Implementing TV White Spaces

Statement

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About this document

This document sets out Ofcom's decision to allow a new wireless technology access to the unused parts of the radio spectrum in the 470 to 790 MHz frequency band. Our decision follows extensive consultation with stakeholders and a pilot.

The new technology, known as white spaces devices, will share this band with the existing uses, Digital Terrestrial Television (DTT), including local TV, and Programme Making and Special Events (PMSE), including in particular wireless microphone users.

The sharing will take place dynamically, controlled by databases which will hold information on the location of DTT and PMSE users and white space devices. They use this information, following the approach set out in this document, to allow white spaces devices access to the spectrum band, but only to the extent that this does not cause harmful interference to the existing users of the spectrum.

Implementing the decisions set out in this document is one of the ways Ofcom is meeting the increasing demand for more spectrum to deliver existing and new services. Our objective is to complete the implementation of our decisions so the new technology can be deployed by the end of 2015.

Contents

Section 1

Executive Summary

1.1 The increasing number of wireless devices has put greater demands on the radio spectrum to deliver existing and new services. Dynamic management of spectrum, coupled with intelligent devices, which know where they are, enable us to free up valuable low frequency spectrum which has until now been unused, by allowing access in places and at times that others are not using it.

1.2 In order to promote innovation, we are making this freed up spectrum available on a licence exempt basis. At the same time, we will take an appropriately cautious approach to managing the risk of harmful interference to existing users. In the longer term, the techniques developed here may be applied in other bands.

1.3 This document sets out Ofcom's decision to move ahead and enable access to unused parts of the radio spectrum in the 470 to 790 MHz frequency band through dynamic sharing controlled by a spectrum database. We refer to the spectrum that is left over by Digital Terrestrial Television (DTT) (including local TV) and Programme Making and Special Events (PMSE) use as TV white spaces (TVWS). We intend to make available access to TV white spaces on a licence exempt basis for devices which meet a minimum technical specification. Devices which know their location, combined with databases, which know where existing services are, will be used to ensure services can coexist sharing the spectrum.

1.4 This decision follows extensive consultation and research over a number of years. This has looked at what spectrum is available within the band and how new uses could coexist with the current uses in the band. Our decision is based upon ensuring a low probability of harmful interference to DTT and PMSE users, and uses above and below the band, as a result of any new services using white space devices. A consultation in 2013 set out detailed proposals for the rules that could be put in place to ensure that both DTT and PMSE users faced a low probability of harmful interference from new services. Stakeholders have responded to this consultation and, in addition, we have enabled a series of pilot trials, and conducted an extensive programme of testing to understand as fully as possible the implications for interference of the regulatory limits proposed. Results of tests were published in November and December 2014.

1.5 As a result of this process we have decided to make some changes to the coexistence proposals that were set out in the 2013 Consultation. The detail of what we have decided and how it differs from our earlier proposals is set out in sections 6 to 9 of this Statement.

1.6 The overarching principle we have applied to setting the coexistence criteria is that we should take a cautious initial approach in order to achieve our aim of ensuring a low probability of harmful interference to existing users. There are a number of reasons for this. Database-controlled dynamic spectrum access is a new approach to spectrum sharing that has not yet been fully demonstrated with a high volume of users. Equipment for white space use is still largely at an early stage of development and, while there is an ETSI harmonised standard and we will specify minimum technical requirements that equipment must meet to operate in white space, we do not yet know what the actual characteristics of mass consumer white space equipment will be. We also do not yet know what the real use cases and volumes of use will be. All this provides a high degree of uncertainty about how use of white spaces, and the market in white space devices, will develop and we therefore have taken the view that, to begin with, we need to set our protection criteria in a conservative way.

1.7 This means that, in relation to both DTT and PMSE use, we have decided to set our regulatory limits at levels which ensure that even in the circumstances where a number of worst case scenarios come together, there is a low likelihood of harmful interference to existing spectrum users. Over time we would hope to be able to better understand the likelihood of some of these worst case scenarios occurring simultaneously, and the genuine effect when they do, and this may mean we can relax the regulatory constraints to allow more white space availability without affecting the likelihood of harmful interference to DTT and PMSE users. Equally, though, we need to be ready to tighten the coexistence framework should that be necessary to secure a low probability of harmful interference.

1.8 It is important to be clear that the approach we have taken in setting our regulatory criteria for white spaces is not intended in any way to define or identify at what point interference from white space (or any other) device would be harmful – we have instead worked to limits that we are confident will offer the protection needed to secure a low likelihood of harmful interference to users.

1.9 This Statement and its annexes include a comprehensive explanation of how, in terms of the technical rules, we intend to authorise access to white space whilst ensuring a low probability of harmful interference to existing users in the band.

1.10 Dynamic spectrum allocation using databases is a new and flexible spectrum access method and technology. As such we expect its implementation to improve and evolve. We identify at Section 11 in the Statement a number of specific technical issues that we already know we would like to look at further to see if we can improve the utility of TV white spaces whilst continuing to ensure a low probability of harmful interference to existing users. Other issues will undoubtedly emerge as the market develops. The framework set out here is intended to allow use of TV white spaces to get underway and provide an opportunity for markets in both applications and equipment to develop whilst also achieving our aim of ensuring a low probability of harmful interference to existing users.

1.11 This is the first time Ofcom has decided to implement spectrum sharing using a database approach. This is an excellent opportunity for all parts of industry to explore these opportunities, and look at ways in which this approach to making spectrum available can form part, or all, of a network strategy that delivers the communications capability that any individual application requires. We are very keen to see how useful it is, and in what ways the regulatory framework could be improved to make it more effective as a means of securing efficient use of spectrum. We expect dynamic spectrum access methods to improve and change over time (as seen in the US for example), but we also want to see how such methods might be applied in other spectrum bands. In line with our duty to ensure the spectrum is efficiently used, we will seek to understand how dynamic access methods can be improved over time. Database control is certainly not the only method of spectrum sharing, but it has the potential to be a very powerful driver of spectrum efficiency when it works effectively.

White Space Availability

1.12 The potential uses of TVWS are still being considered by the industry and so there remains uncertainty about what sort of TVWS availability will be important to allow the technology to be deployed. The coexistence framework is designed to allow as much use as is compatible with a low probability of harmful interference and therefore allows greater powers at closer distances for equipment that will cause less interference. The availability analysis that we have done shows that there should be sufficient availability to support likely use cases in a good percentage of the country.

Section 2

Introduction

2.1 This document sets out Ofcom's decision on the framework that will be put in place to enable dynamic spectrum access to white spaces in the 470 to 790MHz band (the UHF TV band)[1]. This Statement represents the culmination of many years' work to understand the best approach to achieving this, including working closely with: industry and innovators to understand how to create a sufficiently flexible framework to promote innovation; the existing users of the spectrum to ensure that we put in place sufficient protections to ensure a low probability of harmful interference to them and their services; and with the international community to ensure that we move forward in a way that is consistent, as far as possible, with developments elsewhere and which facilitates the development of global standards and markets.

What is TV White Space?

2.2 The UHF TV band is currently allocated for use by Digital Terrestrial Television (DTT) broadcasting and Programme Making and Special Events (PMSE). Currently, Freeview TV channels are broadcast using up to six multiplexes. Each multiplex requires an 8 MHz channel. Multiplexes are transmitted at different frequency channels across the country in the frequency range 470 to 790MHz.

2.3 Whilst a total of 32 channels each 8 MHz wide are reserved for DTT in the UK, only six of these channels are required to receive the 6 multiplexes at any given location. In other words, the vast majority of channels are unused for DTT transmission at any given location. This is required because high-power TV broadcasts using the same frequency need geographic separation between their coverage areas to avoid interference.

2.4 The channels that are not used by DTT at any given location can be used by lower-power devices on an opportunistic basis. This opportunistic access to interleaved spectrum is not new. Programme making and special events (PMSE) equipment such as radio microphones and audio devices have been exploiting the interleaved spectrum for a number of years, and Arqiva Limited (Arqiva PMSE) issues more than 50,000 assignments annually on behalf of Ofcom for this type of use.

2.5 Figure 2.1 below illustrates in a high level way the potential 'white space' for a given DTT channel (channel 59, 774 to 782MHz). High power DTT frequencies which use the same frequencies need to leave space between their coverage areas to avoid interference. Darker green areas on the map indicate the approximate coverage areas of DTT transmissions in channel 59 while lighter green areas indicate the 'white spaces' in channel 59. These 'white spaces' in between can be used by lower power devices.

[1] For the purposes of this Statement we refer to this band as the UHF TV band. However, it should be noted that Ofcom's Decision published on 19th November 2014 set out our decision to make the 700 MHz band available for mobile data use. Our objective is to make the 694 to 790 band available for mobile by the start of 2022 though in practice we expect changes could start to happen as early as 2018. White space use in the 700 MHz band will not therefore be authorised once the clearance process moves forward and references to the UHF TV band should be taken to mean 470 to 694MHz from that point.

Figure 2.1 - Interleaved spectrum and TVWS

2.6 Figure 2.2 below gives an illustration of what this looks like across the UHF TV band at an individual location. The white squares in the chart indicate channels which could potentially accommodate white space use[2].

Figure 2.2 - Illustration of White Space spectrum in London

2.7 We refer to the spectrum that is left over by DTT (including local TV) and PMSE use as TV White Spaces (TVWS). By this we mean the combination of locations and frequencies in the UHF TV band that can be used by new users which would operate in accordance with technical parameters that ensure that there is a low probability of harmful interference to DTT reception or PMSE usage or services above and below the band.

The development of the UK approach to White Spaces

2.8 On 13 December 2007 Ofcom issued a statement entitled “Digital Dividend Review: a statement on our approach”[3], in which we concluded that we should allow access by licence exempt devices to interleaved spectrum in the UHF TV band as long as we were satisfied that it would not cause harmful interference to licensed uses, including DTT and PMSE. This was because we considered that the applications that such devices might enable could potentially bring substantial benefits to citizens and consumers.

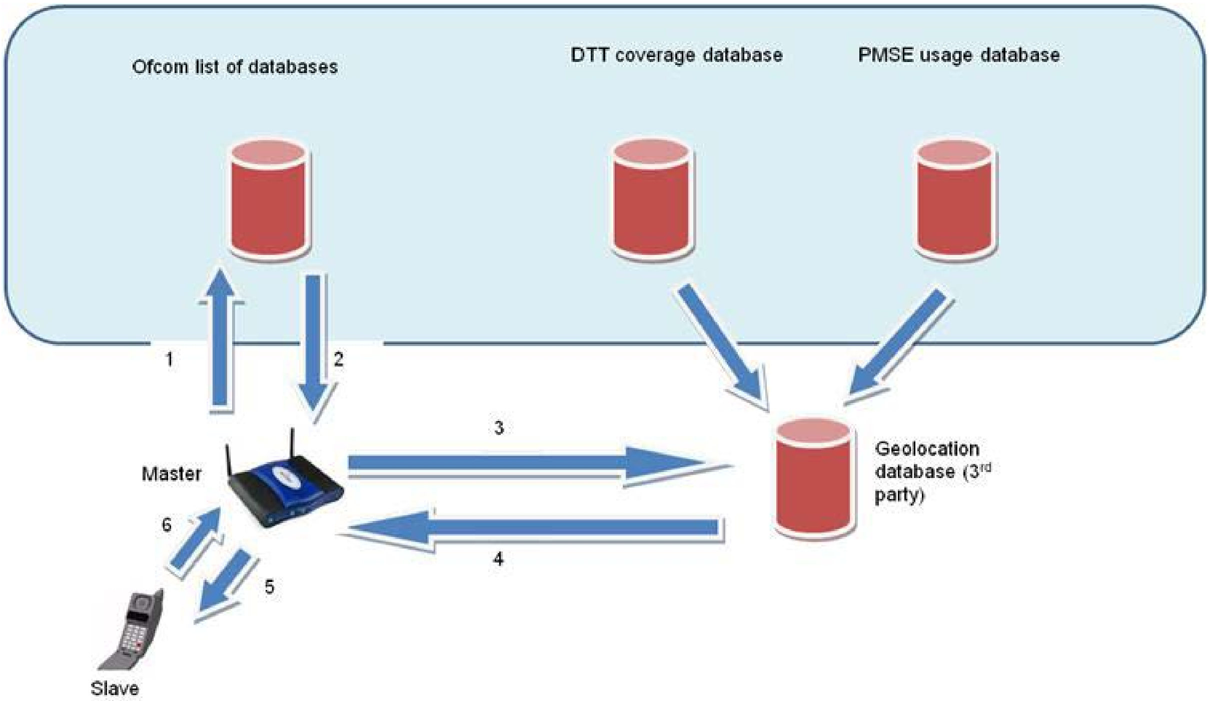
[2] We note that there will also be PMSE assignments in the channels indicated by white squares and white space use could only occur in those channels in locations not used by PMSE.
[3] http://stakeholders.ofcom.org.uk/binaries/consultations/ddr/statement/statement.pdf

2.9 At that time we considered different technological approaches to Dynamic Spectrum Access. A statement in July 2009 ("Digital dividend: cognitive access. Statement on licence-exempting cognitive WSDs using interleaved spectrum"[4]) and a consultation in November 2009 ("Digital Dividend: Geolocation for Cognitive Access. A discussion on using geolocation to enable licence exempt access to the interleaved spectrum"[5]) led us to focus on an approach based on geolocation, under which devices determine their location and query a geolocation database which returns the frequencies they can use at their current location and the power levels they can use.

2.10 A subsequent consultation published on 9 November 2010 entitled "Implementing Geolocation[6]" (the 2010 Consultation) and the statement "Implementing Geolocation: Summary of consultation responses and next steps"[7] in 2011 then set out our proposed approach to implementing geolocation in the UHF TV band.

2.11 The diagram below provides an overview of how we proposed access to white spaces based on geolocation would work in practice. In this model a "master" white space device (WSD) would first consult a list of databases provided on a website hosted by Ofcom (1 and 2). It would then select its preferred database from this list and send to it parameters describing its location and device parameters (3). The database would then return details of the frequencies and power levels the WSD is allowed to use (4). This framework is explained further in Section 3.

Figure 2.3 - Overview of TV White Spaces framework



2.12 Stakeholder responses to our consultation indicated that there was broad acceptance of this conceptual framework and we therefore moved forward with developing proposals as to how we would implement this. For this purpose, we needed to develop detailed provisions covering:

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4 http://stakeholders.ofcom.org.uk/binaries/consultations/cognitive/statement/statement.pdf
5 http://stakeholders.ofcom.org.uk/binaries/consultations/cogaccess/summary/cogaccess.pdf
6 http://stakeholders.ofcom.org.uk/binaries/consultations/geolocation/summary/geolocation.pdf
7 http://stakeholders.ofcom.org.uk/binaries/consultations/geolocation/statement/statement.pdf

- Device authorisation: we proposed that use of white spaces by devices would be licence exempt and that Ofcom would make licence exemption regulations specifying the minimum technical requirements for the equipment that may transmit in these bands, the nature of those transmissions and the conditions under which transmissions can be made;

- Coexistence framework: Ofcom has consistently been clear that use of the UHF TV band by white space devices would only be permitted in accordance with conditions which would ensure that there was a low probability of harmful interference to existing users. This requires decisions on what rules should be set to ensure that is achieved; and

- Arrangements with White Space Databases: we explained our intention to enter into arrangements with 3rd party database providers, which would operate databases that would be capable of taking the data provided by Ofcom and providing responses to WSDs that accurately identify available channels and acceptable power levels.

2.13 On 22 November 2012 we published a consultation entitled "TV white spaces: A consultation on white space device requirements"[8] (the 2012 Consultation). That document set out a proposed regime for authorisation of white space devices, with different usage parameters being anticipated for devices depending on the technology used, the role they play in the network (master or slave) and the spectral emission mask of the device. Following this consultation an ETSI Harmonised Standard has been developed, which provides a common standard across Europe for white space devices. This standard[9] was published in the Official Journal of the EU on 12 September 2014.

2.14 In April 2013 we proposed to explore the implementation of access to TVWS through a pilot. This was supported by industry and preparatory work was undertaken by Ofcom and industry to bring this about. This included developing a set of arrangements for contracting with pilot white space databases, a set of proposals for how the coexistence rules would work and an approach to authorising deployment of devices in various trials.

2.15 On 4 September 2013 we published a further consultation entitled "TV white spaces: approach to coexistence"[10] (the 2013 Consultation). That document set out a proposed approach to how we would calculate where white space devices could operate and with what powers in order to protect existing uses. That approach was then implemented in the pilot.

2.16 In late 2013 following a number of discussions with the database industry working group we concluded a set of arrangements for the pilot. In 2014 eight databases were qualified by Ofcom so they could begin to provide services in the pilot.

2.17 From mid-2014 we authorised a series of trials by issuing pilot trial licences in order to test a variety of innovative applications – including sensors that monitor river levels and rural broadband in hard to reach places. This enabled us to test the various elements of the regime. The trials enabled us to test the protocols for communication between white space devices and databases and to set up and test processes for

[8] http://stakeholders.ofcom.org.uk/binaries/consultations/whitespaces/summary/condoc.pdf
[9] http://www.etsi.org/deliver/etsi_en/301500_301599/301598/01.01.01_60/en_301598v010101p.pdf
[10] http://stakeholders.ofcom.org.uk/binaries/consultations/white-space-coexistence/summary/white-spaces.pdf

interference management. The trials, and the lessons learned from them, are described in more detail in Section 4.

2.18 At the same time we embarked on a substantial programme of coexistence testing to examine whether the propositions in the 2013 consultation about levels of harmful interference were right. The results of those tests were published on 12 November[11] and 17 December[12] 2014 respectively. The results of that testing programme have led us to amend our approach to coexistence such that there is enhanced protection of both DTT services and PMSE use. The detail of those changes and the framework we are putting in place is set out in detail in Sections 7, 8 and 9 and Annexes 1 to 10.

2.19 We received comments from stakeholders to both the 2012 and 2013 Consultations and we have taken those into account, along with other feedback, lessons from the pilot and the results of the testing programme, in refining the framework as set out in this Statement. A summary of responses and how we have addressed the points raised is at Annex 11.

Legal framework

2.20 This section describes our functions and duties in assessing how best to define the requirements for WSDs in relation to their use of white spaces in the UHF TV band, and considers how they apply to achieving our objectives with regard to TVWS. Set out below are our general duties that apply across all our functions, together with a number of specific duties.

Our general duties

2.21 Section 3(1) of the Communications Act 2003 (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.

2.22 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.

Our spectrum duties

2.23 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.

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

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[11] http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2014/TVWS-PMSE_Coexistence_Technical_Report.pdf
[12] http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2014/TVWS_DTT_technical_report.pdf

- 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 the use of that spectrum for wireless telegraphy.

2.25 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.

Wireless telegraphy licences and licence exemption regulations

2.26 Under section 8(1) of the WT Act, it is an offence to establish, install or use wireless telegraphy ('WT') equipment in the UK except where such use is authorised either by the issue of an appropriate wireless telegraphy licence or where the use of such equipment is exempted from the need to hold such a licence by regulations (i.e. a statutory instrument) made under section 8(3) of the WT Act.

2.27 We also aim wherever possible to reduce the regulatory burden upon our stakeholders (in this instance users of radio spectrum) and one way we can do this is, when appropriate, to exempt from licensing the use of specified equipment which is unlikely to cause undue interference to other legitimate users of the radio spectrum.

2.28 Section 8(4) of the WT Act requires that Ofcom must make regulations to exempt the use of WT equipment if the conditions in section 8(5) of the WT Act are met, namely that its installation or use is not likely to:

- involve undue interference with wireless telegraphy;
- have an adverse effect on technical quality of service;
- lead to inefficient use of the part of the electromagnetic spectrum available for wireless telegraphy;
- endanger safety of life;
- prejudice the promotion of social, regional or territorial cohesion; or
- prejudice the promotion of cultural and linguistic diversity and media pluralism.

2.29 In accordance with the requirements of section 8(3B) of the WT Act, the terms, provisions and limitations specified in licence exemption regulations must be:

- objectively justifiable in relation to the wireless telegraphy stations or wireless telegraphy apparatus to which they relate;
- not such as to discriminate unduly against particular persons or against a particular description of persons;
- proportionate to what they are intended to achieve; and
- transparent in relation to what they are intended to achieve.

Radio and Telecommunications Terminal Equipment

2.30 Most radio equipment must be compliant with the Radio and Telecommunications Terminal Equipment (R&TTE) Directive (Directive 99/5/EC) to reduce the risk of harmful interference. The R&TTE Directive has been implemented into UK law by the Radio Equipment and Telecommunications Terminal Equipment Regulations 2000 (SI 2000/730) as amended. Compliance with the relevant ETSI harmonised standard (where there is one) presumes that the equipment conforms with the essential requirements of the R&TTE Directive and the use of these standards has proved a popular method for manufacturers and suppliers to ensure compliance.

2.31 Interface requirements (IRs) for radio equipment provide a link between the requirements of the R&TTE Directive and the use of national radio spectrum. UK Interface Requirements describe the minimum technical specifications, such as power limits, which are necessary to avoid interference between services. The IR normally includes a cross-reference to any appropriate ETSI standard.

Application of our duties in relation to TV White Spaces

2.32 Our policies with regards to TVWS are determined by observance of our general and specific duties above. We have interpreted these duties as requiring us to:

- **Facilitate access to TVWS.** We believe that there are significant benefits to consumers in making TVWS available for use, such as efficient use of spectrum and the emergence of innovative services. We consider that licence exempt access to these bands is the best approach to facilitate these benefits. We set out why we believe this to be the case in detail in the 2010 Consultation.
- **Protect the existing users, namely DTT and PMSE.** DTT is the main platform for provision of TV services and, as such, delivers significant value for consumers. In addition, it performs a very important public policy role in providing universal low cost access to public service broadcasting content, whilst also providing a wide consumer choice of channels. PMSE applications in the band include wireless microphones, in-ear-monitors, talkback and audio links. These services support a wide range of activities from programme making, theatres, concerts, sports event coverage and smaller scale users including churches and schools. We consider that a wide scale deployment of licence exempt WSDs presents a risk of increased interference to DTT and PMSE users. As a result, we are putting in place a regulatory framework that ensures co-existence between the DTT and PMSE users and services above and below the band and the deployment of WSDs, and one that in our judgement ensures there is only a low probability of harmful interference.
- **Minimise the regulatory burden.** A certain amount of regulation is necessary to authorise access to TVWS and to protect the existing users, but we have tried to

keep this as light as possible, consistent with the need to prevent undue interference, in order to maintain flexibility. We are at the very early days of white space development and, although some business models and use cases have already been put forward, including through the trials run this year, it is difficult to predict which models, applications and technologies will succeed. In order to facilitate the emergence of innovative services, we consider we should put in place a framework that is flexible to accommodate different approaches.

Current position

2.33 This Statement therefore sets out the way forward for the implementation of the UK framework for authorising access to TVWS. This includes our decisions on device authorisation (Section 5), coexistence rules (Sections 7-9) and our approach to contracting with and qualifying white space databases (Section 3). The decisions outlined in this Statement take account of the responses to the consultations in 2012 and 2013, information gathered from the co-existence testing programme and the lessons learned in respect of practical operation of the regime from the pilot trials to the extent that we have been able to do so to date.

2.34 The overall framework remains essentially as set out in the earlier documents and is described in Section 3 of this Statement. We intend to implement the approach set out in this document during 2015. We are aware that there is scope for further development and refinement of certain aspects of the framework, but we consider that it represents a sensible starting point. We expect to work with industry in evolving the framework in the future.

2.35 Under the coexistence framework set out in this document the operating parameters will be set at a level that we are confident will achieve our aim of ensuring there is a low probability of harmful interference to both DTT viewers and PMSE users and to services above and below the band. In order to do this we have used conservative estimates throughout. Through our arrangements with databases we will have a number of tools and mechanisms available to us to respond to interference issues. We will want to monitor the deployment and use of WSDs and performance of databases over time to see how the framework can be improved. A key part of this will be a review of our coexistence rules. We anticipate that, given our initially cautious approach, we may be able to relax some rules as we understand more about actual deployments of WSDs and those devices improve. However, we will also be ready to tighten our approach if experience shows this is necessary.

2.36 Ofcom will enter into contractual arrangements with white space database providers who are able to demonstrate that their databases meet certain requirements and are able to provide information on TV White Space availability to devices. In the first instance we are not imposing any charges on databases in respect of those contracts. This is an innovative approach to spectrum allocation and it is not yet clear what the potential uses will be or how much economic activity we can expect to see in the white spaces. Given the experience in the US, we do not expect to see large scale commercial use of white spaces in the immediate future, and consequently we are able to confirm that we would not levy any charges from database providers during the first three years from the introduction of the licence exemption. However, we may consider in future whether it would be appropriate for Ofcom to be able to recover its costs in making white spaces available by charging database providers, provided that this would not inhibit the development of the market. Ofcom would consult fully in advance of introducing any charge to database providers.

Review of use cases

2.37 In the 2012 Consultation we described a number of use cases for access to the TVWS spectrum. These included rural broadband, hot-spot coverage, in-home broadband, in-home multi-media distribution and machine to machine communications. These were identified as illustrations of the nature of white space devices that might emerge over the next few years. During the pilot we have been working with eleven triallists (to date) testing out White Space uses. Those trials have included some of the original use cases that we anticipated, such as rural broadband and machine to machine communications, but they have also included a range of uses that we did not foresee, such as broadband on ships, Wi-Fi and webcam backhaul, AV distribution and digital signage. Similar applications have been trialled or are in use in a number of countries around the world.

2.38 This reinforces our view that the policies with regard to authorising the use of TVWS need to be both application neutral and service-neutral, and as such, support all envisaged use cases as well as hopefully allowing for others that have not yet been envisaged, whilst ensuring a low risk of harmful interference to existing spectrum users.

Impact Assessment and Equality Impact Assessment

2.39 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. As explained earlier, this document implements earlier decisions which were taken to further both our general and our spectrum duties. Our assessment of the impact of our proposals for device authorisation was set out in the 2012 Consultation and our assessment of the impact of our co-existence proposals was set out in the 2013 Consultation. This Statement sets out our decision on these proposals, having taken all stakeholder representations into account.

2.40 Ofcom is separately required by statute to assess the potential impact of all our functions, policies, projects and practices on equality. Equality Impact Assessments (EIAs) also assist us in making sure that we are meeting our principal duty of furthering the interests of citizens and consumers regardless of their background or identity. As explained in our 2013 Consultation, we do not consider the impact of the decisions in this document to be to the detriment of any group within society.

Structure of this document

2.41 In this document we set out the full detail of the approach we are taking, and explain how we will ensure protection for the existing users of the band and what that means for those hoping to operate in white spaces.

2.42 The introduction explains what TVWS is and sets out the history of Ofcom consideration of how to allow licence exempt use within the UHF TV band. It also sets out the legal framework within which Ofcom operates.

2.43 The remainder of this document is structured as follows:

- Section 3 sets out the high level framework for operation of WSDs and its main features.
- Section 4 describes the pilot trials that have been run (or that are still running) and the lessons that have been learned from them.
- Section 5 sets out the detail relating to authorisation of WSDs.
- Section 6 provides an overview of our approach to ensuring that use of white spaces poses a low probability of harmful interference to existing users.
- Section 7 sets out the detail of the rules to ensure coexistence of WSDs with digital terrestrial broadcasting (DTT), including where we have refined the approach in response to testing.
- Section 8 sets out the detail of the rules to ensure coexistence of WSDs with PMSE users, again including where we have refined the approach following testing.
- Section 9 sets out the detail of the rules to ensure coexistence with mobile network use of the spectrum above the UHF TV band, the approach to coexistence with services below the UHF TV band and looks at coexistence with DTT in neighbouring counties.
- Section 10 looks at what the predicted availability of white spaces is under the framework set out in this document.
- Section 11 sets out the next steps towards allowing licence exempt use of the UHF TV band.
- The annexes look at the coexistence calculations in more detail and provide a summary of stakeholder responses to the 2012 and 2013 consultations and how we have addressed them.

Other documents

Alongside this Statement we are publishing, for illustrative purposes, an updated draft statutory instrument (SI), which provides an indication of how we might describe the terms and conditions of the licence exemption regulations with which White Space Devices would need to comply, as well as an updated draft Interface Requirement. The draft SI and draft Interface Requirement will be notified to the EU Commission for comment under the Technical Standards Directive (98/34/EC)[13]. Following completion of that notification process, and after taking into account any points raised by the Commission or Member States, we will publish a final draft SI for consultation prior to it coming into force.

[13] Directive 98/34/EC of the European Parliament and of the Council of 22 June 1998 laying down a procedure for the provision of information in the field of technical standards and regulations and rules on Information Society Services (OJ L 204, 21.7.1998, p.38), known as the Technical Standards Directive, sets up a procedure which imposes an obligation upon the Member States to notify to the Commission and to each other all the draft technical regulations concerning products before they are adopted in national law. Such procedure aims at providing transparency and control with regard to those regulations. See http://ec.europa.eu/enterprise/tris/about/index_en.htm.

Section 3

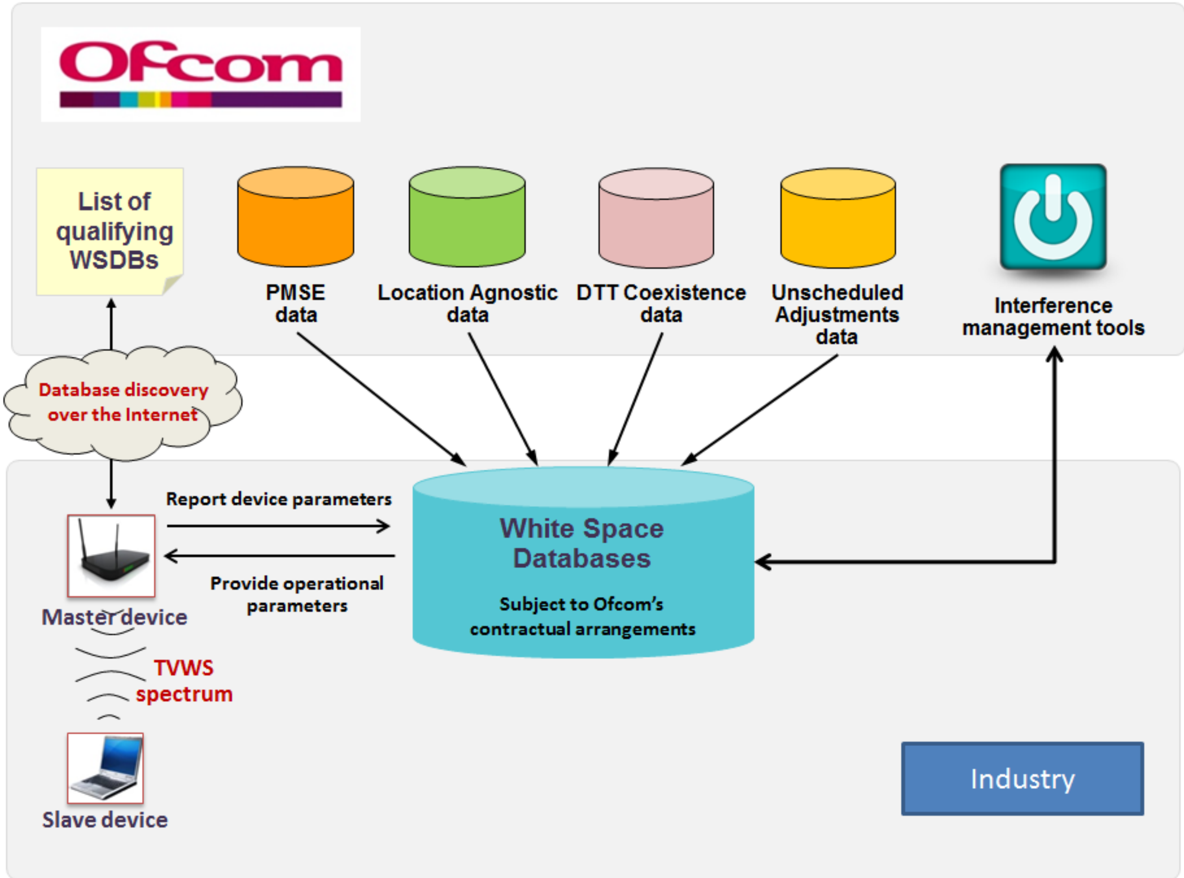
TV White Spaces framework

3.1 In this section we describe at a high level the framework for TVWS in the UK that we will be implementing. It is in line with our previous proposals and decisions in relation to authorising the use of TVWS, as summarised in Section 2.

