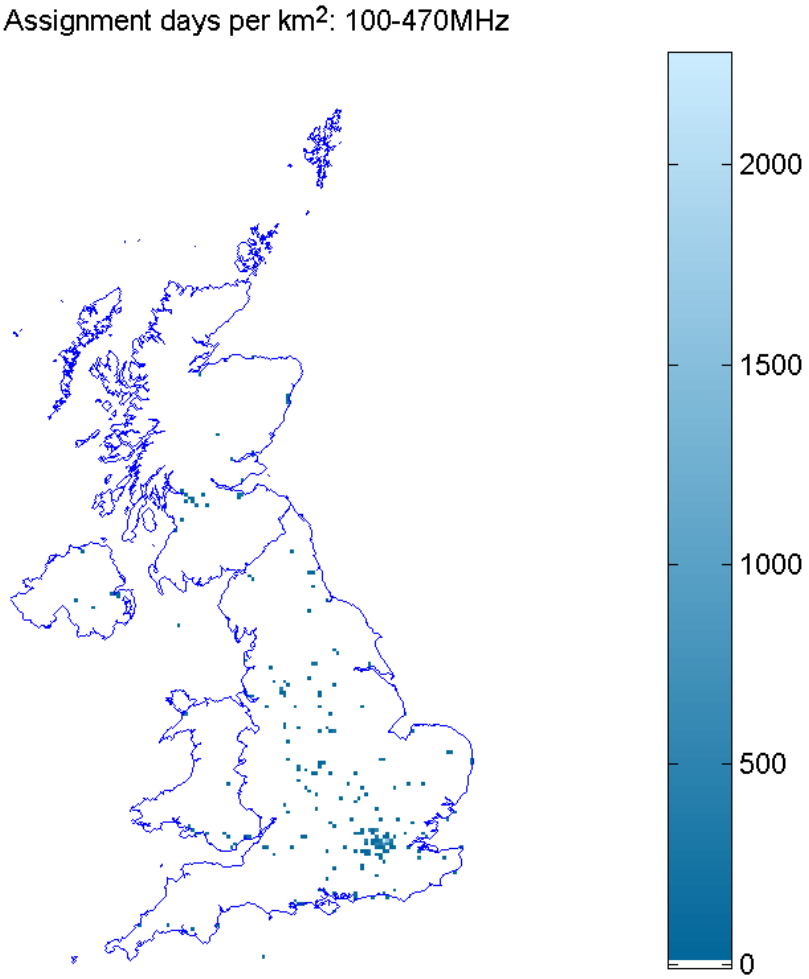

Figure 4.5: The density of frequency usage (in assignment days per km^2) for the frequency bands between 100 and 470MHz, summed over the period 1st April 2004 to 31st March 2005, is shown. Note that wide area assignments are not included.

Figure 4.5 also suggests that the number of locations at which PMSE activity takes place is relatively small. Analysis of the database shows that the number of locations at which PMSE activities take place is limited to less than 3000[25] physical locations. It also shows that this activity is concentrated within just a small proportion of these locations, with 38% of site specific assignments (corresponding to 53% of assignment days) occurring within the 100 busiest locations. The results are shown in Figure 4.6.

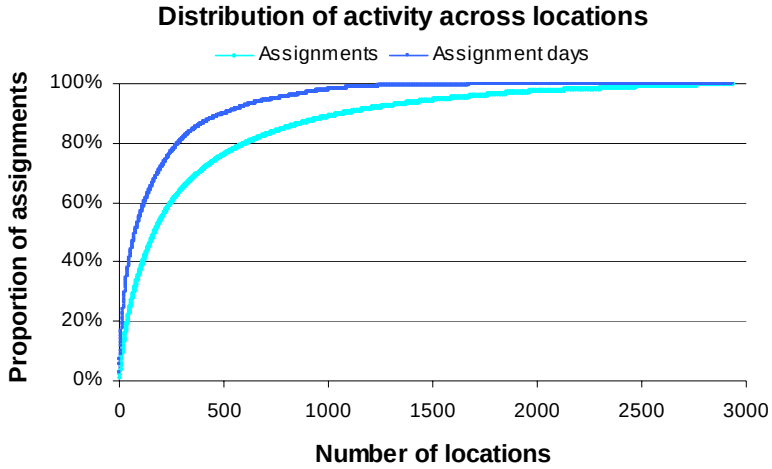

Figure 4.6: Plot of the cumulative sum of assignments and assignment days for locations ranked in order of size, showing that a large proportion of PMSE activity takes place at a small proportion of locations. Wide area assignments (which are not constrained to a specific location) are excluded from this analysis.

4.3 Spectrum usage

This section illustrates how spectrum usage varies between the different bands, between the different types of usage, and between the different categories of use.

Usage, in terms of assignment days, is shown below for each of the PMSE frequency bands.

[25] This analysis was based on the number of discrete national grid references contained within the database for assignments in the sample year. In fact the same event or physical location may be associated with more than one grid reference so this analysis may over-estimate the number of different locations at which PMSE events took place. In the more exhaustive analysis made of the supply and demand for spectrum made later in this report (see Chapter 7) the full list of PMSE locations recorded in the database was included, as was the interference effects associated with use being made at physically identical locations.

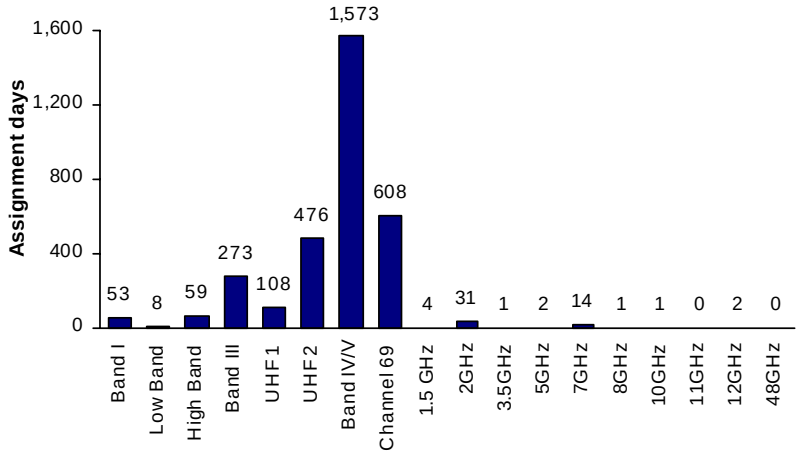

Figure 4.7: The usage per band - given in thousands of assignment days.

Greatest use is made of Bands IV and V which account for almost 50% of all assignment days. The single TV channel, Channel 69 alone accounts for approximately a further 20% of total usage. The main application within these bands (see Figure 4.8 below) is radio microphones. All user categories license spectrum in Bands IV and V but large broadcasters, studios and theatres account for three-quarters of all assignment days.

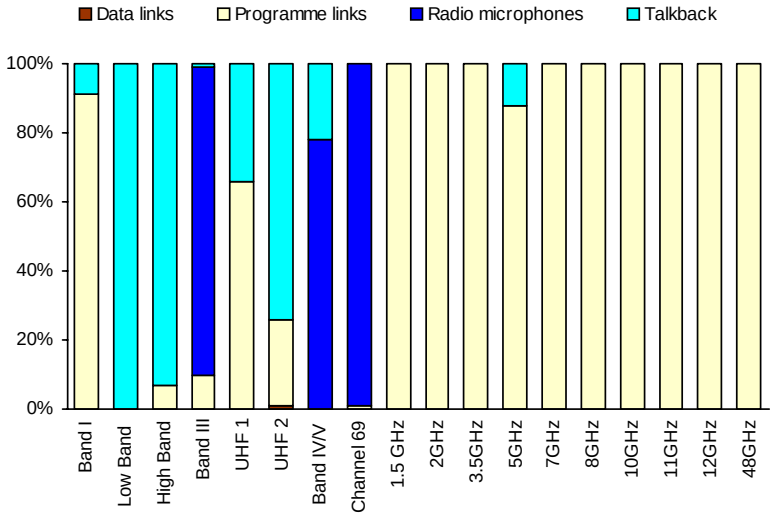

Figure 4.8: The proportion of usage (assignment days) by application within each band.

The bulk of the remaining usage is in the lower bands (below Bands IV and V) where the primary applications are talkback and audio links. The exception is Band III in which there is significant radio microphone usage (see Figure 4.8). These lower bands are used primarily by radio broadcasters including newsgathering, and radio services in hospitals.

Above 1.5GHz, spectrum is assigned less frequently and accounts for less than 1.5% of all assigned days. Applications in this spectrum are wireless cameras and video links which are generally used by only the largest corporations (for newsgathering and outside broadcasts). The 1.5GHz band is used for audio links (part of the band being reserved for digital links) but usage is very low. The overall proportions of usage (in assignment days) for each of the four applications are illustrated below in Figure 4.9.

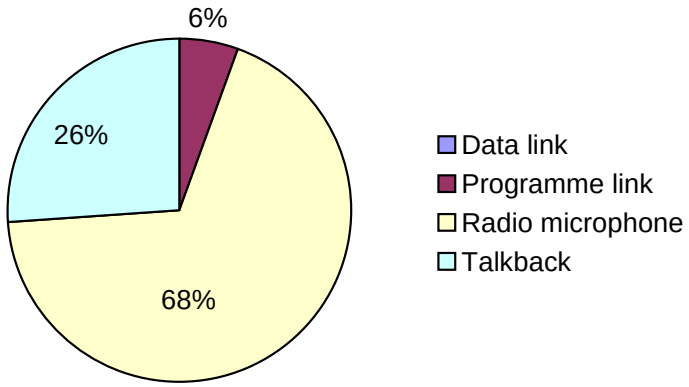

Figure 4.9: The overall split of usage (in assignment days) between the four applications. Note that radio microphones includes IEMs, and programme links covers audio and video links and wireless cameras. The usage of data links amounts to 0.1% of the total.

4.3.1 Short term and long term usage

The split between long and short term usage (assignment days) by band is illustrated below in Figure 4.10.

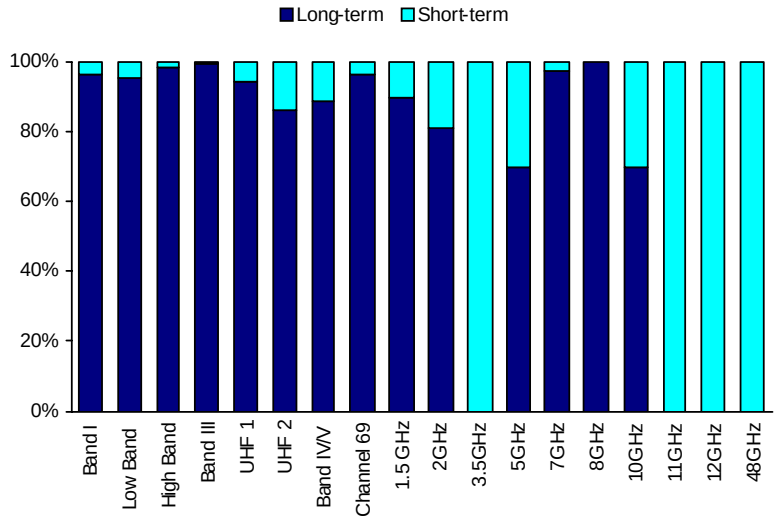

Figure 4.10: The split of usage (in assignment days) between short and long term assignments by frequency band.

91% of all assignment days are accounted for by long term assignments although the proportion of assignment requests for long term assignments is only 25%. This reflects the fact that assignments are generally for either less than 10 days or for close to a year[26]. This in turn reflects the fact that news gatherers, studios and theatres are large users of spectrum and typically make daily use of their frequencies. Short term assignments are typically used at outside broadcasts and similar temporary events. The split between long and short term assignments by band is illustrated below.

[26] Although long term assignments have to be renewed each year, they can run for several years.

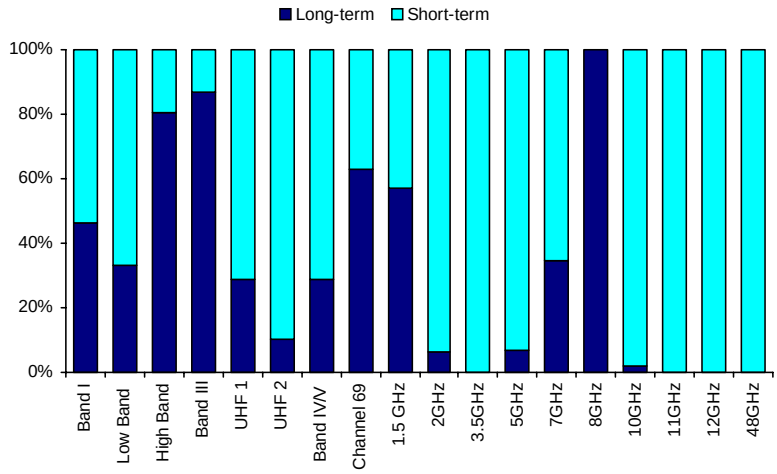

Figure 4.11: The split in the number of assignments between short and long term assignments by frequency band.

4.3.2 Usage by situation

The situation within which wireless is used affects the area over which co-channel usage has to be avoided to prevent interference. Equipment operated indoors is shielded by the building (and is generally for short range, low power use) allowing co-channel frequencies to be re-used relatively close by. Equipment used outdoors requires a greater separation to avoid interference, and airborne equipment needs significantly greater separation. Thus the situation of use affects the extent to which frequencies can be used at the same time within, for example, London. Approximately 20% of total usage is outdoors and 79% indoors. Airborne usage is small, amounting to less than 1% of total assignment days.

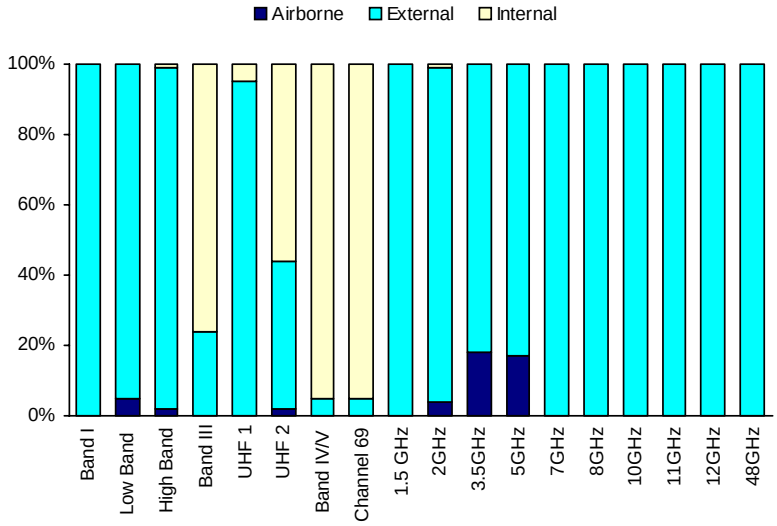

Figure 4.12: The proportions of usage (assignment days) for internal (indoor), external (outdoor) and airborne use are shown for each band.

Figure 4.12 shows how indoor, outdoor and airborne usage splits within each band. Internal use dominates in Bands III, IV and V, where radio microphone use is the dominant application and in the UHF 2 band where the major indoor application is talkback.

4.3.3 Usage by category of use

The following three figures show how usage is split between the categories of use for each of the applications, for each frequency band, and for short and long term assignments.

The first figure shows that radio microphone usage dominates in Community uses, Local entertainment and events, and in Other. Usage is more evenly divided between radio microphones, talkback and programme links for the other categories, Newsgathering, Outside broadcasts and Studio based programme making. Data links only constitute a significant proportion of usage in Outside broadcasts.

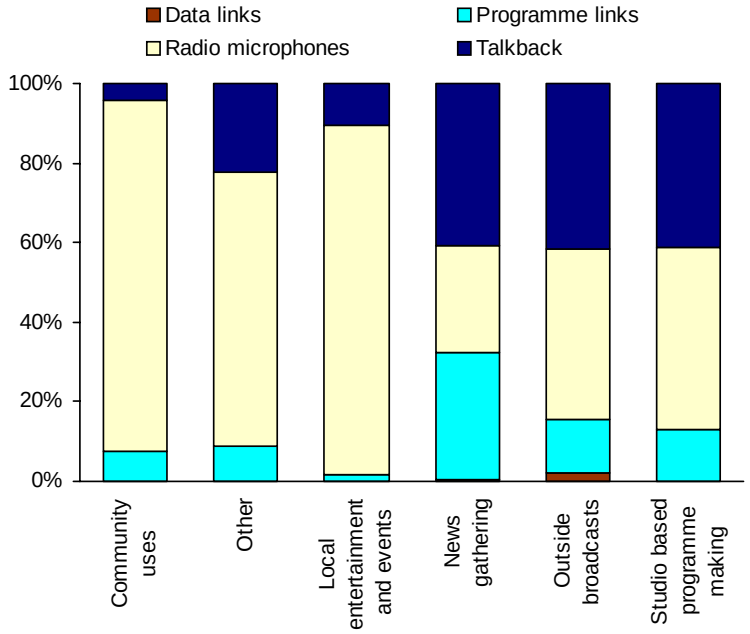

Figure 4.13: The proportion of usage (in assignment days) accounted for by each application is shown for each category of use.

Figure 4.14 shows the relative usage by each category for each frequency band. It shows that:

- Community usage is largely confined to Band III and Channel 69 for radio microphones, and to Band I for programme links used by hospital radios;
- Local entertainment and events usage is greatest in Band III, UHF 2, Bands IV & V, and in Channel 69 reflecting the major use of radio microphones and talkback within this category;
- Usage for Outside broadcasts is found in most bands and dominates usage in the 3.5GHz band;
- Newsgathering and Studio based programme making operate across all except the highest frequency bands.

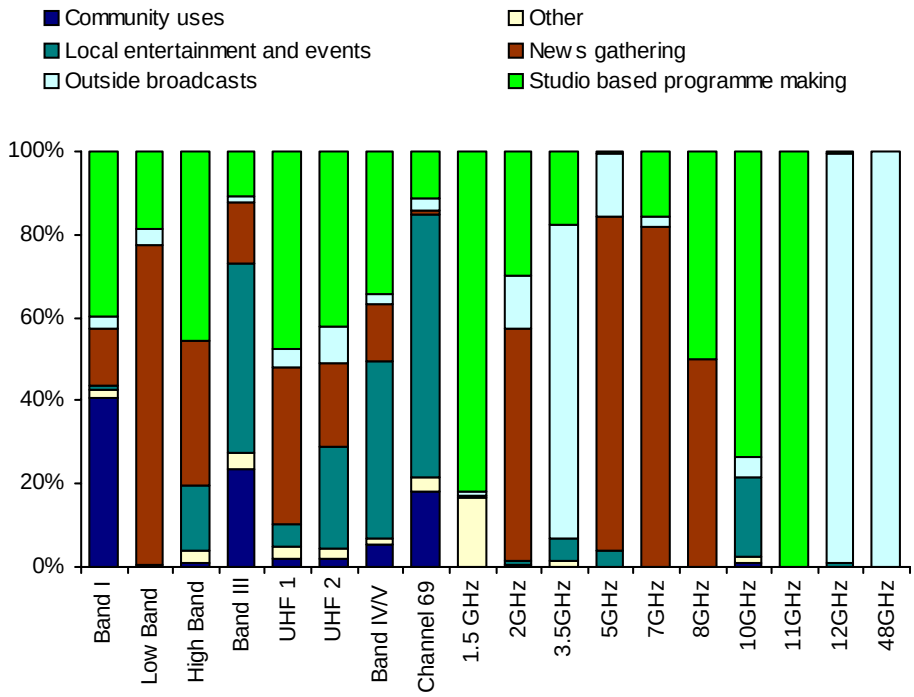

Figure 4.14: The proportion of usage (in assignment days) within each frequency band is split out by category of use.

Figure 4.15 illustrates the split between long and short term assignments for each category of use. Note that these results are given in terms of assignments rather than assignment days. Long term assignments make up the majority in the categories Community uses and Newsgathering, and short term assignments dominate in the case of Outside broadcasts. The Local entertainment and events and Studio based programme making categories have a mix of short and long term assignments.

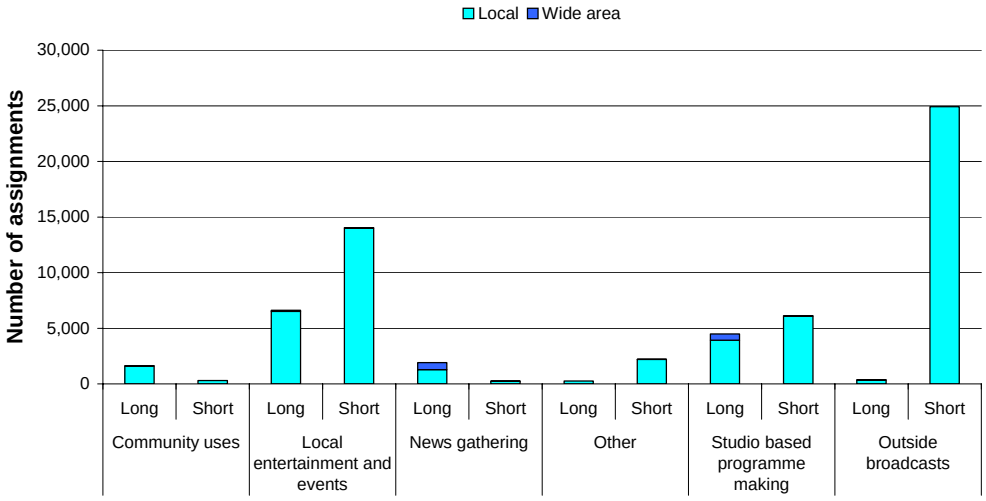

Figure 4.15: The number of short and long term assignments are split out by category of use. In each case the assignments are also split into local and wide area assignments.

This figure also differentiates between local and wide area assignments and shows that wide area assignments are a small proportion of the total (wide area assignments account for 2% of assignments and 8% of assignment days). It also shows that the majority of wide

area assignments are long term (some 97% in terms of assignments and 99% in terms of assignment days).

4.4 Conclusions

The key take-outs from this chapter are:

- Users
  - Usage is highly skewed towards large users. 80% of all assignment days are accounted for by approximately 20% of users. The BBC, the largest user, alone accounts for almost 13% of all assignment days. The top 50 users (3.7% of users) make up 50% of the assignment days; thereafter demand per user tails off sharply;
  - The top 10 users include television broadcasters, theatres and studios, and one radio broadcaster;
- Characteristics of spectrum use
  - Spectrum use can be divided into use that takes place over a geographic region and use that is confined to a specific location. The demand for location specific (local) assignments is highly variable: there are many small "events" and few large ones, the duration can be either short (~12 days) or long (of the order of 10 to 12 months);
  - In terms of assignment days, local assignments make up 92% of the total;
  - The greatest demand (in terms of assignments) occurs in the major metropolitan areas with 50% of assignment days occurring at less than 4% of locations;
- Spectrum usage
  - Bands IV & V and Channel 69 within the UHF TV band account for more than 70% of all assignment days illustrating the importance of these bands;
  - Radio microphones account for 64% of all assignment days (and 46% of all assignments);
  - Talkback is the application with the second highest demand – it accounts for 39% of all assignments and 25% of all assignment days. Hence almost 90% of all assignment days is accounted for by talkback and radio microphones;
  - While only a quarter of all licence requests were related to long term assignments, they amounted to over 90% of all assignment days;
  - Nearly 80% of use, as defined by assignment days, is internal. Less than 20% of use is external, with airborne use less than 1%.

5 THE VALUE CHAIN

The purpose of this chapter is to identify the contribution that spectrum makes to the value chain in some of the most high profile PMSE activities. Much of this analysis is based on our interviews with spectrum licensees and our previous experience in working in these sectors. Whilst we have identified the key activities and segments in the value chain for each product, quantifying the contribution of each activity and segment to the overall value is difficult. In our interviews with spectrum users, executives were usually unable or unwilling to talk about the specific financial contribution of different segments to the value chain. We have probed the relative value that PMSE spectrum brings and compared it with available literature on the sector.

5.1 The programme making value chain

It is important to note that spectrum is an input that plays a different role dependent on the nature of use - the more crucial its role in enabling the activity the more important is its role in the overall value chain for the business. For certain activities such as reality TV, there are no feasible alternatives to the use of spectrum. In others, such as coverage of sports like cricket, where for the most part cameras and commentators work from fixed positions, the quality and efficiency in delivering the output would not significantly reduce without the use of spectrum.

In the following sections, we consider the value chain using the segmentation by the category of use as defined in Chapter 2.

5.1.1 Newsgathering

Newsgathering is an essential part of public sector broadcasting – and is also seen as key to both commercial and dedicated news channels. Our interviews demonstrated that commercial broadcasters consider it essential that they be able to promote a brand providing all the key services including news to its consumers. For others, such as the BBC, it is part of their PSB remit.

Figure 5.1 below summarises the key elements involved in newsgathering.

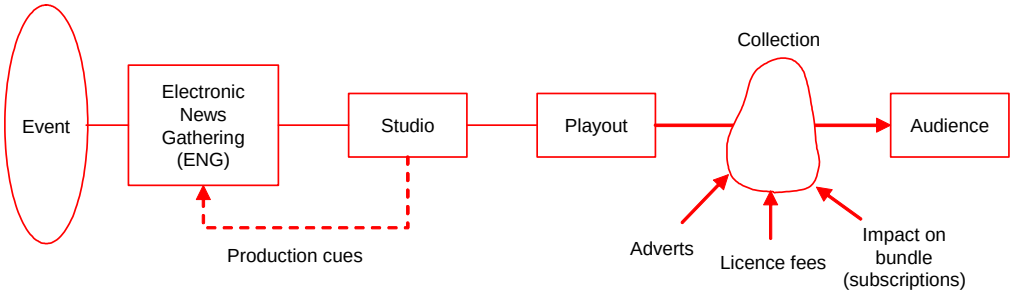

Figure 5.1: The process of newsgathering in broadcasting.

When discussing the value generated by PMSE spectrum in the newsgathering value chain, it is important to understand the mechanisms that news channels use to differentiate their product from the competition. These include, in decreasing order of importance:

- Ability to cover the most interesting and topical news stories and to be the first to present “breaking news”;
- Increasing the proportion of live coverage within the news programme;

- Quality of camera work and unique shots;
- Research into the news clip and the level of "in-depth analysis" around the clip;
- Visual appeal and clarity of speech of the presenter.

Please note that the above valuation is for typical news programmes. Obviously, as is common across the PMSE sector, there are exceptions. For example, programmes such as Newsnight place a greater value on the research and "in-depth analysis" elements.

Presentation value is also added in the studio through the newsreaders, sets, use of graphics and the quality of play-out. The general perception is that advertisements typically erode value from a news programme, though most news programmes (with the exception of the BBC) have some advertisements as an additional revenue source.

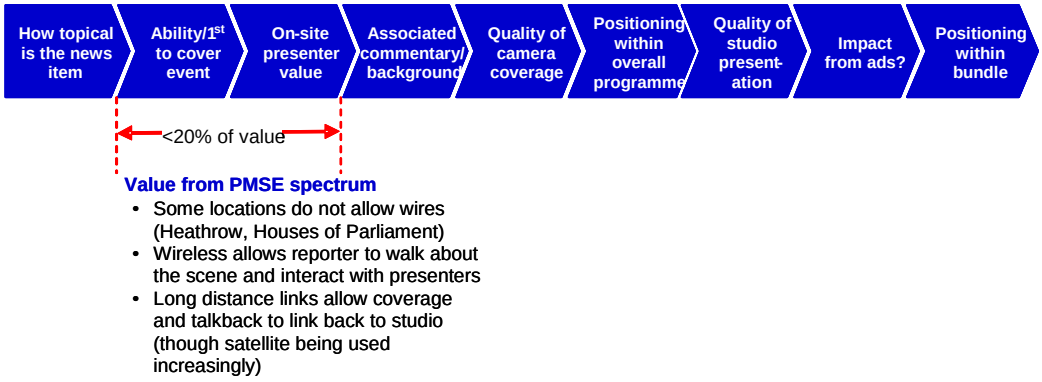

Figure 5.2: The newsgathering value chain and the key advantages facilitated through the use of PMSE wireless.

The main value brought to news programming by PMSE wireless production is the ability to cover a topical event live. As an example, the news broadcasting community point to the beneficial impact the 1991 Iraq War coverage had on the fortunes of CNN.

However, though access to spectrum is critical to news as it is produced today, there are alternatives to spectrum that would enable most news clips to be produced with a reduction mainly in the visual appeal of the programme. Nonetheless, the visual appeal is an important differentiator and news production teams give it considerable value.

There are exceptions to the above comment. It is important to note that there are locations where, without access to spectrum, the news clip cannot be produced. Examples include Westminster (where cables cannot be run through the barricaded windows) and Heathrow (where cables are not allowed for health and safety reasons). Thus naturally, the value of spectrum is enormously increased for news clips from these locations.

5.1.2 Outside Broadcasts

The major use within this category is for sports production including both major sports events, such as premiership football matches, The Open Golf Championship, and the British Grand Prix, and smaller events such as the Chelsea Flower Show.

A key difference from newsgathering is that the OB output is almost always "traded" with coverage rights sold - typically through auctions. The other difference is that assignments are usually short term and localised to the event location.

The typical value chain for sports is shown in the figure below.

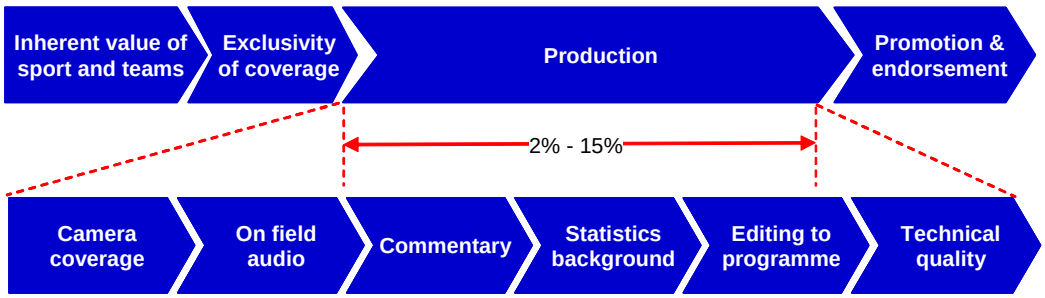

Figure 5.3: The sports production value chain.

Spectrum plays a role within the production element of the value chain - however, it is not the only element. In the value chain above, its role is mainly limited to camera coverage and on-field audio coverage. Production value is also generated by the quality of commentary and analysis, graphics and statistics, editing quality and the overall technical quality of the production (for example, colour balance between cameras).

The main value is in the content – the sport being covered and the teams involved. This value is apparent in the huge variations in auction fees paid, for example, by Sky for the premiership rights versus the coverage of less popular sports such as darts on the BBC.

The actual production of the coverage is a much smaller proportion of value. In a number of our interviews, we were told that viewers will continue to watch coverage even if the production quality goes down marginally. The fact that sports rights holders attribute a smaller value to production is also reflected in the cost pressures faced by the production teams on their budgets – with production typically amounting to a very small proportion of the auction value (for the more popular events like football and cricket).

However, even though production is only a small proportion of value, all sports producers want to be seen as being leading in terms of the quality of their production, especially when compared to the quality seen in other sports and other countries. We have received comments to this effect especially for sports where PMSE spectrum is considered most important (for example, motor racing and golf). However, it is not the most important differentiating character – camera coverage and commentary are considered more important differentiators.

The value of sports coverage is linked to viewing figures which are intrinsic to the sports itself. Quality of the coverage only affects audience figures at the margins since most sports programmes are broadcast exclusively by one broadcaster or another – hence sports fans will not have a choice of broadcaster to watch. Supplementary to the broadcast is the advertising and endorsement revenue and finally the coverage itself.

The role of spectrum for PMSE use in this value chain is restricted to production quality. Without radio cameras, for example, it would be impractical to cover certain signature camera shots in motor racing such as shots from the helmet of the driver or shots of the track from a helicopter or airship. In other sports such as cricket or badminton, while the event can be covered without radio cameras, there will be quality issues related to restriction of the mobility of commentators that may affect the value of the programme.

Given this variation, we present the value generated by sports production through two case studies; Formula One motor racing (F1), and premiership football. The case studies are summarised below.

Outside Broadcasting Supply Chain Case Study: F1 coverage

The host broadcaster undertakes production and transmission of differentiated television feeds of the races and qualifying sessions. This involves the use of footage from a large number of cameras located around the track – some static locations, some hand-held, plus in-car cameras, a rail camera in the pit lane, and cameras in helicopters positioned above the track.

Footage from these different cameras is edited into a race feed by the production teams situated in Outside Broadcast trucks located near to the track. This race feed is then distributed to the series broadcasters either in their home country via satellite, or passed directly to the broadcaster at the track if they have an OB unit present for their own commentary.

A significant amount of equipment is required to develop the race feed. This includes cameras and camera supports; OB trucks with on-board production, sound and vision equipment, wireless communication equipment, helicopters for relaying in-car images and overhead shots, transmission vans with satellite up-link, cables, portable studios for interviews, and power (primary and back-up generators).

Around 2 to 4 OB trucks are typically required at each race. A lead truck takes responsibility for the main free to air (FTA) live race feed. Two of the other trucks take control of a sub-section of the cameras, helping to produce and co-ordinate their feed. The other truck usually leads off the FTA feed and produces the extended feed for pay per view (PPV) viewers or international feed(s).

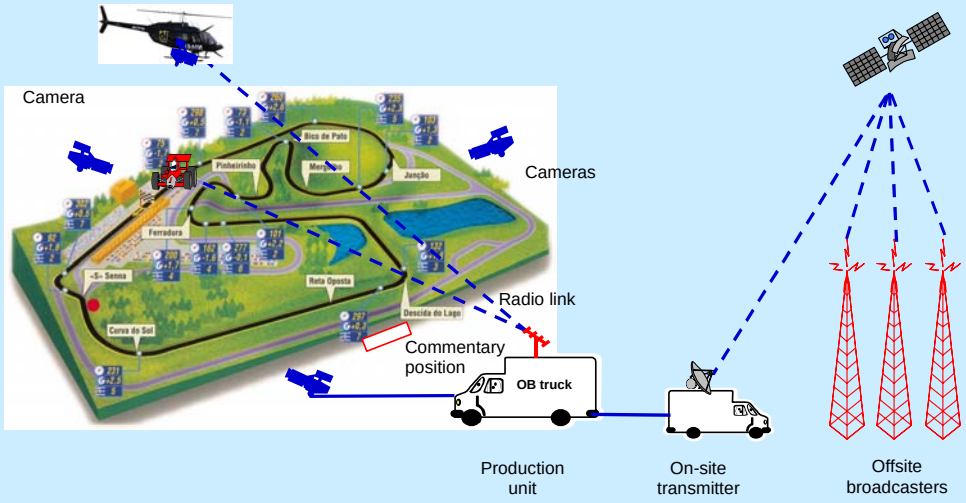

Figure 5.4: Overview of key steps in F1 outside broadcast programme production.

In addition, around 2 to 4 helicopters are required per race to carry cameras and relay footage from the in-car cameras. A large amount of wireless communications equipment is required to carry the signal from the cars to the helicopters, helicopters to the OB units and from the hand-held cameras. This equipment also requires PMSE radio frequency licenses.

The cabling required to link all the equipment together is also significant – typically many kilometres are needed.

The transmission of the race feeds is carried out at on-site OB vehicles with built in satellite up-links. The transmission itself is usually handled by one of the global satellite service

companies.

A large number of staff are required to man the cameras; direct, produce and edit the footage; handle the transmission and communications; and to set-up prior to race day. In total, over 200 staff are typically involved with each race. The main staff consist of cameramen and camera technicians; slow-mo camera operators; directors, assistant directors and switchers; sound engineers and assistants; chief technicians and assistants; vision engineers; staff to organise communications; people to rig up the cabling; and to set-up and man the transmission vans. In addition, producers are required to organise the process. The production unit will be responsible for adding graphics on to the race feed.

In terms of monetary value for the entire series:

- Typical auction value is about EUR500m[27] (this value is estimated, the actual numbers are not in the public domain)
- Production costs are approximately EUR50m for the series

Based on the F1 value chain case study, we note that whilst production costs are only about 10% of the value and spectrum is only one of many enablers for the production, the general consensus is that use of wireless here has far higher inherent value than for many other sports. One of the comments we heard in our interviews is that it would be completely unacceptable to the F1 management if the quality of production in the UK was to be much worse than in other countries. Thus, while viewing figures would not be impacted hugely, the quality of a production without in-car cameras etc. (which cannot happen without the use of wireless) would be much poorer and the image of the host broadcaster would suffer considerably.

The second useful case study is Premiership football.

Outside Broadcasting Supply Chain Case Study: Premiership Football

Premiership football holds 380 games each season. During the course of the season, the twenty teams of the League each play 19 home and 19 away matches. The season is 38 weeks long and therefore there is an average of 10 games per week.

The sports rights are auctioned every 3 years and the average action value across all rights is expected to be between £1bn - £1.5bn. This amounts to about £350m-£500m per season, though the vast majority of this is paid for the live games (at present, BSkyB are the rights holders).

Coverage is of varying sophistication, with the most sophisticated coverage used for games broadcast live (about 70 games). These games are produced in a 16:9 format with at least 22 cameras[28] coverage and typically 16 audio feeds. Six feeds are taken back over fibre to the BT tower for every live game and here wireless has less of a role to play (all the premiership grounds have access to BT fibre). Games not shown live are typically covered with 6-10 cameras and 6 in-stadium microphones (5 crowd/field microphones; 1 interview microphone). Please note that although the matches are not broadcast live, the coverage may still use PMSE spectrum. Key steps in coverage of a typical Premiership game are shown in Figure 5.5.

[27] Numbers are shown in EUR as it is the currency of trade for Formula One rights and production contracts.
[28] It should be noted that only a small number of these cameras are wireless.

