Digital dividend: cognitive access

Consultation on licence-exempting cognitive devices using interleaved spectrum

Consultation

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Contents

Section 1

Executive summary

Background

1.1 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.[1] 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 on a shared (or interleaved) basis.

1.2 In our statement of 13 December 2007 on our approach to awarding the digital dividend,[2] we considered the use of interleaved spectrum by licence-exempt applications (i.e. those exempted from the need to be licensed under the Wireless Telegraphy Act 2006[3]). We concluded that we should allow cognitive access 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 could potentially bring substantial benefits to citizens and consumers in the form of new devices and services.

1.3 Cognitive devices can detect spectrum that is otherwise unused and transmit without causing harmful interference. They have the potential to support a wide range of uses, including high-speed always-on broadband and are particularly suited to using interleaved spectrum precisely because significant capacity is often unused at any one location at least some of the time.

1.4 This document, which is largely technical in nature, consults on proposed parameters for licence-exempt cognitive devices using interleaved spectrum to prevent harmful interference to licensed uses.

Cognitive access to interleaved spectrum

1.5 In their simplest form, cognitive devices rely solely on spectrum-sensing capabilities to detect unused spectrum in which they can transmit. If they fail to detect licensed use of spectrum, harmful interference might occur. To prevent this, two key parameters must be set appropriately:

- The device must be able to determine with sufficiently certainty that the spectrum is not in use in the vicinity. Depending on how this is achieved, parameters such as sensing levels need to be set.

- The device must transmit with relatively low power such that its signal does not travel far from its location.

1.6 In an alternative form, cognitive devices measure their location and make use of a "geolocation" database to determine which channels they can use at their current

[1] See www.ofcom.org.uk/radiocomms/ddr/ for more information about the DDR, including previous publications.
[2] www.ofcom.org.uk/consult/condocs/ddr/statement/statement.pdf.
[3] www.opsi.gov.uk/acts/acts2006/pdf/ukpga_20060036_en.pdf.

location. In this case parameters such as locational accuracy and frequency of database enquiry are important.

1.7 Other parameters such as out-of-band performance and politeness of behaviour also need to be set to ensure optimal use of the spectrum.

1.8 While it is not possible to set parameters such that harmful interference will never occur, it is possible to set them such that there is an acceptably low probability of harmful interference.

Key device parameters

1.9 The main part of this document shows how we have derived the proposed key parameters for successful licence-exempt cognitive access to interleaved spectrum in the UK. Table 1 sets out those we believe necessary if cognitive devices are to use sensing alone. Transmit powers here and throughout this document are effective isotropic radiated power (EIRP) into an 8 MHz bandwidth.

Table 1. Key parameters for sensing

Cognitive parameter	Value
Sensitivity assuming a 0 dBi antenna	-114 dBm in 8 MHz channel (DTT) -126 dBm in 200 kHz channel (wireless microphones)
Transmit power	13 dBm (adjacent channels) to 20 dBm
Transmit-power control	Required
Bandwidth	Unlimited
Out-of-band performance	< -44 dBm
Time between sensing	< 1 second
Maximum continuous transmission	400 milliseconds
Minimum pause after transmission	100 milliseconds

1.10 Table 2 sets out the key parameters that we believe necessary if cognitive devices use geolocation.

Table 2. Key parameters for geolocation

Cognitive parameter	Value
Locational accuracy	100 metres
Frequency of database access	(to be determined)
Transmit power	As specified by the database
Transmit-power control	Required
Bandwidth	Unlimited
Out-of-band performance	< -44 dBm
Maximum continuous transmission	400 milliseconds
Minimum pause after transmission	100 milliseconds

1.11 We have derived these parameters from a mix of theory and measurement. Where a range of acceptable parameters includes those adopted elsewhere in the world, we have proposed the values from the latter in the interest of promoting international economies of scale.

Question 1. The executive summary sets out our proposals for licence-exempting cognitive devices using interleaved spectrum. Do you agree with these proposals?

Next steps

1.12 This consultation closes on 1 May 2009. We recognise that it raises challenging technical and operational issues and therefore plan to engage with stakeholders on our proposals during the consultation period.

1.13 More information about next steps is set out in section 11.

Section 2

Introduction

The DDR and interleaved spectrum

2.1 The configuration of UHF Bands IV and V after DSO, the subject of the DDR, remains subject to change, particularly in the light of our proposals to clear the 800 MHz band (channels 61-69) to align more of the UK's digital dividend with the spectrum being released in other European countries, published on 2 February 2009.[4] Figure 1 shows where interleaved spectrum will be located if we implement those proposals as set out in our consultation document.

Figure 1. UHF Bands IV and V after DSO per current proposals

Channel / Frequency (MHz)											
21	22	23	24	25	26	27	28	29	30	31	32
470-478	478-486	486-494	494-502	502-510	510-518	518-526	526-534	534-542	542-550	550-558	558-566
33	34	35	36	37	38	39	40	41	42	43	44
566-574	574-582	582-590	590-598	598-606	606-614	614-622	622-630	630-638	638-646	646-654	654-662
45	46	47	48	49	50	51	52	53	54	55	56
662-670	670-678	678-686	686-694	694-702	702-710	710-718	718-726	726-734	734-742	742-750	750-758
57	58	59	60	61	62	63	64	65	66	67	68
758-766	766-774	774-782	782-790	790-798	798-806	806-814	814-822	822-830	830-838	838-846	846-854
69											
854-862											

Retained/ interleaved spectrum: channels 21-30, 39-60. Cleared spectrum: channels 31-37, 61-69. PMSE: channel 38.

