# TV white spaces: approach to coexistence

Consultation

Publication date: 4 September 2013

Closing Date for Responses: 15 November 2013

# Contents

**Section 1**

# Executive summary

1.1 Citizens and consumers in the UK continue to increase their use of wireless data devices such as smartphones and tablets. At the same time, there is substantial innovation worldwide in applications, services and devices that use wireless data. As a result, demand for wireless data has grown rapidly, and continues to do so.

1.2 Wireless data communications require access to radio waves, known as spectrum. Spectrum is divided into different frequency bands and allocated for particular types of use. The majority of spectrum is allocated using licences, for instance licences to operate mobile phone services. Other spectrum use is made licence exempt, such as that for Wi-Fi.

1.3 However in some areas, allocated spectrum is not used in all locations and/or at all times. This is referred to as "white spaces" and it can be used by other devices and services. A new way to access spectrum, known as dynamic spectrum access, provides a means to use this spectrum. Under this approach, white space devices can change their spectrum use in response, for example, to the needs of other spectrum users. This is a form of spectrum sharing, and provides a way to use spectrum that would otherwise lie fallow.

1.4 Growth in demand for wireless data makes a strong case for increasing the efficiency of spectrum use through these sorts of techniques. This consultation focuses on white spaces in the frequencies from 470 MHz to 790 MHz (the UHF TV band) which are currently used for Digital Terrestrial Television and by Programme Making and Special Events users.

1.5 This is the first set of frequencies in which we have decided to authorise dynamic spectrum access. However, we see significant scope to enable it more widely and are currently consulting on the future role of spectrum sharing for mobile and wireless data services[1].

## Our proposals

1.6 We have previously decided that white space devices should be permitted to access the UHF TV band subject to ensuring that there is a low probability of harmful interference to other services in and adjacent to the UHF TV band[2]. We will achieve this objective by restricting the power and frequencies at which white space devices can transmit at a given time and location based on calculations of the amount of available white space in each location.

1.7 There is uncertainty about the risk of harmful interference from white space devices. If we allow white space devices to operate at power levels that are too high, we will fail in our overall objective of ensuring a low probability of harmful interference to other services in and adjacent to the UHF TV band. However, if we restrict white space devices too tightly we may sterilise large amounts of spectrum for very little

[1] http://stakeholders.ofcom.org.uk/consultations/spectrum-sharing/

[2] http://stakeholders.ofcom.org.uk/consultations/geolocation/statement/

benefit, because only a tiny minority of users would be adversely affected if white space devices were allowed to operate at somewhat higher power levels.

1.8 Our overall approach to ensuring a low probability of harmful interference to other services in and adjacent to the UHF TV band is to err on the side of caution at this early stage, setting parameters that we believe we may be able to relax in the future in the light of more experience. Later this year, we will test our proposals to the extent practicable in a pilot programme comprising a number of trials around the UK by a range of service providers. As part of the pilot we will allow increased power levels to be used for limited time periods to assist with this testing. We will refine our coexistence proposals in light of evidence both from the pilot and from stakeholders with a view to finalising them in the summer of next year ahead of the launch of a full, nationwide solution in the third quarter of 2014.

1.9 Against this background, we propose in this document a set of parameters and algorithms with the objective of ensuring a low probability of harmful interference from white space devices to:

- Digital Terrestrial Television services;
- licensed users of equipment for Programme Making and Special Events; and
- services above and below the UHF TV band.

1.10 We also set out our proposed approach for how we will avoid causing harmful interference from white space devices to services used by our international neighbours.

## White Space availability

1.11 We have carried out detailed initial modelling of the potential effects of our coexistence proposals on the amount of white space spectrum that will be available for white space devices. The analysis shows white space availability for four different scenarios that vary by device category and antenna height. This analysis suggests that:

- The constraints required for DTT mean that the best performing white space devices can radiate at the maximum permitted power level in three or more 8 MHz channels at around 90% of households in the UK. This figure falls to around 70% for less well-performing devices. However, at lower power levels, devices can access considerably more channels and do so from a larger number of locations;
- The configuration of the DTT network means that there is considerable geographic variability in white space availability. For example, DTT constraints are substantially less severe in London than they are in Glasgow. In Central London, the best performing devices would be able to access nine or more channels at maximum power at 100% of households, while in Glasgow (where the DTT environment is more challenging), these types of device would only have access to three or more channels at around 60% of households; and
- PMSE use is only likely to impose material additional constraints on white space availability in some locations. We estimate, for example, that PMSE constraints (when combined with DTT constraints) reduce the availability of white space in Central London so that better-performing devices would only be able to operate

at maximum power in nine or more channels at around 90% of households. In Glasgow, by contrast, PMSE would impose almost no additional constraint on availability.

## Section 2

# Introduction

2.1 Dynamic Spectrum Access (DSA) is a means for enabling access to spectrum that is unused in particular locations at particular times. White Space Devices (WSDs) do this by using up-to-date information about existing spectrum use in order to identify and access frequencies which would otherwise sit unused, while at the same time seeking to avoid harmful interference into existing users.

2.2 WSDs can potentially provide a wide range of different services such as:

- hot-spot coverage, in a similar way to Wi-Fi hotspots;
- in-home broadband, again similar to Wi-Fi;
- in-home multimedia distribution, for example to send video from one room to another;
- rural broadband; and
- machine-to-machine communications, for example the remote reading of utility meters, monitoring of domestic appliances, or industrial and smart city applications.

2.3 While there are several potential ways of implementing DSA, this consultation is concerned with an approach which uses white space databases (WSDBs) for the UHF TV band, as described below and in our previous statements and consultations[3]. This band is currently used by Digital Terrestrial Television (DTT) and Programme Making and Special Events (PMSE) users. WSDBs will be qualified by Ofcom in a process which will also be tested in the pilot. Qualifying WSDBs will be included on a list, which can be interrogated by WSDs.

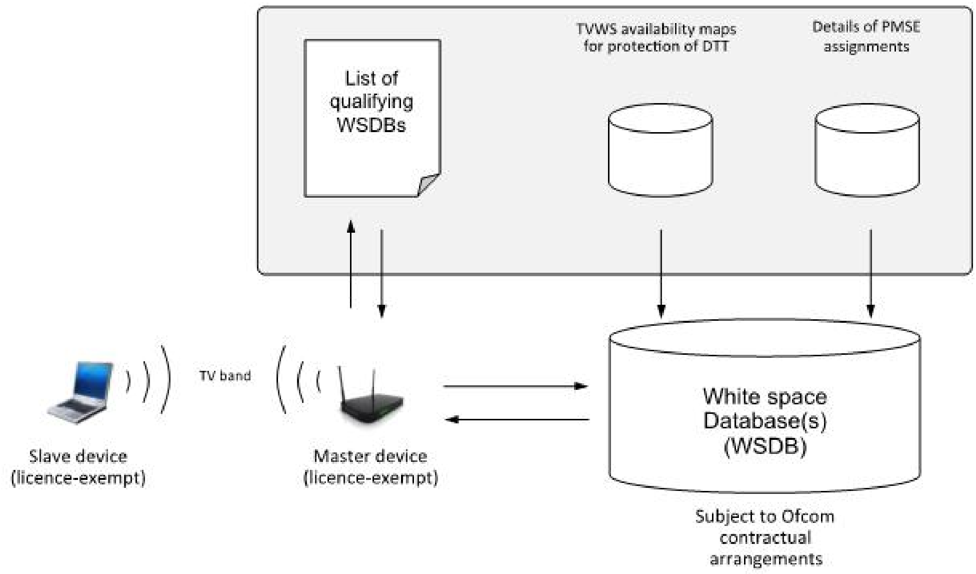
2.4 Under this approach, devices communicate their locations to WSDBs, which in turn inform the devices which frequencies they can use, and at what powers. These powers and frequencies will vary according to the location and characteristics of the device. They also vary over time, so WSDs can, for example, vacate spectrum in response to a change in need by another spectrum user or increase power levels when another user vacates nearby spectrum.

2.5 Not all WSDs will need to communicate directly with a WSDB. Devices may have a "master" or "slave" role. Master devices, as well as being able to use white space

[3] *Digital dividend review: A statement on our approach to awarding the digital dividend*", 13 December 2007, http://stakeholders.ofcom.org.uk/consultations/ddr/statement/;
*Digital Dividend: Geolocation for Cognitive Access, a discussion document, 17 November 2009, http://stakeholders.ofcom.org.uk/binaries/consultations/cogaccess/summary/cogaccess.pdf;*
*Implementing geolocation: consultation*, November 2010, http://stakeholders.ofcom.org.uk/consultations/geolocation/summary;
*Implementing geolocation: Summary of consultation responses and next step,* September 2011, http://stakeholders.ofcom.org.uk/consultations/geolocation/statement/; and
*TV white spaces: A consultation on white space device requirements*, 22 November 2012, http://stakeholders.ofcom.org.uk/consultations/whitespaces/

spectrum themselves, will serve as an intermediary between a database and slave devices. The overall approach is summarised in Figure 1 below.

**Figure 1 – Overview of the TVWS framework**




2.6 At high level, our TVWS framework has the following components:

- Ofcom will run a model which uses algorithms and parameters designed to calculate white space availability in a way that seeks to ensure a low probability of harmful interference to DTT services (this is an amendment to the operating model outlined in previous consultations, where WSDBs performed these calculations). We combine output from the model with additional restrictions that may be required in order to ensure a low probability of harmful interference to services above and below the UHF TV band. We also include restrictions to avoid causing harmful interference to neighbouring countries. Ofcom then provides the output to WSDBs. We will update this output when changes are made to the DTT network, which we expect to take place approximately every six months.

- Separately, we provide information about PMSE usage to WSDBs. This information will be updated every three hours and is supplied to us by JFMG, the organisation that licenses PMSE usage on behalf of Ofcom.

- If necessary to resolve a case of interference, Ofcom will also be able to send updates outside the three hour cycle.

- Before a master WSD can operate, it must contact a qualifying WSDB and inform it of its location.

- The WSDB will run its own model using the PMSE data set and will be required, under the terms of a contract with Ofcom, to use a specific a set of algorithms and parameters designed to ensure a low probability of harmful interference to PMSE services. It will combine the outputs of this model with the outputs from the Ofcom DTT calculations to determine the available channels and powers for the relevant location. In doing so, it uses the more restrictive set of emission limits for each channel (from either the DTT calculations or the PMSE calculations).

- The WSDB will communicate the available channels and powers to the master WSD.

- The master WSD will then broadcast a generic set of operational parameters for use by any slave devices associated with it. These parameters are generic in the sense that they could be used by a slave anywhere within the operating radius of the master unit. If the slaves cannot geolocate, they will need to use these (more restrictive) generic parameters. However, if a slave can geolocate, it can request potentially less restrictive parameters from the WSDB via the master device.

- The master WSD must check with a specified frequency (which for the purposes of the pilot will be every 15 minutes) or whenever it moves location, that the channels and powers it was given by the WSDB are still valid. This means that master WSDs will take account of any unscheduled, out of cycle PMSE updates within that specified frequency. Therefore, for example, a master WSD should stop using any channels it is told are no longer valid, or reduce power if required.

- The master WSD must also instruct its slave WSDs to stop using the same channels (or reduce powers). Moreover, slave WSDs will cease transmitting within five seconds of discovering that they can no longer receive updates from their serving master WSD[4].

- If necessary, Ofcom can make permanent location-specific adjustments (which would be transmitted to all databases) to resolve cases of actual or potential harmful interference or otherwise to address issues arising from use of the model.

## Previous decisions and legal framework

2.7 We have taken into account our various functions and duties in our previous decisions with regards to TVWS. We set out below our general duties that apply across all of our functions, together with a number of specific duties which are of particular relevance to our TVWS framework.

### Our general duties

2.8 Section 3(1) of the Communications Act 2003[5] (the Communications Act) provides that our principal duties in carrying out our functions are:

- to further the interests of citizens in relation to communications matters; and

- to further the interests of consumers in relevant markets, where appropriate by promoting competition.

2.9 In carrying out these duties we are required among other things to secure a number of objectives such as the desirability of promoting competition, investment, and innovation.

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[4] This is a specification in the draft ETSI harmonised standard EN 301 598

[5] 2003 c. 21; http://www.legislation.gov.uk/ukpga/2003/21/contents

## Our spectrum duties

2.10 In carrying out our general duties, we are required under the Communications Act to secure, in particular, the optimal use of the electromagnetic spectrum for wireless telegraphy, and to have regard to the different needs and interests of all persons who may wish to make use of the spectrum for wireless telegraphy.

2.11 In addition, in carrying out our spectrum functions under section 3 of the Wireless Telegraphy Act 2006[6] (the Wireless Telegraphy Act), we are required to have regard in particular to:

- the extent to which the spectrum is available for use or further use for wireless telegraphy;
- the demand for use of that spectrum for wireless telegraphy; and
- the demand that is likely to arise in future for use of that spectrum for wireless telegraphy.

2.12 In carrying out our functions, we are also required to have particular regard to the desirability of promoting:

- the efficient management and use of the spectrum for wireless telegraphy;
- the economic and other benefits that may arise from the use of wireless telegraphy;
- the development of innovative services; and
- competition in the provision of electronic communications services.

## Application to TV white spaces

2.13 In our previous consultations and statements[7], we have reached the conclusion that licence-exempt access to the UHF TV band will promote efficient use of spectrum, bring economic benefits, allow the emergence of innovative services and may lead to increased competition. We also recognised the need to minimise the risk of harmful interference to the incumbent users, namely DTT and PMSE.

2.14 As a result, and as set out in these various consultations and statements, we decided to allow WSDs access to the UHF TV band on a licence-exempt basis subject to ensuring that the probability of harmful interference to existing licensed services, including DTT and PMSE, would be low[8].

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[6] 2006 c. 36; http://www.legislation.gov.uk/ukpga/2006/36/contents

[7] See for example the statement *Implementing geolocation: Summary of consultation responses and next steps,* September 2011 http://stakeholders.ofcom.org.uk/consultations/geolocation/statement/

[8] The outline approach was set out in the *Digital dividend review: A statement on our approach to awarding the digital dividend*", 13 December 2007, http://stakeholders.ofcom.org.uk/consultations/ddr/statement/. Various details and specific aspects of that outline approach have been developed in the subsequent consultations and decisions cited in footnote 2.

## The proposals in this document implement previous decisions

2.15 We are now in the process of implementing this decision. The purpose of this consultation is to set out our proposed approach to the spectrum management decisions that we need to take in order to give effect to this previous policy decision.

2.16 More specifically, this consultation presents proposals for the parameters and algorithms that will determine the available frequencies and powers (TVWS availability) for use by WSDs in our TVWS framework (the coexistence proposals). It also presents proposals on how we will adapt our approach as we learn from practical experience and react to cases of interference.

2.17 These proposals aim to ensure a low probability of harmful interference to other services using the UHF TV band or adjacent bands. They will also determine the total availability of TVWS spectrum.

## White spaces pilot and full solution

2.18 We plan to launch the full TVWS solution nationwide from the third quarter of 2014. However, before then we will conduct a pilot which will comprise trials at several locations around the UK by a range of different service providers using a variety of different types of device. We expect the pilot to run from the fourth quarter of 2013 to the end of the first quarter of 2014.

2.19 The pilot will allow us to test the systems and processes (including regulatory processes) that will enable WSD operation and allow database providers, service providers and device manufacturers to test their own equipment. We will also test any adaptations to our own usual enforcement processes and to the extent practicable, the coexistence proposals set out in this document.

2.20 For a few specific aspects of the coexistence framework (see for example paragraphs 5.37 to 5.40), we will adopt a more limited set of proposals during the pilot than we propose to use in the full solution – these reflect areas where we plan to further assess during the pilot and are highlighted in the rest of this document.

2.21 We intend to launch the full solution on a nationwide basis in the third quarter of 2014. As set out in our previous statements, once we launch the full solution devices will be licence exempt. However, since the pilot will involve specific trials carried out over a limited period of time, we will grant specific licences to those pilot participants for the use of devices in the pilot.

## Next steps

2.22 Our target timeline for these coexistence proposals is as follows:

a) the consultation period will close on Friday 15 November 2013;

b) we will test the proposals to the extent practicable in our upcoming pilots from the fourth quarter of 2013;

c) stakeholders will have the opportunity to provide further comments during the course of the pilot and shortly thereafter;

d) we will review the results of the trials in the pilot and responses to this consultation to inform a Statement that we expect to publish in summer 2014;

e) ahead of launching the full solution we will update our interference management processes. Our proposals for doing so are explained in section 4; and

f) we expect to launch the full solution for WSDs in the UHF TV band in the third quarter of 2014.