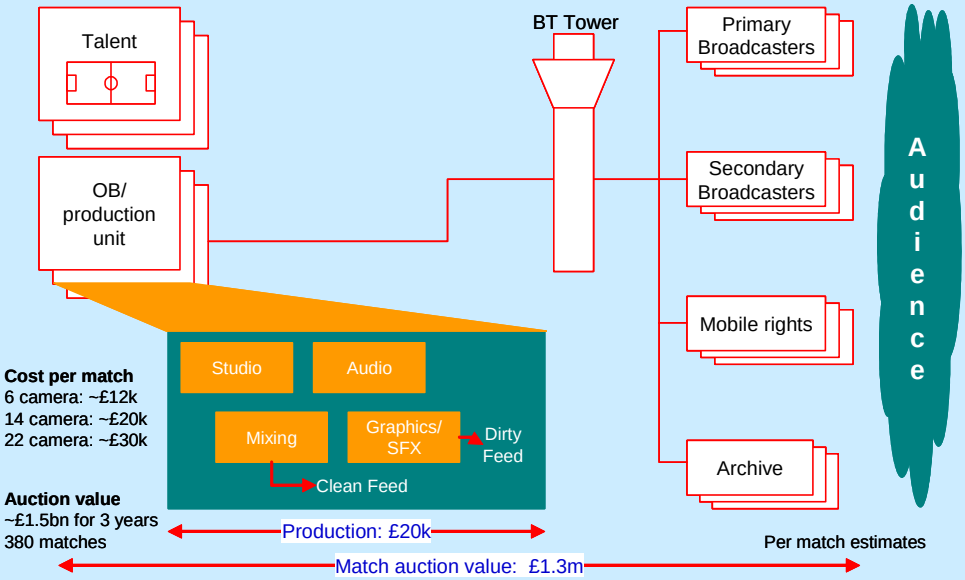

Figure 5.5: Overview of key steps in coverage of Premiership football. Note that Clean feed is the feed without graphics (e.g. scores, player names etc.) and logos added in. Dirty feed is the feed with the graphics – or the picture viewers see at home.

In terms of value:

- The estimated average auction value per match is between £1.3m (if divided across all matches) and £5m (if we only consider the ~70 live Sky matches);
- Production costs are approximately £12k-£30k per match;
- Thus, for both wired and wireless elements, production costs are only between 0.3% and 2.5% of the programme value.

The general consensus from our interviews is that, unlike F1, spectrum adds only a small incremental value to the coverage – "less than 1%". Please note that this is an estimate based on our interviews and is not representative for the entire sports industry though it does serve to demonstrate the competitive nature of programming in the current industry structure and the large variation in the added value of spectrum depending upon the nature of the event being covered.

5.1.3 Studio based programme making

The starting point of any production is the programme concept which drives the entire production process. To convert the concept into reality a whole series of elements come into play – the talent (actors and directors), the location and the actual capturing of the programme. When aired, the programmes derive further value from endorsements and merchandise sales.

A typical studio production value chain is shown in Figure 5.6.

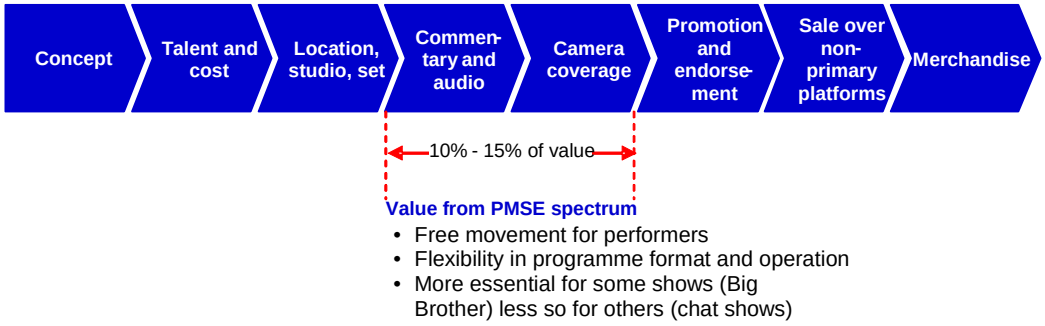

Figure 5.6: Typical value chain for studio production and the key advantages accruing from the use of PMSE wireless.

The programme concept is by far the most important aspect of the value chain followed by the talent. As an example, for programmes where the concept is traded (e.g. Pop Idol, Who Wants To Be A Millionaire, BBC comedies etc.), concept licensing can be as much as 20%-40% of the value of the licensed production. Production, which includes locations, sets, commentary and audio and camera work is a much smaller driver of programme value.

The fact that many producers outsource production to third parties is another indication of how "non-core" to success actual production is (though some outsourcing is also driven by the Broadcasting Act which obliges some outsourcing of production to Independents). Outsourcing is typically to reduce costs and, as in any industry, only operations considered "non-core" or those that are not a source of product differentiation are outsourced (*e.g.* Nike considers itself to be a branding and design company and outsources all shoe production).

The production contracts to third parties are on a cost-plus basis with the contract being both quality and cost driven. Merchandise, alternative access platforms (e.g. DVDs of a successful television show, etc.) are significant only for the most successful programmes.

The value of PMSE spectrum is intrinsically linked to the actual programme. Thus PMSE adds minimal value to talk shows ("we had them 40 years ago in wired studios and little has changed since") but is viewed as essential to reality shows ("Big Brother will be impossible to produce without spectrum"). However, in most cases, the concept and talent will continue to be the most important contributors to value.

Studios primarily use radio microphones and some talkback and IEMs in their productions. They cover a wide array of programming that viewers are used to watching daily. Increasingly, studios are producing programmes such as reality TV programmes which use large amounts of spectrum and which, in some cases, are dependent on its use.

The use of spectrum primarily affects the audio and the camera coverage of the programmes. It also enables free movement for the performers on set. It can enhance the creativity of producers and the flexibility and simplicity of operations within the studio.

In summary, spectrum is important for only a small proportion of programmes produced in studios and even for these programmes it represents a small proportion of value.

5.1.4 Local entertainment and events

The value chain for theatre, the main user category within the local events use category is shown in Figure 5.7.

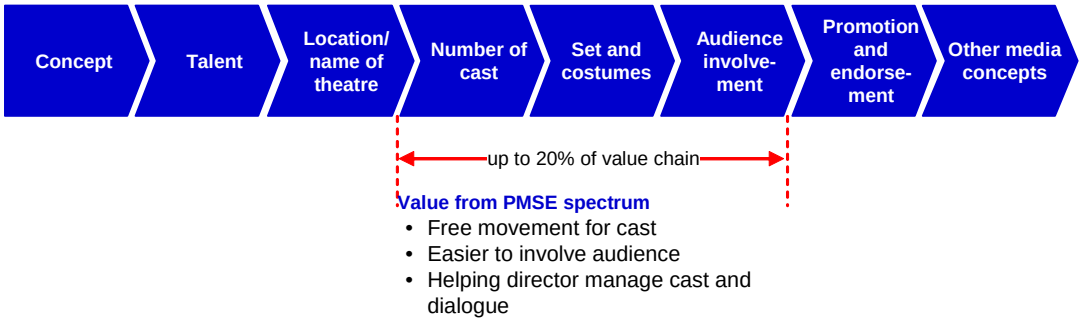

Figure 5.7: Typical value chain for a theatre production.

As with studio productions, the primary value of local shows and entertainment is derived primarily from the concept. The use of specific type of talent adds another element of value - and in some cases may be significant – for example, The Graduate sold out when Jerry Hall played the female lead. Similarly, the location in terms of the geographical area as well as the auditorium or theatre is important for the overall experience of the audience. Large musical productions combining all of these attributes typically have higher ticket prices. Sets and costumes are another key driver of value, with productions such as The Lion King being able to attract both high audience numbers and high ticket prices.

Our interviews suggest that large cast sizes and audience interaction are other important drivers of value, though less important than those above. PMSE wireless is one of the key enablers to being able to use large casts and highly dynamic cast movement.

Finally, endorsements and associated promotional materials add additional revenue. Increasingly, other media such as television or movies are also used to leverage more value out of the most popular shows (for example film versions of popular musicals such as Phantom of the Opera).

The theatre industry players we interviewed claimed that some shows are not possible without wireless, and that it adds significantly to the appeal of others. As mentioned above, the key elements of the value chain impacted by PMSE spectrum are the ability to have larger and more dynamic casts whilst maintaining sound clarity:

- Giving each cast member a radio microphone enables a complex production to be much more easily managed. The wireless microphone is hidden within the costume and the cast member can go on stage without any handover of equipment, thus making handling larger casts more tractable, and simplifying sound delay compensation;
- While, audience involvement is possible with wired microphones, radio microphones make it much simpler and address health and safety concerns associated with wiring harnesses and some equipment mountings;
- Audio quality is enhanced as there is no voice fade (when compared to boom or ceiling mounted microphones);
- IEMs/ wireless talkback offer better controls, cues for dialogue and cues from the producer for impromptu lines that better involve the audience.

The sector is labour intensive and provides a relatively poor return on investment given the risk of shows failing to attract audiences; thus it is very cost-conscious. This sector, therefore, is sensitive to changes in spectrum management and pricing regimes.

Another class of users within this use category are local events organised by local authorities and business conventions. These use radio microphones mainly as an enabler

to better cover a local event. The typical value chain of such events is depicted in the figure below – though it is important to note that the outputs are not commercially traded.

Figure 5.8: Typical value chain for other local events (including local government and corporate events).

While the event organised by these users is not necessarily commercial, attendance is one of the determinants of "success" for the event. The topic/ concept, and the location and marketing of the event have a far more significant role to play in attracting an audience to the event than the quality of audio coverage. Spectrum has a part to play in only the quality of audio coverage element. Thus, from this perspective, PMSE has a relatively minor role in the value chain. PMSE spectrum is viewed as a cost and if the prices rise substantially, the feedback from our interviews is that the users will revert back to wired microphones or may continue but there would probably be (increased) unlicensed use.

5.1.5 Community uses

The common element in these uses is that the end products or services are not for trade. This category covers a wide range of users and a variety of uses. On one end it includes users such as places of worship and schools that primarily use a small number of radio microphones. At the other end, there are hospital radios that use programme links as they provide the cheapest link between studio and the hospital.

The main user segment within this category is places of worship – they account for 43% of use within this category. Radio microphones enable the sermon to be delivered in a much more natural manner – with the preacher talking softly and being able to walk amongst and interact with the congregation.

During our interviews, we were told that a large amount of community based use is unlicensed, though interviewees would not be more specific.

These users tend to be cost sensitive – and their needs are modest compared to the large users. The value of PMSE is purely in the improved quality of the performance – and typically this benefit is received by the audience at the event.

5.2 Conclusions

A key issue demonstrated in this section is the large variation of the contribution of spectrum used for PMSE to the overall programme making value chain and, in many cases, the fragmented nature of the production chain.

- Spectrum is considered to be more important for some categories of use (and for some uses within them) than others:
  - Outside broadcasts, Newsgathering, some entertainment events (e.g. musicals and rock concerts) and certain types of TV programmes (e.g. reality TV) are the uses for which spectrum is most valued. Indeed, there are programmes which would be impossible to produce without use of the spectrum;
  - Use within the categories Studio based programme making (with the exception of some types of programmes), Local entertainment and events (except for musicals and rock concerts), and Community uses, often adds relatively little if any value;

- Despite being essential to production in some cases, PMSE spectrum currently adds less value to the final product than the concept, the talent, costumes, location etc. (all of which in turn are also essential to the final production);
- Where spectrum is deemed essential for a production, the demand from the large commercial broadcasters and production companies is inelastic (thus we were told "will pay for spectrum even if prices rise 100 times"). Clearly any rise in the cost of accessing spectrum would raise production costs – but these would be borne by all the major companies who would continue to compete to make these programmes.

Small industry players (freelancers) are currently able to access spectrum through the non-discriminatory provision of services through JFMG. However competition in PMSE production, and their lack of power in the supply chain means that competitive access to the spectrum would impact these small players most heavily – or restrict their ability to offer a service bundling equipment provision and their expertise. There is a significant risk that unlicensed use will increase for these small players who operate where the risk of interference (to them) is perceived as being low.

6 EMERGING TRENDS AND MARKET PREDICTIONS

In this chapter, we identify the main drivers affecting the demand for spectrum and estimate growth both in the size of PMSE events and in the overall aggregate level of activity. These predictions are made for each category of use for the 10 years to 2014.

6.1 Newsgathering

We see three main drivers to increasing use of spectrum for PMSE purposes for news making:

- News broadcasters increasingly looking to cover a greater proportion of stories "live";
- Increasing local news production driven by growth in digital television and radio;
- Launch of HDTV impacting spectrum requirements for wireless cameras and video links.

We examine the impact of each of these trends below.

In addition:

- We foresee demand for specific applications like point-to-point programme links reducing as news broadcasters migrate to satellite;
- Digital wireless cameras are already deployed in large numbers by the main newsgathering bodies in the main metropolitan areas. We anticipate their continued deployment to local newsgathering bodies;
- Wide-band IEMs are preferred to narrowband technology for talkback and we do not see this trend reversing in the near term. This will drive demand for more spectrum;
- In some situations, news gatherers have used public networks (Tetra or GSM/3G) for talkback and coordination, however, it is not the preferred technology as yet. We do not see a trend towards public network use in the near term, with Tetra/ GSM/ 3G being used primarily as a back-up communication mechanism.

6.1.1 Greater proportion of stories being covered "live"

News broadcasters want to differentiate their product primarily on the basis of covering more news items live. One broadcaster stated that the use of digital wireless cameras offers the opportunity to transform news coverage. We can therefore expect an increase in the use of PMSE frequency assignments and of wireless cameras.

However, given the existing nature of PMSE frequency assignments to news organisations – long term wide area assignments (national, regional or area) – it is difficult to predict the level of direct impact on the demand for spectrum. It is possible for news crews within a given organisation to use the spectrum assigned to them more efficiently – with significant reuse between the teams[29]. Most radio spectrum assignments are short distance (radio microphones, talkback, IEMs, wireless cameras) with the main long distance demand coming from point-to-point links back to the studio. While re-use will be a problem for long distance links, increased migration to satellite for communications back to studios will mitigate this issue.

At the same time, possible demand for additional spectrum for PMSE purposes may result from more and more news channels gathering at the same locations to cover the same

[29] Coordination between news organisations is more difficult, since no-one would like to tell their competition the location of 'breaking news'.

event. In the short term, if there is a demand crunch, news gatherers have told us that they would liaise with each other to ensure that demand is met. A recent example cited in our interviews was for the coverage of Trafalgar200 when a number of broadcasters pooled their spectrum resources.

Given the trend to cover news events through "walkie-talkie" shots rather than through static shots (where the reporter moves about and appears closer to the action) we expect an increase in the use of wireless cameras by mobile crews. This will also naturally increase demand for radio microphones.

6.1.2 Greater proportion of local coverage

The general consensus across broadcasters is that local programming, including news, will command higher a higher number of viewers in the years to come. We are already seeing the beginning of this today. Capital TV, an analogue station, began broadcasting in November 2005 and features events from around Cardiff.

If HMG follows a policy of encouraging more TV and Radio that is solely devoted to "local" content – as is possible if the current trials[30]are successful then there will be more requirements for local content – mainly news. A greater number of channels will lead to pressure for cheaper content – and news coverage is relatively inexpensive to produce compared to other content.

Demand for local TV is likely to be centred on the main metropolitan areas. However, given likely budgetary pressures on local content production, it is likely that most non-news content would not be produced "live".

Some recent market trends include:

- The BBC has outlined plans for a local television news service in cities and counties across the UK and carried out trials of local television and "ultra local" news services on broadband and digital satellite in five areas of the Midlands between September 2005 and August 2006. If the pilot scheme is deemed successful, the BBC hopes to introduce 60 similar schemes across the UK as a key part of its Out of London strategy;
- ITV plc has launched local TV services in the Meridian region, offering a mix of news, community information, local entertainment listings and advertising;
- Mersey Television is launching a grassroots digital public service channel to create a "stronger voice" for local community issues such as health and education and campaigns such as Fathers for Justice.

There is expected to be much less demand for local television in London. At present there seem to be very few initiatives of this nature. One example is a service called RegenTV which is being developed by the London Borough of Newham council in conjunction with IBM to cover community news.

6.1.3 Launch of high definition TV coverage

We expect a slow take-up of terrestrial high definition TV (HDTV) in the UK, though HDTV production is likely to become the norm in the future. BSkyB has already launched premium HDTV channels. Telewest are in partnership with Scientific Atlanta to produce a high definition PVR STB (personal video recorder set-top box) to rival Sky+ (Sky with PVR) and Sky HD (high definition TV). HD-PVRs (high definition PVRs) are already becoming established in some markets, notably US and Japan.

[30] See, for example, http://www.ofcom.org.uk/tv/psb_review/digital_local/.

In the UK, capacity limitations mean that HDTV is unlikely to reach Freeview until after analogue switch off at the earliest. It is possible that this may limit the format to IPTV (broadband television over the internet), satellite and cable. Nevertheless, the BBC has made it clear that it is keen to broadcast high definition content, and may resort to alternative delivery methods in order not to be seen as being left behind. These include simulcasting channels in HD on satellite and cable.

Irrespective of the take-up of HDTV among viewers, production will move to HDTV much earlier. US networks like Discovery are insisting that any content that they procure is shot in the highest quality HDTV (1080) – correspondingly, the BBC has shot the next series of Blue Planet in HDTV. The BBC has also announced that it plans to move all production to HDTV. BBC News anticipates use of HDTV format for all newsgathering.

The impact of HDTV coverage will have two main impacts; additional demand for spectrum for wireless cameras and increased production costs:

- Using the most popular compression method available today HDTV cameras (1080) would need about 6x the amount of spectrum to transmit information (a standard definition picture has 414,720 pixels with HD having 2,073,600, pixels). However, as described in Annex G, we anticipate improved compression technology, and the improved resilience of the digital format compared to today's analogue mode to result in a similar bandwidth requirement for a future HDTV digital link compared to a contemporary analogue link;
- HD production costs are about 20 – 30% higher. The increased costs are driven by equipment upgrades and the greater attention to detail required when filming.

We do not expect the transition to HDTV to have an impact on radio microphones. There is no change in the audio coverage characteristics of HDTV (at least not for news making, though more complex standards for audio (e.g. 5.1 audio which is common for home theatre) may in the long term become more common for some studio production).

Current capacity on radio links will be insufficient for HDTV backhaul to the studio and further encourage news gatherers to move to satellite. We therefore expect the demand for point to point video links to potentially decrease over time with the migration to HDTV.

6.2 Trends in sports production and related outside broadcasting

We see four main drivers to increasing use of spectrum for PMSE purposes for sports:

- Increasing complexity of coverage of sports events;
- Specialist sports events and local sports events being covered to cater for more niche tastes driven by growth in the number of channels;
- Launch of HDTV impacting spectrum requirements for wireless cameras and video links;
- Ever increasing pressure on costs.

We examine the impact of each of these trends below.

6.2.1 Increasing complexity of sports coverage

There has been a considerable increase in the number of cameras and audio feeds used for production of the top sports events – in particular football and rugby on SkySports. The impact has been highest in sports like football, rugby, golf and motor racing with a lesser increase in sports such as cricket and horse racing.

For example, over the past 5 years, the number of cameras used to cover a top football premiership match has increased from 14 to 22+ cameras. The number of audio feeds has increased from about 8 to 16 feeds. There is talk of introducing "player-cams" similar to those recently introduced in American Football. On the other hand, matches involving the "lesser" teams and not covered live are produced with far fewer cameras (8 to 10) and fewer audio feeds (6). We anticipate that the "lesser" matches will migrate towards more complex production.

In motor sport, the number of cameras used in F1 is around 60 (note that not all of these are wireless). In addition, there will be demand for a number of audio feeds from different commentary teams. There is additional demand for long range links between coverage cars (6 to 10), helicopters (2 to 4) and the OB trucks (3 to 4).

The demand for spectrum in golf is driven by camera crews following (high profile) players over each hole – this drives the demand for both wireless camera spectrum and programme links back to an OB receiving site.

The increased complexity of sports coverage will have the following impact on demand:

- Increased demand from an increasing number of wireless cameras. In addition, we expect there to be a transition to wireless cameras for a number of sports, for example golf and athletics, though the transition will be less for sports such as cricket and football. Motor sport has already moved to predominantly wireless coverage;
- There will be an increased use of "high quality" IEMs instead of narrow-band talkback;
- There will be increased demand for high powered radio microphones, especially for sports such as motor sport, golf and cricket;
- There will be a continued increase in the use of radio microphones to add atmosphere – for example, in racing, radio microphones being used at each jump and across the course to catch the "thunder clap" of the horses as they race around the course;
- The other impact on spectrum usage arising from increased use of wireless cameras will be from the use of video programme links to connect the camera back to the OB van. Typically sports like F1 and golf championships will require 30-50 cameras of which about 6-20 will be wireless. In the 2005 Open Golf Championship at St. Andrews, 12 wireless cameras were used (by a number of broadcasters) and many fixed cameras. Many of the wireless cameras required 2 video links to get the signal back to the OB van.

6.2.2 Increased programming diversity and local coverage of sports

As local television takes off, we expect increased coverage of local events such as local football competitions. This trend is already common in the US, where local baseball leagues are routinely covered on television. The trends on the take up of local television news are also relevant for sports (see above).

Another related trend is for increased coverage of sports outside the top leagues – for example, comparative "niche" sport like croquet, pool, X-games, local gymnastics, and others. One of the key service outcomes of broadband is that it enables the distribution of niche content and servicing of the so-called "long tail" to become a reality. For example, more than 80% of all songs downloaded on iTunes are for songs outside of the top 50. With increased take up of broadband content, including television, we expect this trend to become a reality for sports as well.

The impact of local coverage of sport and coverage of niche sports is expected to be much higher in the regions and not in key sporting locations where PMSE spectrum is currently

in most demand. Thus, as for news, while overall demand will go up (in terms of assignment days for local channels), we do not see a direct impact on additional peak demand in areas where demand is already high. As with existing sports coverage, demand will be focussed on relatively small areas, and will be required only for the duration of the event.

6.2.3 Sports coverage in HDTV for top sports

We have discussed the trends in the take up of HDTV in a previous section. These trends are equally valid for sports production. Sports production is currently migrating to HDTV format. For example, Wimbledon 2006 was covered in HDTV as was the 2006 football World Cup (in Germany).

As with news, the impact of HDTV coverage will be on the demand for spectrum for wireless cameras and on production costs. As with news, we do not expect there to be an impact on radio microphones as there is no change in the audio coverage characteristics of HDTV. Backhaul from the sports site (OB trucks to studio) is primarily by satellite already (or by fibre for premiership football) and thus the demand for long range programme links will continue to be low.

6.2.4 Cost pressures increasing the level of outsourcing

There is already a fair amount of outsourcing in match production. For example, in premiership football, while the top matches are covered by Sky or large sports companies like TWI, the non-live matches are typically covered by local sports production companies (often local ITV companies, examples include Central for Leicester or Tyne Tees for Newcastle). The clubs put enormous cost pressures on these local production companies with production budgets less than 25% of the budget Sky or TWI reserve for their productions. One of our interviewees commented that typically the rights owners will "typically shop around for the cheapest quote of acceptable quality".

The professional broadcasting industry has embraced outsourcing - partly as a way of reducing costs. For example, Channel 4 outsource the production of all their programmes, and the BBC have formed BBC Resources as a separate company that competes to win outside broadcasting contracts to cover events for both the BBC and other broadcasters (including commercial organisations such as Channel 5). This has created a highly competitive market for programme production.

Within programme production, many sound and camera specialists are employed on a freelance basis. Many of these specialists have expertise that is suited to a given sport or event type. Hence a camera that covers the Open Golf Championship, broadcast on BBC Television, could be operated by a specialist with knowledge of golf, subcontracted by an OB production company selected by competitive tender. For some small events freelancers are expected to provide a service – including provision of their own equipment (and, implicitly, licenses for its use).

6.3 Trends in studio programming

We see three main drivers to increasing use of spectrum for PMSE purposes in studio production:

- Increasing popularity and breadth of reality genre shows among producers – driven by both consumer demand (though it is likely that this will plateau soon) as well as lower costs of production per broadcast hour;
- Studio based programmes becoming more complex – for example with bigger casts;

- Production of niche content for unique tastes ("long-tail" production);

We examine the impact of each of these trends below.

6.3.1 Increasing popularity of reality television

As a format, reality television is one of the largest users of spectrum for PMSE purposes – using a combination of radio microphones for the cast (10 to15), talkback and/or IEMs for the production crew and some wireless cameras (0 to 5 out of 30 cameras in total).

Reality TV is one of the fastest growing genres on television ever. As one of our interviewees said, the take-up of reality television is driven by the "voyeuristic streak in all humans combined by its ability to fill programming hours at low cost".

Big Brother is one of the most successful formats worldwide, being the synonym for reality television for many. The success of Big Brother is the fact that never before has the act of monitoring other people in a voyeuristic way been the key appeal of a show. Not only do audiences have the opportunity to watch what has happened in the course of a day in a one hour programme, they also have the chance to watch other people's lives 24 hours a day, either on premium television channels or on the Internet.

At the beginning of the development process the only element in place was that nine people would be constantly filmed by more than 20 cameras for three or four months. Key elements introduced over the following 18 months were mainly the confession room and the whole nomination and eviction process, something that would later prove paramount to the show's success. The 2005 series made use of more than 30 cameras (~5 wireless cameras).

Other reality programmes have also become extremely popular – the most notable being FreemantleMedia's Idols (premiered as Pop Idol in the UK). Other reality programmes include Love Bugs, Celebrity Love Island, I'm a Celebrity! – Get me out of here, The Real World and Survivor (some of these were before Endemol's brainchild Big Brother). However, many of them are shot in exotic foreign locations.

There is a consensus that soon there will be adapted versions of the genre – tailored to different tastes. For example, versions of the theme are already being broadcast on adult channels in Spain and Germany. Other versions may be produced soon, though it is likely that Endemol will protect its licence rights vigorously.

The UK is the world's biggest format exporter with the format production market in the UK worth EUR693m over the past three years[31]. While we expect the UK to continue to lead in the production of reality programmes, it is also possible that the demand for reality programming may plateau or decline as the novelty wears off and there is over-exposure to the genre. ITV recently cancelled two reality shows, Fat Families and The Real Good Life.

The impact of increased production of reality shows will be on the use of radio microphones (8 to 20 per studio), talkback (6 to 10) and to a lesser extent on IEMs (3 to 4) and wireless cameras (3 to 5). The additional production associated with these additional shows will result in increased aggregate use of PMSE wireless (as opposed to an increase in use at an individual studio).

6.3.2 Studio based programmes becoming more complex in their themes

One way that channels use to differentiate similar formats or to keep up interest is through more attractive sets (typically exotic foreign locations), talent (for example, the Celebrity

[31] See Screen Digest – www.screendigest.com.

version of Big Brother) or use of a much larger cast (such as the increase in the cast of Big Brother). As mentioned in the previous section, at the beginning Big Brother was filmed with about 20 cameras, though the current series makes use of more than 30 (~5 wireless cameras).

Increasing cast sizes and filming complexity has the following impact on spectrum for PMSE purposes demand:

- Increased transition to wireless cameras;
- Use of additional radio microphones for the larger cast.

However, the impact is likely to be much smaller than for sports or news making, as the requirements for spectrum will be confined to the studio.

6.3.3 Explosion in channels resulting in "long-tail" production for niche tastes

An explosion in channels and the potential take up of streamed television grade content over broadband could have a significant impact on the number of programmes created by studios. The number of licensed channels has increased annually by an average of more than 20% (CAGR) over the past 10 years.

A similar trend is already visible on radio, with niche radio channels targeting very specific audiences. It is estimated that the number of radio programmes produced has increased more than two-fold in the last 5 years (even though the sector revenue growth has remained stagnant and recently even declined marginally).

With the advent of broadband television, it is expected that the number of programmes made will show a similar increase. While the vast majority of niche productions may not necessarily recover their production costs (as is the case with music or computer games), there will be a number of investors and producers driven by their interest, passion and hope.

A similar trend may emerge for studio produced content for television and PCs. However, it is likely that given budget constraints, demand for spectrum per "long-tail" production is likely to be modest. Increasing the number of programmes produced can have the following impact on spectrum for PMSE purposes demand:

- Increased use of radio microphones and talkback as the number of programmes produced goes up and programmes are increasingly shot outdoors;
- Use of wireless cameras will be limited to the top productions, most of the others using high quality production grade digital camcorders;
- Larger studios typically use wideband IEMs, though narrowband equipment could be used where high sound quality is not essential. Narrowband equipment is likely to be much more popular for the "long-tail" low-budget productions;
- The increased number of programming hours driven by the long-tail will probably lead to a small growth in number of studios with much of the increase coming from increased programming output per studio. Since studios typically have long term PMSE frequency assignments (as opposed to the individual programmes), the direct impact of higher programming hours on demand for PMSE spectrum is likely to be limited;
- Spectrum demand from the larger studios is currently focused in and around London. Lower budget productions for the long-tail are likely to be produced in smaller studios on the outskirts of London, especially given the trend of talent moving away to the suburbs in the Richmond/Shepperton area from the smaller studio centres in Soho.

6.4 Trends in theatre production

We do not see any major increase in demand at any particular venue, with the key trends limited to:

- Migration within smaller theatre productions from wired to wireless microphones;
- Top shows becoming more complex with larger casts and separate radio microphones for each cast member, though there will be continuing cost pressures on the theatre community.

We examine the impact of each of these trends below.

6.4.1 Migration of smaller productions to wireless microphones

While all the larger productions have already moved to radio microphones, some of the smaller productions (such as the Polka Theatre and Richmond Theatre) still use ceiling microphones or in some cases no microphones at all. Many of these smaller theatres have been transitioning to radio microphones and we expect this trend to continue.

There are about 400 users from the theatre community listed within the JFMG database (for 2004/05) with another 100 to 200 serviced by hire companies. At the same time, there are probably many more theatre productions (including community theatre) in the UK. For example, www.manchesteronline.co.uk lists about 50 theatre productions (a higher number of local community theatres would not have made the list) while the JFMG database suggests only about 20 theatre licensees in the area[32].

We anticipate that an increasing number of theatres will increase their use of radio microphones and talkback. However, the average demand per smaller theatre is likely to be low – typically 4 to 5 radio microphones and 1 to 3 channels for talkback.

6.4.2 Top shows becoming more complex, though cost pressures continue

Theatre is a labour intensive industry with little scope for cost cutting without affecting the finished product. Correspondingly, theatre is always under financial pressure and ticket prices normally have to rise faster than inflation.

The pressure is much higher on non-musical shows. Musical theatre is the most commercial of the theatre based arts, yielding higher revenue per ticket, playing to fuller houses and with productions running for longer. Although the costs per production are relatively high, musical theatre is still more profitable than other theatre based arts.

While there is pressure to reduce costs in theatres, there is always pressure for "bigger, better" productions, increasing the size of the largest productions. It is now normal for everyone on stage to be using a radio microphone, which was not the case 10 to15 years ago. One reason for this is to avoid the need to switch microphones between performers during the show. More importantly, each cast member having their own radio microphone increases the producer's and the director's artistic freedom[33]. However, cast sizes for indoor productions cannot rise indefinitely as there is a limit due to the size of the stage – and the staff costs of the production. IEMs are also now widely used in musical theatre. Peak usage is currently around 60 radio microphones and IEMs (combined) and industry expectations are that this figure may grow to around 80 – but is unlikely to significantly increase beyond this.

[32] Some of these may use the shared or licence exempt frequencies.
[33] Source: JFMG report on demand for PMSE spectrum.

Wireless talkback is used in addition to wired communications for the coordination of back stage staff. However, the requirement at any one theatre is for just a few channels. We note in Annex G that some theatres and studios are adopting new talkback systems that use license exempt spectrum, and so demand for additional talkback spectrum is unlikely to increase.

6.5 Trends in demand from hirers and vendors

The demand for spectrum from equipment hire companies will be driven by the demand from the end users – that is from the demand for theatre, studio based production houses and from sports. Thus, demand trends for enablers like hire companies are looked at within the end user segments.

The main trend impacting the take-up by the vendor/ hire community is an increase in outsourcing production and the trend away from investment in equipment. This will not impact the demand for PMSE spectrum, as demand is driven by end users (which hirers are not) – this trend is about how price conscious the hire sector is.

The commercially minded users and smaller users are moving to greater and greater use of hired equipment. For example, smaller cost conscious users who have occasional use for wireless equipment prefer to hire equipment. One of the radio companies we interviewed used to have their own radio microphones but have recently moved to hiring them from third parties. Others also spoke of increasing interest in using hired equipment. This reduces the cost of maintenance and they can shop around for the most appropriate piece of equipment. In addition, it is far easier to have operating budgets approved compared to capex budgets.

Within the theatre industry, spotting hit musicals is notoriously difficult and many musicals are stopped before unacceptable losses accrue. In addition, maintaining specialist radio equipment is not a core function. For these reasons hire companies have arisen that supply and maintain radio equipment on a long and short term basis, thus reducing the commercial exposure of the production by avoiding high up-front costs. In general, commercial users tend to focus on reducing risks, and budget on a per production basis. These users therefore tend to hire equipment.

Non-commercial users would tend to take a longer term view and seek to make cost savings in the long term by investing in their own equipment. However, even the BBC hires equipment from time to time and BBC News hired early generation wireless cameras until their proven performance justified the longer term investment of equipment purchase.

These two aspects (risk reduction and subcontracting non-core equipment maintenance) have established a competitive equipment hire sector in the UK. Simultaneously, the availability of equipment for hire and a pool of freelance operators has reduced the barriers to programme making within the UK. This has further increased the competition within programme making in the UK.

A number of the larger operators we interviewed also said that they see an increasing trend towards hired equipment. These larger users often use subcontractors for a significant proportion of their production and the subcontractors in turn use a combination of their own kit (for example, OB vans) and hired equipment for sports production.

The other trend is that the larger companies tend to hire a combination of talent and equipment. Typical rates are about £300 to £600 per day for technicians who bring in their own equipment and also get the necessary licences from JFMG. These freelancers are extremely cost-conscious.

6.6 Translating market trends into demand growth

The trends described above highlight that demand is expected to grow in two main ways:

- Increasing event size: Growth at (existing) events as productions grow or the method of production becomes more complex. This will tend to make the peak events of the future larger than the peak events of today;
- Increasing number of events: Growth owing to increased use as later adopters migrate to wireless technology.

Hence it is useful to consider both of these growth aspects. The growth figures are for 2014 (*i.e.* 10 years ahead of the baseline year 2004/5).

6.6.1 Increasing event size

Based on the knowledge of one of the project team members with many years of experience at JFMG, we selected the following representative event types as the basis of our growth projections for peak events:

- Local external sports event (e.g. a football match);
- Wide area external event (e.g. horse racing or golf);
- A top pop event;
- Peak demand growth from a top theatre;
- Studio based programming – for a large studio;
- Peak demand from news crews;

We estimate peak demand growth for each of these events below.

Local area sports coverage

The main driver of incremental peak demand in sports will be from an increasing complexity of sports coverage; though we expect any incremental demand from increasing complexity to be small. Most top events are already complex and have widespread use of talkback for communications. While we expect growth in peak demand to be moderate, there could be growth from a move to using more wide band talkback (IEMs). We estimate:

- Wireless camera usage to grow by a maximum of 50% from their current usage. Thus (camera control) data links and video links will grow correspondingly by 50%;
- Peak demand for high power radio microphones (audio links) is likely to be stable – we have taken a 10% growth as the worst case;
- We do not expect radio microphone usage to increase significantly – with possibly a maximum increase of 30% for more "interactive" commentary that involves the audience and the crowds;
- Talkback growth will be minimal as peak productions are already complex today – we anticipate that any growth will be limited to 10% or less.

Wide area sports coverage

The key wide area sports events are golf, horse racing and Formula One. As in local area sport, the main driver of incremental peak demand will be from an increasing complexity in sports coverage; though the impact may be different for high power applications. We estimate:

- Wireless cameras to grow by a factor of 2.5 from their current usage. We expect this growth to be higher than for local area sports as any increase in cameras is going to be almost entirely wireless. Thus, data links and video links will grow correspondingly to 250% of their current use;
- Peak demand for high power radio microphones (audio links) is likely to grow at a higher rate than for local event sports given the distances involved – we have taken 20% growth as the worst case;
- As with localised sports, we do not expect radio microphone usage to increase significantly – with a maximum increase of 20% for more "interactive" commentary that involves the audience and the crowds;
- Talkback growth will be minimal as peak productions are already complex today – we anticipate that any growth will be limited to a 10% increase.

Local Entertainment – A top pop show

We expect an increase in the use of wireless cameras and radio microphones as increasingly coverage is "interactive" with the presenters walking around and interviewing the stars, the staff and stars backroom and the audience. We estimate:

- We expect moderate growth in peak radio microphone usage – with a possible maximum increase of about 30% to allow for more interaction with the stars and the audience;
- Talkback growth will be minimal – we have taken 10% growth in the peak case;
- Peak demand for high power radio microphones (audio links) is unlikely to grow at all.

Note that where a pop show is also broadcast additional spectrum will be used to support the OB activities. Growth in peak demand will be mainly driven by the use of more wireless cameras.

Local Entertainment – Top Theatre

We believe that peak demand for top theatres will be relatively modest (increasing from an already high baseline). While there is a possibility of musicals getting more complex in terms of cast size and coordination, the top shows are already produced with more than 60 to 80 cast members. There is a point in a show after which increasing complexity or cast size does not really add value. From our interviews, we estimate this to be about 80 cast members. We estimate:

- Data link usage is close to zero and we expect this low usage to continue;
- Wireless camera use is also minimal, with wireless cameras being used primarily for health and safety purposes (*e.g.* safety checks for trapeze/ "flying" artists in some musicals). Given this low base, we can expect some peak growth for top theatres – from our interviews, we estimate this to be about 30%;
- There is no demand for high power radio microphones (audio links) and this is likely to continue;
- Given the already large cast sizes for the largest theatre productions, we expect no growth in peak radio microphone usage – we have taken a conservative peak growth of 10%;
- Talkback growth will be minimal, and we have assumed 10% growth.

Large studio

Studios have limited use for wireless cameras – with some usage for certain shows (e.g. reality programmes). Peak demand will be driven by increasing complexity of programme production in the major studios. We estimate:

- Data link usage for remote camera control is low at present and we expect it to grow in line with wireless camera growth (and to double in 10 years);
- Wireless camera growth is likely to be driven by certain genre of programming – i.e. reality shows. For example, Big Brother 6 had more than double the number of wireless cameras compared to a couple of years earlier. We estimate peak usage to double in 10 years;
- There is no demand for high power radio microphones (audio links) and this is likely to continue;
- Top studio productions involve large teams and casts and it is unlikely that the complexity will increase significantly from today's level – we have estimated peak growth of about 20% for radio microphones;
- Talkback growth will be minimal – we have estimated this to be about 10%.

Newsgathering

We assess the drivers of an increase in peak demand to be:

- Increasing use of satellite and fibre: Increasing use of satellite (e.g. some broadcasters moving almost exclusively to satellite) and fibre (particularly in London) implies that demand for programme links may reduce in future;
- "Interactivity" of news coverage: We expect a continuing increase in the demand for radio microphones by news crews per event being covered as reporters look to make the production more "interactive" by walking around the event, talking to witnesses and passers-by, etc.;
- We estimate that there will be more use of talkback, as news coverage becomes more complex, but anticipate modest growth since there will be significant re-use of the existing assignments to support new channels.