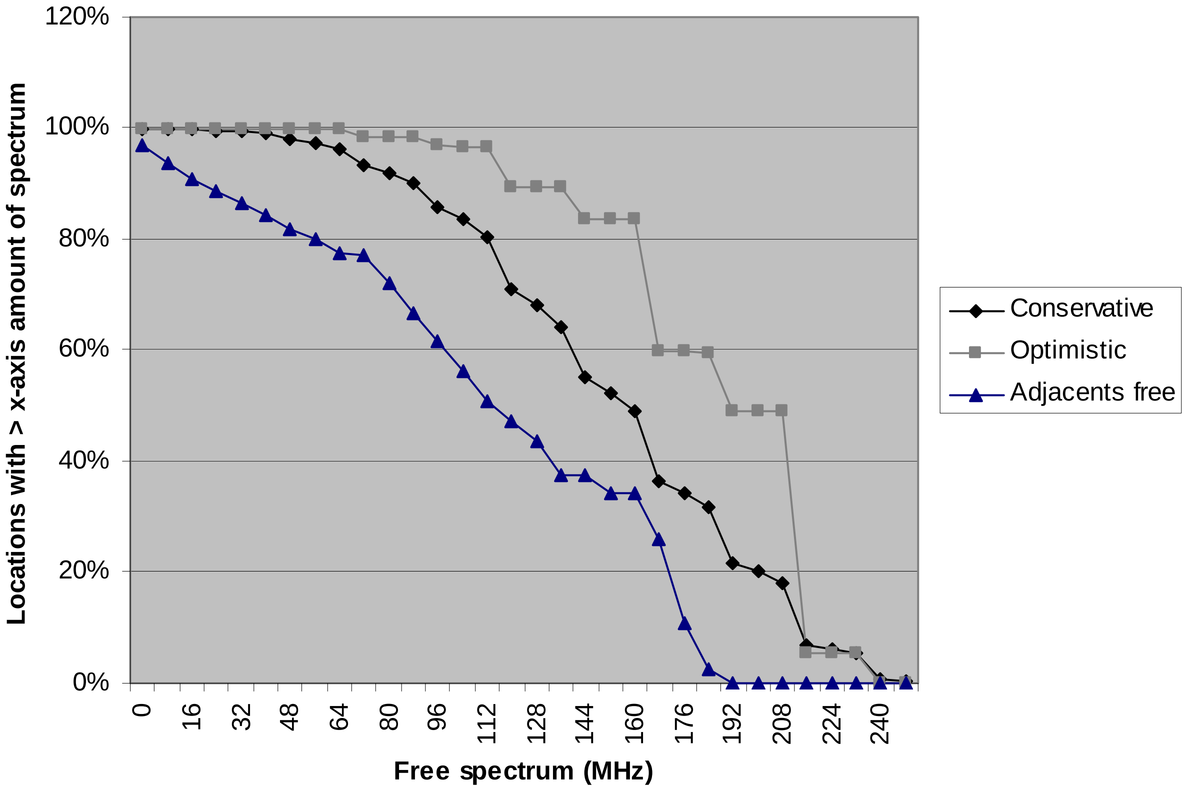
2.2 Modelling shows that there is a substantial amount of interleaved spectrum. This is often termed "white space" because, when plotting a geographic map of television coverage and using colours to denote received signal strength, those areas without signal (and hence where the spectrum is unused) are left uncoloured and so appear white. Figure 2 gives a high-level estimate of the amount of interleaved spectrum in any given location. The two lines labelled "conservative" and "optimistic" assume that all free channels can be used, including those with use in adjacent channels. The two lines form a bound depending on assumptions about television antenna orientation. They show that over 50% of locations are likely to have more than 150 MHz of interleaved spectrum and that even at 90% of locations around 100 MHz of interleaved spectrum might be available. This is a substantial amount, even after allowing for use by PMSE and other low-power services (e.g. local television). By way of comparison, around 80 MHz of spectrum is available in the 2.4 GHz band used for Wi-Fi and 140 MHz was auctioned for 3G use in 2000. Hence, making this spectrum available for use could bring substantial value to citizens and consumers.

2.3 The third line on the chart, labelled "adjacents free," assumes that a channel can only be used if the adjacent channels on either side are also free. As discussed later in

[4] www.ofcom.org.uk/consult/condocs/800mhz/800mhz.pdf.

this document, some have suggested that practical realisations of cognitive devices will need to use free adjacent channels to meet the necessary device specifications. Obviously, there will be less spectrum available when free adjacents are needed. The figure shows that this reduces the amount of spectrum available in 50% of locations from around 150 MHz to 100 MHz. Importantly, it also results in no spectrum being available in some 5% of locations.

Figure 2. Estimated amount of interleaved spectrum



Source: Arqiva.

2.4 This appears to be a substantial amount of spectrum which is unused and could be valuably employed by cognitive devices. It is effectively set aside from high power broadcast use to avoid interference with other nearby channels using the same frequencies. It is therefore only available for low power usage otherwise interference will result.

2.5 In the DDR statement, we decided that we would treat the interleaved spectrum in four different ways:

- We would include the capacity in channels 61 and 62 in the cleared award. This has been superseded by our proposals to clear the 800 MHz band, which would see channels 61 and 62 included in the award of cleared spectrum and DTT moved to channels 39 and 40 instead.

- We would award geographic packages of one or two 8 MHz channels, suitable but not reserved for local television, wherever there was credible evidence of demand. We consulted on the detailed design of these awards on 12 June 2008.[5] We published a statement on the first two geographic-interleaved awards,

[5] www.ofcom.org.uk/consult/condocs/ddrinterleaved/interleaved.pdf.

covering the Manchester and Cardiff areas, on 29 October 2008.[6] We concluded the award for the Manchester area on 5 February 2009,[7] and we expect to hold the award for the Cardiff area in March 2009.

- We would award a single package of most of the remaining interleaved spectrum by beauty contest to a band manager with obligations to PMSE users. We consulted on the detailed design of this award on 31 July 2008[8].

- We would allow licence-exempt cognitive access to interleaved spectrum (then excluding channels 61 and 62) provided this would not result in harmful interference to licensed users. This reflected our duty under section 8(4) of the Wireless Telegraphy Act 2006[9] to exempt from licensing any use of wireless-telegraphy apparatus that we consider is not likely to cause harmful interference.

2.6 This document focuses on the last of these approaches to the interleaved spectrum and consults on the details of how cognitive devices should be allowed to use it on a licence-exempt basis. In particular, it considers the safeguards needed to ensure that cognitive devices will not cause harmful interference to licensed uses of the same spectrum, particularly DTT and PMSE.

Cognitive access

2.7 We consider cognitive devices – sometimes known as white-space devices – to be those that assess the available spectrum, determine which parts of it are currently unused and, as needed, make use of this spectrum when they have information to transmit. They are often described as being particularly suited for high-bandwidth services such as home and business networks, community and campus networks and municipal Wi-Fi.

2.8 We have previously published two documents relevant to cognitive access:

- In our statement of 28 June 2005 on the Spectrum Framework Review (SFR),[10] we noted the potential of cognitive devices to cause harmful interference or reduce flexibility to change the use of spectrum. We suggested that they should only be allowed to use spectrum with the agreement of the licence holder.

- In its report of 12 February 2007,[11] QinetiQ concluded that fully functional cognitive radios were perhaps 10-20 years from realisation and that, at that time, there did not appear to be any applications for which a business case could be made to justify their introduction.

2.9 Nonetheless, the DDR statement considered whether the specific characteristics of interleaved spectrum made it suitable for use by licence-exempt devices, whether low power or cognitive. We examined the merits both of allowing cognitive access and of a dedicated licence-exempt allocation. We concluded that reserving spectrum for licence-exempt use would not be appropriate because it would be difficult to set aside anywhere near as much as 100 MHz without unduly reducing the amount of spectrum available for licensed uses. In contrast, we concluded that cognitive

[6] www.ofcom.org.uk/consult/condocs/notice524/statement/statement.pdf.
[7] www.ofcom.org.uk/media/news/2009/02/nr_20090205a.
[8] www.ofcom.org.uk/consult/condocs/bandmngr/condoc.pdf.
[9] www.opsi.gov.uk/acts/acts2006/pdf/ukpga_20060036_en.pdf.
[10] www.ofcom.org.uk/consult/condocs/sfr/sfr/sfr_statement.
[11] www.ofcom.org.uk/research/technology/research/emer_tech/cograd/cograd_main.pdf.

devices could make flexible use of interleaved spectrum without causing harmful interference to licensed uses. We said that cognitive access would depend on the development of effective spectrum-sensing technology that would avoid transmitting in spectrum used by licensed services. We noted that we would need to specify a number of parameters to which cognitive devices would need to adhere.

2.10 In allowing cognitive access to interleaved spectrum, it is important first to determine the method used to assess whether spectrum is vacant and then to set appropriate parameters for each method selected. For example, if the method selected is spectrum sensing, key parameters are the sensitivity of the cognitive device to detecting signals from other uses and the power levels at which it is allowed to transmit if it concludes that the spectrum is empty. This document discusses how these parameters can be determined and proposes some values.

