Implementing geolocation:

Consultation

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Contents

Section 1

Executive summary

The roles of different types of spectrum

1.1 Spectrum is typically managed in one of two ways. Most spectrum is licensed to a particular user, such as a mobile network operator, who has exclusive rights to make use of the spectrum. The remainder, around 6% or so, is exempted from licensing. Unlicensed spectrum is used by a wide range of devices, most notably devices based on the WiFi and BlueTooth standards. .

1.2 In our Spectrum Framework Review of 2004[1] we noted that both types of spectrum were important. Licensed spectrum enables the deployment of large national infrastructures whereas unlicensed spectrum enables innovative new devices and applications. Since then, there has been dramatic growth in the use of WiFi and Bluetooth, and many new applications for short-range wireless connections.

1.3 Of course, not all innovative ideas are successful and alongside WiFi and BlueTooth sit some initiatives that have yet to gain any traction, such as ultra-wideband (UWB). Our role however is to enable as many new ideas to be tried as possible so that the market and consumers can determine which should succeed, without trying to pre-judge which will be the most successful.

More unlicensed spectrum is needed

1.4 With the success of WiFi has come increased congestion in the frequency band around 2.4GHz where it is commonly deployed. With many ideas for new applications that might be deployed in unlicensed spectrum there is global interest in finding new frequency bands.

1.5 Around the world interest has settled on frequencies in the UHF band (between around 500MHz and 800MHz) used for broadcast TV. These frequencies have two key advantages – there is a relatively large amount of spectrum and signals travel much further than in the bands used for WiFi. However, this spectrum is already used for TV broadcasting.

1.6 It has been known for some time that TV transmissions do not take up all of the spectrum with some gaps being needed to avoid interference. These gaps, or “white spaces”, cannot be used for additional high power TV transmissions. However, lower power unlicensed devices could operate in these white spaces, as long as they can accurately identify where they are.

1.7 Studies as to how the white spaces can be identified and used without causing interference have been taking place for a number of years. There is consensus that the optimum approach is likely to be based on a central database, which would provide information to low-power devices as to whether it is safe for them to transmit, taking into account the location of each device. Trials of a number of new applications using this geo-location database approach are now taking place, particularly in the US and the UK and appear promising.

[1] http://stakeholders.ofcom.org.uk/consultations/sfr/

We have been at the forefront of promoting white space usage

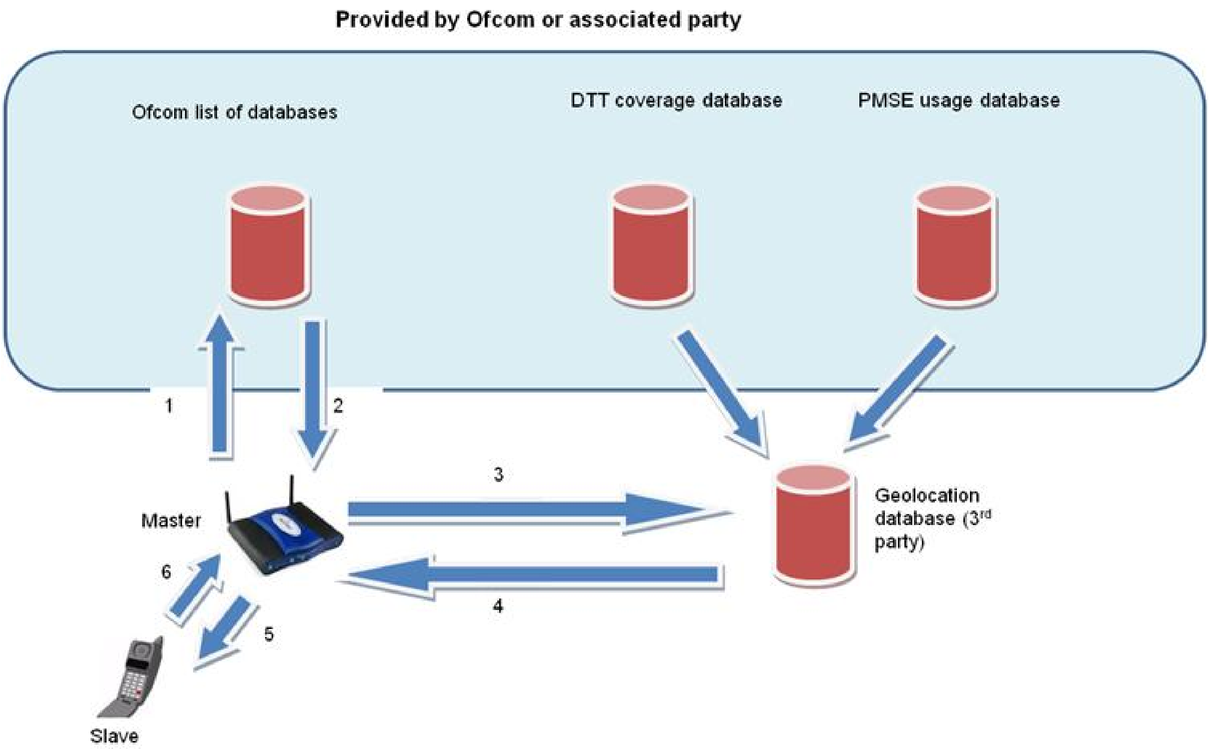
1.8 We believe that enabling new applications in white spaces fits well with our duties to maximise the value of the use of spectrum for citizens and consumers, ensure efficient use is made of it and encourage innovation. Hence, we have led the way with many important studies, measurements and modelling activities backed up with consultation around principles and approaches. As a result of these, we are now proposing a framework whereby interested parties can provide white space databases including exempting white space devices from the need for licensing.

1.9 In enabling white space access we hope that a range of valuable new applications will emerge but as with any innovative new technology we cannot predict what will actually happen. Hence, our approach is to allow as much flexibility as possible for the market to try a range of applications. Equally, we are ensuring that if white space access does not prove successful that the licensed use of this spectrum will not be impacted nor will significant regulatory investment be wasted. We do not expect to see large scale commercial activity before around 2014 and would expect penetration of devices to take some years to build after this. We do not expect white space devices (WSDs) to displace broadband communications via cellular or WiFi but to provide an additional mechanism for communications most of which will be short-range such as enhanced home wireless routers, rural broadband access, data networks in applications such as hospitals and urban wireless data networks.

1.10 In previous documents we have explored the use of unlicensed spectrum, different approaches to white space access and the general principles behind the use of a “geolocation database” to inform devices as to which white spaces are available. We expect this to be our final consultation on this topic focussing in detail on the specific technical and legal instruments needed.

How geolocation will work

1.11 The diagram below provides an overview of how we propose access to the white spaces based on geolocation will work in practice. Broadly, a “master” WSD will first consult a list of databases provided on a website hosted by Ofcom (1 and 2). It will then select its preferred database from this list and send to it parameters describing its location and device attributes (3). The database will then return details of the frequencies and power levels it is allowed to use (4).



1.12 A master device may also signal to a “slave” device (a device that does not need to contact the database) as to the frequencies and power levels it may use when communicating with the master device (5).

1.13 The database would be dependent on access to information about licensed usage in the band provided for digital terrestrial television (DTT) and programme making and special equipment (PMSE – mostly wireless microphones in this band), and algorithms specified by Ofcom to derive the frequencies and channels that devices may use. This should ensure that WSDs do not cause harmful interference to licensed users.

Necessary regulatory instruments

1.14 In order to implement the proposed geolocation process, Ofcom will need to publish a Statutory Instrument (SI) exempting appropriate devices from the need for a licence. In essence, master and slave devices that consult a database listed on the Ofcom website and then only transmit in accordance with the information received would be exempt from licensing.

Obtaining a database listing

1.15 We consider that the database(s) may be more efficiently run by commercial entities as they are likely to have the necessary IT resources. Those interested in running a database would approach Ofcom in order to apply for a listing on a website hosted by Ofcom (or a trusted party) from which WSDs can then select their preferred database. We would need to consider applications against certain minimum requirements and may require entry into a contract and payment for the listing of the database.

Next steps

1.16 This consultation invites responses on the approaches proposed by 7 December 2010.

1.17 During this period and afterwards as appropriate we will work with European bodies such as the Electronic Communications Committee (ECC) within the Central European Post and Telecommunications (CEPT) organisation and the European Commission (EC) to seek a harmonised European solution for the implementation of WSDs. We will also liaise internationally with other bodies such as the Federal Communications Commission (FCC) and other worldwide standards bodies to seek global interoperability for devices as far as possible on a global basis. This may lead us to adopt alternative approaches to the proposed geolocation process.

1.18 At this stage we are uncertain about the balance of costs and benefits and level of interest associated with these proposals. Until we move ahead further in this process these will not become clear. It may be that this balance is such that we choose not to proceed or we seek alternative approaches. Hence, we are unable to make any commitments that we will pursue the proposals set out here.

Section 2

Background

2.1 Since its launch in 2005, our Digital Dividend Review (DDR) has considered how to make the spectrum freed up by digital switchover (DSO) available for new uses.[2] This includes the capacity available within the spectrum that will be retained to carry the six digital terrestrial television (DTT) multiplexes after DSO. This is known as interleaved spectrum because not all this spectrum in any particular location will be used for DTT and so is available for other services as long as they can interleave their usage around the primary users.

2.2 While it is not clear what applications will emerge in the white spaces, suggestions have included rural broadband, WiFi routers with increased range, city-wide broadband data networks, increased wireless device interconnectivity, hospital data networks and much more.

2.3 Enabling devices that could use this spectrum, termed cognitive or white space devices (WSDs or devices), aligns with many of our duties both in furthering the interests of citizens and consumers and those duties related to spectrum. WSDs might enable competition in communications services benefitting consumers as well as, for example, better rural broadband providing citizen benefits. They will increase the efficiency of use of the spectrum retained for broadcasting, are likely to bring economic benefits and many expect they will be a fertile area for the emergence of innovative services and applications.

2.4 There is interest in WSDs in a number of other countries with the greatest progress having been made in the US where the US regulator (the FCC) recently announced their rules for white space access and are in the process of tendering for the provision of the necessary databases. In our work we have sought to align with international developments as far as possible in order to benefit from economies of scale and from innovative new ideas being developed elsewhere. In particular, there is growing consensus, which we agree with, that WSDs should determine their location and consult a “geolocation database” which would inform them of the white spaces available in their location.

Previous consultations on cognitive devices

2.5 We issued a statement on 13 December 2007 entitled “Digital Dividend Review: A statement on our approach”, (the “December 2007 Statement”) where we considered our approach to awarding the digital dividend.[3] Specifically, we considered the use of interleaved spectrum by licence-exempt devices (i.e. those exempted from the need to be licensed under the Wireless Telegraphy Act 2006[4]). We concluded that we should allow access by licence-exempt devices to interleaved spectrum as long as we were satisfied that it would not cause harmful interference to licensed uses, including DTT and programme-making and special events (PMSE). This is because the applications that such devices might enable could potentially bring substantial benefits to citizens and consumers.

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[2] See http://stakeholders.ofcom.org.uk/spectrum/project-pages/ddr/ for more information about the DDR, including previous publications.
[3] www.ofcom.org.uk/consult/condocs/ddr/statement/statement.pdf.
[4] www.opsi.gov.uk/acts/acts2006/pdf/ukpga_20060036_en.pdf.

2.6 We published a consultation entitled "Digital dividend: cognitive access. Consultation on licence-exempting cognitive devices using interleaved spectrum" on 16 February 2009.[5] This predominately consulted on the sensing threshold levels that would be needed for licence-exempt devices making use of sensing alone.

2.7 In a subsequent statement entitled "Digital dividend: cognitive access. Statement on licence-exempting cognitive WSDs using interleaved spectrum" published on 1 July 2009[6] (the "July 2009 Statement"), we noted that there were three mechanisms that could be used by a licence-exempt device operating in these bands to determine which frequencies it could use to make transmissions.

2.8 These were:

- sensing (also known as detection): where devices monitor frequencies for any radio transmissions and if they do not detect any, assume that the channel is free and can be used;

- geolocation: where devices determine their location and query a "geolocation" database which returns the frequencies they can use at their current location. The devices are prohibited from transmitting until they have successfully determined from the database which frequencies, if any, they are able to transmit on in their location. In this case parameters such as locational accuracy and frequency of database enquiry are important; and

- beacon transmission: where a network of fixed transmitters or base stations are established around the country and broadcast signals informing devices as to which channels are free in the vicinity[7].

2.9 We concluded that beacon transmission was inferior to the other two approaches and that we would not consider it further. This is because it required the establishment of a costly infrastructure and because it was inherently inefficient in that beacon transmissions needed to be restricted to smaller areas than the available white space in order to avoid the risk of interference occurring due to unexpected propagation of the beacon signal. However, we will reassess this conclusion if new proposals for beacons are put forwards.

2.10 We noted that there were advantages and disadvantages to both sensing and geolocation. While sensing does not require any form of infrastructure, and hence devices could be autonomous, sensing to very low signal levels is costly and possibly not achievable. Geolocation does not have the inconveniences of sensing but requires a database to be established and kept up to date.