On this basis, we estimate:

- Top news events are covered by a large number of cameras – a significant proportion of which are already wireless. For example, one interviewee estimated that about 20 cameras (shared by all news crews covering the event) covered the Royal Wedding in April 2005. Given the complexity of coverage at peak news events already, we estimate a growth of about 50% for wireless cameras;
- Data link usage for remote camera control to increase at least 50% in line with a growth in the number of remote cameras for coverage;
- Given the trend for "interactive" coverage, we estimate radio microphone usage to grow by about 30% for peak news events over the next 10 years;
- Talkback growth will be modest – we have estimated this to be about 10%.

We have taken the growth estimates for the events above as representative of the growth in the peak demand in the corresponding category of use. The resulting growth predictions are given in Table 6.1.

	Data links	*Audio links*	*Radio microphones*	*Talkback*	*Video links*
Newsgathering	50%	0%	30%	10%	50%
Outside broadcasts	100%	10%	25%	10%	100%
Studio based programme making	100%	0%	20%	10%	100%
Local entertainment and events	100%	0%	20%	10%	100%
Community uses	0%	0%	50%	10%	0%
Other	70%	0%	30%	10%	50%

Table 6.1: Anticipated percentage growth in demand at events over the 10 years to 2014, by application and category of use. Growth for the category "Other" is assessed as the average of the other categories.

6.6.2 Increasing number of events

The growth in the number of events is estimated on the following basis:

- From the JFMG database, for each category of use, we extract the number of licences issued and the total number of assignment days licensed;
- This analysis was performed separately for each category of use;
- Growth in demand is then estimated for each application (data links, programme links, radio microphones and talkback) and for each category of use;

The growth in the number of events is estimated by examining a combination of:

- Growth in number of users within the category of use (e.g. the number of theatres using radio microphones is expected to increase);
- The impact of changing the usage mix within each category of use (e.g. while usage of radio microphones may be going up for top commercial theatres, there will be an increasing number of smaller theatres using radio microphones and this may actually drive down the average across the category);
- The drivers are identified for each of the relevant trends on growth, technology etc., by application and by category of use.

The trends are estimated over the next 10 years for each category.

The key trends for a variety of uses are:

Newsgathering

- We do not estimate any growth in large "generic" broadcasters, though the number of news specialists are estimated to grow from 11 today (as captured by the JFMG database) to 18 in 2014;

- Use of long distance programme links by news crews falling by up to 20% per year (2005-2008) before usage stabilises. The fall is driven by an increasing use of satellite and fibre (in London);
- All news production to move to HDTV by 2010, with the mass move to HDTV occurring as early as 2007;
- Continuing growth in "interactive" coverage drives further demand for programme links (through wireless cameras) and radio microphones.

Outside broadcasts – particularly sports events

- With increasing local TV and local sports production, we have estimated a slow growth in the number of sports producers – growing from about 19 today (JFMG database) to more than 30 in 2014;
- Incremental growth in usage of wireless cameras, radio microphones and talkback is much less than for other categories of use with sports typically covered by wired cameras with the exception of some sports such as F1 and golf.

Outside broadcasts - local radio

With the take up of the internet and digital radio (DAB), we expect some growth in the number of radio channels and a corresponding growth in the number of stations that need PMSE spectrum.

- We estimate the number of radio stations using PMSE spectrum to increase from about 150 today to more than 250 in 2014;
- We estimate a decline in the use of programme links – driven by smaller radio stations entering the customer base as well as increasing use of public mobile phones (as highlighted during the interview programme).

Studios

- With continuing channel proliferation and growth in local television, we have estimated a growth in studios from about 140 today (as captured in our categorisation within the JFMG database) to more than 220 in 2014;
- We expect a significant proportion of studio production to move to HDTV by 2010. However, we do not expect a significant increase in the proportion of wireless cameras used per studio.

Theatre

- We expect a continuation of the trend of growth in theatre users – growing from about 160 today to about 250 in 2014;
- With smaller and smaller theatres joining the customer base, there is a strong possibility that the average use of wireless equipment per theatre across the sector may actually decrease. This may be compensated by growth in use amongst commercial theatres. We estimate that these effects will compensate each other.

Community events

The main growth in average demand for these categories is driven by an increase in the number of organisations using PMSE spectrum within the category of use. We estimate this growth to arise from:

- Public and private organisations: about 260 today to more than 430 in 2014;
- Churches: from about 140 today to more than 230 in 2014;

- Schools: from about 120 today to about 200 in 2014;
- Hospital radio: smaller growth from about 44 today to over 50 in 2014;
- We have estimated a small decrease in the average use per user sector as smaller and smaller users enter the customer base.

Based on the above estimates, we expect:

- The number of licensees to grow 60% over the next 10 years to reach about 2100;
- The majority of this growth to be driven by increased use of radio microphones.

This growth will be reflected in an increased number of events and wide area assignments. Based on the above considerations, we estimate that the growth of the number of events over the next 10 years will be as shown in Table 6.2.

Category	*Growth*
Newsgathering	65%
Outside broadcasts	60%
Studio based programme making	55%
Local entertainment and events	55%
Community uses	60%
Other	60%

Table 6.2: Anticipated percentage growth in the number of events and wide area assignments over the 10 years to 2014, by application and category of use. Growth in the category "Other" was estimated as the average of the other categories.

The application of these growth figures to the analysis of the balance of supply and demand is discussed in Chapter 7.

7 MODELLING SPECTRUM SUPPLY AND DEMAND

The objective of modelling PMSE spectrum assignments was to gain understanding of how use varies both temporarily and spatially in each of the spectrum bands used for PMSE. This helps us understand the practical impact of future spectrum restrictions and the nature of PMSE use that will be most affected by likely changes in spectrum supply.

This chapter provides an overview of the modelling process and explanation of the format of the charts and maps used to present the results. More detail is provided in Annex D.

7.1 Overview of the modelling process

The purpose of the model was to compare the supply and demand of spectrum for PMSE in the years 2004 and 2014. Three supply/demand scenarios are of interest:

- 2004 demand compared with spectrum supply in 2004;
- 2014 demand compared with spectrum supply in 2004;
- 2014 demand compared with spectrum supply in 2014;
  - With regard to the UHF TV spectrum, it is assumed that all retained interleaved capacity is exclusively available for PMSE[34], but that none of the 14 released channels are available to PMSE applications.

In addition to a base case level of supply in each band, it is also of interest to understand how the 2014 spectrum demand in the UHF TV bands IV and V compares to spectrum availability under four alternative Digital Switchover (DSO) scenarios, with progressively more restrictive spectrum supply for PMSE. More detailed information on the use of the UHF Bands IV and V and the impact of DSO is to be found in Chapter 9 and in Annex H.

Our analysis is based on the database of actual assignments granted between 1/4/2004 and 31/3/2005. There were 64,007 assignments in this database distributed across the bands commonly used for PMSE, and the number of assignments was forecast to grow to over 100,000 in 2014.

Some of the bands are alternatives for each other in terms of functionality, and have been grouped together in blocks of substitutable spectrum, as shown in Table 7.1. Owing to the diverse nature of use, we have differentiated between spectrum used by applications that will be most significantly affected by DSO and those that will not, therefore the 3.8MHz of VHF Band III spectrum used by radio microphones has been considered separately from the rest of VHF Band III and grouped with the UHF Band IV & V spectrum and Channel 69.

[34] This spectrum is referred to as the retained interleaved spectrum.

Block 1	Block 2	Block 3	Block 4	Block 5	Block 6
Band I Low band	High band VHF Band III (non-RM) UHF 1 UHF 2	VHF Band III (RM) UHF Bands IV & V UHF Channel 69	1.5GHz	2GHz 3.5GHz 5GHz 7GHz 8GHz 10GHz	11GHz 12GHz 24GHz 48GHz

Table 7.1: Band and block structure of spectrum for PMSE in 2004. This maps the 19 bands available in 2014 into 6 blocks, with VHF Band III being split between two blocks according to radio microphone use.

The 20 bands identified in Table 7.1 are used as the basis for our analysis[35]. For each block we have assumed that overload in one band (which may be due to forecast growth in usage or accommodating currently out of band assignments) can be migrated to other bands within the same block.

To achieve the modelling objectives the methodology illustrated in Figure 7.1 was adopted.

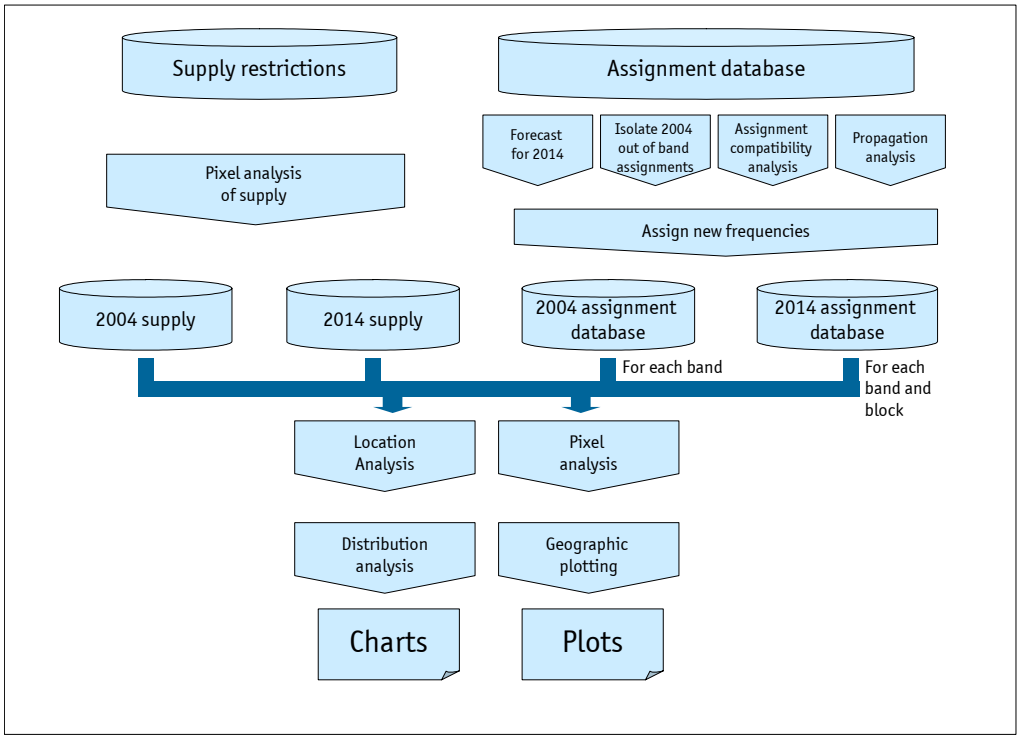

Figure 7.1: Outline of the model methodology

The spectrum supply was assessed by determining the restrictions and additions pertaining to each band in both 2004 and 2014. Some adjustments to these bands are

[35] The assignments are currently distributed across 18 of the 20 bands currently available for coordinated PMSE use and there were no assignments in the 1.8GHz or the 24GHz bands. In our analysis we have assumed that the 1.8GHz band will not be available in 2014 and that VHF Band III can be considered as two logical bands. Therefore a total of 20 bands formed the basis of our analysis.

expected by 2014 and these are reflected in the 2014 supply analysis. The UHF Band IV & V spectrum currently used for analogue TV is available for PMSE in areas interleaved between the coverage areas of TV transmitters. Therefore its availability is based on geographic assessment of current and future broadcast TV transmitter deployment[36].

Some of the current spectrum is at risk of becoming unavailable for PMSE use over the next few years. The most notable reduction in spectrum will occur in both the UHF TV band, where 14 TV channels (*i.e.* 112MHz) are expected to be released for other services after the switchover to digital TV, and the 2GHz band where the band 2.50 to 2.69GHz is due for auction. A detailed assessment of anticipated spectrum supply is contained in Annex C. A summary of the impact of the loss of spectrum, and alternative spectrum, is considered in the discussion of the balance of spectrum supply and demand. Note that the capacity of the interleaved spectrum in 2014 assumes that all such capacity within the TV channels retained for broadcasting is available exclusively for PMSE activities. Detailed aspects including regional variation of supply were included in the detailed modelling. Table 7.2 lists the main spectrum at risk.

Band	Risk	Anticipated reduction in spectrum
Band I	Possible release for Community radio	2MHz out of 6.3MHz
Band III	4 or 5 T-DAB multiplexes may be awarded	2 of 4 sub-bands (500KHz out of 925KHz) and up to 3 out of 19 coordinated radio microphone plus up to 6 out of 15 shared radio microphone frequencies[37].
L Band	Release of T-DAB spectrum overlapping with part of the lower band	3 out of 11MHz.
2GHz	Release of the 2.5 – 2.69GHz band and extensive licence exempt use in the 2.4GHz band	300 out of 475MHz.
5GHz	Expanding non-PMSE use of the RLAN bands A, B and C.	216MHz out of 291MHz.
12GHz	Possible direct satellite broadcasting in the UK	Restrictions on transmit power over the UK

Table 7.2: List of frequency bands whose availability for PMSE use may be reduced in future.

Hence, approximately 120MHz below 2GHz and over 500MHz above 2GHz that is currently available to PMSE users is unlikely to be available through the current administrative assignment regime for PMSE use in future[38].

[36] The ITU-R Regional Radio Conference in May/June 2006 (RRC06) established a new international agreement on how broadcasting spectrum can be used in Europe. The agreement established at RRC06 is fully consistent with Ofcom's plans for the future use of UHF spectrum.

[37] Note, since these calculations were carried out a way to avoid any loss of radio microphone capacity within the Band III spectrum has been identified.

[38] Of course PMSE users could purchase spectrum at auction or negotiate use with the eventual purchasers.

The spectrum demand was established by translating the sample assignment database into a representative database of 2004 demand (where out of band assignments were assigned new frequencies) and a forecast for 2014 based on the growth assumptions developed within the project. Where the out of band assignments or new growth assignments could not be accommodated within a given band, they were assigned frequencies from a nominal 'overflow sub-band' appended to that band.

The supply and demand was assessed for each PMSE location[39] and the impact upon each of these locations from national, regional and area assignments was also taken into account.

Figure 7.2: PMSE locations across the UK. Each circle denotes a location.

[39] In this context a PMSE location is the set of locations associated with a single event. Analysis of the database established that there were 3151 such locations. The majority of assignments are for equipment located at these specific sites; however there are many other assignments granted on a national, regional or area basis that also have an influence on the loading at a particular location.

The 3151 PMSE locations are shown in Figure 7.2 where it can be seen that the highest concentration of locations is in south eastern England, and around 25% of PMSE locations are within Greater London. The area and regional assignments were translated from the text descriptions in the database to a set of circles and polygons that represent the areas. The pattern of these definitions is illustrated in Figure 7.3.

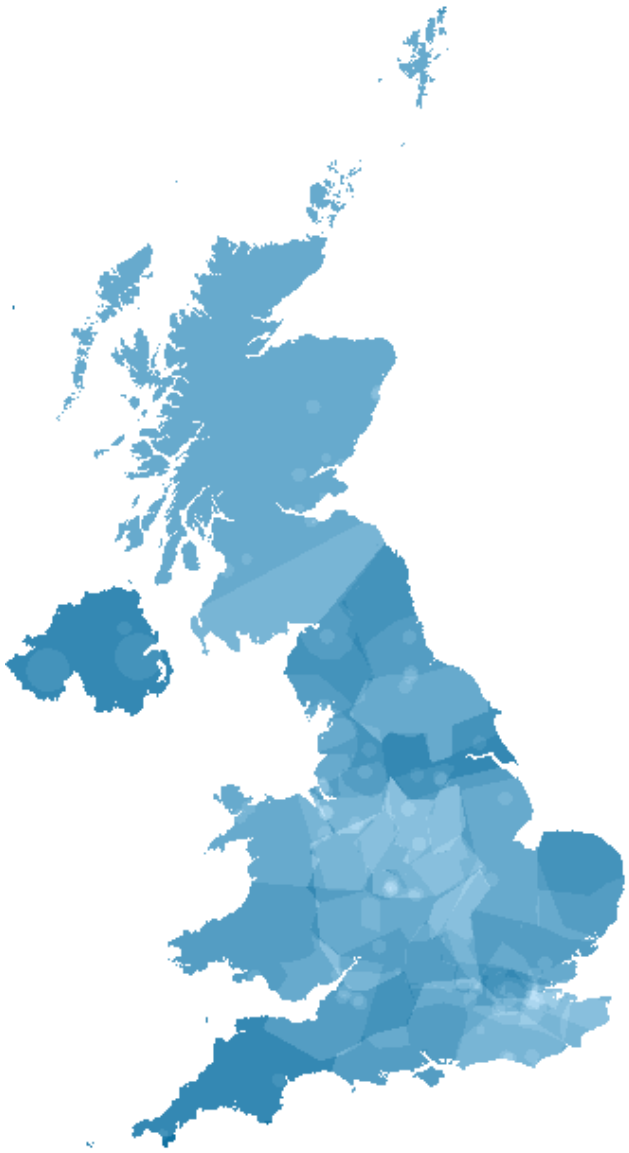

Figure 7.3: PMSE area definitions. Areas are denoted by different shading.

The model outputs were expressed in terms of fractional occupancy, defined as the proportion of spectrum supply necessary to support PMSE usage, including interstitial channels to avoid intermodulation products and adjacent channels. This comparison of demand with spectrum supply was undertaken for each of the bands for the three supply/demand scenarios. In addition, the same analysis was undertaken for the six spectrum blocks, for the two supply/demand scenarios based on 2014 demand.

The distribution of this fractional occupancy at each PMSE location was analysed for a sample period of one year. In addition, to obtain a complete geographic picture of the

peak spectrum occupancy in the sample year, calculations were also performed on a regular 0.5 km grid spanning the UK. This enabled peak fractional occupancy of spectrum to be viewed across the UK and, for the UHF Bands IV & V in particular, the levels of potentially unused spectrum within each geographic area.

7.2 PMSE locations analysis

For each PMSE location the channel occupancy was analysed for each band and block of bands. The list of assignments (and new assignments where appropriate) was assessed for geographic influence on that location[40]. Those assignments that affected the location were mapped onto a 365 day channel map for that location. The channels used were summed for each band and appropriate overhead factors applied to compensate for the need to avoid adjacent channels and intermodulation products.

This spectrum demand was divided by the spectrum supply at the location to determine the fractional occupancy for each of the 365 days. This information was presented in a variety of forms to gain insight into temporal and spatial loading of spectrum used for PMSE. Examples of these are shown in Figure 7.4, Figure 7.5 and Figure 7.6. This allowed us to identify the peak events, determine the background long term levels and to understand how many locations and assignment days would be affected by limiting the amount of spectrum available.

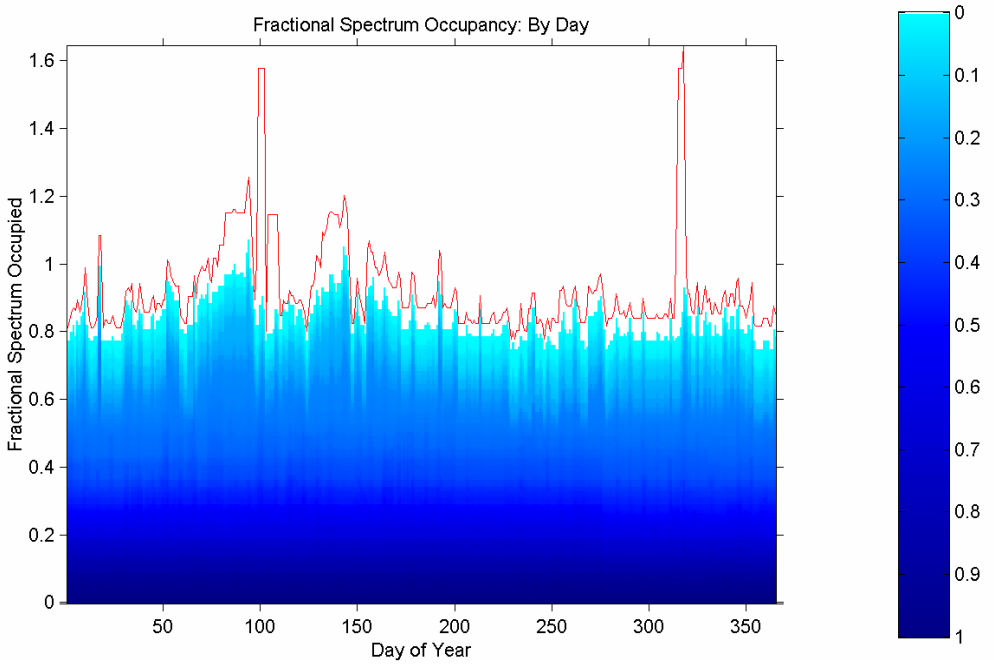

Figure 7.4: Distribution of fractional occupancy experienced on each day of the year. The red line is the peak fractional occupancy experienced at any PMSE location on that day. Values in excess of 1 indicate that demand exceeds supply. The graduated shading shows the proportion of locations that experience that level of fractional occupancy or greater.

[40] The location was considered to have the characteristics of existing (default) PMSE use at that location; for example, if the existing PMSE use at that location was indoors then the impact of other assignments was assumed to be further reduced by in-building attenuation. Hence PMSE locations that were indoors by default tended to have less demand than those that were outdoors.

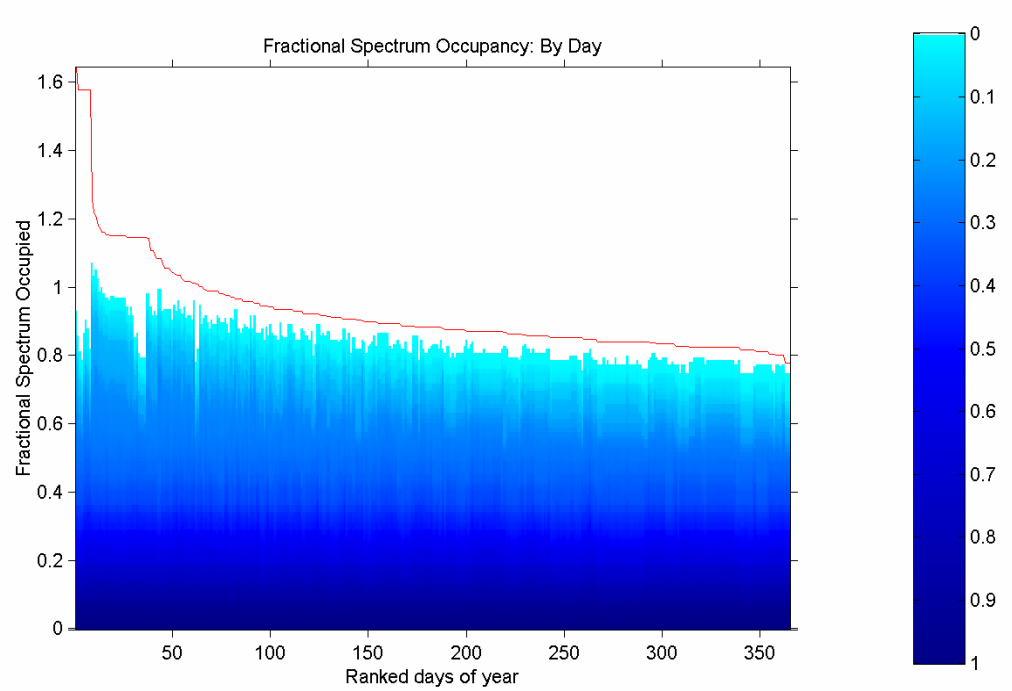

Figure 7.5: Distribution of fractional occupancy for days of the year ranked according to peak fractional occupancy. The red line is the peak fractional occupancy experienced at any PMSE location on that day. The graduated shading shows the proportion of locations that experience that level of fractional occupancy or greater.

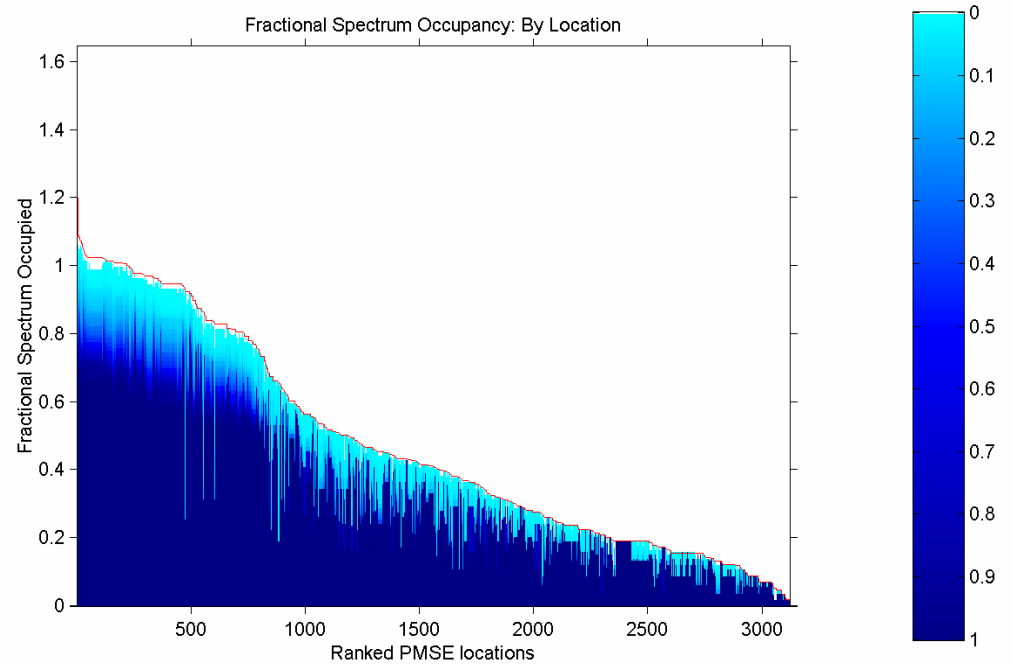

Figure 7.6: Distribution of fractional occupancy experienced at each PMSE location. The red line is the fractional occupancy experienced on the busiest day at that location. The graduated shading shows the proportion of days that experience that level of fractional occupancy or greater. The locations are ranked according to peak fractional occupancy to aid understanding of how widespread the peak loading is.

7.3 Geographic analysis

The PMSE locations analysis provided insights into the spectrum usage at PMSE locations and therefore provided an understanding of the spectrum required to support future PMSE usage. To appreciate how this translates into fractional occupancy across the UK similar calculations were undertaken for each pixel within a 0.5 km grid of locations across the UK.

The conditions at each grid location were assessed and the peak level of demand experienced during the year was determined as if it were a new outdoor PMSE location. The demand at each grid location was divided by the appropriate value of spectrum supply to derive the fractional occupancy.

The spectrum occupancy was plotted geographically with each pixel colour coded to indicate the level of fractional occupancy. To include the actual PMSE locations on the geographic plot, the fractional occupancy levels calculated from the PMSE locations analysis were used to overwrite the appropriate pixels on the geographic plot. The values appropriate to the PMSE locations were overwritten where higher than the underlying pixel data, at all pixels within a 5 km radius of the pixel in which the location lies[41].

An example of a geographic coverage plot shown in Figure 7.7.

[41] If only a single grid location was overwritten then its impact would be very difficult to discern on a nationwide plot, therefore for each PMSE location, grid locations were overwritten (where higher than underlying values) over a radius of 5 km. This allowed a more practical interpretation of geographic impact.

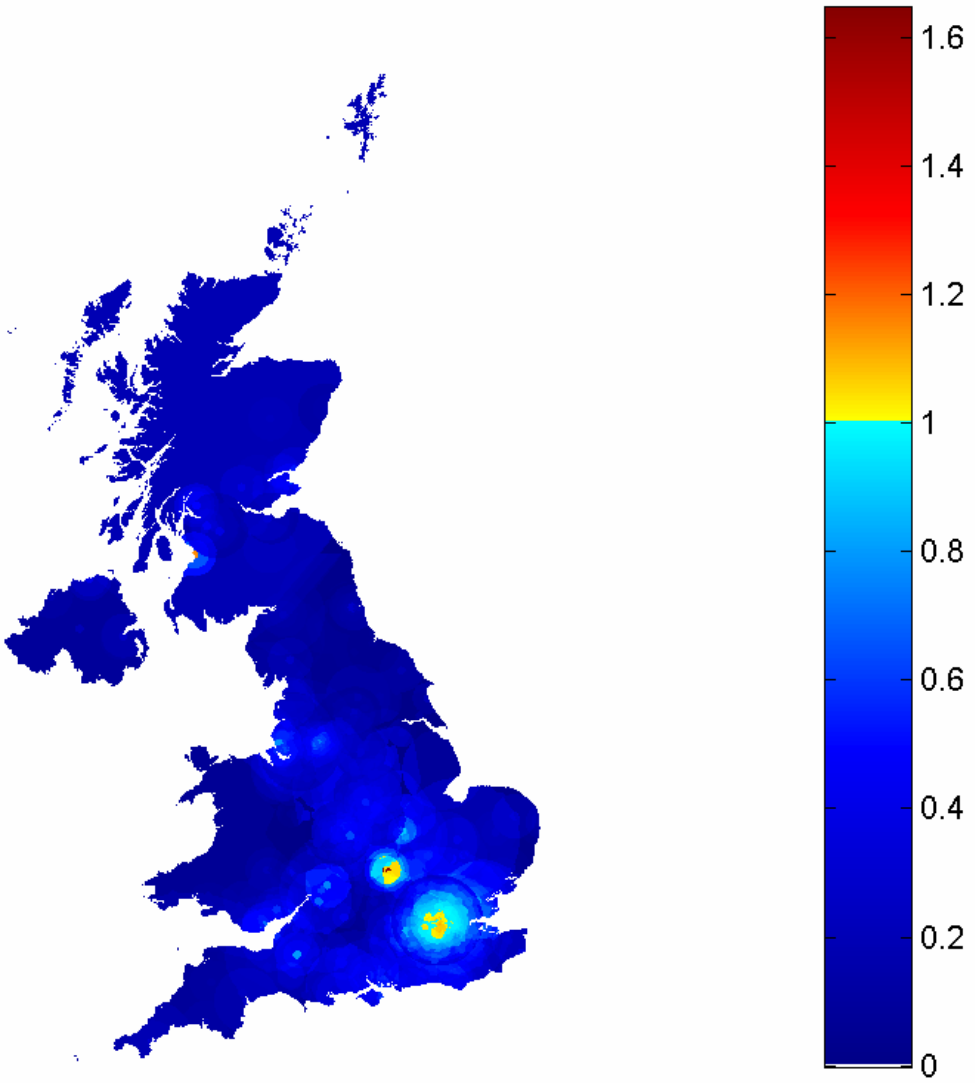

Figure 7.7: Geographic plot of fractional occupancy of PMSE spectrum supply. Each pixel is colour coded to indicate the fractional occupancy at that location. In this example high levels can be seen in the Greater London area, and the highest value of fractional occupancy is at Silverstone Motor Racing Circuit.

To illustrate areas of spectrum shortage for blocks of bands, the spectrum supply was calculated by adding the supply for each of its constituent bands. The demand was calculated by adding together the spectrum demand on each of the 365 days, then choosing the highest overall spectrum demand to represent the grid location.

There is particular interest in the difference between spectrum supply and demand for the UHF Bands IV & V, since this represents spectrum potentially available for additional multiplexes or other uses. This was calculated and presented in a geographic plot for each DSO supply scenario colour coded according to the number of spare 8MHz increments that might be available at each pixel for other purposes. An example of this geographic plot is shown in Figure 7.8.

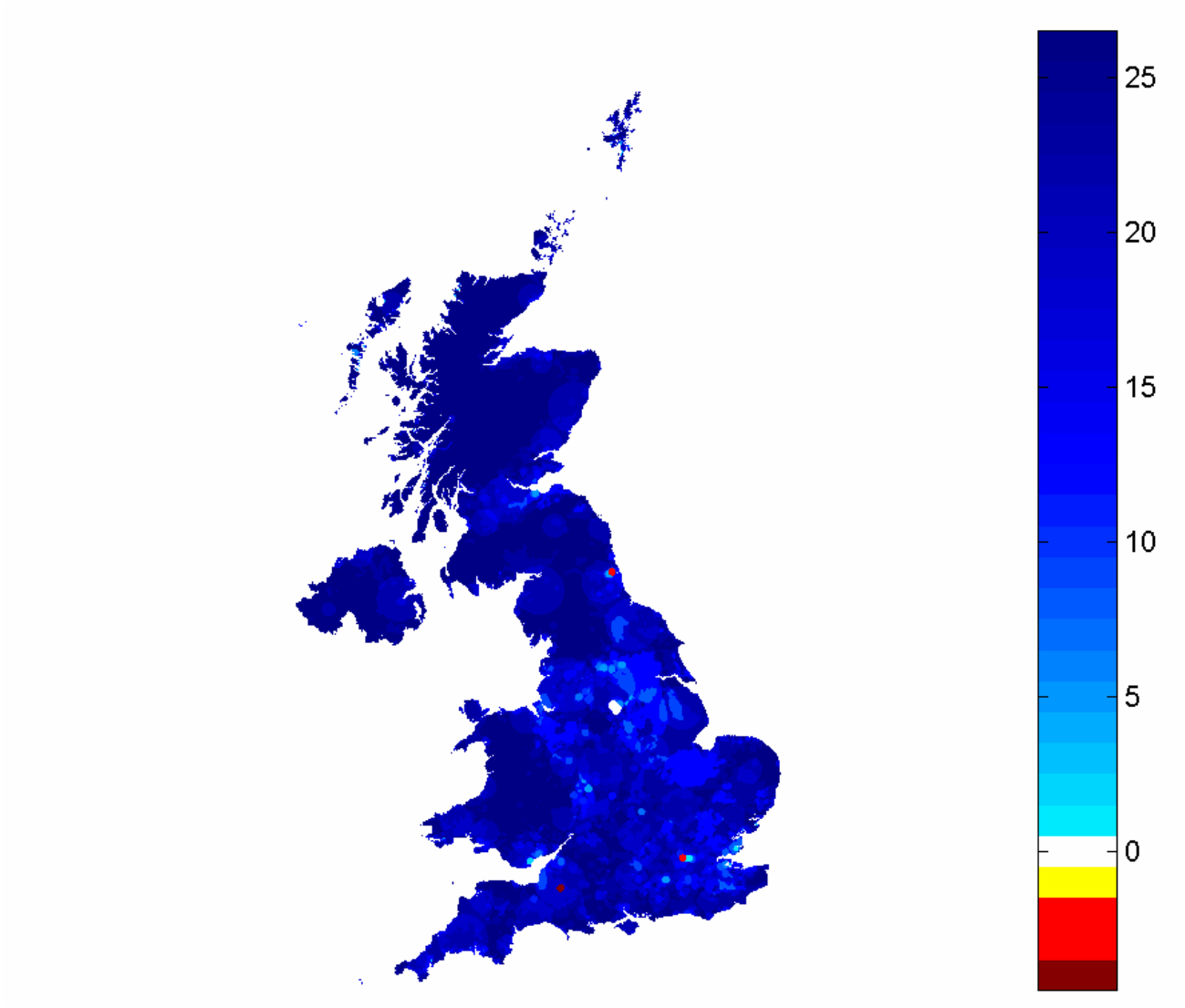

Figure 7.8: Geographic plot in the UK showing the number of unused interleaved channels. In the above example, the number of used channels varies significantly, there is a negative 'surplus' (i.e. a deficit) of unused channels at Glastonbury, London and Newcastle, with up to 26 spare channels in areas away from the main population centres. There is no interleaved capacity available in an area of the Midlands.

However, it should be noted that the calculated number of unused interleaved channels is based on further PMSE type usage and susceptibility. If other applications were considered for this spectrum then the compatibility between the systems would need to be considered in more detail to more accurately define the areas.

8 BALANCE OF SUPPLY AND DEMAND FOR SPECTRUM

In this chapter we present a summary of the results focussing on where there are likely to be spectrum shortages in the future.

The bands were arranged in 6 blocks of substitutable spectrum, and the results are discussed for each of these blocks. Our demand forecast was based upon actual use in each band in 2004/5. The advantage of discussing the results in terms of blocks is that we can then consider the demand being distributed across substitutable spectrum, which is a more realistic response should congestion appear in any given band. This would require equipment to be able to operate in uncongested bands in the block or to be sufficiently flexible to span bands within a block.

8.1 Block 1 – Band I and Low Band

Band I is lightly loaded in 2004, peaking at around 70% fractional occupancy due to heavy use at the British Golf Open Championship at Troon. In 2014 Band I is expected to undergo little growth, but constraints in supply due to the introduction of community radio are expected to raise the peak fractional occupancy to just over 100%. In contrast, Low Band is already heavily used with a fractional occupancy just exceeding 100%. With growth this is expected to reach 114% in 2014.

Analysis of Block 1 assumes that substitution is possible between Band I and Low Band. Although both bands are forecast to have peak 2014 fractional occupancies greater than 100% on an individual basis, these peaks do not occur on the same day at the same location. Therefore analysis of Block 1 resulted in an overall fractional occupancy of just less than 100%. Block 1 is dominated by Band I which occupies 94% of the spectrum in 2004, therefore its occupancy distribution is similar to Band I.

Consequently we do not believe there will be shortages of spectrum in Block 1 provided new PMSE equipment is appropriate for band availability in its area of intended use.

8.2 Block 2 – High Band, VHF Band III (non-RM), UHF1 and UHF2

All of the bands used in Block 2 exhibited peaks that exceeded a fractional occupancy of 100% for the demand and supply scenarios considered, and all of these bands needed out of band spectrum even to meet the 2004 demand. The bands are dominated by short term events as can be seen in Figure 8.1 for the UHF 2 band (which accounts for around 54% of the block).