3.2 The aim of this framework is to enable WSDs to use spectrum in the UHF TV band at a particular location and time on a shared basis subject to ensuring that there would be a low probability of harmful interference to other spectrum users in the band or adjacent to the band.

3.3 The overall approach is summarised in Figure 3.1 below:

Figure 3.1 - Framework for authorising the use of TVWS including the interactions between WSDs and white space databases (WSDBs)



High level framework components

Qualifying white space databases

3.4 WSD operation in TVWS will be controlled by WSDBs qualified by Ofcom to provide spectrum information services to WSDs. A WSD will need to contact a WSDB, which will respond to the WSD with a set of operational parameters including the frequencies and maximum powers at which the WSD can transmit. Ofcom's arrangements with WSDBs will include requirements setting out how those operational parameters should be calculated to meet Ofcom's objective of ensuring a low probability of harmful interference to existing users of the band and services adjacent to the band.

3.5 WSDBs will need to go through a process of qualification in which Ofcom tests a database to gain assurance that the database is capable of operating in accordance with the terms on which it has been appointed. Hence, a key component of the qualification process will be testing that the database is capable of implementing Ofcom's coexistence framework (see Sections 6 to 9).

3.6 In order to perform the necessary calculations that result in a set of operational parameters for a particular WSD, Ofcom will provide a WSDB with certain data. The various responsibilities and data flows are illustrated in Figure 3.1 above.

3.7 There are four data sets that Ofcom will provide to a WSDB:

i) Ofcom will generate a set of data containing the maximum allowed powers a WSD can transmit at in each 100 x 100 m pixel in the UK taking account of the need to ensure a low probability of harmful interference to DTT use of the band and also to respect our international obligations to neighbouring countries use of DTT in the band. We term this data set "DTT Coexistence data". To generate this data set we will use underlying information on the DTT network from the UK planning model;

ii) Furthermore, Ofcom will generate additional constraints that relate to taking account of PMSE use of channel 38, and the services above and below the band. The location of these existing users is not known, so the constraints will be a set of maximum powers for each channel in the band that do not change with the location of the WSD. We term this data "Location Agnostic data";

iii) Ofcom will provide the WSDB with information on licensed PMSE use in the band (other than in channel 38). We term this data "PMSE data". The WSDB will use all this data in accordance with the algorithms specified by Ofcom to calculate the maximum power a particular WSD is allowed at a particular location at a particular time;

iv) Finally, Ofcom may provide WSDBs with data we term "Unscheduled Adjustments data." This a set of revised allowed power limits that we may introduce at a particular geographical area on an ad hoc basis.

3.8 In Ofcom's arrangements with WSDBs, we will specify how a WSDB is to use this data to determine the operational parameters for a WSD. This is explained briefly below and an overview of the calculations is provided in Annex 8.

Master and slave WSDs

3.9 Under the TVWS framework we distinguish between master WSDs and slave WSDs. A master WSD is a device that is able to communicate with and obtain operational parameters directly from a WSDB, whereas a slave WSD is a device that is only able to operate in TVWS when under the control of a master WSD.

3.10 Some deployments of WSDs may only involve a master WSD, for example if a WSD is being used to broadcast content. In other deployments a master may act as a base station or an access point which controls a number of slaves in its coverage area.

Database discovery

3.11 Once a WSDB is qualified, it will be listed in the licence exemption regulations, and it will also be listed in a machine-readable version of that list on a website (https://tvws-databases.ofcom.org.uk/weblist.xml) hosted by Ofcom so that it can be selected by a WSD through a process known as "database discovery".

3.12 Under the framework, it is the master WSD that communicates with a WSDB. Such a device must only use operational parameters given to it by a WSDB that is listed in the licence exemption regulations. A master WSD will download the list of qualifying databases from the website and then select a database with which to exchange parameters as set out below. We may need to modify the list periodically, because new databases get qualified or because we remove a database operator. We would therefore expect that a master WSD would need to periodically reload the list from our website, in line with the ETSI Harmonised Standard. How frequently this should be done will be indicated in the list, and initially we would expect master WSDs to download an updated copy of the list every 24 hours.

3.13 Database discovery will not be carried out by transmissions over TV white space.

Device parameters

3.14 Once a master WSD has selected a particular database, it will report to that database its "device parameters" which identify specific characteristics of the WSD. These will include its location and other information about the device. They are explained in full in Section 5. A master WSD may also communicate to the WSDB the device parameters of any slave WSD it is controlling.

3.15 A European harmonised standard has been developed for the operation of WSDs, including the nature of the data exchanged between WSDs and WSDBs (EN 301 598[14]) (the "ETSI Harmonised Standard"). Under our TVWS framework, automatically configured WSDs will be exempt from licensing. Our WSD authorisation regime is compatible with that harmonised standard and equipment complying with that standard will also comply with our regime. However, as the harmonised standard is voluntary, we have set out the minimum characteristics required for equipment to operate under our framework. The detailed device requirements are set out in Section 5.

Operational parameters

3.16 WSDBs will use device parameters together with information provided to them by Ofcom, to determine, following the coexistence rules set by Ofcom, what frequencies are available for that particular device and at what powers it is able to transmit in those frequencies. This information is known as the "operational parameters" and will be communicated to the device. These operational parameters will only be valid for a short period of time so the device will have to query the database on a regular basis in order to ensure that it can transmit in accordance with valid operational

[14] ETSI EN 301 598 V1.1.1 (2014-02), OJ C 406, 14.11.2014, p.1.

parameters. We explain the different types of operational parameters in more detail below.

Channel usage parameters

3.17 Once a WSD has received operational parameters, it may have a choice of channels and if that is the case it will decide which specific channels and power levels it wants to use. It will then report this information back to the WSDB, which will make it available to Ofcom for spectrum management and interference management purposes.

Exchange of parameters between WSDs and WSDBs

3.18 The exchange of parameters between WSDs and WSDBs could be as follows:

- Once a master WSD establishes a communications link with a qualifying WSDB it will communicate its device parameters to that database. The WSDB will then be able to calculate the operational parameters the master WSD may use. This set of operational parameters will include a number of channels and the maximum power allowed in each channel. The master WSD will select the channels and powers to use, and subsequently report this to the WSDB as the channel usage parameters.

- If a master WSD is part of a network comprising slave WSDs, it will now be able to obtain operational parameters for its slaves as follows. First, the master WSD will request generic operational parameters from the WSDB. These are the channels and powers that a generic slave device within the coverage area of the master can use without causing harmful interference to existing users. Generic operational parameters are quite restrictive, as they are calculated making cautious assumptions about the slave devices. For instance, the master WSD will assume that the slave WSD could be anywhere in the coverage area of the master. The WSDB will estimate the coverage area of the master, and then calculate the generic operational parameters.

- Second, the master WSD will broadcast generic operational parameters. Slave WSDs must listen to the master's broadcast before transmitting and decode the generic operational parameter information. They will use it for their initial transmissions to the master, to report their unique device identifier and possibly other device parameters.

- The slave WSDs could continue using the generic operational parameters for user data transmissions, or could provide the master with additional information about themselves, location in particular, that would grant them better operational parameters. The master would then relay this information to the WSDB, which would calculate operational parameters specific for a particular slave (we refer to these as 'specific operational parameters'). These specific operational parameters are likely to be less restrictive than generic operational parameters.

- Regardless of whether the slave WSD operates according to generic or specific operational parameters, the master WSD serving it will also have to report the slave WSD's channel usage parameters to the qualifying WSDB from which it has obtained operational parameters.

Interference management

3.19 While we believe that the coexistence rules we are putting in place are sufficiently conservative to ensure a low probability of harmful interference, our implementation of the framework will also include a number of tools and processes to enable us to manage any interference that does occur. In developing these we have learnt a number of lessons from the Pilot. We explain briefly below some key elements.

White Space Devices Information System

3.20 WSDBs will make available to Ofcom an information system, referred to as the "White Space Devices Information System" (WSDIS), that provides information for the purposes of carrying out an initial triage of interference cases. This information includes the frequencies and powers used by WSDs in a particular location and at a particular time.

3.21 WSDIS will allow Ofcom to identify WSDs potentially causing interference and act accordingly. WSDBs will have to make this facility available at all times. In the event that the WSDIS is unavailable, for example due to technical issues, WSDBs will be contactable by other means.

Requirements to cease transmissions

3.22 Ofcom will be able to instruct WSDBs to require a particular WSD to cease transmission. As Ofcom will not have a direct connection with WSDs, it will instead inform WSDBs that a particular WSD must be switched off for a period of time, potentially indefinitely, and the serving WSDB will send a message to that WSD to that effect.

Adjustments to the maximum power at which WSDs can operate

3.23 As explained above, one of the data sets Ofcom will be able provide to a WSDB is essentially a set of new maximum power limits for a particular location and channels. This is another tool that may be useful in dealing with any interference issues we identify. For example, it could be used to implement changes required in a particular area if Ofcom has obtained information on which transmitters viewers are actually using for their DTT reception and this diverges significantly from that assumed in the UKPM data (see Section 7 for details of Ofcom approach to identifying which DTT transmitters to take into account in its approach to DTT coexistence).

Requirements to cease providing WSDB services

3.24 Ofcom will be able to instruct a WSDB to cease providing some or all WSDB services (for example, providing operational parameters) for a specified period of time to any WSDs that request them.

3.25 If necessary, for example in response to repeated breaches by a WSDB, Ofcom will be able to remove this WSDB from the list of qualifying WSDBs.

Future developments of the framework

3.26 We set out in Section 11 our Next Steps for taking forward the implementation of the framework. Below we identify two features of the framework which we believe may need to change in the future depending on the level of deployment of WSDs.

Balance of responsibilities between Ofcom and WSDBs

3.27 As explained above, the implementation of the framework will split the responsibility for carrying out the calculations necessary to determine a WSD's operational parameters between Ofcom and the WSDBs. In the future we may revisit the balance of responsibilities and reduce Ofcom's role relative to that of WSDBs. For example, WSDBs could calculate DTT Coexistence data themselves.

Exchange of information between WSDBs

3.28 Under the framework described above, WSDBs will operate independently of each other. For example, each database will not be aware of the devices another database has served. In the future, if there is extensive deployment of WSDs, it may become desirable for the provision of WSDB services to have information about other WSDBs' operations.

3.29 One way to achieve this would be for WSDBs to exchange some information on the operational parameter requests they have served from WSDs. There are different ways this could be implemented. For example, all data could flow to Ofcom and then out to each WSDB in some aggregated form. Alternatively, information could flow directly between WSDBs.

3.30 If the density of WSDs reached significant levels, such exchange of information between WSDBs could have other benefits for Ofcom, such as facilitating the adoption of new coexistence rules to deal with any potential risk of interference created by a large number of devices in a small area or improving Ofcom's interference management capabilities. However, we recognise that there may be a number of practical and legal challenges to introducing such arrangements that would need to be addressed.

Section 4

Pilot

Introduction

4.1 The TVWS conceptual framework designed by Ofcom in consultation with industry represents a first step towards authorising dynamic spectrum access in the UK. In view of the innovative nature of the proposed framework, and the specific coexistence challenges in the UK's TV band, Ofcom proposed in April 2013 to undertake a TVWS pilot.

4.2 The contents of this section are as follows:

- Pilot objectives and timeline (paras 4.3 to 4.7);
- White Space Database contracting and qualification – a description of the contracting and qualification process used for WSDBs during the pilot (paras 4.8 to 4.18);
- White Space trials - a description of the trials which have taken place as part of the pilot (paras 4.19 to 4.36);
- Framework testing – a description of the testing programme carried out by Ofcom, and results of this testing (paras 4.37 to 4.47);
- Pilot findings – a discussion of the findings from the pilot to date and the implications for the full solution framework (paras 4.48 to 4.76);
- Summary of key implications of pilot for implementation of the TVWS framework (paras 4.77 to 4.82).

Pilot objectives

4.3 Ofcom's objectives for the pilot were:

- to provide a proof of concept, i.e. to understand whether the proposed framework for implementing dynamic spectrum sharing using geolocation databases could be made to work in practice;
- to undertake coexistence testing and provide new evidence on how to ensure a low probability of harmful interference to DTT and PMSE; and
- to allow industry to trial a range of potential use cases.

4.4 We assess how well these objectives were achieved in the pilot findings discussion at the end of this section.

Pilot timeline

4.5 In April 2013, Ofcom held a stakeholder event to discuss next steps with TV White Spaces[15]. At the event, initial proposals were presented to run a pilot of the UK framework for access to TVWS in the UK. Stakeholders were invited to respond with expressions of interest if they wished to participate in the pilot. A follow up stakeholder event was then held on 25 July 2013[16] to provide stakeholders with an update on pilot developments.

4.6 Forty expressions of interest were received after the first stakeholder event. Following preparatory work, the pilot commenced on 9 December 2013 with the signing of the first database contract.

4.7 The pilot has had four main parts:

i) **White Space Database contracting and qualification**. This commenced in December 2013 when the first contracts with databases were signed, with qualification commencing in January 2014. The first database qualified in May 2014. To date eight WSDBs have been qualified for the purposes of the pilot, with the final WSDB being qualified in October 2014. The window for new WSDB applications closed at the end of August 2014;

ii) **White Space Trials**. The first trial was licensed in June 2014 and eleven trials have been licensed to date. The window for new trial applications closed at the end of August 2014. Trials are expected to continue until later in 2015 with some trials potentially continuing until the introduction of commercial operation;

iii) **Framework testing**. Framework testing commenced in July 2014 and completed in November 2014;

iv) **Coexistence testing**. A comprehensive testing programme led by Ofcom with the support of stakeholders from January to December 2014. We do not discuss this in detail in this section; further details are provided in Section 6 and in the test reports published in November and December 2014[17][18].

White Space Databases contracting and qualification

4.8 The pilot has given Ofcom the opportunity to test the viability of third party databases as a spectrum management tool in a controlled scenario on a temporary basis. Our approach for WSDBs has involved Ofcom entering into contractual arrangements with database providers, who have demonstrated that their databases meet certain requirements and are able to provide the operational parameters to the individual WSDs.

WSDB provider contract

4.9 Ofcom does not have specific powers to appoint or license spectrum management database operators. The solution that we have put in place for the pilot and that we

[15] http://stakeholders.ofcom.org.uk/binaries/spectrum/whitespaces/Pilot_Slides.pdf
[16] http://stakeholders.ofcom.org.uk/spectrum/tv-white-spaces/white-spaces-pilot/25July2013/
[17] http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2014/tvws-pmse-coexistence
[18] http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2014/tvws-coexistence-tests/

envisage carrying forward for the operational solution is a contract between Ofcom and each of the organisations that set up databases (WSDB providers).

4.10 The WSDB contract used for the pilot included provisions covering, inter alia, the specification of the calculations which the WSDBs must carry out in order to provide the relevant parameters to WSDs, requirements regarding organisational and operational capabilities, and requirements in support of Ofcom's interference management duties.

Qualification of Pilot Databases

4.11 Following some pre-contract checks and signature of contracts by WSDB providers, each WSDB needed to go through a qualification process before commencing operation and supporting trials.

4.12 The objective of qualification was to get to a position where the WSDB provider demonstrated to Ofcom's reasonable satisfaction that their WSDB met the requirements of the contract. Ofcom and each of the WSDB providers worked together to address and where possible resolve issues where the WSDB was not initially meeting the requirements.

4.13 As the requirements in the contract were quite varied and a single qualification method would not suit them all, we adopted three types of approaches:

4.14 **Self-declaration:** the WSDB provider declared compliance with the requirements and provided relevant supporting information. This approach was used to verify the contract requirements such as security in the communications between the WSDB and WSDs, record keeping and auditing, and data protection.

4.15 **Off-line tests:** We used these tests to verify that a database carried out the calculations to determine the operational parameters (frequencies and powers) that should be given to a WSD in particular situations according to the specification in the contract. The WSDB provider was required to run a series of test cases and submit the results to Ofcom. Ofcom then checked the results against its reference results. The tests covered all elements of the calculations.

4.16 **Simulated tests:** We used these tests to verify that a database could receive and correctly incorporate PMSE data and unscheduled adjustments data (i.e. data requiring a database to change the allowed powers in a particular area), and also to check the database could provide Ofcom with an interface through which we could query the WSDB for operational parameters.

4.17 Only once the database had successfully demonstrated complete accuracy in the offline and simulated tests did Ofcom make a decision to qualify the candidate provider.

4.18 In total eight databases achieved qualification as shown in Table 4.1:

Table 4.1 - WSDBs qualified in the pilot

Database provider	Date qualified
Spectrum Bridge	21 May 2014
Nominet	10 June 2014
NICT	10 June 2014
Fairspectrum	10 June 2014
Google	21 August 2014
Sony	8 September 2014
iconectiv	8 October 2014
Microsoft	23 October 2014

White Space Trials

4.19 The second part of the pilot involved the licensing of a number of white space trials. The trials were set up to enable interested parties to trial WSDs in partnership with a qualified WSDB. This afforded both triallists and WSDBs an opportunity to field test the interoperability of WSDBs and WSDs outside of a laboratory environment. Triallists were also able to test their preferred use cases and test the technical capability and operational potential of their chosen supplier's WSDs.

4.20 On Ofcom's side, the trials provided an opportunity to test the proposed pilot framework and to better understand stakeholder interest in white space technology.

4.21 In total 22 licence applications were received covering a range of applications, including public Wi-Fi, webcam backhaul, rural and maritime broadband services, remote sensing, academic research, digital signage, local broadcasting and CCTV distribution. Further details of the use types investigated in trials are provided later in this section. Eleven trials have been licensed to date, with the first licence issued on 18 June 2014. A small number of the other trials may commence in the next few months. The remaining trial applicants ultimately decided not to proceed with their trials.

Trial licensing and risk assessments

4.22 As set out in Section 5, it has been envisaged for some time that WSDs using TVWS should be licence exempt, but the exemption regulations are not yet in place. Trials therefore needed to be licensed in order to operate.

4.23 The licence used for the pilot was based on Ofcom's existing Non-Operational temporary use licence but adapted for the pilot, in particular to include the requirement to comply with the ETSI standard or an equivalent standard notified by Ofcom.

4.24 The pilot licensing arrangements also allowed Ofcom the ability to offer some additional flexibility to triallists to operate in a way which does not strictly conform to the envisaged framework while still limiting the risk of harmful interference. This was helpful for two reasons.

4.25 First, most of the devices used in the trials were originally designed to operate according to the US framework which is somewhat different to the pilot framework. As such, the trials provided a first opportunity for triallists and device manufacturers to test, outside of the lab, the modifications they have made to devices to bring them in line with the UK framework. Most of the devices being used are not yet fully compliant with the ETSI standard (ETSI EN 301 598[19]).

4.26 Second, the coexistence parameters used in the pilot were based on our consultation proposals and had not been fully tested. As such it was judged that there would be an increased risk of interference during pilot operation compared to that envisaged under the proposed licence exempt regime.

4.27 As part of the trial licence application process, Ofcom carried out an additional risk assessment for each trial to look at potential interference to nearby DTT and PMSE users.

4.28 For DTT, we sent postcards to households within a radius of planned master and slave WSD deployments, providing them with a number to call in the event that they experienced interference to their TV reception. We also notified details of potentially affected postcode areas to the organisations which take calls in relation to DTT interference, e.g. Digital UK and the BBC, to provide the best chance that potential white space related interference would be identified.

4.29 For PMSE, we identified PMSE users within a radius of planned master and slave device deployments for each trial and, where necessary, blocked triallist access to channels which were being used by potentially affected PMSE users.

4.30 No interference has been reported to date during any of the trials.

Interference management for the pilot

4.31 The pilot framework includes provisions to ensure that appropriate action can be taken in the event that interference is caused to existing users of the band.

4.32 Ofcom has a Spectrum Management Centre (SMC) team based at Baldock Radio Station in Hertfordshire which is set up to take calls about interference and undertake triage of potential white space interference cases. WSDBs are required to provide contact details to the SMC so that they can contact WSDBs quickly if interference is reported.

4.33 One of the key tools in the pilot framework is the White Space Devices Information Systems (WSDIS) provided by WSDBs. Each WSDB is required to provide a WSDIS. If a report of interference is received with WSDs identified as a possible cause, the SMC can query the WSDIS to ask for details of any WSD(s) being used in the same geographic area as the reported interference. If the report of interference is verified by SMC as being from WSDs, they can use the relevant WSDIS to instruct the active WSDs causing the interference to cease transmission for a specified period of time.

4.34 There have been no reported cases of interference in the pilot to date and so we have not had to use the WSDIS and interference management procedures in a live situation. However as explained further below we have run a number of tests of the

[19] http://www.etsi.org/deliver/etsi_en/301500_301599/301598/01.01.01_60/en_301598v010101p.pdf

pilot tools and procedures so we can work out what is required to have an effective interference management regime for the full solution.

Triallists, databases and device partners

4.35 Figure 4.1 shows the location of licensed trials in the UK. Table 4.2 lists the trials and provides information on the triallists, devices used, WSDB partners and use cases for each of the trials.

Figure 4.1 - White space trials

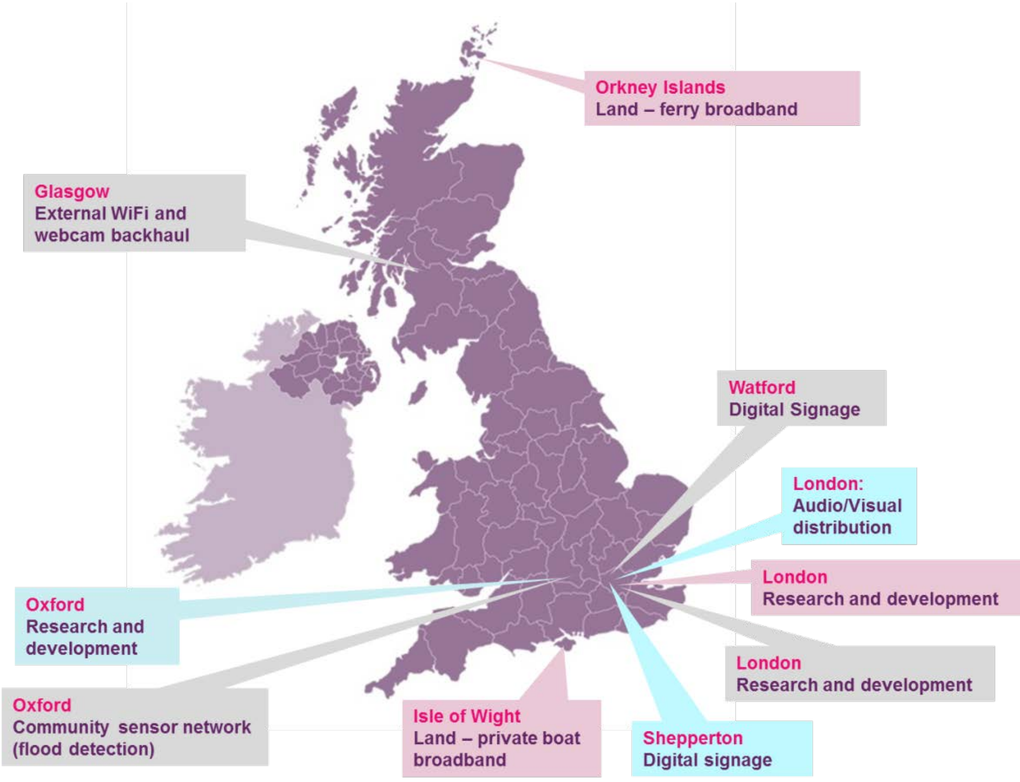


Table 4.2 - White Space trials

Service Provider	Database	Devices	Trial location	Trial application
Centre for White Space Communications, University of Strathclyde	Spectrum Bridge	6 Harmonics	Glasgow	External WiFi and webcam backhaul
Click4Internet	N/A	Neul/6 Harmonics	Isle of Wight	Land↔ private boat broadband
Cloudnet Solutions	Fairspectrum	Carlson wireless	Orkney Islands	Land ↔ferry broadband
CYP (UK) Ltd	Spectrum Bridge	MELD technologies	Shepperton	Digital signage
Google / ZSL London Zoo	Google	Mediatek/6 Harmonics	London Zoo	Live video feeds of animal enclosures
Kings College (as a collaboration with the Joint Research Centre of the EC and Eurecom)	Fairspectrum / Spectrum Bridge	Sinecom/KTS wireless, Carlson wireless, Eurecom, Runcom, Interdigital, NICT	London and others	Research and development
Love Hz Ltd and Nominet Ltd	Nominet	Adaptrum	Oxford	Community sensor network (flood detection)
National Institute of Information and Communications Technology (NICT)	NICT	NICT	London	Research and development.
Nominet	Nominet	Eurecom	Oxford & KCL Strand	Research and development
Peerless AV	Spectrum Bridge	MELD technologies	Watford	Digital signage

4.36 There was one additional trial which took place, details of which the licensee has requested be kept confidential.

Framework testing

4.37 The third part of the pilot involved the testing of Ofcom's TVWS pilot framework to test that it is fit for purpose and to understand what revisions might be necessary or desirable for the full solution framework.

4.38 Framework testing had two parts:

i) Business process testing; and

ii) End-to-end testing

Business process testing

4.39 Business process testing focused on the mechanisms and processes Ofcom used to communicate with WSDBs during the pilot. The objective of the testing was to verify that these mechanisms and processes were fit for purpose, and to understand whether any amendments or improvements to processes may be necessary or desirable for the operational solution.

4.40 The business process tests covered four areas as follows:

i) Transfer of data from Ofcom to WSDBs. This included transfer of DTT and PMSE datasets, including scheduled and unscheduled updates to these datasets;

ii) Contract change management. This covered sending contract change notes to WSDBs in the manner specified in pilot contracts, and WSDBs making the required changes within an agreed time period;

iii) Listing WSDBs on the discoverable list of qualifying databases on Ofcom's website;

iv) Interference management procedures, including:

- communicating with WSDBs using agreed protocols;
- verifying that the WSDB's WSDIS accurately reports devices;
- verifying that the WSDB's interface with Ofcom, to command a WSD to stop transmissions, works;
- verifying that the WSDB contacts the WSD and the WSD stops transmissions within a specified time period.

4.41 Evaluation under areas (i) to (iii) were carried out with all qualifying WSDBs shortly after each was qualified and before the WSDB started supporting a trial. Evaluation under area (iv) related to interactions with WSDBs during trial operation and was only carried out with a subset of WSDBs that supported trials.

4.42 High level findings from the tests are summarised in the pilot findings subsection at the end of this section.

End-to-end (E2E) testing

4.43 E2E testing covered testing of WSDs and WSDBs during live trial operation and assessing compliance against the framework.

4.44 The objective was to visit a range of different trial types where different combinations of WSDBs and WSDs were in use. This enabled us to gain a broad overview of the compliance of WSDBs and WSDs with the pilot framework, and identify areas where adjustments to the framework might be considered.

4.45 Testing was carried out with six trials as shown below. The table shows only the WSDBs and WSD types that were tested at each trial:

Table 4.3 - Trials where E2E testing was conducted

Service Provider	Database	Devices	Trial location
Centre for White Space Communications	Spectrum Bridge	6 Harmonics	Glasgow
NICT	NICT	NICT	London
Kings College (ACROPOLIS)	Fairspectrum	Carlson wireless, Eurecom	London and others
BBG Limited	Spectrum Bridge	MELD technologies	Watford
Google London Zoo	Google	Mediatek/6 Harmonics	London Zoo
Love Hz Ltd and Nominet Ltd	Nominet	Adaptrum	Oxford

4.46 The tests included verification of the following elements:

- at switch on, the master WSD contacts Ofcom and obtains the list of WSDBs;
- the master WSD contacts the WSDB, obtains parameters and operates according to the parameters;
- the slave WSD contacts the master WSD, obtains parameters and operates according to the parameters;
- the master and slave WSD renew the parameters when the time validity expires.

4.47 High level findings from the tests are included in the pilot findings discussion below.

Pilot findings

4.48 In this subsection we describe the key findings from the pilot regarding the implementation of the TVWS framework and comment on the key lessons we believe have been learnt. These are described at a relatively high level; the practical detail of many of the points raised are being taken forward in discussions with WSDB providers as part of preparations for the revised database contract for the full solution.

4.49 The first part of this subsection discusses issues relating to WSDB contracting, qualification and ongoing operation of WSDBs. The second part discusses trial operation of WSDs, and interactions between WSDs and WSDBs.

WSDB contracting and qualification

4.50 Eight WSDBs have been qualified for the purposes of the pilot, with each WSDB investing considerable time, resources and energy to achieve database qualification and support trials. WSDBs have engaged constructively and actively with us in taking forward the pilot, working with triallists and device manufacturers to overcome technical issues and obstacles to progress and in some cases conducting trials themselves. They have also provided feedback to us on various elements of the TVWS framework, suggesting areas for change and ideas for improvement.

4.51 The continued level of interest and engagement of multiple WSDBs in the pilot and ongoing discussions gives us a solid basis on which to continue work towards implementing an operational framework for TVWS in the UK.

4.52 In the following paragraphs we discuss some of the areas of the framework relating to WSDB operation, and related findings from the pilot.

Database contracting

4.53 We consider that the database contract used for the pilot has provided us with a workable basis for WSDB operation. We intend to follow a similar process to that used in the pilot for contracting with and qualifying databases for the operational implementation of the TVWS framework.

4.54 Overall, we consider that the pilot contract has worked successfully and we expect that the database contract for the purposes of the operational implementation of the TVWS framework will be broadly similar to the pilot contract, although we will need to develop and amend certain aspects further.

4.55 We will issue a draft WSDB contract to databases interested in signing contracts to allow commercial operation in due course.

Database qualification

4.56 As noted earlier in this section, qualification for the pilot comprised three parts: self-declaration, offline testing and simulated tests. All three parts proved to be useful and important in providing assurance that WSDBs were able to operate in accordance with the contract and we intend to retain them for the full solution, with some minor additions and refinements made based on learnings from the pilot.

4.57 We have obtained feedback on the qualification process from most of the WSDBs involved in the pilot. In preparation for the operational solution qualification we propose to hold further workshops with WSDBs to discuss our revised qualification proposals.

4.58 Some of the areas where we currently expect to make refinements include the following:

4.59 *Self-declaration* - we intend to provide more guidance to WSDBs regarding what is expected in responses to self-declaration questions and reduce its scope.

4.60 *Offline testing* - we intend to include more comprehensive tests of the intermediate calculations in the qualification for the full solution.

4.61 *Simulated tests* – we are considering including some additional tests. The tests could include:

- More extensive testing of data transfers, and instructions to adjust powers, using the systems put in place for the full solution ;
- WSDIS tests to confirm that each WSDB’s WSDIS functions correctly;
- Cease transmissions / operation tests.

Trial operation

4.62 Eleven trials have been conducted to date and some of these are ongoing. Trials have covered a wide range of WSDBs, WSD types and applications. Some triallists have expressed interest in continuing white space trials for research purposes and others have shown interest in commercial operational use of white spaces.