2.23 The proposals in this document are largely based on computer simulations. We anticipate the pilot will provide useful data which we will take into account in our final decisions on spectrum management. However, we will also aim to learn from real life experience post-launch and review our coexistence proposals at the earliest opportunity. We anticipate this will be no later than 18 months after the launch of the full solution, subject to the extent of WSD deployment, and may well be sooner than that.

## Structure of this document

2.24 The remainder of this document is structured as follows:

- Section 3 presents the coexistence issues;
- Section 4 presents our high level approach to addressing coexistence issues;
- Section 5 presents our proposals for WSD coexistence with DTT services;
- Section 6 presents our proposals for WSD coexistence with PMSE services; and
- Section 7 presents our proposals for WSD coexistence with other services.

2.25 We have published a technical report alongside the consultation document which details the technical work carried out in developing our coexistence proposals. We also intend to publish a series of maps showing indicative white space availability shortly.

2.26 We are seeking responses with evidence to the questions in both this consultation document and the technical report. We list questions from both documents in Annex 4 of this document.

## General impact assessment

2.27 Impact assessments provide a valuable way of assessing different options for regulation and showing why the preferred option was chosen. They form part of best practice policy-making. This is reflected in section 7 of the Communications Act, which means that generally Ofcom has to carry out impact assessments where its proposals would be likely to have a significant effect on businesses or the general public, or when there is a major change in Ofcom's activities. However, as a matter of policy Ofcom is committed to carrying out and publishing impact assessments in relation to the great majority of its policy decisions. For further information about Ofcom's approach to impact assessments, see our guidelines, *Better policy-making: Ofcom's approach to impact assessment*[9].

[9] http://stakeholders.ofcom.org.uk/binaries/consultations/better-policy-making/Better_Policy_Making.pdf

2.28 Specifically, pursuant to section 7 of the Communications Act, an impact assessment must set out how in our opinion the performance of our general duties (within the meaning of section 3 of the Communications Act) is secured or furthered by or in relation to what we propose.

2.29 As explained earlier, this document implements earlier decisions which were taken to further both our general and our spectrum duties. The proposals in this document are a necessary step to allow licence exempt use of WSDs in the UHF TV band, and therefore the benefits of the proposals are the same as those outlined in our earlier decisions: promoting efficient use of spectrum, bringing economic benefits to consumers and citizens, allowing the emergence of innovative services and encouraging increased competition.

2.30 We also explained above that these earlier decisions included a policy decision to allow WSDs access to the UHF TV band subject to ensuring a low probability of harmful interference into existing services. The proposals in this consultation set out our proposed spectrum planning approach to give effect to that policy decision. As such, the impact assessment in this document is about demonstrating why we consider that our proposed approach to spectrum planning should achieve the objective of ensuring a low probability of harmful interference. Against this background, sections 4 to 7 constitute our assessment of the impact of the coexistence proposals.

## Equality impact assessment

2.31 In carrying out our functions, we are also under a general duty under the Equality Act 2010[10] to have due regard to the need to:

- eliminate unlawful discrimination, harassment and victimisation;
- advance equality of opportunity between different groups; and
- foster good relations between different groups, in relation to the following protected characteristics: age; disability; gender re-assignment; pregnancy and maternity; race; religion or belief; sex and sexual orientation.

2.32 Such equality impact assessments (EIAs) also assist us in making sure that we are meeting our principal duty under section 3 of the Communications Act discussed above.

2.33 It is not apparent to us that our proposals are likely to have any particular differential impact on race, disability or gender equality. Specifically, we do not envisage the impact of any outcome to be to the detriment of any group of society.

2.34 Nor have we seen the need to carry out separate EIAs in relation to race or gender equality or equality schemes under the Northern Ireland and Disability Equality Schemes.

[10] 2010 c. 15, http://www.legislation.gov.uk/ukpga/2010/15/contents

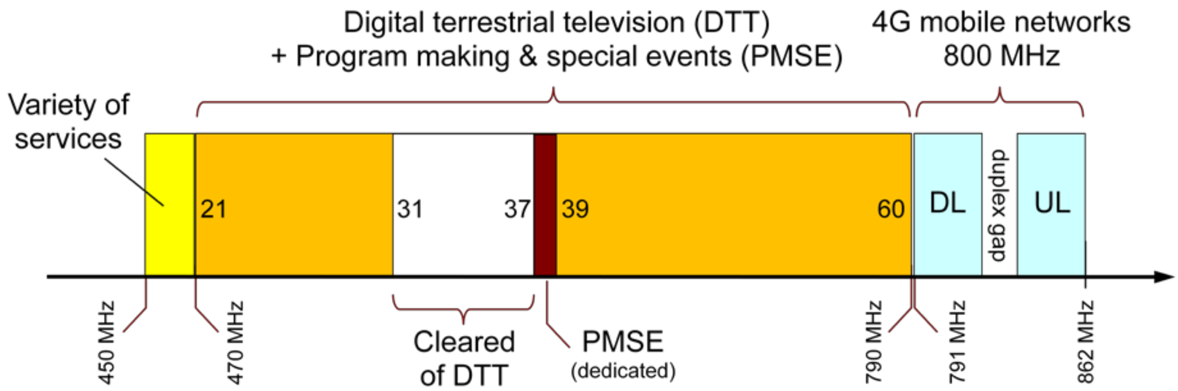
## Section 3

# White spaces in the UHF TV band

## What TV white spaces are

3.1 The UK's DTT network is made up of more than a thousand transmitter masts. These transmitters use radio frequencies (spectrum) between 470 MHz and 790 MHz. Figure 2 below shows this band and adjacent usage. The figure also shows the dedicated nationwide allocation of channel 38 to PMSE.

### Figure 2 – UHF TV band and adjacent bands




3.2 The frequencies used by DTT change from location to location to avoid interference between transmissions from different TV regions. As a result, much spectrum remains unutilised. We refer to the unutilised frequencies as "white spaces". Figure 3 below shows current spectrum utilisation across most of London and its surroundings (the Crystal Palace transmitter region), as an example. The parts of the spectrum marked in white are currently largely unused (apart from time-varying PMSE use – in channels other than 38 – which we discuss later).

3.3 We have recently awarded a licence for the purposes of establishing additional DTT multiplexes in the 600 MHz band (550-606 MHz)[11]. This is pending any potential re-plan of the 700 MHz band (see the following section on Potential changes to the UHF band for further details). If the 700 MHz band is re-planned and the 600 MHz frequencies are required in order to help facilitate this, Ofcom may consider whether or not alternative frequencies can be substituted to enable the multiplexes in the 600 MHz band to continue operating. Provision has also been made for the licence to be terminated on 24 months notice, should the 600 MHz frequencies be required from 31 December 2018 onwards.

3.4 We have also awarded a licence to operate a further multiplex for local TV services.

[11] http://stakeholders.ofcom.org.uk/binaries/consultations/600mhz-award/statement/600_MHz_Statement.pdf

### Figure 3 – Snapshot of White Space spectrum in most of London

### White space spectrum indicated in white - each square is 8 MHz


## Potential changes to the UHF TV band

3.5 We are currently considering future potential use of the 700 MHz band (694-790MHz) for mobile data use, although we have not yet taken any firm decisions on release for that use. We are carrying out preparatory work internationally to make sure that we are in a position to release the band in a timely way if our on-going analysis concludes in favour of release. Our work is subject to detailed considerations of the costs of change as well as its benefits. We are also actively seeking stakeholder input on this work and we have received a number of responses to our call for input asking for comments on the costs and benefits of the 700 MHz release[12].

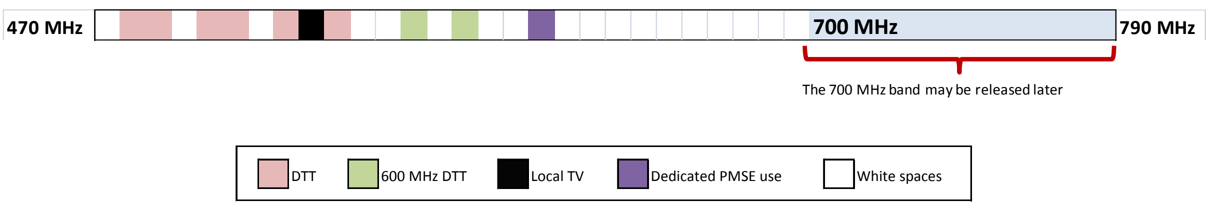
3.6 If the 700 MHz band were released, it would reduce the overall range of frequencies usable in the UHF TV band, because the 694-790 MHz band would no longer be available. Furthermore, the existing DTT network would need to be re-planned to fit in less spectrum. We would expect it to result in less white space in the remaining TV frequencies.

3.7 However, the need for new international agreements makes it unlikely that changes would start to take place until 2018 at the earliest. To maximise white space availability, we expect to allow WSD use within the 700 MHz band to continue throughout the period during which DTT use of the band would gradually reduce and relocate to the 600 MHz band, and up to the time of release of the 700 MHz band for new uses. This is important because any potential clearance of DTT services may take a number of years.

3.8 In the longer term, we may look to expand the range of frequencies that can be used by WSDs beyond those in the UHF TV band. In principle, this could create other opportunities which may counterbalance the potential reduction in white space availability due to the 700 MHz release.

3.9 Figure 4 below shows the same illustrative chart as Figure 3 with potential future changes in spectrum.

### Figure 4 – Future changes in DTT spectrum, London, Illustrative example.




[12] http://stakeholders.ofcom.org.uk/consultations/700mhz-cfi

## The coexistence issues

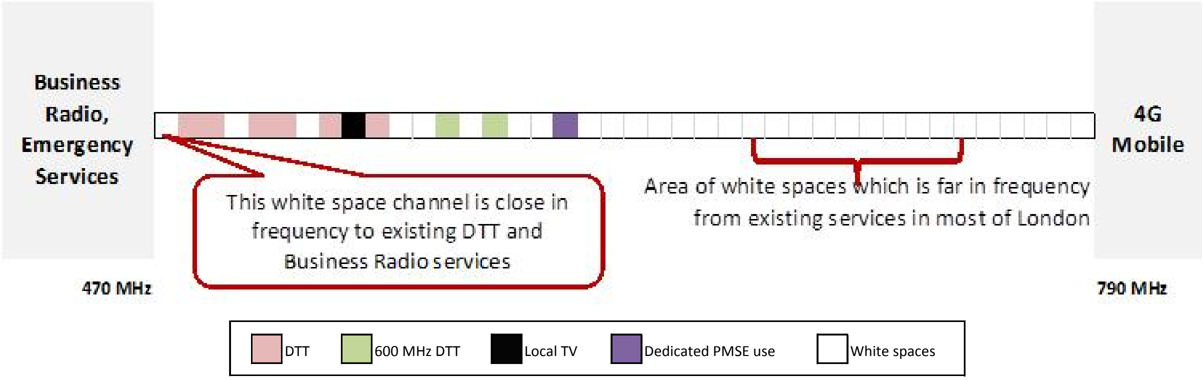
3.10 In managing coexistence between WSDs and existing users of the UHF TV band, we will seek to ensure that there is a low probability of harmful interference to DTT, PMSE and services in adjacent bands. We will achieve this by enabling calculation of the frequencies at which WSDs are allowed to operate, and the amount of power at which a WSD can transmit in each frequency, accounting for:

- services which are close in frequency to white space spectrum;
- services from multiple DTT transmitters; and
- PMSE, which varies in location and frequency.

### Coexistence with services close in frequency

3.11 In general, the likelihood of interference between WSDs and other services reduces if they are further apart in frequency[13]. Hence, other things being equal, WSDs can operate at higher power where there is greater frequency separation. This is illustrated in Figure 5 below.

**Figure 5 – White spaces and adjacent services, London snapshot example**



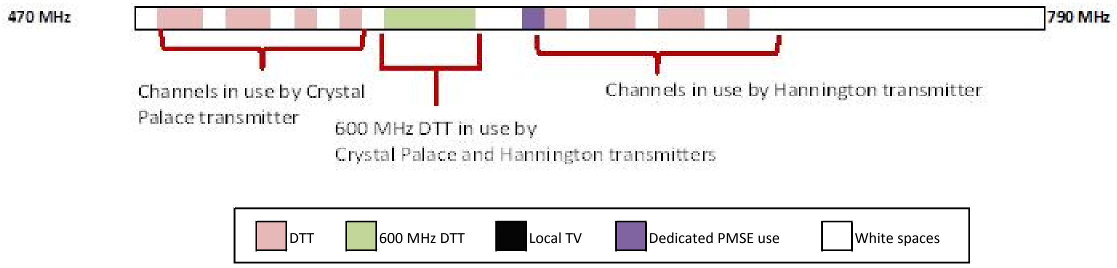

### Coexistence with services from multiple DTT transmitters

3.12 WSDs need to take account not just of the frequencies used for TV reception within their location, but, potentially, also the frequencies used for TV reception in other locations nearby.

3.13 Figure 6 below uses Slough as an illustrative example to show the potential geographical variation of white spaces. DTT reception in parts of Slough is covered by the London main transmitter in Crystal Palace, but other parts are covered by the Hannington transmitter. This means that WSDs in or close to parts of Slough may need to take into account the channels used in Hannington as well as those in the Crystal Palace area, so that they do not interfere with DTT services received from either transmitter.

[13] This dependence on frequency separation reduces as the receiver circuitry becomes increasingly overloaded by a large interferer, and the receiver loses its ability to reject the adjacent channel interferer. This is especially the case where the interferer appears inside the frequency range where wanted signals are also being received.

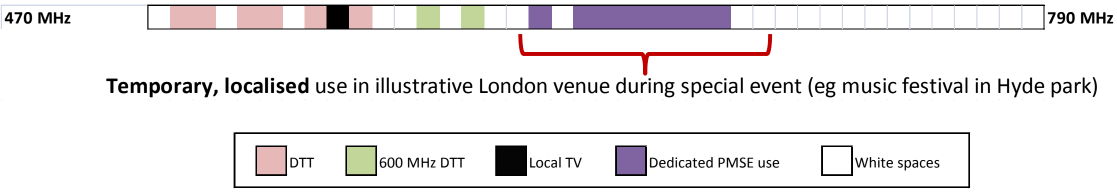
### Figure 6 – Illustrative example in Slough in the border of London / Hannington TV regions, (only channels in current use shown)




### Coexistence with a service that varies in place and frequency (PMSE)

3.14 The white space spectrum is currently utilised in a time-varying fashion by several wireless audio applications, including microphones and in-ear monitors. This use will impact white space availability, although channels used and locations of use will vary. An illustrative example is shown below in Figure 7.

### Figure 7 – Illustrative example usage during a hypothetical event in Hyde Park




## Ensuring a low probability of harmful interference

3.15 In ensuring a low probability of harmful interference from WSDs to services in and adjacent to the UHF TV band, we have considered the maximum power of WSDs and how to account for different types of WSDs.

### Calculating power allowed for a device

3.16 We will ensure a low probability of harmful interference by restricting the power at which a WSD can operate in a given channel. The power level will be communicated to WSDs by a database, and is subject to a maximum allowed power level.