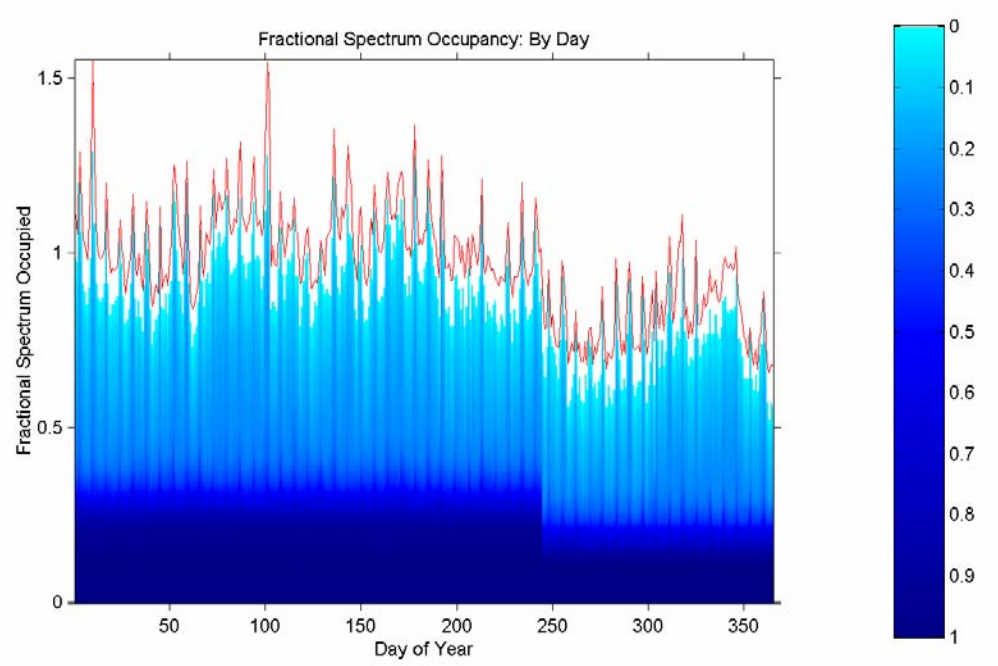

Figure 8.1: Fractional occupancy by day of year for the UHF 2 band based on 2014 supply and 2014 demand. The peak (plotted red line) is the highest fractional occupancy observed on that day at any PMSE location in the UK.

Grouping the spectrum into a block reduces the need to access out of band spectrum for some peak events, since the peak events rarely coincide in time and location. As depicted by the flatter distribution curves the block more efficiently utilises the available spectrum. This is shown in Figure 8.2.

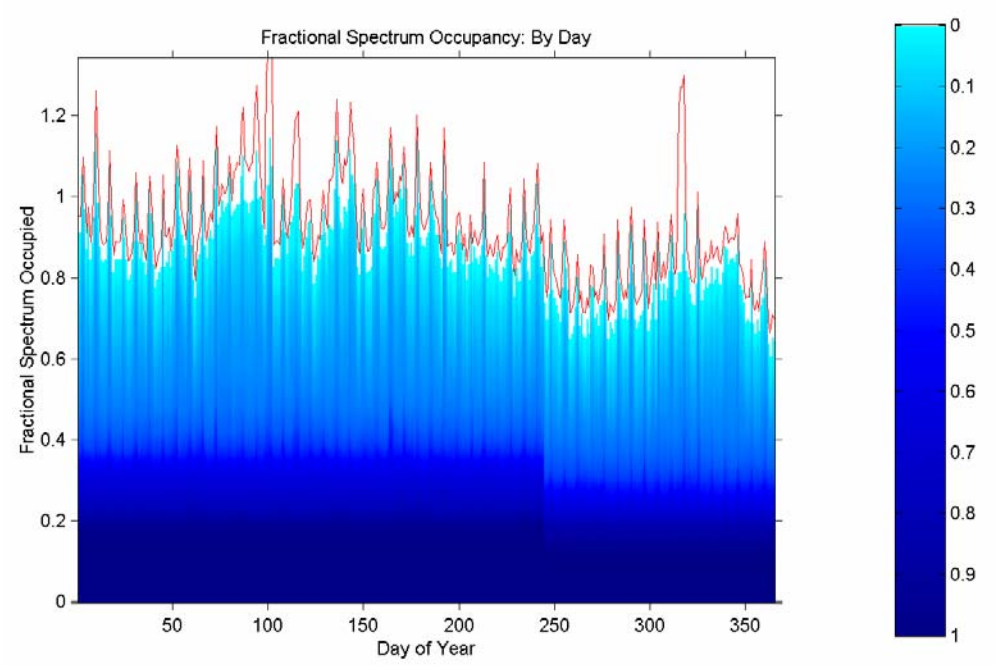

Figure 8.2: Fractional occupancy by day of year for Block 2 based on 2014 supply and 2014 demand.

However the peak fractional occupancy is forecast to be 135% of spectrum supply in 2014. As can be seen in Figure 8.2, peak fractional occupancy in 2014 is likely to be above 80% for most of the year at some PMSE locations. Our results predicted that demand would exceed supply on approximately 27% of days, at 14% of PMSE locations. The fractional occupancy across the UK is shown in Figure 8.3.

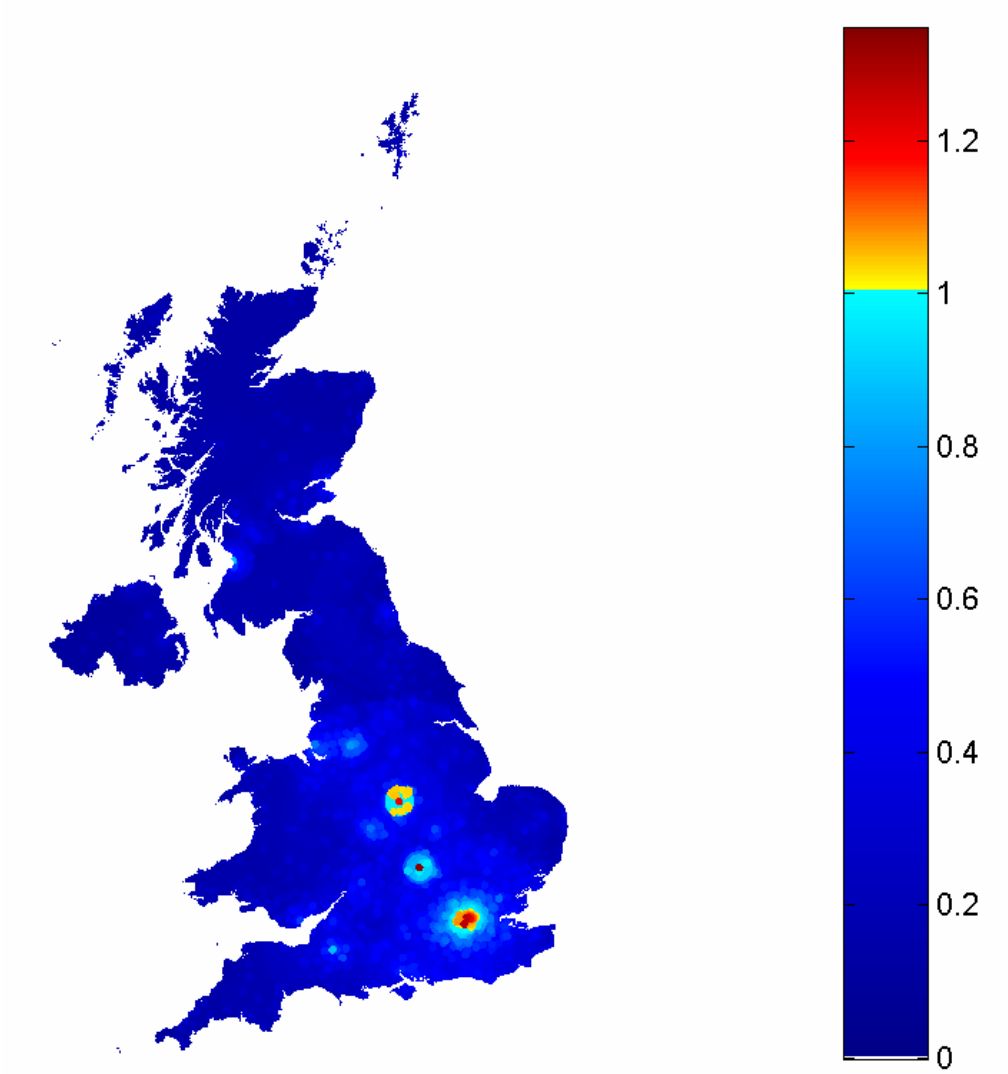

Figure 8.3: Fractional Occupancy across the UK for Block 2 based on 2014 supply and 2014 demand. At each location in the UK, the peak fractional occupancy experienced during the year is plotted. Fractional occupancy values corresponding to PMSE locations are expanded to a radius of 5 km to enhance visibility.

It can be seen from Figure 8.3 that supply is exceeded in only three parts of the country: Central London, Silverstone and Donnington Park motor racing circuit in Derbyshire. Demand is likely to be satisfied by future supply in the remainder of the UK.

Consequently we believe that there will be a shortage of spectrum in Block 2 in some locations. The anticipated supply of spectrum is around 6.1MHz in 2014. Up to a further 2.1MHz is likely to be required at these peak locations to satisfy PMSE demand ideally within a similar frequency range (100 to 470MHz).

8.3 Block 3 – VHF Band III (RM), UHF Bands IV & V and UHF Channel 69

8.3.1 Analysis of bands used for TV

Of the spectrum currently used for PMSE, the UHF Bands IV & V are currently used for broadcast TV. The majority of the PMSE demand in this spectrum is primarily from radio microphones. These are highly localised with very high occupancy at some locations falling to very low levels at most locations. The demand calculations for UHF Bands IV & V differ slightly from the other bands in that the low power indoor assignments at PMSE locations are able to use co-channel digital multiplex frequencies. Therefore it is only the excess indoor demand (that cannot be accommodated within the set of co-channels), that is additional to outdoor use contributing to the overall occupancy calculations.

At outdoor PMSE locations the demand is characterised by a background level of long term assignments at spot locations which is supplemented by additional assignments on a short term basis. At indoor PMSE locations the demand is generally long term and there is substantial overspill from low power indoor assignments that are not able to be wholly accommodated within the non-interleaved channels. Hence the peak occupancy by day of the year shows a consistent level of long term indoor usage, punctuated by slightly higher peaks which are predominantly outdoor events. This is shown in Figure 8.4.

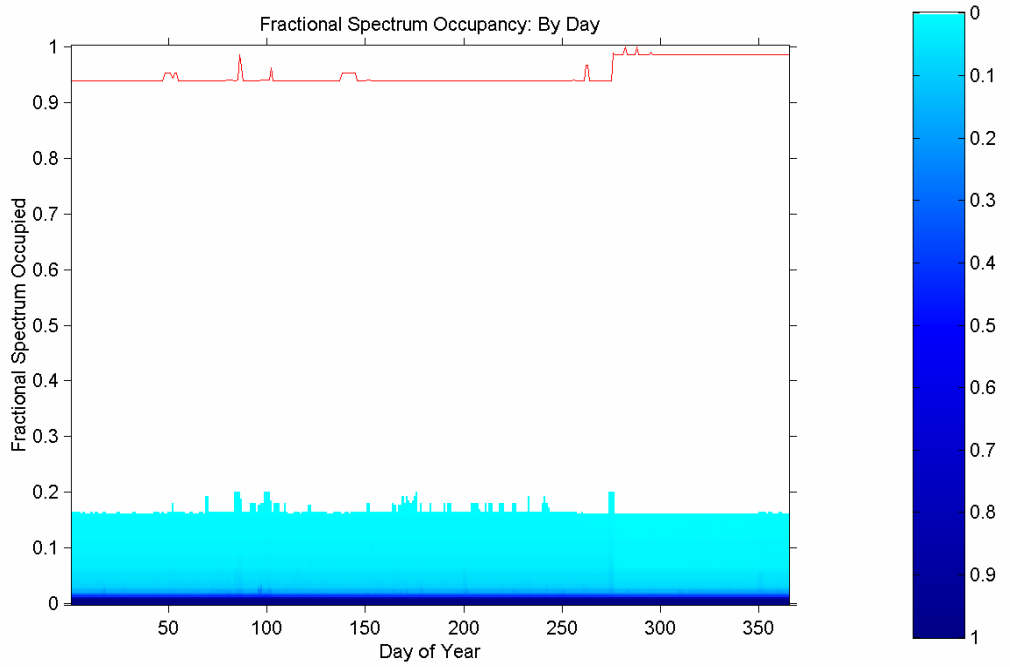

Figure 8.4: Fractional occupancy by day of year for UHF Bands IV & V based on 2004 supply and 2004 demand. The peak on most days is dominated by long term indoor assignments at London television studios. The isolated slightly higher peaks are short term assignments at major outdoor events. The shading below the plotted peak shows that there are very few locations having the peak levels on a given day.

The peak fractional occupancy in 2004 is at a level of 98% which was at the Glastonbury Festival in Somerset. The high levels of indoor use are contributed by the main London BBC and ITV studios.

We found that the demand forecast for 2014 would exceed 2004 supply at some PMSE locations. However with the baseline DSO scenario (exclusive use of 2014 retained

interleaved capacity with 2014 demand), the capacity of the retained interleaved spectrum available is expected to increase in many areas, returning general occupancy levels to similar, or slightly lower, levels than today. Comparison of Figure 8.5 with Figure 8.4 demonstrates this. Further information on the impact of DSO is provided in Chapter 9.

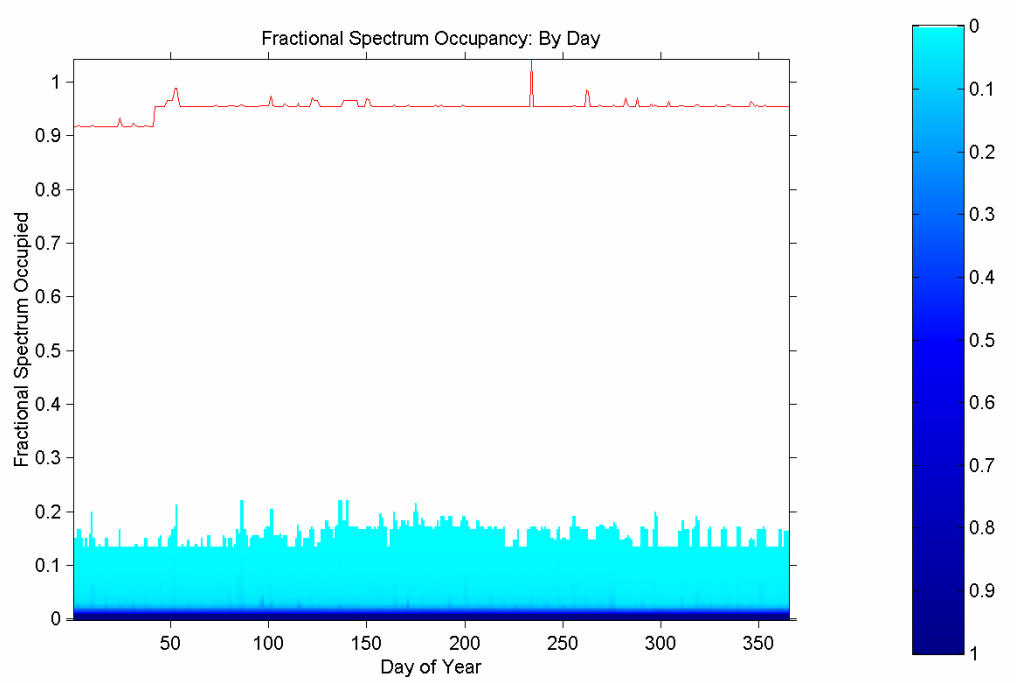

Figure 8.5: Fractional occupancy by day of year for UHF Bands IV & V based on 2014 supply and 2014 demand.

All peaks in 2014 are below the fractional occupancy of 100% except a single peak, which is at a level of 104%. This peak corresponds to predicted demand for the Glastonbury Festival.

The demand is highly concentrated at particular locations and this is illustrated when the fractional occupancy is plotted as a function of PMSE location as shown in Figure 8.6.

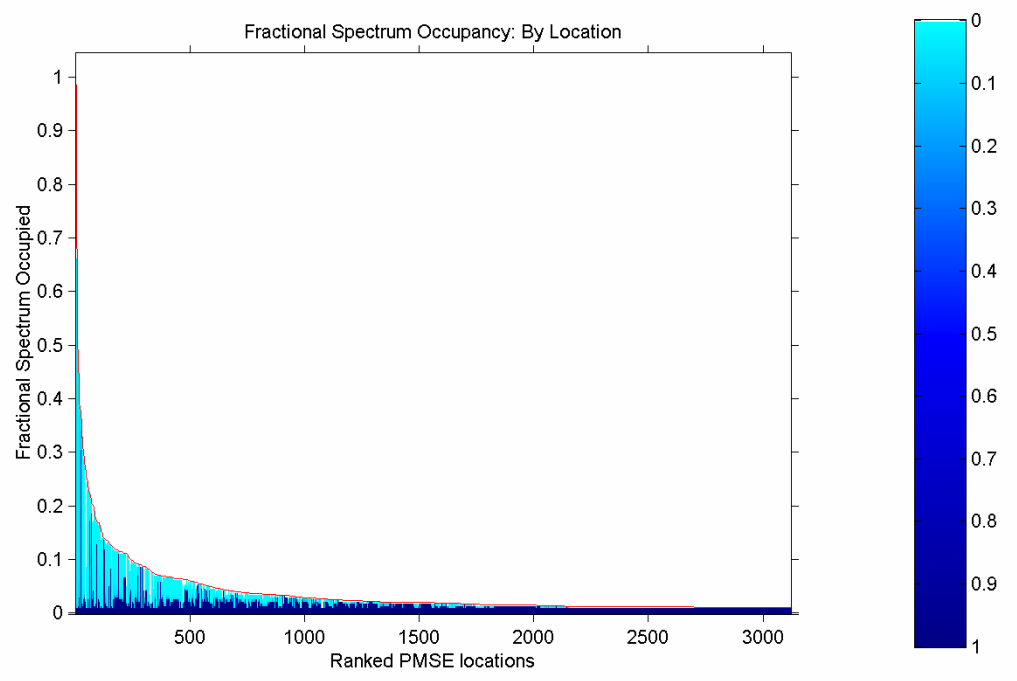

Figure 8.6: Fractional occupancy by PMSE location for UHF Bands IV & V based on 2014 supply and 2014 demand. The 3151 PMSE locations are ranked in order of fractional occupancy.

It can be seen from Figure 8.6 that more than 97% of PMSE locations require 20% of the anticipated spectrum supply of interleaved channels, or less. When viewed on a geographic basis across the UK as shown in Figure 8.7, it can be seen that the usage is concentrated around just a few locations.

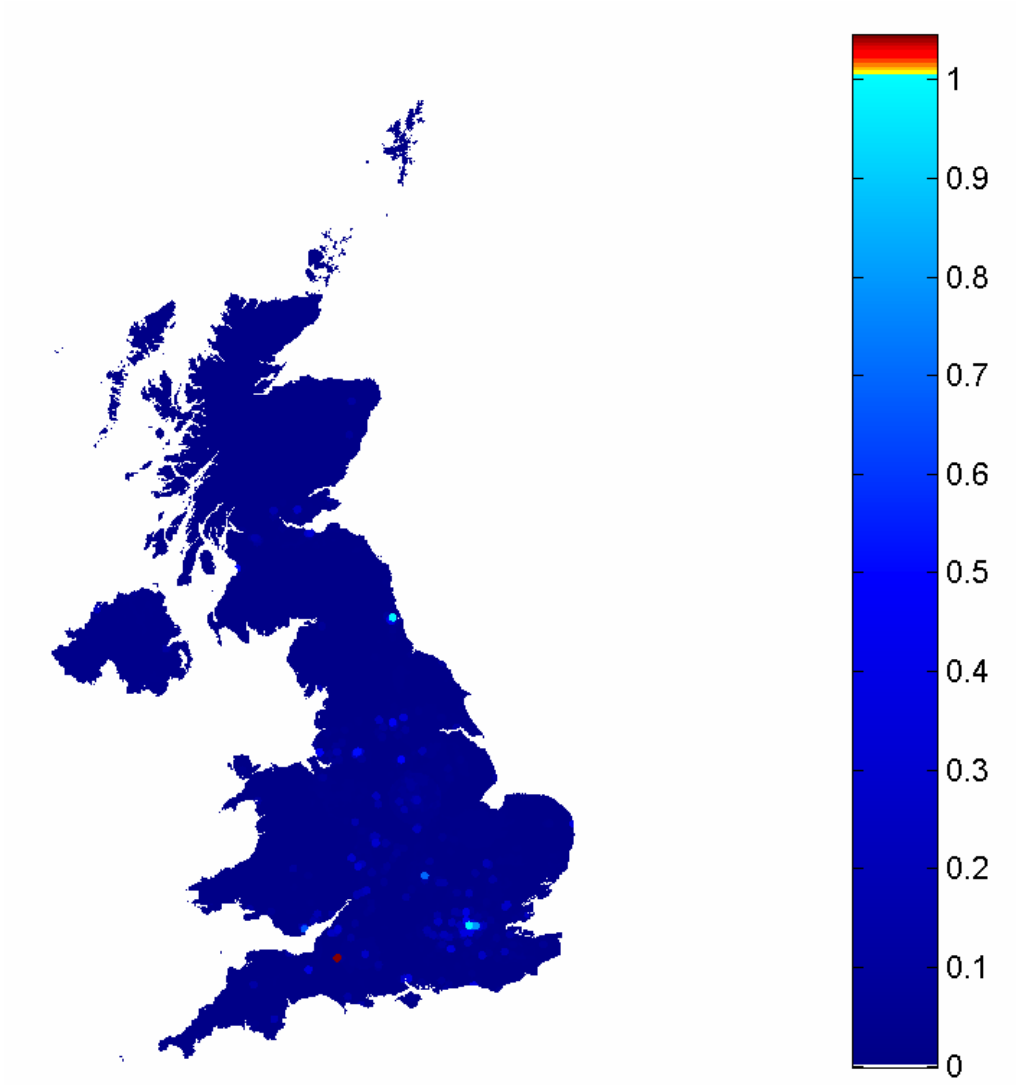

Figure 8.7: Fractional occupancy across the UK for UHF Bands IV & V based on 2014 supply and 2014 demand.

In addition to the peak occupancy at Glastonbury, high levels of occupancy can be observed in Figure 8.7 at Newcastle and Central London. The London locations are the BBC Studios at Wood Lane and the London Television Centre, each of which has high level of indoor studio usage.

8.3.2 Analysis of substitutable spectrum in Block 3

The VHF Band III radio microphone spectrum is regarded as full in many locations and this is borne out by our analysis. The peak fractional occupancy is 100% and this occurs at around 4.5% of the PMSE locations. In 2014, we expect significant growth for radio microphone usage (~30%) and a reduction of 2014 supply from 3.8MHz to 3.2MHz[42]. This exacerbates the scale of overload in the band, with fractional occupancy peaking at 158% as shown in Figure 8.8.

[42] Note, we understand that alternative channels within Band III will now be available resulting in no reduction in radio microphone capacity in this band.

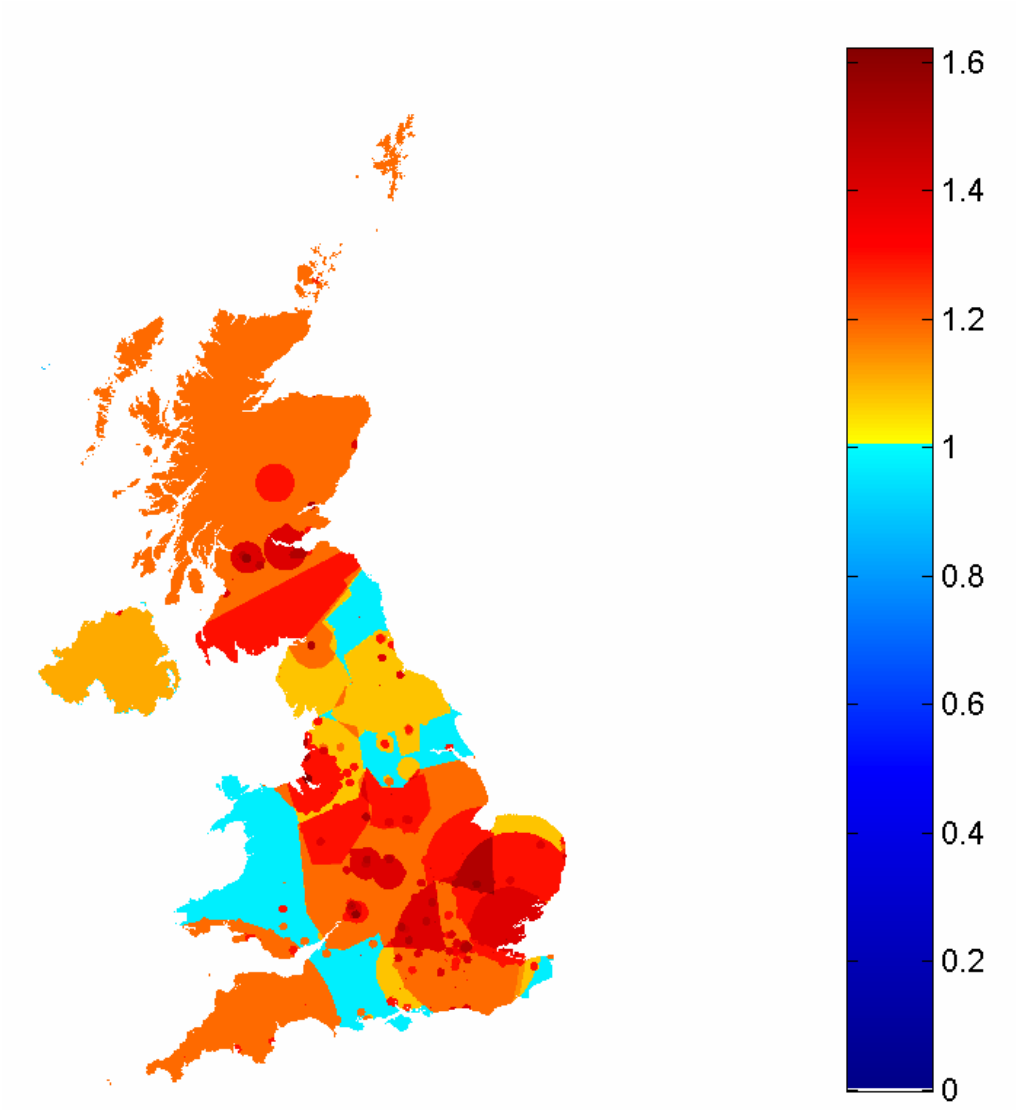

Figure 8.8: Fractional occupancy across the UK for VHF Band III radio microphone spectrum based on 2014 supply and 2014 demand.

Demand across most of the country will result in a fractional occupancy of greater than 100% with particularly high levels in Lancashire, The Midlands, East Anglia, the South East of England, Central Scotland and the border regions. In addition, most cities will experience shortages in this band.

Like UHF Bands IV & V, Channel 69 has heavy usage at a few of the PMSE locations but is sparsely used elsewhere. Main areas of use are theatres and studios, although there is also significant use at outdoor events. The band is full at around 160 of the PMSE locations, the majority of which are indoor locations such as theatres and studios. The outdoor locations are mainly golf courses and cricket grounds. These locations are distributed across the UK in cities and major towns.

The fractional occupancy across the UK for UHF Channel 69, in 2004, is illustrated in Figure 8.9.

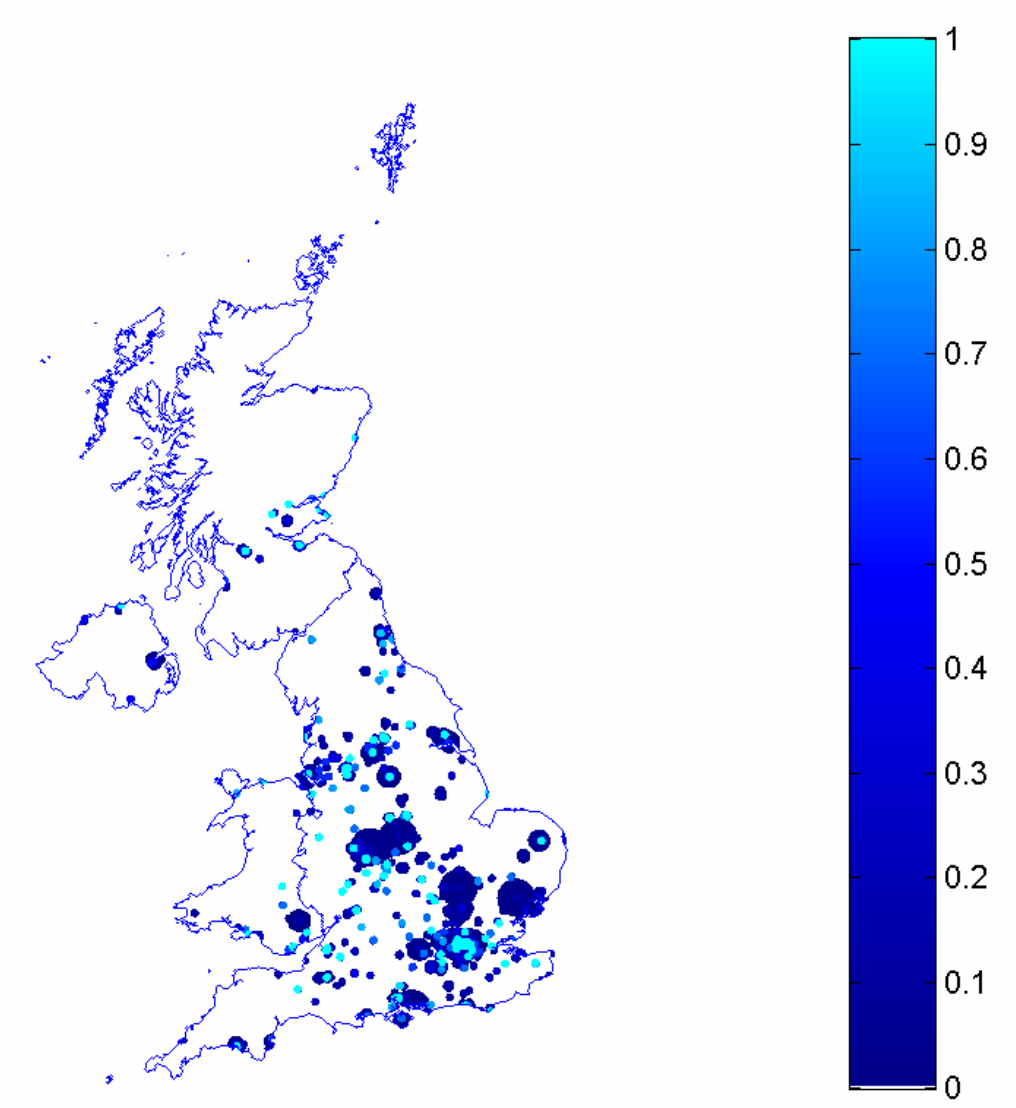

Figure 8.9: Fractional occupancy across the UK for UHF Channel 69 based on 2004 supply and 2004 demand.

Note that we have assumed that new assignments predicted for 2014 in Channel 69 are accommodated within UHF Bands IV & V, therefore the fractional occupancy levels for 2014 are the same as those for 2004. The impact of this growth on overall occupancy within the block is considered below.

8.3.3 Analysis of combined bands in Block 3

In practice, the radio microphone usage predicted for UHF Bands IV & V may also use some channels in VHF Band III and UHF Channel 69. Although both of these bands are currently effectively fully utilised during peak periods at some locations, they are substitute bands for the UHF Bands IV & V outside these periods. To determine the actual occupancy of UHF Bands IV & V in 2014, we assumed that the three bands were fully substitutable and the supply and demand was aggregated across the three bands.

From this analysis, we found that there was sufficient spare spectrum in VHF Band III and UHF Channel 69 at Glastonbury to accommodate the peak demand and reduce fractional occupancy to slightly less than 100%. This is shown in Figure 8.10 for Block 3.

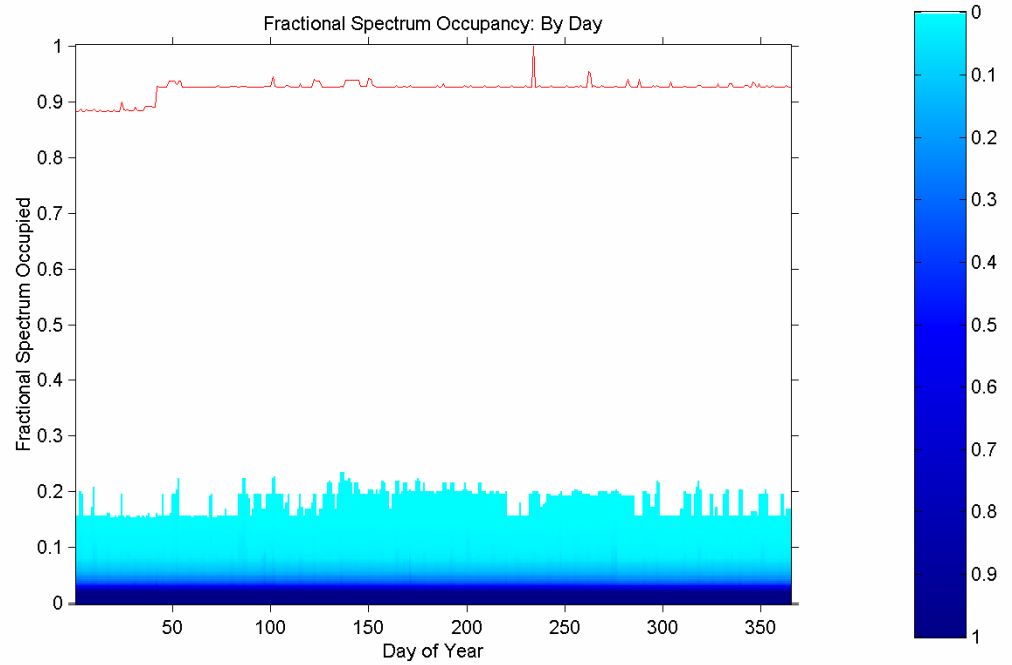

Figure 8.10: Fractional occupancy by day of year for Block 3 based on 2014 supply and 2014 demand. Block 3 comprises the VHF Band III (radio microphones), UHF Bands IV & V and UHF Channel 69.

Assuming that VHF Band III and UHF Channel 69 would be filled in preference to UHF Bands IV & V, we were able to predict that the amount of unused interleaved spectrum that might be available for additional DTT multiplexes or other compatible uses. This spare channel capacity is plotted in Figure 8.11.

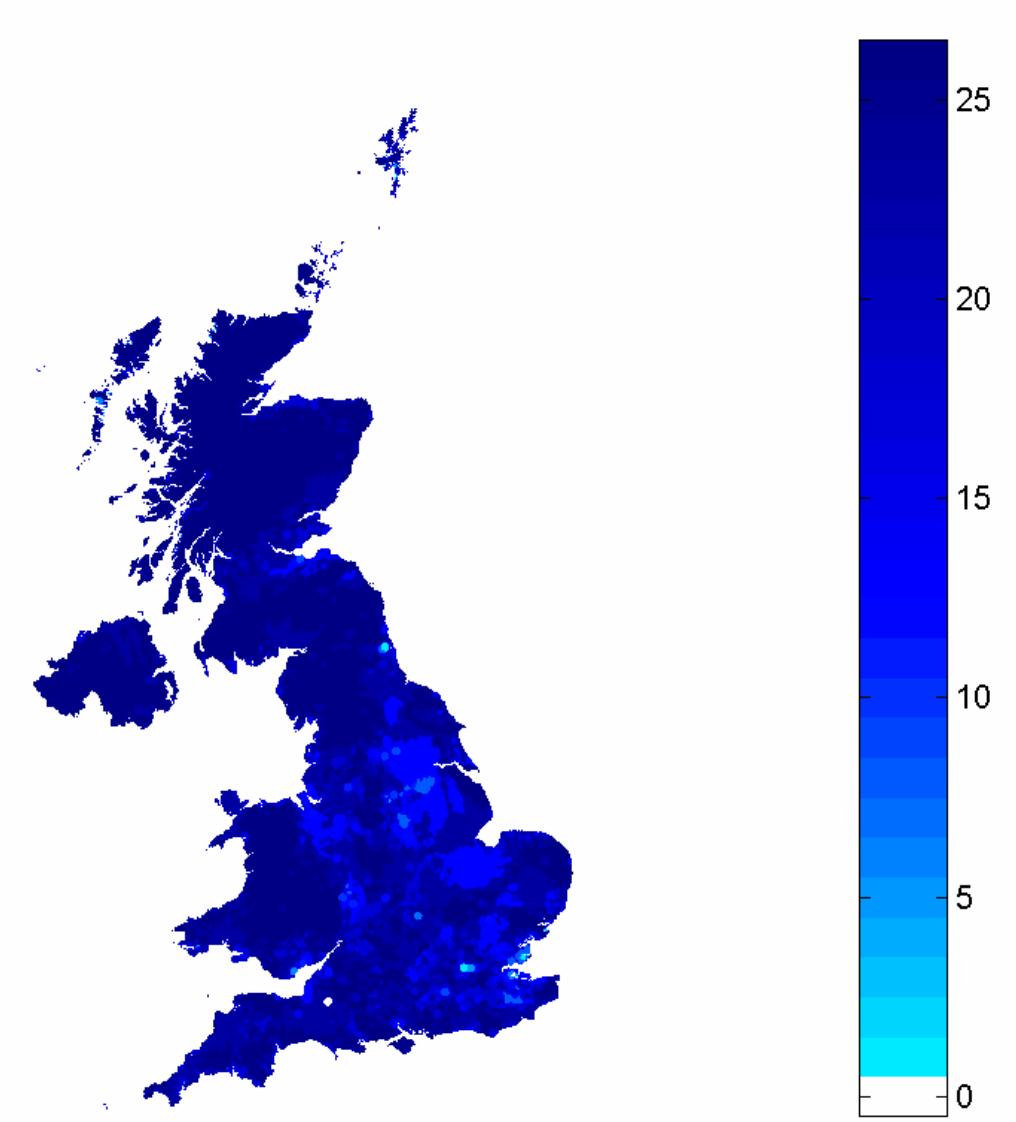

Figure 8.11: Unused interleaved channels in the UHF Bands IV & V in the UK based on 2014 supply and 2014 demand.

Although, Glastonbury is predicted to have no spare spectrum, it can be seen from Figure 8.11 that the majority of heavily populated areas of the UK have significant availability of unused interleaved spectrum. A notable exception to this is Central London which has only a single spare interleaved channel.

8.4 Block 4 – The 1.5GHz band

The 1.5GHz band is lightly loaded in 2004 with peak fractional occupancy of around 17%. Generally, these are annual assignments to provide audio links in support of radio broadcasting, although there are also a few short term assignments (such as for the 'One Big Weekend' concert at Perry Barr Stadium in Birmingham). They are few in number but well distributed across the UK.

The few assignments are all spot assignments but a large number of PMSE locations are affected by interference in London and Birmingham.

The peak fractional occupancy increases to 25% in 2014 based on 2004 supply, but rises to 33% in 2014 due to spectrum supply being reduced. However, Block 4 has low levels of utilisation overall.

8.5 Block 5 – 2, 3.5, 5, 7, 8 and 10GHz bands

The spectrum in these bands is heavily used for video links and at some locations spectrum supply is already greatly exceeded, with fractional occupancies of these bands varying between 100% and 200%. The surplus demand has been accommodated historically using out of band spectrum. The usage comprises a mix of long term and short term assignments as shown in Figure 8.12 for the 2GHz band which is typical for the block.