4.63 In the following paragraphs we discuss findings from the pilot in relation to WSD trial operation.

Transfer of data from Ofcom to WSDBs

4.64 The data transfer mechanisms used for the pilot were interim mechanisms designed to allow the pilot to be up and running quickly and are less suitable for operational use. For the operational solution it is our intention to implement a system that will allow automatic transfer of data and notification of updates using a web-based system. WSDBs will need to implement systems that allow them to accept and process transfers of data from Ofcom in a uniform way using agreed protocols and to agreed timescales.

Geolocation of devices

4.65 During the E2E testing, we did not observe any instances where master devices were able to geolocate successfully. Some devices had geolocation capability but were still unable to geolocate, either due to the indoor location of the trial or due to environmental factors. In all trials attended for E2E testing, coordinates had to be manually inputted into devices to allow them to work.

4.66 As explained further in Section 5, under the terms of our proposed licence exemption, manually configured devices will not be permitted. Shortly after the publication of this Statement, we will publish a consultation on the introduction of licensing arrangements for manually configured devices. Under these proposals, devices that can not geolocate would need a licence in order to operate.

Exchange of parameters between WSDs and WSDBs

4.67 The requirements for exchange of parameters between WSDBs and WSDs are described in Section 5 of this document. In the pilot, we tested the compliance of trial operations with these requirements during E2E testing.

4.68 Our testing demonstrated that, in the main, requirements in this area were implemented correctly and worked as expected during trial operation. For example, at most trials where we undertook E2E testing, we were able to confirm that master devices communicated their device parameters to the relevant WSDB, obtained operational parameters for their own transmissions and transmitted according to those parameters.

4.69 One area that needs further work relates to the exchange of generic operational parameters for the purposes of association between master and slave devices and we discuss this in more detail below.

Generic Operational Parameters (GOPs)

4.70 Under the pilot framework slave devices may only use generic operational parameters (GOPs) for transmissions until they have gone through the necessary data exchange steps with the master device and the WSDB and obtained specific operational parameters.

4.71 Some WSDs used in the trial had not yet been configured to use the full framework rules for exchange of parameters. Other triallists reported that their slave devices were configured to enable use of GOPs but that the GOPs were too restrictive to allow the slave device to communicate with the master. In the trials where GOPs were not used, triallists were able to implement workarounds, e.g. by inputting pre-calculated specific operational parameters (SOPs) into slave devices.

4.72 We considered this feedback from trials alongside our review of responses to the 2013 Coexistence consultation in deciding on the rules for GOPs as set out in Annex 8 of this Statement.

4.73 We recognise that GOPs will still be quite restrictive in some cases and we intend to continue to work with industry to improve this part of the framework; the Next Steps section later in this document provides further details.

<u>Interference management</u>

4.74 To date there have been no confirmed cases of interference reported as a result of TVWS trial operation. As such, the systems we put in place for interference management during the trials have not been tested with live issues. However, we carried out testing of the pilot systems and processes in our business process testing. We identified two areas where we intend to make changes in the operational solution.

4.75 During the pilot, WSDBs each implemented a WSDIS. This meant that, if interference had occurred, the interference management team at Ofcom (SMC) would have needed to carry out multiple queries across multiple systems. This would have taken considerable time and makes triage of possible WSD interference complicated to achieve. We are working with WSDBs to discuss ways to simplify this for the operational solution.

4.76 A second issue related to the functionality and reliability of the “cease transmissions” command provided in WSDIS. In testing, there was limited success in being able to switch off WSDs using this command. The reliability of this command needs to be improved in the operational solution. We intend to include additional tests as part of database qualification to test WSDIS functionality and the cease transmissions command. In addition, we are considering undertaking some early operational testing after a WSDB has qualified and once it is supporting live WSDs.

Summary of key implications of pilot for implementation of the TVWS framework

4.77 The pilot has provided a useful body of evidence which informs the preparations for implementation of a framework for operational use of white spaces in the UK. It has helped to confirm our understanding that there is considerable industry interest from a number of organisations in using TVWS to provide a variety of applications and services. It has also identified the areas of the framework that worked well and the areas that need to be adjusted or need further work. Although a number of the pilot trials are still underway we are satisfied that we have been able to sufficiently test the operation of the proposed regulatory framework to be confident that the decisions set out in this document will work effectively.

4.78 In relation to the pilot objectives, our first objective was to provide a proof of concept for white spaces and spectrum sharing more generally. Our conclusion is that the framework can be made to work satisfactorily. In the pilot not all elements of the framework worked correctly in all trials. However, this reflects the fact that white space technology is not yet mature, with many devices still prototype and in development. Also, the majority of devices are not yet compliant with the ETSI standard. In particular further work is required on the implementation of generic operational parameters and the implementation of the “cease transmissions” command.

4.79 The second objective was to undertake coexistence testing and provide new evidence on how to ensure a low probability of harmful interference to DTT and PMSE. Ofcom undertook a comprehensive coexistence testing programme as part of the pilot and Sections 7 and 8 explain how we have used that evidence in our decisions on coexistence.

4.80 The third objective was to allow industry to trial a range of potential use cases. Triallists in the pilot demonstrated a wide range of uses including Wi-Fi, webcam backhaul, CCTV monitoring, remote sensor monitoring, M2M (machine to machine communications), marine and rural broadband and digital signage.

4.81 Some of the key areas where we currently expect to make changes or undertake further work as result of our review of the pilot are summarised below:

- **Database qualification -** database qualification will remain largely the same for the full solution but with reduced use of self-declaration and more testing of requirements. We expect this testing will be expanded so that it includes virtual or actual devices.

- **Database early operation testing -** to complement additional simulated tests during database qualification, we are considering undertaking some early operation testing after databases have qualified and once databases are supporting live devices. Tests would be conducted remotely and would check that interference management tools and processes worked correctly for live devices.

- **Compliance testing -** evidence from the pilot is that existing devices have limited capability to implement the entire framework. In addition to the changes to qualification and database early operation testing outlined above, we are considering undertaking some compliance testing of the framework. During the first year or so of operation, we would visit some networks and undertake testing. The testing would be similar to the end to end testing that took place in the pilot. This testing would have two purposes: first, to check that framework rules are being followed and second, to generate more evidence to help us improve the framework in the future.

- **Manual configuration of devices -** devices used in all trials involved in the pilot required some manual configuration in order to operate, including input of geographic coordinates and input of specific operational parameters. This will not be permitted under the terms of the draft licence exemption, which is being published alongside this Statement. Shortly after the publication of this Statement, we will be publishing a consultation on the introduction of licensing arrangements for manually configured devices.

- **Generic operational parameters -** we intend to work with WSDBs and other interested parties to discuss potential methods to improve the situation with GOPs and ensure that initial master-slave association can be accomplished successfully in a good number of realistic usage scenarios.

4.82 Moving forward, we intend to work closely with WSDBs and other interested parties to define the detail of the arrangements needed for the operational solution, including a revised database contract. More details of our proposed next steps are set out in Section 11.

Section 5

Device authorisation

5.1 We explain in Section 2 that we have been considering access to TVWS under a licence exemption regime since 2007. In the 2012 Consultation we consulted on proposals as to the technical and operational requirements[20] which we considered should be put in place in order to allow the operation of WSDs on a licence exempt basis. As part of that consultation, we published an example statutory instrument (SI), a draft interface requirement and a draft voluntary national standard (VNS)[21].

5.2 In this section we explain why we consider it appropriate to authorise use of WSDs on a licence exempt basis and set out our updated conclusions on the operational and technical requirements which we consider are necessary in order to ensure that WSDs will operate without causing harmful interference to other users of the UHF TV band. These requirements will be implemented through Ofcom making licence exemption regulations. We explain the process for this in Section 11.

5.3 In light of stakeholder comments and the development of the ETSI Harmonised Standard (EN 301 598)[22], we have made a number of changes to our proposals, which we summarise below. We set out in Annex 11 a more detailed summary of stakeholder representations and Ofcom's position on the issues raised.

5.4 For illustrative purposes, we are also publishing, alongside this document, an updated draft statutory instrument (SI), which provides an indication of how we might describe the terms and conditions of the licence exemption regulations, as well as an updated draft Interface Requirement.

Licence Exemption

5.5 We remain of the view that it is appropriate to authorise the use of WSDs in the UHF TV band through licence exemption and we are working towards that outcome. This is for the following reasons:

- Use of devices on a licence exempt basis would not be likely to lead to harmful interference to other spectrum users or have an adverse impact on technical quality of service, provided that devices:
  - o operate under the control of a geolocation database qualified by Ofcom; and
  - o comply with a set of technical and operational requirements that we consider are necessary to avoid harmful interference.
- Generally, licence exemption entails the least regulatory and administrative burden compared to other forms of authorisation, such as individual licences. There may be a wide variety of use cases for White Space technology. Some of the applications for TVWS that have been proposed by industry could potentially

[20] http://stakeholders.ofcom.org.uk/consultations/whitespaces/
[21] The VNS was intended to provide guidance to manufacturers (in the absence of European harmonised standards) on suitable tests for WSD manufacturers to demonstrate compliance with the requirements of the R&TTE Directive. However, as explained below, this has been superseded by the ETSI Harmonised Standard.
[22] http://www.etsi.org/deliver/etsi_en/301500_301599/301598/01.01.01_60/en_301598v010101p.pdf. This was published in April 2014 and was cited in the Official Journal of the EU in September 2014.

lead to mass market consumer use of devices and/or deployments of a very large number of devices (for example for machine to machine applications). We consider that authorisation on a licence exempt basis would be likely to remove barriers to access to the spectrum, foster innovation and competition in the development of WSDs, and thereby result in benefits to consumers.

5.6 Although we plan to put in place a regime of licence exemption, we are aware from the pilot that the devices currently available would not meet all of the technical and operational requirements that we consider necessary for licence exempt operation. In particular we have seen that devices require manual configuration (i.e. their device parameters would need to be manually inputted). This may be because these devices are prototypes, or because they are intended for professional use and not for a consumer market. We remain of the view that it would not be appropriate to authorise manually configured devices on a licence exempt basis (as discussed at paragraphs 5.28 to 5.30 below), but we are considering whether it may be appropriate to authorise this type of device on a licensed basis. We intend to set out our proposals in this regard in a separate consultation, which we plan to publish shortly after the publication of this Statement.

Device requirements for operation under licence exemption

5.7 Devices will need to comply with minimum technical and operational requirements that we consider necessary to mitigate the risk of harmful interference under a licence exemption regime. These requirements will be captured in the Statutory Instrument (SI) for licence exemption, and an Interface Requirement (IR) document. Devices will need to comply with these requirements in order benefit from an exemption from the requirement for a licence under the WT Act.

5.8 This section describes briefly these requirements, as well as explaining the changes we have made to our proposals since the 2012 Consultation.

5.9 As noted above, following the 2012 Consultation, an ETSI Harmonised Standard for White Space Devices has now been developed[23] and it is no longer necessary to put in place a VNS as suggested in our 2012 proposals. We therefore do not discuss further any of the requirements set out in the draft Voluntary National Specification (VNS). We note that devices that meet the requirements of the ETSI Harmonised Standard benefit from a presumption of conformity with the essential requirements of the R&TTE Directive[24]. For the purposes of our TVWS framework, we consider that compliance with the requirements in the ETSI Harmonised Standard is one way of ensuring compliance with the regulatory requirements for licence exempt authorisation of WSDs set out below. In practice, we would expect that the majority of devices would meet the ETSI Harmonised Standard or would otherwise follow similar standards that ensure compliance with the essential requirements of the R&TTE Directive.

[23] During 2013 and 2014 we were involved through ETSI in developing the ETSI standard. The standard making process in ETSI is contribution driven, so any UK stakeholder with an interest in the device requirements had an opportunity to contribute. As part of this process, we discussed the proposals we had developed for the purposes of the draft VNS and many of the requirements under the ETSI Harmonised Standard are similar to those outlined in the draft VNS, although there are a certain number of differences and refinements to the processes and requirements originally envisaged in the draft VNS.

[24] This Directive establishes the regulatory framework for the placing of radio equipment on the market within the EU. It is implemented in the UK by the by the Radio Equipment and Telecommunications Terminal Equipment Regulations 2000 (SI 2000/730). However, meeting the requirements of the ETSI Harmonised Standard is not the only route to demonstrating compliance with the essential requirements under the R&TTE Directive, and manufacturers can choose to demonstrate compliance by other means.

Data exchange with a WSDB and compliance with parameters

5.10 In line with our proposals in the 2012 Consultation, we intend to specify a set of requirements relating to the exchange of certain information between WSDs and databases. These requirements are intended to ensure that devices communicate to a database the information necessary in order for a database to be able to calculate the frequencies and powers at which a WSD may transmit so as to avoid harmful interference to other spectrum users and to ensure that the database obtains from devices the information necessary for interference management purposes. At a very high level these requirements can be summarised as follows:

- A master WSD shall only transmit in accordance with parameters that it has received from a WSDB that has been qualified by Ofcom (we refer to these as 'operational parameters').
- A slave WSD shall only transmit in accordance with parameters that it has received from a master WSD, which may be 'generic operational parameters' (i.e. operational parameters that can be used by all slave devices operating in the master WSD's coverage area) or 'specific operational parameters (i.e. parameters that are specific to the slave device's characteristics).
- A master WSD or a slave WSD that requires specific operational parameters from a WSDB must report certain specific characteristics (which we call 'device parameters') to the WSDB.
- A slave WSD that intends to use the generic operational parameters broadcasted by a master must report its unique identifier (we describe what this means below).
- A WSD must report back to the database the actual channels and powers that it intends to use (we refer to these as the 'channel usage parameters') and must only transmit in accordance with the channels and powers that it reports to the database.

5.11 The 2012 Consultation proposed that WSDs and WSDBs had to comply with a specific sequence of events. Stakeholders suggested to us that we should be less prescriptive on how the devices exchange data with databases and between themselves. We note that this was an issue that was also raised in the discussions at the ETSI meetings. We believe this is a better approach as it is less restrictive and allows the industry more scope to innovate in the manufacture of devices. We have therefore decided that it is appropriate to change our approach to this and we have instead drafted device requirements that focus on the communications which need to take place, rather than the order in which these take place.

Device characterisation and device parameters

5.12 WSDs will have several operational and technical characteristics. Some of these characteristics will be specified in our licence exemption regulations. We call these 'device parameters'. The way which we define the relevant device parameters is consistent with the ETSI Harmonised Standard and is in line with our proposals in the 2012 Consultation.

5.13 We will specify two parameters which will be used by a database to identify which categories of device a particular WSD falls into and which a database will take into account in determining a device's operational parameters. These parameters will be selected from a predefined set of values and will be declared by the manufacturer:

- **Device category**
  We define two categories: master and slave. A master is a WSD that is able to communicate with and obtains operational parameters from a qualifying WSDB, and a slave is a WSD that is only able to operate in TVWS when under the control of a master WSD.

- **Device type**
  Consistent with the ETSI Harmonised Standard, we define two types of device: type A and type B. A type A WSD is a device that is intended for fixed use only[25]. This type of equipment can have integral[26], dedicated[27] or external[28] antennas. A type B WSD is a device that is not intended for fixed use and which has an integral antenna or a dedicated antenna. WSDBs will allocate different operational parameters to type A and type B devices as one type might be more likely to cause harmful interference than another in certain situations.

5.14 In addition, we define the following device parameters:

- **Unique identifier**
  The unique identifier will be a set of characters which will be used by a database to identify a particular WSD. This will allow the database to log which white space devices are associated with it and which devices are using which channels and powers at any given time. The unique identifier will not be pre-defined but will be declared by the manufacturer and will consist of the unique serial number of a WSD, the WSD's model number or other identifier of the product family to which the white space device belongs and a unique identifier of the manufacturer of the device.

- **Antenna location and antenna location uncertainty**
  As discussed further below, master WSDs will need to have a geo-location capability, and slave WSDs may or may not have a geo-location capability. These device parameters will be used to identify to the database a WSD's location, expressed as its antenna latitude and longitude coordinates and the level of uncertainty in the accuracy of the WSD's antenna latitude and longitude coordinates, specified as $\pm\Delta x$, $\pm\Delta y$ and $\pm\Delta z$ metres respectively, corresponding to a 95% confidence level.

5.15 We note that there are additional device parameters which are set out in the ETSI Harmonised Standard. We discuss each of these below.

- **Device emission class**
  The device emission class relates to the out of block emissions characteristics of the device. Different classes allow manufacturers to trade-off device cost (devices with a better out of block emissions profile are normally more expensive to manufacture) against the TVWS availability that the device will obtain from the

[25] Fixed use in this context means that the device does not move while being used.
[26] Integral antenna: antenna designed as a part of the equipment, without the use of an external connector, which cannot be disconnected from the equipment by a user with the intent to connect another antenna.
[27] Dedicated Antenna: a removable antenna supplied and assessed with a white space device and which has been designed for use with that device.
[28] External antenna: a removable antenna which is designed for use with a broad range of radio equipment and has not been designed specifically for use with a specific product.

WSDB (devices with better out of block emissions are less likely to interfere with existing users and hence will get better TVWS availability). The ETSI Harmonised Standard sets out five classes specified by their ACLR masks. We proposed including four emission classes in our draft VNS and we note that following our 2012 Consultation some stakeholders requested that a fifth emission class be added to allow for cheaper devices. During the development of the ETSI Harmonised Standard, a fifth emission class was added. The new class presents worse out of block characteristics, and as a result devices complying with it will be allowed to transmit at lower EIRP than devices that declare any other class. We think this new class is beneficial as it allows the deployment of devices with a lower cost point than the other classes which is why we supported its inclusion in the ETSI standard. Devices may report their emission class to a database and where they do so this will be taken into account by the database in calculating operational parameters for that device. Where devices do not report their emission class, the database will calculate operational parameters on the assumption that the device falls within Class 5 as set out in the ETSI Harmonised Standard. We have decided not to make the reporting of class mandatory to give industry more flexibility in how it develops devices and the communications between devices and databases. An explanation of how a database will take into account the class of a device if reported to it as part of the device parameters is set out in Annex 8.

- **Technology identifier**
  The ETSI Harmonised Standard defines a Technology ID parameter as a set of characters that allows the database to identify the technology specification used by the white space device. This does not have a predefined value. The manufacturer may use free text that would allow the databases to identify the technology. Different radio technologies may cause different levels of disruption to DTT reception, all the other parameters being equal. WSDBs operating in the UK may, in the future, take this information into account when calculating the allowed channels and powers for a device. At the outset of the implementation of the TVWS framework we will not be taking advantage of this feature but may do in the future following further technical work.

- **Spectral mask improvement and reverse intermodulation attenuation improvement**
  The ETSI Harmonised Standard also defines these two further device parameters. These are not part of the framework we are implementing initially as we believe that they would add significant additional complexity and we are not aware of any stakeholders with plans to build devices which would have these capabilities. We will keep this matter under review.

Operational Parameters

5.16 The operational parameters are generated by a WSDB and will provide instructions to a WSD as to how it may operate in TVWS, for example the frequencies and powers that a WSD must use. Consistent with the ETSI Harmonised Standard and in line with our proposals in the 2012 Consultation, they will include:

- The lower and upper frequency boundaries within which a white space device may transmit.

- The maximum permitted in-block EIRP spectral density between each lower frequency boundary and its corresponding upper frequency boundary.

- Limits on the maximum total number of DTT channels that may be used at any given time and the maximum number of contiguous DTT channels that may be used at any given time.

- The time period during which the operational parameters are valid. In contrast to our proposals in the 2012 Consultation, the time period is specified as start and end timestamps instead of a single validity end time value. This will allow WSDBs to provide operational parameters in advance.

- A parameter indicating the geographic area within which the operational parameters are valid (the location validity parameter). This parameter is in place of our proposal in our 2012 Consultation that a device had to obtain new operational parameters if it moved more than 50 metres away from its reported location. This limit is now a variable parameter which is communicated by the WSDB. This will allow Ofcom to set different limits for different usage scenarios in the future.

- A parameter indicating the time period within which a master device must check with a white space database that the operational parameters it is using are still valid (the T_{update} parameter). We explain the reasons for this new parameter and how it will operate in paragraphs 5.22 to 5.25 below.

- A parameter indicating if a simultaneous channel operation power restriction applies[29]. This parameter is based on a requirement originally set out in the draft VNS. As originally drafted, this limit was applicable to any device that transmitted in more than one channel. In response to our 2012 Consultation stakeholders suggested that this condition overly restricted multiple channel operation, to the extent that it incentivised manufacturers to design devices to operate in a single channel even if they had multi-channel capability. As a result, we decided to maintain the ability to introduce this restriction, but not to have it in place by default. If in future Ofcom decides to activate this parameter, it will implement this through the contract with the WSDB, which would then start taking it into account in calculating the relevant operational parameters for devices.

Channel Usage Parameters

5.17 The channel usage parameters are reported by a WSD to inform a WSDB of the actual frequencies and powers that it intends to use when operating in TVWS. This will enable a database to be able to log the frequencies and powers actually being used by the WSDs it serves, which is important for interference management purposes. They will include the following information:

- the lower and upper frequency boundaries within which the white space device will transmit; and

- the maximum in-block EIRP spectral density at which the white space device will transmit between each lower frequency boundary and its corresponding upper frequency boundary.

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[29] The simultaneous channel operation power restriction can take a value of 0 or 1. A value of 1 indicates that, in case of simultaneous operation in multiple DTT channels, a white space device must restrict its maximum total EIRP to $\{P_{1,i}\}$ dBm, where $P_{1,i}$ is the in-block EIRP provided by the white space database in the operational parameters for DTT channel i specified by the frequency pair $f_{l,i}$, $f_{u,i}$ and where $f_{l,i}$, is the frequency at the lower edge of the i^{th} channel and $f_{u,i}$ is the frequency at the upper edge of the i^{th} channel. A value of 0 indicates that this restriction does not apply.

Location capability

5.18 Location is one of the device parameters that devices may report to the WSDB.

5.19 A master WSD must be able to geolocate horizontally, i.e. height is not mandatory. This is a new requirement following our 2012 Consultation, which is intended to make clear the fact that a master WSD whose location is not known cannot operate at all. A master WSD must report its location and the location uncertainty to the WSDB as part of the device parameters. The uncertainty must be reported with a confidence level of 95%.

5.20 Slave WSDs may or may not have this capability, but if they report their location they must do it with the same confidence level.

5.21 A device may also have the capability to determine its height and report that to the database but this is not mandatory and if a device does not report its height the database will use a default height for the purpose of calculation of Operational Parameters.

Cease transmissions

5.22 In line with our proposals in the 2012 Consultation, we consider that it is necessary for Ofcom to have the ability to switch off a device within a short period of time where required for interference management purposes. Ofcom will not be able to contact a device directly, but would instead instruct a WSDB to send an instruction to devices to cease transmissions. We will have a requirement in the database contract to support this functionality. We also intend to include specific requirements in the licence exemption regulations to implement this capability.

5.23 A master WSD will be required to verify with the serving WSDB that the Operational Parameters it is using are valid, within the time period (T_{update}) indicated by the WSDB[30]. If a master WSD is not able to verify that the operational parameters it is using are still valid or if a WSDB instructs the master WSD that the operational parameters are not valid, then the master WSD must stop transmitting and instruct all slave WSDs that it controls to stop transmissions.

5.24 This is a change from our proposal in the 2012 Consultation where we said that a master WSD shall cease transmission within 60 seconds of receiving the WSD shut-down instruction from a WSDB. When we discussed this requirement with industry, it became apparent that the key issue here is not the time it takes the WSD to shut down after receiving the WSDB command (this can be very short), but instead it is the process of getting the command from the WSDB to the WSD. This is because WSDBs will normally not maintain a permanent connection with WSDs. We have therefore changed our approach to require the master WSD to check validity of parameters as outlined above; we consider that the revised approach will be a more practicable way to ensure that WSDs are switched off quickly where necessary for interference management reasons.

5.25 There will also be requirements on slave WSDs. A slave WSD must cease transmissions when instructed to do so by its master WSD, and within five seconds of discovering that it can no longer receive transmissions from its master WSD.

[30] T_{Update} is one of the operational parameters provided by the database. Ofcom will indicate to the WSDBs which value to use. We intend to set this value to 15 minutes initially.

Discovery of qualifying WSDBs

5.26 Ofcom will specify in the licence exemption SI the list of the WSDBs that Ofcom has qualified to operate in the UK. Master WSDs can only use operational parameters that have been generated by a database on that list. In order to facilitate operation of devices, we will also publish a machine readable version of the list in our website at https://tvws-databases.ofcom.org.uk/.

5.27 We may need to modify the list periodically, because new databases get qualified or because we remove a database operator. We would therefore expect that a master WSD would need to periodically reload the list from our website, in line with the ETSI Harmonised Standard. How frequently this should be done will be indicated in the list, and initially we would expect master WSDs to download an updated copy of the list every 24 hours.

User access restrictions

5.28 In order for our framework to function effectively, a master WSD will need to accurately report its device parameters, in particular its location, in order for a WSDB to provide it with suitable operational parameters (i.e. parameters which ensure that a WSD will only transmit on frequencies and at powers which ensure harmful interference is not caused to other spectrum users).

5.29 We do not think that it is appropriate to authorise WSDs that can be manually configured on a licence exempt basis. This is because, we would be concerned about end-users (who would be unlikely to have the expertise needed to accurately configure a device) having the ability to input or modify the device parameters, in particular in relation to the location of a device. If the WSD reports inaccurate device parameters to a WSDB, the WSDB may provide operational parameters that could result in interference to other spectrum users in the proximity of that WSD.

5.30 As a result, for licence exempt operation devices would need to be designed such that it must not be possible for a user to modify or tamper with the hardware or software settings of the device related to the exchange of parameters with the database, or the parameters themselves. As noted above, separately we are considering whether to authorise devices which require manual configuration on a licensed basis.

Section 6

Coexistence approach

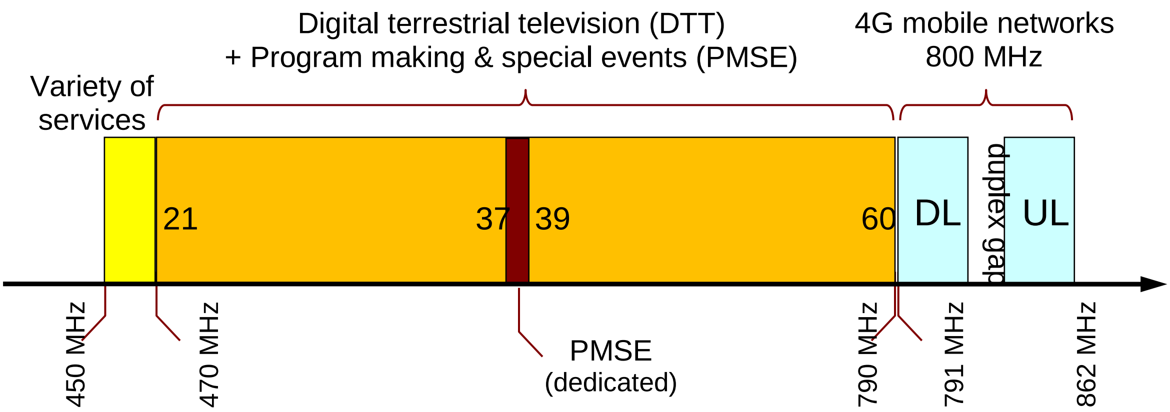
6.1 This section sets out how we have approached the task of ensuring that the use of WSDs will result in a low probability of harmful interference to existing users. It describes where the various co-existence issues arise and how we propose to resolve them in each case.

6.2 The basic coexistence framework is the same as the framework proposed in the 2013 Consultation, but we have changed the proposed regulatory power limits for protection of DTT, PMSE, and services below the band, and have added protection against intermodulation products for PMSE users. Below, we set out at a high level how our decisions on regulatory limits differ from the proposals in the 2013 Consultation document.

The coexistence issues

6.3 Figure 6.1 below shows the users in the UHF TV band and in adjacent frequency bands with whom WSD devices will coexist.

Figure 6.1 - UHF TV band and adjacent bands



6.4 This band is currently used for DTT broadcasts and by PMSE, with indoor PMSE use permitted anywhere in the UK throughout the band, subject to licensing, and outdoor use constrained by location in order to avoid harmful interference to DTT users.

6.5 The spectrum immediately above 790 MHz is used by 4G mobile services. The spectrum immediately below 470 MHz is used by a variety of services including business radio, PMSE, scanning telemetry, short range devices, and maritime, Prison Service, and Revenue and Customs. Each of these existing uses must be protected from harmful interference from WSDs, and each has different characteristics that must be taken into account.

6.6 In managing coexistence between WSDs and existing users, 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 via the calculation of the maximum allowed power at which a WSD can transmit in each frequency, accounting for the other spectrum users as mentioned above.

6.7 These calculations are only concerned with establishing the maximum allowed powers from the point of view of coexistence. In practice, devices may well operate at much lower powers than the maximum limits because of other constraints such as use cases and battery limitations, or the need to comply with guidelines from the International Commission on Non-Ionizing Radiation Protection (ICNIRP)[31].

6.8 In the 2013 Consultation we proposed a set of coexistence rules. These proposals made a set of assumptions about how WSDs would operate and the impact that they would have on existing users at relevant power levels. We have conducted an extensive test programme and looked at evidence provided by stakeholders to test those assumptions and help us establish a coexistence framework that achieves our goals.

6.9 We published data on our PMSE coexistence testing in November 2014[32], and data from our DTT coexistence testing in December 2014[33]. In January 2015 the BBC and Arqiva published the results of testing that they had done on the impact of white space devices on DTT reception[34]. We have also taken account of stakeholder comments in response to our 2013 Consultation. There is a summary of consultation responses at Annex 11 of this document.

6.10 Taken together, the results of the tests suggested that the overall framework for co-existence set out in our 2013 Consultation was capable of defining appropriate maximum power levels per frequency to protect existing users. However, in particular circumstances in which a number of worst case scenarios happened to exist simultaneously, the parameters used to set the maximum power levels in our consultation proposals may not have been sufficient to ensure that there would be a low probability of harmful interference to DTT and PMSE and spectrum users below the UHF TV band.

6.11 We stated in the 2013 Consultation that we intended to take an initially cautious approach to protection of existing users in the first stages of authorising white space use. We still believe that this is appropriate because it provides more certainty for existing users. We have therefore adopted a cautious approach in interpreting the available evidence and adjusting the coexistence calculations.

Future monitoring and review

6.12 We expect that it may take some time for use of WSDs to become widespread in the UK, based on the current availability of equipment and what we have seen of the development of the use of TVWS in the US. We will carefully monitor the use of WSDs, looking in particular at whether the framework is adequately protecting existing users, whether the framework provides sufficient white space in relevant areas to meet demand and any developments that could better inform our regulatory framework.