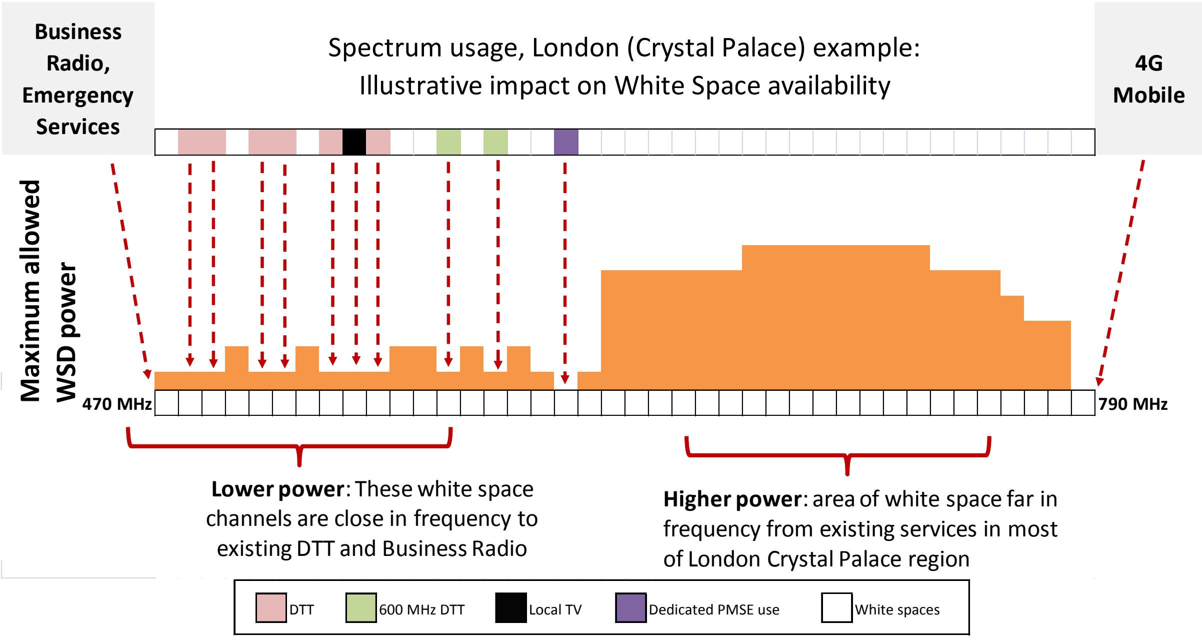
3.17 We propose that no WSD at any location can operate at a power greater than 36 dBm/(8 MHz). We consider that such a cap on the maximum permitted power is important in avoiding the overloading of DTT receivers. We note that this is the limit the Federal Communications Commission has imposed in the US for WSD deployment. It is in our view a sensible value which caters for most of the envisaged TVWS use cases in the UK.

3.18 This maximum WSD power level will then be reduced, where necessary, taking into account a number of parameters. In some channels devices will not be able to operate at all, for example because of their proximity to channels in use. Other channels will be open to operation but at a lower power, with any remaining channels available at the maximum allowed power level. All of the constraints will be taken into account simultaneously, as required for a given location. This will be done by enforcing the most restrictive emission limits for each channel.

3.19 Figure 8 shows an illustrative example for the maximum allowable power in a London location, taking into account DTT, PMSE use at channel 38 and adjacent services.

The orange squares represent allowed white space power for each channel with taller columns indicating a higher permissible power level. Arrows link usage to impact on allowed power.

**Figure 8 – How the coexistence proposals will determine White Space availability – Illustrative example.**




## Accounting for different types of WSD

3.20 Databases will need to treat different types of WSD differently. This means that devices which cause less interference can make use of more white space. Our coexistence proposals are intended to generate allowable powers which vary for these different categories in order to maximise white space availability whilst ensuring a low probability of harmful interference.

3.21 For the full solution, there are several different types of distinction that we will apply:

- First, there are two overall types of device, type A (fixed location) and type B (portable/mobile).

- Second, each of these may conform to up to five different spectrum emission masks, which define how much power a device may "leak" into frequencies adjacent to those where it operates.

- Third, in developing our approach to ensuring a low probability of harmful interference to DTT, we have also considered the impact different radio technologies may have on DTT receivers. The signals from some WSDs are more disruptive to DTT reception than others, and those sorts of WSD would therefore need to operate at lower powers to avoid causing harmful interference. More benign WSDs cause less harmful interference at a given power level and could therefore be permitted to operate at higher powers. As a result, we consider that it is appropriate to differentiate devices by "protection ratio" category – we propose to allow for three different categories of device in this regard. These proposals are explained in more detail in paragraphs 5.37 to 5.40 below.

3.22 Taking these three types of distinction together, there are potentially 30 different categories of device. However, for practical purposes, in the pilot we will only take account of the first and second variations (so there will be ten different categories of device).

**Section 4**

# Coexistence framework and approach

4.1 WSDs are an emerging technology. We will therefore need to define the coexistence algorithms and parameters (coexistence proposals) initially in the absence of extensive practical experience, so the implications remain uncertain. In this section, we outline some of the sources of this uncertainty and how we propose to deal with them, both in defining our current proposals and also in anticipating how we will vary these proposals in light of more evidence.

## Sources of uncertainty and their implications

4.2 Some of the sources of uncertainty are as follows:

- there are a number of proposed use cases for WSDs, each of which has different implications for the extent of the coexistence challenge, and we do not know which are most likely to be taken up or used extensively;
- the future technical performance of WSDs is unclear, as new device technologies are only now beginning to emerge and few prototypes are available;
- the pace of future deployment of WSDs is unknown; and
- modelling interference is a complex task. It is largely based on empirical measurement and is significantly affected by atmospheric physics and terrain and clutter environments. Existing planning tools were developed for specific purposes, and we need to be cautious in how we interpret the results they provide in the context of the type of coexistence analysis we are carrying out. Similar considerations apply with respect to PMSE – we believe it will be possible to refine our parameters over time as we gain more experience.

4.3 Given the level of uncertainty, our choice of initial parameters is very much an exercise of judgement. Theoretical modelling of interference can provide guidance about the likely effects of WSDs, but can never be perfect. The likelihood, for example, of a DTT viewer suffering harmful interference depends on a wide range of factors many of which, such as the precise clutter environment or the type of receiver that an individual viewer is using, cannot practically be known with any certainty. Modelling of this type of interference therefore relies on statistical simulations and there is often considerable uncertainty both about the underlying distributions of the input variables, and their correlations.

4.4 At one extreme, we might seek to ensure a zero risk of harmful interference to existing users. However, such an approach would sterilise large amounts of spectrum at great cost and with only limited benefit (only a very few users might be protected). This would not strike the right balance taking account of our functions and duties and would not be in the interests of consumers and citizens. At the other extreme, we might seek to adopt parameters that ensured there was a very significant amount of white space, but this could also be very costly as it could lead to a large amount of harmful interference.

4.5 However, one of the benefits of the geolocation database approach to enabling WSDs is that we are able to respond to experience.

4.6 With this in mind, our overall approach to deal with the sources of uncertainty is to adopt an initially cautious approach in setting our coexistence proposals which we consider will achieve our objective of ensuring a low probability of harmful interference to other services. We will use those proposals in the pilot and then identify where there is scope to relax parameters (and increase the amount of available white space) where there is sufficient evidence that this can be done without increasing the probability of harmful interference.

4.7 We consider it much less likely that we will need to tighten the initial parameters, but will nonetheless stand ready to do so either temporarily (and if so, rapidly) or on a more permanent basis if there is evidence that the overall approach is not enabling us to meet our objective of ensuring a low probability of harmful interference to other services.

4.8 At a more detailed level, there are a number of specific measures we propose to adopt to deal with the types of uncertainty highlighted above. These relate both to the categorisation of devices, and to the opportunities we have to test and refine our coexistence proposals both during the pilot and on an ongoing basis thereafter.

4.9 The technical performance (or strictly, the propensity to cause interference) of WSDs is one of the main sources of uncertainty. This is determined in part by the wireless communication standard used by the WSD to transmit data (IEEE 802.11af, Weightless, WiMax, and others). As WSDs are an emerging technology it is not yet clear what protocols will be used. As we have outlined above, we propose to address this form of uncertainty by allowing for alternative protection ratio categories – by default a device will be assumed to be in the worst technology category, unless it can be demonstrated that a device met a higher standard. It would be the responsibility of WSD manufacturers to demonstrate this compliance. This proposal would ensure that WSDs are given operational parameters that ensure a low probability of harmful interference to existing spectrum users while enabling better performing WSDs to have access to more white space.

4.10 We will have several opportunities to test and refine our proposals. The first opportunity to collect additional evidence will be during the upcoming pilot. The pilot will allow participants with an interest in launching WSDs or WSDBs to test them in fixed areas, and will enable us to evaluate the processes underpinning the overall framework for WSD regulation. The proposals in this document will determine the power levels and frequencies to be used by the WSDs during the pilot. In addition during certain periods and locations of the pilot we may, cautiously, allow power levels above those permitted by our current proposals. This would allow us to monitor for any resulting interference for testing purposes.

4.11 Where appropriate, the coexistence proposals will be updated to reflect evidence gained during the pilot, as well as responses to this consultation. We will publish the updated proposals in a Statement which we anticipate will be in summer 2014, and this will determine the parameters when the full solution is launched in the third quarter of 2014.

4.12 We acknowledge that there are limits to how much we can learn during the pilot. For instance, the number and range of devices in operation is likely to be limited. For this reason, and to allow further learning from real life experience, we also intend to conduct a further review after launch of the full solution. We anticipate that, subject to the extent of WSD deployment, this review will occur no later than 18 months after launch although we may review the parameters sooner than that if we believe there to be sufficient evidence.

4.13 We believe this overall approach will:

- minimise the risk of early interference, providing assurance to existing users of spectrum;
- allow WSD providers to assess white space availability under fairly restrictive conditions, which may be later relaxed depending on experience and testing; and
- nonetheless allow WSD deployment to proceed. The number of devices will inevitably increase over a number of years, making spectrum availability less critical in the initial years. We think it is unlikely that our cautious approach at this stage will create spectrum constraints which are too restrictive and prevent WSD deployment.

## How we will address short term interference issues

4.14 While we believe that the coexistence proposals set out in this document are cautious and likely to result in very few cases of harmful interference, we must be prepared to react if any harmful interference does occur. This includes immediate reaction to individual cases and the ability to review proposals in reaction to a systemic pattern of cases.

### Immediate reaction to interference

4.15 WSDs will introduce a new potential source of interference. We will therefore develop processes for reacting to interference complaints from DTT viewers and PMSE users to account for the possibility of interference caused by WSDs. These processes may result in changes to the availability of white space where interference occurs. We intend to work closely with other organisations that have related roles, including the BBC, DMSL and JFMG, and propose that WSDB providers have obligations to support our interference management functions.

4.16 We intend to use the pilot to test possible approaches. We propose that our processes will include, but not be limited to, the following features:

- we inform organisations operating existing helplines that receive interference complaints from DTT viewers about the possibility of WSD related interference in advance;
- we obtain information from WSDBs which would be used to check for WSD presence at the location of the complaint. Problems observed in DTT reception can have a range of causes. These include poor coverage, problems in the transmission network, TV equipment which is inadequate or incorrectly installed, or external interference from a number of sources. A triage system should be able to identify likely explanations for a complaint. Having information about WSD presence would make it possible to identify whether the operation of WSDs could be a possible cause of interference;
- we develop tests to establish whether WSDs are likely to be the source of a specific instance of interference. These tests may include a temporary reduction in WSD power, change of frequency, or a temporary suspension of WSDs in a

given location. We will be able to provide unscheduled adjustments to all the databases to achieve this; and

- we make permanent, localised adjustments to white space availability. Where appropriate, a resulting change in white space availability in a particular location would be provided to all WSDBs in order to stop interference and to prevent its recurrence. Adjustments may be made for a single 100 metre x 100 metre pixel or for multiple pixels.

4.17 We will review these processes following the conclusion of the pilot, and consider what processes will be required for the full solution.

4.18 Once we move into the full solution, providers of commercial services using WSDs will look for a considerable degree of certainty about the circumstances in which these processes might apply. We consider that the information from the databases should be sufficient to allow WSDs to operate with a low probability of causing harmful interference. We would therefore expect there only to be a few cases requiring specific interference management.

### Reactions to systemic patterns of interference

4.19 As well as reacting to individual cases of interference, we may need to respond quickly to systemic patterns of interference. Whilst we consider such interference unlikely, given the cautious approach we have taken, we believe that it is prudent to consider how we would respond to such an event. In addition to the process above, we will have the ability during the pilot to reduce allowed powers in a generalised fashion below what is suggested by these coexistence proposals in reaction to a pattern of cases of interference. We might achieve this by providing an overlay layer to WSDBs which they would add to the underlying DTT data we had already provided.

4.20 We may need the ability to make similar adjustments once the full solution is in place – although we will seek to define parameters at the outset in such a way that this kind of adjustment is unlikely. Given the number of possible scenarios which may result in a need to consider fine tuning the white space calculation, we do not propose to define precisely the circumstances in which we would carry out such fine tuning. Any fine tuning would be guided by the principle of ensuring a low probably of harmful interference.

## Future review of coexistence proposals

4.21 We intend to review the coexistence proposals set out in this document in light of evidence that emerges in the pilot and in light of new evidence presented to us through this consultation process. We will then publish a statement setting out the initial coexistence proposals for the full solution.

4.22 Following the launch of the full solution, we will continue to monitor the effectiveness of the parameters and algorithms and we plan to carry out a review within the first 18 months of operation. This would enable us to adjust the algorithms and parameters, and would allow for a more detailed and refined adjustment than the one detailed above responding to systemic patterns of interference.

4.23 The review will take into account any additional evidence from real world operation of WSDs, including but not being limited to any observed cases of interference, improved understanding of WSD use cases, and any improvements in modelling tools achieved by that time.

4.24 It may be that the best way to manage WSD coexistence is by creating a mechanism by which we would continuously adapt our approach rather than having regular reviews. We propose that this question itself should be addressed in this future review, by which time there will be some real world experience to inform the design of a more sophisticated system for adjustments.

4.25 While a review could result in either a tightening or a relaxation of constraints imposed on WSDs, as explained in this section we have selected the initial constraints cautiously with the goal to allow later relaxation while maintaining a low probability of harmful interference if experience confirms this judgement. We therefore anticipate that the review is more likely to result in a relaxation of constraints.

## Section 5

# WSD coexistence with DTT services

## Introduction

5.1 DTT is the main user of the UHF TV band and therefore the measures to ensure a low probability of harmful interference to DTT will have the largest impact on white space availability. This section covers:

- *the DTT network.* We detail what DTT services are available or about to become available and how those services are accessed;
- *ensuring a low probability of harmful interference to DTT services.* We explain our proposals for defining the parameters and algorithms for calculation of maximum allowable WSD power levels in any location. In formulating these proposals we have considered usage of aerials at rooftop level, indoor aerials (including both set-top and loft aerials) and use of alternative transmitters other than the main transmitter planned for a given location; and
- *white space availability.* We illustrate the consequences for white space availability of the parameters and algorithms mentioned above.

## The DTT network – implementation proposals

5.2 In the UK, television services are provided on three main platforms: DTT, satellite and cable. DTT is the most popular means of receiving subscription free TV. More than 11m households currently receive DTT services.

5.3 The DTT network consists of a number of high power TV broadcast transmitters distributed across the UK. The transmitters are generally sited on the top of hills and use tall masts so that broadcasts reach as many households as possible. These 'high power, high tower' transmitters are supplemented by a larger number of smaller transmitters which fill gaps in the coverage of the high power transmitters.

5.4 The DTT network is currently planned using a computer model called the UKPM. We use the outputs of the UKPM as the basis for determining our policy proposals for ensuring a low probability of harmful interference to DTT. While the UKPM is a sophisticated model, and its output has been calibrated extensively over the years in the context of estimating gross DTT coverage, the UKPM was not designed for purposes of analysing coexistence between DTT and other services. We have therefore had to use our judgement in determining what measures we consider necessary to achieve our stated aims.

5.5 DTT broadcasting uses a series of 'multiplexes'. A multiplex aggregates several TV channels together into a single digital signal which is then transmitted in a single 8 MHz channel.

5.6 Currently six multiplexes support all of the existing TV services available on the DTT network. Three of these are Public Service Broadcasting (PSB) multiplexes, and carry all of the PSB channels as well as several commercial channels. The remaining three multiplexes carry further commercial channels.

5.7 There is an additional licensed multiplex which broadcasts from three transmitters in Northern Ireland carrying RTÉ and TG4 services, an additional licensed multiplex which broadcasts to Manchester and an additional multiplex licensed for Cardiff.

5.8 In addition new DTT services are being planned, as explained in Section 3, which we expect to become operational by around the end of this year:

- two multiplexes will be deployed in the 600 MHz band covering most areas of the UK and carrying national services in high definition. This deployment is part of a wider strategy for the UHF TV band which aims to encourage take-up of DTT receivers which support more efficient broadcast technologies and eventually support potential release of the 700 MHz band (currently used by DTT) for mobile data services[14]; and
- a multiplex for Local TV services.

5.9 Against this background, we detail below our proposed approach to ensuring a low probability of harmful interference to DTT services viewed using an outdoor aerial and our approach for those viewing DTT services using an indoor aerial or from a transmitter that is not their main transmitter.

## Viewers using rooftop level aerials

### Existing spectrum planning approach

5.10 DTT planning has generally sought to ensure that almost all of the UK population is covered from a DTT transmitter, with reception achieved by using a rooftop level aerial pointing at that main transmitter.