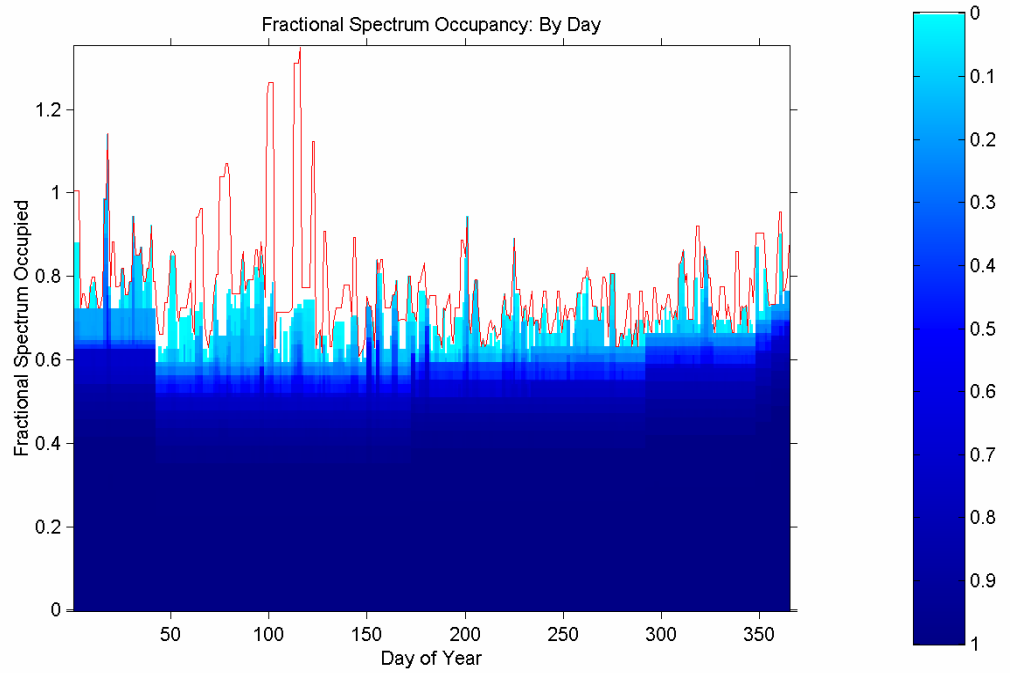

Figure 8.12: Fractional occupancy by day of year for the 2GHz band based on 2004 supply and 2004 demand

The peak fractional occupancy of 135% was at Donnington Park motor racing circuit for the World Superbike Championship, but there was also high demand at Ascot, Aintree, Brands Hatch and Silverstone. There is a high level of annual assignments which account for around 50% of the spectrum occupancy and the demand is well distributed across all the PMSE locations. Overall performance of Block 5 is similar in shape to the 2GHz band which is the largest of the bands making up the block.

We have forecast high growth of 100% for video links and this is reflected in the results for Block 5 in 2014. However there is a benefit in interleaving the short term assignments and the aggregation of supply and demand has resulted in higher average utilisation levels of the spectrum. This is shown in Figure 8.13.

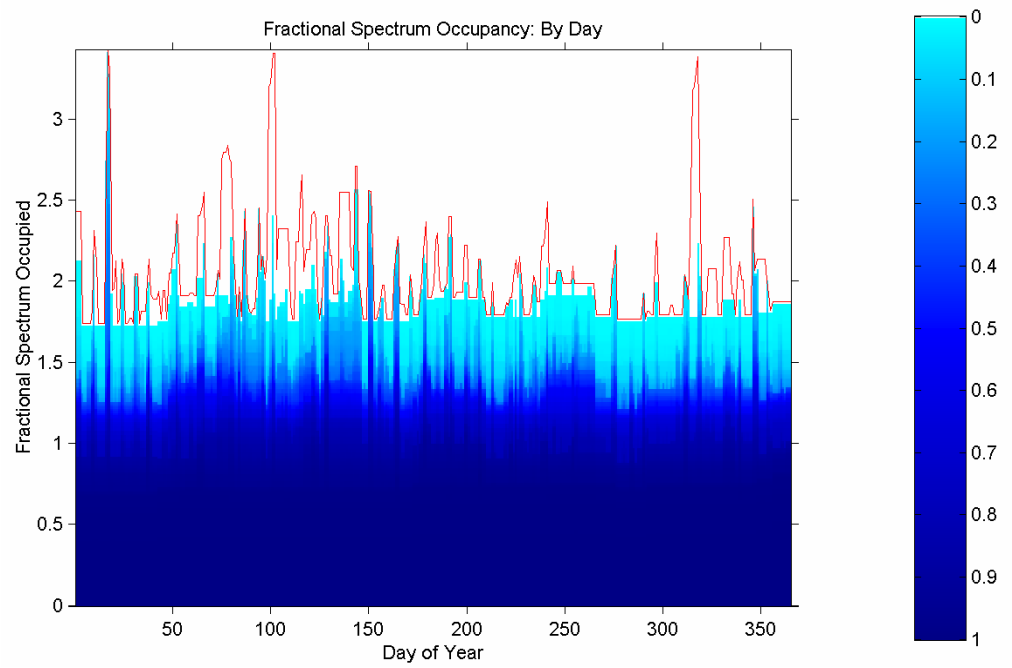

Figure 8.13: Fractional occupancy by day of year for Block 5 based on 2014 supply and 2014 demand.

In 2014 and based on supply in 2014, fractional occupancy is 350% and the demand exceeds supply over the vast majority of the UK as shown in Figure 8.14.

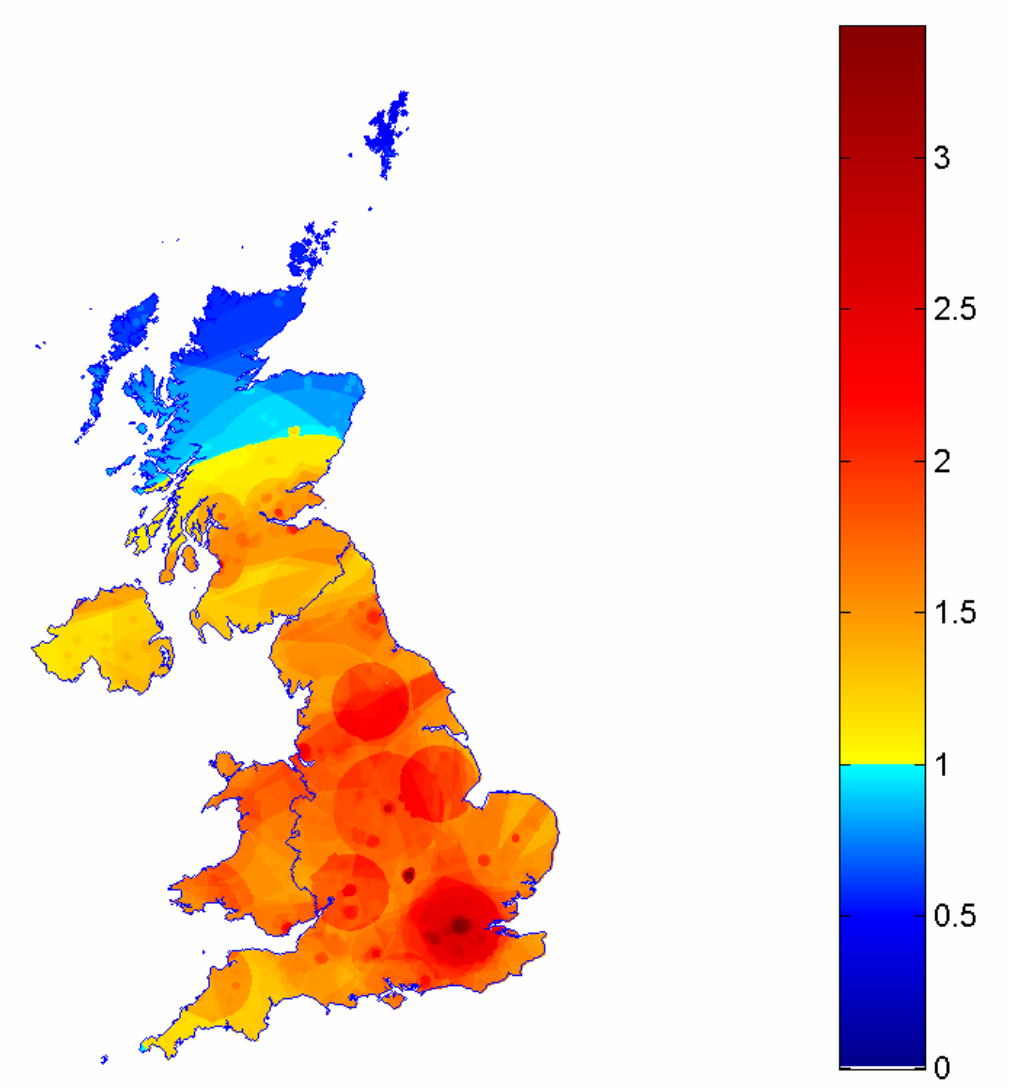

Figure 8.14: Fractional occupancy across the UK for Block 5 based on 2014 supply and 2014 demand.

Overall, we forecast that there will be substantial shortages of spectrum in the range 2 to 10GHz arising from the combination of the release of spectrum for other purposes and increasing use of video links and digital transmission. With predicted supply being around 1.2GHz for 2014, access to a further 3.1GHz would need to be available if the forecast PMSE demand is to be fully satisfied.

8.6 Block 6 – 11, 12, 24 and 48GHz bands

The constituent bands in Block 6 are primarily used for short range video links. Of the 4 bands only the 12GHz band has significant use at present. It is used extensively across much of the UK for links of short range and there are a few longer range links in southern England. The fractional occupancy peaks at 88% in Central London as shown in Figure 8.15.

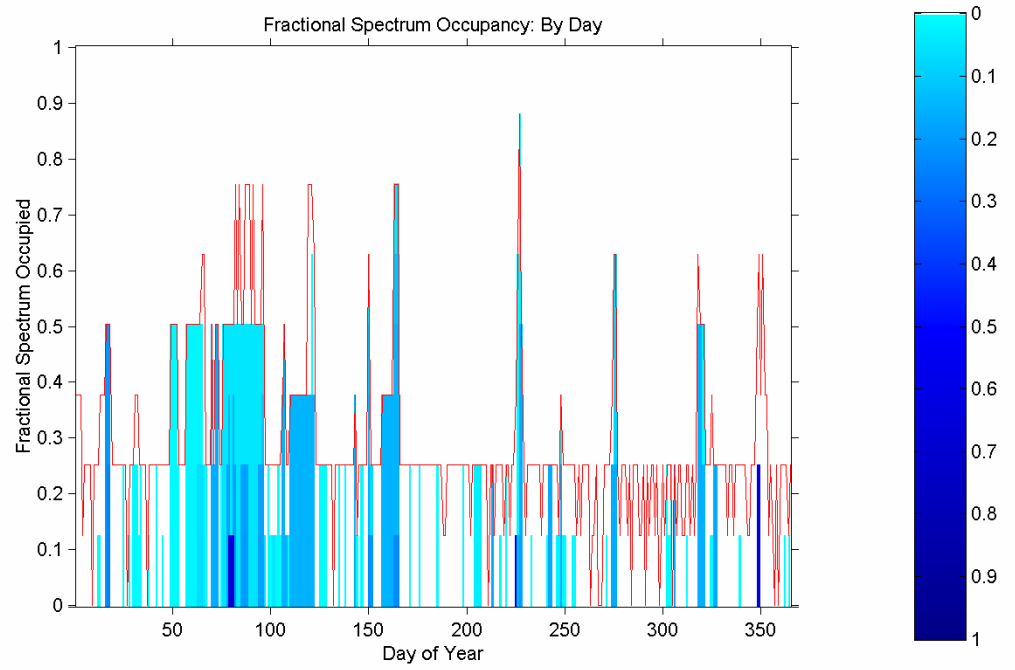

Figure 8.15: Fractional occupancy by day of year for the 12GHz band based on 2004 supply and 2004 demand.

The peak usage is due to outside broadcast coverage at the Festival of Remembrance at the Royal Albert Hall; its interference increases the effective occupancy at around 40 PMSE locations across Central London. In the other bands fractional occupancy is much lower with only two assignments in total. Therefore there is substantial spare capacity in these bands. In 2014, the demand is forecast to more than double in the 12GHz band which results in a fractional occupancy of 250% in this band. The geographical distribution of the peak fractional occupancy in the 12GHz band in 2014 is shown in Figure 8.16, and demonstrates peak fractional occupancy exceeding 100% in London and other metropolitan areas and at sports venues.

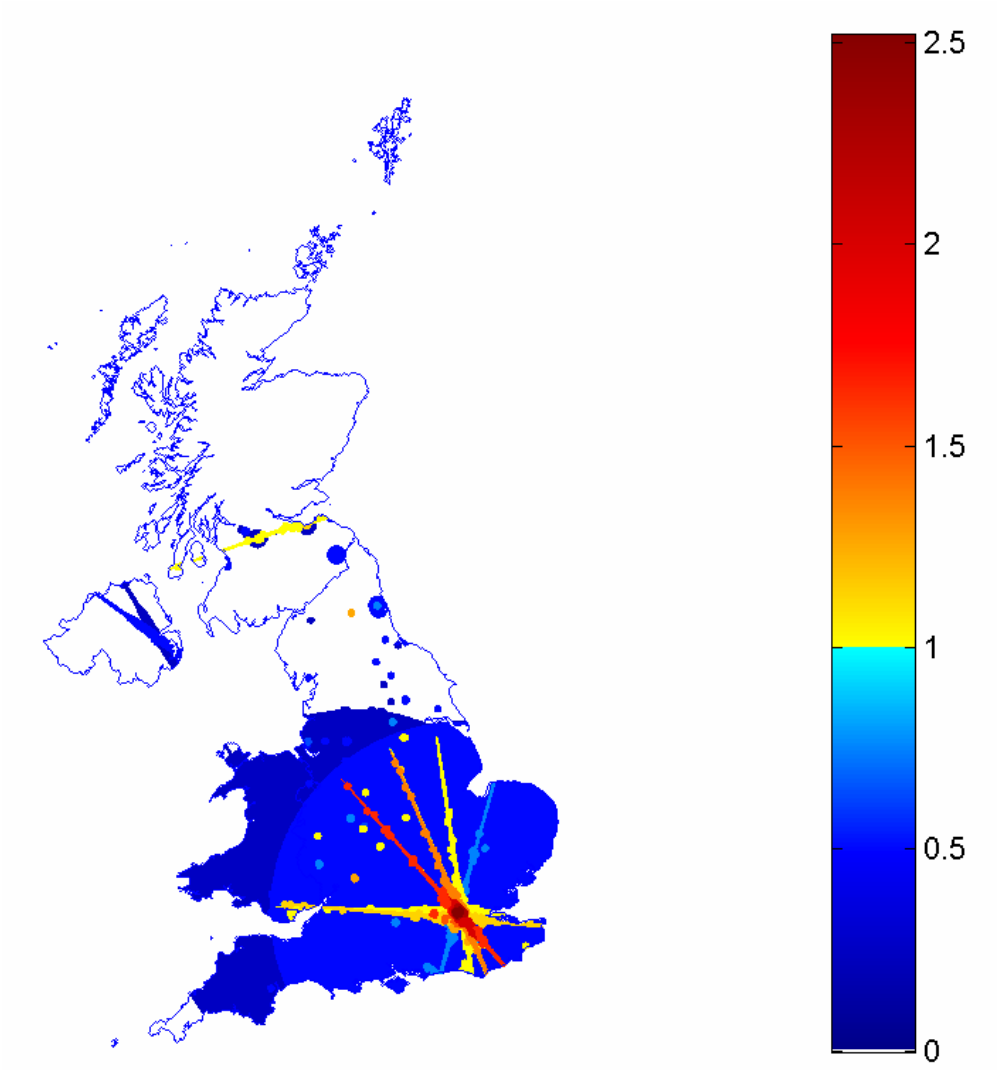

Figure 8.16: Fractional occupancy across the UK for Block 6 based on 2014 supply and 2014 demand. The white areas correspond to zero PMSE usage.

However, the capacity available in the other bands is sufficient to compensate for this. The distribution of fractional occupancy of the block in 2014 is shown in Figure 8.17.

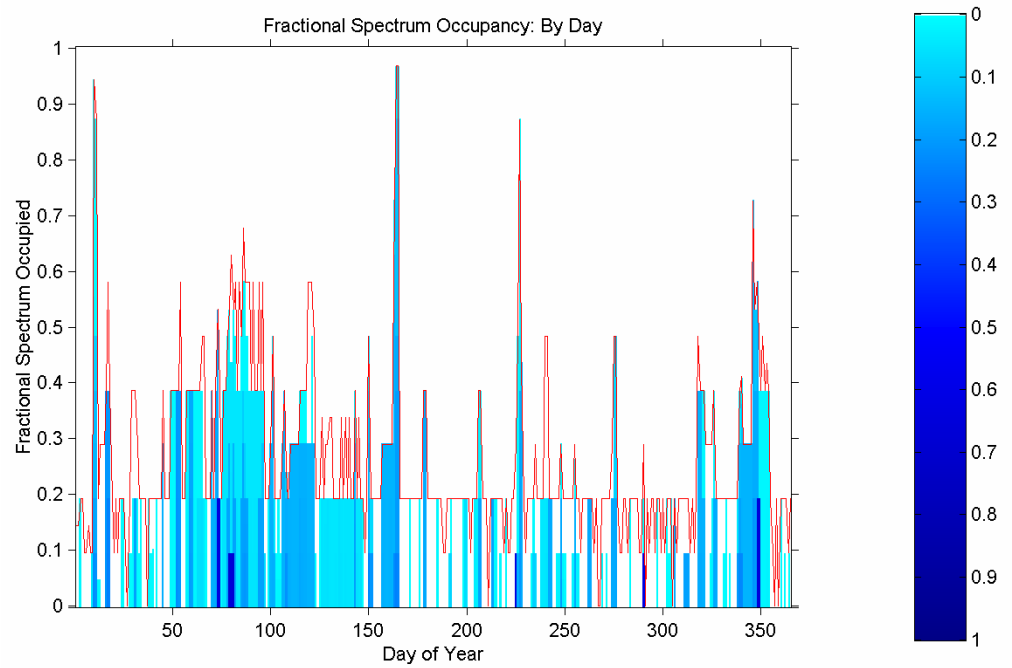

Figure 8.17: Fractional occupancy by day of year for Block 6 based on 2014 supply and 2014 demand.

The peak fractional occupancy in Block 6 is 98% at locations in Central London, which also affects many locations in the south-east of England. The combination of bands in Block 6 means that there is no shortage of spectrum in this block. However, accommodating the demand is possible due to the availability of spectrum at 48GHz which constitutes approximately 38% of spectrum supply in Block 6. Use of the 48GHz is likely to be less popular but as can be seen in Figure 8.17, there are comparatively few events for which this measure would be necessary.

9 USE AND USAGE OF THE INTERLEAVED SPECTRUM

The UHF broadcasting band from 470 to 854MHz is currently used to broadcast analogue TV and a limited number of digital TV multiplexes within the UK. In September 2005, the UK Government confirmed that terrestrial television broadcasting would transition to an all digital network between 2008 and 2012. The ITU-R Regional Radio Conference in May/June 2006 (RRC06) established a new international agreement on how broadcasting spectrum can be used in Europe. The agreement established at RRC06 is fully consistent with the UK's plans for the future use of UHF spectrum. In particular, the plan:

- Identifies a frequency plan using 256MHz to support 6 digital multiplexes;
- Establishes protection for 112MHz (the digital dividend) that may be used for other purposes.

Whilst broadcasters primarily use this UHF spectrum, relatively low power devices can re-use the same frequencies outside of the broadcast area. This is termed interleaved use and the mosaic of spectrum and areas available for low power operation is referred to as interleaved spectrum. Currently this interleaved spectrum is used exclusively by programme makers and organisers of special events for applications such as low power radio microphones and talkback systems which operate on a no protection, no interference basis. The 112MHz digital dividend represents approximately 30% of the spectrum currently used by broadcasting which, after digital switchover (DSO), may be used for purposes that are incompatible with programme making and special events. This would lead to a reduction in the spectrum available for PMSE. Furthermore, additional applications may be permitted to share access to the interleaved spectrum, leading to a further reduction in spectrum availability for PMSE uses.

This chapter reviews the nature of PMSE use and considers the impact of digital switchover and these additional changes upon the ability of future PMSE users in the UK to use low power applications in the broadcast band and in related spectrum used for similar applications. Section 9.1 describes the use of spectrum for broadcasting in the UK and the impact of digital switchover upon the interleaved capacity that would be available. Section 9.2 describes the users and presents a quantitative analysis of their usage of the TV spectrum while Section 9.6 summarises our conclusions.

Further details of the analysis of the balance of supply and demand may be found in Annex H.

9.1 The use of TV spectrum in the UK

The provision of contiguous and almost ubiquitous TV coverage is achieved by broadcasting from a number of main transmitter sites, supplemented by a large number of lower power relay stations which provide coverage in areas where reception from the main transmitters is inadequate. With analogue TV technology, transmitters broadcasting in geographically adjacent areas cannot use the same TV channel without causing interference to TV viewers. Thus the TV transmitters broadcast on a frequency plan designed to avoid this situation – resulting in a pattern where different frequencies are used in neighbouring coverage areas. A simplified illustration of this is shown in Figure 9.1(a).

A low power device, such as a radio microphone, operating in the coverage area of a TV transmitter, would cause interference to TV viewers if it transmitted within the TV

channel[43] used to provide coverage, and can also cause interference when transmitting within either of the adjacent TV channels. However, provided transmissions are carefully controlled, low power devices can transmit within other TV channels without causing interference. The examples (b) and (c) in Figure 9.1 illustrate the areas where Channels 22 and 23, respectively, could be used by low power devices without contravening either the adjacent or co-channel criteria.

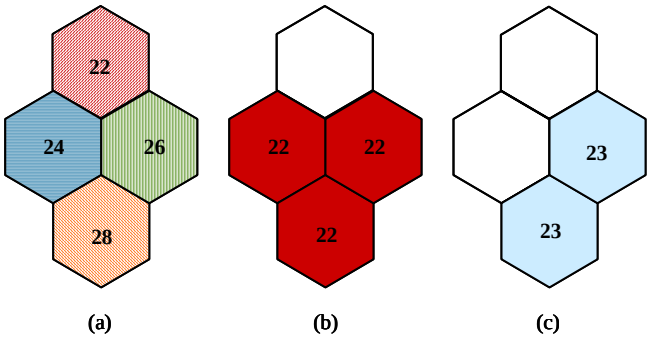

Figure 9.1: Subplot (a) illustrates the principle of how different TV frequencies (Channels 22, 24,26 and 28 in this example) are used to transmit television signals in neighbouring coverage areas, in a cellular-like reuse pattern. Subplot (b) illustrates how frequencies within Channel 22 can be used to support radio microphones in the coverage areas where Channel 22 is not used to transmit TV, nor where Channel 22 is adjacent to the TV channel used in the same geographical area. Subplot (c) illustrates that radio microphone use is not permitted within Channel 23 where TV signals use the adjacent channels, 22 or 24, but can be used elsewhere.

The mosaic of channels and areas available for low power operation is referred to as the interleaved spectrum, and the use of spectrum by compatible applications is referred to as interleaved use. Ofcom licenses the broadcasting of TV broadcast signals with specific characteristics (including antenna location, height and power), and can license other uses of the UHF TV spectrum, including applications in the interleaved spectrum, subject to acceptable interference limits. Currently this interleaved spectrum is used exclusively for the purposes of PMSE, and assignments are managed by JFMG.

In practice, the broadcast TV frequency plan is considerably complicated by the topography of the coverage areas, varying transmitter heights and powers, and by the need for lower power relay transmitters. Furthermore, the restrictions on the use of low power devices can be complicated by overlapping coverage from two or more TV transmitters, local shielding (such as provided by indoor operation) and on precisely where its transmission is located within the 8MHz width of the TV channel. Consequently the geographic distribution of the interleaved spectrum is also more complex than illustrated in Figure 9.1 and a real example is shown in Figure 9.2. JFMG uses a comprehensive geographic information system detailing where and under what conditions each TV channel can be used by a variety of different applications whilst ensuring that assignments to PMSE users do not cause interference to TV viewers.

[43] The low power applications typically occupy a much smaller bandwidth than the TV signals, and several may be transmitted within a single TV channel.

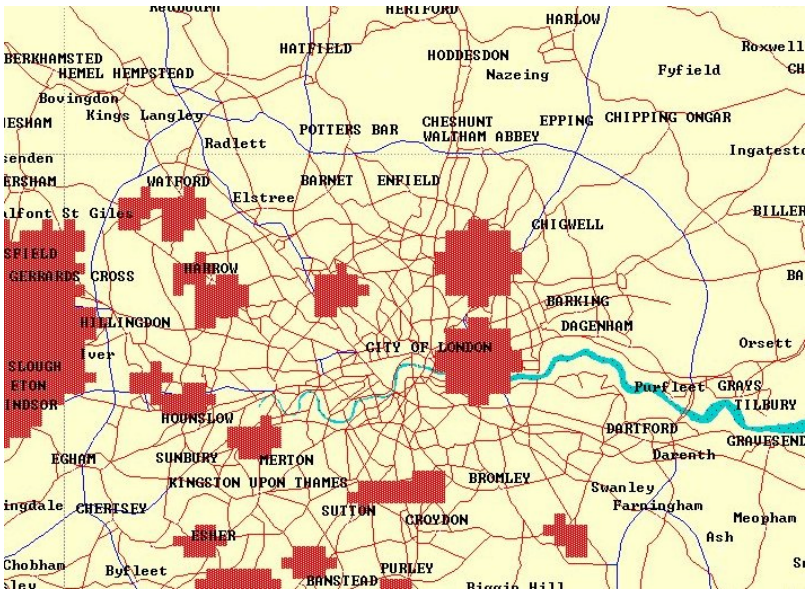

Figure 9.2: The complex geographical distribution of interleaved spectrum is demonstrated in this figure which shows the red areas where Channel 66 cannot be used in London. This figure was provided by JFMG.

With digital TV the same principles apply and low power devices can be operated in the interleaved spectrum. However, because the impact of interfering signals on digital TV reception is different, the conditions of usage are different. This is discussed further in Annex F, but a key difference is that digital TV signals are less susceptible to interference, and operation of low power devices is generally possible in adjacent TV channels.

9.1.1 The digital switchover plan

Before evaluating the impact of digital switchover on the availability of TV spectrum for PMSE activities we summarise the current use of UHF TV spectrum in the UK and how this is expected to change with the switchover to digital networks.

The spectrum between 470 and 862MHz is divided into a total of 49 channels, each 8MHz wide, numbered from Channel 21 to Channel 69. With the exceptions listed below, all are currently used for TV broadcasting within the UK.

- Channel 36 is used for aeronautical radar at a limited number of airports. Away from these locations (including the area within the M25) it may be used for radio microphones.
- Channel 38 is reserved for radio astronomy observations. Away from the three UK radio telescopes (including the area within the M25) it may be used for radio microphones.
- Channel 69 – this channel is not used for TV transmissions and is available exclusively for PMSE applications across the whole of the UK[44].

The current use of the band for TV transmissions (analogue TV signals for BBC1, BBC2, ITV, C4 and Channel 5, together with the existing digital multiplexes) is illustrated in Figure 9.3 in which the number of TV transmitters broadcasting on each channel is shown. A total of 5,092 assignments are currently used to provide the combined analogue and digital coverage.

[44] The bottom 250 kHz is not available and a 1MHz section is available only for indoor use of radio microphones.

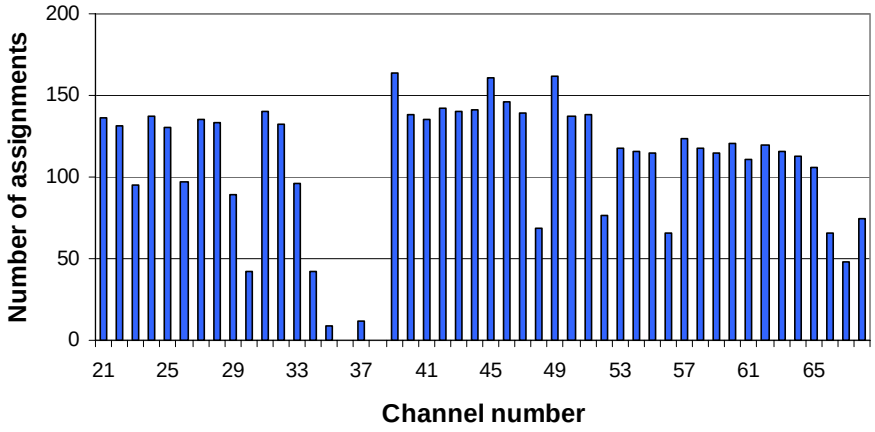

Figure 9.3: Current TV usage within the UHF TV bands IV & V (470 to 854MHz) showing only Channels 36 and 38 unused. Usage is given in terms of the number of TV transmitters broadcasting on each channel.

As part of the preparations for RRC06, Ofcom and the Department for Culture, Media and Sports (DCMS) conducted a number of consultations on the options available for the transition to digital terrestrial TV. The most recent consultation, Planning Options for Digital Switchover, was issued on 9th February, 2005 and closed on 21st March, 2005. This was followed by an Ofcom Statement on 1st June 2005 which identified Option 3 as the preferred option.

In Option 3 all three PSB multiplexes adopt the 64 QAM mode of modulation and provide the same coverage as is achieved with the current analogue network (namely 98.5% of the population). The 8k OFDM modulation format is to be adopted allowing some in-fill transmitters on the South and East coasts to operate on the same frequency as the local main transmitter. The commercial multiplex operators are to provide at least the same level of coverage as they do today on their current multiplexes.

For the purposes of this investigation, the study team were given access to Version 3 of the Digital Switchover Plan (DSOv3). As shown in Figure 9.4, 32 channels (Channels 21 to 30 and 41 to 62) are used to provide TV coverage across the UK and 14 channels (Channels 31 to 35, 37, 39, 40, and 63 to 68) are unused[45]. These are often termed the released channels, or the digital dividend.

In the DSOv3 plan, approximately 20% of the transmitter sites, which cover the vast majority of households, transmit 6 digital multiplexes, and the remaining sites transmit only three. Only 4,087 assignments are used to support the all-digital TV network, which suggests that further TV broadcast assignments could be inserted into the DSOv3 plan. We consider the impact of deploying up to four additional multiplexes in our analysis.

[45] Note that in DSOv3, channels 31, 38, 64, 65 and 68 are used only in the Channel Islands. Ofcom has informed the study team that the Channel Islands is being replanned to ensure that these channels are available across the UK. We have therefore omitted their use in Figure 9.4, but have not added in the 8 additional assignments that would be needed to provide the Channel Islands with coverage, since it is not known what channels will be used.

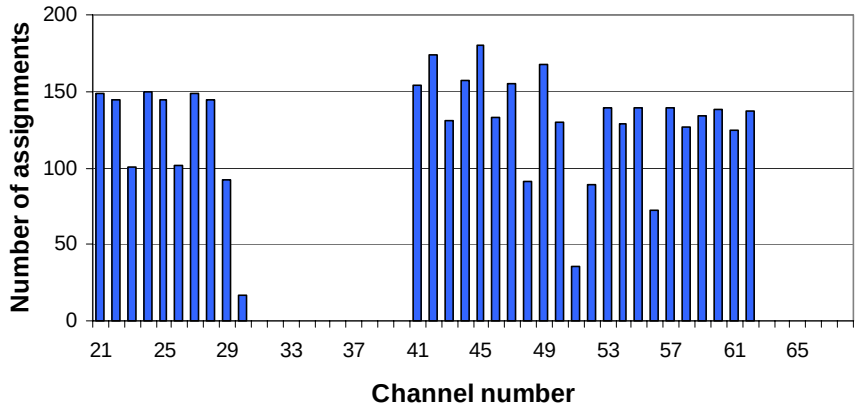

Figure 9.4: The usage of TV channels within the UHF TV bands for TV transmissions as it would be following the full switch over to digital TV according to DSO Option 3.

Note that the digital switchover plan envisages an overnight change from the current situation to the all digital plan to be carried out on a region by region basis, with London being switched last around 2012. This step change transition process means that it is only necessary to evaluate the situation before and after switchover.

9.1.2 Impact on the availability of interleaved spectrum

The loss of 14 channels is not the only factor that may affect PMSE activities within the TV spectrum – one must also consider the utility of the interleaved spectrum in both the pre- and post-DSO environments. This section illustrates the impact of digital switchover on the number of interleaved channels that could be available (the retained interleaved spectrum) and shows that in some circumstances fewer channels may be available but in others more may be available[46].

In order to describe the impact of protecting adjacent channels, Figure 9.5 shows a simplified analogue situation[47] in which four channels are used to provide analogue-only coverage in an area of interest. Owing to the co-existence rules to protect analogue TV, these four channels and their 8 adjacent channels are prohibited to radio microphones[48], leaving 34 out of the 46 channels available for PMSE use. It also shows the equivalent digital situation in which 3 multiplexes are transmitted in the area but now only these channels are prohibited to radio microphones. However, there are 14 less channels available in total, leaving only 29 channels for PMSE use. In this example, the loss of interleaved channel capacity exceeds any benefits from reduced co-existence restrictions.

[46] Note, they may not necessarily be exclusively available for PMSE uses as they are at present.
[47] It is noted that the existing TV network transmits up to 5 analogue signals in areas where Channel 5 provides coverage, and 6 digital multiplexes from the 80 main transmitter sites.
[48] This is a simplification of the actual restrictions but adequate for the purposes of this illustration. As noted earlier, the detailed protection requirements are built into the JFMG database.

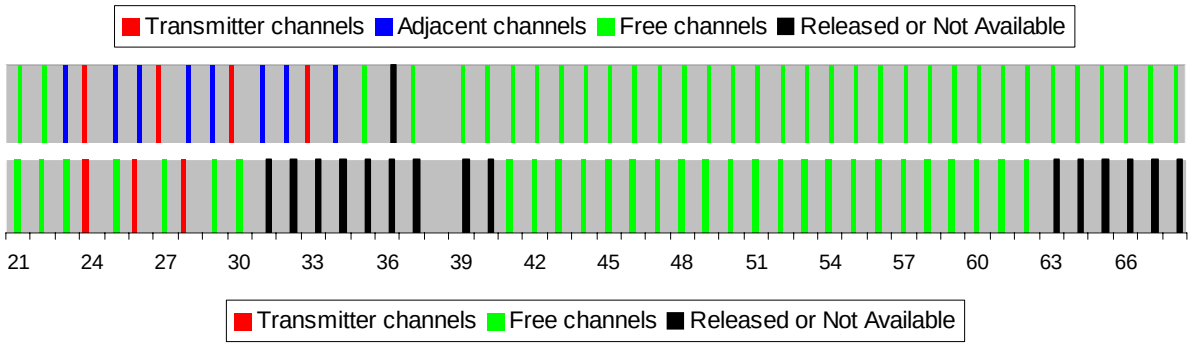

Figure 9.5: Comparison of pre-DSO spectrum with 4 analogue transmitters and post-DSO spectrum with 3 digital multiplexes. In the case of analogue TV (upper sub-plot) both the 4 transmitter channels and their 8 adjacent channels have to be protected. In the case of digital transmitters (lower plot) only the 3 transmitted channels require protection. Channel 38 has not been included since ability to use this channel will vary from region to region. Channel 36 is assumed not to be available in both analogue and digital cases, and channels 31-37, 39, 40 and 63-68 are assumed released or not available post-DSO.

In contrast Figure 9.6 illustrates the situation where there are two relay stations as well as a main transmitter site potentially providing coverage close to the area of interest, and where transmissions from all three have to be protected. In the analogue case, the four channels from each station and their 23 adjacent channels (one is adjacent to channel 69) are prohibited to radio microphones leaving 11 out of 46 available. In the digital case, however, only the 12 multiplexes have to be protected which leaves 20 channels available for PMSE use.

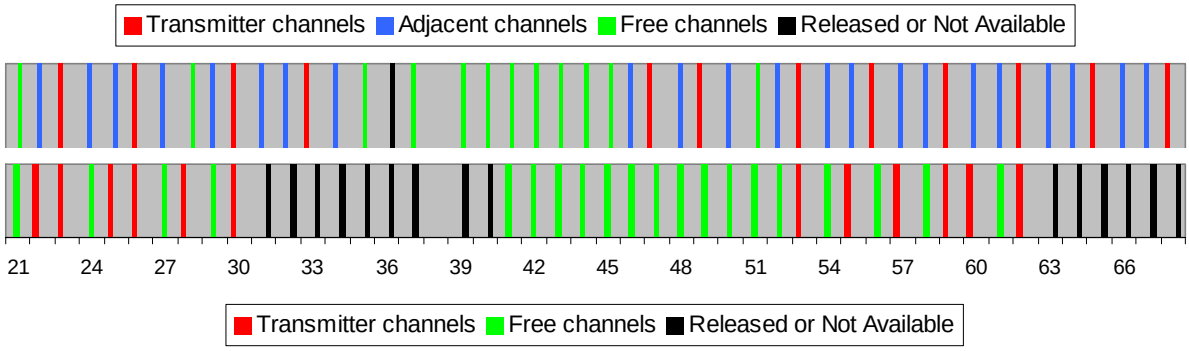

Figure 9.6: Comparison of pre-DSO spectrum considering the effect of relay stations. In this example, we have 12 analogue transmitter channels (plus their 23 adjacent channels) to be protected, versus 12 digital multiplexes to be protected (i.e. 6 digital multiplexes of a main transmitter and 2 relay stations each with 3 multiplexes). Again the upper and lower plots correspond to the analogue and digital cases respectively and the same assumptions on channels assumed to be Released or Not Available are maintained.

Thus, where today there are a large number of channels available for PMSE use, such as away from relay stations and within the coverage of the main transmitter, the number after DSO will be reduced. But where the number is currently significantly restricted to avoid adjacent channel use, typically in areas with a large number of relays, there could be more spectrum available post-DSO. Further, as described in Annex F, indoor co-channel use of low power devices, such as radio microphones, can be permitted within the

coverage area of a digital TV multiplex. This has the potential to further increase the number of channels that can be utilised by PMSE applications.

9.1.3 Overview of interleaved capacity across the UK

BBC Research and Development have published a white paper[49] on the availability of the retained interleaved spectrum for PMSE post-DSO and their results were made available to us to support our analysis.

As stated above and in Annex F, the ability to use interleaved channel capacity for any service depends upon the technology of the TV receivers required to be protected (digital or analogue), and the characteristics of any potential interleaved application. Key characteristics include the power level, and whether the operating environment is indoors or out[50]. A high power, outdoor analogue link would be more constrained in its operation, than a low powered, indoor digital link.