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[31] ICNIRP is a charitable body of independent scientific experts established by the International Radiation Protection Association whose principal aim is to disseminate information and advice on the potential health hazard of exposure to non-ionising radiation including electromagnetic fields. For more information, see http://www.hse.gov.uk/radiation/nonionising/faqs.htm

[32] http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2014/TVWS-PMSE_Coexistence_Technical_Report.pdf

[33] http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2014/TVWS_DTT_technical_report.pdf

[34] *WSD Coexistence Testing at the Building Research Establishment: An experimental validation of Ofcom Regulatory Proposals*, White Paper WHP288, http://www.bbc.co.uk/rd/publications/whitepaper288

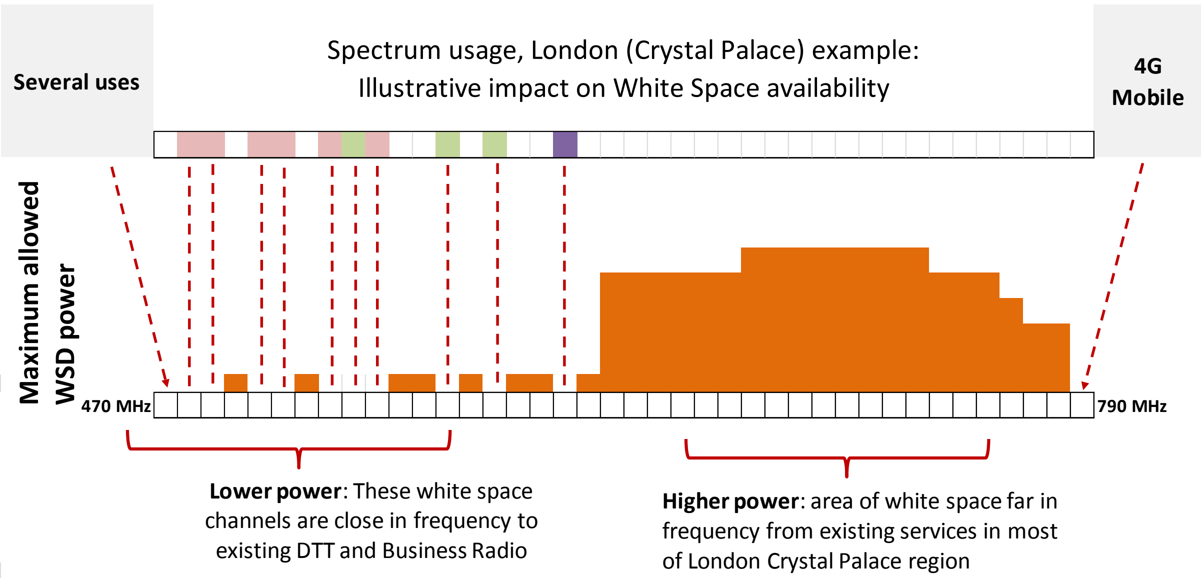
6.13 It is our intention to continue working to identify and address issues in the coexistence framework where it may be appropriate to make changes, taking input from stakeholders where appropriate. We provide more information on our planned next steps in Section 11.

Summary of coexistence framework

6.14 The following is an overview of the coexistence approach for each existing use type depending on the characteristics of those uses. The detail of our coexistence approach for each of these use types is presented in Sections 7 to 9 and in Annexes 2 to 7.

6.15 Figure 6.2 shows an illustrative example of the White Space availability in a London location. It shows how local presence of DTT, PMSE and other services reduce white space availability in channels adjacent in frequency to those used by existing users.

Figure 6.2 - Spectrum usage and impact on White Space availability (illustrative only)



6.16 The height of the orange columns represent allowed white space power for each channel with taller columns indicating a higher permissible power level.

6.17 In order to ensure that existing users are protected, the WSDBs will be required to apply the coexistence approach summarised at a high level in Table 6.1 below:

Table 6.1 - Summary of approach to coexistence by existing use type

Existing use type	Approach	Changes in comparison to the 2013 Consultation
DTT (UK viewers)	WSD powers will be strongly constrained in channels locally used for DTT and, less severely, in channels adjacent to that use	No material changes in the framework by which we calculate constraints. We have tightened parameters so that our criteria are stricter by: • 19 dB in channels locally used by DTT • 9 dB in channels adjacent to those locally used by DTT In areas where we find evidence of exceptional localised TV coverage issues which are not already reflected in the modelling, we will apply additional local constraints as required.
DTT (viewers in neighbouring countries)	Specific maximum power limits required to protect services in other countries are generated for relevant locations, primarily around the coast of the UK and along the border with the Republic of Ireland.	No change.
PMSE	WSD powers are strongly constrained in channels locally used for PMSE and, less severely, in channels adjacent to that use. When WSD and PMSE users are extremely close to each other, some power restriction will apply to all channels to account for intermodulation (an interference mechanism). No WSD use will be allowed in channel 38 and WSD powers will be restricted throughout the UK in channels 34-41 to protect channel 38 users. We intend to include PMSE venue boundary data in the data provided to WSDBs	The constraints to account for intermodulation are new; otherwise no material changes in the framework by which we calculate constraints. We have tightened parameters so that our overarching criteria are stricter by 27 dB. Constraints to use of channels adjacent to channel 38 are up to 20 dB stricter. We anticipate that we may be able to relax these regulatory limits over time as the market in WSDs develops and we learn more about WS uses and the actual impact of WSD use on PMSE users.
Services below the band	Specific maximum power limits are generated for WSD operating in channels 21-24 anywhere in the UK.	The restrictions are stricter than those in the 2013 Consultation, in particular to class 4 and 5 devices.
Mobile at 800 MHz	No WSD use of channel 60 is permitted anywhere in the UK.	No change.

6.18 WSDBs will apply the approach summarised in Table 6.1 taking into account the different classes and types of device. Devices which are less likely to cause interference will have better white space availability.

6.19 WSDBs will then compare the maximum allowed power limits in each available channel and allow the WSD to operate in any available channel at or below the lowest relevant maximum power limits derived. In all cases a WSD will not be permitted to operate in any channel at a power level that is above the maximum permitted for the protection of any category of existing user. See Annex 1 for an overview of how power limits of WSDs will be determined.

6.20 Finally, there is an overall cap of 36 dBm/(8 MHz) regardless of class, type or location of device. This is the same approach as proposed in the 2013 Consultation. 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 very similar to the limit the Federal Communications Commission has imposed in the US for WSD deployment[35].

Multiple WSDs and interference aggregation

6.21 In our coexistence framework, we have implicitly assumed that at any one time only one WSD radiates per pixel/location and per DTT channel. In practice, a WSDB or multiple WSDBs may provide services (information on available channels and permitted powers) to multiple WSDs in the same geographic area and the same DTT channels. This may result in an aggregation of interferer signal powers and, if they all choose to transmit at the maximum allowed power, an increased probability of harmful interference to the existing services in the area.

6.22 We believe that such aggregation of interference is unlikely to be problematic in the short term, for the following reasons:

a) Evidence suggests that devices (in particular mobile devices) rarely transmit at the full power they are capable of transmitting, to conserve battery among other reasons. This can make a large difference: as an illustration, one study of behaviour of mobile handsets suggests one may need between 25 and 2,000 mobile handsets transmitting at typical power to generate the maximum power of a single handset.[36]

b) Received power reduces rapidly with increasing geographic and frequency separation from a transmitter, and as such, interference tends to be dominated by one interferer; additional interferers which are physically further away, and/or further away in frequency quickly become irrelevant in comparison.

c) In order for WSDs to coexist successfully with each other, many will implement polite protocols, such as “listen-before talk” used in Wi-Fi, or frequency hopping used in Bluetooth. In such cases, it is unlikely that WSDs will transmit at the same time and at the same frequencies when in close proximity.

[35] The limit adopted by the FCC is 36 dBm/(6 MHz), which is slightly higher in power density than the limit here, but identical in total power per channel.

[36] Based on ITU document 5-6/81-E “Additional System Characteristics of an operational IMT network deployed in Australia in the 800 MHz band”. Although handsets can transmit at up to 24 dBm, the study found they spend 90% of the time transmitting at 8 dBm or below in an urban cell, and on average the transmission level was -9 dBm. The difference between 24 dBm and 8 dBm is a factor of 25; between -9 dBm and 24 dBm there is a factor of 1,995.

d) Our approach for the calculation of WSD emission limits is cautious. The emission limits include implicit margins which will provide some mitigation of interference aggregation.

6.23 We will continue to monitor this issue as the market develops, and if required we may adapt the framework to further reduce the probability of interference caused by aggregation effects.

Terminology

6.24 In sections 7, 8 and 9, we use the term "interference" to mean the following:

> "Man-made radio frequency power present at a receiver, for which the transmission was not intended or wanted (for example, power generated by a WSD transmitter into a PMSE receiver). Interference will always be present to some degree, because there is always a degree of leakage from every transmitter into other frequencies and, while physical separation and frequency separation will reduce the power of any transmission, that power does not completely disappear. The level of interference is important: it may be infinitesimally small and undetectable by instruments, or it may be detectable with the help of instruments (such as a spectrum analyser) but not cause any disturbance to the receiver that can be perceptible without instruments, or it can be sufficiently high that its effects are perceptible."

6.25 In Sections 7, 8 and 9, we refer to the ETSI Harmonised Standard in the following context. For the purpose of carrying out our coexistence testing and developing our approach to ensuring a low probability of harmful interference to existing spectrum users, we have had regard to the technical characteristics of devices as set out in the ETSI Harmonised Standard for White Space Devices (EN 301 598). This is because we note that devices that meet the requirements of the ETSI Harmonised Standard benefit from a presumption of conformity with the essential requirements of the R&TTE Directive. This Directive establishes the regulatory framework for the placing of radio equipment in the European market. However, we recognise that meeting the requirements of ETSI Harmonised Standard is not the only route to placing equipment in the market under the R&TTE Directive, and manufacturers can choose to demonstrate compliance by other means. In practice, we would expect that the majority of devices would meet the ETSI Harmonised Standard or would otherwise follow similar standards that ensure compliance with the essential requirements of the R&TTE Directive.

Section 7

Coexistence in relation to DTT

7.1 This section describes the DTT services in the UK, our approach to ensuring a low probability of harmful interference into DTT, and explains how we have used the evidence gathered since the 2013 Consultation to calibrate our approach.

The DTT services

7.2 In the UK, television services are provided on three main platforms: DTT, satellite and cable. DTT is the most popular means of receiving free to view TV. More than 11m households currently receive DTT services on their main TV set, and nearly three quarters of homes use DTT on at least one TV set[37].

7.3 The DTT network consists of 80 high power (main) TV broadcast transmitters distributed across the UK and approximately 1,100 lower power transmitters. The main transmitters are generally sited on the top of hills and use tall masts so that broadcasts reach as many households as possible. These main transmitters are supplemented by a larger number of smaller relay transmitters which fill gaps in the coverage of the high power transmitters. The network has been planned to provide reception to household rooftop aerials at 10m height.

7.4 DTT broadcasting uses a series of 'multiplexes'. A multiplex aggregates typically 8 to 13 TV channels together into a single digital signal which is then transmitted in a single 8 MHz channel.

7.5 There are currently six multiplexes with coverage that extends to almost all of the country. 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. The PSB multiplexes were designed to replicate the reach of the analogue TV they replaced, and they provide coverage to around 98.5% of the population. The remaining multiplexes were not subject to the same policy, and cover around 90% of the population.

7.6 Viewers in Northern Ireland receive additional services with specific Irish relevance (RTÉ and TG4). These are broadcast via a combination of UK-based and Republic of Ireland based transmitters (transmissions of the latter "overspill" into Northern Ireland). The UK transmission side comprises an additional licensed multiplex which broadcasts from three transmitters in Northern Ireland. There is also an additional licensed multiplex which broadcasts to Manchester and a multiplex for Local TV services, which currently broadcasts local channels to 15 areas.

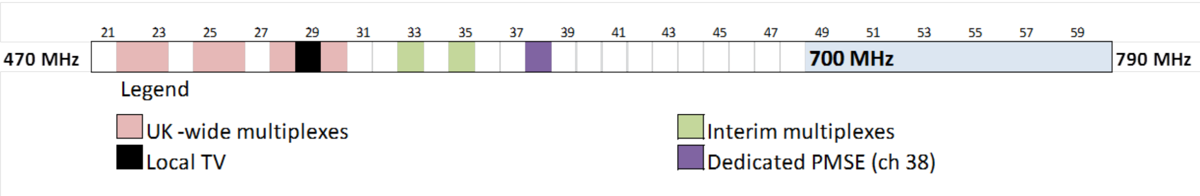
7.7 An interim multiplex has been deployed in the 600 MHz band, and another is planned to launch soon. They will cover around 70% of the UK population carrying national services in both high definition and standard definition. The 700 MHz band is currently in use by DTT, PMSE and the TVWS pilots. It will be released around 2022, but clearance of existing uses will start earlier, and it may be cleared of White Space use as early as 2018. The interim multiplexes in the 600 MHz band are planned to be

[37] BARB Establishment Survey, as quoted in *The Future of Free to View TV, Ofcom,28 May 2014*, paragraph 4.5
http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/discussion/ftv.pdf

turned off when the 700 MHz band is cleared, and as a result we do not expect there to be a significant change in availability of white space[38].

7.8 Figure 7.1 below shows the position of all of the multiplexes in the London region served by the Crystal Palace transmitter in London, as an illustration of the DTT use of the band. The pink squares show the main DTT multiplexes and the white squares indicate potential white space availability.

Figure 7.1 - Multiplexes in use in London



Information about the transmitter in use in each location

7.9 Each DTT transmitter is able to cover a certain area; in practice there are areas of overlap between coverage areas, where it is possible to receive coverage from more than one DTT transmitter.

7.10 Our experience from our coexistence tests has shown that, on some occasions, the available models and datasets will not identify correctly the transmitter in use, and therefore the channels in use in a given location. We will aim to improve information on actual transmitter usage across the UK. We will do this by:

- Using existing knowledge about which transmitters viewers normally use. For example, we understand that viewers in general prefer transmitters that provide a full set of Freeview programming channels over transmitters that provide a smaller set of channels. We provide detail of how we will incorporate this knowledge in our methodology in Annex 2.

- We plan to improve information on actual transmitter usage throughout the UK. We will work with stakeholders to determine how best to collect new information on actual transmitter usage. When there is clear evidence of a different transmitting station (or transmitting stations) than indicated by the planning model in use in given areas, we will substitute (or augment) the database of planned transmitters with the new information and will use that as the basis of our DTT co-existence calculations.

7.11 We will not seek to add additional transmitter stations to the list of potential stations in use purely on the basis of predictions from the planning model (i.e. where reception is theoretically possible from two or more stations). This is because there is little evidence that this would improve the identification of transmitting stations actually in use and it would risk providing significant over-protection of DTT, and sterilise spectrum unnecessarily. Nevertheless we will use predictions of multiple transmitter availability to inform and prioritise the process of gathering information on actual transmitter usage.

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[38] See *Decision to make the 700 MHz band available for mobile data - statement*, p2.17
http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/statement/700-mhz-statement.pdf

7.12 We have not yet incorporated any additional information on actual transmitter usage for the purposes of the pilot or in the tool we have been using to calculate TVWS availability for the purposes of this Statement. Thus the figures and maps shown elsewhere in this Statement are based on existing datasets[39]. Therefore, although in most areas of the UK only one transmitting station would be in use in a given pixel, there are some areas where White Space availability has been reduced because the channels used by two or three stations have been taken into account in our co-existence calculations.

7.13 For the purposes of the operational implementation of our TVWS framework, we expect to only take into account one single transmitter for a given pixel, although in some circumstances we may depart from this in the light of clear evidence of alternative or additional transmitters actually being in use. The methodology described in this section continues to allow for two (or more) different transmitters serving a pixel to be taken into account to allow for cases where clear evidence is available on multiple transmitting station usage.

7.14 We mentioned earlier that in some parts of Northern Ireland, coverage of some channels is provided from transmitters placed in the Republic of Ireland. This is the result of commitments between the UK and Republic of Ireland Governments in the Belfast agreement and a Memorandum of Understanding entered into between the two Governments in 2010. As this coverage from Republic of Ireland transmitters is being used to accomplish a UK coverage policy objective, we continue to consider that it is appropriate to include the UK coverage from these transmitters in our calculations.

7.15 Our position as explained above is materially the same as in the 2013 Consultation. The main difference is that in the consultation we talked about the planned transmitter for each location, a terminology that was arguably ambiguous. We are now clarifying that our intention is to protect the transmitter in actual use in each location, as explained above.

Indoor aerials

7.16 The DTT network is planned for reception using rooftop aerials, not indoor aerials, and this is reflected in our spectrum management decisions in general. In some areas, it may be possible to receive a signal using an indoor aerial, with varying reliability, but this is not a policy objective. Therefore, the parameters we have set out are designed to ensure a low probability of harmful interference to viewers using rooftop aerials. In practice, these parameters are also likely to provide a degree of incidental protection to reception via indoor aerials, because they will restrict WSD powers in the channels used for DTT reception in a given location.

Our approach to ensuring a low probability of harmful interference

7.17 We use an existing industry DTT planning tool (UKPM) to take account in our framework of detailed information about the location, power, and frequency of all DTT transmitters, the likely transmitter in use in any location, the terrain between any location and the received power from the transmitter serving it. All of this information and other data are used in order to determine our rules for WSD - DTT coexistence.

[39] The implementation is based on protection of the best main station coverage, the best Nations 3PSB coverage and the best ‘other’ 3PSB coverage.

7.18 The detailed calculations used are described in Annex 2. At a high level, our approach is modelled using the following ideas:

a) Households can only receive DTT if the *wanted signal level* (i.e. the strength of the TV signal) is above a certain minimum. This minimum value depends on receiver performance.

b) Presence of interference will raise the minimum signal level required;

c) The UKPM uses a statistical approach to estimate, for each given location, the wanted signal level and the level of interference from distant DTT transmitters, while also taking into account the characteristics of receivers.

d) Using the statistics above, UKPM will estimate a probability that points within a particular locality are covered. This estimate is called location probability. The UKPM divides the UK into 100m by 100m squares, called “pixels”, and this is what a “locality” means in this context.

e) We treat WSDs as an additional interferer in this calculation, and we introduce additional statistics about how sensitive DTT receivers may be to WSD interference (the protection ratios). Broadly speaking, the closer in frequency the WSD is to a channel locally used for DTT, the more sensitive receivers will be, and this is reflected in protection ratios.

f) We also introduce statistics about the path that signals may have to travel between the WSD and the DTT antenna (the coupling gain). If WSDs are operated very close to a DTT aerial, they are more likely to cause picture break up and this is reflected in the coupling gains.

g) Because WSDs are an additional interferer, their presence will reduce the location probability estimate.

h) We set a reference level of *reduction in location probability* that would be exceeded only infrequently, typically when WSDs get very close to receivers.

i) This reference level is set so that, even in these infrequent cases, it should still be much more likely that DTT reception will be unaffected.

j) The method above will in many cases result in powers above the cap of 36 dBm. We then apply that cap, which in practice will reduce further the aggregate probability of a WSD causing picture break up to TV receivers.

7.19 As a consequence of the above:

a) The methodology above will result in some extremely low powers allowed for WSDs in the same channels that are in use for DTT in a given area (co-channel operation).

b) We believe co-channel operation at such low powers is likely to be in practice of little use for WSDs. This is both because the WSD powers are so low, and because WSDs in these channels would suffer high levels of interference from DTT. Therefore, we do not expect that WSD co-channel use will occur in practice.

c) Even if a given channel is not used for TV reception at the same location as the WSD, the WSD power may be restricted because that channel is in use in some other location. The degree of the restriction will depend, among other things, on the distance between the WSD and the closest place where that particular channel is in use for TV reception.

d) Channels closest in frequency to those used for TV reception in a given area will suffer the tightest restrictions. With larger frequency separation, the maximum allowable powers will increase.

How we used the results of tests to adjust our approach

7.20 We note that, 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. This is important context in understanding the role of "reduction in estimated location probability" in our approach. It is not, in itself, an accurate estimate of the number of locations which may suffer harmful interference caused by WSDs. It is one parameter that needs to be calibrated in conjunction with several others in order to produce a model that overall results in a real-life low probability of harmful interference. In the rest of this document we will refer to "location probability" as a shorthand for the estimate of location probability.

7.21 We have therefore used extensive evidence from testing to calibrate the set of parameters in our approach as set out below. In so doing, we have changed some parameters significantly, but the structure of the approach is the same as that in our 2013 Consultation.

7.22 We have calibrated our proposals in light of both "aggregate" and "parameter by parameter" comparisons with test results. We used the consultation responses and other stakeholder input to identify areas of particular interest for testing. We conducted laboratory tests, tests in open field, and tests in a sample of households in selected areas of the UK. As mentioned above, the results of the tests were published on 17 December 2014. In addition, the BBC and Arqiva (who operates the DTT infrastructure in the UK) have conducted their own tests and provided additional data[40]. We have conducted the following comparisons and made adjustments to the coexistence framework set out in the consultation document:

a) **Aggregate comparisons.** We operated WSDs at very close proximity to a sample of DTT households in our tests, increasing the power gradually, and recorded the point at which there was picture break up. We ensured that the WSD was deployed in a set of extreme conditions, that is, in a way that makes picture break up more likely: the WSD transmit aerials were at the same height as rooftop aerials, and placed directly in front of the DTT receive antenna, pointed towards the receiver. We conducted tests in areas where DTT coverage is potentially more vulnerable to WSD interference. We tuned the WSD to operate at the channels used by DTT locally, or adjacent to those. We then calibrated our model, through changes to two of the specific parameters used (an allowance for the prediction error in UKPM and a change to the 90th percentile of coupling gain) as set out in paragraphs 7.52 and 7.58 below, to constrain the WSD maximum allowed powers in such a way that, even in these very extreme conditions, only a small minority of cases would have observed any picture

[40] Paper WHP288: WSD Coexistence Testing at the Building Research Establishment: An experimental validation of Ofcom Regulatory Proposals, BBC/Arqiva, Jan 2015 http://downloads.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP288.pdf

break-up. In actual deployment, we would expect conditions similar to those in which we tested to occur rarely, if ever at all, and we will continue to develop interference management procedures as an additional safety measure.

b) **Parameter by parameter comparisons.** We ensured that values of individual parameters each represented a reasonably cautious choice, and in aggregate they represent a cautious reference set of values. The emphasis is on the aggregate effect of these choices: if a particular set-up exceeds the reference value for one or even several parameters, this does not mean that interference will occur.

7.23 We explain these comparisons in more detail next.

Aggregate comparisons

7.24 We measured the point of picture break up at 133 households across the UK by placing a WSD in a very challenging position. We calibrated our approach by adjusting parameters in such a way as to reduce WSD powers, to the point where only a very small proportion of the tests would have experienced some picture break up under these conditions. This is not to say that this small proportion is an acceptable threshold; we emphasise this percentage only applies to the subset of households subject to the extreme conditions created by our tests.

7.25 Figure 7.2 below illustrates the outcome of this calibration process with an example using some of the households we tested – those covered by the Crystal Palace transmitter. The picture to the left shows the test results compared to the maximum powers allowed by the rules in the 2013 consultation. The picture to the right shows the same comparison after calibration. In each chart, points with negative margin (to the left of the Y-axis) show tests where the maximum powers allowed by the rules would have caused picture break up. After calibration, there are no negative margins in this example.

7.26 The different lines in the chart refer to different frequency separation between WSD and DTT. Most of the points with negative margin referred to co-channel transmission (both WSD and DTT using the same channel).

Figure 7.2(a) - CDFs of margins against the consultation WSD power limits

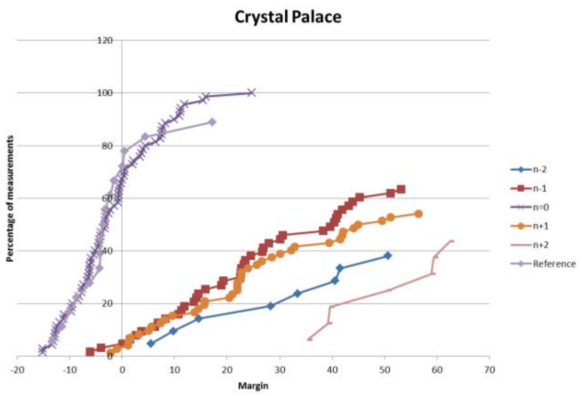
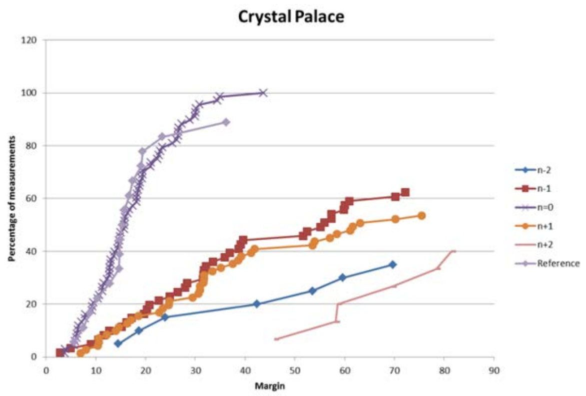


Figure 7.2(b) - CDFs of margins against the planned WSD power limits



Data about the transmitter in actual use in each location

7.27 In making this calibration, we had to address the limitations of the input data to our model about which transmitter is actually in use in each locality. Each transmitter uses different channels. The consequence is that, if the input data about the transmitter in use is incorrect, our model will reduce maximum allowed WSD powers for the wrong channels. This means these cases cannot be used for meaningful calibration, and we excluded them from the process described above. We will instead address this issue by seeking to improve the data, as mentioned earlier. This is explained in more detail in Annex 2.

Data about DTT field strength / Thanet area

7.28 Our test programme showed that the data about the DTT signal strength predicted by the UKPM may be incorrect in some localities within the Thanet area. The UKPM usually provides a very good estimate of average field strengths in any area and this behaviour is not typical across the UK.

7.29 We will compensate for this by including a local adjustment in the rules, applicable only to the Thanet area where we identified the problem. The rules will be made stricter by a 10 dB adjustment, applied as an overlay to other DTT data. Figure 7.3 below shows the area to which the modified rules will apply. More detail is included in Annex 2.

Figure 7.3 - Area within which the modified rules will apply within Thanet

7.30 It should be noted that the area chosen for the Thanet tests has produced results with UKPM field strength prediction errors which are very atypical of the normal prediction errors from the model. However it is possible that a limited number of other areas of the UK may exist where the UKPM on average significantly over-predicts the wanted DTT field strengths.

7.31 There may also be a limited number of other areas of the UK where the UKPM on average significantly under-predicts the wanted DTT field strengths. In such cases, the model may provide TVWS powers which are more restrictive than strictly required in order to ensure that there is a low probability of harmful interference to DTT in those areas.

7.32 We do not intend to incorporate an additional margin across the UK to allow for location specific anomalies in the model. This is because UKPM has previously been calibrated using a very large number of field strength measurements across the UK to give a near zero mean prediction error and we believe its performance is well-known, apart from a few anomalies in certain areas.

7.33 However, we will continue to review existing up-to-date DTT field strength measurements from across the UK and future field strength measurements. We believe more information will become available in any case, because additional measurements have been planned to assist in future refinements to UKPM. Where necessary, we will make further location specific adjustments to the TVWS power limits to reflect any localised gross discrepancies in the model (smaller discrepancies will be allowed for by the additional margins built into the model). These adjustments could increase or reduce the TVWS power limits in the areas affected and it is expected that such adjustments will only be required in a small number of specific instances.

7.34 We will work with broadcasters in the Technical Working Group to prepare a database of DTT field strength measurements across the UK. This will inform decisions on whether to make any further location specific adjustments to the TVWS power limits to compensate for any gross errors in the UKPM field strength predictions.

7.35 In parallel, we will work with broadcasters on potential improvements to the accuracy of UKPM field strength predictions. These improvements would seek both to improve the overall prediction accuracy, and to remove instances of more significant discrepancies such as in Thanet. If such improvements were made to the model, we would then remove any localised corrections to the TVWS power limits where they were no longer required.

Use of device classes and its effect on our calibration

7.36 A WSD, as with any wireless transmitter, will inevitably "leak" power into channels close to the one it is using (this is known as out of band emissions). The amount of leakage varies from device to device, and is normally greater in the channels immediately adjacent to the one in use.

7.37 In general, our framework will provide greater white space availability to devices with the least leakage, because of the reduced potential for interference. As explained earlier, the ability of the framework to discriminate between better and worse devices relies on a rough approximation: rather than accounting for particular characteristics of each device, WSDs are classified into one of five classes, by comparing devices' out of band emissions to a table with reference values for each device (the mask).

7.38 A device would only be considered as meeting the requirements for a certain class if it performs as well as, or better, than the mask for that class in every channel. Not only that, but each individual 8 MHz channel is split into 80 "slices", 100 kHz wide, and only the performance of the worst "slice" is taken into account. The end result is that in most channels, devices will over-perform their class (i.e. have less leakage than the class implies) often by large margins. This is an additional, implicit safety margin.

7.39 As described above, we have calibrated our framework against the results of tests performed with real devices, and the results show that devices do outperform their classes (as expected). The consequence is that if future devices do not outperform their classes to the same extent as the ones we used in tests, there would be a greater risk of harmful interference than currently anticipated. Conversely, if future devices outperform their classes by more than the devices we used, the framework may lead to an unnecessary sterilisation of spectrum.

7.40 We believe this is an important issue and it should be a priority for the Technical Working Group to monitor developments and suggest improvements to the framework to avoid increases in the risk of harmful interference to existing users or of unnecessary sterilisation. One way of achieving this would be to develop the class framework so that it reflects real performance more closely. There may be several ways to achieve this, which would need careful consideration before being implemented. For example:

a) Devices could report by how much they over-perform their class;

b) A greater number of classes could be introduced, so a better fit could be found for any given device.

c) Devices could report a different class for DTT and for PMSE. This would reduce the gap between classes and real performance because the current system is based on the performance of the worst 100 kHz "slice" of spectrum within a 8 MHz channel, which is appropriately cautious for PMSE but very pessimistic for DTT (where, by and large, propensity to interference depends on the **average** performance across the 80 "slices" contained within 8 MHz, not on the worst performance).

Parameter by parameter comparisons

7.41 We have adjusted the following parameters, using evidence from our own testing campaign, and tests conducted by the BBC and Arqiva:

<u>Protection ratios</u>

7.42 Protection ratios measure how sensitive DTT receivers are to the type of interference that may be created by WSDs. In general, the ability of a DTT receiver to work depends on how strong the TV signal it receives, and how strong the interfering (WSD) signal is. The protection ratio is the ratio between those two quantities at the point at which a viewer starts seeing picture break up. The implication is that the WSD power will have to be lower than that point (which is relative, varying with local TV signal strength).

7.43 The sensitivity to adjacent channel interference varies significantly between receivers. In our 2013 Consultation proposals we used as a reference the 70th percentile receiver – i.e. we set our parameters based on a receiver that is worse than 70% of receivers in the market in terms of sensitivity to WSD interference. We continue to use the 70% reference point, but we have measured protection ratios for a larger number of receivers since the consultation. We have therefore updated our protection ratios as described below.

7.44 Sensitivity to adjacent channel interference also depends on the type of WSD and on the behaviour of WSDs, and we made more varied measurements in respect to these. We observed that, under certain circumstances, some WSDs can be driven to bursty, "stop/start" behaviour in transmissions, i.e. where the WSDs transmit for a few seconds, then fall silent. Some DTT receivers are particularly sensitive to this type of behaviour.

7.45 In our 2013 Consultation, we proposed to generate TVWS availability datasets corresponding to three categories of protection ratios: "high", "medium" and "low", which would categorise the propensity of different WSD radio technologies to cause harmful interference to DTT. Following the pilot and our testing programme, we have decided to classify protection ratios in two categories: "high" and "low". "High" reflects the "stop/start" behaviour to which some DTT receivers are particularly sensitive and which we therefore consider have a greater propensity for causing harmful interference into DTT. Devices classified as "low" will see more White Space availability[41]. WSD manufacturers will have an incentive to tailor their designs to minimise their interference potential ("low" classification) and thereby maximise the powers they can use.

7.46 Our updated "low" protection ratios are not significantly different from the ones we published in the 2013 Consultation, but include some refinements to reflect the additional data we have (detailed in Annex 9) from testing a wide range of DTT receivers with a current WSD. The "high" protection ratios are significantly higher than those in the 2013 Consultation (meaning that we would expect them to result in less White Space availability).

7.47 We will work with input from WSD manufacturers to determine whether gated TVWS traffic (which can produce bursty, "stop/start" behaviour in transmissions) that can produce the "high" protection ratios will represent a likely mode of real-world operation. If so, we will work within the Technical Working Group to develop a standardised test methodology for making protection ratio measurements using gated TVWS traffic. Once that methodology was agreed, device manufacturers or organisations responsible for the specification of WSD radio technologies would be required to present Ofcom with evidence in the form of protection ratio measurements against pre-specified DTT receivers. We would consider the potential need for any changes to the statutory instrument at this stage.