2.11 It is generally not possible to design a cognitive device to be able to detect and avoid every technology that might be deployed in the spectrum in the future. Hence, there is a risk that cognitive access to interleaved spectrum might reduce the value of subsequently deploying different technologies. If it became clear in due course that a valuable new licensed use could not be deployed as a result of cognitive access, we would review the situation and determine whether to modify the parameters relating to cognitive devices.

Overview of responses to the DDR award-design consultations

2.12 Our consultation document on the detailed design of the cleared award, published on 6 June 2008,[12] proposed not allowing licence-exempt cognitive access to the interleaved spectrum in channels 61 and 62 given the greater uncertainty about their future use because of their proposed inclusion in that award. 20 responses (five of which were confidential) addressed this question. Since then, and as noted above, we have proposed to clear these channels, as a result of which they would not be available for cognitive access in any case.

2.13 Our consultation documents on the detailed design of the DDR geographic-interleaved and the band-manager awards both asked the same questions about cognitive access, namely:

- Are there types of DTT transmission other than DVB-T and -T2 that should be protected from potential cognitive devices or other factors that we should take into account?
- Are there any potential future PMSE applications other than currently available wireless microphones, in-ear monitors and talkback systems that should be protected from potential cognitive devices?
- Is there sufficient evidence to require protection for other services such as mobile television, bearing in mind the potentially negative implications of such protection for deploying cognitive devices?

2.14 A total of 23 responses (4 of which were confidential) addressed these questions.

- Most respondents, consisting in general of existing licensed users of interleaved spectrum, suggested that in principle all services should be protected and questioned the value of cognitive access. Many, however, recognised that

[12] www.ofcom.org.uk/consult/condocs/clearedaward/condoc.pdf.

protecting all services in practice was likely to be problematic. They urged caution in allowing cognitive access, with some suggesting that cognitive devices should be comprehensively proven not to cause harmful interference before being allowed to operate.

- One respondent was concerned about the ability of cognitive devices to accurately use sensing or signal-level detection and suggested that the use of geographic databases was more likely to provide protection against harmful interference. Another suggested that cognitive devices and spectrum liberalisation were incompatible and that, if cognitive access were to be allowed, licensed use should be restricted to specific technologies. However, a better solution was not to allow cognitive access at all. A third group of respondents noted that cognitive technology might be used to bring benefits to particular communities, such as those who are disabled, and that it might be appropriate to offer some level of protection to these users.

- For DTT, it was stressed that protection would have to be offered to DVB-T2, which tended to be more “fragile” and also difficult to detect, as well as DVB-T.

- For PMSE, it was noted that wireless cameras might soon be able to use interleaved spectrum and that they should be offered protection. Digital wireless microphones are also increasingly being used, and while these are generally more robust to interference than analogue microphones, there was some concern that certain types of modulation or coding might be discouraged by the possible deployment of cognitive devices. Some respondents noted the need for PMSE users to share with us details of devices that are currently being designed.

- Some respondents pointed to work in the US and noted that cognitive devices under test at that time were proving poor at detecting wireless microphones. They cautioned against accepting results and conclusions from the US without further scrutiny. Others suggested that detailed and comprehensive testing would be needed to confirm that harmful interference was not experienced and, moreover, that “harmful interference” would need very careful definition as all interference would be harmful to PMSE applications.

- Views on mobile television were mixed. Some respondents felt that its deployment in this spectrum was unlikely and hence protection unnecessary. Others thought that protection should be offered to any use that might emerge, including mobile television, but did not suggest how this might be achieved.

2.15 We recognise and agree with many of these concerns. They are discussed in more detail in subsequent sections of this document.

2.16 In all cases, we have placed non-confidential responses on our website.[13]

Structure of this document

2.17 This document is structured as follows:

- Section 3 considers deliberations about licence-exempt cognitive access to interleaved spectrum in the US and the EU.

[13] Cleared award: www.ofcom.org.uk/consult/condocs/clearedaward/responses/. Geographic-interleaved awards: www.ofcom.org.uk/consult/condocs/ddrinterleaved/responses/. Band-manager award: www.ofcom.org.uk/consult/condocs/bandmngr/responses/.

- Section 4 discusses in overview three approaches to determining whether spectrum is free for use by a cognitive device and considers how the appropriate transmission parameters should be set.
- Section 5 considers the detection parameters necessary for a cognitive device to operate successfully through spectrum sensing.
- Section 6 considers some of the issues associated with using a database of which frequencies a cognitive device is allowed to use at which location.
- Section 7 considers the transmission from some appropriate infrastructure of a beacon – signal providing information on which frequencies are available for cognitive use in the vicinity.
- Section 8 considers the three different approaches proposed to enable a cognitive device to determine which spectrum it can transmit in.
- Section 9 considers other parameters that need to be set appropriately.
- Section 10 outlines the path we plan to follow to maximise the probability of achieving international harmonisation around an acceptable standard.
- Section 11 summarises our conclusions and next steps.

Section 3

International developments

Introduction

3.1 Many other countries are engaged in the process of DSO and hence are also considering whether and how to realise a digital dividend. This section considers deliberations about licence-exempt cognitive access to interleaved spectrum in the US and Europe.

Developments in the US

3.2 On 4 November 2008, the Federal Communications Commission (FCC) adopted a report setting out rules allowing licence-exempt cognitive devices to operate in interleaved spectrum.[14] These are complex but in outline require cognitive devices to use both spectrum sensing and geolocation. The devices must sense both television signals and wireless microphones down to -114 dBm. They must also locate their position to within 50 metres and then consult a database that will inform them about available spectrum in that location. Mobile devices may then transmit at up to 100 mW unless they are using a channel adjacent to a television station, in which case their transmission power can only be 40 mW. Out-of-band emissions must be 55 dB below the in-band levels. Different rules apply to fixed devices (assumed to be base stations, likely providing a rural-coverage service). Detailed rules associated with the frequency of database access and sensing are provided.

3.3 Devices that use sensing alone are allowed in principle. Their output power is restricted to 50 mW, and they must be submitted in advance to the FCC for laboratory and field testing so the FCC can determine whether they are likely to cause harmful interference. The exact process that the FCC will use to determine this has not been specified.

3.4 Devices without geolocation capabilities are also allowed if they are transmitting to a device that has determined its location. In this case, one device would be acting as a "master" for a network and the other "slave" devices would operate broadly under its control in terms of the spectrum they would use.

3.5 The FCC has set aside two channels in each location for wireless-microphone use alone and therefore not available to cognitive devices.[15] These "safe-harbour" channels are intended to provide wireless microphones with spectrum in which it is guaranteed that cognitive devices will not operate.

3.6 The FCC report includes a detailed discussion about whether cognitive access should be licensed, licence-exempt or subject to light licensing. It concludes that the best way to facilitate innovative new applications is via licence-exemption and that licensing would not be practicable for many of the new applications envisaged. It also notes that any licenses would be difficult to define and subject to change (e.g. if television coverage was replanned), so the rights awarded would be rather tenuous.