### The approach for TV white spaces

5.11 We consider that our coexistence proposals for white spaces should in practice maintain the current level of coverage achieved by the DTT network today. Specifically, the proposals should ensure a low probability of harmful interference to DTT viewers using a rooftop aerial.

## Viewers using indoor aerials

5.12 Despite the DTT network being planned on the basis of reception using a rooftop aerial, some viewers use an indoor aerial to receive DTT broadcasts. Loft aerials, as well as aerials positioned next to TV sets, are classed as indoor aerials. These aerials are typically less effective at receiving DTT broadcasts given their indoor location and technical characteristics, and are more likely to be affected by interference from other sources.

### Existing spectrum planning approach

5.13 When making other spectrum management decisions and interference management decisions in the past we, and Government, have made clear that as the DTT network is not planned for indoor aerials such as set-top aerials, it is not for us to take measures to minimise the risk of interference to indoor aerial reception. Planning a

[14] http://stakeholders.ofcom.org.uk/consultations/600mhz-award/summary

network for reception via indoor aerials would be significantly more challenging and costly than the current network.

The approach for TV white spaces

5.14 Implementing our proposals for TVWS does not change our view that the possibility of DTT reception via indoor aerials is an incidental consequence and not an objective of the current approach to DTT planning. We therefore have not developed algorithms or parameters that are designed specifically to ensure a low probability of harmful interference to indoor aerials for receiving DTT.

5.15 Nevertheless, our proposals for ensuring a low probability of harmful interference to reception via rooftop aerials will forbid WSD operation in channels that are used by DTT in any given area, and restrict power in channels close to those. This will also have the effect of lowering the probability of harmful interference into indoor aerials. The performance of loft aerials is closer to that of rooftop aerials, and so our proposals for rooftop aerials should provide a good degree of protection for this type of indoor aerial in particular.

5.16 As we do not know the locations of the minority of viewers attempting reception via indoor aerials at any given time, measures to reduce further the probability of interference into indoor aerials would require widespread sterilisation of spectrum in all locations where reception could be taking place (not just those areas where such reception is taking place), which we do not consider justified or consistent with existing practice.

## Viewers using alternative transmitters

5.17 Due to the way signals propagate, it is inevitable that viewers in many areas are able to receive signals from more than one transmitter. As a consequence, it is possible that some viewers use a transmitter other than the one planned to serve their location. In some instances this may be by choice, to receive a particular regional service. In others, this may be a historical accident. We do not have reliable information on the extent of alternative transmitter use or the locations where it is common.

Existing spectrum planning approach

5.18 In our past regulatory decisions, we have adopted an approach to spectrum planning that has typically not sought to minimise the risk of harmful interference to alternative transmitters. For example:

- we set coverage goals for the DSO to achieve coverage at similar levels to the analogue network, ensuring that a transmitter was available for the locations where the vast majority of the population lives (around 98.5%), but not setting any goals to preserve areas of overlap or to secure coverage from more than one transmitter[15];

- we have required broadcasters to clear channels 61 and 62 (790 MHz – 806 MHz)[16]. These channels were used for DTT in the past but have now been

[15] Statement on Planning Options for Digital Switchover, 1 June 2005, http://stakeholders.ofcom.org.uk/consultations/pods1/statement/

[16] *Digital Dividend, Clearing the 800 MHz band,* http://ofcom.org.uk/consult/condocs/800mhz/statement/clearing.pdf

licensed for 4G mobile use as part of the 800 MHz band. In planning for clearance of channels 61 and 62 and associated TV infrastructure changes, we asked the planners to aim to recover original coverage provided by the main transmitter to each location, but did not ask for protection of areas of overlap where alternative transmitters may be in use; and

- our longstanding approach to DTT interference has been that it is the householder's responsibility to ensure that it has an adequate aerial and receiver installation, and that it should ensure its aerial is aligned with the best transmitter for their location, or coverage cannot be guaranteed[17]. Installations that do not use the correct transmitter may, as a result, receive poor signal levels and provide an unreliable service.

## The approach for TV white spaces

5.19 In line with our existing approach to spectrum planning, we propose that white space availability should in general be calculated taking into account only the planned transmitter(s) for any given location. Households which suffer coverage loss due to use of alternative transmitters will normally have a remedy available in the form of realigning the aerial to the recommended transmitter.

5.20 While we do not expect a significant impact on DTT viewers as a consequence of this proposal, if we come to observe material evidence to the contrary we will consider the need to change the data provided to WSDBs. In order to make a decision to depart from our usual approach to spectrum planning, we propose to take into account:

- how high the numbers of viewers affected by interference in specific areas of overlap between transmitters are; and
- any indications that there are locations where the transmitter in actual widespread use is not the one predicted by the model (in which case we may revise the data provided by Ofcom to WSDBs to take into account the transmitter which is actually being used rather than the transmitter that was planned for use in that area).

5.21 There are two exceptions where we propose to act proactively to take use of alternative transmitters into account in our calculations in advance of more evidence:

a) **Overspill from the Republic of Ireland**. The UK and Republic of Ireland Governments have worked together to make broadcast channels from the Republic of Ireland available to around 94% of viewers in Northern Ireland. This followed commitments set out in the Belfast agreement[18] and a Memorandum of Understanding between the two Governments in 2010. Coverage is achieved via a mix of overspill coverage from the Republic of Ireland and a multiplex in Northern Ireland. As the overspill is being used to accomplish a broader policy objective, in this case it is appropriate to treat it as if it were coverage from a main

[17] See for instance, Guidelines for Improving Digital Television and Radio Reception, from the Radiocommunications Agency (RA). Ofcom was created by the merger of several regulators including the RA. http://ofcom.org.uk/static/archive/ra/publication/ra_info/ra415/ra415.htm

[18] https://www.gov.uk/government/news/access-to-republic-of-ireland-digital-tv-channels-confirmed-for-northern-ireland

transmitter based in the UK. This means that we would seek to protect it proactively via the coexistence proposals.

b) **Viewers whose main transmitter is in a different nation.** In areas near the borders between England and Scotland and England and Wales, the main transmitter planned for some viewers may be in a different nation, due to planning constraints. This results in viewers receiving nation-specific programming (such as broadcasts in Welsh language) for a different nation to that where they live. Some of these viewers may be remedying this by using an alternative transmitter. We recognise this is an issue which raises questions of national identity and citizenship. For this reason we propose to implement our coexistence proposals initially by identifying areas where coverage could be possible via a secondary transmitter in the same nation and taking these transmitters into account in our calculations, as well as the main transmitter. Further mitigation could be achieved over time via improvements to the dataset to acknowledge data on real usage.

## Ensuring a low probability of harmful interference to DTT services – technical summary

5.22 The following is a high level summary of how we propose to ensure a low probability of harmful interference to DTT. Section 4 of the Technical Report presents this analysis in more detail.

### How DTT receivers work

5.23 DTT receivers are able to produce a TV image by decoding a *wanted signal* that is provided by the transmitter they are tuned to. However, in addition to the wanted signal, receivers will also be affected by noise and interference. By noise we refer to electronic signals created by natural sources such as ambient temperature. Interference involves man-made *unwanted signals*, which are detrimental to the process of receiving and decoding images and sound. These include signals produced by other electronic equipment and other wireless equipment, including DTT transmissions other than those a receiver is tuned to.

5.24 Receivers are manufactured, and networks are designed, so that receivers can function in the presence of a certain amount of noise and interference. Such levels of noise and interference, which do not interrupt TV reception, are not considered harmful.

5.25 Radio planning typically assumes an expected level of noise plus interference, known as the noise-plus-interference floor, and receivers are expected to be able to operate effectively in the presence of this floor.

### Ensuring a low probability of harmful interference to DTT services

5.26 Broadcasters plan DTT coverage based on a model which calculates location probability. This is the probability with which a DTT receiver would operate correctly at a specific location.

5.27 The presence of any interferer results in a reduction in location probability. The ability of a DTT receiver to tolerate interfering signals will vary depending on how strong the DTT wanted signal is in a given area. All other things being equal, in areas of strong DTT signal, receivers can tolerate more interference. The limiting cases are areas of weak signal, where receivers are more susceptible to interference. We therefore base our proposals starting at these edge of coverage areas.

5.28 Under current DTT planning, a location is considered to be at the edge of DTT coverage if the location probability is 70% in conditions of DTT self-interference that might be experienced during 1% of the time over the period of a year as a result of atmospheric conditions known as ducting. At other times, the location probability at the edge of coverage is likely to be considerably greater than predicted by the model.

5.29 As already stated, our overall objective is to ensure a low probability of harmful interference to DTT services from WSDs. Given that the current modelling of DTT location probability was designed for purposes other than coexistence analysis, we need to be cautious as to the extent to which the current modelling of can accurately capture the real-life likelihood of harmful interference to the reception of DTT broadcasts. This is in light of our recent experience with LTE base stations in the 800 MHz band. In our assessment of the likely effect of LTE deployment, we estimated that around 900,000 households would be affected. We based this estimate on our modelling of the resulting degradation in location probability. DMSL, the body responsible for mitigating interference into DTT, has since carried out a number of pilots and estimates that the total number of households likely to be affected will be just 90,000[19]. Subsequent evidence in the early stages of actual roll-out have provided further evidence in this regard – the observed cases of interference to DTT are substantially fewer than predicted by modelling of the impact on DTT location probability.

5.30 While location probability is a key parameter in quantifying the quality of DTT coverage, its calculated value is very much dependent on assumptions regarding the statistical distributions of received signals[20]. We consider that it is more appropriate to use a target rise in the noise-plus-interference floor (rather than a reduction in location probability) as the technical criterion for setting WSD emission limits. Furthermore, we also consider that it is important to specify the probability with which a target rise in the noise-plus-interference floor might be exceeded.

5.31 We consider that we can meet the objective of a low probability of harmful interference to DTT by setting emission limits for WSDs such that there is only a 10% likelihood that the rise in the noise-plus-interference floor exceeds 1 dB at the edge of DTT coverage. The overall probability of harmful interference combines the 10% likelihood of an increase of 1 dB in the noise-plus-interference floor with the likelihood that that increase prevents a DTT receiver from operating normally.

5.32 A 1 dB rise in the noise-plus-interference floor at the edge of coverage is a common technical assumption in coexistence studies. This is because wireless systems are usually engineered to operate at a safe margin above expected levels of noise-plus-interference, and as a result, a 1 dB rise is not considered to result in perceptible interference in practice. Hence we would expect that only a small proportion of the 10% of households predicted to experience a 1 dB rise or more in the noise-plus-interference floor would suffer harmful interference.

[19] https://at800.tv/press-releases/at800-updates-estimate-of-likely-impact-of-4g-at-800-mhz-on-freeview/

[20] For example, the current planning model assumes that received signal powers have a Gaussian distribution with a standard deviation of 5.5 dB everywhere.

5.33 At the edge of DTT coverage a 1 dB increase in the noise-plus-interference floor is equivalent to a 7 percentage point reduction in location probability as modelled by the UK planning model[21]. As we explained above, in light of real-life evidence of deployments at 800 MHz, we consider that a modelled 7 percentage point reduction will in practice translate to a significantly lower reduction in the number of locations which will lose DTT coverage.

5.34 Away from the edge of coverage (i.e. closer to a DTT transmitter), maintaining a 7 percentage point modelled reduction in location probability allows for a greater increase in the noise-plus-interference floor because the wanted signal is stronger. Hence, other things being equal, WSDs will be allowed to transmit at greater powers closer to DTT transmitters.

5.35 In order to ensure that there is no more than a 10% likelihood of degradation in location probability exceeding 7 percentage points, we need to make assumptions about the statistics of radio propagation from WSDs to DTT receivers (WSD-DTT coupling gains) and the statistics of DTT receiver performance (WSD-DTT protection ratios).

5.36 We have modelled coupling gains by using the statistics of nearest neighbour household separations for urban, suburban and rural environments.

5.37 The protection ratio defines the ratio of wanted power to unwanted power at the point of receiver failure. We have measured protection ratios for 50 DTT receivers using an interfering signal from a WSD using the Weightless technology standard[22]. However, we recognise that other radio technologies can have time-frequency signal structures which may be more or less disruptive to the operation of DTT receivers – i.e. they may imply different protection ratios.

5.38 In principle it should be possible for more benign devices to operate at higher powers than devices with more disruptive signal structures. For the full solution, we therefore propose to generate TVWS availability datasets corresponding to three categories of protection ratios: “high”, “medium”, and “low”. These protection ratio categories will characterise the propensity of different WSD radio technologies to cause harmful interference to DTT.

5.39 By default, devices will be categorised in the least benign, “high” protection ratio category. However, it will be open to the organisations responsible for the specification of various WSD radio technologies to present us with evidence in the form of protection ratio measurements against pre-specified test procedures which might enable their devices to be categorised more favourably. We would examine the evidence and assign each radio technology to one of the three protection ratio categories[23]. This information will be shared with the WSDBs, so that they can select

[21] In previous technical discussions among stakeholders a reduction of 1 percentage point in location probability due to interference from WSDs had been used as a reference value for analysis purposes. Such reduction in location probability is equivalent to a 0.15 dB rise in the noise-plus-interference floor, which is difficult to even measure in practice. We therefore consider that a 1% reduction in location probability is too cautious and will not cause harmful interference in practice.

[22] http://www.weightless.org/about/what-is-weightless

[23] A device technology will need to be at least as benign as implied by the relevant protection ratio category. In other words, the protection ratios for a technology that is categorised as “medium” would need to be at least as low as the “medium category” protection ratios; the protection ratios for a technology that is categorised as “low” would need to be at least as low the “low protection ratio” category.

the appropriate TVWS availability dataset in accordance with the reported technology identifier of individual WSDs.

5.40 We will not however implement the protection ratio category approach for the pilot as we will need to gather further evidence before we are in a position to do so.

*Q1: Do you have any comments on our proposed approach to ensuring a low probability of harmful interference to DTT services? Please state your reasons for your comments.*

## Consequences of our proposals for white space availability

5.41 The proposals described in this section result in restrictions on WSD power and so, TVWS availability, which vary depending on the geographic location of the WSD, its frequency separation from DTT channels in use, and the strength of the DTT signal in a given area.

5.42 Here we present the results of our modelling of TVWS availability for a geolocated WSD[24] in relation to DTT throughout the UK.

### TVWS availability UK-wide

5.43 Figures 9 to 12 show the statistics of TVWS availability at every 100 metre x 100 metre pixel throughout the UK for the case of the four WSD deployment scenarios in Table 1.

**Table 1 – Scenarios examined for UK-wide TVWS availability.**

| Scenario | WSD type | WSD class | WSD antenna height (metres) | Use case (geolocated WSD) |
|---|---|---|---|---|
| 1 | A | 1 | 15 | Base station |
| 2 | A | 4 | 10 | CPE with roof-top antenna |
| 3 | A/B | 4 | 1.5 | Access point |
| 4 | A/B | 5 | 1.5 | Portable/mobile device |

5.44 Types A and B in the table refer to fixed and portable/mobile devices, respectively. The WSD class identifies the extent to which the emissions of a WSD leak into adjacent channels (class 1 represents least leakage).

5.45 The figures below show the percentage of households where a given minimum number of DTT channels are available for use by a geolocated WSD when it transmits at a given radiated power. The WSD powers are in dBm over 8 MHz. Note that the maximum permitted power of a WSD is capped at 36 dBm over 8 MHz.

5.46 We have calculated TVWS availability at every 100 metre × 100 metre pixel in the UK. We have considered all 40 DTT channels as available for WSD use, with the exception of channels 38 and 60. The results do not include location-specific restrictions in relation to DTT across borders or PMSE.

[24] The presented results apply to geolocated WSDs only. If a WSD is not geolocated (e.g. a slave WSD which has not yet attached to a master) then the uncertainty in its location will mean lower TVWS availability.

5.47 The results for scenarios 1 and 2 can be extended to type B WSDs by relaxing the emission limits by a nominal building penetration loss of 7 dB (type B WSDs at a reported height of 2 metres or more will be assumed to be located indoors). The results for scenarios 3 and 4 apply to both type A and type B WSDs.

5.48 With the current version of the modelling tool that we have used to derive these estimates, we have not been able to account for the particularly high susceptibility of TV receivers when WSDs radiate nine channels above the DTT service. As a consequence, the results that we have presented in the figures below are likely to overstate the TVWS availability by up to one channel for any given power level. Taking account of this over-estimation, the results indicate that:

- TVWS availability reduces considerably where the WSD exhibits large amounts of out-of-block spectral leakage (higher classes).