2.11 At this stage in the development we concluded that it was appropriate to proceed with regulation enabling both sensing and geolocation in order to enable device developers to select their preferred approach.

2.12 In the July 2009 statement we set out the device parameters needed for sensing although we did not issue an SI, preferring to delay this until such time as there was a clear need.

[5] http://stakeholders.ofcom.org.uk/consultations/cognitive/
[6] http://stakeholders.ofcom.org.uk/binaries/consultations/cognitive/statement/statement.pdf
[7] Note we only considered beacon transmission in general and not specific cases such as the use of beacons to protect wireless microphones (which is generally not needed in the UK).

2.13 A related topic is the potential award of "geographic interleaved (GI)" licenses. These are local (as opposed to national) awards in the interleaved spectrum that might be used for local TV or other applications. We have still to decide how many GI licenses we will award, where they will be and what restrictions, if any, might be placed on their use. Any GI award will reduce the amount of spectrum available for licence-exempt access and at this stage we are not able to say whether this reduction will be material in any location.

Geolocation

2.14 On 17 November 2009, we published a discussion document[8] entitled "Digital Dividend: Geolocation for Cognitive Access. A discussion on using geolocation to enable licence-exempt access to the interleaved spectrum" (the "November 2009 Consultation").

2.15 We set out five key issues to be addressed in developing a geolocation approach.

- *The information to be provided by the device to the database(s)*. We suggested that this be flexible with the device allowed to select from providing only its location through to providing location, locational accuracy[9], device type and preferences as to the amount of information that it receives.

- *The information returned from the database(s) to the device*. We suggested that this should be a list of frequencies and power levels for each geographical pixel or location.

- *The frequency of update of the database(s) and hence the periodicity with which devices will need to re-consult*. We suggested that devices consult the database every two hours.

- *The modelling algorithms and device parameters to be used to populate the database(s)*. We made some detailed suggestions as to propagation algorithms, assumed device sensitivity and methodology that would enable the database to derive the list of frequencies that could be available for WSDs from the information provided about licensed use.

- *The maintenance of the database(s)*. We sought views as to who should be responsible for the database and on what terms, where the costs might fall and what role it would be appropriate for regulators to play.

2.16 The responses to the November 2009 Consultation[10] were predominantly supportive to our proposed way ahead with some useful suggestions for improvement or for additional flexibility. Sixteen responses were received (one of which was confidential). Most supported our proposals and many made constructive suggestions for how they might be improved. There was a high degree of consensus across most of the questions that we asked. Of those who expressed concern, one respondee felt that the white spaces might be used by mobile operators in conjunction with licenses in the digital dividend spectrum and that this should be studied before licence-exempt access was taken any further. Another said that Ofcom was not taking interference concerns seriously enough and wanted a wide

[8] See http://www.ofcom.org.uk/consult/condocs/cogaccess/
[9] Defined as the radius of an area that the device is 95% that it actually resides within.
[10] See http://stakeholders.ofcom.org.uk/consultations/cognitive/?showResponses=true

range of reassurances and increases in protection. Details of the responses on a question by question basis are provided below.

2.17 Question 1: *Should we suggest only high level parameters, leaving further work to industry, or should we seek to set out full details of parameters to be exchanged?* There was widespread agreement that we should only suggest the high level parameters and also that standardisation of parameters was needed, although most respondees did not recommend any particular body where parameters could be standardised. One respondee urged that we remained involved in this area.

2.18 *Question 2: Should both closed and open*[11] *approaches be allowed? Should there be any additional requirements on the providers of closed databases?* Respondees generally argued for flexibility with any arrangement of closed and open databases being allowed to co-exist. Some suggested that there must be at least one open database to ensure that all devices could operate but that multiple open databases should be encouraged. Others noticed that closed databases could cause consumer concern, particularly if shut down. A few reminded us that we would need to police all the databases to ensure correct content.

2.19 *Question 3: What information should be provided to the database? Are our assumptions about fields and default values appropriate?* Respondees agreed with our proposals. A few argued for flexibility in adding further parameters or defining inputs such as the geographical area of interest in more detail. Some felt that further work was needed on the accuracy of location-based systems (which is already underway as a research topic within Ofcom) and some that height information would also be needed.

2.20 *Question 4: Should the translation from transmitter location to frequency availability be performed in the database or in the device?* Many respondees agreed that the database was the correct location. A few commented that translation in the device should also be allowed although some expected this only to happen in the longer term as devices became more capable.

2.21 *Question 5: Have we outlined an appropriate information set for the database to provide to the device? Can industry be expected to develop the detailed protocols?* All respondees agreed with our suggestions. One noted that in the case of master-slave operation the radius of validity of the returned information might be needed, however, the device should be able to specify this itself. One respondee asked that they be involved in setting parameters.

2.22 *Question 6: Is a two-hourly update frequency an appropriate balance between the needs of licence holders and of cognitive device users?* Respondees generally thought that two-hourly updating was the right balance but some pointed out that if time validity is provided then a general update frequency is not needed. One respondee requested further work be done to understand how frequently channels were needed at shorter notice than this. Another commented that two-hour updating might result in over-booking of channels just in case one was needed at short notice.

2.23 *Question 7: Is there benefit to devices receiving a time validity along with any database request and to act accordingly?* All respondees agreed that this was a sensible suggestion.

[11] Open databases are those that any device can consult, closed databases are available only to particular types of devices (eg from one manufacturer) or particular classes of user (eg those who have signed up).

2.24 *Question 8: What role could push technology play?* Most respondees thought that there was a role for push technology as many expected master devices to be permanently connected to the Internet or to have cellular connectivity. However, most respondees agreed that it should not be assumed but should be an option alongside the time validity. One noted that an acknowledgement for any pushed data would be needed while another felt it should be compulsory to enable rapid updating of PMSE usage.

2.25 *Question 9: Do you have any comments on the suggested approach to implementing the database for DTT?* Only a few respondees addressed this question. They thought that the signal levels proposed may need adjustment as future DTT modes are introduced or to take into account interference to loft mounted antennas and portable reception.

2.26 *Question 10: Do you have any comments on the suggested approach to implementing the database for PMSE?* Only a few respondees addressed this question. Some argued that the -77dBm level was too conservative and need not be used everywhere but that -67dBm could be used for indoor applications. A few commented that the 20dB building loss was too high and some suggested 7dB be used instead. One was more critical, suggesting a large downward revision of signal levels allowed and that large numbers of multiple devices be taken into account.

2.27 *Question 11: Do you believe it is practical to implement such a database?* All respondees agreed this was practical. One noted that if the computations proved complex then simplifications could be made so long as they were conservative.

2.28 *Question 12: Is it appropriate for third parties to host the database? If so should there be any constraints? If not, who should host the database instead?* Respondees thought it was acceptable for third parties to host the database as long as appropriate commercial arrangements were well defined including the need to be neutral in dealing with all types of devices. Some thought database providers should be licensed so their correct operation could be ensured. Many thought that the best way to overcome any concerns was to seek multiple providers. A few noted the need for Ofcom to carefully regulate all parties.

2.29 *Question 13: How can any costs best be met?* Most respondees recognised that there were costs associated with the database provision and that they might need to be met in some way. However, views were divided as to the best way to achieve this. Some suggested that funding models would emerge over time and did not need consideration yet, whereas others accepted funding might be needed in the shorter term and some felt this should be provided by the regulator (or other public body). Some suggested costs must fall with those who caused them.

2.30 *Question 14: What are the difficulties and expected costs to licence holders in providing the necessary information to the database? Could this information be provided in any other way?* Respondees felt that the costs to the licence holders should not be materially different from those they bear today and indeed that automated methods of registering devices might actually reduce these costs. Some felt that any PMSE band manager could readily provide this information and one provided proposals for how changes to TV planning could be handled.

2.31 Our conclusions from these responses (elaborated on in more detail in the rest of this document) were that:

- Our approach of setting out the key parameters we would expect to see transferred to and from the database is appropriate. We should let industry and standards bodies determine the detailed protocols.

- We should be flexible with regards to the number and form of databases. However, each database will need to be registered and there must be a mechanism to verify its correctness.

- An implication of this is that there will need to be an agreed process whereby all database owners can download the parameters of licensed operation from single databases likely owned by the PMSE band manager and the broadcasters.

- At present we should require translation within the database, not the device. Licence holders find this preferable and there is little call for device translation. However, we might review this decision in the future.

- Providing a time-validity stamp to the data is a better solution than setting a minimum update time. The default might be two hours initially.

- Database providers can use push technology as well if they wish but it is not something we need to incorporate into any regulations at this point.

- Further discussion was needed with licence holders and other stakeholders to set the parameter values used in the propagation modelling.

- There does not appear to be any reason to prevent bodies other than Ofcom hosting any databases as long as they are appropriately regulated.

- There is little consensus on what any costs might be and where they should fall. However, it is not clear that this issue needs to be addressed immediately and might best be revisited as the market structure becomes clearer.

2.32 We subsequently held a workshop with respondees where we discussed the detailed parameters used in the database and reached agreement on values, or means to determine values.

Licence exemption and Ofcom directory for geolocation database(s)

2.33 Based on the responses that we received, workshops held with key stakeholders and further analysis and thinking we then concluded that:

- The device would be licence exempt.

- In order that Ofcom can manage the databases the device would initially consult an Ofcom list of databases and select from this its preferred database.

- The device would contact this preferred database and provide as a minimum its location, the accuracy of that location (unless better than 100m[12]), its model identifier[13] and height above ground level if mounted on a mast or similar. It might

[12] Since we are assuming 100m pixels for coverage modelling, any greater accuracy than 100m for location will probably not bring benefits and hence we assume a default value of 100m.
[13] This will be a unique text string set by the manufacturer at the time of placing the device on the market and communicated to the database provider. For example, it might have a form such as “MOT-WSD-M635”. The information can be used to tailor responses according to the devices out-of-

also provide further information including the amount of data it wished to receive in response.

- The database would return an information set which must include start and end frequencies for available bands, associated maximum power levels, a time validity for the information and a notification of any requirement for sensing to be used in addition.

- Many different database ownership options might emerge and we should be as flexible as possible in allowing one or more databases and providing mechanisms for future changes.

2.34 Subject to responses to this consultation document we will then need to:

- consult on and later publish a Statutory Instrument (SI) exempting appropriate devices from the need for a licence;

- make arrangements to enable information about licensed services in the relevant spectrum to be made available to a database; and

- specify requirements to be met by geolocation database(s) that wish to be listed on the Ofcom website.

Our duties relating to licence-exempt access to interleaved spectrum

Our general duties

2.35 Under section 3(1) of the Communications Act, it is our principal duty in carrying out our functions:

- 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.

2.36 In carrying out this principal duty, we are required to secure a number of objectives such as the desirability of promoting competition, investment and innovation.

Our spectrum duties

2.37 In carrying out our general duties, we are required 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.

2.38 In addition, in carrying out our spectrum functions, we are specifically required to have regard in particular to:

- the extent to which the spectrum is available for use or further use for wireless telegraphy;

- the demand for use of that spectrum for wireless telegraphy; and

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band emissions, if known, or to apply different regulation to particular classes of device as appropriate.

- the demand that is likely to arise in future for the use of that spectrum for wireless telegraphy;

2.39 and 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 ECSs.

Our duties in relation to the proposed licence exempt access

2.40 We believe that, in particular, licence-exempt access to these bands will promote efficient use of spectrum, bring economic benefits, allow the emergence of innovative services and may lead to increased competition. We set out why we believe this below.

2.41 *Efficient use of spectrum*: Unlicensed access to the interleaved spectrum allows additional use in these frequency bands. Without this access the “white spaces” would remain unused. Such access must increase the efficiency of use of the spectrum although at this stage it is not clear by what factor.

2.42 *Bring economic benefits*: At this early stage it is difficult to predict what the economic benefits of licence-exempt access might be as this depends on the applications that succeed and the adoption levels of enabled devices. As set out in Annex 6 we estimated that unlicensed access might lead to benefits in the region of £170m - £270m NPV over the next 20 years.

2.43 *Innovative services*: Licence-exempt spectrum is often an area where innovative new services emerge since the barriers to entry are low. Examples of this include WiFi, BlueTooth and myriad short range devices. The interleaved spectrum brings advantages over other licence-exempt spectrum in that its propagation characteristics allow greater range and that in many locations there is more bandwidth available than other similar bands. Many key players such as Google, Dell and Intel anticipate significant innovation in this band. Clearly it is not possible to predict that innovation will happen but opening this band to licence-exempt use seems likely to stimulate a range of new uses and ideas.

2.44 *Promoting competition*: It may be that some of the applications to emerge provide competition to existing providers. For example, some have suggested that white space devices in homes could provide data coverage to those passing by and that with the extended range in these frequency bands, providing near-complete coverage of cities is practical. In this case, opening these bands might provide competition both for cellular data networks and public WiFi networks in the more dense urban areas.

2.45 Hence we believe that enabling licence-exempt access to the interleaved spectrum aligns well with many of our duties in relation to radio spectrum with few, if any, downsides.