3.7 The key implication that might be drawn from the US work is that sensing alone is currently insufficiently reliable to be used for cognitive devices. This was particularly

[14] http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-08-260A1.doc.
[15] Television channels in the US are 6 MHz rather than the 8 MHz European standard.

the case when detecting wireless microphones but also true in some cases when detecting television signals. Given the broad similarities between the licensed use in the US and the UK this suggests that devices that rely on sensing alone may not be readily implementable at present.

Developments in Europe

3.8 Work on a pan-European specification for cognitive devices is taking place within Task Group 4 of the European Conference of Postal and Telecommunications Administrations (CEPT). This work is currently at an early stage. It is not clear how the results will be promulgated. We will continue to contribute to this work, looking for the least intrusive way to achieve effective harmonisation (see section 10).

Section 4

Determining free spectrum and setting transmission levels

Introduction

4.1 A cognitive device needs to determine that spectrum is free and then only transmit according to an appropriate range of parameters such as power levels and out-of-band emissions. This section discusses in overview three approaches to determining whether spectrum is free: detection, geolocation databases and beacon reception. It goes on to consider how the appropriate transmission parameters should be set. Much of the work reported in this and subsequent sections has been informed and influenced by substantial stakeholder engagement, debate and dialogue during the process of developing the proposals in this document.

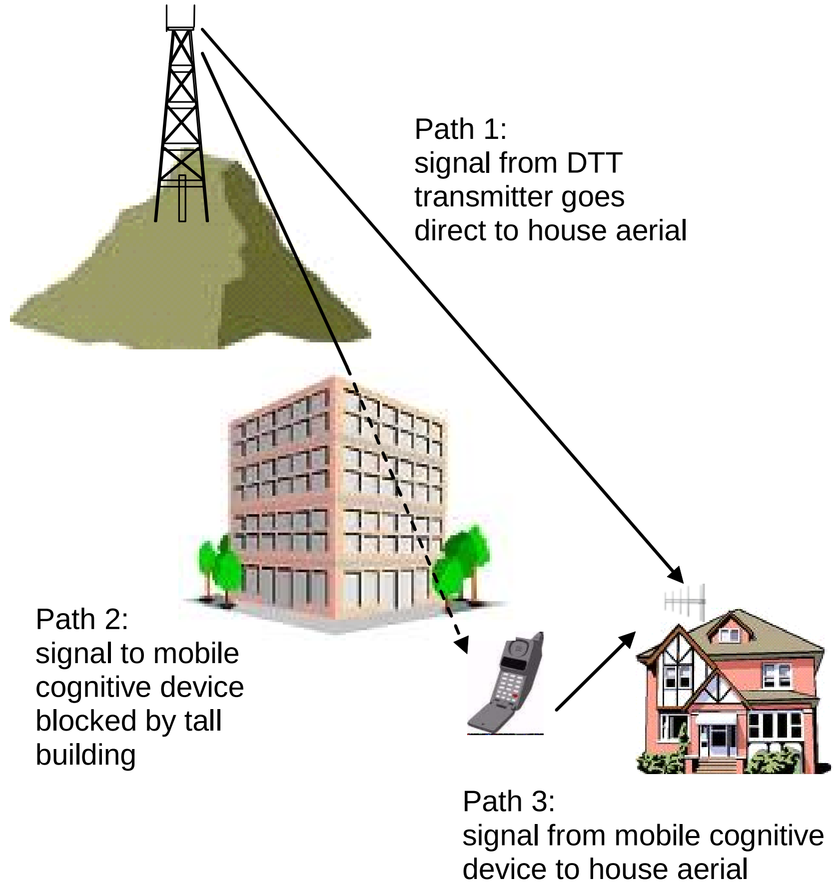
Detection

4.2 If a cognitive device transmits near the receiver of a licensed use of interleaved spectrum, it might cause harmful interference. If detection is used, the device seeks to avoid causing harmful interference by monitoring the spectrum for transmissions. It deduces that there are no nearby active receivers in that spectrum if it cannot detect any transmissions because there would be nothing for them to receive.

4.3 However, there is a problem with this approach often termed the “hidden-terminal” issue. This arises because the receiver of a licensed use is better able to receive the transmission than the cognitive device. Figure 3 illustrates this.

4.4 A house receives a DTT signal using a rooftop directional aerial mounted clear of surrounding buildings (path 1). Nearby is a mobile cognitive device attempting to detect the same signal at street level, but it is blocked by surrounding buildings (path 2) and therefore much reduced in strength. The cognitive device might erroneously conclude that there are no transmissions and hence no active nearby receivers, transmit and cause harmful interference to the rooftop aerial (path 3). A similar situation can be envisaged with respect to PMSE applications, including wireless microphones.

Figure 3. The hidden-terminal issue



4.5 The approach suggested to solving this problem is to determine two parameters. The first is the minimum signal level, or “sensitivity” at which the receiver from the existing service is able to deliver that service or the minimum level that it is likely to experience in practice. For a DTT receiver this would either be the minimum level at which an acceptable picture can be displayed or the minimum signal strength within “protected coverage regions”. The second parameter, termed the “additional margin” is an estimate of the difference in signal level that might be caused by the hidden terminal problem. For example, this might be based on an estimate of the maximum difference between signal levels at rooftop level and at street level. The addition of the sensitivity and the additional margin becomes the “sensing level”. If a cognitive device does not detect a signal above the sensing level it can consider the channel to be unused in its vicinity.

4.6 Determining the sensitivity of a device is relatively straightforward. It is often quoted in device specifications and can readily be confirmed in laboratory trials. For example, a number of DTT receivers could be procured, a test signal inserted into their aerial socket and the strength of this signal reduced until the picture quality visibly deteriorates.

4.7 Determining the additional margin is much more problematic. The difference in signal level caused by the hidden-terminal problem will vary substantially with geometry according to the composition of nearby buildings, street width, distance from the transmitter, height of the rooftop aerial and so on. It is impossible to measure all situations. The best that can be achieved is to either model or measure a set of locations selected as carefully as possible to be representative and then assume that the results will generally be valid. The measurements themselves will be probabilistic in that they will show that, for example, in 90% of cases the margin needed is less than, say, 20 dB and in 99% less than 25 dB. These values may also have substantial error bars associated with them. Interpretation is then needed as to which level of probability to adopt.

4.8 There is a further problem due to use of adjacent channels. For many devices, including most DTT receivers, a strong signal on a channel adjacent to the one to which they are tuned can also cause interference. Hence, a cognitive device that has discovered an empty channel may need to check the adjacent channels (termed the "n±1" channels) and modify its transmissions if it discovers that these channels are in use. Indeed, for some receivers, it may be necessary to scan more widely, perhaps including n±2, n±3 etc.

4.9 Detection is discussed in more detail in section 5.

Geolocation databases

4.10 An alternative to sensing is for a cognitive device to know its location and to have available a database of which frequencies it is allowed to use at which location. This overcomes most of the problems associated with sensing but leads to other issues such as:

- How will the device know its location?
- Who will maintain the database? Will there be one provider for all bands or a separate database per band? What will the commercial arrangements be? Will there be competition concerns?
- What availability is needed for the database? Is it acceptable for it to be offline for substantial periods?
- How will devices download updated versions of the database? How frequently should they do so? What will the loading on the spectrum be as a result?