- In scenario 1, where the WSD spectral leakage is low, around 90% of household locations will have access to 3 or more 8 MHz channels at a power of 35 dBm/(8 MHz).

- In scenario 4, where the WSD spectral leakage is high, only just under 70% of household locations will have access to 3 or more 8 MHz channels at a power of 35 dBm/(8 MHz). However, this availability rises to just under 90% at a power of 25 dBm/(8 MHz). For comparison, LTE mobile phone handsets use 23 dBm.

- A comparison of scenarios 2 and 3 indicates the impact of WSD antenna height on TVWS availability. As can be seen, TVWS availability is somewhat lower for a WSD antenna height of 10 metres since it is equal to the planned DTT receiver antenna height and so creates a greater potential for interference. However the difference in maximum permitted emission limit is only 2 to 3 dB.

**Figure 9 – UK-wide TVWS availability for scenario 1. Class 1 WSD with an antenna height of 15 metres.**

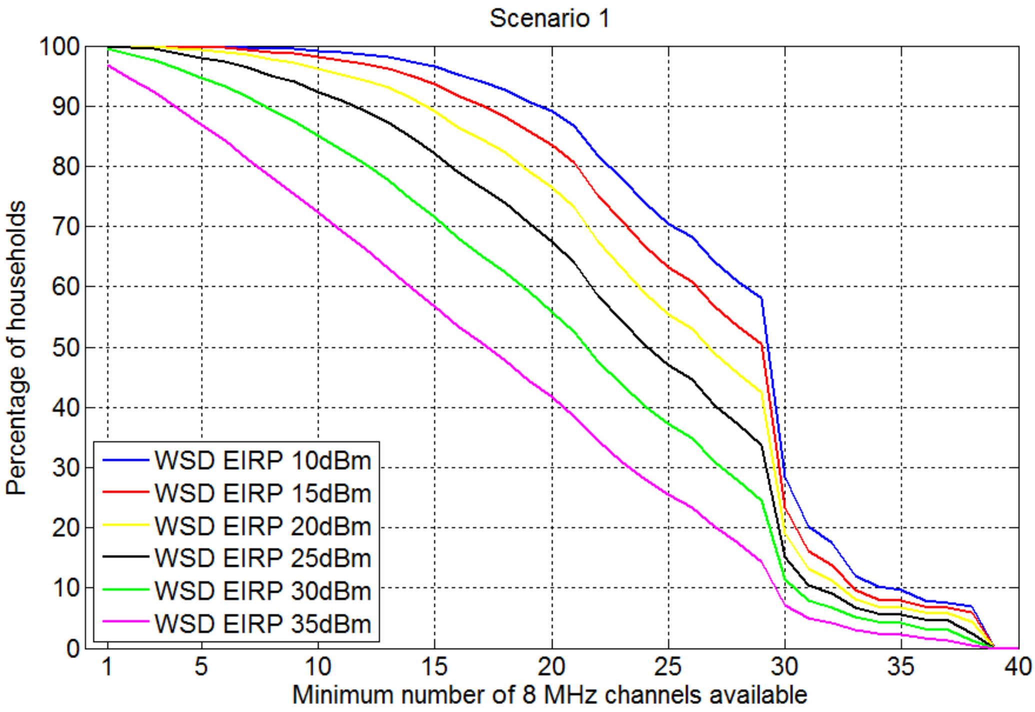



**Figure 10 – UK-wide TVWS availability for scenario 2. Class 4 WSD with an antenna height of 10 metres.**

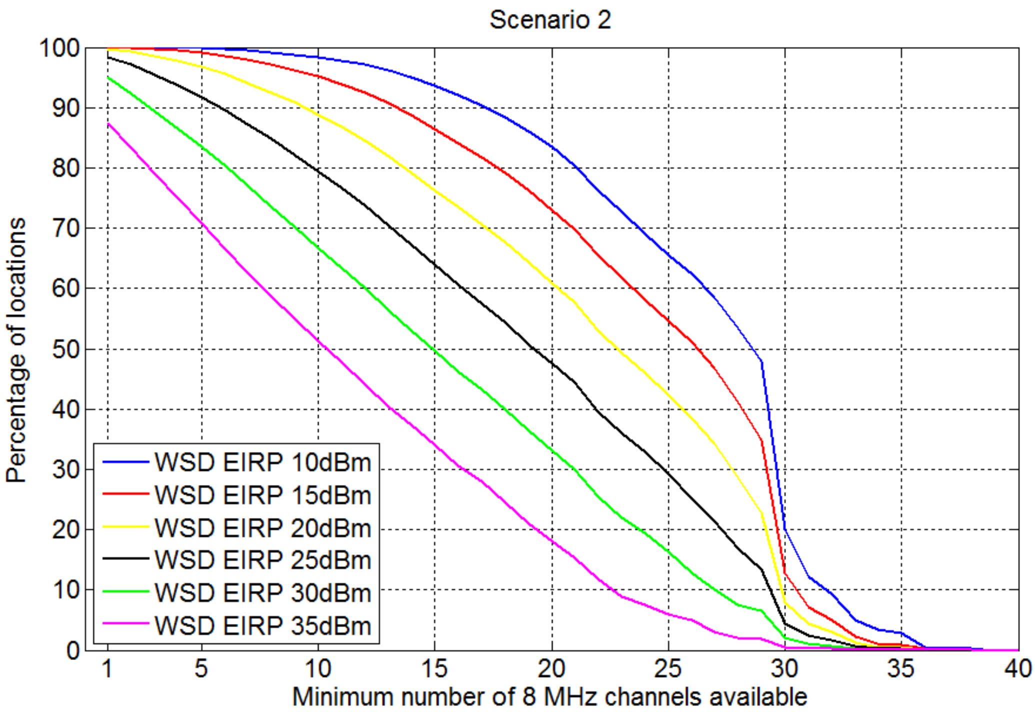


**Figure 11 – UK-wide TVWS availability for scenario 3.**
**Class 4 WSD with an antenna height of 1.5 metres.**

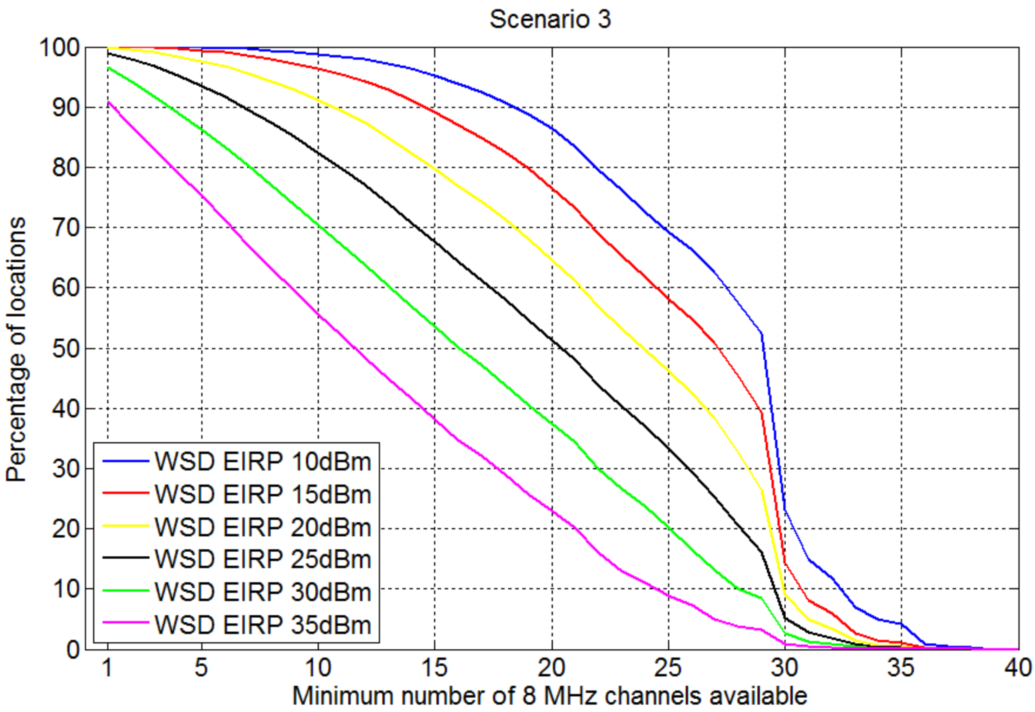
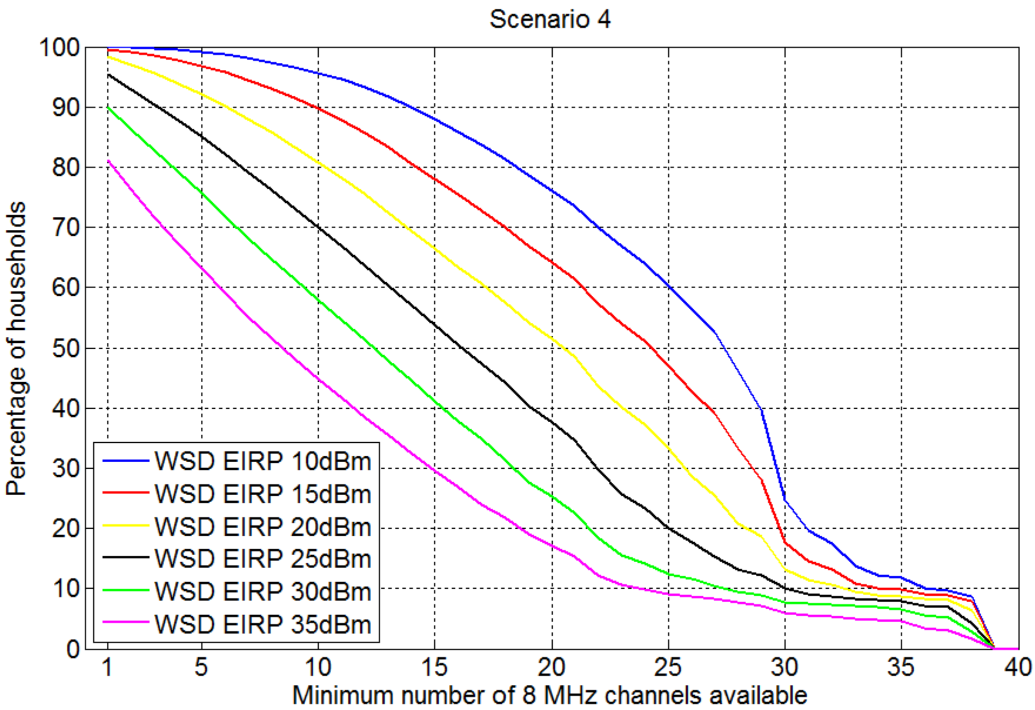



**Figure 12 – UK-wide TVWS availability for scenario 4.**
**Class 5 WSD with an antenna height of 1.5 metres.**



## TVWS availability in London and Glasgow

5.49 Figures 13 and 14 show the statistics of TVWS availability in 10 km × 10 km areas of London and Glasgow for scenarios 1 to 4. The vertical axes here are in percentage of locations rather than households for purposes of combining with the PMSE results of Section 6[25].

5.50 The area examined in London is centred on National Grid Reference TQ 300 800 and includes Camden and Islington to the North, Paddington and Kensington to the West, Clapham and Brixton to the South, and Bermondsey to the East. The area examined in Glasgow is centred on National Grid Reference NS 590 650 (Glasgow Central Station).

5.51 The results show that there is significantly less TVWS available in Glasgow than in Central London in relation to DTT.

5.52 In London, there is a main DTT transmitter station (Crystal Palace) close to the city, with no alternative main stations of any significance, though there are some small 3PSB relays. This means that the DTT coverage is quite robust and so large WSD powers are possible.

5.53 In Glasgow, the main DTT transmitter station (Black Hill) is further away to the East of the city. Some locations in Glasgow are better served by another main station, Darvel which is some way to the South of the city. There are also some 3PSB relays in Glasgow centre, which cover more of Glasgow than the relays in London do. As a result, the permitted WSD powers are more restricted in Glasgow than they are in London.

[25] As noted in paragraph 5.48 our modelling in relation to DTT over-estimates TVWS availability by up to one channel.

### Figure 13 – Availability of 8 MHz channels in Central London in relation to DTT.

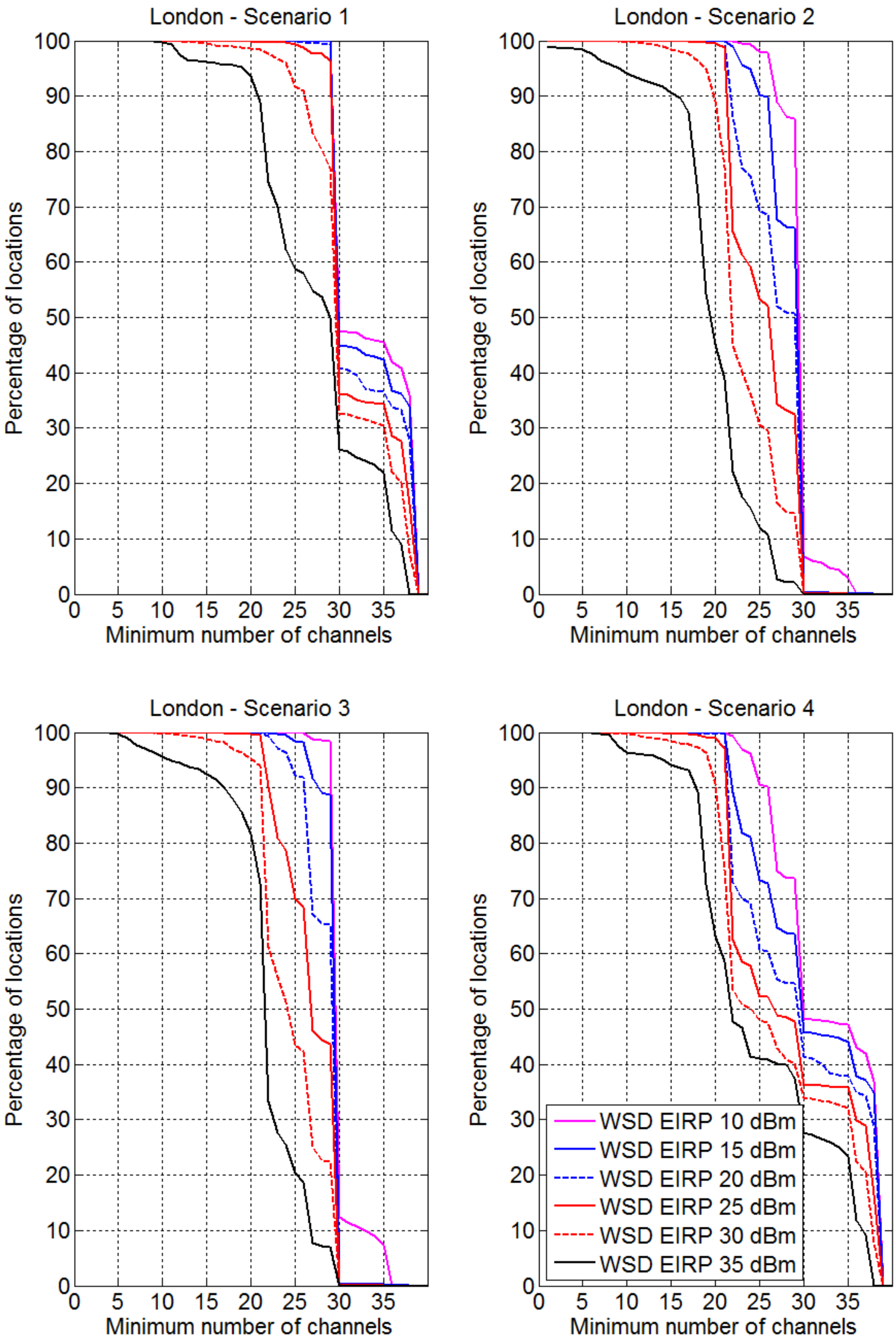
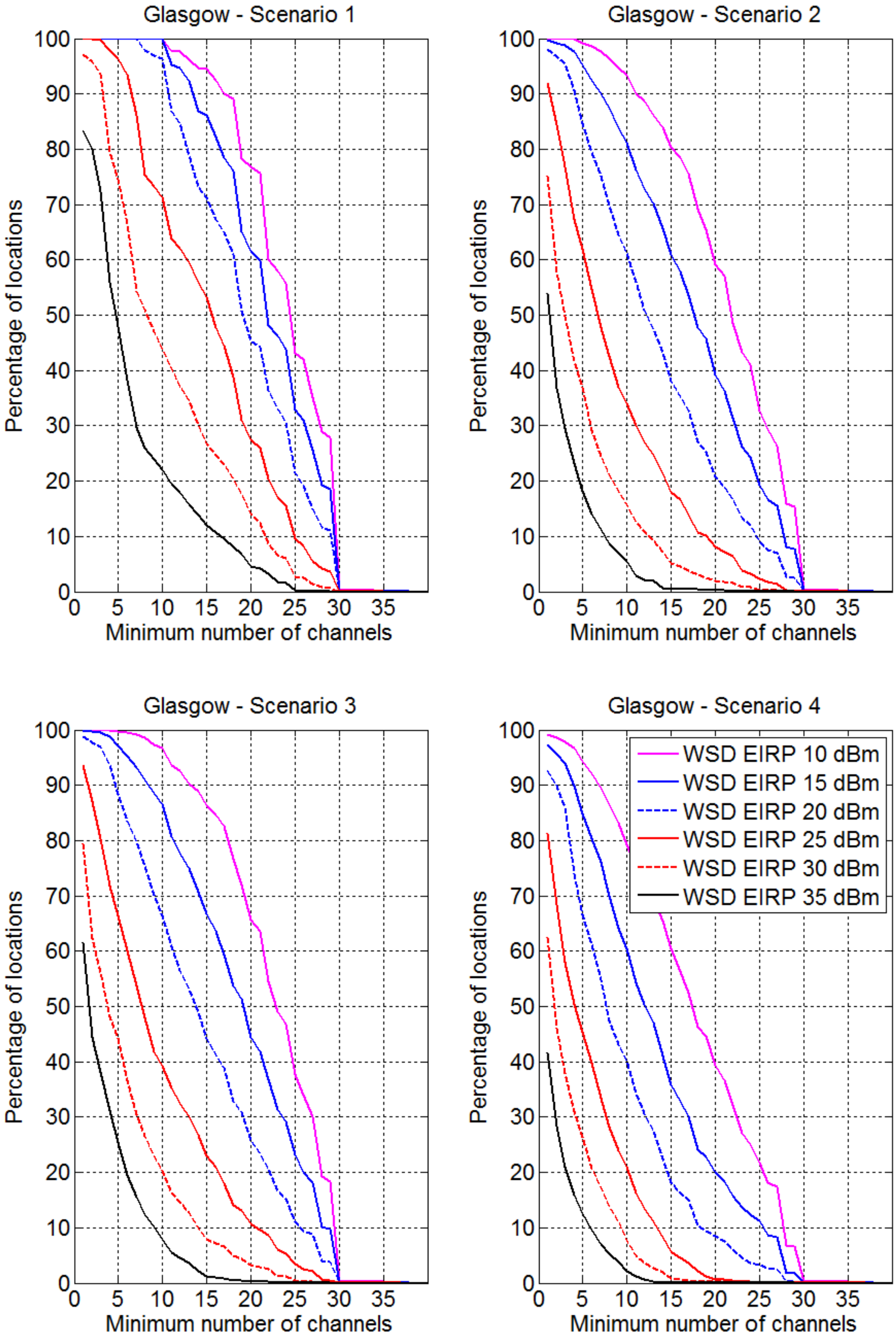