7.48 Upon examining such evidence, Ofcom would, if appropriate, adopt an approach in due course where we assign each radio technology to one of the two protection ratio categories. This information would be shared with the WSDBs, so that they could select the appropriate TVWS availability dataset provided by Ofcom in accordance with the reported technology ID of individual WSDs.

7.49 Absent such evidence, a WSD radio technology would be assigned, by default, to the "high" protection ratio category (that which represents the greater propensity for harmful interference).

7.50 Until the need for a "high" protection ratio category to reflect real world WSD behaviour has been confirmed, and until a standardised test methodology for gated TVWS traffic has been developed, a WSD radio technology would be assigned, by default, to the "low" protection ratio category. This is the default assumption that was made in the 2013 Consultation for receiver protection ratios. In the short term (it is envisaged that the standardised methodology would be developed within the next 12 months), there would be a low probability for harmful interference because most current usages in the TVWS pilots do not implement a use case equivalent to the gated TVWS traffic and only a proportion of the early prototype WSDs that we tested delivered a poorer DTT receiver protection ratio when the traffic was gated.

[41] We decided against a medium category because the WSDs either exhibited "bursty" behaviour or they didn't, and the impact of protections ratios was either large or small, so we did not see the need for the medium category.

Wanted signal levels / margin for UKPM prediction errors

7.51 As explained above, the TV signal level in any location (called the "wanted signal") is an important part of the calculation – broadly speaking, in areas with higher signal levels, TV receivers will be better able to tolerate WSD interference. We use detailed data about TV signal levels across the country from the UKPM.

7.52 We have added an allowance for prediction error of 9 dB for co-channel operation compared to our 2013 Consultation proposals. This is applied as a reduction to the maximum allowed signal powers across the board for co-channel operation. This is to ensure that coverage will be robust to WSD interferers even in locations where the UKPM predictions are optimistic. In our measurements, we did observe some large deviations in some localities from the predicted wanted signal levels and those actually observed.

7.53 In practice, this means that channels used for DTT in given area will likely be unusable for WSD in that area, and suffer more restrictions in neighbouring areas where those channels are not in use.

7.54 The additional allowance does not apply to adjacent channels (i.e. for calculations where the WSD and DTT are not operating in the same channel). This is because adjacent channel operation in practice benefits from implicit margins because of the class system, as explained earlier. The end result is that we were able to calibrate our framework so that it would achieve positive margins in the vast majority of our challenging tests, as described earlier, without the need for additional margins in adjacent channels.

Coupling gains

7.55 The power radiated by any WSD will always be significantly attenuated by the path it travels between the WSD transmitter and the TV receiver. This path includes air, obstructions (such as trees, buildings and terrain), antennas, the cable between a TV antenna and a TV receiver, and it may include walls. The attenuation along this path is called the coupling gain. Broadly speaking, the larger this attenuation in relation to the path loss between the DTT transmitter and the TV set, the more power can be allowed to WSD transmissions, because it is the WSD signal level after attenuation that determines whether picture break up will occur or not.

7.56 In the 2013 Consultation, we generated some statistics about where the WSDs may be in relation to the TV aerial, given the coarse DTT location information we have (which is based on a 100m by 100m grid). We used as our reference the 70th percentile, i.e. we set our parameters based on a point within that coarse location which is worse than 70% of points.

7.57 We have also considered measurements from the BBC and Arqiva. Broadly speaking, they indicate that the underlying statistics we used for how the coupling gain behaves for WSD locations near a TV receiver are not far from reality. However, they have argued that the 70th percentile is insufficiently conservative for the model.

7.58 We agree with this argument, both on the basis of analysis they presented (see BBC/Arqiva report[42]) and based on our own "aggregate" measurements (described

[42] WSD Coexistence Testing at the Building Research Establishment: An experimental validation of Ofcom Regulatory Proposals, BBC/Arqiva, Jan 2015 http://www.bbc.co.uk/rd/publications/whitepaper288

above), which showed that some parameters in our model needed to be tightened. For this reason, we have maintained the underlying statistical model, but we have decided instead to set the level more conservatively at the 90th percentile, for cases where DTT and WSD are close together.[43]

Our approach to location uncertainty

How we deal with WSDs whose locations are not accurately known

7.59 In practice, we expect some uncertainty around the locations of WSDs, because:

i) GPS measurements on board devices have a margin of error, which devices will report to the database.

ii) Some devices do not have GPS or other means to report locations (and are called non-geolocated slaves – masters must always report their locations);

iii) In the early phases of connection between masters and slaves, a geolocated slave will have information about its own location, but this will not yet have been passed on to the master and database.

7.60 In each of these cases we take a cautious approach. We calculate power limits that we consider are appropriate for the purposes of ensuring that even where a WSD is in the worst possible location in terms of proximity to a DTT aerial, there would still be a low probability of harmful interference into DTT. This is done channel-by-channel: the worst possible location may be different for two different channels. The "worst possible location" will depend on the case: it may be the worst case within GPS error margins (case i), or the worst case within the potential coverage area of its master (cases ii and iii).

7.61 We recognise that this approach means that we may risk sterilising a larger amount of spectrum than may be strictly necessary in order to be confident that harmful interference is unlikely to occur. However, in adopting this approach we have decided to err on the side of caution because we consider that, on balance, a more stringent restriction on the power levels a device may operate at where it is not able to supply a WSDB with its exact location is appropriate for the purposes of the early stages of WSD authorisation in order to ensure there is a low probability of harmful interference to DTT viewers in their vicinity. For a dynamic spectrum access model that relies on geo-location, it will always be the case that more specific and accurate geo-location data will result in more efficient use of spectrum.

How we deal with uncertainty about the location of DTT receivers within a pixel

7.62 For a given WSD, the framework will need to ensure a low probability of interference both for DTT receivers which may be near to it and for those which may be far away, using different approaches to each as follows. The UKPM divides the country into 100m x 100m squares (pixels), as described earlier. We do not know where within a pixel DTT receivers are, which introduces two questions. One is the distance between the WSD and the DTT receiver. The other is whether the TV aerial will be

[43] That is, when they are both in the same pixel, or no more than 2 pixels away from each other. These are known as tiers 0 (same pixel), 1 (adjacent pixel) and 2 (there is one pixel of separation between the pixel where the WSD sits and that where the DTT receiver sits). More information is provided in Annex 2.

pointing directly at the WSD; TV aerials in general are good at attenuating emissions from directions they are not pointing to. Both of these factors need to be taken into account in our statistical approach about "coupling gains", mentioned earlier.

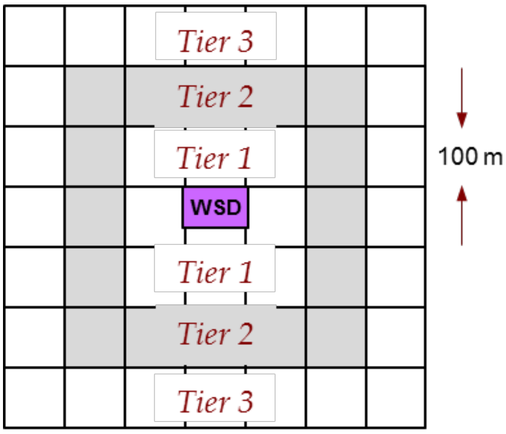
7.63 Because of the coarse granularity implied by pixels, we split the problem in several tiers:

a) When WSD and DTT receivers are very close together (Tiers 0/1). This refers to receivers in the same pixel or neighbouring pixel to the WSD (see Figure 7.4 below). In this case, we rely on statistics for both the distance between WSD and DTT and for whether the DTT antenna is pointing towards the WSD or not. We pick the 90th percentile point within possible locations (i.e. a point that is worse than 90% of the places where the DTT receiver may be).

b) When WSD and DTT receivers are far apart (Tiers 3 and above). This refers to receivers which are 3 pixels away from the WSD. At larger distances, the "low resolution" quality of the pixel approach matters less. For this reason, we simply use the distance and angle between pixels as an estimate of distance and angle between WSD and DTT.

c) A case in between (Tier 2). This refers to the case where there is one pixel of separation between WSD and DTT receiver. In this case, we rely on statistics for the distance between the two, but we use the angle between the two pixels to determine whether the DTT antenna is pointing towards the WSD.

Figure 7.4 - Illustration of "tiers" of pixels in relation to distance to WSD



7.64 This approach is explained in more detail in Annex 2.

Conclusions

7.65 In broad terms, the adjustments to parameters result in tightening the criteria for co-channel WSD-DTT coexistence by an aggregate amount in the region of 19 dB in comparison to the 2013 Consultation proposals. This is the result of:

- tighter coupling gains: when a WSD and a DTT receiver are close together, we use a value for the coupling gain which is worse (imply tighter restrictions on WSDs) than 90% of locations; previously, we had used the 70th percentile instead; and

- an additional 9 dB margin for UKPM prediction errors.

7.66 For adjacent channel WSD-DTT operation, the criteria are tightened by an aggregate amount in the region of 10 dB compared to the 2013 Consultation proposals. This is the result of the tighter coupling gains as explained above.

7.67 We will also tighten WSD constraints relating to DTT in exceptional cases, where the DTT signal predictions of the UKPM are atypically overoptimistic. We are applying this rule initially to the Thanet area, where we will tighten restrictions by an additional 10 dB. We will keep under review whether there is a need to apply a similar treatment to any other areas.

Section 8

Coexistence in relation to PMSE

Introduction

8.1 PMSE services use the UHF TV band in frequencies which are not used by DTT broadcasts in a given location. Because they make use of gaps between DTT use, in some respects they can be thought of as the first devices using white spaces. They use the spectrum, in the vast majority of cases, to provide wireless audio links – for example, when a singer is performing on a stage in a theatre or concert, this spectrum is often used to carry the sound from a microphone held or worn by the singer into a sound system. This section covers:

- PMSE use of the UHF TV band. We detail the different uses PMSE makes of the UHF TV band and how it is licensed.
- Our approach to ensuring a low probability of harmful interference to PMSE services through restricting the power of a WSD signal at the PMSE receiver.
- The way we calculate permitted power levels for different types and classes of WSD and the parameters we have used in those calculations and how they have been informed by stakeholder input and our testing programme.
- How we ensure a low probability of harmful interference for PMSE use in Channel 38.
- Our treatment of a specific interference mechanism: intermodulation.
- An explanation of the changes we have made to our 2013 Consultation proposals and the reasons for these changes.

The PMSE services in the UHF TV band

8.2 There are five main types of PMSE equipment which operate in the UHF TV band:

- Wireless microphones - microphones such as those used by a singer on a stage;
- In-ear monitors (IEMs) – small devices that can typically be plugged into a sound engineer’s ear and are used to monitor programmes; they can similarly be used by performers;
- Talkback – “walkie-talkies” type equipment, used for instance in carrying instructions from a programme director to camera and sound operators;
- Programme audio links - these cover several types of links for carrying audio wirelessly between two points in programme-making, such as between a studio and a transmitter.
- Data links - used for remote control of cameras and other equipment and also for signalling.

8.3 The licences issued in this band are location specific and time-bound; i.e., they authorise the use of the spectrum at specific locations and dates. This is with the exception of UK-wide licences that are issued for use of channel 38 (606 to 614MHz), where the licences do 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 in an uncoordinated manner. News gathering is one service which makes use of channel 38.

8.4 The number of PMSE channels authorised for use depends on the nature of the PMSE event. This can range from a single channel in a small event, up to 40 or more for wireless microphones and IEMs in a major production. The channel frequencies authorised are not based on any specific raster, and are selected to minimise the impact of inter-modulation products and to interleave with other PMSE users. Where multiple PMSE channels are authorised for use, these may span a single 8 MHz DTT channel, or multiple (contiguous or non-contiguous) DTT channels.

8.5 PMSE use can occur both indoor and outdoor. Use can be permanent or ongoing (such as in a West End theatre), or it can be temporary, running from a few hours for a concert, to a few days for a sports event (e.g. the Open Golf Championship) or festival (e.g. Glastonbury).

Ensuring a low probability of harmful interference to PMSE services

Overarching approach

8.6 In the 2013 Consultation we set out a proposed approach to ensuring a low probability of harmful interference to PMSE services. Our approach was based on ensuring an adequate protection ratio between the wanted PMSE signal[44] and any potential interfering white space signal at the PMSE receiver (i.e. the WSD interfering signal should be sufficiently far below the PMSE signal at the same frequencies[45] as not to cause audio degradation). This required us to set parameters for assumed *wanted signal level* at the PMSE receiver and *protection ratios*.

8.7 We use these figures to set a maximum allowed level of interfering signals at the PMSE receiver, which we call our overarching coexistence criterion, because it determines the maximum permitted WSD transmitter powers at any distance from a PMSE receiver (when applied together with a propagation model and information about device class and type). We are confident that this remains a robust methodology and our overall approach has not changed.

8.8 However, following responses to the consultation, our testing programme, and in line with our stated intention of taking an initially cautious approach to ensuring a low probability of harmful interference, we have concluded that there should be some changes to the specific parameters used as set out below.

[44] Wanted PMSE signal, or wanted signal level, is the power at the PMSE receiver which was transmitted by a PMSE transmitter and intended for that receiver – for example, a PMSE system may be designed with a receive antenna which is meant to receive a signal from a nearby wireless microphone. In this example, the wanted signal level is the power at that receive antenna from that wireless microphone.

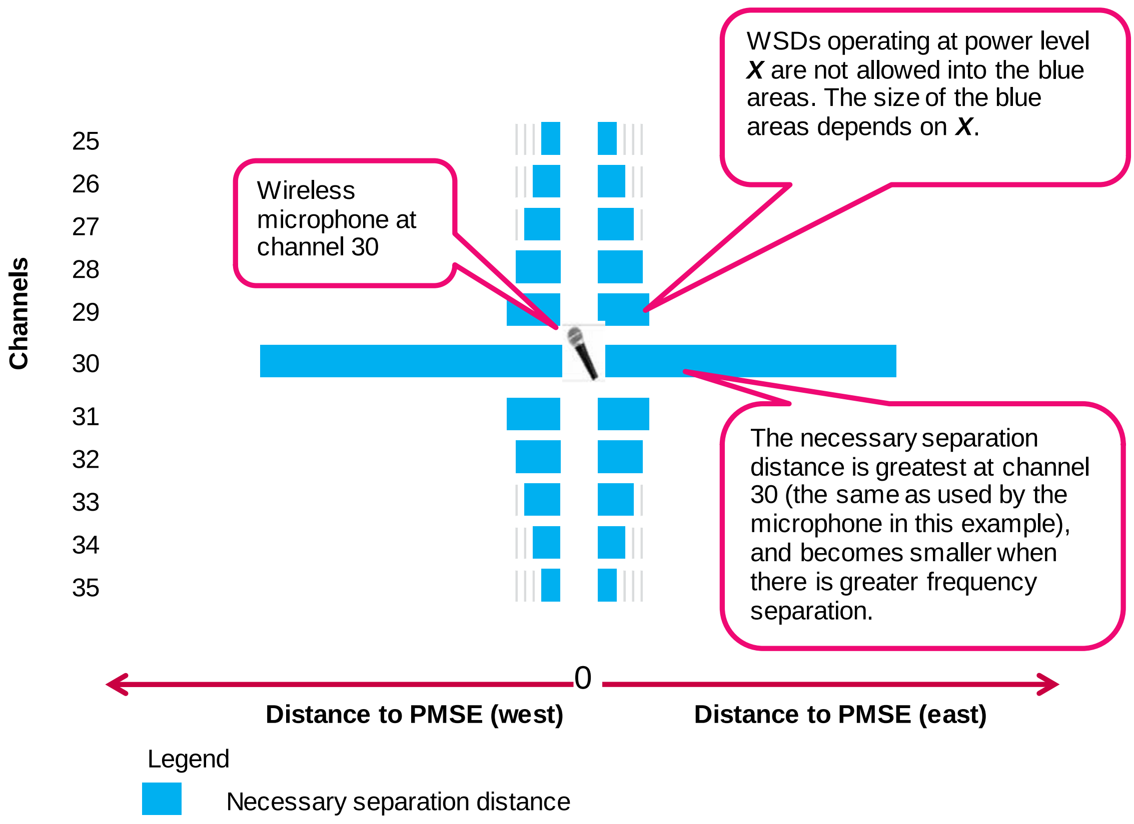
[45] Protection ratios are also calculated for the case where WSD and PMSE are at different frequencies. In this case, the WSD signal level at the PMSE receiver does not necessarily need to be lower than the PMSE wanted signal level.

8.9 In practice, our approach ensures a low probability of interference by ensuring that there is sufficient separation between WSDs and PMSE users, either as physical separation, or frequency separation, or both. This is because when WSDs are physically distant from PMSE equipment, the distance between the two will attenuate the WSD emissions. In addition, PMSE equipment will be most susceptible if WSDs are transmitting in the same frequencies (co-channel); and will be in general less susceptible with greater frequency separation[46].

8.10 The requirement for separation is variable and depends among other things on the characteristics of the WSD, the type of PMSE equipment, and whether WSD and PMSE use occurs indoors or outdoors.

8.11 One way to visualise the approach is shown in Figure 8.1 below. For a WSD which intends to transmit at a given power, the minimum permitted distances to PMSE users are shown in the solid blue bars. The length of the blue bars show that at greater frequency separation, the WSD is allowed to operate at a given power geographically closer to the PMSE device as shown below[47].

Figure 8.1 - Consequences of the framework for separation between WSDs and PMSE (for a given WSD power level)



[46] This is reflected in the protection ratios, which are most strict for co-channel operation and become less strict if there is frequency separation between the WSD transmitter and PMSE receiver.

[47] The example illustrated in Figure 8.1 is expressed in separation distances, which will vary depending on the power required by the device. The database will actually implement this as follows: given a distance from a PMSE user, it will cap powers that can be used. These are two equivalent ways of expressing the same concept: that at shorter distances (in either geography or frequency), less power is allowed, and at longer distances, more power is allowed.

How we used the test results and other evidence to adjust our proposals

8.12 We have calibrated our proposals in light of both “aggregate” and “parameter-by-parameter” comparisons with test results. We conducted laboratory tests and tests in PMSE venues, both during live shows and under controlled conditions. We used the consultation responses and other stakeholder input to identify areas of particular interest for testing[48]. As mentioned earlier in this document, the results of the tests[49] were published in November 2014. We used these results as follows:

- **Aggregate comparisons**. In our “real life” tests, including at a theatre and at an outside broadcast, we operated WSDs at very close proximity to PMSE users at high powers without causing audio-break up. This allowed us to understand the “real life” or aggregate effect of our proposed limits. The aggregate effect of the limits we have set are much lower than those used in the “real life” tests, which means that they would provide a large “safety margin” for those cases tested. This means that, where the particular conditions and equipment used in other PMSE usage scenarios are worse than those used in our testing, interference would still be unlikely to occur.

- **Parameter-by-parameter comparisons**. Based on our laboratory tests and “real life” tests, we have chosen individual parameters that represent a reasonably cautious choice, and in aggregate they represent a cautious reference scenario. The emphasis is on the aggregate effect of these choices: if a particular set-up exceeds the value for one parameter, this does not mean that harmful interference will occur. Even if all values for all parameters are breached, this does not mean that interference will occur.

8.13 As a result of these comparisons, we have reduced the allowed maximum power limits of WSDs operating near PMSE users in order to ensure there will be a low probability of harmful interference to PMSE users. In aggregate, we have tightened our overarching criterion by 27 dB. We have done this by tightening two parameters: assumed wanted signal power at the PMSE receiver and protection ratios; we explain how we have done this below.

8.14 This approach to coexistence with PMSE is based on making conservative assumptions on a number of parameters and reflects our cautious initial approach to setting the coexistence criteria. We consider that this is the correct approach at this early stage of development of the TVWS framework. Consequently we anticipate that we may be able to relax these regulatory limits over time as the market in WSDs develops and we learn more about WS uses and the actual impact of WSD use on existing users.

[48] Areas of particular interest in the consultation response included the wanted PMSE level, protection ratios and intermodulation, and these received particular attention in our testing. Stakeholders have also expressed particular concern with musical theatre and outside broadcasts, which prompted our decisions to conduct tests in these environments. For more on the consultation responses, see Annex 11.

[49] *TV white spaces: PMSE coexistence tests,* November 2014 http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2014/TVWS-PMSE_Coexistence_Technical_Report.pdf

Main aggregate comparisons

8.15 The real-life tests we performed in a theatre and in an outside broadcast suggest that interference at any perceptible level to PMSE users from WSDs would be very unlikely to occur under the framework. In particular:

- We performed tests at Queen's Theatre, a theatre in the West End of London during a rehearsal with full cast for a musical production present. We measured the device as class 3. At 10m separation from a receiver, the framework would allow it to operate at 5.9 dBm/8 MHz on the first adjacent channel. We operated it at 9m separation, and at 28 dBm/8 MHz, during a musical show rehearsal. We were not able to create audio degradation at that power, so it is possible that the "safety margin" in that case was larger.

- We measured *wanted signal levels* in Queen's and other venues. As explained earlier, this is a key parameter in our overarching approach. We found signal levels were generally more likely to dip to very low levels in Queen's compared to the other venues. All other things being equal, wanted signal levels that dip to very low levels make a set up more likely to suffer harmful interference. This helps show that the Queen's Theatre result was not a case where conditions were exceptionally favourable (i.e. where the wanted signal levels present would help avoid harmful interference).

- In an electronic news gathering (ENG) test during an outside event by Radio Derby. We measured the device as class 3. At 10m separation, the framework would allow it to operate at 5.1 dBm/8 MHz on the first adjacent channel. We were able to observe the onset of audio quality degradation at some point between 24-36 dBm/8 MHz (at 9m separation).

8.16 The large "safety margins" that we observed at these tests suggest that our rules will very likely be able to accommodate a wide variety of PMSE use even if the set-up is, for some reason, more vulnerable to interference than those we tested, or if a particular type of WSD happens to be more likely to create interference than those we used in our tests.

<u>Implications in terms of distances</u>

8.17 In terms of necessary separations between a PMSE receiver and a WSD, a 36 dBm type A WSD will only be able to operate at a distance of 440m from an indoor PMSE assignment, when both are using the same channel (in an urban environment). The comparable distance, using the 2013 Consultation parameters, was 90m.

8.18 These distances will increase if the PMSE assignment is in a suburban environment (to 800m in the example above); or if the PMSE user is outdoor (to 700m for urban or 1260m for suburban).

8.19 All of the distances above are calculated before our approach to location uncertainty is taken into account, which in practice can only increase the actual separations (as explained later in this Section).

Main parameter-by-parameter comparisons

Wanted PMSE signal

8.20 The wanted PMSE signal level will vary over time and between uses. In our model, the lower the wanted signal level is, the lower the WSD signal at the PMSE receiver would need to be in order to protect against interference. The databases will not know the actual wanted power levels of any given PMSE user, so for the purposes of setting regulatory limits this is one of the parameters we set as part of a cautious scenario that appropriately reflects actual current usage. Over-estimating the wanted signal level in our reference scenario would lead to a risk of interference to PMSE users. Under-estimating it would prevent white space use unnecessarily.

8.21 The tests showed that the wanted signal power at the PMSE receiver can suffer from significant fading due to the rich scattering environment, varying from as high as -30 dBm down to values well below the nominal operating level of -65 dBm which we had assumed in our 2013 coexistence consultation. The tests also showed that the protection ratios for PMSE equipment are greater (PMSE equipment is more susceptible to WSD radiation) than the values we had proposed in our 2013 Consultation.

8.22 In the 2013 Consultation we proposed using a level of -65 dBm for all PMSE uses, other than Programme Audio Links which were set at -73 dBm. These values were based on the default PMSE field strengths for protection under the Geneva 2006 (GE06) Agreement.

8.23 In view of the tests, we decided to set the wanted signal level for all PMSE users at -78 dBm[50]. This is because:

- Our observations of PMSE signal power statistics at Queen’s Theatre, the New London Theatre, Wembley Arena and at a live broadcast by Radio Derby the wanted signal level very rarely dipped below this (3% of time in Queen’s theatre, less than that in other venues[51]).

- In the lab, we demonstrated PMSE equipment we tested had sensitivity levels of between -75 dBm and -88 dBm. We would expect users in general to operate their equipment well above the sensitivity level, as otherwise they would be exposed to audio degradation caused by relatively small changes in the environment even in the absence of WSDs.

Protection ratios

8.24 In order to calculate the protection ratios we have to understand how susceptible the PMSE device is to interference from the WSD. In the 2013 Consultation we proposed appropriate protection ratios for each class of WSD, and each PMSE type, at different channel offsets. We have since carried out more tests, and changed the way in which we test.

8.25 These additional laboratory protection ratio tests were designed to detect very small audio effects, even some which may not necessarily be perceptible, for example, to an audience in a theatre. Note that the level of audio quality used in the

[50] Except for programme video links, for which we set -65 dBm/8 MHz, as explained in Annex 4.
[51] On the basis of a one second wanted signal average.

measurements is not intended to reflect any view of what might constitute ‘harmful interference’: it was necessary to set a consistent level of audio quality across all tests to ensure comparable results, and we set the highest level we could measure given our initially cautious approach. This is explained in detail in the test report.

8.26 As a result, the protection ratios which we have measured in the laboratory are greater (represent a greater susceptibility to WSD interference) than the values we had measured in preparing the 2013 Consultation.

8.27 In measuring these protection ratios we were cautious in a number of ways which are not explicitly taken into account in our model:

- Our protection ratios are based on a worst case in terms of frequency. Each WSD channel is 8 MHz wide. PMSE microphones typically use 200 kHz – that means that the 8 MHz channel contains in practice 40 possible slots where the microphone could operate. We measured protection ratios for adjacent channels by placing the PMSE microphone in the worst possible slot – i.e. the one closest to the WSD.

- Our protection ratios are based on a worst case in terms of the WSD behaviour – when they are continuously transmitting.

- Our protection ratios are based on the audio sample least likely to “mask” audio degradation – we found piano samples would not mask the type of background hiss that WSDs could create. We found that, when listening to speech, the same background hiss would often be imperceptible.

Additional assurance that the probability of harmful interference will be low

8.28 In addition to the margins and benchmarks above, we have adopted a conservative approach in respect of additional elements of our framework:

- When we account for WSD location uncertainty (as explained later in this section) we add an extra layer of conservatism by assuming that the WSD is in the worst possible location it could be within the margin of error for its location.

- Protection ratios were measured using the worst case conditions – as described earlier.

8.29 Even if, in an unlikely case, the whole “safety margin” is used up, this does not necessarily mean that sound degradation will be perceptible. These parameters are based on protection ratios at a point where audio degradation is barely perceptible for listeners who are specifically listening for interference, in a quiet environment, with closed headphones. In a theatre environment, or during news broadcasts, for an audience without closed headphones the same levels of audio degradation may well be imperceptible.

Approach to location uncertainty

8.30 As explained in the DTT section, we expect some uncertainty around the location of all WSDs, either because:

- GPS measurements made by devices have a margin of error, which devices will report to the database;
- Some devices do not have GPS or other means to report locations (and are called non-geolocated slaves – masters must always report location); or
- In the early phases of connection between masters and slaves, a geolocated slave will have information about its own location, but this will not yet have been passed on to the master and database.

8.31 In each of those cases we take a cautious approach. If there is a PMSE user within the possible locations where a WSD may be (called “candidate locations”), we consider that WSD and PMSE users are within 10m of each other. These candidate locations are defined as follows:

- If there is no reported location for a slave, either because the slave is non-geolocated or because it is in an early stage of its connection with a master, the candidate locations are those within the master’s potential coverage area. This potential coverage area is calculated using a cautious approach taking into account the area that the master could potentially reach;
- Where the uncertainty is caused by an error margin reported by the device, the candidate locations are those within an area which is the size of the error margin.

8.32 We then calculate power limits such that a WSD in that worst possible location would still meet a low probability of harmful interference. This is done channel-by-channel: the worst possible location may be different for two different channels. The approach is explained further in Annex 1 in particular at paragraphs A1.27 – 1.29.

8.33 We recognise that this approach means that we may risk sterilising a larger amount of spectrum than is strictly necessary in order to be confident that harmful interference is unlikely to occur. However, in adopting this approach we have decided to err on the side of caution because we consider that, on balance, a more stringent restriction on the power levels a device may operate at where it is not able to supply a WSDB with its exact location is appropriate for the purposes of the early stages of WSD authorisation in order to ensure there is a low probability of harmful interference to PMSE users in their vicinity.

Uncertainty about location of PMSE equipment within known venues

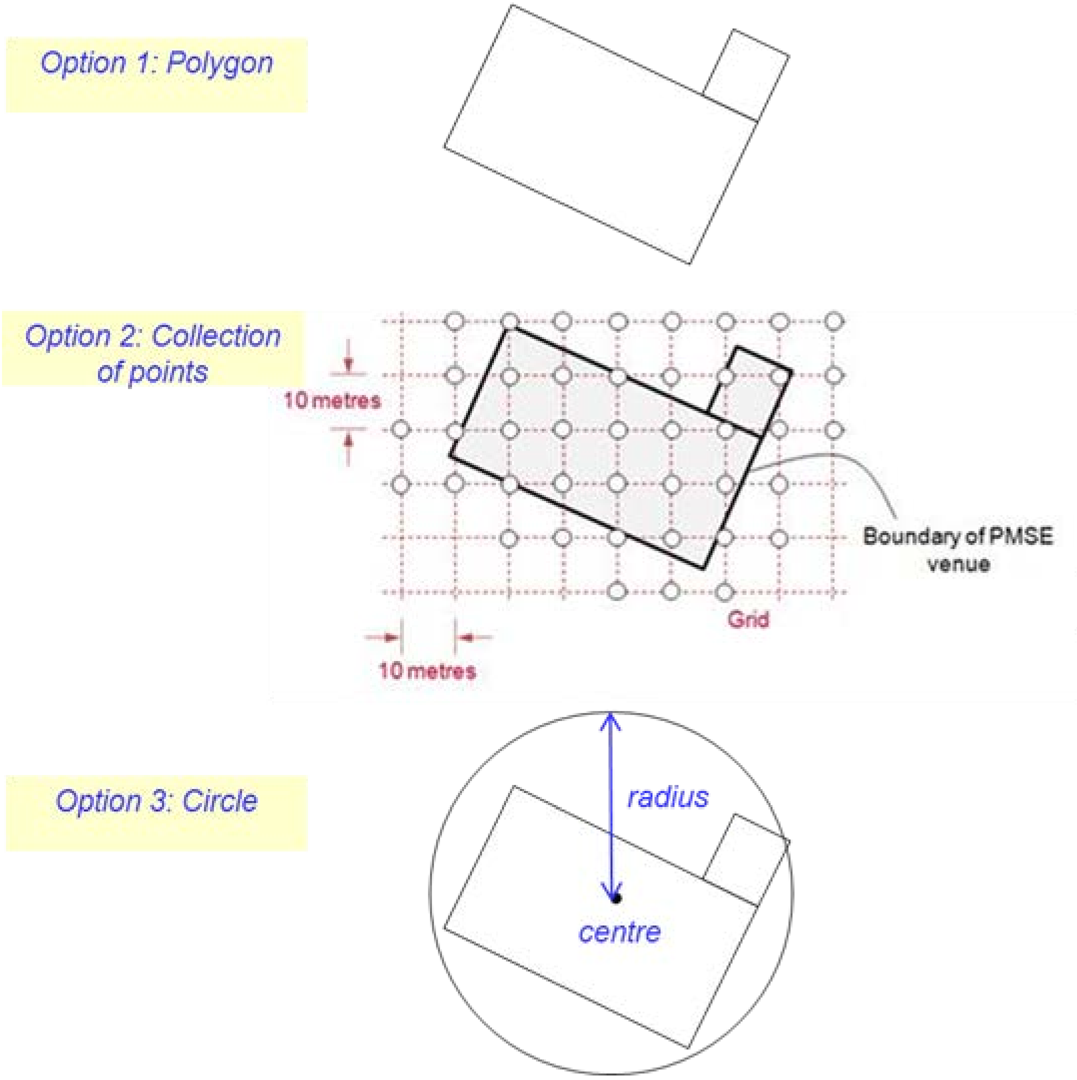
8.34 The location of PMSE users is registered as a single point in the database. Some PMSE venues are very large, which means that there is in practice some additional uncertainty about the location of PMSE equipment.