The main output of the BBC white paper was a comparison of the number of interleaved TV channels that could be used pre- and post-DSO by 10mW radio microphones, 5W audio links and 1W digital camera links – all for the outdoor environment. The paper assessed the difference in the number of TV channels that could be used across the UK for 10mW outdoor radio microphone links post-DSO (based on DSO plan 3COM3PSB Task3.12, Version 1), compared to the current capability. It also assessed the situation for 5W audio links and 1W digital wireless cameras. In summary the paper stated that:

- For 10mW radio microphones: "The overall availability of channels after switchover is significantly better than at present", but noted that there are "areas for which there are losses after switch-over", and further noted that the some areas of Kent will have fewer than 5 channels available after switchover.
- For 5W audio links: "The channel availability after switchover should, on the whole, be more favourable than at present", and noted that only in a few locations (North Yorkshire, Suffolk and North Uist) are there areas of [capacity] loss.
- For 1W digital wireless cameras: This is the application that is likely to be "hardest hit". "Many areas would lose at least 3 channels" and whilst some areas would become better off (e.g. along the Welsh border), other areas will become worse-off (e.g. London).

Based on this, the impact of digital switchover should be interpreted as better overall with the possible exception of 1W digital wireless cameras. However, in our interviews with users there was no significant demand for wireless cameras at these frequencies, and very few instances of their use in an analysis of all licences issued in the year 2004/5. This is therefore a moot point. The BBC conclusion is predicated upon available interleaved capacity being used exclusively for PMSE applications. Further, the scope of the BBC report does not include a comparison of how this interleaved capacity matches the demand for PMSE applications. Subsequent sections of this chapter consider these aspects.

9.2 Users and applications

All four of the primary wireless applications used in PMSE activities; radio microphones, talkback, programme links and data links are used within the interleaved spectrum. However, as shown in Figure 9.7 radio microphones dominate use within this spectrum.

[49] Available from http://www.bbc.co.uk/rd/pubs/whp/whp125.shtml.

[50] The ability to co-exist successfully also depends upon transmitter and receiver characteristics as well as the bandwidths of the signals, their centre frequency offsets, coding and modulation schemes. We have assumed that the bandwidth of the potential interleaved applications is small compared to the 8MHz TV signal.

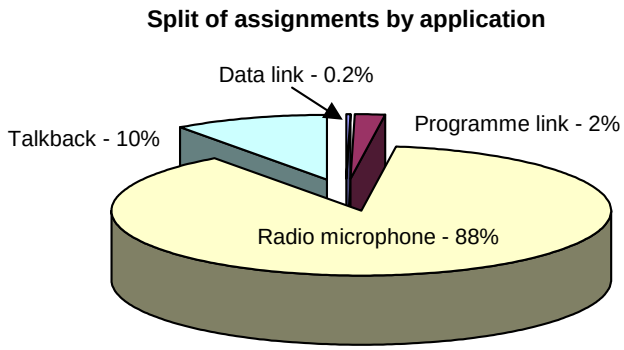

Figure 9.7: The percentage of assignments for the four different PMSE applications within interleaved spectrum. These data were extracted from the JFMG database of assignments for the year 2004/5.

Each TV channel has a bandwidth of 8MHz which is much greater than the bandwidth required by radio microphones, talkback or audio programme links. This means that several PMSE assignments can be made on different frequencies within a single TV channel.

However, many PMSE activities take place within a confined area such as the stage of a theatre, a studio or a stadium. In these situations the wireless transmitters, operating in close proximity to each other, will interact to generate unintentional (inter-modulation) frequencies which can interfere with the reception of signals from other equipment. The problem can be avoided by using an appropriate subset of frequencies with the result that only about 5 to 10 radio microphones can be used simultaneously within a single TV channel, and talkback and audio programme links are limited in a similar way. The higher bandwidth required for video links and wireless cameras limits them to one per TV channel.

9.2.1 Activity trends within interleaved spectrum

A measure of PMSE activity can be obtained by considering the number of assignments and the number of days for which they are active. Figure 9.8 uses the number of assignment days per month averaged over a year to show the trend in activity over the past four years.

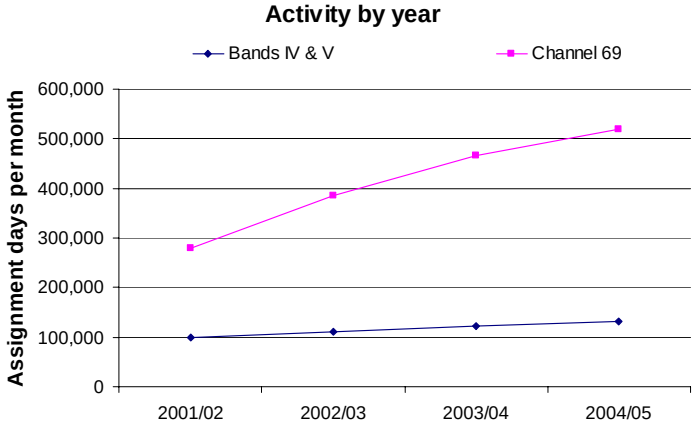

Figure 9.8: The average number of assignment days per month is shown for four recent years. Activity within Channel 69 is shown separately from other assignments within the UHF TV spectrum. (Figures taken from the Ofcom record of PMSE usage.)

The historical records for Channel 69 include an allowance for shared usage of radio microphones which is large and uncertain[51]. The activity associated with Channel 69 is therefore shown separately here.

The results show a significant growth in activity in the use Channel 69, and steady but slower growth within Bands IV & V.

9.2.2 Users of the interleaved spectrum

Interleaved spectrum is used by a diverse range of PMSE users, as demonstrated by the following examples selected from the licensing database.

- Places of worship
- Universities
- Sports clubs
- Holiday camps
- Hotels and casinos
- Supermarkets
- Radio stations
- London Stock Exchange
- Museums
- Schools
- Embassies
- Local councils

The way in which applications are used varies according to the type of event. Radio microphones are widely used in a host of situations – but the number used varies according to the type of event. Typically TV studios, outside broadcast events, musicals and rock concerts would use a large number of radio microphones and IEMs. Users of one or just a few radio microphones include conference centres, corporate events, churches, and pubs and clubs. The use of talkback is primarily indoors in studios and theatres.

During the sample year just over 32,200 co-ordinated frequency assignments were made within the interleaved spectrum to approximately 726 different organisations. Of these, 5100 were within Channel 69. The total number of assignments across all PMSE activities was 64,007.

The total PMSE usage, in terms of assignment days within the TV spectrum was 2.2M out of a total of 3.2M assignment days for all PMSE activities during the year.

Figure 9.9 shows how usage is split between the five different categories[52] of use. Usage is largest for the Local entertainment and events category, which includes use in theatres, concerts, travelling shows and similar entertainment activities. This reflects both the long term nature of their usage, particularly in theatres, and the large numbers of equipments used in some shows. The second largest usage is in studios.

Usage is also significant for Newsgathering and Community use, the latter use encompassing schools and places of worship.

[51] This allowance assumes that each shared licence is equivalent to 14 assignments active for 365 days per year.
[52] Note that this categorisation is not precise as the category of use is inferred from the user organisation and a number of organisations have usage in more than one category. Those for which a category could not be inferred are included under Other.

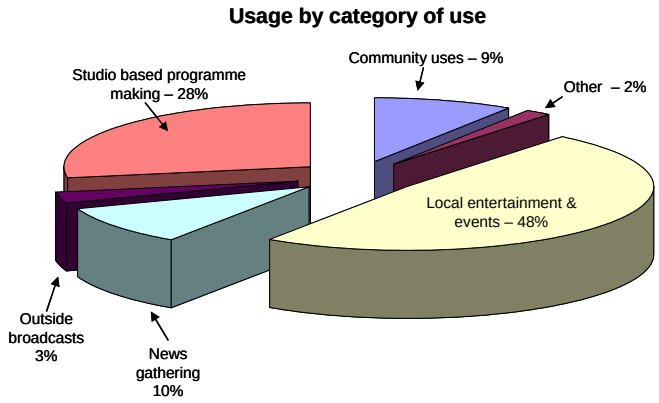

Figure 9.9: Usage (in assignment days) of the TV broadcast spectrum for the purposes of PMSE split by category of use.

Although there are many and various users, usage is dominated by a relatively small number of large users. This is illustrated in Figure 9.10 which shows that 80% of usage is by 20% of the users. The largest users are mainly theatres and TV studios but the largest user by a substantial margin is the BBC. Its use includes studio production, outside broadcasting and newsgathering.

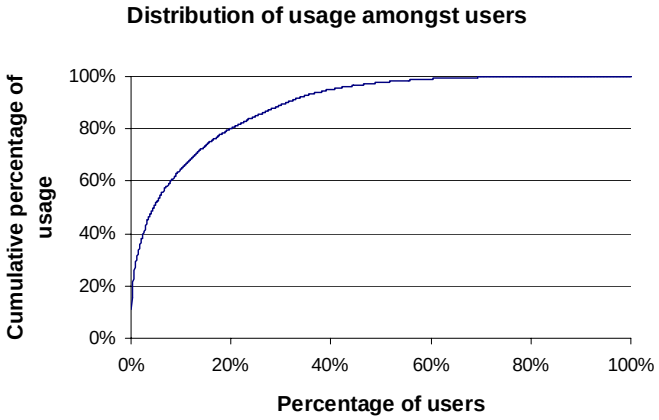

Figure 9.10: Cumulative distribution of the percentage of assignment days versus the % of users of TV broadcast spectrum.

9.2.3 Users of shared frequencies

Because shared licences permit the licensee to use any number of radio microphones, at any time, anywhere within the UK there are no records of actual usage. Our interviews with industry players strongly suggest, however, that there is considerable use of shared frequencies. This is supported by the fact that 1716 organisations were licensed to use the shared frequencies in Channel 69[53] during the year 2004/05.

Our discussions with industry also suggested that there is a significant amount of unlicensed use of the shared frequencies. This illegal use, and allegedly inadequate enforcement against it, is of concern to the larger users who value interference-free operation.

[53] In addition, some 582 organisations had shared radio microphone licences in VHF Band III.

9.3 Spectrum usage

This section illustrates how usage is distributed across the TV spectrum, and how usage is divided between the different PMSE applications, between indoor and outdoor use, and between short and long term usage.

9.3.1 Distribution over TV channels

Figure 9.11 shows how usage is spread across TV channels 21 to 69. Radio microphone usage clearly dominates with 84% of all usage (1.837M assignment days, see Table 9.1) while talkback makes up 15.6% of all usage (340,000 assignment days). The popularity of Channel 69, which can be used across the UK is also clear. The distribution of usage reflects both the TV channels that are available in areas of PMSE activity and the availability of equipment. Channels 67 and 68 are popular because many Channel 69 radio microphones can be retuned to frequencies in the two lower TV channels.

Duplex talkback equipment that pairs frequencies in the TV channels 39 to 41 with frequencies in channels 49 to 51 is readily available and this is reflected in the use of these channels. Typically 40MHz separation between transmit and receive frequencies is required, but this system uses 80MHz separation. Since channels 39 and 40 will be released, use of the paired channels 49 and 50 will also be lost, corresponding to nearly one third of talkback use in the UHF TV bands. Channel 21 is also widely used for talkback because of the relative ease of retuning UHF2 talkback equipment to operate at the lower edge of Band IV.

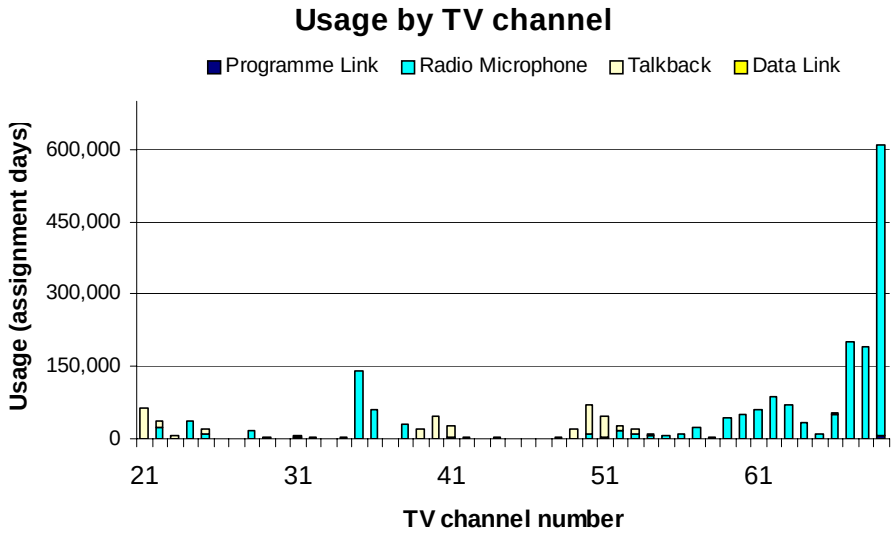

Figure 9.11: Usage (in assignment days) in each of the TV channels (21-69) for the four PMSE applications.

Programme links account for less than 0.5% of usage, with their heaviest use occurring in Channel 69 where high power operation is possible (since it is not used for terrestrial television transmission). Data link usage amounts to just 0.01% of total usage, all of which is to be found in Channel 21.

Assuming 14 TV channels will no longer be available for PMSE use following the switchover to digital TV, it is of interest to understand the use that is currently made of the affected channels. This is summarised in Table 9.1 along with the usage in Channels 21, 69 and 67 to 69.

	Radio microphones	*Talkback*	*All applications*
All channels (21 to 69)	1,836,833 (84.0%)	340,151 (15.6%)	2,187,061 (100%)
Released channels (31-35, 37, 39, 40)	8%	21%	10%
Released channels (63-68)	30%	2%	26%
All released channels	38%	23%	36%
Channels 67 to 69	54%	1%	46%
Channel 69	33%	0%	28%
Channel 21	0%	18.5%	3%

Table 9.1: Total usage across all TV channels is given for radio microphones and talkback (in assignment days). In each case the percentage of usage for the specified application is given for the various subsets of the TV channels of interest. Thus 30% of all radio microphone usage occurs within the released channels, 63 to 68.

The results show that 38% of radio microphone usage, and 23% of talkback usage, would be affected by loss of access to the released channels. The importance of Channel 69 for radio microphones, and of Channel 21 for talkback, is also clear.

9.3.2 Internal and external use

Figure 9.12 shows the usage for each application split between indoor (internal) and outdoor (external) use. Indoor use clearly predominates with 95% of radio microphone and 98% of talkback usage being indoors. There is also a small amount of airborne use in which links to planes or helicopters are used to provide aerial coverage of an event. Total airborne usage during the year 2004/05 was 9 days. This small amount of usage is not considered further in this section.

The situation of use (indoor or outdoors) is important since it dictates the level of interference that will be received or transmitted from or to other users. Typically external radio microphone use must consider other users within a distance of 1Km, but this reduces to as little as 100m where both users are indoors and their frequency use is carefully co-ordinated[54].

[54] This has been achieved at The Palace and The Prince Edward theatres for example.

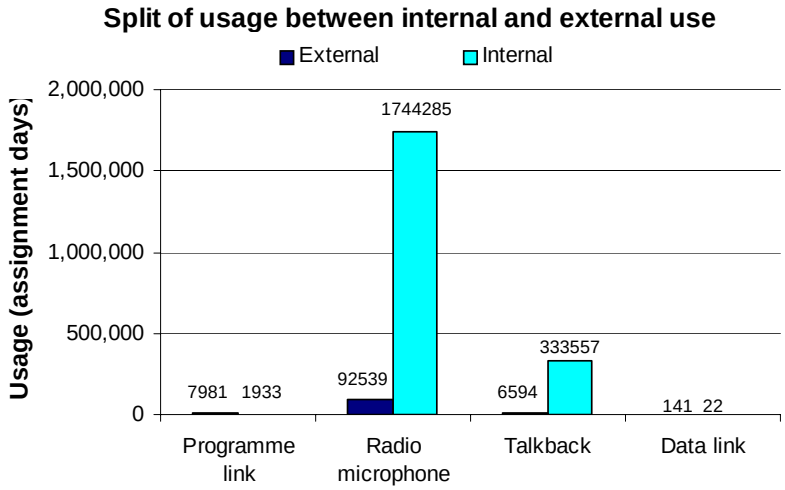

Figure 9.12: The situation of use for different PMSE applications within interleaved spectrum. Note, the difference between the total radio microphone usage here and that given in Table 9.1 is due to the exclusion of airborne assignments in this plot.

9.3.3 Duration of use

As a general rule PMSE activities tend to be either short term in nature or to run throughout the year. Outside broadcasting events, outdoor shows, rock concerts, fetes and similar events all have durations measured in days whereas newsgathering, theatres, studios and churches will have a year round operation to support. Within the interleaved spectrum more than 95% of assignments are either for less than 31 days or for longer than 300 days. Figure 9.13 illustrates how assignments are split between long and short durations both by application and by indoor/outdoor usage.

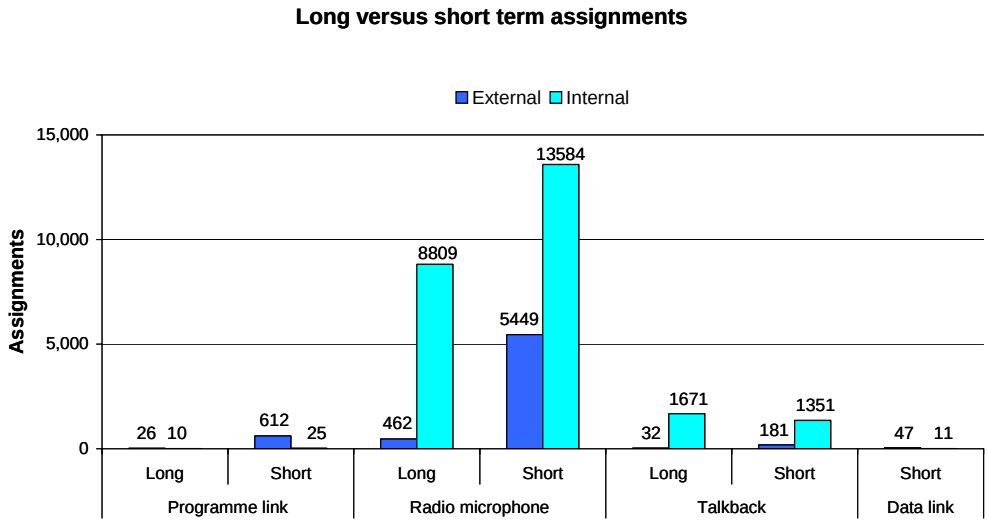

Figure 9.13: The number of PMSE assignments considered long or short term is shown for each application and situation of use in the UHF TV band. In this analysis a duration of more than 300 days was considered long but this can be varied between 30 and 300 with little substantive effect on the results.

Short term assignments dominate in the case of programme data links but, as discussed above, these applications are used relatively little in the interleaved spectrum. Both

talkback and radio microphones show a much higher proportion of long term assignments (33% and 53% of radio microphone and talkback assignments respectively) reflecting their wide spread use in theatres and studios. Overall 34% of assignments within the interleaved spectrum are long term and the great majority of such assignments are indoors.

9.4 Variability in PMSE activity

A characteristic of PMSE activity in the UHF TV spectrum (and in PMSE spectrum in general) is the high degree of variability in the level of usage from place to place, with time, and from event to event.

9.4.1 Geographic distribution of use

Figure 9.14 shows the density of usage[55] in interleaved spectrum across the UK over the year 2004/5.

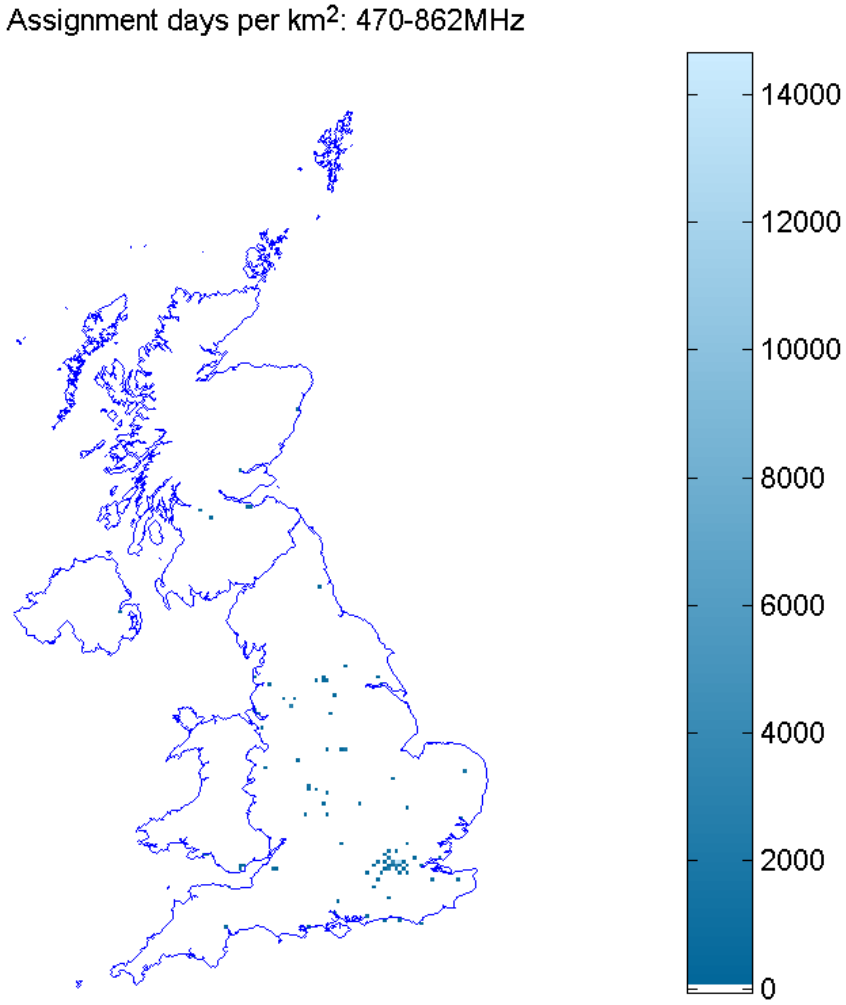

Figure 9.14: The density of PMSE usage (in assignment days per km^2) in interleaved spectrum between 1st April 2004 and 31st March 2005.

[55] Note that a small percentage of assignments, 0.3%, within the TV spectrum are for wide area use, but these have been excluded from the results shown here.

It clearly demonstrates that there are a relatively few areas of high activity, a greater number with a lower level of activity, and large areas with little activity. Given that many of the uses of PMSE relate to locations where people gather to produce or participate in some form of activity, very often entertainment, it is not surprising to find that the areas of highest activity are the major metropolitan areas and the lowest are the more remote rural parts of the country.

It is of interest to note that only 3151 distinct locations of use are identified in the licensing database. These locations range from sports venues, to individual West End theatres, to corporate offices. Hence, other than the wide area licences, there are a limited number of distinct locations across the country where spectrum is licensed for use.

9.4.2 Variation with time

The earlier analysis (Section 9.3.3) showed that 34% of assignments within the interleaved spectrum were long term (typically for a year). Figure 9.15 shows how the number of remaining short term assignments varies across the year.

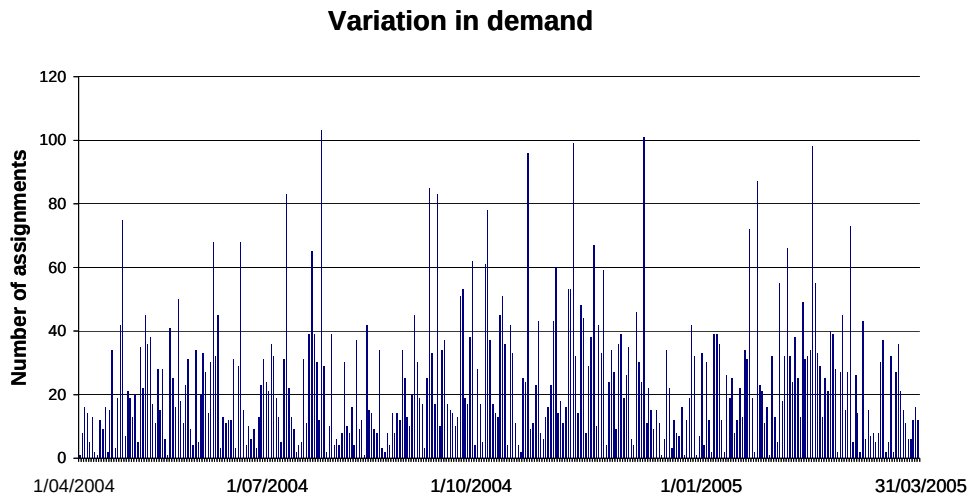

Figure 9.15: The number of short term assignments made within the M25 and finishing on a given date are shown over 12 months. Assignments within Channel 69 are not included in this plot but show a similar pattern.

The number of assignments plotted here is the number finishing on a given date. Since the great majority of short term assignments are of only a few days duration, this provides a good indication of the level of PMSE activity immediately prior to the date. The results are taken from the area within the M25 and illustrate how the level of PMSE activity varies throughout the year. Typically peak use occurs at weekends.

With radio microphones, the same frequency can be re-used a number of times across the area of the M25. Therefore, although the analysis above illustrates the level of PMSE activity within the area, it should not be taken as a measure of the spectrum actually used to support the activity.

9.4.3 Variation from event to event

The variability in activity arises from the highly variable nature of PMSE activities, and we therefore expect the number of assignments in use at any one time and place to be highly variable. Since the larger PMSE events, in terms of the spectrum required, are likely to be most affected by any reduction in the available interleaved spectrum it is of interest to

understand the distribution of events by size. This was obtained by summing the number of assignments made for the same geographic location, which finished on the same date (the latter requirement separates different events which occur at the same place but at different times). The resulting distribution for the size of PMSE events is given in Figure 9.16.

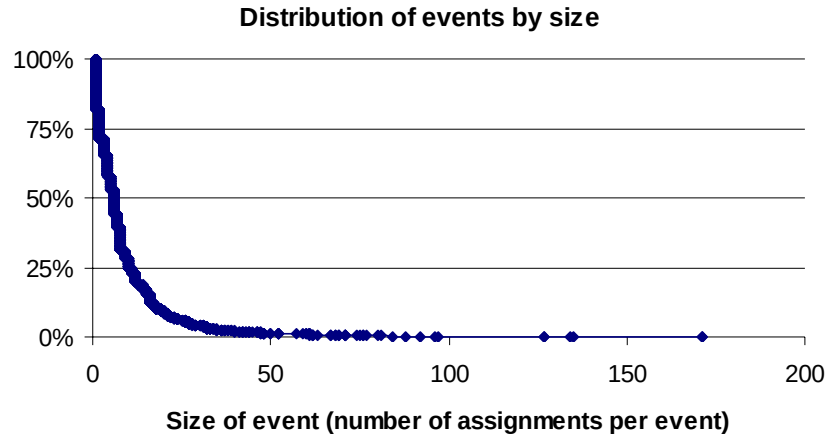

Figure 9.16: This plot shows the percentage of events that are larger than a given size (the x-axis) as determined by the number of frequencies assigned to the event. Note that an event can be short or long in duration – a long running show would be counted as a single event. This analysis included all site specific assignments during the year both indoors and outdoors.

Figure 9.16 shows that some events can require a large number of assignments but that the number of such large events is relatively small. Indeed, although the largest event used 171 assignments only 1.3% of events required 50 or more assignments and 50% required 6 or fewer.

Note that, since the great majority of assignments are for radio microphones with a bandwidth of 200kHz, the number of assignments provides a reasonable indication of the amount of spectrum used at an event.

Note also that some large events may involve assignments at more than one location, and different PMSE users at the same event sometimes cease their operations on different days. As a result, this analysis will under-estimate the number of large events by a small amount.

9.5 Observations on users and usage

The key observations to be drawn from the analysis of users and their usage are:

- Total PMSE usage within the TV channels 21 to 69 amounts to 2.2M assignment days out of a total of 3.2M across all PMSE spectrum;
- A large number (726) and a wide variety of organisations make use of the TV spectrum for PMSE activities including broadcasters, theatres, schools, sports centres and places of worship. However, the majority of usage is accounted for by just a few users. The top 11 users account for 33% of usage, and the largest 20% of users account for 80% of usage;
- The majority of usage is in theatres and studios (approximately 75%) and is dominated by radio microphones which contribute 84% of usage and talkback (15% of usage);

- Apart from area assignments, spectrum is used in a limited number of (mainly urban) locations;
- Usage is distributed unevenly across the TV spectrum:
  - The highest level of usage is in Channel 69 (28%) and Channels 67, 68 and 69 together account for 46% of usage;
  - 36% of usage is currently within the channels identified for release subsequent to digital switchover (though approximately 40% will be effected, since some of these channels are paired with unreleased spectrum for talkback use, and whose utility would be affected);
  - 18% of talkback usage is accommodated within Channel 21;
- The majority of usage is indoors (95% of usage) and 34% of assignments are long term;
- The distribution of PMSE activity is highly skewed with a relatively small number of large events (both long and short term).

9.6 Conclusions

The modelling methodology used to analyse the balance of demand and supply for spectrum within the UHF TV bands, and the detailed analysis of the implications of DSO, are given in Annexes D and H to which the reader is referred. A summary of the conclusions drawn from this analysis is given here.

PMSE activities make extensive use of UHF Bands IV & V and this usage is expected to grow substantially by 2014. On the basis of the current spectrum supply (Pre-DSO), we expect demand for PMSE applications to outstrip supply by 42%.

However, our analysis of PMSE users and assessment of the supply and demand in UHF TV spectrum has demonstrated that use is heavily skewed. In particular:

- The vast majority of use is indoors (95%);
- The majority of usage is accounted for by just a few users. The top 11 users account for 33% of usage, and the largest 20% of users account for 80% of usage.

This means that the impact is limited to a few locations and events, and with current supply, growth would be severely limited at these locations.

With the introduction of all digital TV transmission consistent with the DSOv3 plan, and assuming that 14 channels will be released for other uses incompatible with PMSE, the capacity of interleaved spectrum available for outdoor PMSE-like applications will increase compared to 2004 levels[56].

Our analysis has shown that if exclusive use of the retained interleaved capacity by PMSE is maintained, there will be sufficient capacity across the UK to host anticipated future PMSE events in 2014. The single exception to this is at Glastonbury where a small amount of the future growth would need to be satisfied with capacity from alternative bands (Band III and/or Channel 69).

Furthermore:

- The vast majority of interleaved capacity is unused at most locations, most of the time. Post-DSO, we anticipate that more than 95% of locations will require less than 20% of the available retained interleaved capacity;

[56] It is possible that the released channels will be used for a similar broadcasting applications (e.g. two PSB Multi-Frequency Network HDTV multiplexes) that would further supplement interleaved capacity.

- Additional digital multiplexes could be deployed in virtually all parts of the UK without impact on future PMSE events, with the exception of Glastonbury, Newcastle and Central London;
- As today, interleaved capacity will vary significantly across the country – deployment of more than 2 additional multiplexes from the main TV transmitters would result in no interleaved capacity for outdoor use being available in some parts of the Midlands (where there is currently no PMSE use).

To further accommodate the future growth of PMSE radio microphone usage, VHF Band III and Channel 69 could be used in preference to UHF Bands IV & V to help alleviate congestion in whatever interleaved capacity is available for PMSE use. However, our analysis showed that this would be of very marginal benefit.

9.6.1 Impact on PMSE users

The impact of the digital switchover is not only on overall capacity of spectrum available for PMSE, it also has a direct impact on the equipment currently used for PMSE. Of the current PMSE usage in the UHF TV bands, 36% of use is in channels that will be released, though the amount of use likely to be affected is closer to 40% since use of released channels is paired with other frequencies for talkback. All these users would be likely to require new equipment post-DSO.

The fragmented nature of interleaved spectrum Post-DSO, will also have an impact on the flexibility requirements for future equipment. For touring shows, there is some evidence that DSO will marginally constrain the ability of touring shows to use the same equipment at multiple venues for outdoor shows. However, constraints on indoor use (95% of the total), can be removed altogether assuming co-channel use is possible, significantly simplifying touring show equipment planning.

The proximity of Channel 21 to UHF2 band makes Channel 21 particularly suited to accommodating overspill from the congested UHF2 band (particularly in London). We therefore anticipate that different channels will be valued differently by PMSE users and this should be considered when interleaved capacity is being made available by Ofcom.

Where legacy equipment still exists but the frequencies are no longer available for PMSE, there is risk of illegal use. In particular, Channel 69 is heavily used for both shared and co-ordinated use, and equipment used in Channel 69 can tune to Channels 67 and 68 which are channels that are to be released for other purposes. There is therefore a possibility that illegal operation of equipment in the released channels would occur. Ofcom may therefore wish to review enforcement measures for the released spectrum prior to its award.

9.6.2 Sharing interleaved capacity

Whilst interleaved capacity is, in general, lightly loaded, some events at some locations use all of the capacity available some of the time. Sharing with other, non-PMSE but complementary, applications could increase overall use and the economic benefit to the UK of the UHF TV band.

However, our interviews with industry revealed that existing PMSE equipment and programme-making practice is either not compatible with sharing with other applications, or is only compatible if sharing is co-ordinated in a similar manner to existing PMSE use. Whilst coordination by JFMG (or a similar body) is likely to allow significantly increased use of interleaved capacity, it may not be compatible with sharing for some alternative applications – such as consumer devices.

Up to 50% of PMSE equipment in the UHF TV band will need to be re-tuned or replaced; there is a possibility that any replacement equipment could have functionality that would both permit high quality programming and be compatible with increased sharing. With industry, Ofcom should investigate whether or not solutions exist that would permit increased sharing. It is possible that these might need to apply only to new applications in the UHF TV band, but with a high level of replacement there is scope to encourage greater flexibility within equipment used for PMSE.

10 ECONOMIC ASSESSMENT

The purpose of this section is to estimate economic values associated with the use of spectrum by the PMSE sector. The economic value metrics considered are:

- Cost-effects: evaluation of the additional value to users of being able to use PMSE applications instead of the next best alternative;
- Value-effects: Using a case-study based approach, this section considers the cost-effects (as above) in conjunction with improvements that PMSE applications add to the quality/value of the end products and services;
- Qualitatively, we consider the economic impact of the use of spectrum on consumers and wider society.

10.1 **Introduction**

Spectrum is an intermediate input rather than a final product and its value stems from the end products and services it is used to produce. The primary benefit of the use of spectrum is obviously related to the users of spectrum – or the entities that license spectrum - through a reduction in costs or an improvement in quality of the end product or service. However, the consumption of end products or services also leads to benefits to consumers and – to a limited extent – wider society. The aim of this section is to identify the types of benefits generated by the use of spectrum to these different stakeholders and to highlight their scale.

It is usually difficult to attribute the end-value of the final product to the intermediate input components, and therefore we have only quantified the value in areas where there is available data and a framework to provide reasonably robust estimates. In other areas, we have provided a qualitative assessment of the relative scale of the expected value. The assessment in this section is primarily based on our discussions with industry experts and users of PMSE spectrum. The PMSE sector is not homogenous in the way it uses spectrum or the benefits that accrue from such use. To simplify the analysis, but to consider benefits and needs of "similar" users, we have based our assessment upon the categories of use identified in Chapter 2.

10.2 **Methodology**

PMSE is different to some other uses of spectrum in that for many users there are no alternatives available that could provide the same service – especially to the same quality. For example, in the mobile sector, a reduction in spectrum can be offset by an increased investment in the infrastructure allowing higher frequency re-use. However, as argued later in this report, for some live sports broadcasting, no alternative to wireless technology can achieve the coverage required and higher frequency re-use at the event cannot be readily achieved. Hence, the decision to use spectrum for PMSE is not related to cost-efficiency only – at times it is the only option available. Hence, some methods of spectrum valuation, such as those that are based on estimating the increased costs due to marginal reductions in spectrum are not applicable in this case. Similarly, using some alternatives to wireless PMSE applications that do not confer the same advantages of wireless devices, fails to capture some of the benefits of PMSE use.

If an alternative were to be able to provide the same level of quality, Willingness to Pay (WTP) for the end products and services would not increase with the use of spectrum. The necessity of spectrum to maintain quality means that consumers also benefit from its use as an input. Hence our evaluation needs to consider changes in consumer surplus – the

difference between WTP and the price – in addition to changes in costs. We will also consider if the change in quality of output results in any benefits to wider society.

10.2.1 Framework of analysis

In this section we highlight the framework for evaluating the different benefits of spectrum use.

10.2.1.1 Cost effects

Cost effects equate to the change in cost-base from savings (or costs) for PMSE users from using spectrum. Given the wide number of PMSE users, it is not possible to undertake this analysis at a bottom-up level and calculate costs for various user groups. Instead, we undertake the analysis for a typical user in each category.

For many traditional uses of spectrum, due to availability of alternatives that can result in the same quality of output, cost-savings represent the opportunity cost of spectrum use. In the case of PMSE, because alternatives often do not exist, cost effects represent a lower bound of the actual opportunity costs of spectrum to the users as these do not include the impact of any reduction in quality.

The main driver of cost effects is the impact of using any alternative. Our approach is to look at the next best alternative to the use of PMSE spectrum instead of the cheapest that is currently available. In some cases, there is no other option but to use PMSE spectrum in which case we are unable to present any estimates.

When estimating the cost for a typical user, we assume the entire use of spectrum is replaced with an alternative rather than only a marginal change. This is to take into account all the drivers of costs of using the alternative, some of which - like labour costs - may not come into play for small changes. Also given the lack of adequate substitutes, for marginal changes most users tend to try to work within the existing capacity (through sharing spectrum, etc.). We discuss the differences in cost between total and marginal changes in spectrum use Section 10.3.1.4.

The cost effects are measured by estimating the additional daily cost that would arise if the current spectrum assignment is replaced with an alternative input (assuming no spectrum is available for PMSE use). The key steps in the calculation are highlighted in Figure 10.1.