4.11 Geolocation databases are discussed in more detail in section 6.

Beacon reception

4.12 This approach requires the transmission from some appropriate infrastructure of a signal providing information on which frequencies are available for cognitive use in the vicinity. Cognitive devices tune to this channel and then use the information provided to select their preferred frequency. They may still need to sense whether these frequencies are in use by other cognitive devices, but this is far less onerous since there is often a lesser need to ensure that cognitive devices do not interfere with each other. If the cognitive device is unable to find a beacon it is safest for it not to transmit, since it may be within the area covered by the beacon but shielded from receiving it. If it were to transmit on a randomly selected channel it could cause harmful interference.

4.13 While this resolves the sensing problem at the cognitive device it raises many other problems:

- Who provides the beacon signal? What are the commercial arrangements and if there is only one provider are there competition concerns?

- How is the beacon information kept up to date, especially where the licensed services are changing rapidly?
- What spectrum is used for the beacon?
- What technical parameters and protocols are used by the beacon transmitter?
- How to prevent the beacon signal being received outside of its intended coverage area and as a result being incorrect?
- Should there be separate beacons for separate frequency bands or one beacon for all the bands into which cognitive access is allowed?
- Is it acceptable for use of cognitive devices to be denied access to the spectrum if the beacon fails or is taken off-air for any reason?

4.14 Beacon reception is discussed in more detail in section 7.

Transmission parameters

4.15 Once a cognitive device has determined that it can use spectrum, there must be some restrictions on its transmissions. The most important of these parameters is the power level. As the power a cognitive device is allowed to transmit increases, so the range of its transmissions will grow. This means it has the potential to interfere with receivers further away. The further away the receiver, the greater the potential for the hidden-terminal issue to occur due to the increasing differences in the geometry of the signal reception that are possible. Another way to look at this would be that measurements of the additional margin needed would generally exhibit a higher probability of a larger margin as the range increases.

4.16 However, as discussed above, the additional margin can only be estimated, and understanding how it changes with transmit power adds a further variable in that the additional range achieved by a higher-power cognitive device is itself highly variable according to local topography. Hence, any correlation between cognitive transmit power and the additional margin can only be approximate.

4.17 Another restriction on power levels is the ability of existing devices such as DTT receivers to reject signals in adjacent or near-adjacent channels. If a cognitive device detected a free channel and transmitted in this channel, an existing device tuned to a nearby channel might not be able to adequately filter out the cognitive transmission, resulting in harmful interference. As shown later, this is likely to be a more significant limit on transmit power than consideration of the additional margin.

4.18 In any case, it seems sensible to require the cognitive device to use transmit-power control (TPC) such that if it requires less power at a particular moment because the device it is communicating with is nearby, it reduces its power level to the minimum needed for successful communication. TPC is widely adopted in many wireless devices and has the additional benefit of increasing battery life. The effect of TPC is difficult to quantify because it is unclear how often devices will operate below full power, but it can only reduce the interference caused to other devices.

Section 5

Detection

Introduction

5.1 The concept of detection as a mechanism for determining free channels was introduced in section 4. This section considers the device parameters that we would need to specify to ensure that a cognitive device that relied on sensing alone did not cause harmful interference to licensed spectrum users. It deals separately with the technical issues associated with protecting DTT, PMSE (specifically wireless microphones) and mobile television. In developing this analysis, we have worked closely with relevant stakeholders to understand their spectrum use and concerns and with a range of experts to gain as diverse a set of views as possible.

Protecting DTT

Introduction

5.2 Based on the discussion above, for DTT we need to determine the sensitivity, the additional margin, the adjacent channel performance and then set the power levels accordingly. Note that all figures for the cognitive device assume a 0 dBi antenna.

Sensitivity

5.3 We have commissioned a range of measurements of available DTT receivers. These have been performed on our behalf by ERA. One such study analysed the potential for harmful interference to 15 digital set-top boxes commonly available on the UK market.[16] ERA's measurements indicated that -84 dBm is the threshold of DTT visibility (i.e. the minimum useable signal level before the observed picture starts to degrade). This value is consistent with the figure suggested by the White Spaces Coalition in the US and by other studies.[17]

5.4 We have also looked in detail at the expected post-DSO signal levels for viewers around the UK. DTT networks are planned for viewers to receive a minimum signal level of approximately -70 dBm. Our assessment, based on detailed modelling work, is that typically around 99.8% of those within coverage areas will receive a signal above -70 dBm and 99.9% above -72 dBm. This is illustrated by figures 4 and 5. Figure 4 shows the range of signal levels experienced averaged across three representative channels (channels 23, 43 and 54). Figure 5 shows a small section of figure 4 focusing on the low signal levels.

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[16] www.ofcom.org.uk/research/technology/ctc/era05-07/2007-0631.pdf.

[17] See, for example, Technical Parameters and Planning Algorithms, JPP/MB/1, Joint Frequency Planning Project, July 2003.