8.35 It is our intention in due course to implement a system that will include information about the boundaries of known venues so that this additional uncertainty is taken into account. We will not necessarily need information about every possible PMSE venue, but will be particularly interested in venues which are large, where a very high audio quality is very critical, or where there is some other risk factor. This is because our framework already implies safety margins as explained above, which will mitigate any risks associated with that.

8.36 There are a number of possible implementations of venue boundaries we are currently considering, as detailed below:

- **Polygons**: We could provide the database with a table with one polygon per venue, described by a list of vertices.
- **A collection of points:** We could overlay a polygon on a 10m by 10m grid and provide databases with a list of points that described the position of the venue. This is similar to providing a very low resolution picture of venue boundaries.
- **A circle**. We could represent each venue simply as a circle, represented by a centre and a radius.

Figure 8.2 - Options for defining PMSE venue boundaries



8.37 We believe any of these implementations would be adequate in terms of managing risks of harmful interference into PMSE receivers. Our current preferred approach is to use polygons as they are more accurate than the alternatives, but we will confirm this when we have evaluated the practical implementation consequences further.

8.38 Our intention is to include information about venue boundaries, where appropriate, in the framework from the time when it becomes operationally active. However, if it becomes clear that it would be impractical to achieve this we will consider at the time how to proceed, including for example by adopting some additional interim restrictions.

8.39 Once venue boundaries are implemented, we intend to require that the databases, when calculating the distance between a PMSE assignment and a WSD, consider that the PMSE receiver could be anywhere within a venue, and therefore the relevant distance is that between the WSD and the closest point within the venue[52].

8.40 As part of our initially cautious approach, when a geolocated device is known (within its margin of error) to be inside the identified boundaries of a PMSE venue at a time when that venue has an active assignment, we intend to deny any White Space availability to that device. This is to avoid audiences in theatres and live events operating mobile white space devices within a venue. In principle, in such a scenario, the probability that they could be extremely close to a PMSE receive antenna is greater than in other cases – i.e. when it has not been established that the WSD is within the venue. If WSDs and PMSE receivers are extremely close, there is a greater risk that the safety margin implicitly built into our framework will be used up.

8.41 An undesirable but unavoidable consequence of this approach is that devices that are near a venue but where the error margins of their geolocation capability indicates that they could be inside the venue will also be denied availability.

8.42 We will not apply the same logic to non-geolocated devices. This is because a non-geolocated device could be anywhere within a large area, and the probability that it will find itself extremely close to a PMSE receive antenna is much smaller than in the case of a geolocated device that reports that it is inside a venue. In addition, non-geolocated devices in practice will be subject to our cautious approach to location uncertainty, as explained in paragraphs 8.30 to 8.33. This will typically result in lower allowable powers for non-geolocated devices compared to geolocated devices, therefore reducing further the probability that it will cause harmful interference.

Approach to intermodulation products

8.43 This section explains how our framework will deal with an interference mechanism called intermodulation. Transmitter intermodulation occurs within a radio microphone transmitter when a strong radio signal from another transmitter is received at the radio microphone transmitter. These intermodulation products can be created between radio microphones, and PMSE users will manage their use to minimise the risk of these effects occurring.

8.44 Intermodulation may occur when:

- two transmitters operating at different frequencies are close to each other. These may be two WSD transmitters or a WSD transmitter and a PMSE transmitter; and
- these transmitters, interacting with each other, generate a residual signal at a third frequency, not originally used by either transmitter.

8.45 This residual signal will have lower power than the original signal which caused it. In the context of WSD – PMSE coexistence, such a signal may represent a risk if it coincides with the frequency of a nearby PMSE receiver.

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[52] As in paragraph 8.31, if this distance is below 10 meters we will consider the distance as 10 meters.

8.46 Such a scenario requires a degree of coincidence to occur. The two transmitters and the victim PMSE receiver must be in close proximity. The frequencies used by the transmitters must be such that the intermodulation product coincides with that of the nearby PMSE receiver.

8.47 When they do occur, the interference effect occurs on a different frequency to the one originally transmitted by the WSD. Because the frequency of the intermodulation product is hard to predict, we need to constrain power at all channels for devices that are close to a PMSE user. This is a mechanism we did not address in the 2013 Consultation proposals.

8.48 We have therefore adopted an approach which takes account of the risk of intermodulation as follows:

- We will apply constraints that apply at all frequencies when WSD and PMSE are very close together, for the reasons explained above. We used the results of our tests to derive constraints, as explained in Annex 4. For example, a WSD 10m away from a PMSE receiver operating at the same height, would be restricted to no more than 26 dBm/8 MHz in all channels to satisfy the intermodulation constraints.

8.49 As elsewhere in the framework, the database will identify the most stringent power limits in each channel before providing operating parameters to a WSD, so in any situation where the power limits required to protect against intermodulation are more stringent than those required to protect against adjacent channel leakage or interference to DTT the WSD will be subject to the limits required to protect against intermodulation.

Intermodulation products created in WSD transmitters

8.50 Our laboratory tests only produced evidence of intermodulation products created in PMSE transmitters (i.e. a WSD transmission enters a PMSE transmitter, and the latter creates an intermodulation product).

8.51 In theory, it would also be possible for these to be created in WSD transmitters (a WSD or PMSE transmission enters a WSD transmitter, which then creates an intermodulation product). However, all the WSDs we obtained and tested in laboratory performed sufficiently well that in the most part we were unable to create this type of intermodulation in the laboratory[53].

8.52 On the single occasion when we were able to create an intermodulation product in a WSD this was at sufficiently low levels so as not to create any significant risk of harmful interference in the context of this framework.

8.53 For these reasons we have not introduced limits into the framework to take account of WSD to WSD intermodulation at this time. However, this position is based on the WSDs we have observed, which perform significantly better than specified in the ETSI Harmonised Standard. We will therefore:

- Continue to argue at ETSI that better standards in this respect should be required.

[53] For the most part any intermodulation products present were too weak to be measured by the laboratory equipment and would therefore not create any significant risk of harmful interference.

- Consider this issue again when we next review our framework, in light of any developments of new WSD equipment.

Approach relating to protecting PMSE users in channel 38

8.54 The overall approach described above requires us to know where the PMSE user and the WSD are. We have described already how we deal with cases when the location of the WSD is uncertain. However, we also have to deal with the case when the location of the PMSE user is unknown, that is, for PMSE users in Channel 38.

8.55 As a starting point, we need to guard against co-channel interference to PMSE use by WSDs. As set out in the 2013 Consultation we remove this risk by preventing any WSD use in channel 38.

8.56 We then need to address the risk from WSD use in adjacent bands. We have approached this in much the same way as for the protection of PMSE use in other channels as set out above. In this case however, in the absence of any information on the location of a potential PMSE user, we make an assumption about the possible distances between the WSD and any potential PMSE user. In order to derive assumptions about the likely distance between WSDs and PMSE users we considered both indoor and outdoor PMSE uses and the different characteristics of fixed and mobile WSD use.

8.57 We considered the following reference scenarios, adopting a cautious approach:

i) A theatre production. A WSD base station (type A device) just outside the theatre, 20m away from the PMSE receiver.

ii) A theatre production. A portable WSD (type B device) in the front row of the audience, 10m away from the PMSE receiver, and held by an audience member.

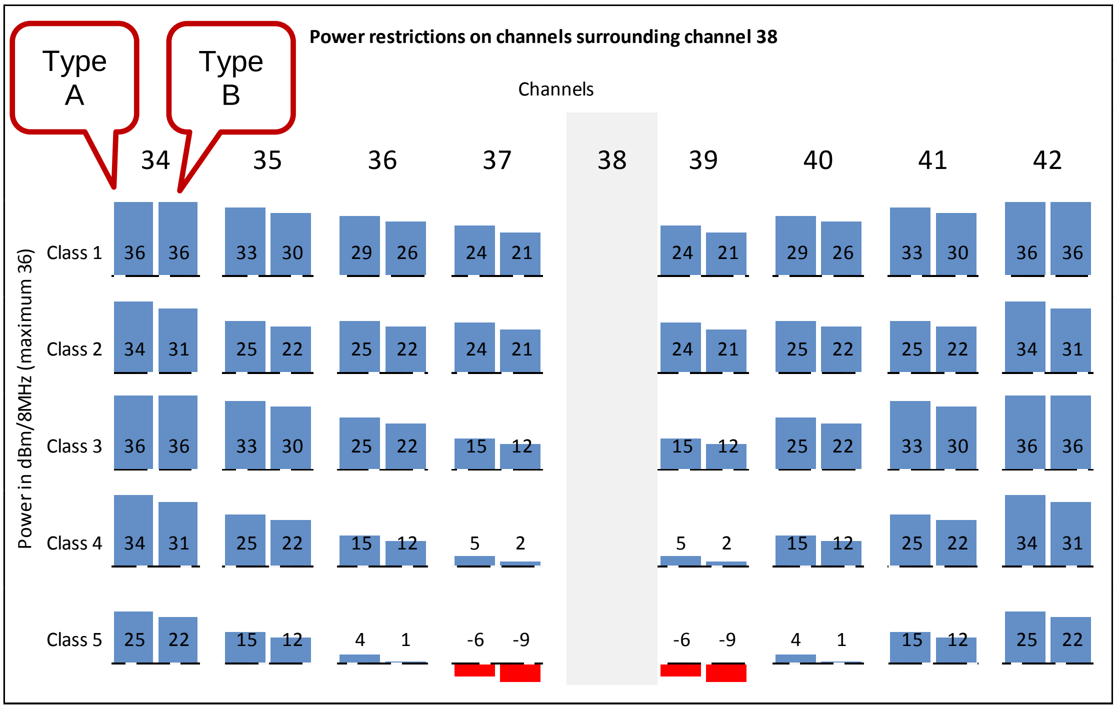
iii) An outside broadcast. A base station is 30m away from the broadcast equipment. We used a larger separation distance than in scenario (i) because users in an outside broadcast are more able to spot a base station and move a few meters away from it.

iv) An outside broadcast. A passer-by is carrying a WSD, 10m away from the broadcaster's equipment.

8.58 Our calculations show that the outside broadcast was the most vulnerable case, so we based our parameters on scenarios (iii) and (iv). Apart from the inputs above[54], we have applied the same values for wanted PMSE signal and protection ratios as for other PMSE use. We then apply the framework in the same way as for PMSE users whose location is known, but in this case we apply power restrictions on White Space use in channels 34-37 and channels 38-41 throughout the UK, as shown in Figure 8.3. These parameters are significantly more restrictive than the proposals in the 2013 Consultation.

[54] The parameters include body loss for the scenario where a WSD is held by someone.

Figure 8.3 - Power restrictions on channels surrounding channel 38



In the figure, there are two vertical bars relating to each channel. The bar to the left shows the restriction for type A devices and the bar to the right shows the restriction for type B devices.

What happens in a scenario for channel 38 which is 'worse' than our "reference scenario"?

8.59 We have conducted the real-life tests under more challenging conditions than those in the reference scenarios. We have found that we could not create any audio degradation even at powers much above those described:[55]

- Our tests at Queen's Theatre, with full cast present. We operated a class 3 WSD at 28 dBm at 9 meters from the PMSE receive antenna with no observed audio degradation. The device was not handheld, which makes it even more challenging (holding a device attenuates its radiated power; this is known as "body loss"). This was 13 dB/16 dB (for type A / type B) above the allowed power in our framework (15/12 dBm).

- In an electronic news gathering (ENG) test, during an outside event by Radio Derby, we created "stress test" conditions with a WSD "base station" parked directly in front of the bus which included the ENG radio microphone receive antenna, at the same height and with 8m of horizontal separation. Again the WSD was not handheld. Even in these conditions, and at the limit of their range, we could not hear degradation when the WSD was transmitting at 24 dBm, but we could hear some at 36 dBm. This means the onset of audio quality degradation occurred between 9-26 dB above the parameters set out above.

[55] Again, see our test report for more details: *TV white spaces: PMSE coexistence tests,* November 2014 http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2014/TVWS-PMSE_Coexistence_Technical_Report.pdf

- As mentioned earlier in this section, our measurements of wanted signal levels in other PMSE venues help suggest that that the Queen's Theatre result was not a case where conditions were exceptionally favourable (i.e. where the wanted signal levels present would help avoid harmful interference).

How likely is it that scenarios such as these or worse will arise?

8.60 In practice, for a given PMSE user at channel 38, a number of coincidences would be required before conditions similar to these "stress tests" could arise. In mathematical jargon, the aggregate probability of our stress test scenario could be decomposed into a number of uncorrelated random variables:

- The PMSE user would have to be very close to a WSD. Even if in a future proliferation of WSDs scenario one in every hundred channel 38 microphones happens to be very close to a WSD, this alone would reduce the aggregate probability of such a scenario arising for a given channel 38 microphone by a factor of one hundred.

- White Space channels next to channel 38 (especially channel 37 and 39) would need to be available. Very often, this will not be the case. In the West End, and for big events, PMSE users tend to take up every available channel, further reducing the probability that a WSD would be able to operate at all anywhere near the places where most professional use occurs. If availability exists at greater frequency separation, the likelihood of audio degradation goes down.

- Where a channel close to 38 is available, the WSD will need to have chosen such a channel– out of a maximum of 39 channels possible.

- A WSD would need to have chosen a power close to the maximum allowed. For example, a class 1, type A device would be allowed to transmit at 24 dB at channel 37; however many devices may only need a small fraction of this power, which would make interference less likely. For example, a study has shown that mobile phones, despite being able to transmit up to 24 dBm, spend 90% of their time transmitting at no more than 8 dBm[56]. In practice, high powered WSDs tend to be base stations which are very unlikely to be situated within 10m of a stage, and that can be easily be spotted and avoided by a TV crew (in the case of an outside broadcast).

- The simple fact that someone carrying a WSD operating on channel 37 happens to pass by a channel 38 user would not be sufficient for harmful interference to be caused; it would need to transmit at the same time that a wireless microphone is in use.

8.61 While many of the points above are fairly obvious, each of them do nonetheless further reduce the real life probability of a scenario similar to those described above. Even if all of these circumstances were to occur simultaneously (which we consider is unlikely), we would still expect to see a positive safety margin.

8.62 In setting the constraints above, we have also considered the potential for intermodulation products, but have found that this was not a dominant constraint.

[56] ITU document 5-6/81-E "Additional System Characteristics of an operational IMT network deployed in Australia in the 800 MHz band".

Impact of the PMSE coexistence rules

8.63 We recognise that the combined effect of the decisions set out here constitutes a relatively large change from the 2013 Consultation proposals: we are 27 dB stricter. In other words we now require that the WSD interference level present at a PMSE receiver, in the channel used by the PMSE receiver, should be 27 dB lower than that allowed by the 2013 Consultation proposals. We have also similarly reviewed the powers allowed at adjacent channels to those in local use by PMSE, and channels adjacent to channel 38 UK-wide. We have also introduced a new equation to deal with the intermodulation mechanism. We consider that these changes are appropriate in order to ensure there is a low probability of harmful interference to PMSE users in the early stages of WSD authorisation. We will consider whether there may be scope to refine or relax these parameters in future where appropriate.

Section 9

Coexistence in relation to users above and below the TV band, and cross border issues

Introduction

9.1 This section explains the measures we will adopt to ensure a low probability of harmful interference to users above and below the band, and in neighbouring countries within the band:

- *4G services.* The 800 MHz band (791 to 862MHz) is adjacent to the top end of the UHF TV band and is used for 4G mobile deployment. We have decided not to allow WSDs to operate in channel 60 of the UHF TV band in order to ensure low probability of harmful interference to 4G services;

- *Services below the band.* Frequencies between 450 and 470MHz 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 consider that the parameters we set out below place appropriate constraints on WSD operation in the lower frequencies of the band to ensure a low probability of harmful interference to these services;

- *Cross-border implications.* The UHF TV band is in use primarily for DTT in neighbouring countries. We outline the restrictions we will put in place to ensure use of WSDs in the UK will not cause harmful interference to our neighbours.

9.2 The parameters explained below for 4G services and cross-border issues are unchanged from those in our 2013 Consultation. We have made the parameters for services below the band stricter than those proposed in the 2013 Consultation.

4G services

9.3 The frequencies immediately above the UHF TV band (800 MHz band) are used for 4G mobile. In our 2013 Consultation we proposed not to allow WSDs to operate in channel 60 (the channel at the top of the UHF TV band, and the one closest to 4G services), but explained that we did not consider it necessary to restrict WSD operation in channels 59 and below.

9.4 We have decided to adopt these proposals and explain below at a high level why we believe this will meet our goal of a low probability of harmful interference. Annex 6 presents this analysis in more detail. Details of the responses on this topic are in Annex 11.

How the 4G network operates in the 800 MHz band

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

9.6 For 4G services in the 800 MHz band, this is reversed, meaning that downlink communications from base stations to mobile devices 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 devices rather than base stations as their receivers are further away from the UHF TV band.

Existing interference to mobile devices

9.7 4G mobile devices are subject to some adjacent channel interference as part of their normal operation: including interference from other mobile devices, and interference from base stations (in particular mobile devices and base stations operated by networks other than the network used by the mobile station).

9.8 Mobile devices experience much more interference from base stations in adjacent channels than from other mobile devices. 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

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

9.10 We consider that we can meet our objective of ensuring a low probability of harmful interference to 4G services because we consider that the risk of interference from TVWS devices is lower than that of interference which may be experienced from base stations in adjacent channels.

9.11 Our detailed calculations in Annex 6 indicate that the levels of interference experienced by mobile devices are potentially higher from the base station than a WSD operating in channel 60. 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.

9.12 A mobile device may, however, be considerably closer to a WSD than to an adjacent channel base station. As a result, the mobile device 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 cause a degradation in the service. We will therefore adopt a guard band at channel 60, meaning that no WSD could operate using that channel.

9.13 Our analysis indicates that interference levels from WSDs operating in channels 59 and below, and which are filtered by the duplex filter in the mobile will be lower than potential interference from base stations, even when WSD and mobile device are at close range. Therefore we do not consider that any additional restrictions are required below channel 60 to ensure a low probability of harmful interference to 4G services.

Services below the UHF TV band

9.14 There are a large number of different users of spectrum close to the lower end of the UHF TV band, between 450 and 470MHz (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.

9.15 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).

9.16 We explain below at high level the revised rules and why we believe they will meet our goal of a low probability of harmful interference. Annex 7 presents this analysis in more detail. Details of the responses on this topic are in Annex 11.

Revised rules

9.17 Figure 9.1 below shows our revised rules for the bottom of the UHF TV band. The rows show different classes of devices and the columns show different channels. Channel 21, being closest to the band edge, faces the most stringent cap. Class 1 devices, which have the least power leakage into adjacent channels, face the least restrictive constraints.

Figure 9.1 - Rules for channels 21 to 24

Ensuring a low probability of harmful interference to services below the UHF TV band

9.18 There is a variety of uses in the band, and our intention is that all such uses should face a low probability of harmful interference. We have not looked at all such uses individually. Instead, we have used breathing apparatus equipment used by the Fire and Rescue Service as a reference. 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.

9.19 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 devices on breathing apparatus.

9.20 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.

9.21 The preferred means of protecting services below the band proposed in our 2013 Consultation was to restrict the level of unwanted WSD emissions below 470 MHz.

9.22 A reduction of this nature was not adopted as part of the ETSI Harmonised Standard[57]. We have therefore developed the alternative approach presented in the 2013 Consultation which was to introduce class-specific restrictions on the in-block EIRPs of WSDs in channels 21 to 24.

9.23 These restrictions have the effect of reducing the out-of-band emissions below 470 MHz to a level of -44 dBm/(100 kHz), irrespective of the maximum power of the WSD.

Cross-border issues

9.24 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.

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

9.26 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

[57] It was considered that the proposed reduction was a UK specific requirement since no other jurisdictions within Europe had licensed breathing apparatus in this band.

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.

9.27 The GE06 Plan specifies the following trigger field strength levels[58] used for the protection of broadcasting services:

Table 9.1 - 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

9.28 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.

9.29 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).

9.30 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. In the future, we could improve on this starting point via bilateral coordination with neighbouring countries, which would allow us to include information in the framework about what channels are actually in use in areas close to UK borders and coast. This would improve White Space availability.

9.31 This approach is the same as that proposed in the 2013 Consultation. We have invited feedback in the UK and internationally and received little comment, but the comments we have received have been generally favourable. We remain of the view that this is an appropriate approach. Therefore we will calculate the maximum allowed WSD power at any location and channel such that the GE06 international co-ordination trigger thresholds are not exceeded 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 decisions for white space availability

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

[58] 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 174-230MHz and 470-862MHz (RRC-06) Geneva, 15 May - 16 June 2006.

9.33 Figures 9.2 and 9.3 show the resulting WSD power restrictions in the areas near the Isle of Wight and Dover, for 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.

Figure 9.2 - TVWS availability on the Isle of Wight in channel 21

Figure 9.3 - TVWS availability near Folkestone and Dover in channel 21

Section 10

White Space availability

Introduction

10.1 In this section we present some illustrative information on the likely TVWS availability which will exist under the framework as set out in this Statement. The information is only illustrative for a number of reasons. In particular the simulations have been generated using the tools currently available to Ofcom and these do not completely implement the framework in all respects and have not been completely verified. Through the process of implementing the TVWS framework Ofcom will be improving its tools and qualifying WSDBs. When that process is complete more accurate and comprehensive TVWS availability information will be available. However, we believe the information presented in this section provides a useful indication of the likely availability.

10.2 As explained in this Statement we have changed the detail of our approach to coexistence in a number of areas to impose more restrictions on WSDs as we believe this is necessary to achieve our objective of a low probability of harmful interference to other services in and adjacent to the UHF TV band. The consequence of this is that TVWS availability is reduced compared to that which we estimated based on our 2013 Consultation proposals. As we illustrate below in some cases there remains a significant amount of TVWS spectrum availability but in others availability is limited. As expected the amount of spectrum available is particularly dependent upon the required power of a WSD and its location.

Scenarios for TVWS availability

10.3 The potential uses of TVWS are still being considered by the industry and so there remains uncertainty about what sort of TVWS availability will be important to allow the technology to be deployed. Also our framework allows considerable flexibility in the type of deployment that could be undertaken as it accommodates for example both fixed and portable devices, devices with varying classes of emission (the extent to which emissions of the device leak into adjacent channels) and different WSD antenna heights. Accordingly there are many potential scenarios for which TVWS availability information could be presented.

10.4 In the light of feedback from stakeholders on the potential use cases and the types of deployment in the Pilot we have selected 4 scenarios which we believe provide a useful indication of the opportunity created by the implementation of the TVWS framework in the UK. The scenarios are set out in Table 10.1 below together with some brief comments on the potential use cases and types of WSD to which they may relate.

Table 10.1 - Specification of scenarios for TVWS availability

Scenario	WSD type	WSD class	WSD antenna height (m)	Location uncertainty (m)	Relevant use cases / deployment types
(a)	Fixed (Type A) Geolocated	1	10	5 (outdoor)	Could be relevant for base stations or access points, for example for a rural broadband network, machine to machine sensor network, a public / municipal Wi-Fi network, or backhaul e.g. for web cams
(b)	Fixed (Type A) Geolocated	1	5	5 (outdoor)	Same as scenario (b) but could also be relevant for home Wi-Fi networks
(c)	Portable/ mobile (Type B) Geolocated	1	1.5	150m (outdoor)	Could be relevant for home Wi-Fi access points, client devices including range extenders for Wi-Fi and broadband networks, for digital signage deployments, and sensor equipment in machine to machine network
(d)	Portable/ mobile (Type B) Geolocated	4	1.5	150m (outdoor)	Same as scenario (c) but at a lower emissions class, so potentially more relevant to cases where the cost of equipment needs to be low

10.5 TVWS availability varies significantly depending on the location of the WSDs because the strength of the signal of the DTT networks is different in different locations, and PMSE use is generally location specific, and there are many areas of the UK where there is little or no PMSE use of the UHF TV band. Accordingly, it is useful to examine availability both in terms of summary UK wide statistics and also in some particular geographical areas. We have selected a variety of locations for illustration consisting of 10 km by 10 km areas in: Central London, Glasgow, Croydon, Milton Keynes, and the Yorkshire Dales.[59] We believe these represent some variety in terms of urban, suburban, rural, extent of PMSE use and DTT coverage.

10.6 For practical reasons we present different TVWS availability information for the UK wide cases and particular geographical areas.

- The potential UK-wide TVWS availability information only takes account of our approach to coexistence with UK DTT, and the removal of Channel 38 and 60. It does not take account of our other location agnostic restrictions and those to take account of PMSE use and cross border restrictions. Also as explained below it does not reflect our approach to protect the DTT transmitter in actual use.

- The potential TVWS availability in the selected geographical areas takes account of the required restrictions to implement our approach to coexistence[60], although as discussed in Section 8 we have not yet implemented the PMSE

[59] The actual simulation area is a subset to ensure that all constraints are included.
[60] Note that in the simulations channel 21 is excluded completely.

venue boundaries approach and therefore the simulations continue to use the existing pilot approach in which each PMSE assignment is treated as a single location. In areas of significant PMSE use, such as Central London, this change is likely to reduce availability relative to that shown in the simulations. The simulations take a snap shot of PMSE use of the band on 25 August 2014.

UK-wide availability

10.7 Figures 10.1 to 10.4 show the statistics of TVWS availability at every 100 metre x 100 metre pixel throughout the UK for scenarios (a) to (d) set out in Table 10.1. We have calculated TVWS availability taking account of DTT at every 100 metre × 100 metre pixel in the UK in all channels in the UHF TV band except for channels 38 and 60 which are excluded. The figures below show the percentage of households where a given minimum number of 8 MHz 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.

10.8 As explained in Section 7 our policy is to protect the DTT transmitter in actual use in each location. Typically we therefore will only protect a single transmitter for a given pixel, although there are circumstances where we may depart from this in the light of clear evidence of alternative or additional transmitters actually being in use. However, we have not yet incorporated any additional information on actual transmitter usage into the tool we have been using to calculate TVWS availability for the purposes of this Statement. Thus the figures and maps shown below are based on existing datasets in which protection is based on the best main station coverage, the best Nations 3PSB coverage and the best 'other' 3PSB coverage. Therefore, although in most areas of the UK, only one transmitting station would be in use in a given pixel, there are some areas where white space availability will have been reduced because the channels used by two or three transmitters are considered protected.

10.9 The following charts show UK-wide availability for scenarios (a) to (d) only taking account of UK DTT use and the exclusion of channel 38 and 60 for a range of power levels.

Figure 10.1 - Scenario (a) WSD antenna height at 10m and class 1

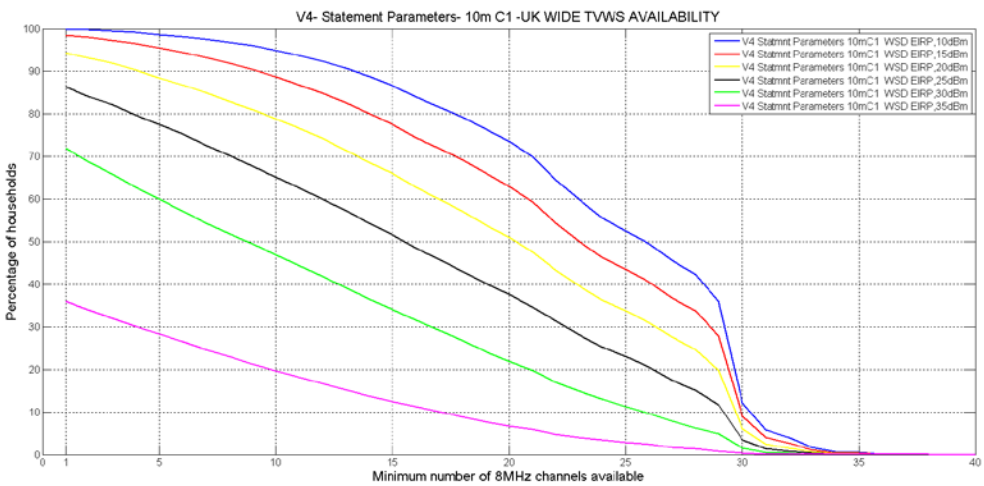


Figure 10.2 - Scenario (b) WSD antenna height at 5m and class 1

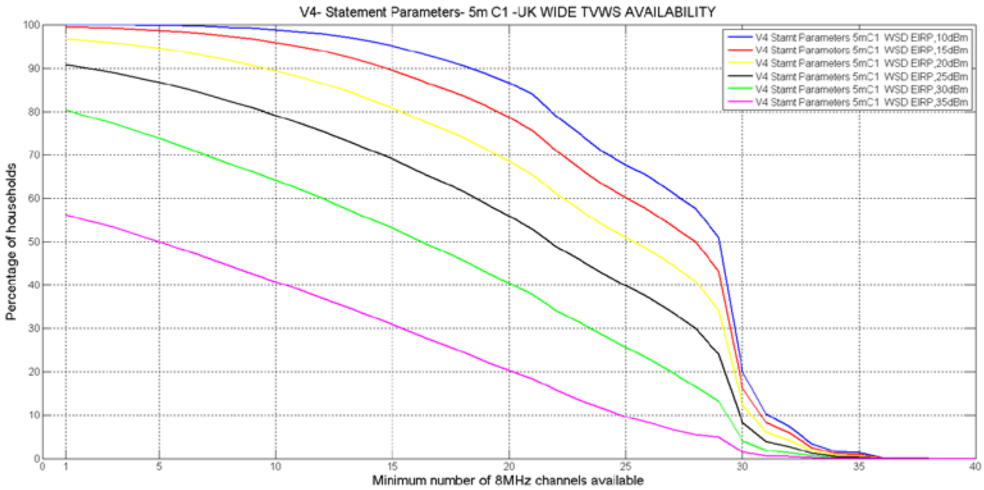


Figure 10.3 - Scenario (c) WSD antenna height at 1.5m and class 1

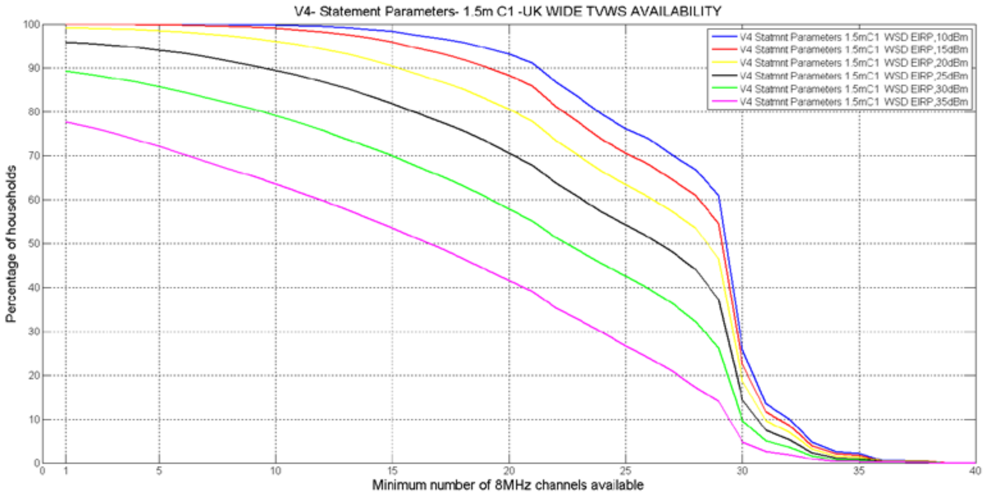
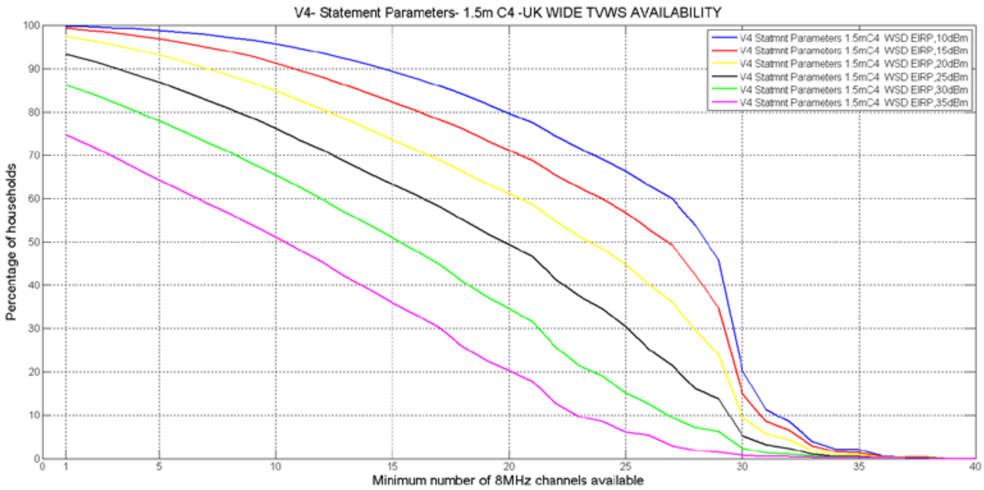


Figure 10.4 - Scenario (d) WSD antenna height at 1.5m and class 4



Observations

10.10 We make the following observations based on these simulations:

- Scenarios (a) and (b) both show that there is likely to be limited availability for deployment of WSDs with relatively high antenna heights where they need to operate at the maximum power allowed under the framework. For example in scenario (a) there are five channels available in only 28% of locations and in scenario (b) the equivalent figure is 50% of locations. This suggests that it is likely to be difficult to deploy high power base stations or access points on a national basis. However there will be some areas of the country where there will be availability at such antenna heights and power levels.