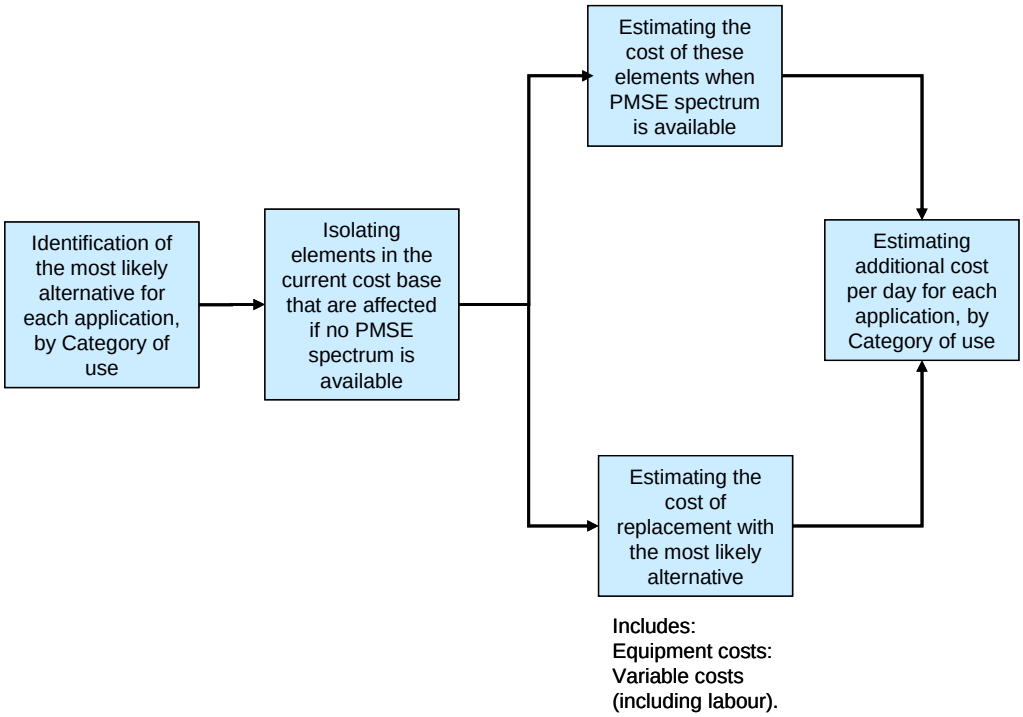

Figure 10.1: Key stages in the estimation of cost effects.

The assumptions behind the analysis are summarised in Annex E.

10.2.1.2 Value effects

Value effects reflect the additional value generated from the use of spectrum that would not be possible with the alternatives. Together with the potential cost savings, it represents the true opportunity cost of the use of spectrum for the PMSE sector. Value effects can materialise in the form of additional revenue, increase in brand value, helping achieve professional obligations (as in the case of PSBs) etc. In other cases, producers are unable or not aiming to internalise the benefit of spectrum use and the economic benefit is forwarded to the consumer of the end product or service. For example, the use of spectrum applications in places of worship or public hospitals is mostly for the benefit of consumers.

Whereas the costs of using spectrum are related to the underlying use of resources, the value generated from the use of spectrum is embedded in the context of who the user is and the nature of the end product or service. There is often a significant difference between the actual cost of the spectrum use (which is a small percentage of total) and the value generated from the (programme) output. For example, where the benefits of wireless technology such as mobility are essential (such as coverage of Golf events) the added value from the use of spectrum is multiplied many times over. The value generated by the use of spectrum varies more by this underlying context of use than by particular industries or PMSE sectors. Given the difficulties in quantifying value effects (detailed in the box on the following page), we use a case-study approach to highlight the variation in the way the value is generated by different types of users of spectrum in order to reflect its importance to users. The three key areas we consider are:

- Financial incentives: whether the use is for commercial or normative considerations. Commercial uses derive value from additional revenues but in other cases, especially

public sector considerations (including community uses), the monetary considerations are less important;

- Essentiality: whether or not there is an alternative available for spectrum use. Where alternatives are not available, a larger proportion of value addition of the end product or service can be attributed to spectrum use;
- Chargeability: whether or not consumers pay directly for the product and therefore where the costs of spectrum are more easily passed on.

Difficulties in quantifying value-effects

It is difficult to estimate the aggregate value generated by the users of spectrum in the same way as the cost effects. This is because:

- Unlike cost effects, most users find it very difficult to attribute the share of overall value that is specific to a particular input such as spectrum. Cost of spectrum in overall production costs is often very low – hence finance mangers are less inclined to analyse its benefit in detail. Hence, only very limited estimates of value are available;
- Users are not inclined to talk about the profits they make from the use of spectrum, especially if their considerations are commercial[57];
- For products where spectrum is an essential input (in many cases, perhaps one of many essential inputs) it is difficult to ascertain what value to assign to the spectrum. For example, while programs such as Big Brother may not exist in their current form without radio microphones, it is difficult to argue that all its value is linked to spectrum use, even though all of the end product's (e.g. the programme or event) value-addition may be lost without the use of spectrum;
- Many end products and services are undertaken for non-commercial reasons and therefore a) there are often problems in isolating a benchmark to estimate a monetary value and b) often the surplus from the improved quality is forwarded directly to consumers. For example, for church sermons it is difficult to gauge a monetary value derived from the use of radio microphones;
- Many end products are not traded – for example news is often broadcast on free-to-air channels and funding is not hypothecated to elements such as use of spectrum. Often these channels run at a loss and are only providing the service to meet their public service remit or as part of a brand strategy. Their value is linked to the bundle of programs they are part of and it is almost impossible for users to identify a monetary value for the separate contribution of spectrum for PMSE purposes, which is only a small input in the overall value chain;
- Lastly, without monetary estimates for individual categories it is difficult to compare or provide an overall figure for value effects.

10.2.1.3 Value to customers and wider society

At the time of writing this report, there had been no published research into consumer willingness to pay for the enhanced quality of programming achievable through the use of PMSE wireless technology, and the scope of the project excluded the use of expensive and

[57] To inform our analysis, we asked respondents in our interview programme about the specific value they associate with spectrum use and their willingness to pay for spectrum. In general the respondents found it either difficult to answer these questions in a quantitative manner or declined to share the information for commercial reasons.

time consuming consumer surveys to elicit such data. Furthermore, our interviews with industry experts revealed that consumers find it difficult to place a value on marginal changes in programming quality. We therefore made a qualitative evaluation of the value to customers and wider society based on the available literature, our interview results, and analysis of the licensing data.

10.3 Economic evaluation of spectrum use by the PMSE sector

10.3.1 Cost effects

The comparison of current and potential costs of the most likely alternative suggests that the average cost for a typical user will increase in all the cases apart from those in the category Local entertainment and events, where there will be a small saving – but for all, there will be a significant drop in quality or convenience compared to the use of spectrum.

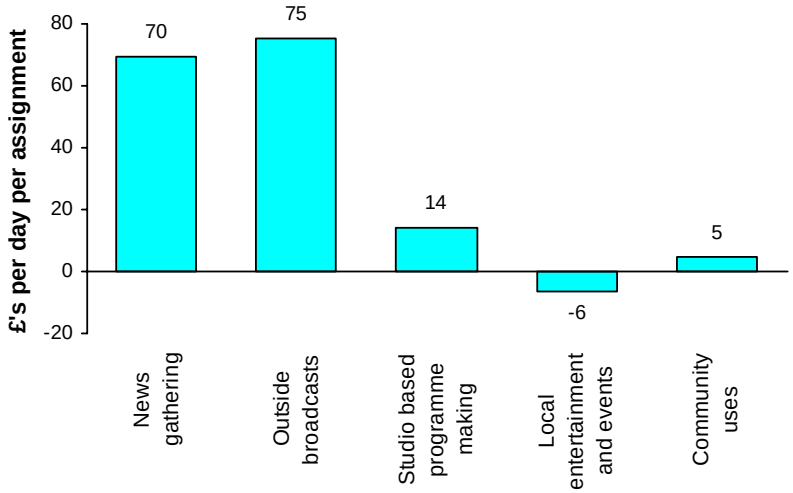

Figure 10.2: The additional cost of using the most likely alternative to PMSE spectrum (in £'s per day per assignment) for each category of use.

These estimates are based on a series of estimates and assumptions that are described in detail in Annex E. The key considerations include:

- The elements in the resources that are affected if spectrum is not available for use and an alternative needs to be employed, including both equipment and non-equipment elements such as labour[58]. The assumptions are given in Annex E.
- The alternatives including a) the most likely alternative, b) the additional costs related to using the alternative, c) how the end product based on the alternative compares to spectrum use, and d) other possible alternatives. The assumptions are given in Annex E[59].
- Assumptions relating to utilisation of equipment and the need for additional labour resources (as identified in Annex E).

[58] The specific brands for the hardware are chosen based on the recommendation of users and vendors from our interviews. The interviews are also the basis of the volume of applications used by a typical user. We also used a slightly dated report by JFMG (undertaken in 1999) as a benchmark against which to check our estimates.

[59] It is important to note that the estimated volume and scale of costs is based on a combination of discussions with hardware vendors and users, our internal understanding of the industry and surveys on the internet. We have sourced the information where it is taken from a published source or a website.

Cost is likely to increase most for outside broadcasting, followed by newsgathering. In contrast, studios and community users face only a minor addition to costs, and for local entertainment and events, spectrum use is the more expensive option and costs are estimated to be reduced by £6 per day for every assignment not used.

The costs for newsgathering and outside broadcasting are, in part, a high scale of fixed costs that are distributed over a small number of assignments. This means that costs that are common across assignments such as some equipment costs (spare talkback kits) and some variable costs (labour costs) are shared over a smaller number of assignments for a particular user. In the following sections we show that the balance of these "common" costs between applications and the number of assignments is the key driver of the scale of additional costs between users. Another factor in the high costs for newsgathering and outside broadcasting is that, in addition to common costs, the best alternative is to lease more expensive transponder capacity on satellite links.

10.3.1.1 The nature of alternatives

Table 10.1 identifies the most likely alternative that we have assumed in our economic valuation (and comments on the suitability of the alternative).

Sector	*Talk back*	*Radio microphones*	*Programme links*
Newsgathering	PMR: Provides roughly similar quality of service	Wired microphones: Since the other wireless options do not provide adequate quality	Wired cameras and a satellite link back to the studio[60]: Preferred to VT cameras.
Outside broadcasts	PMR: Provides roughly similar quality of service	Wired microphones: Other technologies do not provide adequate quality	Wired cameras and a satellite link back to the studio: only available option, especially for live coverage.
Studio-based programme making	DECT: Due to shorter distances and confined spaces with little outside interference	Wired: Likely to be the most reliable alternative but with serious mobility impediments	Wired cameras: likely to be replaced by multiple (wired) cameras to get variation in shots
Local entertainment and events	DECT: where distances involved are short enough	Wired: Likely to be the most reliable alternative but with mobility impediments	Negligible use – very rarely used by theatres and other key users in this areas
Community uses	PMR Licence exempt: Low quality but for community uses it would suffice	Wired: Likely to be the most reliable alternative but with mobility impediments	5.8GHz link: Only used by hospital radio within the community uses category

Table 10.1: Most likely alternatives for talkback, radio microphones and programme links.

[60] Note that leased lines and satellite would typically be used as a programme link back to the studio for ENG.

The most likely alternatives to spectrum use are rarely good substitutes, because they often have negative implications for the quality of the end product and service. For example, often the most likely alternative is a wired substitute for the wireless application. However, considering that wired alternatives are usually more reliable and in some cases cheaper, it begs the question as to why would users use the wireless option in the first place? The key benefit of wireless applications is that they offer higher mobility i.e. if mobility were not an important factor wireless would not have been used. Hence, whilst we cost wired substitutes as the alternative, it is clear that they inhibit certain activities and are not a perfect substitute to wireless applications.

The difference in alternatives between different uses is obviously linked to the particular needs of users within different categories of use. For example, newsgathering typically needs long-distance communications and therefore PMR is the most likely alternative, in studios the distances are rarely longer than a few 10's of meters and therefore a likely alternative is DECT, which works better over short distances. Nevertheless, there are a few common trends as well. The key alternatives to talkback are fairly similar and only differ between PMR, DECT or Cellular phones or a wired kit depending on the distance and the tolerance to interference of the particular user. For radio microphones, radio cameras and data links, however, wired alternatives are the overwhelming preference in all categories of use.

In order for the cost to be compared with the current spectrum pricing regime, we have estimated the cost of the most likely alternative on a per assignment basis. This has included amortising equipment costs, taking into account utilisation rates as well as identifying the daily cost of variable elements. We have assumed an equipment cost amortisation period of 7 years, based on our discussions with vendors, a major broadcaster and hire companies; of course lifetimes vary with component class and manufacturer. Details of the assumptions made for utilisation and other costs are available in Annex E.

10.3.1.2 Analysis of equipment versus variable costs

The cost of using the alternative is a mixture of equipment and variable costs. For simplicity, the variable costs are assumed to include labour costs.

The costs of using the most likely alternative are overwhelmingly skewed towards variable costs. Our assumptions for amortisation (amortised over 7 years) and utilisation rates imply that the additional cost of hardware is distributed over 640 days for low utilisation uses (used 25% of days in a year) and 1,920 days for high utilisation uses (used 75% of days in a year). Hence, a wired radio microphone costing £800, in a high utilisation environment such as a studio, only contributes 41p to the cost of the alternative on a per day basis. Therefore, the net impact of equipment costs on the absolute cost of an alternative is small (ranges between 1% for news and outside broadcasting to 17% for community uses) relative to variable costs. These cost estimates are shown in Table 10.2.

	Cost per day of using alternative to spectrum (£)	*Variable cost per day (£)*	*Equipment cost per day (£)*	*Equipment as a % of total*
Newsgathering	87.30	86.16	1.14	1.3%
Outdoor broadcasts	94.09	92.92	1.17	1.2%
Studio-based programme making	29.29	26.95	2.34	8.0%
Local entertainment and events	10.93	9.70	1.24	11.3%
Community uses	11.28	9.38	1.91	16.9%
* Costs are only estimated for elements in the total that will change if the most likely alternative is used. Hence, these costs relate to a subset of all costs.				

Table 10.2: Split of equipment and variable costs in total.

Equipment costs are still important because they dominate upfront cash flow and are often an impediment to the take up of other alternatives. Yet, in the context of PMSE, the wireless hardware required for PMSE use is often more expensive than the equipment required for the most likely alternative, especially when the alternative happens to be a wired application. These are shown in Figure 10.3.

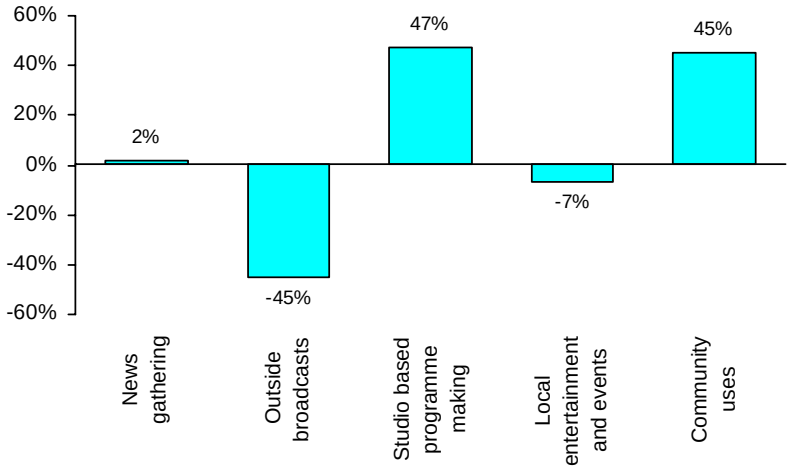

Figure 10.3: The percentage increase in equipment costs if the most likely alternative is used, for each category of use.

The cost of equipment for the alternative, compared to PMSE equipment use, is much higher for studios and community uses and much lower for outside broadcasting.

Studios need to use additional wired cameras to provide the additional camera angles in the absence of a highly mobile wireless camera. In the community use group, local hospital radios are assumed to substitute existing programme links with 5.8GHz license-exempt wireless equipment (with an estimated cost of £4,500). The cost difference of alternatives is less stark for talkback and radio microphones than for programme links.

The difference in the case of Newsgathering, Outside Broadcasts or Local entertainment and events is not substantial. However, equipment costs of the alternative are significantly lower for outside broadcasting because we have assumed that the alternative is a wired camera which would be considerably less expensive.

It is important to note that we are estimating the cost on the basis of users owning the hardware, whereas in reality a large proportion of hardware is hired. In these cases, the hire costs include an element of cost of capital as well as an additional margin. As a conservative estimate, these could add as much as 10% to 20% of capital expenditure (or savings in the case of outside broadcasting and entertainment and events) on hardware.

In addition, it is notable that our estimates for equipment cost are on the basis that current users need to purchase new equipment. In reality though, PMSE users have already incurred expense on applications that currently use spectrum which may become redundant or lose substantial value if spectrum availability is restricted. Indeed, in our interviews a leading newsgathering organisation suggested that "millions of pounds of equipment" is at risk if they are not able to use spectrum or if they have to use alternative spectrum bands.

Variable costs can be divided into three categories: cost of spectrum (for example in the use of PMR spectrum), cost of transponder capacity or leased lines, and labour costs. Like equipment costs, variable costs can also increase or decrease depending on the alternative use assumed. Whether or not costs increase primarily depends on the extent to which common variable costs like labour costs can be distributed over a large number of assignments. Additionally, it is important to note that when alternatives are used, users save a substantial sum on spectrum fees which range between £2 and £36 for a 48 hour license.

All user groups will face variable labour costs, but only newsgathering and outside broadcasting incur costs in the other two categories (spectrum use fees and transponders/leased line rental). These costs include the cost of PMR licences for talkback units (£10/day per unit) and the cost of leasing transponder capacity for satellite links (approximately £100,000 per year per video link which can be used for assignments across the UK). The high cost of leasing transponder capacity is a key reason for the higher cost of newsgathering and outside broadcasting.

For uses other than Newsgathering and Outside Broadcasts, labour costs dominate total costs. The applications that use spectrum for PMSE reduce the requirement for resources such as assistants to manage cabling (potentially a health and safety hazard). They also save the expense of managing any additional hardware that would be required if spectrum were not being used (for example additional camera men and cameras to provide additional angles for coverage).

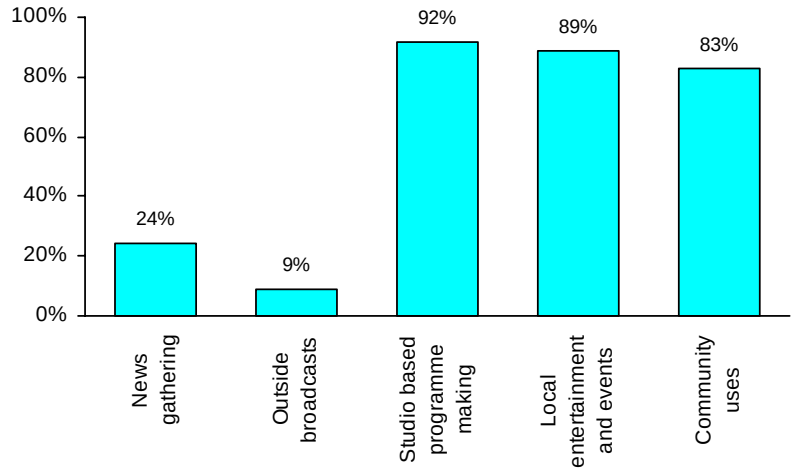

Figure 10.4: Share of labour costs in overall cost of the most likely alternative.

We have estimated the cost of labour on the basis of the current average daily cost of hiring staff through agencies. Annex E (fourth table) gives a summary of the labour assumed to be required if the most likely alternative is used. Whereas only assistants are required to handle wired equipment for newsgathering and outside broadcasts, studios and theatres also require the use of sound engineers. Studios may also need additional assistants if boom microphones are used.

The daily rate of labour is assumed at between £250 per day for a stage or boom microphone assistant, £350 for a sound engineer, and £500 for an expert sound engineer or a camera man. Clearly, paying these rates only makes sense if the use is not regular. However, if no spectrum is available and use of additional labour is required on a longer term basis, users would employ staff, and reduce costs somewhat. Though the utilisation of full-time staff is likely to be much lower than hired staff, the yearly costs of labour can be less than half. Keeping in mind that a significant proportion of staff is full-time employed, we assume that the average cost of labour is 25% less than the daily rate mentioned in Annex E (assuming full-time employees make up half of all staff and their implied cost is 50% of the daily rate). Since labour costs dominate, the costs of the most likely alternative is highly sensitive to assumptions on these labour costs. As an illustration, if the average labour costs were 25% higher than the average daily rates assumed above, the most likely alternatives for Local entertainment and events would cost at par rather than being cheaper than the current use of spectrum.

10.3.1.3 Impact by band

Since access to any given spectrum band is currently used by many different users, the cost impact of a reduction in spectrum on an individual band depends on the mix of assignments to the different categories of use and what the best alternative would be. Using the share of assignments by band for the different categories of use and the estimated additional cost of using the most likely alternative by different uses, we calculated the average cost increase for a licensee of an assignment in a each band, if no spectrum were to be available. The results are given in Figure 10.5.

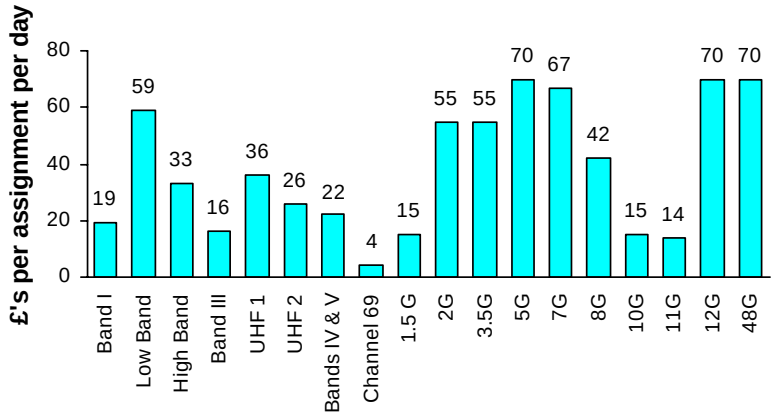

Figure 10.5: Implied average increase in costs (in £'s per assignment per day) for current licensees by band, in the situation in which no spectrum is available for PMSE activities.

The cost increases by band reflect the balance of usage in that band. For example, bands over 12GHz and 48GHz are only used by the BBC and the costs are equivalent to the cost of newsgathering. On the other hand Channel 69 is mostly used by theatres, in the community or by studios and therefore costs are much lower.

The estimated costs in this section are based on the assumption that all PMSE bands are unavailable to users. If only a particular band of spectrum became unavailable the least cost alternative method could be the use of new or adapted equipment in an alternative PMSE band. In this case, the alternative costs above might be over-estimates.

10.3.1.4 Marginal change versus total change

Our estimates in this chapter have been based on looking at the cost impact on the user of spectrum if no spectrum were available. The primary reason for adopting this approach is the difficulty of evaluating the marginal change in spectrum because of the rather unique way spectrum is used by the PMSE sector. Unlike other uses, PMSE users generally cannot substitute spectrum with alternative inputs which result in like-for-like quality for the output. Therefore, for marginal reduction in spectrum, at least in the short to medium term, most interviewees in our survey suggested that they would learn to use the existing capacity more effectively, reduce the number of devices (*e.g.* cameras or microphones) deployed, or simply discard the activity enabled by spectrum.

As opposed to total change in spectrum availability, marginal changes in spectrum do not affect all the PMSE users; they only affect peak usage by users that face a constraint in their use of spectrum. Hence, the impact is skewed towards certain uses and users. It follows that most users believe that they have access to ample spectrum and a marginal decrement in the availability of spectrum is unlikely to change usage patterns. Hence spectrum demand is generally inelastic. For example, a large majority of interviewees who responded to the question in our survey suggested that they would not change their use of spectrum if the price went up or down by 100%.

Ofcom's approach to pricing spectrum for other uses has been based on marginal changes in the use of spectrum. These estimates for marginal changes are likely to be somewhat different than for a total change in spectrum. It is clear from our discussions with users that the alternatives to wireless applications for PMSE remain the same even if the change in spectrum availability to users is marginal. The one caveat is the case where capacity is only restricted in a particular band and users can compensate for this by moving into another band. Under such circumstances, the most likely alternative will probably be to

continue to use spectrum in a different band. Thus we might expect marginal costs to be less than the costs calculated above assuming that no spectrum is available.

The scale of the additional costs with marginal changes in spectrum availability are likely to depend on how much of the current use of spectrum will be displaced and substituted by the most likely alternative. Some key aspects to consider in this regard are:

- For small changes in the availability of spectrum, because of quality issues, most users are likely to prefer to use existing capacity more efficiently;
- In the first instance, users are unlikely to invest in hardware or employ staff in the same proportion as we have estimated. In fact, for small changes users may not hire additional staff and may use existing labour resources. For example, theatres may recruit a stage assistant if dozens of wireless microphones are replaced by wired alternatives but not if only a couple of microphones need to be replaced. Areas where additional staff use may be necessary include use of boom microphone assistants. Hence, the additional costs at this stage would be a much smaller proportion of the total costs, but there would be quality impacts;
- Peak users of spectrum will be affected first, *i.e.* mostly large business entities including, for example, the BBC and large theatres, and coverage of large sporting or social events;
- For larger reductions in spectrum users will substitute spectrum use with the alternative. Initially though they would tend to only use hired equipment and hire staff on a daily rate. This implies that their overall costs would increase gradually and could even become higher than the costs presented in Figure 10.5. Costs could be higher because a) equipment hire costs would include return on capital and a profit margin, b) hired staff costs are likely to be more than for full time employed staff and c) the common costs are likely to be distributed over a smaller number of assignments;
- As more spectrum becomes unavailable, the additional cost will tend towards the cost estimated for the case of no spectrum.

10.3.2 Value effects

The scale of the added value of spectrum varies with the nature of the user and the context of use. For example the value of being able to cover a radio interview during an election campaign may differ from the value of being able to improve the acoustic quality of a school play – but both may rely upon radio microphones. For other uses (such as the broadcast of sports such as golf) where alternatives to wireless applications do not exist, it could simply be a large part of the overall value of the production[61]. In Annex E, we provide a detailed overview of the typical drivers of value for different categories of use.

Here, we evaluate three important factors that affect the value of spectrum which we have termed "financial incentives", "essentiality", and "chargeability". In the following sections, we define these terms, and provide detailed examples of where spectrum sits in the value chain of uses that fall within these categories and what that means relative to our previously calculated estimates of value.

[61] For example, one interviewee stated that without PMSE spectrum and with no major investment in alternative sources and technologies, in the short run they would be unlikely to cover anything more than the first and last 3 holes of an 18 hole golf course during a live tournament and therefore the telecast would lose most if not all of its value.

10.3.2.1 Financial incentives

Variations in how the incentives that apply to the users of spectrum are structured lead to differences in value generated for the end products. Whereas, a commercial enterprise often has direct monetary incentives, public sector organisations have very different considerations for utilising spectrum to enhance the quality of their end products or services. In fact, some not-for-profit organisations and community users improve the quality purely for the benefit of consumers and do not directly benefit from its use at all (for example, improved quality of church sermons, etc.).

The value of end products or services for non-commercial, especially public sector, organisations with a normative remit has been analysed in the economic literature for many industries. The BBC itself is the largest user of spectrum for PMSE and its remit and the value it derives from the use of licence fees has been discussed and evaluated in detail[62]. However, there is very little information on how this value changes with marginal changes to quality, especially those aspects that are likely to be affected by PMSE spectrum use. For example, how does the use of radio microphones for coverage of The Open Golf Championship improve the value for the BBC? Although it is clear that without adequate programme quality the BBC would not be able to compete with rivals for its viewing share, it does not face the same risks as commercial networks. Lack of commercial risks is one reason why the BBC is able to move into commercially uncharted areas such as ultra local news (see Chapter 6).

This variation in value generated by firms with commercial and non-commercial financial incentives is most obvious in the case of the broadcasting sector where public sector broadcasters compete directly with commercially funded channels. However, it extends to users in other sectors as well. For example, the use of spectrum by hospital radio services, although in their case reasonable alternatives to PMSE spectrum are available.

10.3.2.2 "Essentiality"

Licensing of spectrum is a small proportion of aggregate costs for most PMSE users. However, the actual services and aspects of the end products or service that are enabled or enhanced by the use of wireless applications (over and above what can be achieved by an alternative method of coverage) can often become a key part of the final experience for the consumer. As a result, PMSE wireless applications can become an essential ingredient for some programmes or events. Equally, without spectrum, a large part of the value generated can be compromised for the user. Therefore, the more essential the impact of spectrum is to the final experience for the consumer, the more value it generates.

More essential use of spectrum implies that there is unlikely to be an adequate alternative to it. Hence, the opportunity cost calculations done in the previous sections would be less relevant to these uses. The evolution of wireless technologies and the increase in their adoption has increased the proportion of activities for which spectrum use is essential. Where as, a few decades ago, large theatres would have been able to produce good quality acts without the use of wireless using a combination of wired and boom microphones, today it is almost standard for them to provide radio microphones to most of their cast. According to our interviews, a key impact of these changes has been the enhancement of the consumer experience and of their expectations. Consumers are now more discerning, and they expect the use of wireless technologies in West End musicals. Hence, radio microphones are becoming an essential ingredient for theatres.

As mentioned in Chapter 6, the trend is toward enhanced consumer expectations which makes spectrum indispensable for more and more of the PMSE products and services (this

[62] The future of Television funding, Ofcom report by Human Capital, September 2005.

is particularly true in broadcasting with live news programming, reality TV etc.). Still, according to our respondents, although far from desirable, televised coverage of many sports would be possible even if less spectrum were available. There would be some deterioration of the end product, but it would not be critical. However, there are a small number of sports where the provision of adequate spectrum for PMSE purposes is absolutely essential such as the Silverstone Grand Prix or the British Open Golf Championship. For these events, the use of wireless technology is absolutely essential and lack of spectrum might actually result in the event moving out of the UK. Therefore any reduction in the availability of spectrum would reduce the profits related to the UK operations of these sports (for example gate receipts, production profits, profits from advertising media).

An example is given in the following box.

Essentiality Case Study: The Formula 1 Grand Prix at Silverstone

An area where spectrum use is critical to the acceptable end quality of the product vis-à-vis consumer expectations is in sports broadcasts. Telecast rights are one of the key revenue streams for many sports. In fact, many broadcast companies are now able to charge higher premiums through the use of Pay TV services by providing better quality telecasts (for example, special premiership matches on Sky box office). Formula 1 (F1) motor racing is one sport that relies heavily on TV audiences which generate income both in the form of rights fees paid by broadcasters and through sponsorship deals with companies keen to access the television audiences.

The British Grand Prix at Silverstone is a key part of the 19 races around the world. The format of production broadcast around the world is fairly standard and requires extensive use of radio spectrum allocated to PMSE because the alternatives are inadequate and would not provide the same viewing experience (e.g. providing in-car camera views). Guaranteeing the quality of the broadcast is therefore an important pre-requisite for any circuit to be included in the calendar. In the event of an inability to secure spectrum for PMSE, there is the possibility that event organisers would remove that particular race circuit from the series. (Indeed, the failure to provide adequate event infrastructure has already threatened racing at Silverstone.) Therefore, lack of adequate spectrum for PMSE could risk the loss of the economic surplus from F1. (While the actual user of spectrum is ITV's production unit in the UK, the cost of production is taken into account by F1 in granting the media rights to the firm. F1 does not make any payments in lieu of production to ITV.) Key UK businesses intimately related to F1 activities would lose profits and these companies include the race track owner, the broadcaster and the UK based teams.

Clearly, the move of F1 from Silverstone would not mean a blackout of the sport on UK television. Nor does it necessarily imply a reduction in its popularity worldwide, perhaps not even in the UK. The race would most likely move to another venue. However, there would be a direct loss in economic benefit to the F1 group of companies and their associates.

The estimated economic loss would include:

- Loss in profits for Silverstone: from an average of around 100,000 ticket sales amounting to an estimated £20 million in gate receipts; from circa 5,000 premium hospitality tickets resulting in about £5 million in gate receipts; and from the sale of food and merchandise on race weekends. It is important to note that margins for Silverstone are not high – Silverstone has been loss making. The contract to bring the race to Silverstone alone costs over £12m a year.
- Loss in profit for ITV: While ITV is not paid for production of the race at Silverstone, the

purchase of rights includes an implicit discount for the production costs – ITV's profit margin on this amount would be lost if the race were moved to another country. In addition, the lack of a British Grand Prix is likely to reduce the interest of UK TV advertisers, especially if the race is moved to a country where the timing of the race takes it out of peak hours. ITV currently pays around £40m for rights to the 19 races and is thought to make a small profit from advertising revenue and sponsorships (the sponsorship by Foster's alone is worth over £3m). The amount of revenue (and the value of the rights) linked to the British Grand Prix is likely to be much more than the other races and this additional revenue would be at risk if the race were to move out of the UK.

Hence, a move from Silverstone due to a lack of availability of PMSE spectrum could cost the F1 group of companies and their associates several million pounds in lost economic value. Even though we cannot estimate the exact value, it is clear that the scale is high enough to make the cost of spectrum relatively insignificant (compared to current spectrum usage fees). The willingness to pay for the spectrum for an F1 broadcaster would be much higher than in a sport for which spectrum is not as essential. Therefore, as spectrum becomes more essential the demand for spectrum becomes more inelastic and the value it generates for the user more substantial.

10.3.2.3 "Chargeability"

The value of PMSE spectrum to different users also differs depending on whether or not users have the ability to internalise the net benefit from consumers. It is not likely that for each marginal change in quality users would pass on the cost of the product to the consumer. However, in our survey, respondents mentioned that they use wireless technology either because without it that they would be unable to charge the same amount to consumers or because wireless capability enhances sales of their product (either in terms of timing or volume). Prominent examples include the use of wireless by theatres, concerts and other entertainment events and use by independent production houses which then sell programmes to TV networks. An example is given in the following box.

Chargeability Case Study: West End theatres[63]

Theatre is one of the few users where spectrum for PMSE is used extensively and they also charge the consumers for the end product. There are around 541 theatres in the UK. Much of the high volume activity for theatres is limited to the London West End theatres, which according to the Society of London Theatres (SOLT) generated over £320 million in revenue in 2003. Two thirds of this was related to musicals (£210 million) followed by another quarter from plays and opera. The average revenue per attendee varies significantly with the type of performance, the production, the talent in the show, etc.. For example, the average ticket price was £32 for musicals but £57 for opera. Within musicals the high-end large productions can ask for over £150 for the best seats, compared to as little as £10 for cheaper tickets in smaller productions. Hence, it is reasonable to assume that there is a link between the underlying costs, the quality of production and the ticket prices.

A typical musical generates as much as £27,750 per performance. Typically, according to our discussions with respondents large musicals use more than 50 radio microphone assignments which at around £36 for a 48 hour licence would amount to around £900 per night (or roughly 3.2% of revenues). However, without the use of spectrum the cost is likely to go up by

[63] Note: All financial figures for West-end musicals are from the SOLT Box Office data report 2003.

approximately £432 a day as estimated in the previous section (i.e. 1.6% of revenue receipts). For the overall West End musical market, this amounts to an additional cost of £3.4 million (assuming 7 performances a week) per year. Currently, annual licenses are significantly cheaper (on a per day basis) and would further increase the cost impact of using an alternative.

In addition to these cost savings, there is likely to be a value effect as well. For example, the most likely alternative to wireless use in theatres is either a wired or boom microphone. Either of these severely restrict the movement of actors and restrain the creative elements of the show. Although we did ask respondents, including those associated with the theatres in the West End, about the perceived impact on revenues of using wired radio microphones in theatres they could not suggest a figure, although it was suggested that the impact is likely to be negative. However, as an illustration, if the average ticket price paid by musicals went down by £1, it would result in a net decrease of revenue of £7.3 million. Together with the cost effects it would suggest that the direct economic loss to West End musicals would amount to £10.6m or around 5% of the current revenue base.

Hence, individual industries" marginal changes to revenue can have a significant influence on the bottom-line. For example, enhancing the user experience sufficiently to justify 1 percent of the average ticket prices, amounts to approximately £10m for theatres in the West End.

Chargeability is different from other aspects of the use of spectrum because it represents the potential for the producer to internalise the surplus from better quality products or services. Where the product is not traded and is not directly charged, often this surplus is forwarded to the consumer. Clearly, these users are also likely to be more sensitive to the consumer experience so as to be able to improve their revenues. Hence, the greater the ability of users to charge consumers of the PMSE end products or services, the higher the value they will generate from spectrum use.

Apart from these key factors, many of the community uses for spectrum such as those in state schools, community centres and other non-profit based organisations are often not related to generating additional revenue. These users consider other social factors in the use of spectrum to justify their offering . The impact of changes in spectrum use on the value they generate is more likely to be represented as a reduction in consumer utility, which is discussed in the next section.

In the above mentioned examples we have only looked at the direct impact of changes in spectrum use on the users of spectrum. However, as with any other industry, there are knock on effects on associated industries. For example, with any loss of F1 at Silverstone there would be other businesses that would suffer consequential fallout. The UK may lose its image of being the "home" of Formula 1. Most of the major teams participating in the sport are based in the UK, including Ferrari. Many of the European teams have their R&D headquarters in the UK. Only in 2004, Mclaren opened a technology centre on a 50 hectare site just outside Woking in Surrey. If F1 leaves the UK it may remove the incentive to base these activities in the UK, and the related economic benefits . The same argument applies to the economic benefits associated with theatres and other industries.

10.3.3 Value to other stakeholders

Analysis of the impact of spectrum is incomplete without a discussion of the impacts on the eventual consumers of the end products and services and any associated benefits that society may generate from them. We have not quantified these benefits due to lack of data and the difficulty of eliciting consumer valuations for marginal changes of quality in surveys. However, we find no reason why the consumer benefit from the use of spectrum

for PMSE should generate any more consumer surplus or wider societal benefit than would be possible by other uses.

10.3.3.1 Value to consumers

The value to consumers of PMSE products is the consumer surplus (or the utility that consumers get, over and above what they pay) for the output or activity enabled by spectrum for PMSE purposes. In cases where spectrum-based output is not traded, for example use of spectrum by churches, the entire surplus is passed on to consumers.

Consumers of PMSE end products and services benefit from two aspects of spectrum use.

- Potentially lower prices of end products due to lower costs: For products for which consumers pay money, PMSE use can reduce overall costs for the producers since the alternative to spectrum use costs more. This can be reflected by the producer in lower prices in some cases. The overall scale of this effect is likely to be small because:
  - Producers may not be able to readily forward the marginal cost changes on to the consumers, hence in many cases the price paid by consumers would not change in the short run whether or not spectrum or the alternative is employed by the user;
  - Even if the user is able to forward the saving to the consumer, the change is likely to be very small (spectrum is a small proportion of overall costs) ;
- Better quality: The main benefit of spectrum use to consumers is the improved quality of the end products or services that would not be possible without the wireless PMSE applications. Examples are the utility that consumers get from additional camera angles in a football match or a live broadcast of an offshore news event through radio cameras in helicopters.

Given the scale of costs involved, most users of PMSE spectrum are unlikely to price products any differently. The vast majority of PMSE users do not charge consumers directly and therefore the surplus related to lower prices is likely to be small. The consumers who may benefit include broadcasters who purchase programs from production houses and studios or local commercial entertainment events like theatres.