Our expectations for geo-location

2.46 As set out above, we plan to enable licence-exempt access as we believe this is in line with our duties and will bring significant benefits. However, there are issues to be resolved and potential problems with using these bands. While it is not our role to predict what might emerge and by when, we do believe that it is worth setting out our expectations at this stage in order that those unfamiliar with this area are better able to judge what the implications might be.

2.47 In the short term (between now and 2013) we do not expect mass deployment. Our experience is that new concepts take some time to move from prototype through silicon design and fabrication to mass market device. With the development of standards and databases still underway we are only at the start of this process. It is possible that some niche applications may emerge, for example rural broadband, where high levels of silicon integration are not needed.

2.48 In the longer term (2014 and beyond) we hope to see the increasing emergence of devices. We might expect these to follow a classic “S-shape” penetration curve so that in the first few years (perhaps 2014 and 2015) penetration is relatively low but might build beyond that. Initial applications might be variants of existing systems – for example home routers with greater range or better tailored towards video content – with the more innovative applications emerging later. There might also be enhancements to the manner in which white space is used which are discussed in Annex 7.

2.49 At this stage, we do not expect licence-exempt access to these bands to materially change the mobile communications environment. We expect cellular communications to continue to be the main means of connectivity when outdoors and for WiFi to remain important indoors. Access to these bands might lead to innovative new devices or connectivity or more choice and competition.

Q1: What are your views on the likely use and take-up of WSDs? Do you intend to participate in this area, for example by hosting a pilot or developing equipment?

Structure of this document

2.50 This document is structured as follows:

- Section 3 sets out how we envisage geolocation to work.
- Section 4 considers the structure and form of the SI.
- Section 5 considers the processes for registering and validating the database.
- Section 6 sets out next steps.
- Annex 4 provides more details on the database procedures and algorithms.
- Annex 5 provides technical background on DTT location probability calculations.
- Annex 6 provides our impact assessment.
- Annex 7 discusses possible extensions of white space access in the future.

2.51 In this document, we will refer to licence-exempt devices accessing the interleaved spectrum as “white space devices (WSDs)” rather than the previous terminology we have used of “cognitive devices”. We propose this change in terminology because:

- Where a database is used the device is not exhibiting intelligent or cognitive behaviour but merely responding to the information received from the database.

- In the US the term WSDs has become common usage and we see no value in having different terminology for the same device.

Section 3

Geolocation in practice

Overview of our suggested process

3.1 Our suggested process to enable spectrum access to WSDs via geolocation is discussed below.

The geolocation device

3.2 There are two types of WSDs:

i) "master devices" that contact a database to obtain a set of available frequencies in their area; and

ii) "slave devices" which obtain the relevant information from master devices but do not contact the database themselves.

3.3 For example, a master device might be a wireless router in a home – similar to a WiFi router but operating in the interleaved frequencies – while the slave devices might be other wireless devices in the home such as laptops and printers that are connected to the router.

3.4 In order to be used legally within the UK, any device that emits a radio signal must either have a licence or be exempted from licensing. We therefore propose to exempt WSDs from the need to be licensed. This is set out in greater detail in Section 4.

Geolocation database

3.5 The function of the database is to take as inputs an appropriately amended version of the DTT coverage plan, the PMSE usage, any other licensed usage and parameters provided by the WSD and return to the WSD a list of information enabling it to access the spectrum. This is set out in more detail in Section 5. We have not yet discussed conditions of access to the amended version of the DTT coverage plan and the PMSE usage with the relevant parties but will move to do so if the outcome of this consultation is favourable.

Ofcom

3.6 Ofcom (or trusted party) will provide a list of databases on a website in a form that is readable by WSDs[14].

3.7 Further work will be required to establish how access to the licensing information for DTT and PMSE would be facilitated.

3.8 This licensing information would include an amended version of the DTT coverage plan. This would be provided in terms of predicted signal level for each 100m x 100m tile comprising the UK. Amendments to the plan will be needed to accommodate factors such as the location probability within each pixel, the time variation probability and the use of less than perfect TV antennas, especially in areas of good signal

[14] We will define the format to be used in due course, likely in conjunction with the first database suppliers.

strength. Further changes may be required in those channels close to the upper band edge (the boundary between channel 60 and 61) both to provide protection to licensed use in channels 61 and above and also to reflect the increased interference that might be experienced in channels below the band edge from licensed use in channels 61 and above. We intend to work with the broadcasters through the JPP to reach agreement on the required amendments.

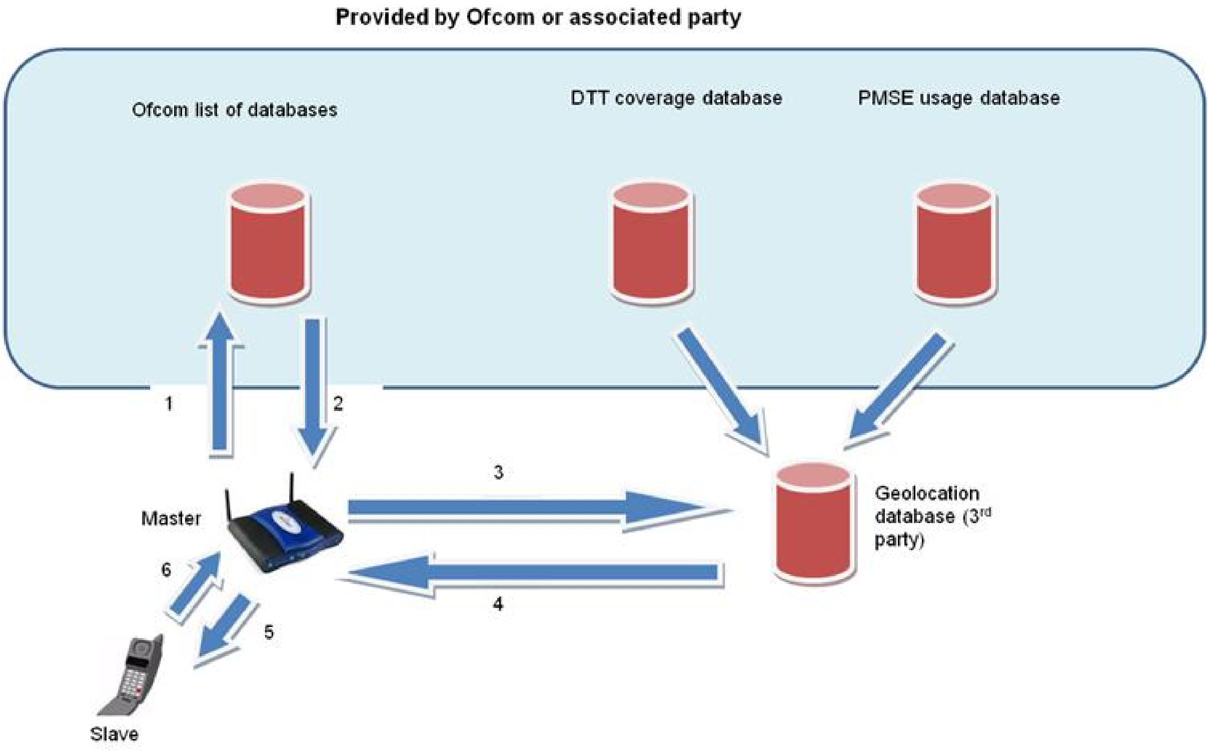
3.9 Database providers would be able to download this information. Ofcom would send notification of any changes to the DTT database to database providers. Details such as the formatting used will be discussed with database providers in due course.

3.10 We would also need to foster a link between database providers and the PMSE licensing data to enable database providers to obtain real-time information on PMSE usage. Details such as the formatting used could be discussed with database providers in due course.

3.11 It is possible that there may be other uses of the interleaved spectrum such as local TV. As these emerge we will work with licensees to understand the best means whereby appropriate information can be passed to any database provider.

The process

3.12 The process that a device follows is shown in the diagram below and discussed in more detail in this section.



3.13 The process is as follows:

1. The master device contacts a website maintained by Ofcom or similar body (1 on the diagram) which holds a list of the geolocation databases (2 on the

diagram). Each contact is valid for 24 hours – if longer than that has expired then the device will need to reconsult.

2. The master device then decides which of these geolocation databases it wishes to consult (if there is more than one) (3 on the diagram). The device will send to its selected database as a minimum:

   - Its location provided in terms of a latitude – longitude positional fix.
   - Its determination as to the accuracy of that location to a 95% certainty provided in metres.
   - Its model type provided in terms of manufacturer and model number.
   - Its height above ground level if it is a fixed terminal mounted on a mast or similar.

3. The database will provide by way of a response (4 on the diagram) a set of available frequencies in the master device's area, each of which includes the following:

   - The start and stop frequency for the channel.
   - The allowed power level for using the channel.
   - The channel validity time (ie the time that the device is allowed to use the channel before having to re-check with the database).
   - Whether sensing is required in addition to geo-location (note, this requirement is not proposed to be used in the UK but included to aid international harmonisation). If sensing is needed then the sensing level in dBm and the type of primary usage (eg DTT) will also be provided.

   This response is based on information the geolocation database has accessed from the DTT coverage map and the PMSE usage database which has been processed using the algorithm provided in Annex 4.

4. A master device can then signal allowed frequencies and power levels to any slave devices on its selected channels (5 on the diagram) and the slave can respond with confirmation or data (6 on the diagram).

Taking account of the separation between master and slave devices

3.14 The slave devices will be some distance from the master device. As a result, they may be closer to a licensed receiver than the master and when they transmit they may cause interference. To prevent this occurring the master device needs to inform the database of the possible distance away that slave devices may be located and the database can then take this information into account when assigning frequencies and power levels.

3.15 We propose that an effective way for the master device to do this is to increase its location uncertainty by an amount related to the maximum expected range between the master and slave device. Hence, if the master device knew its location accuracy to 100m and it knew that the maximum range to a slave device was 500m it would report a location accuracy of 600m to the database. The database would then search across all pixels within the possible location circle and return a result based on the minimum power level across all pixels for each frequency.

3.16 However, the master device will not be able to know with certainty the maximum distance to the slave device. This will depend on the power levels it allows the slave device to use and the link budget for the technology selected. There may be significant differences between technologies – for example one that makes use of spreading might be able to achieve a much greater range (but lower data rate) than another for a given power level. As part of any device conformance process we would expect manufacturers to demonstrate how they have determined the maximum master to slave range.

3.17 Master devices will be free to select the power levels allowed for communication with the slave. These must be no greater than the power levels that the master device has been authorised to use, but may be less. The advantage of selecting a lower power level will be a small radius of location uncertainty which may translate to a wider range of frequencies to select from.

3.18 Some applications envisage more complex coverage. For example, a point-to-point link might have a narrow beam of coverage. In such an application using location uncertainty to signal the link range would result in a database search across a circle rather than a segment of a circle, which might result in less spectrum appearing to be available than is actually the case. Other example can be envisaged, such as base stations where the coverage is known and is perhaps far from circular due to local terrain.

3.19 We are not proposing to try to signal complex coverage areas from the WSD – to do so would require complex parameter definition. However, we do envisage that such a WSD user might pre-agree with the database provider the attributes of their device (eg beamwidth, known coverage area) and that the database would recognise an enquiry from such a device through the model identifier and tailor the returned information accordingly.

Section 4

Exempting the white space devices

Introduction

4.1 In order to be used legally within the UK any device that emits a radio signal must either have a licence or be exempted from licensing. In our December 2007 Statement on DTT we discussed whether WSDs should be licensed or exempted and have concluded that greater value can be delivered if they are exempt from licensing. Hence, we intend in due course to consult on and publish a Statutory Instrument (SI) which provides the necessary legal framework for their operation. Similar to the SI for other licence exempt usage we may decide to reference a published Interface Requirement (IR) in the final SI. The IR would normally contain the technical and or usage parameters (shown below) that the equipment will have to comply with.

Draft structure of the SI

4.2 We believe that two different kind of devices need exemption

i) "master devices" that contact databases to obtain a set of available frequencies in its area; and

ii) "slave devices" which obtain the relevant information from master device but do not contact the database themselves.

4.3 Exemption from licensing of a "master device" would be subject to the following :

i) Determining its location and assessing the accuracy of that location with 95% certainty. This location accuracy should reflect the maximum area of operation within which slave devices can be located.

ii) Consulting a list maintained by Ofcom of geolocation databases and selecting one of these databases unless it has previously consulted the list within the last 24 hours.

iii) Sending its location and accuracy of that location to the selected geolocation database along with its model identification and for devices mounted on a mast or similar its height above ground level.

iv) Receiving from that database a set of parameters including the frequencies of allowed operation, associated power levels, geographic validity of operation and time validity of operation. Other parameters may also be provided.

v) Operating in accordance with these parameters, ceasing transmission immediately where the time validity expires or where it moves outside of the geographic area of validity.

vi) Operating in a "fair" manner, sharing the available spectrum resource as evenly as possible across competing users in line with the recommendations in "Spectrum Commons Classes for Licence Exemption"[15].

vii) Provision from the device manufacturer as to the out-of-band performance of their device in terms of relative power levels emitted into adjacent bands up until n+/-9 or until power falls to the noise floor.

viii) Managing slave devices as required by signalling to them the parameters by which they may communicate with the master device.

ix) Maintaining a record of all active slave devices and requiring slave devices to stop transmission if the master device needs to cease transmission for any reason including an expiry of time validity or moving outside the geographical area of validity.