- Scenarios (a) and (b) show that if base station or access points can be deployed needing lower powers, for example 25 or 20 dBm, then availability is significantly greater. For example in scenario (a) there are five channels available in approximately 77% (at 25 dBm) and 88% (at 20 dBm) of locations. In scenario (b) the equivalent figures are higher: 86% and 95%.

- Scenarios (c) and (d) provide an indication of the likely availability for a range of use cases where the WSD antenna can be at a low height and in such situations the power needed may be lower, e.g. in the 10 to 20 dBm range, in which case the availability is in excess of 90% of locations.

Availability in particular areas

10.11 In each of the locations set out below we calculated the potential TVWS availability in a 10 km by 10 km area. We have used PMSE assignments live at any time on 25 August 2014 as a snapshot of PMSE activity in the area. In some of the areas there are many assignments while in others there are fewer or none as shown in the table below.

Table 10.2 - Number of PMSE assignments in selected areas

Area	No of PMSE Assignments at 25 Aug 2014
Central London	4,625
Glasgow	255
Croydon	14
Milton Keynes	4
Yorkshire Dales	0

10.12 We have calculated the WSD emission limits at the centre of every 100 metre × 100 metre pixel in the examined area taking account of all the restrictions that our approach to coexistence as set out in this Statement requires. As noted above these simulations are the output of a model that has not been fully verified and so the results may not be completely accurate. We set out below a selection of charts and maps providing statistics on availability in these areas and some observations on what the simulations illustrate. The maps illustrate availability at a particular power level for a particular scenario and we have selected a power level that in general terms indicates there is some potential availability. Generally speaking in these areas the availability is likely to increase at lower power levels and decrease at higher power levels as can be inferred from the charts.

Central London

10.13 The simulations in this area show that deploying a network that requires high power and high WSD antenna heights is likely to be challenging. However at lower powers, for example 23 dBm, there seems likely to be more scope to deploy base station and access points with high antennas. There also appears to be potential for availability for deployments of WSDs with low antenna heights at low powers.

Figure 10.5 - Availability in Central London – Scenario (a)

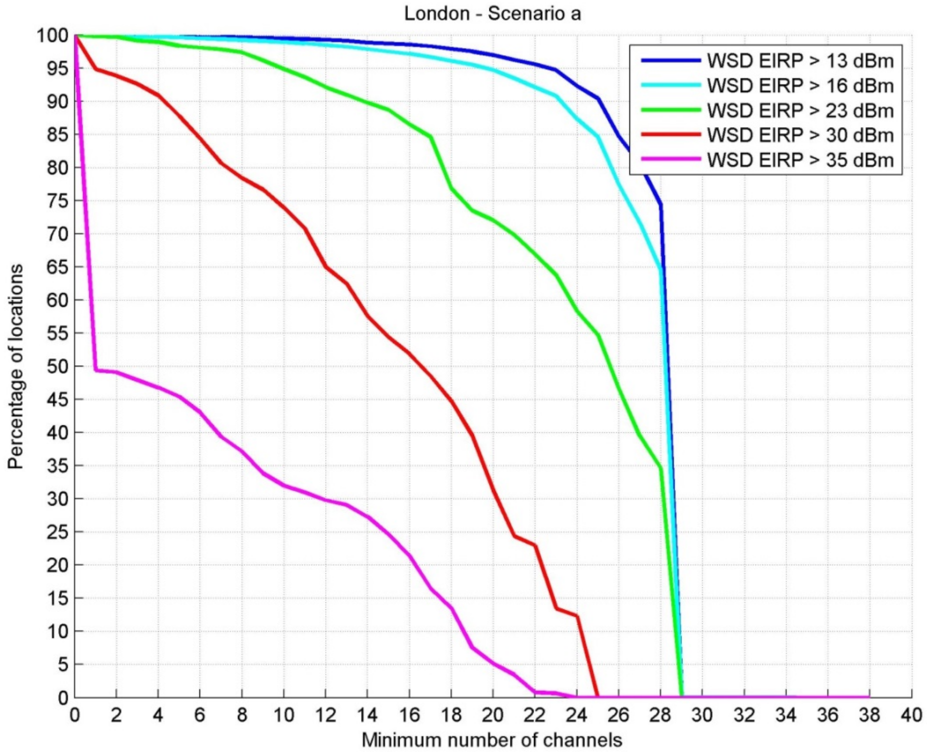


Figure 10.6 - Availability in Central London – Scenario (a) WSD at 23 dBm

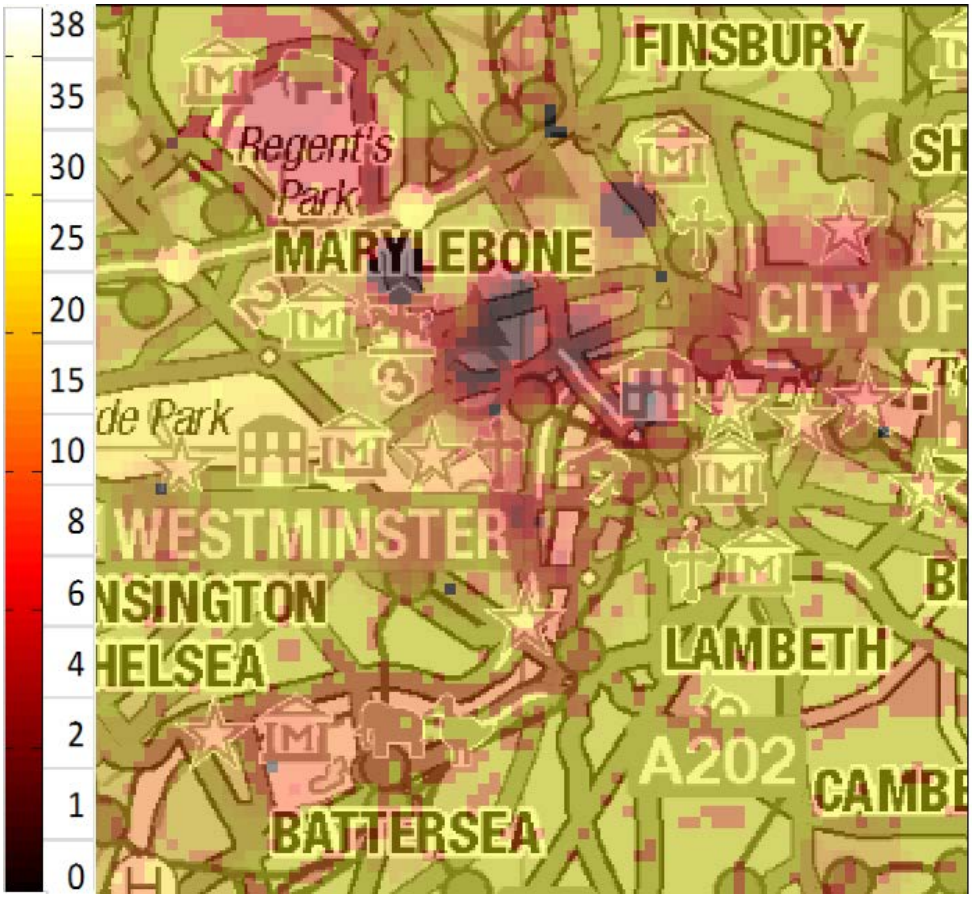


Figure 10.7 - Availability in Central London – Scenario (c)

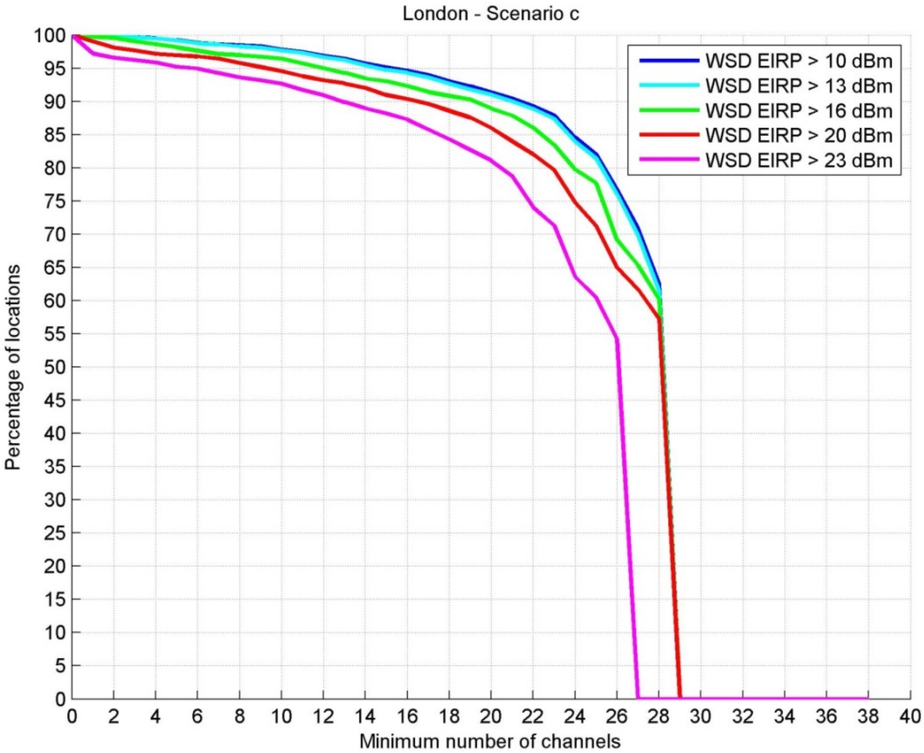
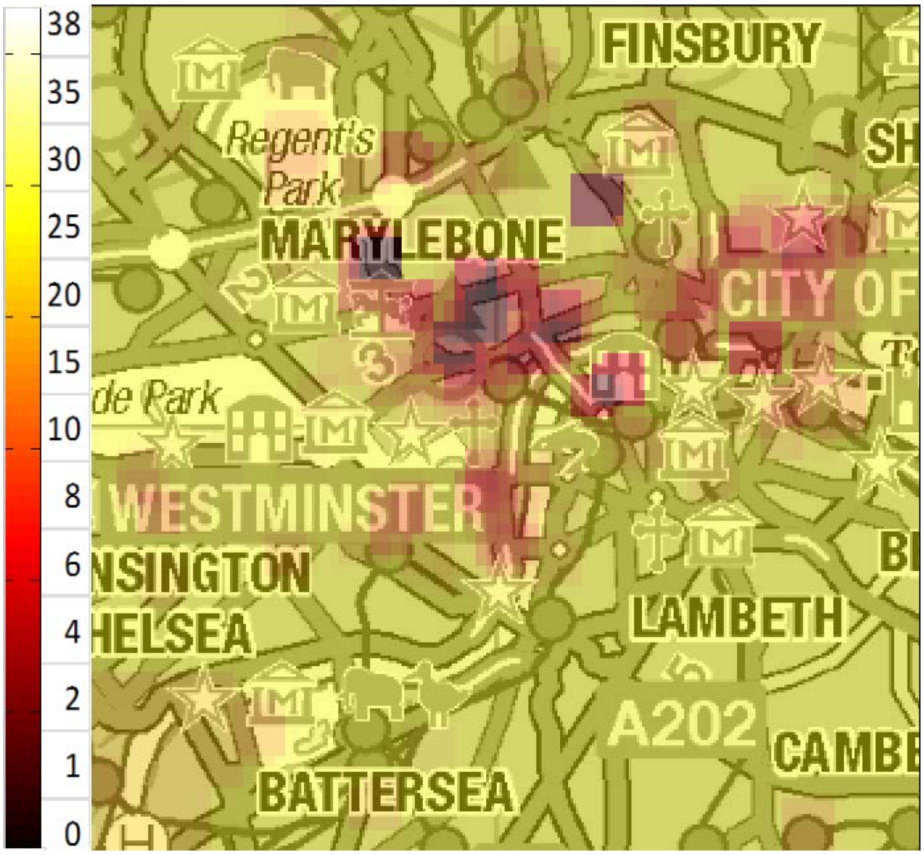


Figure 10.8 - Availability in Central London – Scenario (c) WSD at 13 dBm



Glasgow

10.14 The simulations in this area show that deploying a network that requires high power and high WSD antenna heights does not appear to be very feasible. Even at lower powers, for example 23 dBm, deploying a network of base stations or access points appears to be challenging but may be feasible with careful choice of locations. There appears to be reasonable availability for low power and low WSD antenna height deployments including client devices.

Figure 10.9 - Availability in Glasgow – Scenario (a)

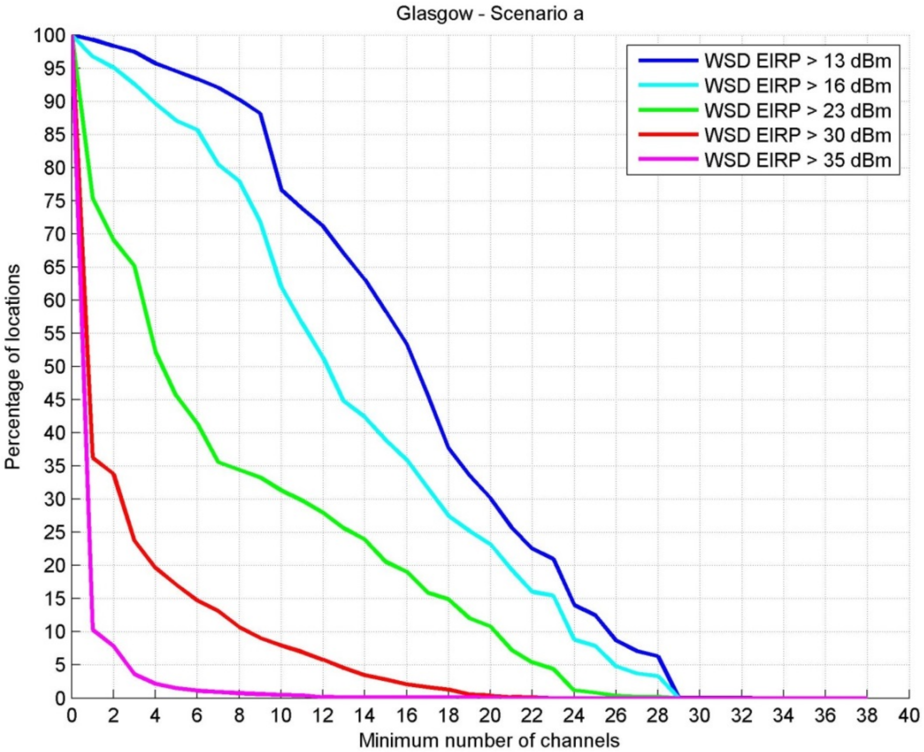


Figure 10.10 - Availability in Glasgow – Scenario (a) WSD at 23 dBm

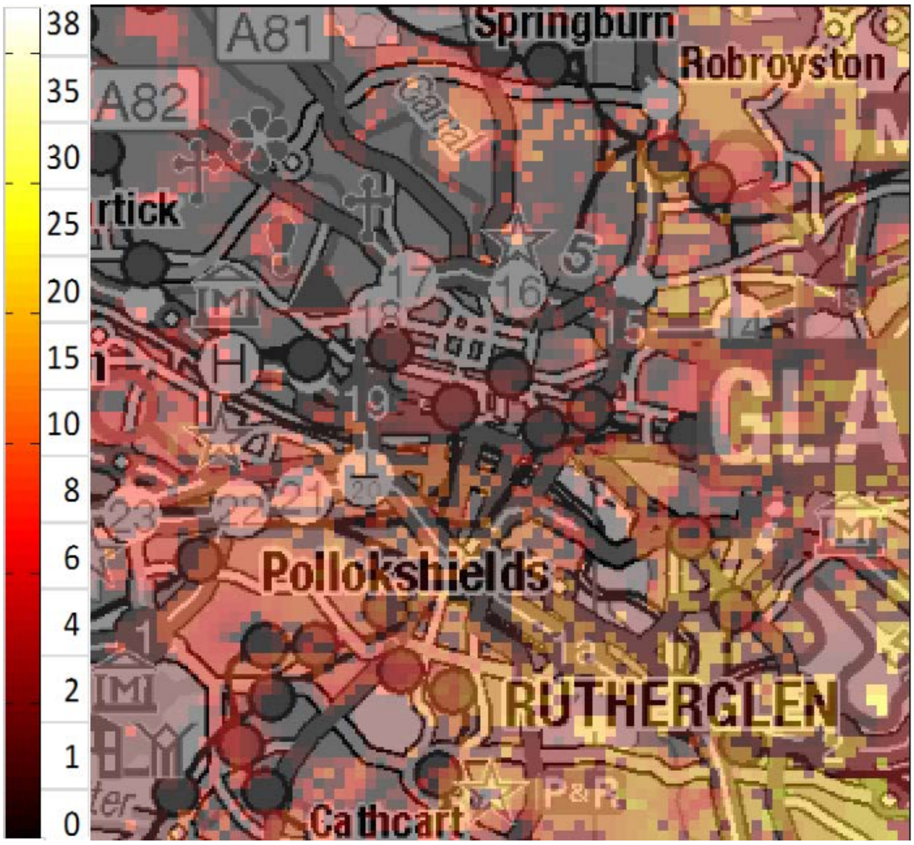


Figure 10.11 - Availability in Glasgow– Scenario (c)

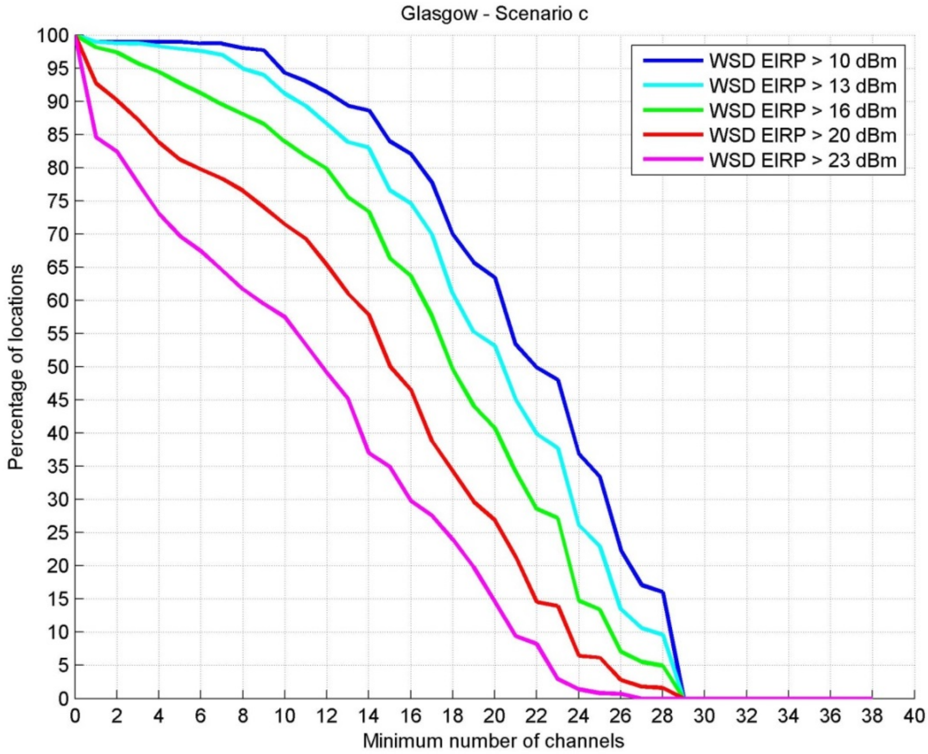
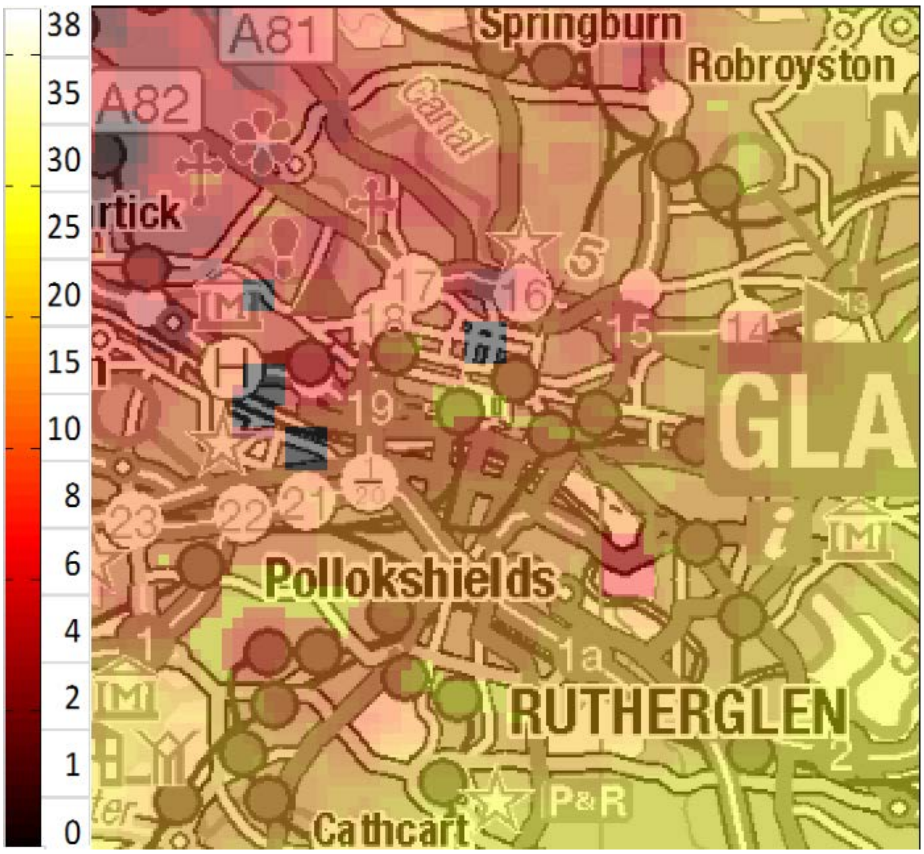


Figure 10.12 - Availability in Glasgow -Scenario (c) WSD at 13 dBm



Croydon

10.15 The simulations in this area indicate good availability in all scenarios, though it is more limited in scenario (a) at the highest WSD powers. This suggests that it is likely to be possible to deploy a wide range of networks in this area.

Figure 10.13 - Availability in Croydon – Scenario (a)

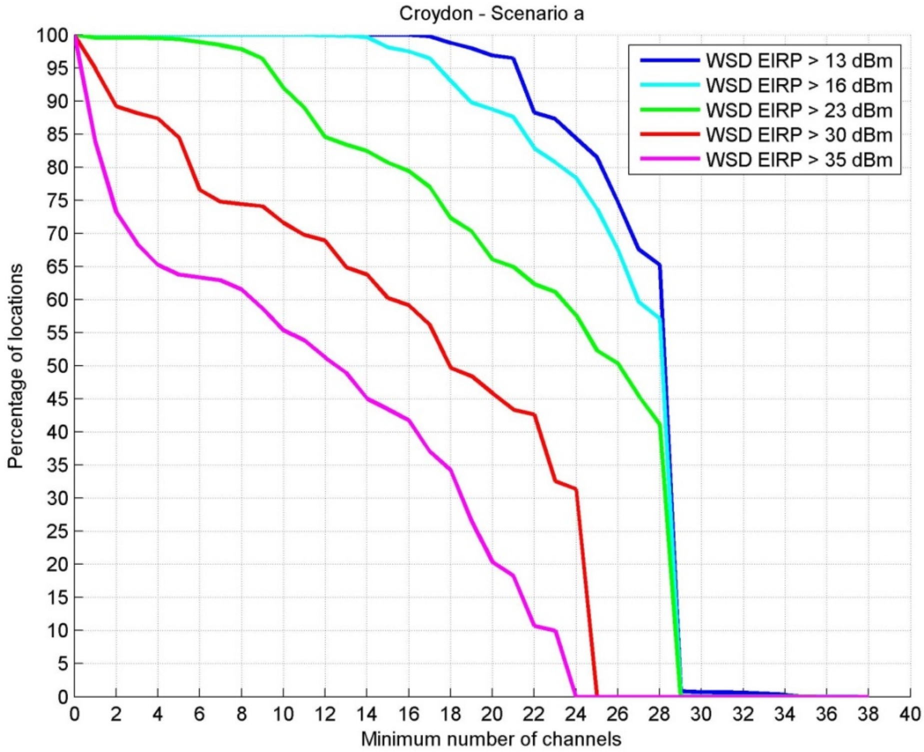


Figure 10.14 - Availability in Croydon – Scenario (a) WSD at 23 dBm

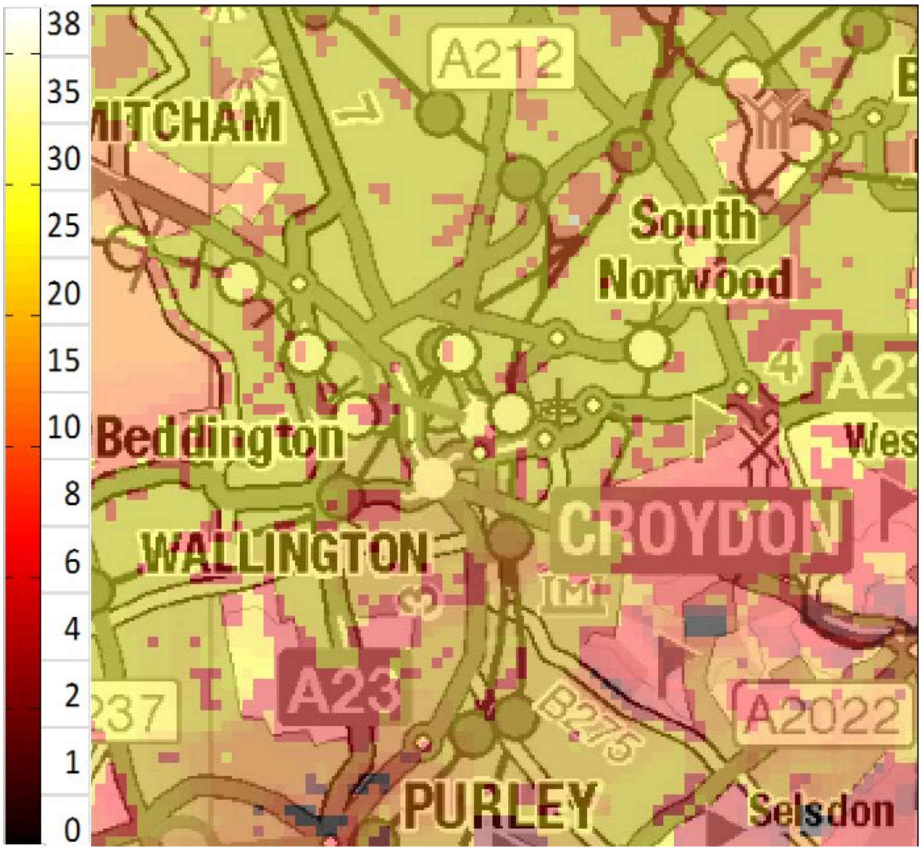


Figure 10.15 - Availability in Croydon – Scenario (c)

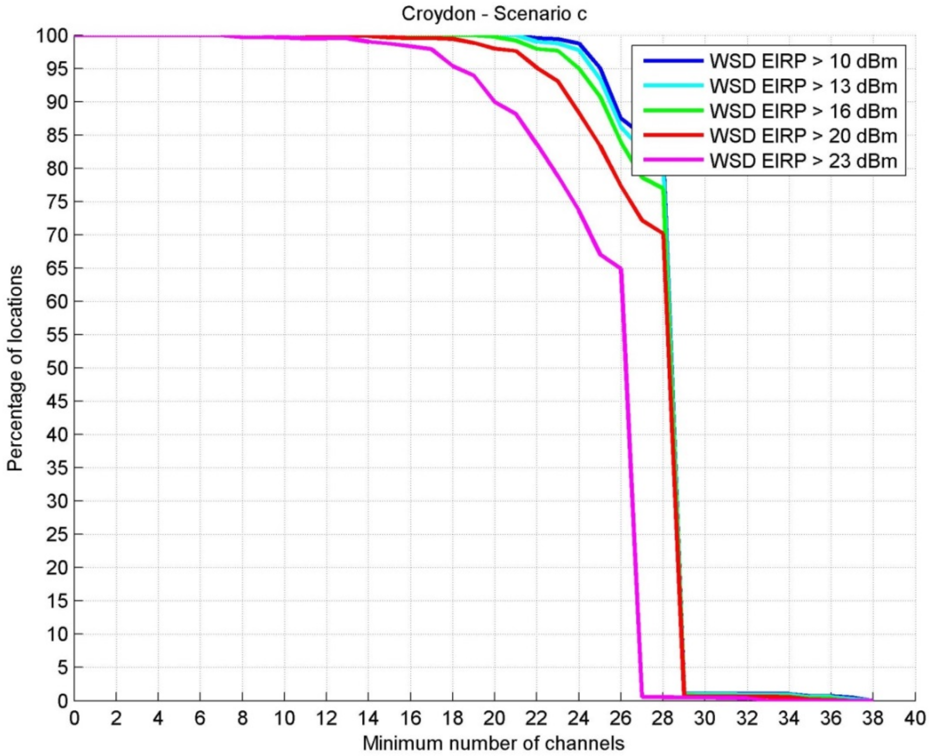
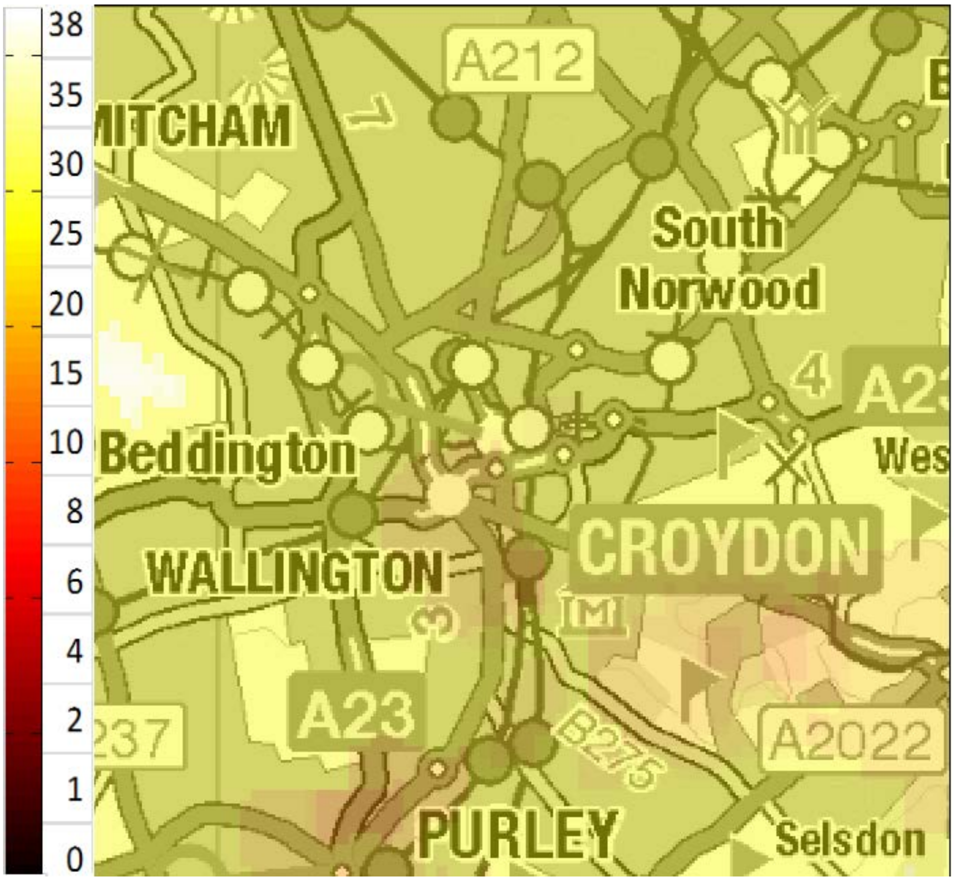


Figure 10.16 - Availability in Croydon – Scenario (c) WSD at 13 dBm



Milton Keynes

10.16 The simulations in this area indicate that it is likely to be possible to deploy a relatively low power and low WSD antenna height network. It would appear to be more challenging to deploy a network that needs high power base stations or access points but there is still some availability so it may be possible with careful selection of locations.