**Figure 14 – Availability of 8 MHz channels in Glasgow in relation to DTT.**



## Section 6

# WSD coexistence with PMSE services

## Introduction

6.1 PMSE services are the other user of the UHF TV band, and make use of spectrum not used by DTT broadcasts. As they make use of unused spectrum, in some respects they can be thought of as the first devices using white spaces. This section covers:

- *PMSE use of the UHF TV band.* We detail the different PMSE uses made of the UHF TV band and how it is licensed.

- *Ensuring a low probability of harmful interference to PMSE services.* We explain our proposals for defining the parameters and algorithms for the calculation of the maximum allowable WSD power levels in any location.

- *PMSE management*. We set out the changes that will be required to the management of PMSE use in the UHF TV band as a consequence of our proposals.

## PMSE use of the UHF TV band – implementation proposals

6.2 There are five main PMSE services that are used in the UHF TV band: wireless microphones, in-ear monitors, talkback, programme audio links, and data links. These services support a wide range of activities such as programme making, theatre productions, concerts, sports event coverage and smaller scale users including religious buildings and schools.

6.3 Use of these PMSE services is licensed and is managed on behalf of Ofcom by Arqiva Limited (as JFMG) to whom Ofcom has contracted out PMSE licensing services.

6.4 The licences issued by JFMG are location-specific and time-bound, meaning they authorise use of spectrum at specified locations for a specified time period. JFMG typically records information such as the type of PMSE usage, their locations, receiver heights (for some applications), frequencies, times of use, and whether the use is indoor or outdoor.

6.5 One exception to this is channel 38 (606 – 614 MHz) where JFMG does not record the location of PMSE services. A licence is still required to operate PMSE equipment in channel 38, but they are not location-specific, so they provide spectrum access rights at any location, albeit in an uncoordinated manner. News gathering is one service which makes use of channel 38.

6.6 In order to seek to ensure a low probability of harmful interference to PMSE services, we propose to restrict WSD operation wherever licensed PMSE services are in use. Due to the fact that PMSE services can operate at any location using channel 38, these restrictions will also apply to channel 38 at all locations.

## Ensuring a low probability of harmful interference to PMSE services – technical summary

6.7 The following is a high level summary of how we propose to ensure a low probability of harmful interference to PMSE services. Section 5 of the Technical Report presents this analysis in more detail.

### Ensuring a low probability of harmful interference to PMSE services

6.8 For PMSE services we consider that we can meet our objective of ensuring a low probability of harmful interference by setting emission limits for WSDs with direct reference to the typical level of wanted signal power at the PMSE receiver. We will limit the power of WSDs so that the WSD signal power received at the PMSE receiver is less than the wanted signal power by a specified protection ratio. This requires us to make assumptions about three types of variable:

a) *The wanted signal power at the PMSE receiver*. We have determined this with reference to the default PMSE field strengths to be protected in the Geneva '06 Agreement and / or Annex 5 of the Chester Agreement[26] for the five types of PMSE use. It is common practice to use these in coexistence studies.

b) *The protection ratio*. This is the ratio of the received wanted power over interferer power at the point at which a PMSE receiver fails. We have undertaken a number of measurements to quantify the protection ratios for the five equipment types of PMSE use. We believe our measurements are representative of the equipment typically used by the PMSE community.

c) *The level of interfering signals at the PMSE receiver*. We have used the urban, suburban and open profiles of the extended Hata radio propagation model for this purpose.

6.9 Given the choices we have made about the above variables – which are discussed in more detail in the accompanying Technical Report – we consider that our proposed WSD emission limits will result in a low probability of harmful interference to PMSE. Our view is further strengthened because:

a) PMSE equipment in practice operates at levels of wanted power which are higher than the default protected levels referred to in Geneva '06 and/or Chester Agreements;

b) We do not account for the mitigating effects of directional antennas at PMSE receivers. These can simultaneously boost the wanted signal while attenuating an interferer; and

c) In deriving protection ratios, we have assumed that PMSE operates within a DTT channel near the edge that is closest in frequency to the WSD signal. This over-estimates the extent of interference (particularly in the first adjacent channel) since in practice PMSE may operate anywhere within a DTT channel.

6.10 Unlike DTT, we do not propose to use multiple categories of protection ratio for PMSE. This is because PMSE equipment is narrowband and is largely insensitive to the type of radio technology used by devices. It is the leakage of emissions from

[26] http://www.archive.ero.dk/132D67A4-8815-48CB-B482-903844887DE3?frames=no&

WSDs into the PMSE channel that is the dominant source of interference. We have used an interfering signal based on the WiMAX technology standard to measure protection ratios.

### PMSE services with a known location

6.11 PMSE usage in all channels 21 to 60 (with the exception of channel 38) is subject to a location-specific licence, meaning the permitted location of the PMSE use is known and is recorded. This enables the emission limits for WSDs to be determined taking into account the separation distance between the WSD and the PMSE receiver, and where available the height of the PMSE antenna. For example, more stringent emission limits apply for smaller separation distances.

6.12 As a precautionary step, we have proposed not to allow WSDs (masters or slaves) to operate immediately outside the boundaries of a PMSE venue (this can extend up to 14 metres outside the boundaries).

6.13 In instances where slave WSDs are non-geolocated and the coverage area of their serving master WSD overlaps with a PMSE venue, we have additionally assumed that the PMSE receiver is always a distance of 10 metres away from the slave WSD. We consider this to be a cautious assumption, as given the size of coverage areas of master devices there is a low probability that a slave WSD will be less than 10 metres from a PMSE user within that coverage area.

### PMSE services with an unknown location – channel 38

6.14 PMSE usage in channel 38 is subject to a UK-wide shared licence issued by JFMG, meaning the location of the PMSE use is unknown. We propose to treat PMSE use in channel 38 in the same way as PMSE use in any other channel in terms of the technical parameters.

6.15 In determining the emission limits for WSDs, we assume that there is always a PMSE use of channel 38 at a distance of 10 metres away. This is consistent with our treatment of slave devices which are not geo-located, and means that our proposals take into account potential PMSE use in channel 38 in all locations at all times even in instances where channel 38 is not in use at a given location. The implication is that WSDs will not be able to use channel 38 in any location and that there will be restrictions nationwide in neighbouring channels.

## Impact of WSD use on existing JFMG spectrum management processes

6.16 PMSE use is normally carefully planned in advance. An example scenario is a music festival, where performers require use of wireless microphones and supporting staff require in-ear monitors. Event organisers will ensure that the licences they apply for from JFMG have adequate availability of frequencies.

6.17 However in some cases unexpected interference may be observed at late stages of testing before an event starts, which renders some of the frequencies licensed in advance unusable. Current practice is for JFMG to allow PMSE users to use alternative frequencies as this is quicker than attempting to detect and resolve the cause of the interference. JFMG is often able to find these alternative frequencies promptly.

6.18 PMSE services which change frequency in order to avoid interference would however not be protected by WSDBs until information about the change is provided to the WSDBs. The current refresh cycle of PMSE usage data for WSDBs is planned as three hours, meaning that PMSE services would be unprotected from WSD operation until the next scheduled update was carried out.

6.19 We are therefore intending that unscheduled updates of PMSE usage can be provided to WSDBs outside of the three hour refresh cycle (referred to as “unscheduled updates”). Unscheduled updates would be provided using the same mechanism (under the Ofcom WSD contract) as scheduled updates. As master WSDs check with WSDBs every 15 minutes to reconfirm their operational parameters protection of PMSE services that have moved frequency would be achieved within 15 minutes of the information being provided to WSDBs. If a WSD is unable to make contact with a WSDB to reconfirm its operational parameters, it would cease operation[27].

6.20 Unscheduled updates would also address the theoretical situation in which there are no free channels available for PMSE services that are suffering interference to move to. Using an unscheduled update it would be possible to ensure that no WSD operated using a particular channel within 15 minutes of the update reaching the WSDB, thus providing a channel for PMSE services to move to. This would be for the purposes of ensuring a channel is free for PMSE use. However, we consider this situation is unlikely to arise in practice.

6.21 Certain events, where demand for spectrum is likely to be very high, are designated as Major Events in accordance with the contract between Ofcom and Arqiva Limited. There are 24 major events, which include events such as Wimbledon and Glastonbury, currently listed on JFMG’s website for 2013[28].

6.22 For Major Events, JFMG’s event planning procedures are used, so that instead of frequencies being assigned as soon as possible after they are received, requests are held until the overall demand is clearer. This allows the best possible use of PMSE spectrum and the opportunity to borrow spectrum from other radio sectors should it be needed. Given the high profile nature of such events, we are considering whether to provide for routine bookings additional channels for the time of the event for the purpose of allowing last minute replanning.

*Q2: Do you have any comments on our proposed approach to ensuring a low probability of harmful interference to PMSE services? Please state your reasons for your comments.*

## Consequences of our proposals for white space availability

6.23 The proposals described in this section result in restrictions on WSD power – and so, TVWS availability – which vary depending on the geographic location of the WSD, and its frequency separation from PMSE use of the spectrum in the area.

[27] This is a specification in the draft ETSI harmonised standard EN 301 598

[28] http://www.jfmg.co.uk/pages/events/eventslist.htm

6.24 Here we present illustrative examples of TVWS availability for a geolocated[29] WSD in relation to PMSE usage in selected areas of Central London and Glasgow, and for the four WSD deployment scenarios in Table 1.

## TVWS availability in London

6.25 London has a considerably higher geographic concentration of PMSE deployments than in any other UK city. We have conducted our study in a 10 km × 10 km area centred on National Grid Reference TQ 300 800. This area includes Camden and Islington to the North, Paddington and Kensington to the West, Clapham and Brixton to the South, and Bermondsey to the East.

6.26 We have used PMSE assignments live at any time on 25 May 2013 as a snapshot of PMSE activity in the area[30]. The calculated restrictions account for a total of 5003 PMSE frequency assignments. We have assumed these to be for wireless microphone use.

6.27 We have calculated the WSD emission limits at the centre of every 100 metre × 100 metre pixel in the examined area. We have considered all 40 DTT channels as available for WSD use, with the exception of channels 38 and 60. The results do not include any restrictions which apply in relation to DTT. No cross border restrictions apply in London.

6.28 Figure 15 shows the percentage of WSD locations in the examined area where a minimum number of DTT channels are available for use by a WSD when it transmits at a given radiated power. The WSD powers are in dBm over 8 MHz. Note that the maximum permitted power of a WSD is capped at 36 dBm over 8 MHz.

6.29 A key observation is the importance of keeping WSD antenna heights to the minimum necessary in order to benefit from maximum TVWS availability. As can be seen, TVWS availability is considerable greater in the low-height scenarios 3 and 4 (height of 1.5 metres) even though the WSDs in these scenarios have relaxed spectrum emission masks (class 4 and 5). In these scenarios, around 99% of locations have access to 21 channels or more at a power of 35 dBm/(8 MHz).

6.30 Even in scenarios 1 and 2 (heights of 15 and 10 metres, classes 1 and 4), around 99% of locations have access to 12 to 13 channels or more at a power of 35 dBm/(8 MHz).

6.31 Since there are two channels where WSDs will not be permitted to operate, the maximum number of available channels is 38. Depending on their emission class and their intended transmit power, WSDs may be prohibited from using some or all of the three channels on either side of channel 38. For example, for a class 5 device at 35 dBm/(8 MHz), the maximum number of available channels is 32.

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[29] As with the previous section, the results we present here apply to geolocated WSDs only. If a WSD is not geolocated (e.g. a slave WSD which has not yet attached to a master) then the uncertainty in its location will mean lower TVWS availability.

[30] 25 May 2013 was a Saturday and part of a Bank Holiday weekend. This date was chosen as it was considered to be representative of a relatively high period of PMSE use.

6.32 Figure 16 shows the overall TVWS availability in relation to both DTT[31] and PMSE. This means that the more stringent of the WSD emission limits in relation to DTT and PMSE apply. The results indicate that in scenario 1 around 97% of locations have access to 3 channels or more at a power of 35 dBm/(8 MHz). In scenario 4, around 97% of locations have access to 7 or more channels.

[31] As noted in paragraph 5.48 our modelling in relation to DTT over-estimates TVWS availability by up to one channel.