4.4 Exemption from licensing of a "slave device" would be subject to the following:

i) Receiving a signal from a master device indicating that a channel is available for use along with an allowed power level.

ii) Operating in accordance with the signalling from the master device.

iii) Ceasing transmission immediately when instructed by the master device or within 5 seconds of not receiving a response from the master device to a transmission.

iv) Transmitting only to a master device (and not directly to other slave devices).

v) Provision from the device manufacturer as to the out-of-band performance of their device in terms of relative power levels emitted into adjacent bands up until n+/-9 or until power falls to the noise floor.

Q2: Are these appropriate conditions for licence exempting the WSDs?

Verifying device operation

4.5 It is clearly important that WSDs perform so as to avoid harmful interference to other services. The conformance of radio devices is covered by Directive 1999/5/EC on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity (the "RTTE Directive)[16]. This requires manufacturers to ensure that devices placed on the market are compliant.

4.6 Voluntary European Harmonised standards, developed by the European Telecommunications Standards Institute (ETSI), are the preferred method for manufacturers to show that their radio products comply with the RTTE Directive.

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[15] See http://stakeholders.ofcom.org.uk/consultations/scc/statement/ . This sets out that a fair wireless user is one that shares the resources equitably with other users, and behaves appropriately according to its needs. To behave fairly a device should implement a method to become aware of other users of the same resources, not monopolize the resources so that other users cannot access them and implement a method to reduce its channel occupancy when there is congestion.

[16] http://www.rtte.org/documents/RTTEoj.pdf

However, while some standards bodies are currently working on WSD standards, no such standards currently exist for WSDs and may not be available for some time.

Q3: Is the lack of European harmonised standards problematic for development of WSDs?

Section 5

Obtaining a database listing

Introduction

5.1 The responses to our November 2009 Consultation predominantly favoured a flexible model to the provision of databases where any number of "open" or "closed"[17] databases might emerge. Reponses also indicated a preference for industry to provide the database rather than Ofcom. We would also prefer industry provision as we believe that such a database may eventually need to service millions of requests per day and that servicing each request may require a material amount of data processing. Hence, the database provision may entail significant IT resources which Ofcom does not possess but an external company may be well placed to provide.

5.2 However, at all stages in our consultation and discussion on white space access to the DDR spectrum we have made it clear that we will only allow such access if it does not cause harmful interference to licence holders in the band which includes the broadcasters and PMSE community. Prevention of harmful interference is controlled by the parameters in the database and therefore we, and affected stakeholders, need to have confidence that these are maintained accurately and that there are processes in place for rapidly dealing with cases where inaccuracies occur.

5.3 We consider that the database(s) may be more efficiently run by commercial entities as they are likely to have the necessary IT resources. Those interested in running a database would approach Ofcom in order to apply for a listing on a website hosted by Ofcom (or a trusted party) from which WSDs can then select their preferred database. We would need to consider applications against certain minimum requirements and may require entry into a contract and payment for the listing of the database.

Requirements of the geolocation database

5.4 The geolocation database will only function is it has access to up-to-date DTT and PMSE licensing information, and it is important to note in this context that the PMSE data may change on an hourly basis. We have not yet discussed conditions of access to the amended version of the DTT coverage plan and the PMSE usage with the relevant parties.

5.5 Database providers must use the propagation algorithms and interference parameters as set out in Annex 4, or alternatives that can be shown to always return results that are the same or more conservative and have been approved by Ofcom.

5.6 Database providers must supply at least the minimum set of parameters in response to an enquiry. These are defined for each geographical location ("pixel") as a set of lower and upper frequencies and for each frequency the maximum power, time validity and any need for sensing.

[17] We define an "open" database as one that any device can access where as "closed" database can only be used by a subset of devices, eg those from a particular manufacturer or user community.

5.7 Databases must provide a response within 10 seconds[18].

5.8 Databases must not discriminate between devices in providing the minimum information levels. However, they may provide additional information to certain classes of devices.

5.9 Database operators will update their algorithms or parameter values within a week of receiving notification from Ofcom that they are to do so. In the case where Ofcom deems that the interference is significant (for example with safety of life or other serious implications) they may be asked by Ofcom to “blank out” parts of the database to prevent any access to particular bands in particular areas and must do this in less than an hour.

Q4: Do you have any comments on these requirements? Are there any other requirements that should be placed on the database?

Responsibilities of the database provider

5.10 Our current thinking is that database providers would not be responsible for interference that occurred to licence holders if this was a result of:

- incorrect information within the DTT or PMSE databases;
- inaccuracies of the propagation algorithm provided, or
- inaccurate information provided by the WSDs.[19]

5.11 However, they would be responsible for interference caused and potentially liable to pay compensation (for example to viewers or affected licensees) in the cases that:

- they incorrectly implemented the algorithms provided by Ofcom,
- they failed to update the database within the timescales required (which are likely to be of the order of two hours),
- they failed to change the algorithms within a period of a week in the case that Ofcom decided changes were needed.

Q5: Do you have any comments on these responsibilities?

Q6: Might you be interested in becoming a database provider? If so, can you provide more details on the extent and timing of likely provision?

[18] This will be measured as the time between the enquiry arriving at the database and the response leaving the database, ie it will not include delays in the communications channels.
[19] It would be the responsibility of Ofcom to investigate and put in place measures to resolve interference in these cases.

Section 6

Next steps

6.1 We are requesting comments on this consultation by 7 December 2010. We will give due consideration to all responses in determining the most appropriate course of action.

6.2 This may include moving directly to consult on an SI (such as that provided as an example in Section 4) and publishing the application criteria for a database listing and contractual conditions for successful applicants. Alternatively, we may decide that it is appropriate to pause for further consideration or to achieve international harmonisation.

6.3 We are currently participating in European harmonisation activities around WSDs including CEPT working group SE43. These discussions are still at a relatively early stage and it is currently unclear where they will lead. We expect SE43 to provide a final report before the end of 2010 but this may lead to further European-level activities perhaps within ECC, EC or ETSI. We will continue to play a part, seeking to achieve European harmonisation around the concepts and ideas set out in this document. If it becomes clear that harmonisation will result in different concepts than those set out here then we will consider whether to modify our proposals. We will also work with other countries, such as the US, to seek global alignment as far as possible.

6.4 At present the timing on any such harmonisation is unclear and hence we cannot at this stage determine whether it is better to move ahead or await harmonisation. This may become clearer before the end of the consultation period of this document.

6.5 Given the lack of certainty it is possible that if we move ahead with the proposals set out here that we might have to amend any SI that we issue and that, in the worst case, we might have to terminate a contract with a database provider or require substantial modifications to their database. We see these outcomes as highly undesirable and would not proceed with our proposals if we thought them likely. If we do decide to move ahead with our proposals prior to achieving harmonisation we will attempt to describe the risks associated with international harmonisation as clearly as we are able to at that point.

Q7. Is our approach of working with Europe where possible, but moving ahead alone if no European approach appears forthcoming, appropriate or should we await European harmonisation regardless of how long this might take?

6.6 As we move ahead through this process and understand in more detail the associated costs, such as those of providing licensing data to the geolocation database operators it is possible that we will conclude that the costs are such that we are unable to proceed directly with our proposals. In this case, we may investigate alternative approaches or alternative routes for funding. If these are not successful it is possible that we might not move ahead with these proposals on cost grounds.

6.7 If we do decide to move ahead prior to any European harmonisation that might occur and if the costs do not prove problematic then we would expect to issue a SI around the middle of 2011 and to have the acceptance procedure for database applications in place in around the same timescales. Subject to interest from industry this might pave the way for initial deployments in the second half of 2011 although we would anticipate that these would be small-scale trials.

Annex 1

Responding to this consultation

How to respond

A1.1 We invite written views and comments on the issues raised in this document, to be made by 5 p.m. on 7 December 2010.

A1.2 We strongly prefer to receive responses using the online web form at [www.ofcom.org.uk/consult/condocs/] as this helps us to process the responses quickly and efficiently. We would also be grateful if you could assist us by completing a response cover sheet (see annex 3) to indicate whether or not there are confidentiality issues. This response cover sheet is incorporated into the online web-form questionnaire.

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

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

Professor William Webb
Ofcom
Riverside House
2a Southwark Bridge Road
London SE1 9HA

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

A1.6 It would be helpful if your response could include direct answers to the questions asked in this document, which are listed together in annex 3. It would also help if you can explain why you hold your views and how our proposals would impact on you.

Further information

A1.7 If you want to discuss the issues and questions raised in this consultation or need advice on the appropriate form of response, please contact Professor William Webb on 020 7981 3770.

Confidentiality

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

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

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

Next steps

A1.11 Following the end of the consultation period, we will publish a note summarising the responses we have received. We will decide what to do next in the light of those responses.

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

Our consultation processes

A1.13 If you have any comments or suggestions on how we conducts our consultations, please call our consultation helpdesk on 020 7981 3003 or email us at consult@ofcom.org.uk. We would particularly welcome thoughts on how we could more effectively seek the views of those groups or individuals, such as small businesses or particular types of residential consumers, who are less likely to give their opinions through a formal consultation.

A1.14 If you would like to discuss these issues or our consultation processes more generally, you can alternatively contact Vicki Nash, Director Scotland, who is our consultation champion:

Vicki Nash
Ofcom
Sutherland House
149 St. Vincent Street
Glasgow G2 5NW

Tel: 0141 229 7401
Fax: 0141 229 7433

Email vicki.nash@ofcom.org.uk

Annex 2

Response cover sheet

A2.1 In the interests of transparency and good regulatory practice, we will publish all responses in full on our website: www.ofcom.org.uk.

A2.2 We have produced a cover sheet for responses (see below) and would be very grateful if you could send one with your response. (It is incorporated into the online web form if you respond in this way.) This will speed up our processing of responses and help to maintain confidentiality where appropriate.

A2.3 The quality of discussions can be enhanced by publishing responses before the period closes. In particular, this can help those individuals and organisations with limited resources or familiarity with the issues to respond in a more informed way. Therefore, we would encourage respondents to complete their cover sheet in a way that allows us to publish their responses upon receipt rather than waiting until the period has ended.

A2.4 We strongly prefer to receive responses via the online web form, which incorporates the cover sheet. If you are responding via email, post or fax, you can download an electronic copy of this cover sheet in Word or RTF format from the consultations section of our website at www.ofcom.org.uk/consult/.

A2.5 Please put any parts of your response you consider should be kept confidential in a separate annex to your response and include your reasons why this part of your response should not be published. This can include information such as your personal background and experience. If you want your name, address, other contact details or job title to remain confidential, please provide them in your cover sheet only so we do not have to edit your response.

Cover sheet for response to an Ofcom discussion document

BASIC DETAILS

Document title:

To (Ofcom contact):

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

CONFIDENTIALITY

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

Nothing	☐	Name/contact details/job title	☐
Whole response	☐	Organisation	☐
Part of the response	☐	If there is no separate annex, which parts?	

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

DECLARATION

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

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

Name   Signed (if hard copy)

Annex 3

Consultation questions

Q1: What are your views on the likely use and take-up of WSDs? Do you intend to participate in this area, for example by hosting a pilot or developing equipment?

Q2: Are these appropriate conditions for licence exempting the WSDs?

Q3: Is the lack of European harmonised standards problematic for development of WSDs?

Q4: Do you have any comments on these requirements? Are there any other requirements that should be placed on the database?

Q5: Do you have any comments on these responsibilities?

Q6: Might you be interested in becoming a database provider? If so, can you provide more details on the extent and timing of likely provision?

Q7. Is our approach of working with Europe where possible but moving ahead alone if no European approach appears forthcoming appropriate or should we await European harmonisation regardless of how long this might take?

Annex 4

Database procedures and algorithms

Introduction

A4.1 The input to a geolocation database will typically be licensed usage (set of appropriately modified DTT coverage plans, PMSE coverage information, any other licensed use), information supplied by device manufacturers as to the out-of-block performance of their devices and positional information from a WSD master device. The database will supply a list of available frequencies and associated radiated powers to WSDs. Hence, a translation must be performed between these input data and output parameters.

A4.2 It is clearly critical that this translation is performed appropriately. If it is not then there is a risk either of harmful interference occurring to licensed users or of the WSDs having access to the spectrum limited unnecessarily. This annex sets out the draft rules for performing such a translation.

A4.3 It is likely that we will refine these rules as more information and experience becomes available and as we work with database providers. This section should be seen as indicative guidance rather than definitive and final procedures and parameters. However, we would welcome any comments at this stage on these proposals.

Overview of the translation process

A4.4 The database will provide a WSD with a maximum power level that it can use in a given location and for a given set of lower and upper frequencies. In arriving at these data, the algorithms employed need to ensure that a device in that location transmitting with the given power level will not cause harmful interference to a licensed user.