The value from better quality is likely to make up most of the consumer surplus. Consumer surplus is usually estimated through survey techniques that estimate consumers' willingness to pay. Ordinarily this would imply asking consumers about the difference in value they put on two products of different quality. However, in the case of spectrum for PMSE this is likely to be very difficult. The changes in quality in most cases are marginal. Consumers are not used to paying by programme or for incremental improvements in programming. Most consumers, where they pay at all, pay for a bundled package and are not used to valuing the cost of an individual programme, let alone a particular aspect of a programme (for example, the value associated with mobile presenters in game shows because of the use of radio microphones). Many wireless applications are for the back end of the productions and allow a smoother flow of the programme or other peripheral aspects of the production which are often not noticed by ordinary viewers.

In our survey we asked the users and consumers of spectrum enabled PMSE products and services about their ability to quantify their valuation of the improvement in quality due to spectrum use. However, they were unable to quantify the benefit. We also interviewed experts in the advertising and media sectors who have it in their interest to understand variations in consumer valuations for different products. According to them most consumers value the marginal element of quality only as part of the overall experience. Hence, unless the quality difference results in a noticeable change in the consumer experience, the change in consumer utility would be minimal. For example, the majority of

the valuation that a football match viewer makes of the programming is related to watching the actual match live. Additional camera angles and wireless microphones improve the experience for the consumer but only to a very limited extent. On the other hand where spectrum is essential the change in quality may be substantial and hence the consumer valuation may also be substantial (for example, if lack of spectrum reduces the number of holes covered in the broadcast of a golf event).

10.3.3.2 Value to the wider community

As the regulator, Ofcom needs to be aware of the wider impact of PMSE spectrum use on the community and the citizen and consumer, and if there are any positive (or negative) externalities from the use of spectrum that the market is unable to internalise either immediately or over time with help from transitional measures. However, as mentioned before, it is important to recognise that it is not in all areas of use that spectrum use is absolutely essential and where lack of spectrum would result in an economic activity not taking place, possibly resulting in an indirect loss to the wider community.

In most cases of spectrum use, only a marginal element of quality of the end-activity is at risk which is unlikely to have significant direct effects or externalities. This is not to say that society does not benefit at all from marginal changes in the quality of PMSE products and services. Clearly, a wide number of users and industries and their viability and competitiveness both nationally and internationally are affected by the use of spectrum, which has some spill over affects. For example, the quality of British TV programming or the quality of theatre in the West End reflects on the image of UK plc. These secondary affects may often be very material - the lack of adequate spectrum to cover major sports event would severely inhibit the ability of the country to hold major sporting events like the Olympics or the football World Cup.

With the exception of similar examples to those outlined above we found it difficult to articulate examples of market failures or to find major market failures or externalities that are not, or could not be, taken into account by the key players in the spectrum market. There are, however, secondary financial implications (not necessarily amounting to material economic benefits) for downstream and associated industries of the use of spectrum (such as jobs linked to associated industries). The importance of many of the PMSE uses such as community use in churches and schools also has ethical and political implications. Would local communities find it acceptable that places of worship or hospitals and schools were being denied the use of wireless microphones? Whilst technology use by these particular groups does not amount to a tangible economic benefit, they would have repercussions for welfare and public policy. Yet, from the perspective of economic evaluation there is no reason to expect that the financial implications will lead to any economic surplus that would not be generated if spectrum were being used for purposes other than PMSE.

10.4 **Conclusions**

It is not possible to provide a single figure to reflect the economic value generated by the use of spectrum by the PMSE sector. This is because of two reasons: adequate alternative inputs to spectrum are not available for PMSE, hence the value of spectrum is not restricted to cost savings which is often the case in other sectors. Second, the diversity of the users and uses in PMSE is such that it is not possible to construct an overall estimate of the economic value generated from the better quality of end products and services that use of PMSE spectrum enables.

The use of the most likely alternative if spectrum is unavailable can increase costs by as much as £75 per assignment but costs can also go down. This was reflected by many users

in our survey who suggested that it is not the cost of spectrum but the quality improvement it delivers and the functionality it enables that drives their use of spectrum. The value of spectrum differs with both the nature of use and the nature of the user. Some users benefit from the added value of spectrum in the form of greater monetary benefits; some (and this includes a broad proportion of users) internalise the benefits in a non-commercial sense through meeting their operational obligations; and others pass on the benefit to consumers. Often, spectrum use only has a marginal impact on the quality of the end product and service but there are situations where the use of spectrum is essential and the amount of economic value at risk should the spectrum be unavailable runs into millions of pounds for a handful of assignments.

Very few users are able to directly internalise the benefit in the form of greater revenue because most of the PMSE end products and services are not paid for at the point of consumption. Hence, it is likely that the use of spectrum results in a significant consumer benefit because the consumer receives a much better quality of service without having to pay for it. However, we have been unable to estimate the scale of this benefit.

Similarly, we have not found any major benefits to wider society, although it is important that any policy decision should take into account secondary implications of the use of spectrum on society – such as the implication of spectrum trading on use by non-profit organisations.

11 SUMMARY

Programme making and special events (PMSE) describes a wide range of activities that use wireless primarily in support of programme making and broadcasting. Programme making here is broadly defined and includes the making of TV, film, radio, advertisement and corporate material through to the production of plays, concerts and shows of all sorts and sizes. The users range from the major broadcasters and West End theatres to village halls and individual professionals.

A common feature of many PMSE activities is their temporary nature. Facilities are often required for just a few days at one location to cover a specific event, such as a pop festival or a golf championship. Other PMSE activities, such as a theatre production and studio based programme making, take place over much longer periods. Yet other PMSE activities, most notably newsgathering, need to use their wireless equipment on a daily basis and across wide geographic areas such as a county or region. As a consequence, co-ordinating the use of frequencies between the different and varying users and uses is a continuous task. It is currently carried out by JFMG Limited on behalf of Ofcom.

JFMG currently has access to multiple frequency bands between 50MHz and 48GHz but this situation will change within the next few years as a significant amount of this spectrum will become unavailable for PMSE use. The two key changes are in the 3G extension band (2.5 to 2.69GHz) and the UHF TV bands (470 to 862MHz). The former is extensively used by the PMSE community for wireless cameras but is expected to become unavailable to PMSE users following its release to the market around 2007. The latter band supports the vast majority of radio microphone usage, which itself accounts for almost 70% of all usage. With the switchover to all digital terrestrial TV taking place between 2008 and 2012, around 30% of this spectrum is expected to be released for new applications. Its loss could have a severe impact on many PMSE users.

JFMG assigns licences and frequencies to, and collects fees from, the users of PMSE spectrum. Historically, these fees have been based on the recovery of administrative costs but it is Ofcom's intention to introduce market based methods into the management of this spectrum. The introduction of such methods, however, is complicated by the fact that much of the PMSE spectrum is shared with other primary users, by the potential adverse consequences of spectrum fragmentation with multiple spectrum management organisations, and the uncertainty over the future supply of spectrum. Ofcom has therefore delayed the introduction of both spectrum trading and administered incentive pricing to allow time for further review and consideration of the alternatives for the management of this spectrum.

This report supports this process by providing a comprehensive review of the PMSE sector.

11.1 Uses and users

Approximately 64,000 individual PMSE frequency assignments are made to around 1300 different organisations and individuals each year. The users, and the uses to which they put the spectrum, are diverse but a relatively small percentage account for the majority of the activity. Of the approximately 1300 users just 50 account for 50% of all spectrum usage[64], with the BBC alone accounting for 13%. The other major users of the spectrum are the TV and radio broadcasters, theatres, and TV studios. Places of worship, educational establishments and hospital radio figure prominently amongst the smaller users.

[64] By usage we mean the total number of frequencies used by an individual user times the period for which the frequencies were used.

The simplest use of PMSE spectrum would consist of a single person, such as a performer or a compere, using a radio microphone to transmit their voice to a PA system. However, other PMSE activities make use of a combination of wireless equipment applications of which there are four basic types.

Radio microphones

The most commonly used application is radio microphones. These are hand held or more discrete body worn microphones which transmit high quality audio over short distances. They are widely used by performers, presenters and reporters in TV shows, plays, news programmes, musicals and concerts where they do away with the need for cables and allow the performers greater freedom of movement. TV studios, theatres and rock concerts are particularly large users often using tens of radio microphones at a single location, and in excess of 100 in the largest cases.

Talkback

The second most commonly used application is talkback. Talkback refers to any voice communication used to relay instructions amongst those involved in the production of programme material or an event. For example, a programme producer will use talkback to pass instructions to a cameraman or to cue a presenter. Talkback is used both to provide local communication links, for example within a studio, and longer distance links between an outside broadcasting event and the broadcasting studio.

Programme links

Programme links are point to point links that carry either audio or video signals. They may be used within the locality of an event, for example to relay a presenter's audio signal back to an outside broadcasting vehicle, or to carry signals over longer distances from an event back to a studio. Note that radio microphones operating with greater than 50mW transmit power are classified as (audio) programme links and wireless cameras are classified as (video) programme links.

Data links

Data links are used for control purposes, typically for configuring the colour balance and other parameters of wireless cameras. They are most commonly used within the locality of an outside broadcasting event.

11.1.1 Categories of use

The above applications are used in different combinations to support different PMSE activities which can be divided into five broad categories.

Outside broadcasts

The category Outside broadcasts encompasses all situations in which temporary programme making facilities are established outside of a studio for the purpose of recording or broadcasting of any event other than a news event. Representative examples include the live TV broadcasting of sports events, radio broadcasting of concerts, or the recording of a football match for later transmission.

As illustrated in Figure 11.1, PMSE frequencies will be used at an outside broadcasting event for both on-site communications and for links back to the studio. Thus radio microphones, talkback, programme and data links are used within the area of the event, and programme and talkback links are used between the site and the studio.

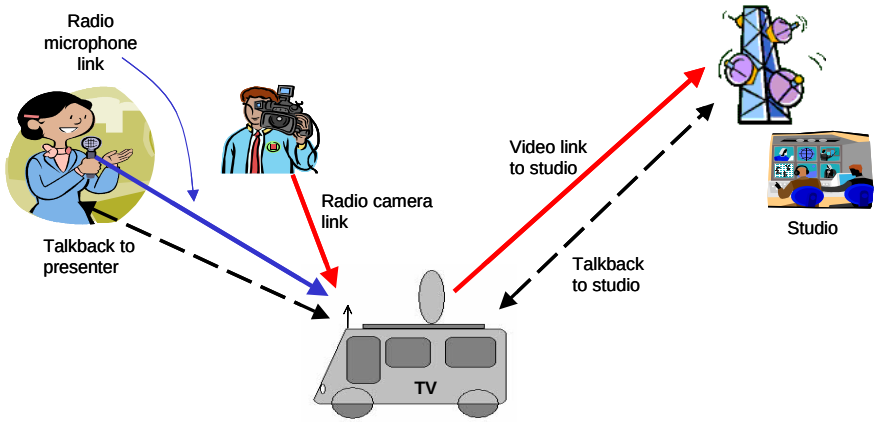

Figure 11.1: This figure illustrates the combination of PMSE applications that one broadcaster might employ to cover an outside broadcasting event. At an event covering a wide area (such as a golf match) radio microphone and wireless camera links may need to be extended through the use of intermediate audio or video programme links but these are not shown in this figure.

The major users are broadcasters and production companies that produce outside broadcast content for the broadcasters.

Newsgathering

Newsgathering is similar to outside broadcasting in that it requires the temporary provision of programme making facilities away from the studio environment. The key difference is that news teams need to be able to respond to news events wherever and whenever they occur. Thus they need to be able to establish their facilities at short notice anywhere within their geographical area of operation.

Any one news event will occur within a small area and will require both on-site wireless facilities and links back to a studio. Thus radio microphones, talkback, programme and data links are used within the area of the event, and programme and talkback links are used between the site and the studio.

The major users within this category are the large broadcasters such as the BBC, Independent Television News and BSkyB.

Studio based programme making

Although production in TV and other studios takes place at the same location, radio microphones, talkback and, to a lesser extent, wireless cameras are widely used. Avoiding the use of cables gives greater freedom of movement to presenters and other participants, allows greater flexibility in programming formats, and brings productivity gains. Large studio complexes are some of the biggest users of radio microphones.

Studio based programme making can also include an element of outdoor work and this gives rise to requirements similar to those of newsgathering. Thus this category of use also includes higher power talkback and programme links.

Studios are operated by both broadcasters (radio and TV) and independent production companies. Video production companies and, to a lesser extent, film studios also make use of radio microphones, wireless cameras and talkback.

Local entertainment and events

This category encompasses a broad range of activities including theatres, concerts, touring shows, business events, and other public and private events. Use by local councils, governmental organisations and small-scale commercial users is included here.

Theatres are the largest group within this category both in terms of the number of licensees and the amount of spectrum used. Theatres and concerts will use radio microphones and talkback but many of the other activities falling into this category will be small and use just one or a small number of radio microphones.

Community uses

This diverse category covers all events whose end product is for use within the community. Typical examples include the use of radio microphones within places of worship, educational institutes, and amateur dramatics.

Typically, activities within this category will be small in scale and the majority will use only radio microphones.

11.1.2 Shared use

Radio microphones operate at very low transmit powers and therefore only interfere with each other when in close proximity. Many users will use only one or two radio microphones, and are unlikely to operate close to another user. For these users, coordination is unnecessary and JFMG has therefore designated a number of frequencies for shared use in Band III and Channel 69. Users are issued with a one or two year licence which permits them to use any of the shared radio microphone frequencies in any part of the country.

11.2 The supply of spectrum

Currently, JFMG has access to spectrum in a total of 19[65] bands ranging from 50MHz to 48GHz. As illustrated in Figure 11.2 almost half of this spectrum is shared on a secondary basis with either the MOD or with the terrestrial TV broadcasters.

The frequencies below Bands IV & V (that is below 470MHz) are generally used for talkback and audio programme links whilst those at and above 2GHz are used for video programme links and wireless cameras. The band at 1.5GHz is used for digital audio programme links. The UHF TV bands, Bands IV & V and TV Channel 69[66], are used very largely for radio microphones, with some radio microphone usage in Band III as well.

[65] A further band at 1800MHz has been available for digital radio microphones. However, it is used and Ofcom now intends to release the band into the general market place.

[66] Channel 69 is treated separately from the remainder of the UHF TV spectrum because no TV broadcasting takes place within this channel in the UK and the conditions under which PMSE operations takes place are, as a result, significantly different to those in the remainder of the TV spectrum.

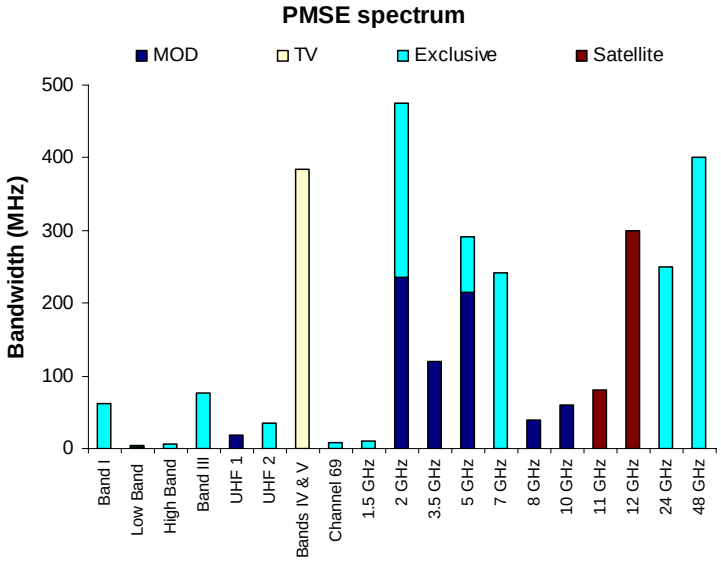

Figure 11.2: This figure shows the bands and the bandwidths available for assignment to PMSE activities. Note that the bandwidth shown has been expanded by 10 for bands up to UHF 2. Also shown are the bandwidths shared with the Ministry of Defence or with terrestrial TV transmissions (colour coded dark blue and cream). The remainder of the spectrum is used exclusively by PMSE users although account has to be taken of satellite services operating in continental Europe in the 11 and 12GHz bands.

11.2.1 Spectrum at risk

Some of the current spectrum is at risk of becoming unavailable for PMSE use over the next few years. The most notable reduction in spectrum will occur in both the UHF TV band, where 14 TV channels (*i.e.* 112MHz) are expected to be released for other services after the switchover to digital TV, and the 2GHz band where the band 2.50 to 2.69GHz is due for auction. Table 11.1 lists the spectrum at risk in this way.

Band	*Risk*	*Anticipated reduction in spectrum*
Band I	Possible release for Community radio	2MHz out of 6.3MHz
Band III	4 or 5 T-DAB multiplexes may be awarded	2 of 4 sub-bands (500KHz out of 925KHz) and up to 3 out of 19 coordinated radio microphone plus up to 6 out of 15 shared radio microphone frequencies[67].
L Band	Release of T-DAB spectrum overlapping with part of the lower band	3 out of 11MHz.

[67] Note, since this work was undertaken a way to avoid any loss of radio microphone capacity within the Band III spectrum has been identified.

Band	Risk	Anticipated reduction in spectrum
2GHz	Release of the 3G extension bands and extensive licence exempt use in the 2.4GHz band	300 out of 475MHz.
5GHz	Expanding non-PMSE use of the RLAN bands A, B and C.	216MHz out of 291MHz.
12GHz	Possible direct satellite broadcasting in the UK	Restrictions on transmit power over the UK

Table 11.1: List of frequency bands whose availability for PMSE use may be reduced in future.

Hence, approximately 120MHz below 2GHz and over 500MHz above 2GHz that is currently available to PMSE users is highly unlikely to be available for PMSE use in future.

11.3 The economics of PMSE spectrum

11.3.1 Value chain analysis

We have evaluated the contribution that PMSE spectrum, makes to the overall process of programme production and broadcasting. This work was largely based on interviews with spectrum users, and it is noted that many executives were unable or unwilling to talk about the specific financial contribution attributable to the use of the spectrum.

A key finding is the large variation in the contribution that PMSE spectrum makes to the overall value chain and, in many cases, the fragmented nature of the production chain. The use of spectrum in support of PMSE activities can often be an integral part of the process. It can be complex with all PMSE applications being used simultaneously to ensure a successful output. At the same time there are many uses and users for which the key benefit obtained through the use of the spectrum is simply convenience and for which there is little or no direct impact on the quality or financial value of the output. Specifically:

- Spectrum is considered to be more important for some categories of use (and for some uses within them) than others:
  - Outside broadcasts, Newsgathering, some entertainment events (e.g. musicals and rock concerts) and certain types of TV programmes (e.g. reality TV) are the uses for which spectrum is most valued. Indeed, there are programmes which would be impossible to produce without use of the spectrum;
  - Use within the categories Studio based programme making (with the exception of some types of programmes), Local entertainment and events (except for musicals and rock concerts), and Community uses, often adds little if any value;
- Despite being essential to production in some cases, PMSE spectrum currently adds less value to the final product than the concept, the talent, costumes, location etc. (all of which in turn are also essential to the final production).

Where spectrum is deemed essential for a production, the demand from the large commercial broadcasters and production companies is inelastic (thus we were told that users “will pay for spectrum even if prices rise 100 times”). Clearly any rise in the cost of accessing spectrum would raise production costs – but these would be borne by all the main players who would continue to compete to make these programmes. However, the

cost of spectrum is of significant concern to the smaller industry players and, in particular, to freelancers.

Spectrum is currently available on a non-discriminatory basis from JFMG. Should this arrangement change – for example, through the introduction of market based pricing – the smaller players would be more at risk because of their lack of power in the supply chain and their limited ability to compete with the larger players. There is a risk that unlicensed use would increase particularly where the risk of interference is perceived as being low.

11.3.2 The value of PMSE spectrum

It is not possible to provide a single figure to reflect the economic value generated by the use of spectrum within the PMSE sector for two reasons. Firstly, adequate alternative inputs to spectrum are often not available, hence the value of spectrum cannot be estimated from cost savings as is the case in other sectors. Secondly, the diversity of the users and uses within the sector is such that it is not possible to construct an overall estimate of the economic value generated through the better quality of end products and services that result from the use the spectrum. Nevertheless, we have identified the value of PMSE spectrum for a number of example situations and considered the implications for consumers and the wider society.

The use of the most likely alternative to the use of spectrum can increase costs by as much as £70 to £75 per assignment, for newsgathering and outside broadcasts, but can also result in reduced costs of £6 per assignment in the case of local entertainment and events. This reflects the opinion of users in our survey who suggested that the drivers for the use of the spectrum are often the quality improvement it delivers and the functionality it enables.

The value of spectrum differs with both the nature of use and the nature of the user. Some users benefit from the added value of spectrum in the form of monetary benefits; some (and this includes a broad proportion of users) internalise the benefits in a non-commercial sense through meeting their operational obligations; and others pass on the benefit to consumers. Often, the use of the spectrum has only a marginal impact on the quality of the end product and service, but there are some uses for which the use of spectrum is essential and the economic value at risk without the use of spectrum can run into millions of pounds for a handful of assignments.

Very few users are able to directly internalise the benefit in the form of greater revenue because most of the PMSE end products and services are not paid for at the point of consumption. Hence, it is likely that the use of spectrum results in a significant consumer benefit because the consumer receives an improved quality of service without having to pay for it. However, we have been unable to estimate the scale of this benefit.

Similarly, we have been unable to find any major benefits to wider society.

11.4 The demand for spectrum for PMSE activities

We have predicted the likely growth of both the number of events and the size of those events for the different categories of use. Our predictions are based on a number of assumptions about future trends in consumption. The primary ones are that:

- A greater proportion of news will be covered live in future;
- Television viewing will be driven by increasing local news and content;
- The launch of HDTV will increase spectrum requirements for wireless cameras and video links;

- Production will become increasingly complex (with greater combined use of the different PMSE applications) especially for live events and outside broadcasting; and
- Local event and niche programming will increase, primarily based on the take-up of VoD through broadband TV.

The prediction of peak demand is based on an examination of the level of use if two or more local events were held in proximity to each other and by estimating the usage impact of the trends highlighted above. Our estimates suggest that over the next 10 years, peak demand for:

- Data links could increase by between 50-100%, mainly on account of increased use of wireless cameras;
- Programme links could also increase significantly by up to 100%, driven by increasing production complexity;
- Radio microphone use will increase by between 20 to 30%;
- Talkback will grow minimally at less than 10% over the same period.

To determine the increase in the number of events, we estimate that the number of licensees could increase by up to 60% over the next 10 years to reach around 2,100 licensees. Demand growth will primarily be for radio microphones (by 60%). There will be only a moderate increase in licences for programme links due to growth in wireless cameras and demand will be stagnant for data links

11.5 **The balance of spectrum supply and demand**

The objective of modelling PMSE spectrum assignments was to gain understanding of how use varies both temporarily and spatially in each of the spectrum bands used for PMSE. Three supply/demand scenarios are of interest:

- 2004 demand compared with spectrum supply in 2004;
- 2014 demand compared with spectrum supply in 2004;
- 2014 demand compared with spectrum supply in 2014.

In addition to a base case level of supply in each band, it is also of interest to determine the 2014 spectrum demand in the UHF bands IV and V compared to spectrum availability under four alternative Digital Switchover (DSO) scenarios, with progressively more restrictive spectrum supply for PMSE.

Our analysis is based on the database of actual assignments granted between 1/4/2004 and 31/3/2005. There were 64,007 assignments in this period distributed across the bands commonly used for PMSE, and the number of assignments was forecast to grow to over 100,000 in 2014.

Some of the bands are alternatives for each other in terms of functionality, and have been grouped together in blocks of substitutable spectrum, as shown in Table 11.2. The 3.8MHz of VHF Band III spectrum used by radio microphones has been considered separately from the rest of VHF Band III and grouped with the UHF Band IV & V spectrum and Channel 69.

The 20 bands identified in Table 11.2 are used as the basis for our analysis. For each block we have assumed that overload in one band (which may be due to forecast growth in usage or accommodating out of band assignments) can be migrated to other bands within the same block.

Block 1	Block 2	Block 3	Block 4	Block 5	Block 6
Band I Low band	High band VHF Band III (non-RM) UHF 1 UHF 2	VHF Band III (RM) UHF Bands IV & V UHF Channel 69	1.5GHz	2GHz 3.5GHz 5GHz 7GHz 8GHz 10GHz	11GHz 12GHz 24GHz 48GHz

Table 11.2: Band and block structure of spectrum for PMSE in 2004. This maps the 19 bands available in 2014 into 6 blocks, with VHF Band III being split between two blocks according to radio microphone use.

The spectrum supply was assessed by determining the restrictions and additions pertaining to each band in both 2004 and 2014. Some adjustments to these bands are expected by 2014 and these are reflected in the 2014 supply analysis. The UHF Band IV & V spectrum currently used for analogue TV is available for PMSE in areas interleaved between the coverage areas of TV transmitters. Therefore its availability is based on geographic assessment of current and future broadcast TV transmitter deployment.

The spectrum demand was established by translating the assignment database into a representative database of 2004 demand (where out of band assignments were assigned new frequencies) and a forecast for 2014 based on the growth assumptions summarised previously. The supply and demand was assessed for each PMSE location where there is current use and the impact upon each of these locations from national, regional and area assignments was also taken into account.

For each PMSE location the channel occupancy was analysed for each band and block of bands. This provided insights into the spectrum usage at PMSE locations and therefore provides an understanding of the spectrum required to support future PMSE usage. To appreciate how this translates into spectrum occupancy across the UK similar calculations were undertaken for each pixel within a UK grid of locations.

11.5.1 Analysis results

Block 1

Analysis of Block 1 assumes that substitution is possible between Band I and Low Band. Although both bands are forecast to have peak 2014 fractional occupancies greater than 100% on an individual basis, these peaks tend not to occur on the same day at the same location. Therefore analysis of Block 1 resulted in a fractional occupancy of just less than 100%. We do not believe there will be shortages of spectrum in Block 1 provided new PMSE equipment is appropriate for band availability in its area of intended use.

Block 2

All of the bands used in Block 2 exhibited peaks that exceeded a fractional occupancy of 100% for the demand and supply scenarios considered, and all of these bands needed out of band spectrum even to meet the 2004 demand. Grouping the spectrum into a block reduces the need to access out of band spectrum for some peak events, since the peak events rarely coincide in time and location. The forecast fractional occupancy of Block 2 is shown in Figure 11.3 for each day of the year in 2014.

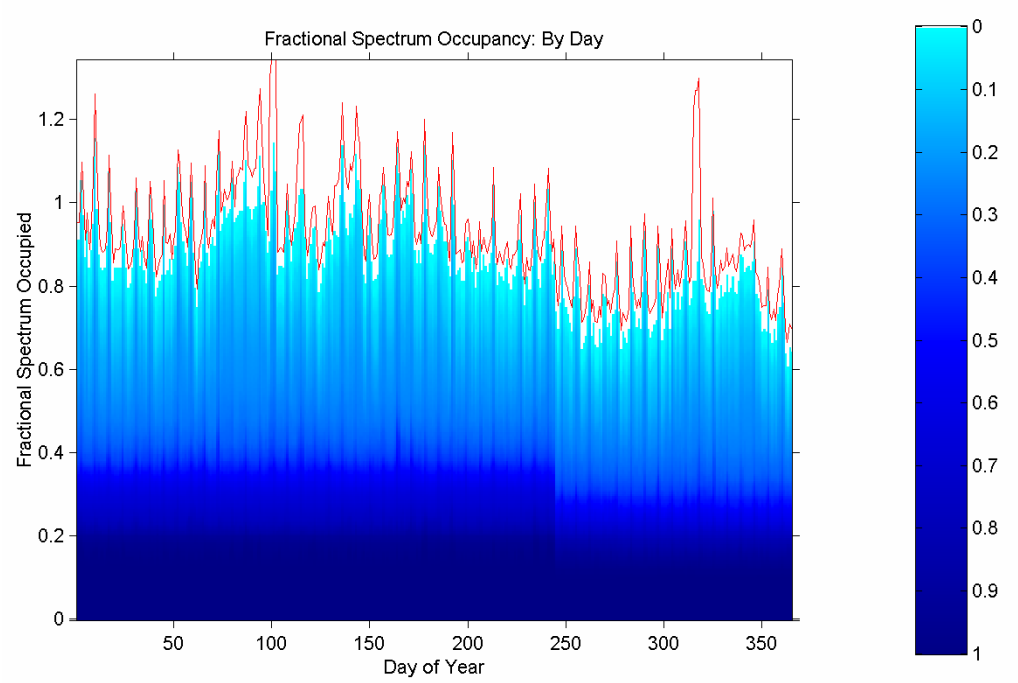

Figure 11.3: Fractional occupancy by day of year for Block 2 based on 2014 supply and 2014 demand.

The peak fractional occupancy is 134% which corresponds to an additional spectrum requirement of 2.1MHz.

Block 3

The demand for spectrum in Block 3 is dominated by UHF Bands IV &V. The main PMSE uses in these bands are radio microphone applications which are also able to be accommodated to some extent by VHF Band III and UHF Channel 69. The areas of highest demand are:

- Major outdoor event locations such as Glastonbury;
- Areas of restricted supply such as Newcastle;
- Locations having high indoor and outdoor usage such as the major TV studios in Central London.

The demand for PMSE is expected to increase substantially by 2014, and is forecast to outstrip supply based on current spectrum availability. However, the spectrum supply of interleaved channels is also expected to increase. Assuming that the supply and demand of VHF Band III, UHF Channel 69 and UHF Bands IV & V can be aggregated, we do not predict any shortage of spectrum in 2014, however demand approaches supply at Glastonbury, Newcastle and Central London.

With demand assumed to occupy substitutable bands in preference to UHF Bands IV & V, The number of unused interleaved channels for the baseline DTT scenario is shown in Figure 11.4.

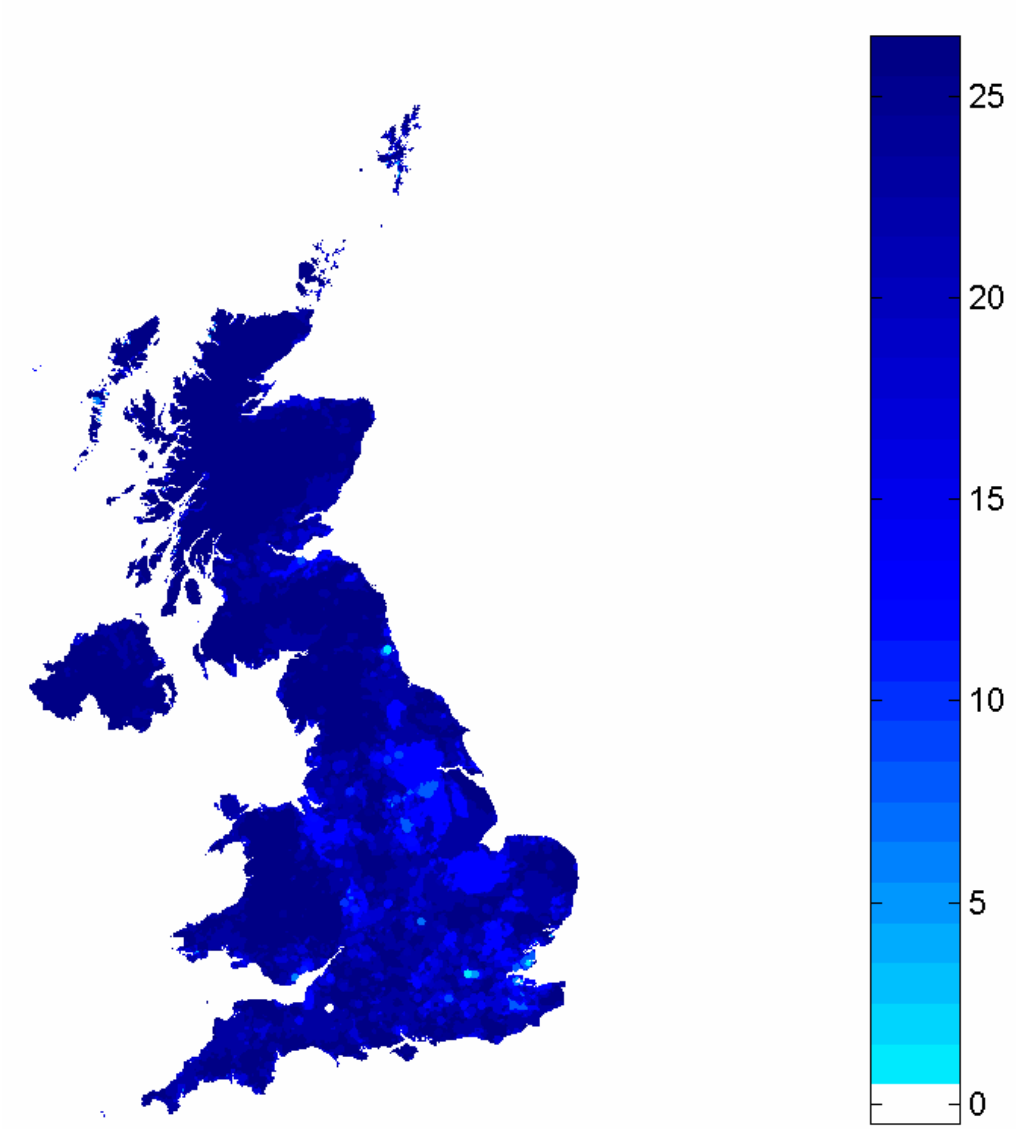

Figure 11.4 Unused interleaved channels in the UHF Bands IV & V in the UK based on 2014 supply and 2014 demand.

It can be seen that there is an opportunity for deployment of significant additional DTT multiplexes across most of the UK with the exception of the three congested areas.

Block 4

Block 4 has low levels of utilisation overall which are expected to reach only 33% by 2014.

Block 5

We forecast that there will be substantial shortages of spectrum in the range 2 to 10GHz arising from increasing use of video links and digital transmission. These shortages are likely across the UK as shown in Figure 11.5.

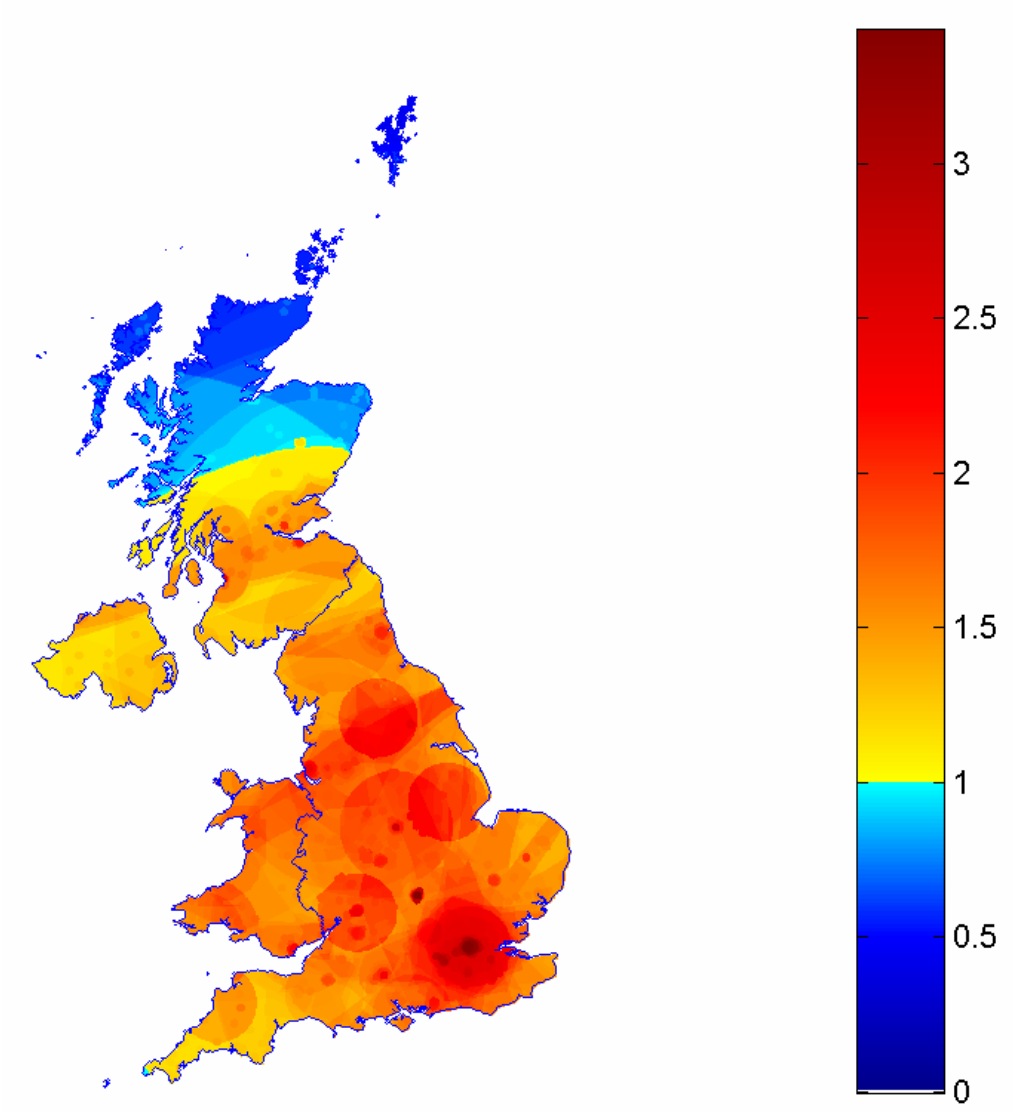

Figure 11.5: Occupancy across the UK for Block 5 based on 2014 supply and 2014 demand.

With predicted supply being around 1.2GHz for 2014, access to a further 3.1GHz would need to be available if the forecast PMSE demand is to be fully satisfied at Silverstone and Greater London.

Block 6

The combination of bands in Block 6 means that there is no shortage of spectrum in this block. However, accommodating the demand is possible due to the availability of spectrum at 48GHz which constitutes approximately 38% of spectrum supply in Block 6. Use of the 48GHz is likely to be less popular but there are comparatively few events for which this measure would be necessary.

11.5.2 Main findings from the analysis

In summary, the analysis of supply and demand resulted in three main findings:

- To accommodate growth in talkback, audio links and data links, approximately 2MHz of additional spectrum is required between 100MHz and 470MHz;

- Growth in use of radio microphones could be accommodated within the retained interleaved DTT channels and in many parts of the country, except for Central London, Glastonbury and Newcastle there is an opportunity to introduce further multiplexes without compromising capacity for PMSE;
- To accommodate growth in video links and the increasing use of digital cameras, approximately 3GHz of spectrum is required between 2GHz and 10GHz.