Figure 4. Distribution of received signal strength across channels 23, 43 and 54

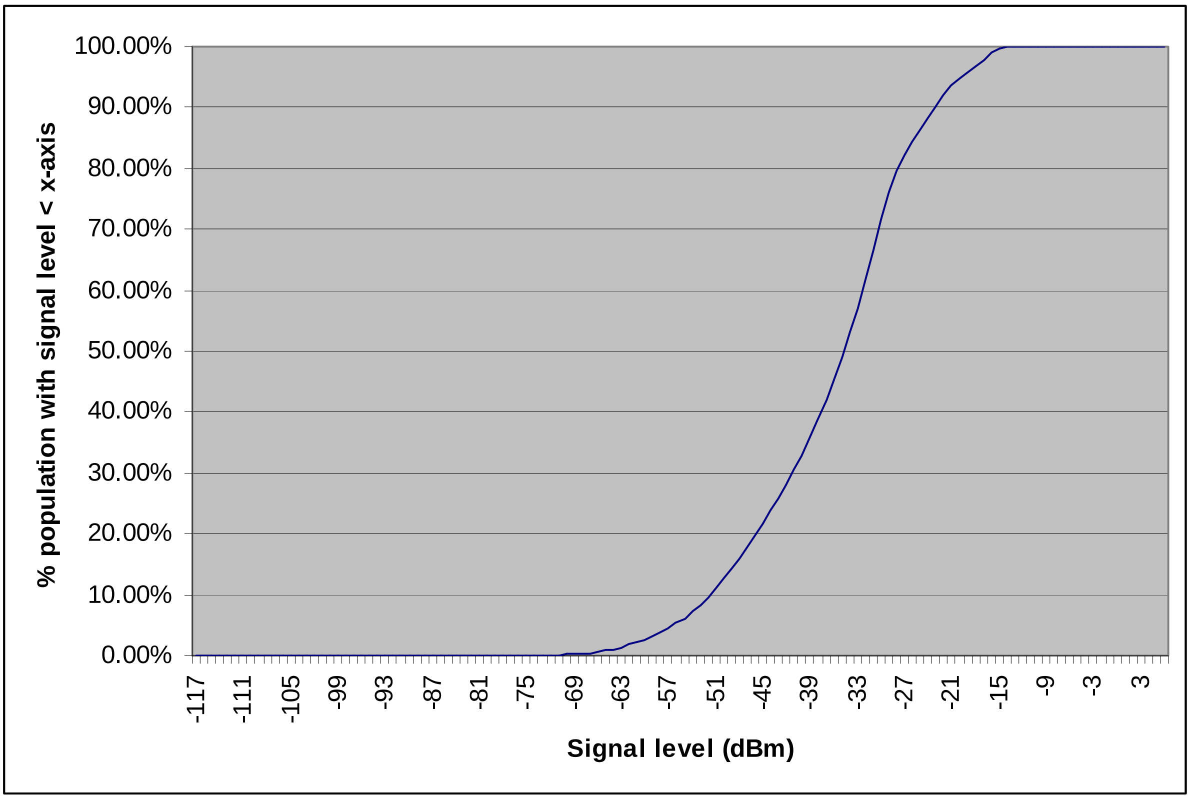
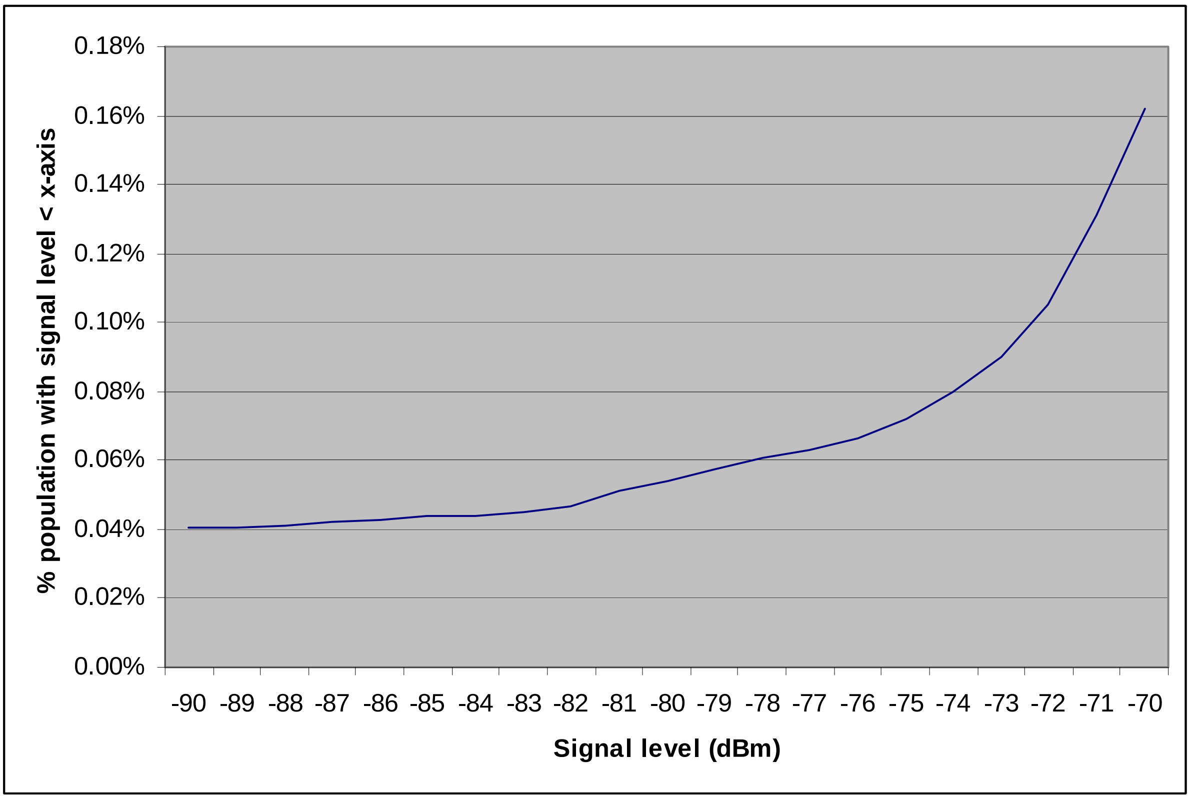


Figure 5. Detailed view of part of figure 4



5.5 From figure 5 it can be seen that only 0.1% of the population receive a DTT signal below -72 dBm. These levels are reasonably consistent across rural, suburban and urban areas, with less than a 2 dB variation between them.

5.6 So, although DTT receivers are capable of receiving signals to a level as low as -84 dBm, less than 0.1% of households who are considered to be in an areas covered by television broadcast will actually experience a level below -72 dBm. We think it appropriate to protect DTT down to -72 dBm. Note that this does not mean that the remaining 0.1% will experience interference, but that there will be some low probability that they might, which we discuss further below.

5.7 Hence, we propose to adopt -72 dBm as the sensitivity level for DTT.

Question 2. Do you agree that the sensitivity level for DTT should be -72 dBm?

Additional margin

5.8 It is possible to consider a very wide range of different scenarios for the position of the cognitive device and the DTT receiver, each of which could have differing requirements for an additional margin. It is not practical to consider every possible situation that might arise, but here we examine a range of situations that we consider to represent likely worst cases. By this we mean situations that might happen with reasonable frequency and appear to us to be likely to lead to worst-case interference probabilities. We exclude situations that we consider to be highly unlikely on the basis that including these would likely result in excessively cautious margins, unduly reducing the value that could be derived from cognitive access.

5.9 The scenarios can be divided into the two discrete cases of external antennas (typically rooftop mounted) and internal aerials (typically mounted on top of the television). Protection of internal/set-top aerial reception is not conferred under our current interference policy or any decisions we have made in relation to DSO, but given their widespread use – approximately 5% of households use them for reception on their primary television set and around 45% on additional sets – we believe it appropriate to provide some degree of protection for them in practice.

External antennas

5.10 We consider the likely worst case to be that illustrated in figure 3, above. We asked a consulting company, ERA, to undertake both a measurement and modelling campaign to determine the additional margin needed. After extensive measurements and modelling activities they reported the margins shown in table 3 below.

Table 3. Summary of hidden node margins for different area types

Environment	Hidden node margin (dB) for % of locations		
	90%	95%	99%
Densely urban	18.5	22.4	29.2
Urban	28.1	30.2	32.5
Suburban	30.5	31.4	32.9
Rural	14.9	15.6	16.6

5.11 We consider it important to offer protection in all areas and so take the worst case, namely the suburban results. We note that the public-service broadcasting (PSB) multiplexes have a coverage obligation of 98.5% of households, and this should not be changed by cognitive access. ERA's results show that the absolute worst-case margin covering virtually 100% of locations is around 35 dB. This also includes allowance for misalignment of antennas (where the cognitive device's antenna is oriented in a different plane from the polarisation of the DTT transmitter's antenna).

5.12 Overall, then, we select a margin of 35 dB, assuming a 0 dBi antenna at the cognitive device. A typical DTT antenna will have a gain of around 12 dB and cable losses of around 5 dB. Hence, we can calculate the level that a cognitive device needs to sense to as:

-72 dBm - 35 dB (margin) - 12 dB (antenna gain) + 5 dB (television feeder loss)

5.13 This implies that the cognitive device fitted with a 0 dBi antenna would need to sense to -114 dBm to ensure an acceptably low probability of harmful interference. We can calculate the resulting probability of incorrectly deducing that spectrum is unused by combining the distribution for signal levels received in practice, as shown in figures 4 and 5, with the probability of a given margin occurring as provided by ERA's work (and assuming that there is no correlation between DTT signal level and actual margin in any given location). If we do this, using the -114 dBm sensing level results in a probability of harmful interference of 0.04%. That is, when a cognitive device decides to transmit, there is a 0.04% probability that it will cause harmful interference to a DTT receiver. In practice, its transmission will be intermittent and there may not be a DTT receiver in the vicinity that is turned on and tuned to a channel close to that selected by the cognitive device, so the probability of harmful interference will be lower than this.