A4.5 Interference to a licensed use will occur at the receiver of the licensed user. Hence, the database will need to be supplied with the coverage area within which receivers might be located, the level of interfering signal they can tolerate both in-block and out-of-block before the interference becomes harmful, the relative out-of-block emissions of the WSD and the coupling loss between the WSD and the receiver. If all these are known then the device radiated power can be determined.

A4.6 For receivers to operate without harmful interference they need the wanted signal to exceed the interfering signal by a ratio known as the carrier-to-interference protection ratio. This differs for different technologies but can generally be characterised in advance using either device specifications or actual measurements. Then, using information on the likely wanted signal strength based on propagation predictions, the maximum permitted interfering signal strength can be predicted at the receiver. Protection ratios are specified as a function of interferer-victim frequency separation. In addition, protection ratios can also be specified as a function of the wanted signal power, in which case the protection ratios can also be used to implicitly model the non-linear behaviour (*overloading*) of the licensed receiver.

A4.7 At the point in time when a device manufacturer seeks type approval for their device (or self-certifies) they will need to provide Ofcom with the worst-case out-of-block emissions for that device stated in terms of emitted EIRP power levels relative to the wanted signal for frequencies extending to n+/-9 (+/- 72MHz).

A4.8 In outline the algorithm employed is then:

For each possible channel that the WSD might operate on do the following:
For each possible location pixel that the WSD might be in do the following:
Find the minimum power level based on in-band emissions
Find the minimum power level based on out-of-band emissions
Set the minimum of these two values as the allowed power
Repeat for all possible locations and take the minimum value as the allowed power level for that channel
Repeat for each channel

A4.9 The minimum in-band power is found by:

For channels n-9 (-72MHz) through n+9 (+72MHz) including channel n (the channel currently under consideration) do the following:

- Lookup the C/I ratio needed for the licensed service at the given offset (eg for channel n-9 lookup the C/I ratio needed when the interfering signal is 72MHz from the wanted signal)
- Calculate the minimum distance from the WSD to a licensed receiver operating at this offset using the known location of the WSD and receivers
- Use the appropriate propagation algorithm and antenna parameters to determine the coupling loss associated with this distance (or if the WSD and licensed receiver are in the same pixel use the minimum coupling loss – see Annex 5)
- Lookup the expected minimum signal strength in that pixel as provided by the appropriate database (or if not available assume the minimum usable signal level)
- Compute the sum "expected minimum signal level" – "C/I ratio" + "coupling loss" to derive allowed transmit power

Repeat for each channel and take the lowest power level across all channels

A4.10 The minimum out-of-band power is found by:

For channels n-9 (-72MHz) through n+9 (+72MHz) including channel n (the channel currently under consideration) lookup the C/I ratio needed for in-band interference and then do the following:

- Lookup the out-of-band emission levels for the WSD relative to the in-band power
- Use the coupling loss and wanted signal levels derived in the in-band calculations above
- Compute the sum "expected minimum signal level" – "C/I ratio" + "coupling loss" + "relative OOB emission level" to derive allowed transmit power

Repeat for each channel and take the lowest power level across all channels

A4.11 Examples of these calculations are given later. We next discuss appropriate levels for C/I protection ratios for DTT and PMSE and the propagation algorithms to be used.

DTT protection levels

A4.12 Over many years broadcasters have carefully predicted the signal levels that will be received from their transmitter networks and have refined and validated these predictions. This implies that the database will not need to perform propagation modelling on behalf of DTT. However, before making use of the DTT predicted signal levels we need to modify them to take account of location probability, time probability, non-optimal antennas and band edge effects at channels 60/61. We may also need to take other factors into account. These issues will be discussed and agreed with the broadcast community before implementation of the database and some initial thinking is provided below.

A4.13 The location probability, presented in more detail in Annex 5, results in some TV receivers in the reference pixel having a lower signal level than the “centre point”. Because we wish to protect all receivers we need to reduce the predicted level to account for this. We propose to reduce the level by a margin that accounts for at least 99% of receivers in the area, although we would not reduce the level below the minimum sensitivity of receivers since in this case these receivers would not be able to receive a TV signal at present.

A4.14 The time probability occurs because at some times interference will be received from continental transmitters. As with the location probability, for those pixels that might be affected by this we need to reduce the signal level accordingly, again not reducing it further once it has reached the minimum sensitivity level.

A4.15 Non-optimal antennas may be deployed where the signal level is high since adequate performance may well be achieved still. Models of the likely additional loss of signal have been developed[20] and we will use these to adjust downwards the predicted signal levels in pixels with relatively good signal strength.

A4.16 Finally, we propose not to allow white space operation in channel 60 both to protect licensed operation in channels above 60 and also because there may be additional interference experienced in channel 60 as a result of use in channels 61 and above. We will also give consideration as to whether lower power levels should be adopted in channels 58 and 59.

A4.17 In previous consultations and statements we have reported on measurements that have determined the necessary C/I ratio for DTT. These suggest that devices can operate with 20dB for co-channel interference, -30dB on n +/-1, -47dB on n+/-2, -49dB on n+/-3, -65 on N+/-4 through N+/-8 and -43dB on n+/-9. We may update guidance on these levels from time to time and may issue protection ratios specific to particular technologies or devices if their impact on DTT differs materially from these numbers.

A4.18 Regarding co-channel interference, the WSD cannot take up the entire 20dB ratio as this would then not allow for other forms of noise and interference. General engineering rules suggest allowing a margin of around 6-10dB such that the interference does not materially degrade this margin. Also, since there might be co-channel and adjacent channel interference present simultaneously, the allowed levels on each need to be reduced by 3dB to ensure the combined effects are not problematic. Hence, taking a conservative approach, the modelling should not allow interference from a cognitive device to a DTT receiver at a level of 33dB C/I (ie the cognitive signal should be at least 33dB below the received DTT signal).

A4.19 A similar approach is needed to set the adjacent channel C/I ratio. Adding in the same margins increases the ratio to -17dB C/I (ie the cognitive signal must be no

[20] http://stakeholders.ofcom.org.uk/binaries/research/tv-research/aerials_research.pdf

more than 17dB above the received DTT signal on the adjacent channel) on n +/-1, -34dB on n+/-2, -36dB on n+/-3, -52dB on N+/-4 through N+/-8 and -30dB on n+/-9.

A4.20 Making use of the existing DTT signal level predictions and the assumptions above for C/I co-channel and adjacent channels for DTT receiver performance should be sufficient to enable the database to calculate the associated WSD transmit powers.

PMSE protection levels

A4.21 In our cognitive statement we noted that most PMSE equipment was operated at signal levels of above -67dBm. While the equipment was capable of operation at much lower levels, using -67dBm provided an adequate margin to ensure a reliable link. However, we accepted that there were some cases where levels as low as -77dBm or even lower were used and suggest that -77dBm be used to determine the limit of PMSE coverage for the purposes of the geolocation database. Hence, using the combination of transmitter power, free space path loss, building penetration (where appropriate) and a minimum signal level of -77dBm the PMSE database provider can determine the location and predicted signal strength of PMSE receivers. Alternatively, they can use deployment information provided directly by the PMSE equipment user.

A4.22 In our statement we suggested that PMSE devices would need a minimum of 25dB C/I for co-channel interference and up to -70dB for channels separated by at least 4MHz. Using the same approach as for DTT this allows us to determine the maximum interference levels as 38dB co-channel and -55dB on n+/-1 adjacent channels. These levels can then be used to determine the signal level that a WSD could generate.

Propagation from WSDs

A4.23 With the information described above a modelling tool will have as an input the possible location of any licensed receivers (DTT and PMSE) and the signal level they would likely experience. It will therefore be able to derive the maximum signal strength allowed from a WSD. The final stage in the process is to translate this into an allowed transmit power for a given location. This is achieved using a propagation model that predicts the difference in signal level between that transmitted by the WSD and that received by the licensed device.

A4.24 We propose that different propagation models should be used in assessing interference to PMSE and to DTT. This is because PMSE terminals are typically at low height – below rooftop level – whereas DTT is typically received from a rooftop antenna which is at, or above rooftop level.

A4.25 For DTT we propose the use of the Hata model with the "base station" height set at rooftop level (around 10m) and the terminal height at 1.5m. The basic model is given by:

A4.26 $$\text{Loss} = 69.5 + 26.16\log f - 13.82\log h - C_H + (44.9 - 6.55\log h)\log d \text{ dB}$$

A4.27 At the frequencies of interest, the antenna correction factor C_H is very small and can be ignored. With the assumptions above this can be simplified to:

A4.28 $$\text{Loss} = 55.68 + 26.16\log f + 38.35\log d \text{ dB}$$

A4.29 where d is the distance from the base station in kilometres and f is the frequency in MHz.

A4.30 For PMSE we propose the use of the propagation model developed by Ofcom for terminals operating at low heights[21]. The model comprises two prediction elements: one for line-of-sight (LOS) and one for non-line-of-sight (NLOS) and an associated distance below which the LOS model is used and above which the NLOS model is used.

A4.31 One of the key parameters for the model is the percentage of locations at which the transmission loss is less than predicted. Where this occurs there is some chance that harmful interference will take place since the signal from the WSD will be stronger than the threshold assumed. However, even in this case harmful interference is still unlikely since there would need to be a licensed receiver actually in that location operating close to its minimum C/I ratio with its antenna oriented such that it received the interfering signal strongly. It is not possible to definitely determine the likelihood of harmful interference where the transmission loss is less than predicted since this depends on real-world geometries and deployment patterns.

A4.32 We specify a 0.1% level for the percentage of locations at which the transmission loss is less than predicted. This implies that there is a very low probability that the transmission loss will be lower and hence the interference level higher than expected. In most cases the converse will be true and the interference levels will be substantially lower than predicted.

A4.33 We specify that the building separation distance in the model be set to 50m and for simplicity that the transition distance between models be set to 0. In this case, the model becomes:

- $L_{los} = a + 20\log\left(\frac{d}{1000}\right)$
- $L_{nlos} = b + 40\log\left(\frac{d}{1000}\right)$

where d is the distance in metres between the WSD and licensed receiver while parameters a and b are frequency dependent as set out in the table below. The breakpoint distance is 2,100m – below this distance the LOS equation applies while above this distance the NLOS equation applies.

Table 1. Modelling values for propagation from WSDs

	Frequency (MHz)		
	400	*600*	*800*
a	73.9	77.4	79.9
b	111.7	116.8	120.5

[21] See section 4.8 of http://stakeholders.ofcom.org.uk/market-data-research/technology-research/research/propagation/low/

A4.34 In the case where the WSD and licensed user are in the same pixel then minimum coupling loss approaches must be used. In our statement on cognitive we derived the minimum loss for DTT as 55dB and for PMSE as 32dB.

A4.35 The coupling loss will then need to be determined as the propagation loss plus antenna gain and other factors such as polarisation loss. Antenna gains are of most relevance where directional antennas are used, for example with DTT reception. If no information on the direction of pointing of the licensed antenna is available or can be reliably derived then the worst case assumption of the antenna pointing directly at the WSD must be assumed. Otherwise, the actual direction and performance of the side-lobes of the antenna can be taken into account.

Example calculations

A4.36 The database will then need to adopt the following approach, or one which returns identical results. Firstly the database provider will need to select their operating parameters as follows:

i) Determine the channel bandwidth it will adopt. This is up to the database provider and may depend on the applications it anticipates that the WSDs accessing its database will adopt.

ii) Determine the frequencies over which it will provide information. This can be all of the interleaved frequencies (470-550 MHz and 614-790 MHz) or some subset as selected by the database provider.

iii) Determine the geography over which it will provide information. This could be all of the UK or some subset.

A4.37 When a device sends a request for information the database will need to determine all the 100m x 100m tiles that it might be in based on its reported location and the uncertainty caused by its reported location accuracy. For each of these tiles it will need to work through all the possible channels (depending on the channel bandwidth selected and frequencies over which the database will operate). In each channel it will need to determine the maximum power that a WSD could transmit before causing possible interference.

A4.38 In order to determine the maximum power the database needs to consider (1) the effects of the wanted emissions in the channel selected both on licensed use (both DTT and PMSE) in that channel and in neighbouring channels up to 72MHz away (n+/-9) (2) the effects of the unwanted out-of-band emissions in neighbouring channels up to 72MHz away (n+/-9). Each of these is discussed below.

A4.39 When considering the wanted emissions the database must calculate the minimum allowed level across 19 channels (from n+9 to n-9). For each channel it needs to assess (1) the tolerance of the licensed use to emissions in channel n (ie the protection ratio needed for adequate reception when an interferer is x MHz from the licensed signal) and (2) the path loss from the WSD to the licensed use. Combining these gives the maximum transmitted power.

A4.40 For example, for a given channel n there may be licensed use in a neighbouring channel (say n+1). The protection ratio needed might be -17dB – that is the signal in channel n can be 17dB greater than the signal in channel n+1. The coupling loss might be 100dB and the minimum signal level at the receiver -80dBm (or the actual signal level can be taken into account). The allowed transmit power level is then -80 + 17 + 100 = 37dBm.