Figure 10.17 - Availability in Milton Keynes – Scenario (a)

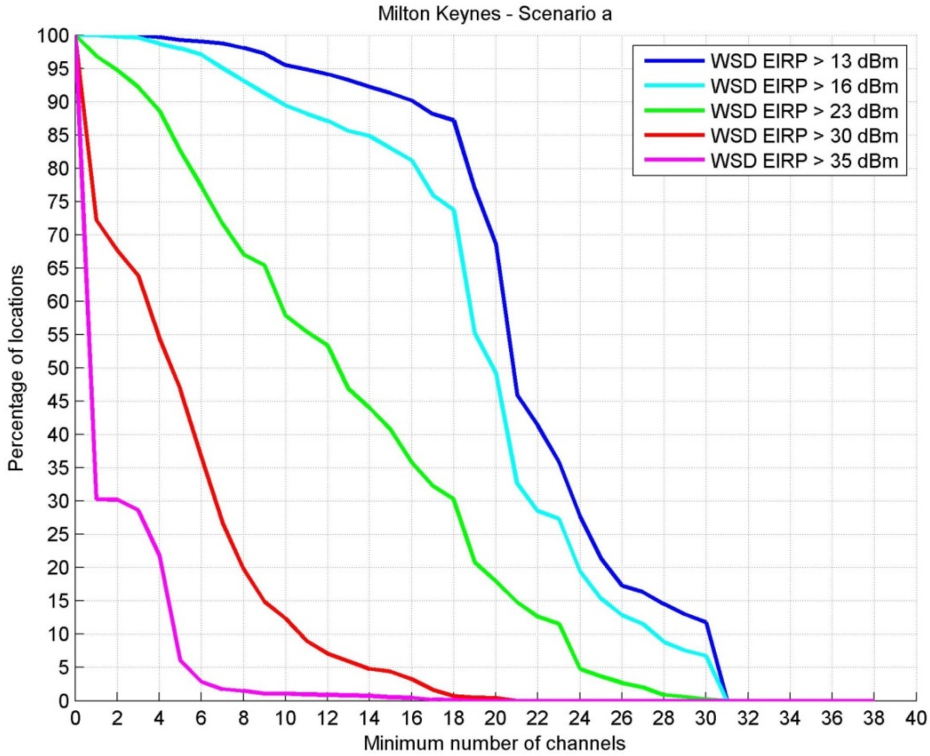


Figure 10.18 - Availability in Milton Keynes – Scenario (a) WSD at 23dBm

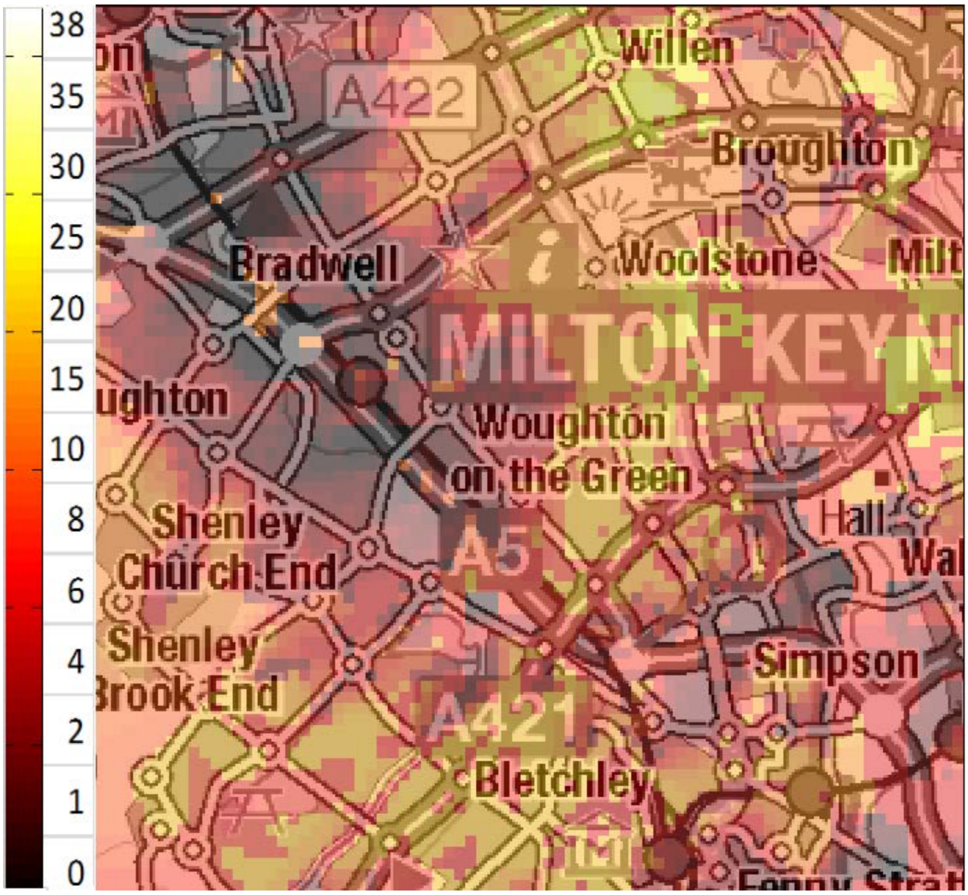


Figure 10.19 - Availability in Milton Keynes – Scenario (c)

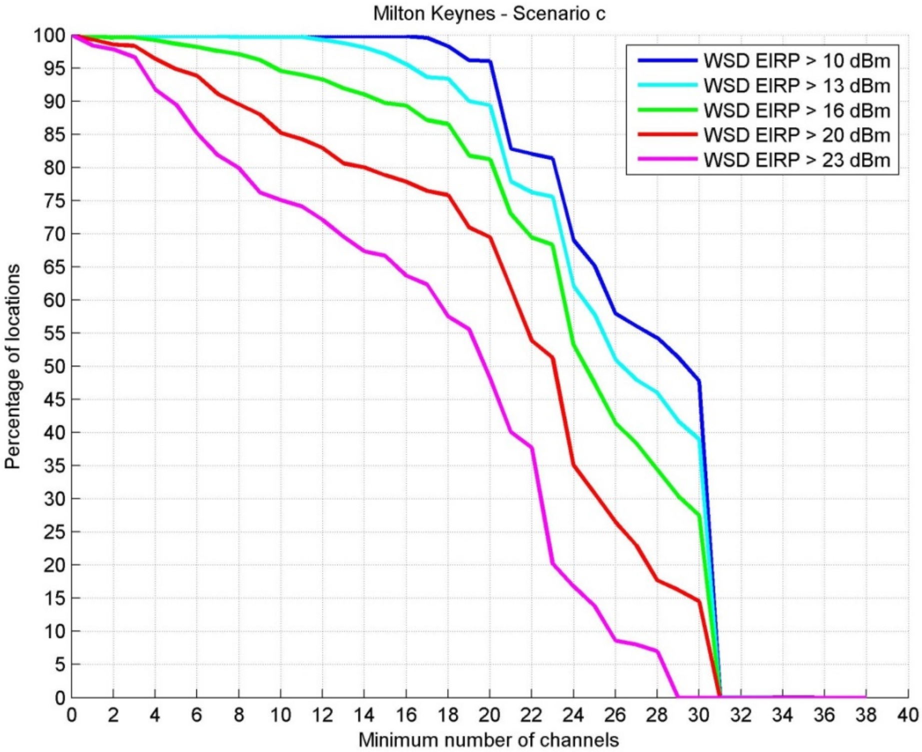
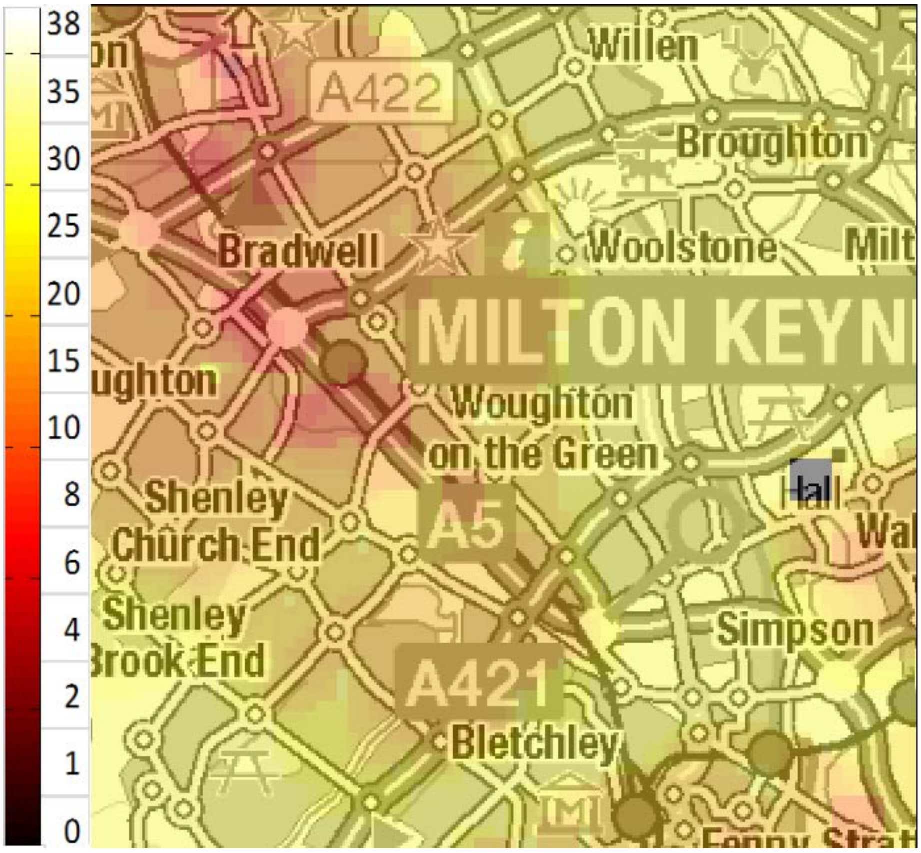


Figure 10.20 - Availability in Milton Keynes – Scenario (c) WSD at 13 dBm



Yorkshire Dales

10.17 The simulations in this area show that deploying a network that requires high power and high WSD antenna heights is challenging. However at lower antenna heights, for example 5m, and lower power, for example 23 dBm, there appears to be considerable scope to deploy base stations and access points. There also seems to be considerable availability for low power and low antenna height deployments including client devices.

Figure 10.21 - Availability in Yorkshire – Scenario (b)

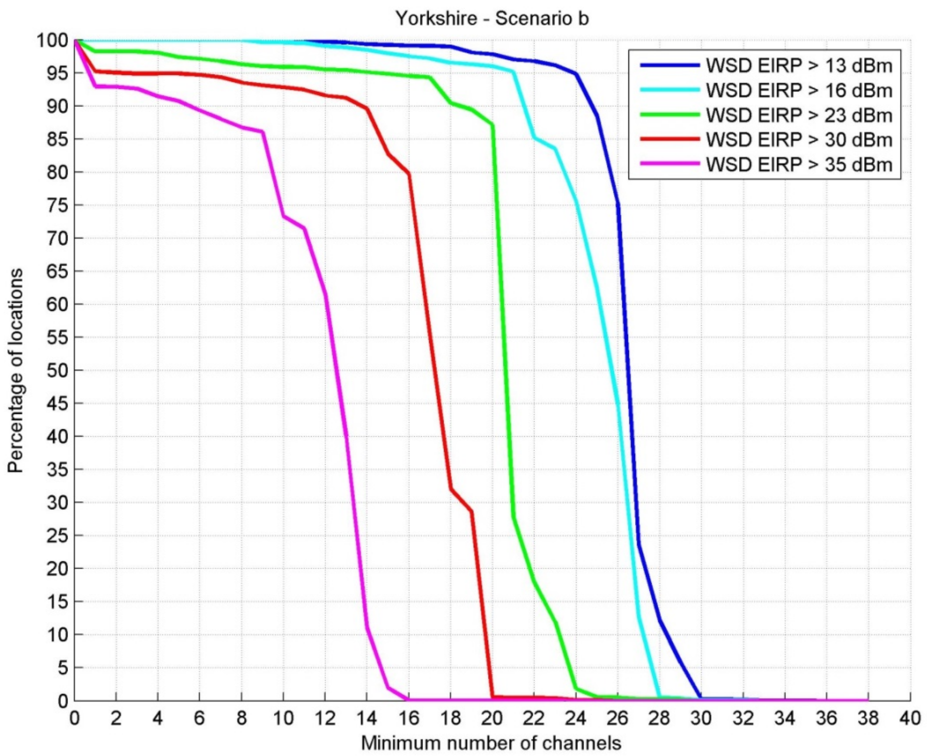


Figure 10.22 - Availability in Yorkshire – Scenario (b) WSD at 35dBm

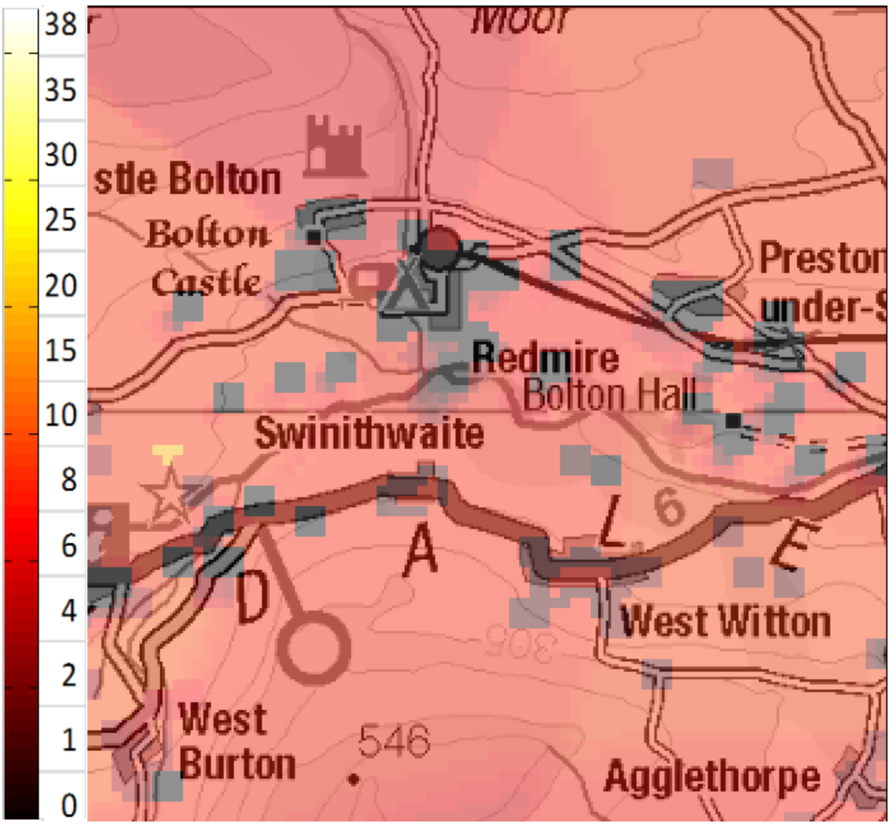


Figure 10.23 - Availability in Yorkshire – Scenario (c)

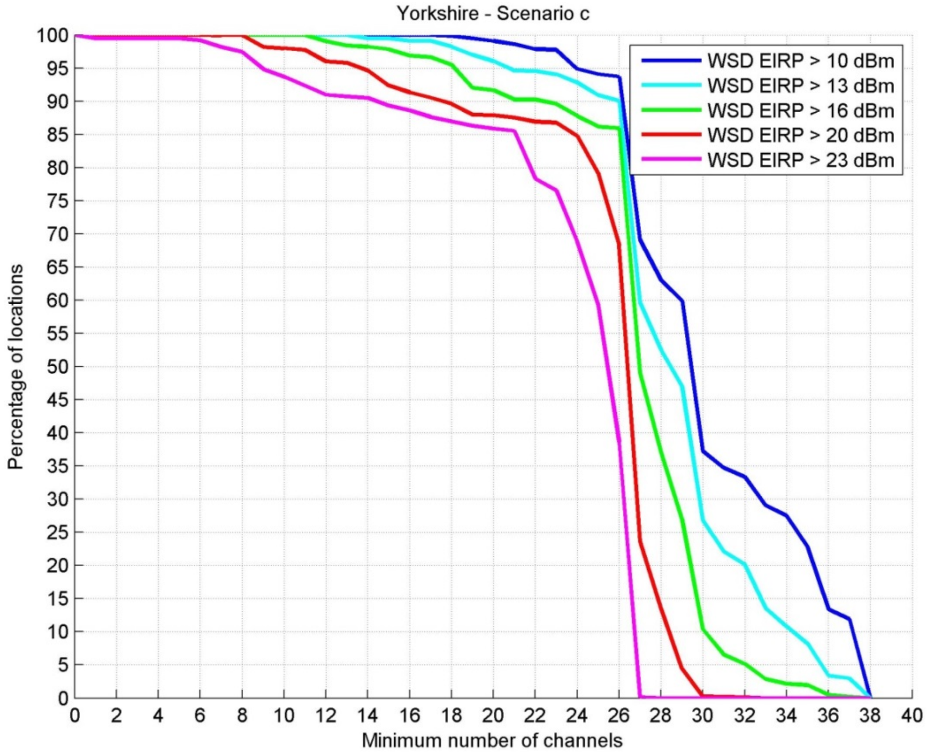
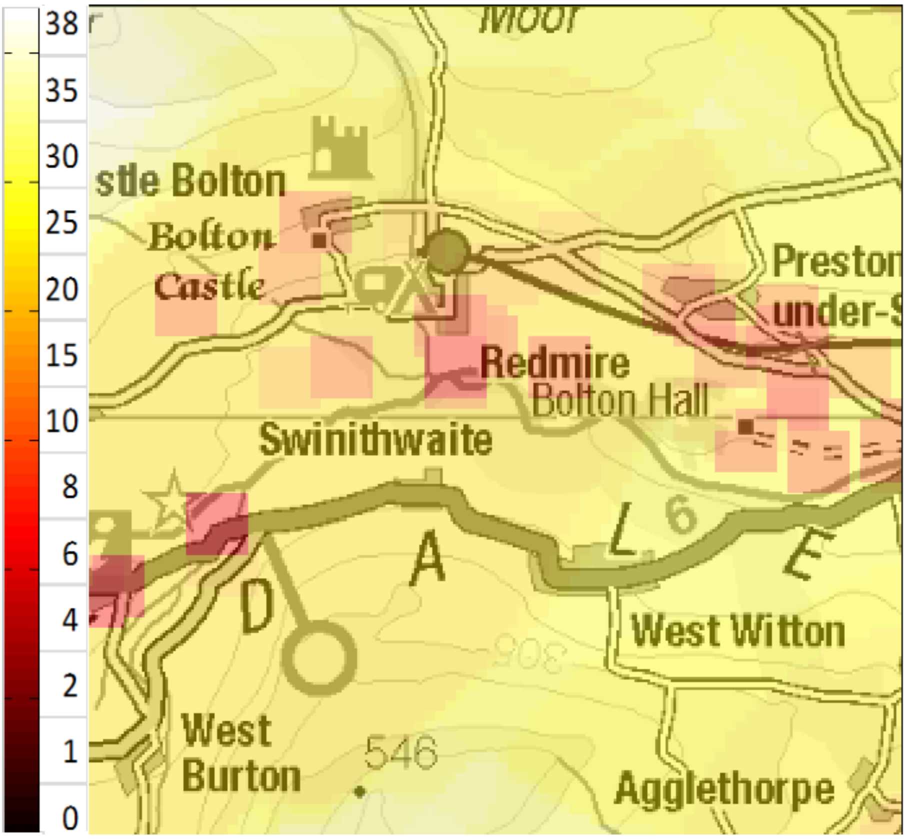


Figure 10.24 - Availability in Yorkshire – Scenario (c) WSD at 16 dBm



Section 11

Next Steps

11.1 This Section describes the next steps Ofcom will be taking regarding the implementation of the TVWS framework. The first part explains the key next steps to be undertaken for the framework to go live and devices to be deployed commercially. The second part explains how Ofcom sees the framework being developed in the future beyond the initial implementation.

Practical and legal implementation

11.2 Broadly there are two elements to implementing the framework: one concerned with appointing databases and the other with exempting WSDs.

Device licence exemption

11.3 This Statement has explained in Section 5 the technical and operational conditions which Ofcom considers are required to authorise WSDs on a licence exempt basis. Alongside this Statement we are publishing for illustrative purposes, an updated draft statutory instrument (SI), which provides an indication of how we might describe the terms and conditions of the licence exemption regulations with which White Space Devices would need to comply, as well as an updated draft Interface Requirement. In accordance with the Technical Standards Directive (98/34/EC)[61], we expect to notify the draft SI and draft Interface Requirement to the Commission. The Commission and other Member States may make comments on the draft SI during a three month public consultation (and potentially a further three months if any concerns are raised). Following that consultation, we will need to take account of any comments received and will then publish a notice of our proposals to make the licence exemption regulations. Assuming there are no concerns raised with our requirements, we anticipate publishing the notice of proposals to make the licence exemption regulations around summer 2015, subject to the progress of database qualification.

Databases

11.4 In order to implement the TVWS framework we will need to undertake the process of qualifying white space databases. Broadly this will follow the process used in the Pilot but modified to reflect the lessons we have learnt and the changes to our approach. At a high level we expect the process to involve:

- Finalising detailed technical requirements for databases. The calculations required to determine a WSD’s operational parameters are set out in Annex 8. There are some other technical requirements concerned with the exchange of data between Ofcom and the databases that will need to be specified.

[61] Directive 98/34/EC of the European Parliament and of the Council of 22 June 1998 laying down a procedure for the provision of information in the field of technical standards and regulations and rules on Information Society Services (OJ L 204, 21.7.1998, p.38), known as the Technical Standards Directive, sets up a procedure which imposes an obligation upon the Member States to notify to the Commission and to each other all the draft technical regulations concerning products before they are adopted in national law. Such procedure aims at providing transparency and control with regard to those regulations. See http://ec.europa.eu/enterprise/tris/about/index_en.htm.

- Discussions with databases on the terms of the database contract.
- Pre-contract checks on databases that wish to sign contracts with Ofcom.
- Execution of contracts between databases and Ofcom.
- Qualification of databases by Ofcom involving testing and review of information provided by databases to provide evidence they are likely to be able to comply with the technical requirements of the contract.
- Systems testing with databases to ensure that the data flows between Ofcom and databases work as intended.

11.5 We are targeting execution of contracts with the first set of databases that wish to be appointed around spring 2015 and to complete qualification by around summer 2015, subject to further discussions with the databases concerned. We would anticipate publishing the statutory consultation on the licence exemption regulations once we have qualified the first set of databases for inclusion in the list in the statutory instrument.

Future developments of the TVWS framework

11.6 Ofcom sees the approach to the implementation of the TVWS framework set out in this Statement as an appropriate starting point for proceeding with implementing the authorisation of use of WSDs in the UHF TV band. That is to say we believe it offers a viable way forward that we can implement now but one which we anticipate can be refined in the future to meet our objective of ensuring efficient use of the UHF TV band. We set out below some of the key areas that we anticipate will require further development. We would be interested in feedback from the industry on these areas and whether there are other particular aspects of our implementation of the framework that we should consider developing in the future.

11.7 This Statement has set out in detail our initial framework for ensuring a low probability of harmful interference to existing services. We envisage that the detail of how we achieve that outcome will change over time and we will engage with stakeholders over the evolution of the framework. We expect to make changes to detailed aspects of the framework consistent with the policy objectives set out in this Statement. We would expect to update stakeholders on any changes we are making in an appropriate manner. It is possible that some changes could have the potential to have a significant impact on some stakeholders. In such cases we would expect to consult as appropriate.

Key areas for development

11.8 Through the Pilot, consideration of consultation responses and discussions with stakeholders we have identified a number of areas where it is likely to be possible to improve on our initial implementation. We list these issues below. As explained below we expect to take these forward over the next year or so with stakeholders support.

11.9 The following technical aspects of the framework Ofcom anticipates will be subject to further study and possible change:

a) Choice of propagation model in calculations to define coexistence parameters with DTT. This would include a review of the use of the extended Hata model, the assumption of 0 dB standard deviation for longer path distances, the use of Infoterra clutter data and potentially other more sophisticated terrain-based prediction models. It could also include a review of current modelling of household installation gains.

b) Choice of propagation model in calculations to define a master WSD coverage area and coexistence parameters with PMSE. This would include a review of the use of the extended Hata model, our approach to clutter data and consideration of the use of more sophisticated terrain-based prediction models.

c) UK DTT Planning Model data that is used in the DTT coexistence calculations – ensuring that the underlying data in the model better reflects the actual position regarding DTT viewers' reception in any particular pixel for example in terms of the transmitters that provide TV services to the viewer and the DTT field strength. This could also include a review of whether the definition of the threshold of coverage (99% time, 70% locations) reflects actual transmitter usage in weak signal areas.

d) Categories of protection ratios for DTT – consideration of whether different device technologies or use cases may be more likely to disrupt DTT receivers and whether and how the framework should take account of this.

e) Pixel resolution in the calculation limits to protect DTT services in neighbouring countries.

f) Whether narrowband WSDs, when not in the vicinity of PMSE users, may be allowed additional power to recognise the fact that they do not use the entire 8 MHz channel and therefore their total power in the channel is lower than a comparable wideband device.

g) Further consideration of whether there are genuine likely worst case scenarios for PMSE use that are not foreseen by the framework and where further information would help us to better understand and take account of the issues.

h) WSD to WSD transmit intermodulation – consideration of whether this is an issue that we should seek to raise during a further ETSI review process in the future.

i) Default WSD sensitivity level used in master WSD coverage area calculation – a value of -114 dBm/100 kHz will be used at the beginning but further consideration will be given to whether a higher level would be more realistic.

j) Transmissions within PMSE venues – following implementation of venue boundaries, consideration of how to minimise WSD transmission within venues, taking account of the need for slave WSDs to be able to make initial contact with masters.

k) Determination of generic operational parameters and master-slave association – we plan to review, following the implementation of the approach set out in this Statement, the extent to which master-slave association imposes a constraint on the deployment of WSDs, and if so what changes may be possible and how to address any related risks to PMSE.

l) Consideration of the ETSI Harmonised Standard – a review of how the current standard could be developed, for example whether new emission classes, or a refinement to the class system for WSDs in relation to their propensity to cause interference to DTT receivers, would be beneficial, so that this can be fed into a future ETSI review process.

m) Planned consultation on whether to introduce a licensing regime to authorise manually configured devices (i.e. that require the user to determine and specify the device parameters) that will not meet the requirements of the licence exemption.

Ensuring ongoing stakeholder input

Technical working group(s)

11.10 In order to take forward the technical work on the areas identified above and others related to the development of the TVWS framework and its implementation, Ofcom is considering the best way to involve stakeholders. We believe there is merit in having a forum where detailed technical discussions can occur and to which stakeholders are able to contribute their own expertise and evidence. Accordingly, we propose to refocus the TVWS technical working group with new terms of reference. The focus of the group will be on providing Ofcom with technical evidence to assist us in ensuring that the coexistence framework continues to result in a low probability of harmful interference and, consistent with that objective, facilitating the use and development of the TVWS framework. Ideally the group would have members with expertise covering broadcasting planning and coexistence, PMSE coexistence, WS database operation and the manufacture of WS equipment and development of WS services. We also expect that it may be helpful to have some sub-groups more restricted in scope which focus on particular issues.

11.11 Ofcom will be giving further thought and discussing with stakeholders the best way to evolve the technical working group. We would welcome any thoughts stakeholders may have on this. Please send these to TV.WhiteSpaces@ofcom.org.uk.

TVWS stakeholder updates

11.12 We are conscious that there are many stakeholders who will be interested in both the progress of implementing the TVWS framework and in the technical work on potential improvements but who will not be directly involved for a variety of reasons. Accordingly, Ofcom plans to invite stakeholders to come together to discuss developments and issues of interest. We are not proposing any fixed schedule for these meetings, but we would expect to hold the first shortly after the licence exemption comes into force. We also plan to continue to issue a monthly newsletter between now and the TVWS framework being implemented to update stakeholders on the work. If you have **not** attended one of the past TVWS stakeholder events and would like to be on the invitation list for such meetings, and if you do **not** already receive the newsletter and would like to, please send your contact details to TV.WhiteSpaces@ofcom.org.uk

Overarching review

11.13 In the 2013 Consultation we proposed the idea of a general review of the effectiveness of the TVWS framework and suggested doing this within the first 18 months of operation. We continue to believe that a general review to look at the effectiveness of the TVWS framework in the round is likely to have some merit. In particular we note that the framework we have set out here does not explicitly consider the impact of significant numbers of WSDs being in operation. We believe the key trigger for such a review will be the emergence of significant applications with the potential for high-volume dissemination and so will keep the timing open for the time being, whilst we keep the development of white space equipment and use under review.