## Figure 15 – TVWS availability in Central London in relation to PMSE.

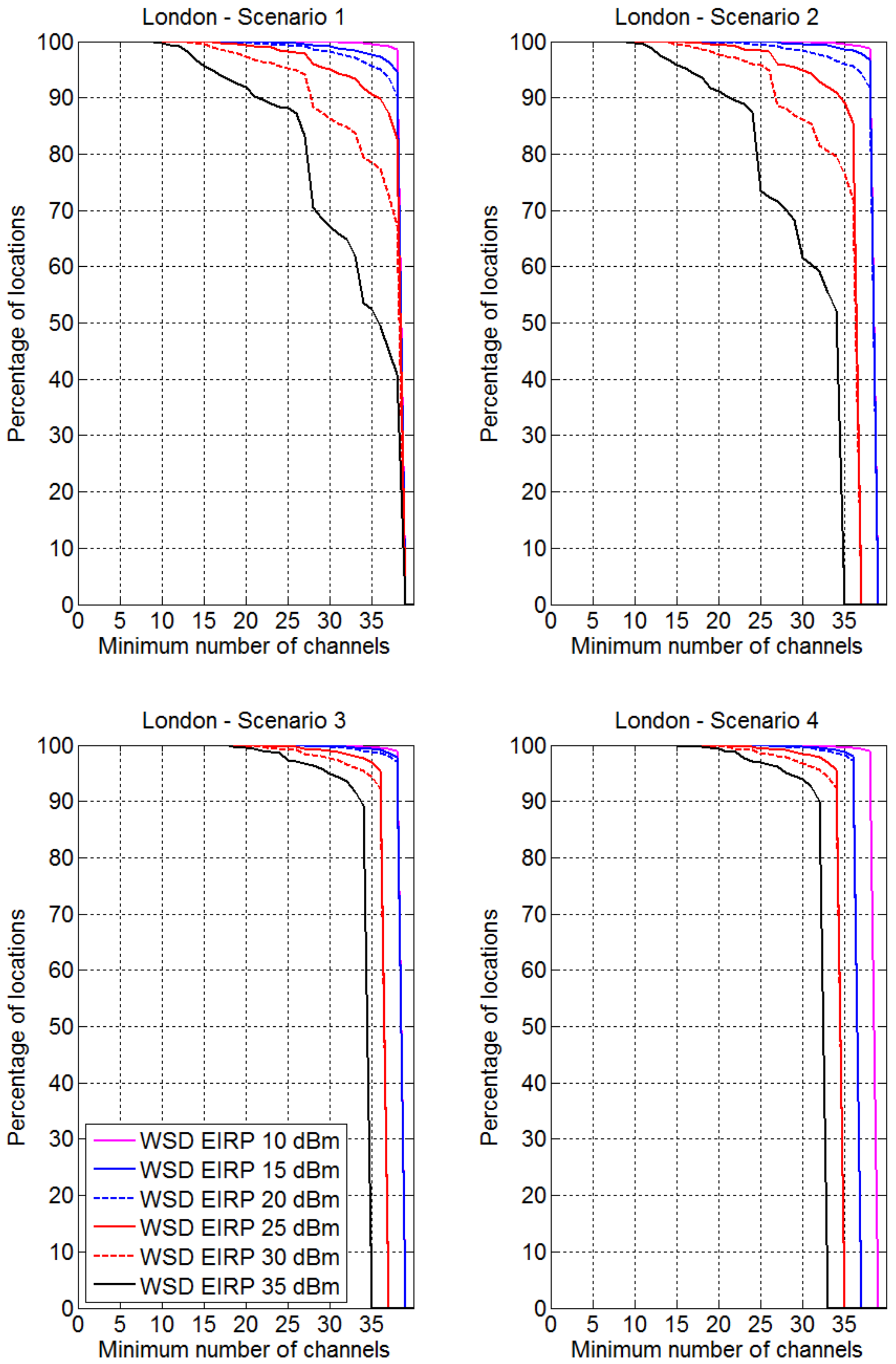
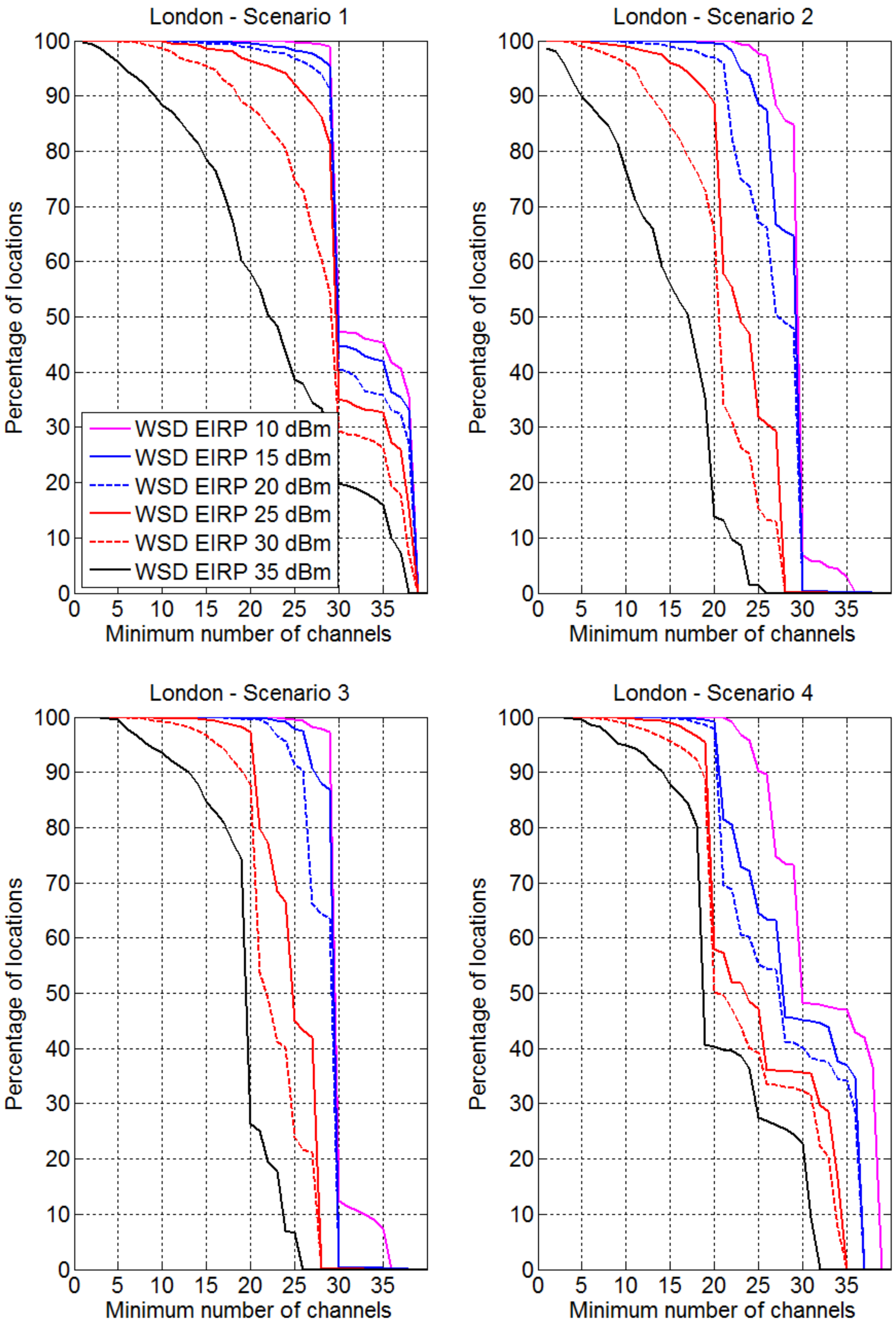


**Figure 16 – TVWS availability in Central London in relation to DTT and PMSE.**




## TVWS availability in Glasgow

6.33 We have conducted a similar study in a 10 km × 10 km area in Glasgow centred on National Grid Reference NS 590 650 (Glasgow Central Station).

6.34 We have again used PMSE assignments live at any time on 25 May 2013 as a snapshot of PMSE activity in the area. The calculated restrictions account for a total of 201 PMSE frequency assignments.

6.35 Figure 17 shows the percentage of WSD locations in the examined area where a minimum number of DTT channels are available for use by a WSD when it transmits at a given radiated power. The results are consistent with those for London, but reflect the lower prevalence of PMSE use in Glasgow. Under all four scenarios, more than 99% of locations would have access to 21 or more channels at a power of 35 dBm.

6.36 Figure 18 shows the overall TVWS availability in relation to both DTT[32] and PMSE. The Figure shows that availability in Glasgow is mainly constrained by DTT use. In scenario 1 only around 55% of locations have access to 3 channels or more at a power of 35 dBm/(8 MHz). In scenario 4, only 16% of locations have access to 3 or more channels.

[32] As noted in paragraph 5.48 our modelling in relation to DTT over-estimates TVWS availability by up to one channel.

**Figure 17 – TVWS availability in Glasgow in relation to PMSE.**

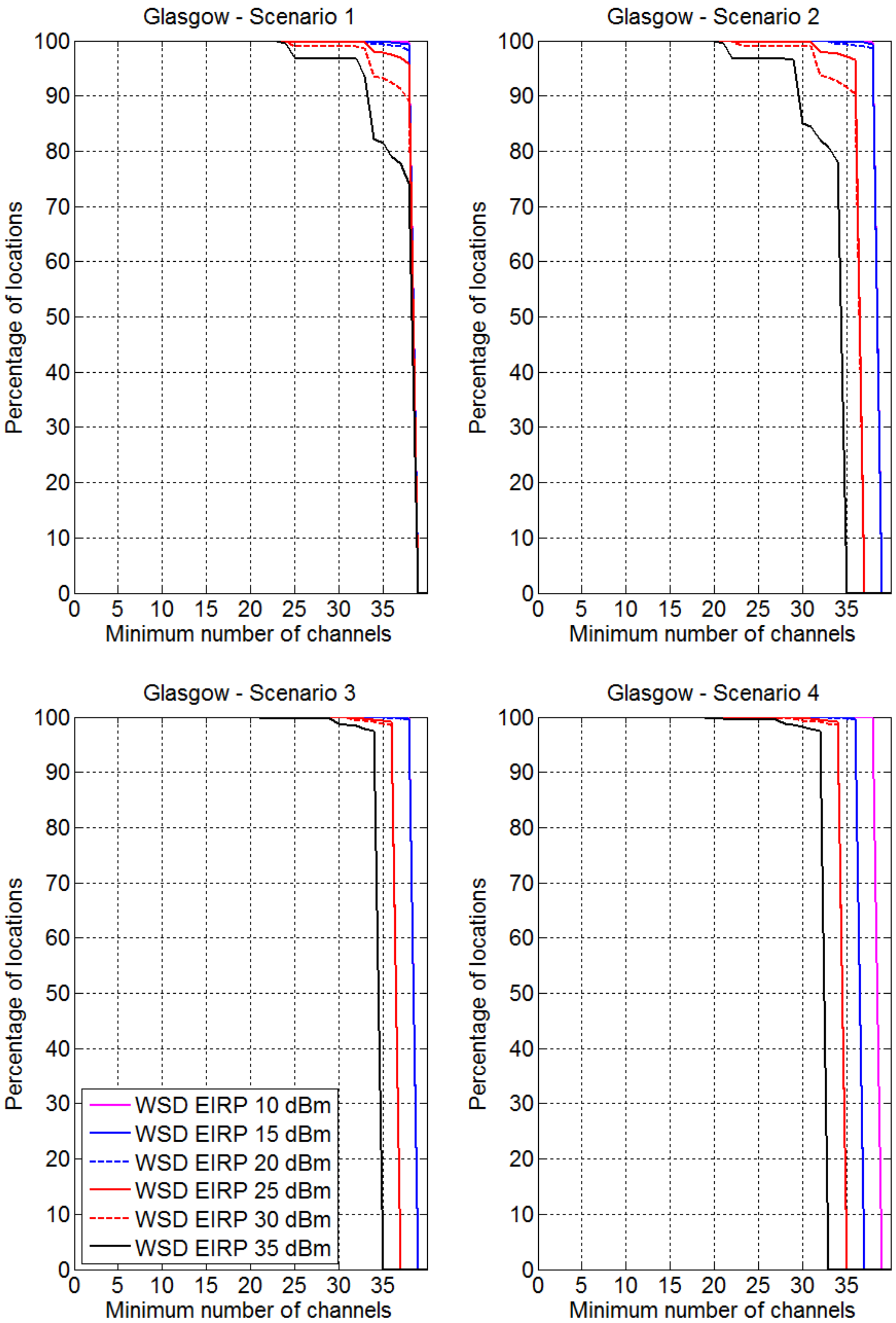
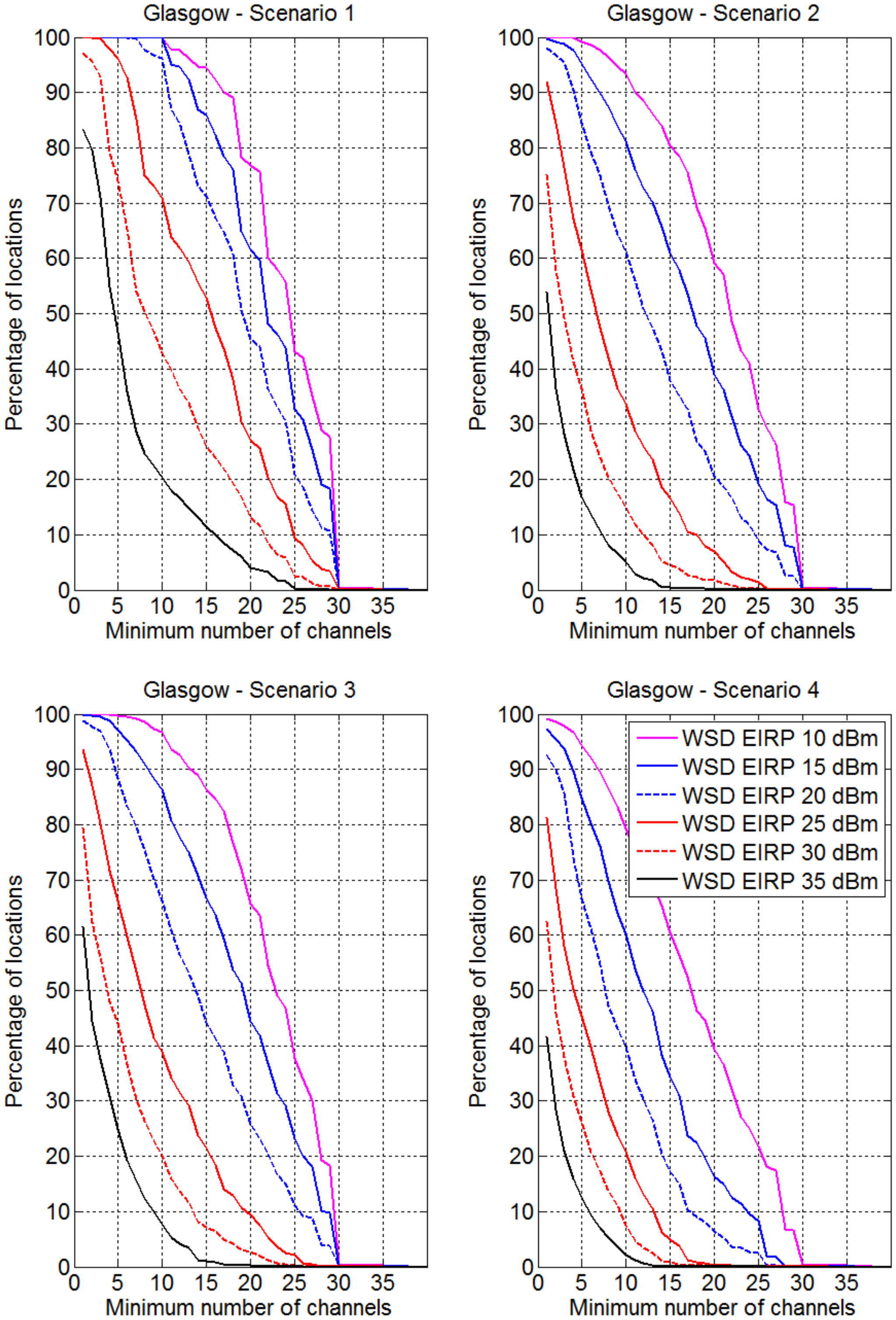


**Figure 18 – TVWS availability in Glasgow in relation to DTT and PMSE.**



## Section 7

# Other coexistence issues

## Introduction

7.1 We have also considered the potential impact of WSD use on a number of services in addition to the existing users of the UHF TV band (DTT and PMSE). This section covers:

- *4G services.* The 800 MHz band (791 MHz – 862 MHz) is adjacent to the top end of the UHF TV band and has been awarded for 4G mobile deployment. We have considered whether to place additional constraints on WSDs operating in the upper frequencies of the UHF TV band in order to ensure low probability of harmful interference to 4G services. We present proposals to place constraints on WSD operation in the upper frequencies of the band to ensure a low probability of harmful WSD interference into these services;

- *Services below the UHF TV band.* Frequencies between 450 MHz and 470 MHz are used for business radio, PMSE, scanning telemetry, short range devices, and maritime, Prison Service, and Revenue and Customs purposes. Some of these frequencies are also under consideration for Fire Service use. We present proposals to place constraints on WSD operation in the lower frequencies of the band to ensure a low probability of harmful interference to these services;

- *Cable services.* Cable equipment, unlike wireless equipment, does not use an antenna to receive radio signals and therefore is inherently more robust to interference, all other things being equal. WSD operation will be relatively low power and we do not have evidence to suggest WSDs are likely to cause harmful interference to cable services; and

- *Cross-border implications.* The UHF TV band is in use primarily for DTT in neighbouring countries. We outline initial proposals to ensure use of WSDs in the UK will not cause harmful interference to our neighbours. We also outline how we will engage with neighbouring countries to refine these initial proposals.