Internal antennas

5.14 We can envisage three situations of possible concern here.

i) The cognitive device and DTT receiver are in the same room.

ii) The cognitive device and DTT receiver are in the same building.

iii) The cognitive device is in a different building or outside the building.

5.15 Where the devices are in the same room the signal levels will be broadly similar and hence the cognitive device will typically have little trouble identifying a DTT signal. There is some possibility of fades occurring in different parts of the room – at these frequencies fades will be around 60cm apart, but in general these fades will only be a few dBs deep and will very rarely exceed 10 dB. Measurements made by the "coalition" in the US[18] suggested that the variation within a room was never measured as greater than 5 dB. Therefore, we consider that the margin needed for external antennas will be more than sufficient to accommodate this case.

5.16 Where the cognitive device and the DTT receiver are in the same building, there is a much greater possible variance in the signal level. This will vary from building to building and is not possible to characterise comprehensively. The same US measurements reported above also considered this variation for a number of different buildings and concluded that the variation was always less than 20 dB. In this case, the margin suggested for external antennas remains sufficient. Further, we believe in general that viewers can retain some control over the use of cognitive devices within their own homes such that if there are problems, they can restrict the use of cognitive devices to control them.

[18] See http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6519732745

5.17 Where the cognitive device is in a different building or outside the building, we can envisage the possibilities shown in figures 6 and 7.

Figure 6. Geometry of interference for an outdoor cognitive device and indoor set-top antenna

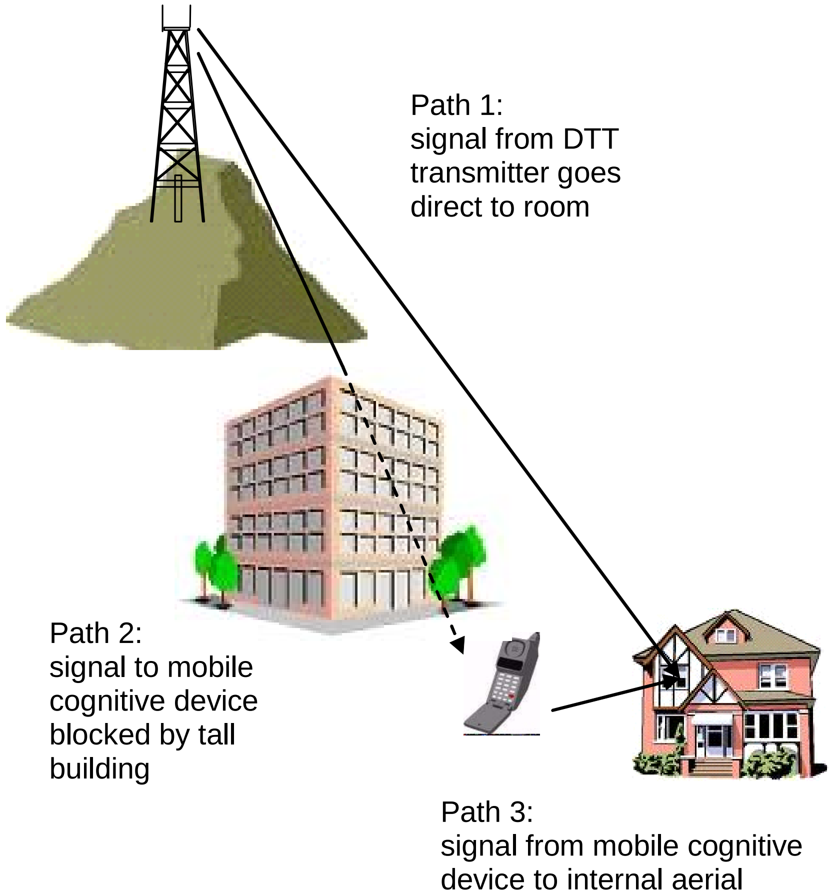
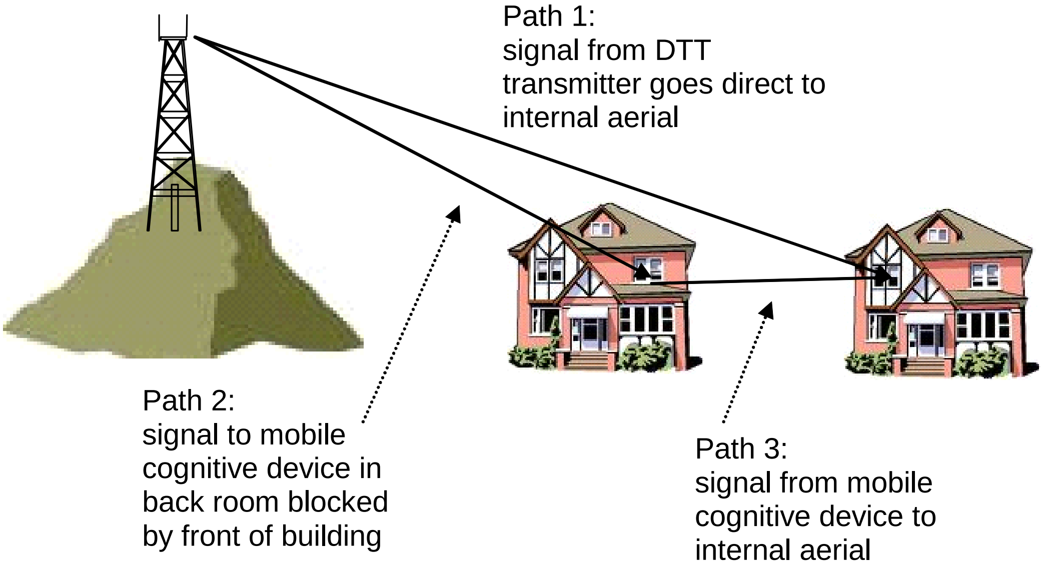


Figure 7. Geometry of interference for a cognitive device in one building and an indoor set-top antenna in another



5.18 The case of the outdoor cognitive device is very similar to that of the external antenna. However, the wanted signal received by the internal aerial will be lower than that of the external antenna due to its reduced height, the building-penetration loss and the lower gain of internal aerials. Therefore, a lower margin is needed in this case and the margin provided for external antennas will be sufficient.

5.19 The case of the cognitive device in a different building is more complex to characterise. Here, the signal level received by the cognitive device will have many similarities to the internal aerial but with additional shadowing caused by the building it is in. The signal it receives will be some combination of the direct signal passing through the building and reflections received off other nearby buildings directly into the room where the cognitive device resides.

5.20 ERA used ray-tracing to model this case where it was found that the maximum margin required was 28 dB, 7 dB less than the outdoor case considered earlier. Therefore, the sensitivity calculated for the outdoor case will be sufficient to provide protection in this case. However, we accept that this did not cover the case of an external antenna and will undertake further work in parallel with this consultation to understand whether this would lead to a requirement for an increased margin.