A4.41 Having found the minimum power across all 19 channels and set this as the WSD power the out-of-band emissions can then be tested. For each channel the WSD power is reduced by the adjacent channel leakage ratio for that device. The co-channel protection ratio for the licensed use is then used to test whether the emissions would exceed this.

A4.42 For example, if it is decided that 37dBm is possible in channel n, and there is licensed use in channel n+1 and the protection ratio is 33dB for co-channel usage and out-of-band emissions in channel n+/-1 for the device are at -45dB and the path loss is 100dB then the test is whether 37-45-100 > -80 -33 so whether -108 > -113. In this case, it is greater implying that the out-of-band emissions would potentially cause interference and that hence the in-band levels need to be reduced by 5dB to remove this risk. This sets the allowed transmit power level at 32dBm.

A4.43 This is completed for all tiles where the WSD might be located and the lowest power level from all tiles is returned to the WSD device. This is then completed for all channels and the set of allowed channels with associated power levels returned to the device.

A4.44 A simplified example of this calculation is shown in the tables below where only 5 available 8MHz channels are shown for simplicity, only DTT is shown and database is testing whether the mobile can transmit on channel 3. Note all numbers are examples only and not suggested as those that will be adopted in practice.

A4.45 The first table below considers interference resulting from the wanted emissions of the WSD to DTT.

Channel	C/I required by DTV (dB)	Received signal level at DTV (dBm)	Coupling loss to nearest DTT user (dB)[22]	Maximum WSD transmit power (dBm)
1	-20	-75	105	50
2	-17	-70	115	62
3	+33	-75	145	37
4	-17	-80	95	32
5	-20	-60	140	100

A4.46 The second table, below, considers interference from out-of-block emissions.

Channel	C/I required by DTV (dB)	Received signal level at DTV (dBm)	Coupling loss to nearest DTT user (dB)	Out-of-band emission (dB relative)	Maximum WSD transmit power (dBm)
1	+33	-75	105	-65	62
2	+33	-70	115	-45	57
3	+33	-75	145	0	N/A
4	+33	-80	95	-45	27
5	+33	-60	140	-65	112

[22] Based on the Hata model and known separation between WSD and nearest licensed user as detailed earlier.

A4.47 Similar tables would also need to be constructed for PMSE.

A4.48 The WSD must transmit at the lowest of all of these maximum power levels – in this case the constraint is the out-of-band emissions on channel 4 resulting in a maximum power level of 27dBm for transmission on channel 3.

A4.49 The process would then be repeated for other possible locations of the WSD for channel 3. For example, if the location uncertainty was 200m then the device could be in around 12 possible tiles (based on the area of a circle with radius 200m). The maximum power for each tile might be as follows:

Tile ref	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034
Max level (dBm)	27	28	29	28	25	26	26	27	25	31	32	31

A4.50 The minimum level across all tiles is found in tile reference[23] 1027 and 1031 at 25dBm. Hence, for transmission on channel 3 the WSD would be informed that it could transmit a maximum of 25dBm.

A4.51 This whole process (including possible locations) is then repeated for other channels. For example, for channel 4 the wanted and unwanted tables for the first tile would be as follows:

Channel	C/I required by DTV (dB)	Received signal level at DTV (dBm)	Coupling loss to nearest DTT user (dB)	Maximum WSD transmit power (dBm)
1	-23	-75	105	53
2	-20	-70	115	65
3	-17	-75	145	87
4	+33	-80	95	-18
5	-17	-60	140	97

A4.52 The second table, below, considers interference from unwanted emissions.

Channel	C/I required by DTV (dB)	Received signal level at DTV (dBm)	Coupling loss to nearest DTT user (dB)	Out-of-band emission (dB relative)	Maximum WSD transmit power (dBm)
1	+33	-75	105	-65	62
2	+33	-70	115	-65	77
3	+33	-75	145	-45	82
4	+33	-80	95	-0	N/A
5	+33	-60	140	-45	92

A4.53 In this case the lowest level is caused by the wanted emissions affecting co-channel DTV usage and the maximum power is only -18dBm. (This is much lower as the path loss to the nearest co-channel licensed user is much less on channel 4 than it was on channel 3).

[23] In practice NGR coordinates would likely be used to identify tiles

Annex 5

Degradation in DTT location probability

Introduction

A5.1 As mentioned in Annex 4, in determining the minimum signal level for DTT reception within a pixel it is necessary to understand the variation in signal level across a pixel both due to signal level variation and also due to time-varying DTT self-interference. This annex discusses how we will take these factors into account.

A5.2 The DTT *location probability* is defined as the probability with which a DTT receiver would operate correctly at a specific location; i.e., the probability with which the median wanted signal level is appropriately greater than a minimum required value.

A5.3 Location probability is widely used in the planning of DTT networks in order to quantify the quality of coverage, and is typically calculated for every 100 m × 100 m pixel across the country. The presence of any interferer naturally results in a reduction of the DTT location probability. Such a reduction is therefore a highly suitable metric for specifying regulatory emission limits for WSDs devices operating in DTT frequencies.

Definition of location probability

A5.4 The DTT *location probability* is defined as the probability with which a DTT receiver would operate correctly at a specific location; i.e., the probability with which the median wanted signal level is appropriately greater than a minimum required value.

A5.5 Consider a pixel where the DTT location probability is q_1 in the absence of interference from systems other than DTT. Then we can write (in the linear domain)

$$q_1 = \Pr\left\{P_S \geq P_{S,\min} + \sum_{i=1}^{K} r_{U,k} P_{U,k}\right\} = \Pr\{P_S \geq U\} \quad (1)$$

where $\Pr\{A\}$ is the probability of event A, P_S is the received power of the wanted DTT signal, $P_{S,\min}$ is the DTT receiver's (noise-limited) reference sensitivity level[24], $P_{U,k}$ is the received power of the k^{th} unwanted DTT signal, and $r_{U,k}$ is DTT-to-DTT protection ratio for the k^{th} DTT interferer.

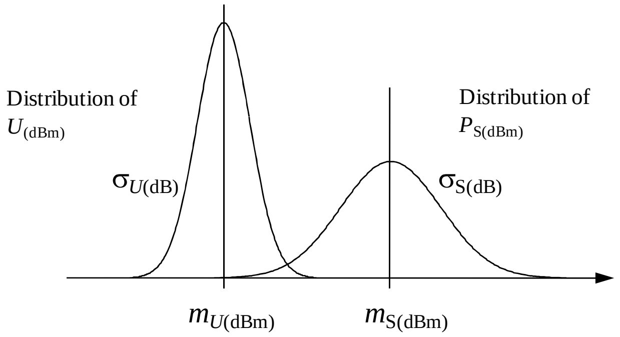
A5.6 Equation (1) is a direct result of the definition of protection ratio; i.e., the minimum ratio of wanted signal power to interferer signal power (as measured at the input to the receiver) required for the correct operation of the receiver.

A5.7 In the planning of DTT networks, $P_{S\,(\mathrm{dBm})}$ and each individual $P_{U,k\,(\mathrm{dBm})}$ are modelled as Gaussian random variables. Note that in Equation (1), the powers are summed in the linear domain. For this reason, the most accurate way of calculating the probability q_1 is to use a Monte Carlo simulation where a large number of trials are performed with values for each variable generated according to their Gaussian distribution.

[24] The reference sensitivity level of a receiver is the minimum wanted signal power for which the receiver can operate correctly in a noise-limited environment.

A5.8 An approximation of the exact calculation could also be performed as described next. Here, the terms $P_{\mathrm{S\ (dBm)}}$ and $U_{\mathrm{(dBm)}}$ are modelled as Gaussian random variables with medians $m_{\mathrm{S\ (dBm)}}$ and $m_{\mathrm{U\ (dBm)}}$, and standard deviations $\sigma_{\mathrm{S\ (dB)}}$ and $\sigma_{\mathrm{U\ (dB)}}$, respectively. The terms $m_{\mathrm{U\ (dBm)}}$ and $\sigma_{\mathrm{U\ (dB)}}$ can be derived via numerical techniques such as the Schwartz-Yeh algorithm or Monte Carlo simulations. The relationship between parameters q_1, $P_{\mathrm{S\ (dBm)}}$ and $U_{\mathrm{(dBm)}}$ in a pixel is illustrated in Figure (1) below.

Figure 1: Distributions of wanted DTT power and DTT-to-DTT interference power in a pixel.



A5.9 From Equation (1), and based on the approximation explained above, the location probability can be readily expressed in closed form as

$$q_1 = 1 - \frac{1}{2}\operatorname{erfc}\left\{ \frac{1}{\sqrt{2}} \frac{m_{\mathrm{S\,(dBm)}} - m_{U\,(\mathrm{dBm})}}{\sqrt{\sigma^2_{\mathrm{S(dB)}} + \sigma^2_{U\,(\mathrm{dB})}}} \right\}. \qquad (2)$$

Calculation of WSD in-block emission level for a specific degradation in location probability

A5.10 In the previous section we showed how the DTT location probability can be calculated as a function of the median and standard deviations of the DTT signal power and DTT-to-DTT interference power within a given pixel.

A5.11 Let us now consider a WSD device which operates at a frequency $f_{\mathrm{CR}} = f_{\mathrm{DTT}} + \Delta f$, and radiates with an in-block EIRP of $P_{\mathrm{IB}}^{\mathrm{WSD}}$. Note that for the special case of co-channel interference, $\Delta f = 0$.

A5.12 The presence of the WSD interferer will inevitably reduce the DTT location probability from q_1 to $q_2 = q_1 - \Delta q$. Assuming a coupling gain, G, the received WSD interferer power is then given by the product $G\,P_{\mathrm{IB}}^{\mathrm{WSD}}$. Following the framework described in Equation (1), we may write (in the linear domain)

$$q_2 = \Pr\left\{ P_{\mathrm{S}} \geq P_{\mathrm{S,min}} + \sum_{i=1}^{K} r_{\mathrm{U},k} P_{\mathrm{U},k} + r(\Delta f)\, G\, P_{\mathrm{IB}}^{\mathrm{WSD}} \right\} \qquad (3)$$

A5.13 The coupling gain includes path loss, receiver antenna gain, as well as receiver antenna angular and polarisation discrimination. The coupling gain, $G_{\text{(dB)}}$ is typically modelled as a Gaussian random variable with a median value, $m_{G\ \text{(dB)}}$, and a standard deviation $\sigma_{G\,\text{(dB)}}$.

A5.14 As explained for the case of Equation (1), the most accurate calculation of q_2 can be performed by using Monte Carlo simulations. However, as for the case of q_1, an approximation could be made in order analytically derive q_2. By expanding Equation (3), we have

$$
\begin{aligned}
q_2 &= \Pr\left\{ P_{\text{S}} \geq P_{\text{S,min}} + \sum_{i=1}^{K} r_{\text{U},k} P_{\text{U},k} + r(\Delta f)\, G\, P_{\text{IB}}^{\text{WSD}} \right\} \\
&= \Pr\left\{ P_{\text{S}} \geq U + r(\Delta f)\, G\, P_{\text{IB}}^{\text{WSD}} \right\} \\
&= \Pr\left\{ r(\Delta f)\, G P_{\text{IB}}^{\text{WSD}} \leq P_{\text{S}} - U \right\} \\
&= \Pr\left\{ r(\Delta f)\, G P_{\text{IB}}^{\text{WSD}} \leq Z \right\} \\
&= \Pr\left\{ P_{\text{IB}}^{\text{WSD}} \leq \frac{1}{r(\Delta f)\, G} Z \right\} \\
&= \Pr\left\{ P_{\text{IB}}^{\text{WSD}}{}_{\text{(dBm)}} \leq Z_{\text{(dBm)}} - G_{\text{(dB)}} - r(\Delta f)_{\text{(dB)}} \right\}
\end{aligned}
\qquad (4)
$$

A5.15 Then assuming that $Z_{\text{(dBm)}}$ is a Gaussian random variable with a median value, $m_{Z\ \text{(dBm)}}$, and a standard deviation $\sigma_{Z\,\text{(dB)}}$, the immediate implication of Equation (4) is that (in the logarithmic domain) the maximum permitted WSD device in-block EIRP is given by

$$
P_{\text{IB}}^{\text{WSD}}{}_{\text{(dBm)}} \leq m_{Z\,\text{(dBm)}} - m_{G\,\text{(dB)}} - r(\Delta f)_{\text{(dB)}} - \mu(q_2)\sqrt{\sigma_{Z\,\text{(dB)}}^2 + \sigma_{G\,\text{(dB)}}^2} - \text{IM}_{\text{(dB)}}. \qquad (5)
$$

A5.16 The term $\text{IM}_{\text{(dB)}}$ is a *safety margin* which can be judiciously set by the database to provide an additional margin of protection to DTT services[25]. The term $\mu(q_1)$ represents the number of standard deviations which would allow a location probability of q_2 to be achieved. In other words

$$
1 - q_2 = \frac{1}{2}\text{erfc}\left\{\frac{\mu}{\sqrt{2}}\right\} \quad \text{or} \quad \mu(q_2) = \sqrt{2}\,\text{erfc}^{-1}\left\{2(1-q_2)\right\}. \qquad (6)
$$

A5.17 Note that the median $m_{Z\,\text{(dBm)}}$ and standard deviation $\sigma_{Z\,\text{(dB)}}$ would need to be derived via numerical techniques such as the Schwartz-Yeh algorithm or Monte Carlo simulations.