## 4G services – implementation proposals

7.2 In February 2013 Ofcom announced the winners of the 4G mobile spectrum auction. Two separate bands of spectrum were auctioned – 800 MHz and 2.6 GHz – with the former located just above the UHF TV band. Four mobile operators (Telefónica (O2), Vodafone, Everything Everywhere, and Hutchison 3G) were awarded parts of the 800 MHz spectrum. 4G services, utilising the 800 MHz spectrum, are now being launched.

7.3 In our 2010 consultation *Implementing Geolocation*, we stated that we would not allow WSDs to operate in channel 60 (the channel at the top of the UHF TV band, and the one closest to 4G services) in order to prevent interference to licensed services in channel 61, and because the licensed services in channel 61 might cause interference to WSDs operating in channel 60.

7.4 Having carried out a technical review (see further below), we remain of the view that it is necessary to prevent WSDs from operating in channel 60 in order to ensure a low probability of harmful interference to 4G services. We do not consider it necessary however to restrict WSD operation in channels 59 and below.

**Ensuring a low probability of harmful interference to 4G services – Technical summary**

7.5 The following is a high level summary of how we propose to ensure a low probability of harmful interference to 4G services. Section 6 of the Technical Report presents this analysis in more detail.

How the 4G network operates in the 800 MHz band

7.6 Mobile networks are often designed so that the uplink communications from mobile stations (handsets, tablets, etc.) to base stations take place at lower frequencies in the band, while downlink communications from base stations to mobile stations take place at higher frequencies in the band.

7.7 For 4G services in the 800 MHz band, this is reversed, meaning that downlink communications from base stations to mobile stations take place at the lower frequencies of the band (this places the mobile receive channels immediately above the UHF TV band and is a means of reducing interference from 4G services into DTT services). We have therefore focused our technical analysis on the potential for harmful interference from WSDs to mobile stations (rather than base stations as they are further away from the UHF TV band).

Existing interference to mobile stations

7.8 4G mobile stations are subject to two forms of adjacent channel interference as part of their normal operation: interference from other mobile stations, and interference from base stations (that is mobile stations and base stations operated by networks other than the network used by the mobile station).

7.9 Mobile stations experience much more interference from base stations in adjacent channels than from other mobile stations. This is because base stations have much higher powers, and their transmissions are closer in frequency to the mobile station receive channels.

Ensuring a low probability of harmful interference to 4G services

7.10 We have used base station to mobile station interference as a benchmark for assessing the impact of interference from WSDs to mobile stations, given that mobile stations are able to function in the presence of interference from base stations in adjacent channels.

7.11 We consider that we can meet our objective of ensuring a low probability of harmful interference to 4G services by ensuring that mobile stations are not subject to interference greater than that from base stations in adjacent channels.

7.12 Given the same distance between a WSD and a mobile station and an adjacent channel base station and a mobile station, the levels of interference experienced by the mobile station would be significantly higher from the base station. This is because of the higher power at which the base station transmits; the band-edge filtering at the mobile station which attenuates WSD signals but not base station signals; and the tight spectral masks of WSDs.

7.13 However due to the expected use cases and proliferation of WSDs, there is a risk that mobile stations near the edge of coverage of its serving base station may be considerably closer to WSDs than to adjacent channel base station. In particular, mobile operators may have the potential to collocate their base stations to reduce the risk of interference. As a result, the mobile station may be sufficiently near to a WSD in channel 60 that it experiences higher levels of interference than it would experience from adjacent channel base stations and this level of interference may be harmful.

7.14 We therefore propose a guard band at channel 60, meaning that no WSD could operate using that channel.

7.15 As interference levels from WSDs operating in channels 59 and below are expected to be three orders of magnitude lower than those operating in channel 60, we do not consider that any restrictions are required below channel 60 to ensure a low probability of harmful interference to 4G services.

## Services below the UHF TV band – implementation proposals

7.16 There are a large number of different users of spectrum close to the lower end of the UHF TV band, between 450 MHz and 470 MHz (known as the UHF 2 band). This means that a wide range of equipment, each with differing technical characteristics and resistance to interference, operates in the UHF 2 band.

7.17 In order to ensure a low probability of harmful interference into equipment in the UHF 2 band, we consider that it may be necessary to place power restrictions on WSDs operating in the lower section of the UHF TV band (in channels 21 to 24). These restrictions would however not be required if the draft ETSI harmonised standard EN 301 598 was amended, as we intend to propose, to reduce unwanted out-of-band emissions from WSDs between 230 MHz and 470 MHz.

### Ensuring a low probability of harmful interference to services below the UHF TV band – Technical summary

7.18 The following is a high level summary of how we propose to ensure a low probability of harmful interference to services below the UHF TV band. Section 7 of the Technical Report presents this analysis in more detail.

7.19 We have determined the parameters for ensuring a low probability of harmful interference to services below the UHF TV band with reference to breathing apparatus equipment used by the Fire and Rescue Service. We consider this equipment to be particularly likely to be vulnerable to emissions from WSDs because of its frequency location next to the UHF TV band, and the possibility of small distances between breathing apparatus equipment and WSDs. We are also particularly conscious of the safety of life nature of the service.

7.20 We consider that we can meet our objective of ensuring a low probability of harmful interference to services close to the lower end of the UHF TV band by ensuring that breathing apparatus equipment is not subject to out-of-band emissions from WSDs at a level greater than that determined from previous studies which examined the impact of 4G mobile stations on breathing apparatus.

7.21 In order to apply those studies to the WSD case, we have adjusted for the fact that signals at lower frequencies travel further than those at higher frequencies. Our analysis suggests that there are two potential approaches to achieving our objective:

- Our preferred approach is to propose an out-of-band emission limit for WSDs that is 8 dB more stringent that the current limit specified in the draft ETSI harmonised standard. This would ensure that the probability of harmful interference is so low so as not to be significant in the operation of the breathing apparatus. We intend to propose a revision to the ETSI harmonised standard to take account of this.

- An alternative approach – which we would propose to adopt if our proposed revision to the ETSI standard is not adopted – would be to impose in-block emission limits on WSDs using the channels at the lower end of the UHF TV band. Class 1 and 3 WSDs would be subject to emission restrictions in channels 21 and 22. Class 2 and 4 WSDs would be subject to emission restrictions in channels 21 to 23. Class 5 WSDs would be subject to emission restrictions in channels 21 to 24.

## Cable services

7.22 Cable networks are different to wireless technologies such as DTT, PMSE and WSDs. They do not use spectrum and therefore we do not take them into account in our spectrum planning decisions.

7.23 In any event, we do not consider that the deployment of WSDs is likely to cause harmful interference to cable services.

7.24 For DTT, PMSE and WSDs, transmission and reception occurs via the air, using antennas or aerials. By contrast ingress of radio signals into cable equipment is incidental, and it occurs, in the absence of robust shielding of cable equipment, due to any components acting as rudimentary antennas. All other things being equal, the lack of purpose-built antennas reduces the potential for interfering signal power entering receivers and therefore also reduces any probability of harmful interference into cable services.

## Cross-border issues

7.25 The UK is a party to the GE06 Plan (which is part of the Geneva 2006 (GE06) Agreement). This aims to protect DTT services in signatory countries by ensuring cross border emissions do not exceed certain levels. These emission levels can be relatively high if they are subject to co-ordination agreements: typically a neighbouring country is likely to allow higher emissions into some channels, if emissions are restricted to specific locations where these channels are not being used for DTT.

7.26 Countries can develop spectrum usage as long as it does not cause any harmful interference to neighbouring countries.

7.27 Administrations signed up to the GE06 Plan, such as the UK, can request additional DTT requirements to those registered in the GE06 Plan, but they must operate below a specific co-ordination trigger field strength level if they wish to proceed without a co-ordination agreement. If this level is exceeded international co-ordination agreement(s) are required to protect existing broadcast services. If emission levels are considered low and unlikely to cause interference, such co-ordination is not required. PMSE devices historically have not been subject to international co-ordination due to their extremely low power operation, meaning there is no risk of harmful interference to neighbouring countries' DTT services.

7.28 The GE06 Plan specifies the following trigger field strength levels[33] used for the protection of broadcasting services:

**Table 2 – GE06 co-ordination trigger levels.**

| Broadcasting System Modifying the Plan | Trigger Field Strength (dB(µV/m)) | | |
|---|---|---|---|
| | Band IV - CH's 21-34 (470-582MHz) | Band V - CH's 35-51 (582-718MHz) | Band V - CH's 52-69 (718-862MHz) |
| DVB-T | 21 dBµV/m | 23 dBµV/m | 25 dBµV/m |

7.29 If these levels are exceeded international co-ordination is triggered. Affected administrations analyse each case to determine any incompatibilities with registered services and in most cases the negotiation results in agreeing a level of outgoing/incoming field strengths acceptable to both parties.

7.30 As with PMSE, WSDs have no official internationally recognised frequency plan or treaty to govern registration, deployment, interference potential and requirement for co-ordination, but the UK is internationally bound by the GE06 Treaties to ensure that its neighbouring countries' DTT services do not suffer harmful interference from its secondary services (which include PMSE use and WSDs).

7.31 While the trigger field strength levels were created for managing DTT to DTT interference, we believe that they also provide a good starting point for determining power levels for WSDs which will not cause harmful interference into other countries.

7.32 We consider this to be a sensible approach because a fixed WSD is very similar to a low power DTT relay in terms of its deployment. Portable and mobile WSDs typically operate at lower powers and are therefore less likely to cause cross-border interference. Our proposed restrictions would however apply to both fixed and portable and mobile WSDs.

7.33 Our proposed approach is therefore to calculate the maximum allowed WSD power at any location and channel such that the GE06 international co-ordination trigger thresholds are not exceed in our neighbouring countries. We have specified these restrictions for a number of representative WSD antenna heights and will apply them as an overlay on the restrictions relating to DTT in the UK.

## Consequences of our proposals for white space availability

7.34 We have calculated restrictions on WSD powers based on the GE06 international co-ordination trigger levels of Table 2 and for a representative number of WSD antenna heights.

7.35 Figure 19 and Figure 20 show the resulting WSD power restrictions in the areas near the Isle of Wight and Dover. We have assumed a WSD antenna height of 10 metres. These results do not account for any restrictions which might apply in relation to DTT, PMSE, and other services above and below the UHF TV band in the UK. The coloured pixels are the locations where restrictions apply.

[33] Annex 4 - Final Acts of the Regional Radiocommunication Conference for planning of the digital terrestrial broadcasting service in parts of Regions 1 and 3, in the frequency bands 174-230 MHz and 470-862 MHz (RRC-06) Geneva, 15 May - 16 June 2006

**Figure 19 – TVWS availability on the Isle of Wight in channel 21**


**Figure 20 – TVWS availability near Folkestone and Dover in channel 21**


7.36 It may be possible to improve these restrictions by bilateral negotiations leading to agreements where the locations of channel use in neighbouring countries are taken into account. This would mean that the maximum device power at particular channels could be increased, taking into account DTT services in neighbouring countries. We will engage with our neighbours soon after publication of this document to commence this process.

*Q3: Do you have any comments on our proposed approach to ensuring a low probability of harmful interference to 4G services above the UHF TV band? Please state your reasons for your comments.*

*Q4: Do you have any comments on our proposed approach to ensuring a low probability of harmful interference to services below the UHF TV band? Please state your reasons for your comments.*

## Annex 1

# Responding to this consultation

## How to respond

A1.1 Ofcom invites written views and comments on the issues raised in this document, to be made **by 5pm on 15 November 2013**.

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

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

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

Mark Binns
Spectrum Policy Group
Floor 3
Ofcom
Riverside House
2A Southwark Bridge Road
London SE1 9HA

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

A1.6 It would be helpful if your response could include direct answers to the questions asked in this document, which are listed together at Annex 4. It would also help if you can explain why you hold your views and how Ofcom's proposals would impact on you.

## Further information

A1.7 If you want to discuss the issues and questions raised in this consultation, or need advice on the appropriate form of response, please contact Mark Binns on 020 7783 4471.

## Confidentiality

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

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

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

## Next steps

A1.11 Following the end of the consultation period, Ofcom intends to publish a statement in summer 2014.

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

## Ofcom's consultation processes

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

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

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

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

Tel: 020 7981 3601

Email Graham.Howell@ofcom.org.uk

## Annex 2

# Ofcom's consultation principles

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

## Before the consultation

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

## During the consultation

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

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

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

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

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

## After the consultation

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

## Annex 3

# Consultation response cover sheet

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

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

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

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

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

## Cover sheet for response to an Ofcom consultation

### BASIC DETAILS

Consultation title:

To (Ofcom contact):

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

### CONFIDENTIALITY

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

Nothing ☐ Name/contact details/job title ☐

Whole response ☐ Organisation ☐

Part of the response ☐ If there is no separate annex, which parts?

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

DECLARATION

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

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

Name Signed (if hard copy)

## Annex 4

# Consultation questions

A4.1 The following is a list of consultation questions raised in this document and the technical report.

*Q1: Do you have any comments on our proposed approach to ensuring a low probability of harmful interference to DTT services? Please state your reasons for your comments.*

*Q2: Do you have any comments on our proposed approach to ensuring a low probability of harmful interference to PMSE services? Please state your reasons for your comments.*

*Q3: Do you have any comments on our proposed approach to ensuring a low probability of harmful interference to 4G services above the UHF TV band? Please state your reasons for your comments.*

*Q4: Do you have any comments on our proposed approach to ensuring a low probability of harmful interference to services below the UHF TV band? Please state your reasons for your comments.*

*Question T1: Do you have any comments on our proposal to cap the maximum in-block EIRP of all WSDs at 36 dBm/(8 MHz)?*

*Question T2: Do you have any comments on our proposed approach for calculating WSD emission limits, as expressed in Equation (4.3), in relation to DTT coexistence calculations?*

*Question T3: Do you have any comments on our proposed approach for dealing with the uncertainty in the locations of DTT receivers in relation to DTT calculations?*

*Question T4: Do you have any comments on our proposed target of a 10% likelihood of a 1 dB rise in the noise-plus-interference floor at the edge of DTT coverage?*

*Question T5: Do you have any comments on our proposed approach for calculating coupling gains in relation to DTT calculations?*

*Question T6: Do you have any comments on our proposed protection ratios in relation to DTT calculations?*

*Question T7: Do you have any comments on our proposed approach for dealing with the uncertainty in the locations of WSDs in relation to DTT calculations?*
*Question T8: Do you have any comments on our proposed approach for calculating WSD emission limits, as expressed in Equation (5.2), in relation to PMSE coexistence calculations?*

*Question T9: Do you have any comments on the PMSE wanted signal power levels that we propose in relation to coexistence calculations?*

*Question T10: Do you have any comments on our proposed approach for calculating coupling gains in relation to PMSE calculations*

*Question T11: Do you have any comments on our proposed approach for dealing with the uncertainty in the locations of WSDs in relation to PMSE calculations?*

*Question T12: Do you have any comments on our proposed approach for dealing with the uncertainty in the locations of PMSE receivers in relation to PMSE calculations?*

*Question T13: Do you have any comments on our proposed approach for the derivation of WSD-PMSE coupling gains for non-geolocated slaves in relation to PMSE calculations?*

*Question T14: Do you have any comments on our proposed protection ratios in relation to PMSE calculations?*

*Question T15: Do you have any comments on our assessment that a margin for uncertainties in radio propagation is not necessary given the proposed parameters for derivation of coupling gains in relation to PMSE coexistence calculations?*

*Question T16: Do you have any comments on our proposed WSD emission limits in relation to PMSE use in channel 38?*

*Question T17: Do you have any comments on our proposal not to permit WSDs to operate in channel 60?*

*Question T18: Do you have any comments on our proposal that, if the unwanted emissions limit (over 230-470 MHz) in the draft ETSI standard (EN 301 598) is tightened by 8 dB, there should be no further restrictions on the operation of WSDs in relation to services below the UHF TV band?*

*Question T19: Do you have any comments on our proposal that, if unwanted emissions limit (over 230-470 MHz) in the draft ETSI standard (EN 301 598) is not changed, there should be restrictions on the in-block powers of WSDs in channels 21 to 23?*