[25] The value of this margin might, for example, be increased in response to a proliferation of CR devices and an increase in the potential for aggregate interference to DTT services.

Calculation of WSD out-of-block emission level for a specific degradation in location probability

A5.18 Equation (4) explicitly describes how the maximum permitted WSD in-block EIRP can be calculated such that it results in a degradation $\Delta q = q_2 - q_1$ in DTT location probability. However, Equation (4) also implicitly specifies the maximum permitted WSD out-of-block EIRP through the use of WSD-to-DTT protection ratios.

A5.19 This is because the protection ratio is a function of both the spectral leakage of the WSD transmitter and the spectral selectivity[26] of the DTT receiver. Specifically, the protection ratio $r(\Delta f)$ is given (in the linear domain) by

$$
\begin{aligned}
r(\Delta f) &= \frac{P_{\mathrm{S}}^*}{P_{\mathrm{AC}}^*} = \frac{P_{\mathrm{S}}^*}{P_{\mathrm{I}}^*}\frac{P_{\mathrm{I}}^*}{P_{\mathrm{AC}}^*} = r(0)\frac{1}{\mathrm{ACIR}(\Delta f)} \\
&= r(0)\left(\mathrm{ACLR}_{\mathrm{WSD}}^{-1}(\Delta f) + \mathrm{ACS}_{\mathrm{DTT}}^{-1}(\Delta f)\right)
\end{aligned} \quad (6)
$$

where * denotes the value at the point of receiver failure, P_{I} is the interference power, and P_{AC} is the power of the adjacent channel interferer. ACIR is the adjacent-channel interference ratio, $\mathrm{ACLR}_{\mathrm{WSD}}$ is the adjacent-channel leakage ratio of the WSD transmitter, and $\mathrm{ACS}_{\mathrm{DTT}}$ is the adjacent-channel selectivity of the DTT receiver.

A5.20 If the receiver selectivity is defined as a function of the wanted signal power, then the protection ratios can also be used to implicitly model the non-linear behaviour (*overloading*) of the DTT receiver.

A5.21 The protection ratio $r(\Delta f)$ in Equation (4) implicitly identifies the spectral leakage of the WSD device via the adjacent-channel leakage ratio $\mathrm{ACLR}_{\mathrm{WSD}}(\Delta f)$.

A5.22 Then, by definition, the maximum permitted WSD out-of-block emission level is given (in the logarithmic domain) as

$$P_{\mathrm{OOB\,(dBm)}}^{\mathrm{WSD}}(\Delta f) = P_{\mathrm{IB\,(dBm)}}^{\mathrm{WSD}} - \mathrm{ACLR}_{\mathrm{WSD\,(dB)}}(\Delta f). \quad (7)$$

A5.23 Naturally, the extent of interference caused by a WSD device is a function of both its in-block and out-of-block emission levels. This is evident from Equations (4), (6) and (7).

A5.24 Since the ACLR of the WSD device is implicitly incorporated in the protection ratios used in Equation (4) to derive the maximum permitted WSD in-block levels, it is important that the ACLR of WSD devices is determined for use by geo-location databases. Otherwise the geo-location database would need to be established based on an ACLR value that is only representative of the spectral leakage performance of WSD devices.

[26] The selectivity can derived from measurements of the protection ratios of DTT receivers in the presence of adjacent channel test interferers. The selectivity of the DTT receivers is calculated by accounting for the contribution to interference caused by the spectral leakage of the test interferer.

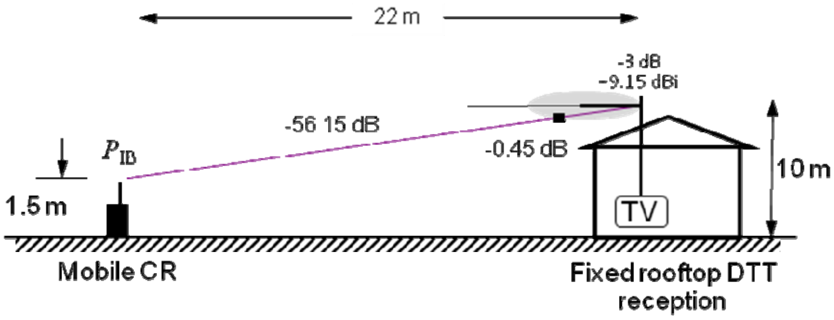
Reference geometries

A5.25 In this section we examine the two geometries described below.

a) Mobile WSD operation and fixed roof-top DTT reception

A5.26 Figure (3) shows the relevant reference geometry. This geometry was also used in CEPT Report 30 for the calculation of the emission limits for mobile/fixed communication network terminal stations in the 800 MHz Digital Dividend band.

Figure 2: Reference geometry for mobile WSD device. Shown path loss is for a carrier at 650 MHz.



A5.27 The DTT receiver antenna would provide a 3 dB polarisation discrimination with respect to a randomly oriented mobile WSD device.

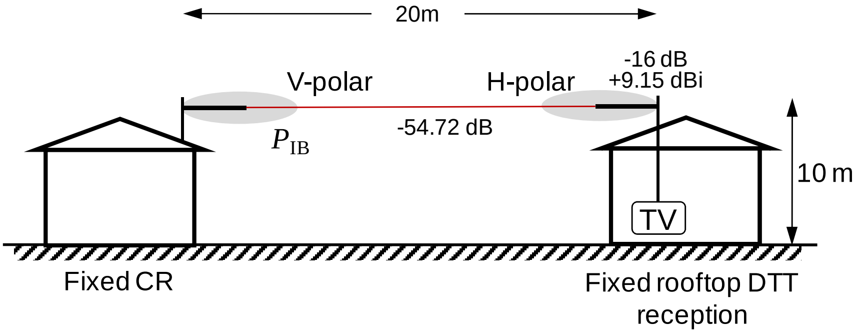
A5.28 Note that this reference geometry corresponds to a worst-case scenario for the following reasons:

- It is assumed that the WSD device is located along the azimuth bore-sight of the DTT receiver's antenna.
- For a DTT antenna which complies with the ITU-R BT.419-3 directional pattern, the horizontal separation of 22 m results in the largest median coupling gain, $m_{G\ (\mathrm{dB})}$.

b) Fixed roof-top WSD transmission and fixed roof-top DTT reception

A5.29 Figure (4) shows the relevant reference geometry.

Figure 3: Reference geometry for mobile CR device. Shown path loss is for a carrier at 650 MHz.



A5.30 The DTT receiver antenna would provide a 16 dB polarisation discrimination with respect to a opposite-to-DTT polarised fixed CR transmitter.

Annex 6

Impact assessment

Introduction

A6.1 The analysis presented in this annex represents an impact assessment, as defined in section 7 of the Communications Act 2003.[27]

A6.2 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 we have to carry out impact assessments where our proposals would be likely to have a significant effect on businesses or the general public or when there is a major change in our activities. However, as a matter of policy, we are committed to carrying out and publishing impact assessments in relation to the great majority of our policy decisions. For further information about our approach to impact assessments, see the guidelines "Better policy-making: Ofcom's approach to impact assessment," which are on our website at www.ofcom.org.uk/consult/policy_making/guidelines.pdf.

The citizen and/or consumer interest

A6.3 If white space access is allowed, we expect there to be citizen and consumer benefits. White space access might be used, for example, to facilitate wireless distribution around the home, local- or personal-area networks, wireless systems within public spaces and many other applications not yet envisaged.

A6.4 However, if white space access causes harmful interference to licensed use of the interleaved spectrum, there might be consumer and citizen concerns. For example, interference to DTT would cost to correct, and interference to wireless microphones could disrupt shows and other activities. In practice, we do not expect these concerns to materialise. As discussed in previous consultation documents, we intend to licence-exempt white space access only if the risk of harmful interference to licensed services is acceptably low.

A6.5 It seems unlikely that white space access would affect different groups of citizens and consumers in different ways. Since we do not know the applications for which WSDs will be used, we cannot be sure which citizens and consumers will benefit most. It seems likely, though, that they will be approximately evenly distributed throughout the UK population (as opposed to its geography). If harmful interference were to occur, its effects would probably be greatest for those in specific geographic areas with relatively poor DTT coverage or particular PMSE geometries, but such areas are also generally evenly distributed across the population. Hence, as a first approximation, we would not expect white space access to favour one group of citizens or consumers over another, regardless of the detailed technical choices made.

Our policy objective

A6.6 Our policy objective for the DDR is to maximise the total value to society that using the digital dividend is likely to generate over time. We believe that if white space

[27] www.opsi.gov.uk/acts/acts2003/pdf/ukpga_20030021_en.pdf.

access can be permitted without an unacceptable risk of harmful interference to licensed uses, it will allow additional access to spectrum that would otherwise not be possible and this will generate additional value for society.

A6.7 If white space access is allowed, we would expect the market to take some time to deliver devices and for their use to become widespread. Typically, this can take anything from three to 10 years for products of this sort.

Assessment of allowing white space access

The value of white space access

A6.8 White space access might bring significant economic benefits. The use of WSDs might enable new applications or make existing applications less expensive, which could bring significant benefits to consumers.

A6.9 However, estimating the value that these applications might bring in practice is very difficult because, at present, it is unclear what their scope, function and take-up might be.

A6.10 In examining the possible value of licence-exempt use of the cleared spectrum in the DDR statement, we identified a range of possible applications and identified benefits of their using this spectrum, generally based on cost savings that could be made relative to deploying the same applications at higher frequencies. The results are summarised in table A1 below.

Table A1. Potential value of licence-exempt use of the digital dividend (£m)

Use	Assumptions	Understanding of use	Economic value (£m)
Household WLANs	20% of UK households use Wi-Fi; 10% benefit from increased range	Good	55-85
Business WLANs	75% coverage of office, retail and public-service environments	Good	55-100
Municipal Wi-Fi	UK central business districts obtain 100% coverage	Good	25-35
Shared household Internet connection	2% of households that do not otherwise obtain wireline broadband access	Reasonable	15-20
Industrial monitoring/automation	20% Wi-Fi coverage of UK manufacturing workspace	Loosely defined	20-30
Agricultural monitoring/automation	1% of UK farms adopt smart monitoring	Loosely defined	1-3
Total			**170-270**

A6.11 It can be seen that we estimated allowing licence-exempt access to the cleared spectrum could deliver direct economic benefits in the region of £170-270m in net present value (NPV) over 20 years (i.e. of the order of £10-20m per year). Many of these estimated benefits have been derived from an assumption that WLAN systems could be deployed with greater range than is currently achievable on a licence-exempt basis at 2.4 GHz.

A6.12 In addition to these direct benefits, white space access could also bring wider economic and social benefits by enabling more connected businesses and communities and increasing access to digital services by specific stakeholder groups. Assuming the additional broader social value of white space access represented up to 20% of the above direct economic benefits, licence-exempt access to the cleared spectrum could generate total value to society in the range of £200-320m (NPV) (approximately 120% of £170-270m).

A6.13 The benefits of white space access, in the form we have proposed in this consultation document, are likely to be somewhat less than the estimates for licence-exempt applications provided above because of the additional costs and possible deployment restrictions of WSDs using interleaved spectrum compared to the assumed environment of “non-white space” licence-exempt devices using cleared spectrum. However, estimating how much less is difficult until more information on white space device costs becomes available.

Potential impacts on licensed users

A6.14 White space access might lead to costs for licensed users in two broad ways:

- through the increased risk of harmful interference to existing licensed uses; and
- through constraining the future development of more valuable licensed uses of the spectrum.

A6.15 We believe that the approach proposed here of geolocation effectively removes the risk of harmful interference to licensed uses, provided the requisite database is developed and maintained to the standards required. If interference does materialise we can rapidly modify the algorithms in the database to remove it. Hence, we do not believe there will be any material impact on licensed users.

A6.16 It has been argued that the presence of WSDs might prevent new licensed uses in the future because it would be difficult to remove them from the band or ensure they did not interfere with the new use. We note that with a geolocation approach it would be possible to clear licence-exempt use from this band by setting the parameters in the database accordingly, although clearly this would disadvantage users of geolocation devices and would only be undertaken after a full impact assessment, consultation and clearly demonstrating such an action would be proportionate.

A6.17 Overall this potential future value at risk would be low because:

- the spectrum concerned is likely to be used for DTT for a considerable period given the planning assumptions being made for DSO. Any major changes of use in some or all of the affected frequencies would probably require lengthy consultation and planning. Hence, the date of introduction of any major new licensed applications will probably be at least a decade or more away;
- new licensed applications could be introduced without risk of harmful interference through their appropriate inclusion in the geolocation database.

A6.18 For these reasons, we believe that new licensed applications will not be put at any risk by the introduction of white space devices on a licence-exempt basis.

Possible problems

A6.19 With any new technology or approach it is difficult to be entirely sure as to where problems might occur. We believe that the general categories of possible problems are:

- Interference to licensed users.
- Failure of a database operator to operate in accordance with the contract.
- Failure of devices to act appropriately.

A6.20 Each of these is discussed in more detail below.

A6.21 **Interference**. It is possible for a range of reasons that interference might occur. These include inaccurate licence databases, incorrect algorithms and insufficient margins. In general, we have taken a cautionary approach in selecting margins in order to ensure there is a very low probability that interference will occur. Nevertheless, we cannot be certain that no interference will ever be experienced.

A6.22 If we become aware of interference we will investigate the cause as we would normally do for any interference situation. If this investigation shows that it is due to white space devices then endeavour to remove it. If it is serious, we will immediately deal with the problem by removing the relevant frequencies and areas from the database which we will require database providers to reflect within one hour. We will then assess how we need to modify our algorithms or licence databases in order to address the problem – for example we might increase the margin required in certain cases. Once we are satisfied that we have resolved the issue and that algorithms have been updated by database providers we will "re-open" the affected frequencies.

A6.23 As a result, we believe that we can quickly and effectively address any interference caused, albeit potentially at the cost of reducing the amount of white space available to WSDs.

A6.24 A separate issue is interference to indoor TV antennas. Indoor reception is not planned for nor specifically protected under current DTT planning guidelines and throughout our consultations on cognitive / white space we have not considered explicitly protecting such reception. Indoor reception will, however, mostly be protected by the approach we have adopted to protect rooftop reception. We discuss why this is for a range of scenarios below:

i) *WSD some distance from the receiver*. In this situation the database will over estimate the wanted DTT signal level at the indoor receiver because of the assumption of a rooftop receiver. The signal will be weaker as a result of a less directional antenna, building penetration loss and lower antenna height. However, the database will over-estimate the signal level from the WSD because it will not assume building penetration loss and will assume higher antenna directivity and height. In essence, the same reason why the DTT signal is weaker at the receiver will also hold true for any interfering signal from the WSD and as a result the C/I ratio experienced will be approximately unchanged. Hence the indoor reception will receive similar protection to the outdoor reception.

ii) *WSD in the same pixel as the receiver (ie less than 100m away)*. In this situation the database will overestimate the DTT signal level at the indoor receiver as discussed above. It will use a minimum coupling loss for the signal from the WSD which may be too high or too low. If the WSD is in the same room as the indoor receiver then the coupling loss will be lower than assumed (and hence the level of the interfering signal greater). If the WSD is in a neighbouring property then the various wall losses and building penetration losses may be such that the coupling loss is greater than assumed. There is an infinite range of possible scenarios and hence it is not possible to say with certainty what the actual coupling loss will be. However, for the lower coupling losses (greatest interference potential) the device will be in the same house as the indoor receiver and hence under the control of the viewer potentially enabling them to take some action (such as turning off the WSD).

A6.25 Hence, the likelihood of interference depends broadly on whether WSDs are operated in the vicinity of indoor TV receivers using the same or neighbouring channels. As the examples in Annex 4 show, the coupling losses associated with operation in the same pixel are typically 50dB or more lower than the path loss values for operation some distance away. Hence, the devices will naturally strongly prefer to use channels where there is no DTT reception in the vicinity both on co-channel and neighbouring channels. As a result we would expect most cases to fall within (i) above where we have concluded that indoor TV receivers will gain similar levels of protection to rooftop aerials. Therefore, we do not expect to see any material rise in interference to indoor TV reception, even though it is not given explicit protection.

A6.26 Were there to be a significant rise that led to concern resulting in a decision that greater protection for indoor reception is proportionate it would be possible to quickly address this by reducing the minimum coupling loss assumed for operation in the same pixel. This could be changed in the algorithm and reflected within geolocation databases within a week under our current proposals.

A6.27 **Database failure**. We can envisage a number of possible areas of failure. If a database provider fails to correctly implement algorithms, as soon as we are aware of this we will require them to correct their error. If they fail to do so in a timely manner we are able to remove them from the list of approved databases with the result that WSDs will no longer consult them. It is also possible that a database provider might cease operation, perhaps due to bankruptcy or similar. Depending on whether there were other providers it is possible that there might be a period where it was not possible for WSDs to operate.

A6.28 **Device failure**. It is possible that devices might not act in accordance with the instructions from the database. We would expect that through the type approval process that devices would be tested to ensure this did not occur but it remains possible that there might be a failure in certification or similar affecting an entire class of devices. As soon as we become aware that a class of device is not acting in accordance with the exemption regulation we can choose to take action. When devices access the database they will present their model identifier and using this we can, for example, provide them with reduced power levels compared to other devices or in extreme cases not provide them with any available frequencies. Hence, we can rapidly disable them. We would then seek to understand why the problem has occurred and take appropriate measures.

Annex 7

Possible future extensions of white space access

Introduction

A7.1 We believe that the mechanisms and protocols set out in this consultation are sufficient to enable white space access and are not proposing any extensions to these at this point. However, in discussions, some stakeholders have expressed interest in opening further frequency bands and in providing reservations of some frequencies. This annex sets out our thinking on these issues and how they might be incorporated into our proposals in the future.

Additional frequency bands

A7.2 The concept of white space is not inherently linked to any particular frequency band and in principle could be extended to other bands outside of the UHF interleaved spectrum. Interest has focussed on interleaved spectrum initially because:

- There appears to be a relatively large amount of white space available (compared to eg cellular bands) as a result of the manner in which TV transmission is planned.
- The use of the band is relatively static compared to other uses.
- The ownership of any white space does not reside with the licence holders in the band since they are licensed on a transmitter-by-transmitter basis.
- The low frequencies are favourable for some of the applications envisaged.

A7.3 In our Spectrum Framework Review, we considered white space access (termed cognitive access at the time) and noted that where licence holders had licenses that included white spaces (for example a national licence such as the mobile operators hold) that it should be up to the licence holder as to whether they wished to enable white space access into their spectrum. This is because we believed that these licence holders owned the white space and so should be able to decide, and profit from, any usage. Hence, we have no plans to mandate white space access into such bands. However, should the licence holders wish to enable it, we would be prepared to work with them to put in place any further regulation or mechanisms that might be needed.

A7.4 It may be worth investigating further whether white space access might be advantageous in frequencies owned by Government users such as the MoD and CAA. This spectrum is owned by these departments and does not fall within the remit of Ofcom so it would be up to the department to determine whether to allow such access. It does appear to us, *prima facia*, that white space access might fit well with applications such as military usage and would allow the MoD to better share its spectrum, but more study would be needed to assess whether this was the case.

A7.5 For most possible bands there may need to be some incentive on the band owner to enable white space access. Such incentives would most likely be financial and might take the form of some sort of payment for access. We consider how this might be accommodated within white space access below.

A7.6 If further frequency bands were enabled, these could be directly incorporated into any database and signalled to WSDs using the protocols that we have set out in this document. We do not envisage any change of regulation or harmonisation would be directly needed.

Principles of reserved access

A7.7 The proposals in this document for white space access do not provide for any reservation of frequencies or any means to directly manage the interference that might occur between WSDs. This is in line with the regulations for most licence-exempt bands such as at 2.4GHz where users have no guarantees as to the level of interference that might occur (and where some congestion problems have already been noted).

A7.8 Some possible uses of white space require the construction of a network – for example the provision of broadband service to highly rural communities. Typically, those constructing such a network seek means to protect their investment and are wary of deploying costly infrastructure if there are no guarantees that sufficient spectrum will continue to be available and that interference levels will not become problematic. Hence, if it were possible to provide some form of reserved or protected access this might enable additional applications to be deployed. Equally, reservation might exclude latter uses of the spectrum which might generate equal or greater value.

A7.9 The use of a database approach does enable us in principle to consider a means to provide varying degrees of protection to licence-exempt users. On obtaining a list of available frequencies a device could select its preferred one and ask the database to reserve it within the database for a given time period. We firstly discuss whether this would be appropriate and then how it might be done.

A7.10 In the past we have noted that if there was less demand than supply for spectrum then licence-exemption was often justified because it removed the unnecessary bureaucracy needed in providing licenses. However, if the demand was greater than supply then licensing was an appropriate way to ensure the resource was used by those that would generate the greatest value and to avoid the “tragedy of the commons”[28]. It is unclear whether demand for white space will exceed supply and indeed the situation may vary geographically.

A7.11 If supply remains greater than demand then reservation does not make sense. Users can develop equipment and construct networks as necessary safe in the knowledge that there will be adequate spectrum for their needs for the foreseeable future. However, with very little understanding of what the white space might be used for it is difficult to determine the likelihood of supply exceeding demand.

A7.12 Conversely, if it is clear that demand will exceed supply, this does not automatically imply licensing should be used. Either rationing should occur within a licensing

[28] This occurs when a free resource is over-used rendering it of little value to anyone. It might occur with WSDs if there was so much interference between them that few useful applications could be supported.

system or through the device protocols themselves (as occurs, for example, with WiFi). In previous publications we have suggested that the decision as to which approach to adopt should be based on likely economic value generated by either but with much uncertainty as to what a licensed access model to white space would look like and hence what applications might be deployed, performing such an assessment is very difficult and likely to have large margins for error.

A7.13 White space use, particularly in rural areas, might fall in between. General experience suggests that congestion in rural areas is very unlikely but uncertainty around the future use of white space suggests it cannot be completely excluded. In such a situation, if there is an application that generates high consumer or citizen value but can only occur with the certainty of reservation then it may become appropriate to reserve access. Such an application might, for example, be rural broadband provision bringing a high societal value by assisting the delivery of universal broadband.

A7.14 Our current thinking is that at this stage it is not possible to analytically determine the optimal approach to exempting or reserving access within the white space. With a database structure it is possible to change approach at any point – for example by subsequently removing some spectrum from the database and reserving it for particular applications. Hence, our preference is to utilise a simple licence-exempt access mechanism initially when supply will exceed demand and to consider reservation systems further if it becomes clear that congestion is building or that the applications that require reservation will generate more value than those that do not.

Practicalities of reserved access

A7.15 The approach set out above of starting without reserved access and potentially changing over time does require that reserved access can be introduced without modification to existing devices. Here we set out some thoughts as to how reserved access might fit within the structure for WSDs proposed in this document.

A7.16 In overview, the flow of information might works as follows:

i) Device sends request to database as suggested in this consultation.

ii) Database returns available frequencies as suggested in this consultation.

iii) Device selects preferred frequency and sends reservation request to the database along with identification details.

iv) Database marks frequencies as used within the area and for the requested length of time.

v) Appropriate payment is made from a pre-arranged account.

A7.17 Variations on this approach are possible – in particular there may be pre-agreed information held at the database such as the coverage area required by the device across which reservation will be needed.

A7.18 In order to introduce such an approach further signalling protocols need to be defined between the WSD and the database. These can be developed as needed and introduced into WSDs subsequently manufactured. It may even be possible to introduce them into existing WSDs via a software update. Databases can be updated as needed. If there are multiple databases then they will need to communicate the reservation between themselves.

A7.19 If it is not possible to update existing WSDs they should still work within the structure set out above. They would simply stop after step (ii) as set out above. Hence, we envisage that it would be possible to introduce reservation at some future point should it be justified.

A7.20 An alternative, simpler approach might be possible in the case of PMSE. If PMSE WSDs used the PMSE database as their geo-location database this could provide assignments and mark these as reserved. Because the PMSE database is then fed to other geolocation databases this would have the effect of reserving those frequencies.

Revenue flows from reserved access

A7.21 If there is no cost in making a reservation then there is a risk that unnecessary reservations will be made since there will be no penalty in requesting too much spectrum or for too long. Hence, it seems likely that for reservation to work there will need to be some cost to the WSD – either direct monetary cost or some similar mechanism such as the use of reservation tokens.

A7.22 Where white space access is to frequencies owned by licence holders, such as the Government or mobile operators, as noted earlier, the decision to enable white space access is for the licence holder and they should be able to select the terms of entry and collect any revenue deriving from the use.

A7.23 Where access is to spectrum not owned by a licence holder, as is the case for the interleaved spectrum, then our initial thinking is that any payments should be treated in the same manner as licence fees and returned to Ofcom (who passes them onto the Treasury). We do not believe that the database operators should be allowed to retain them as this may create an incentive structure that does not mirror the best use of the spectrum. This would imply Ofcom setting the prices (or at least the algorithms used to derive the prices) and requiring the database providers to implement them. This would also resolve potential problems with multiple database providers since there would be no incentive for one provider to try to compete with another to reserve spectrum. Instead, any provider would approve a reservation request that fitted with the algorithms set by Ofcom and then immediately communicate this to all other providers so that they would set the spectrum as "reserved" within their database.

Summary

A7.24 The discussion in this annex suggests that while it might be valuable at some future time to extend white space access to additional frequencies and to incorporate reservation mechanisms, that these can be incorporated at a later stage as it becomes clear that they would add value.