Polarisation

5.21 We do not know the type of antenna that a cognitive device will use, but if it is a portable device with similar form factor to a mobile telephone, it will likely have an omni-directional antenna. The alignment of the antenna will be somewhat random – it may be vertical (e.g. if held to the head), horizontal (e.g. if located in a laptop) or somewhere between. In the worst case, it would be 90° misaligned to the polarisation of the DTT signal. Through a process of making over 100 measurements, we found that the difference in the signal level seen by the cognitive device at the optimal and "worst" orientation was 6 dB. We have included this within our margin calculations reported above. Hence, we always assume the worst-case polarisation.

Other losses

5.22 The cognitive device could have further shielding (e.g. as a result of being in a jacket pocket or briefcase). In general, if this shielding is minimal, it will only add perhaps 1-2 dB onto the signal loss, which is within the error margins of the measurement and modelling reported here. If the loss is greater, the cognitive device will likely not be able to establish a connection with another cognitive device and will rapidly stop transmitting in any case. While there clearly are scenarios in which problems might occur, we believe that these will be relatively rare and allowing for them on top of all the other worst-case scenarios we have modelled would be overly cautious, especially given that we have made many other worst-case assumptions.

Question 3. Do you agree with an additional margin of 35 dB resulting in a sensitivity requirement for cognitive devices of -114 dBm?

Adjacent channel issues and transmit power

5.23 To understand how a device should behave with respect to adjacent-channel use in interleaved spectrum, we need to consider the geometry shown in figure 3. Here, a cognitive device transmits near a house receiving a DTT signal. Based on the adjacent-channel selectivity of the DTT receiver and the likely path loss between the cognitive device and the receiver, we can determine the maximum transmit power that can be allowed.

5.24 While there are many different variations of path loss, we consider a worst-case but likely situation is the cognitive device in the street outside the house, the antenna on the rooftop and the cognitive device in the main beam of the receiver antenna. In this case, the distance between the cognitive device and the antenna is typically at least 10 metres. This leads to a free-space path loss of approximately 50 dB assuming free-space propagation. We assume that the path is approximately 45° from horizontal. The gain of a typical omni-directional antenna at 45° elevation is around 4 dB less than the 0° gain, hence around -2 dBi, while that of a typical Yagi-type UHF antenna is around 10 dB lower than the 0° elevation, which is typically around 12 dB, hence around 2 dBi. In addition, we expect cable losses from the television aerial of around 5 dB. This leads to a total path loss in the region of 50 + 2 - 2 + 5 = 55 dB.

5.25 The worst case would be a DTT receiver operating at the margin of planned coverage, receiving -72 dBm wanted signal. ERA noted that, on an adjacent channel (n±1), most receivers needed a carrier-to-interference (C/I) ratio of around -30 to -40 dB depending on the technology generating the interference and factors such as the number of Quadrature Amplitude Modulation levels used in DTT transmission. Of these, the vast majority fell below -30 dB. Taking 30 dB as appropriately cautious, the adjacent-channel signal should not exceed -72 + 30 = -42 dBm. Hence, the maximum transmitted signal level would be around -42 + 55 = 13 dBm EIRP (20mW).

5.26 In the n±2 and subsequent adjacent channels, DTT receivers have much better filtering. The same measurements showed that they have a rejection figure on average 13-16 dB better in these channels than in the n±1 channel. This would, in principle, allow greater transmit powers – around 26 dBm (400 mW) – if not operating in immediately-adjacent channels. However, as the transmit powers increase, the risk of the signal propagating into an area nearby where the spectrum is in licensed use increases. Quantifying this risk is very difficult, but it suggests some caution in the use of higher powers. For that reason, it might be appropriate to restrict the power in non-adjacent channels to 20 dBm (100 mW).

Question 4. Do you agree with a maximum transmit power level of 13 dBm EIRP on adjacent channels and 20 dBm on non-adjacent channels?

Overall level of risk

5.27 In deriving these parameters we have tried to adopt what we consider to be a “realistic worst case”. That is, we have ignored cases which are even worse but we consider highly unlikely, but otherwise have opted in favour of protection. As a result we consider that, if anything, our parameters tend towards being more restrictive to cognitive devices than might be needed. For example, the probability of a cognitive device being in exactly the worst position (having minimum path loss to DTT receiver) and being exactly the worst antenna polarisation alignment and the receiver being right on the edge of coverage and the device itself not reducing its power through power control and the television being on and tuned to the worst possible frequency is likely extremely low indeed. It may be that over time as cognitive devices are deployed and greater understanding is gained as to the interference caused that it is possible to revise the parameters more in favour of the cognitive device.

5.28 Some of the transmit restrictions on cognitive devices come about because of the receiver performance of DTT equipment. If receiver specifications were improved to have greater adjacent channel selectivity then the need to use reduced power levels in adjacent channels could be removed. While we do not think it appropriate to expect consumers to replace DTT equipment purely to avoid cognitive interference, we do think there might be merit in progressively expecting better receiver performance from manufacturers such that over time, the installed base becomes more spectrum efficient. For example, simply by announcing that cognitive specifications were to be relaxed from a particular date we could attempt to influence manufacturers to design their equipment to accommodate this.

Question 5. Would it be appropriate to expect DTT equipment manufacturers to improve their receiver specifications over time? If so, what is the best mechanism to influence this?

Protecting wireless microphones

Sensitivity

5.29 In the same piece of work reported above, ERA also measured the sensitivity of a range of wireless microphones and concluded that the average sensitivity was -91.5 dBm[19] at the input of wireless microphone receiver. However, when making measurements in a range of venues they noted that the receivers were typically operated at signal levels above -67 dBm in order to ensure a high quality link.

5.30 Hence, we propose to adopt -67 dBm as the reference receive level of wireless microphones.

Question 6. Do you agree that the reference receive level for wireless microphones should be -67 dBm?

Additional margin

5.31 The additional margin geometry for a wireless microphone is quite different from that for DTT. For wireless microphones the worst case would likely be a cognitive device immediately outside of a theatre.

5.32 As with the DTT case, ERA conducted some very detailed measurement and modeling work across a range of venues including a TV production studio, a concert arena and a West End theatre. This involved 3D modeling of the venue and computer prediction of signal levels via ray-tracing, coupled with measurements to validate a subset of the modeled results. This work suggested that in all cases considered the margin would be below 39 dB.

5.33 However, in addition to this margin there is a possibility of “body loss” caused when a person wearing a wireless microphone is oriented such that their body is between the transmitter and the cognitive device. This factor was not taken into account in the modeling work and needs to be added to the margin. Measurements made in a controlled anechoic chamber suggest that the worst case body loss is in the region of 20 dB As a result, the total margin becomes 59 dB.

Question 7. Do you agree with an additional margin of 59 dB for wireless microphones?

5.34 This results in a sensing level of -67 - 59 = -126 dBm, 12 dB lower than for DTT. However, wireless microphone signals operate within a bandwidth of 200 kHz while DTT signals have a bandwidth of 8MHz. The narrower bandwidth reduces the noise

[19] For wireless microphones all power levels are quoted for 200 kHz channels.

detected by 16 dB. Hence, although the level is lower, the detection task may be less onerous for the device than DTT detection.

Question 8. Do you agree with a sensitivity requirement for -126 dB (in a 200 kHz channel) for wireless microphones?

Transmitter levels

5.35 A similar approach to that adopted for DTT can be used to determine the maximum transmitter levels based on the probability of causing harmful interference to wireless microphones when operating in adjacent channels.

5.36 First, we need to estimate the minimum likely path loss between a cognitive device and the wireless-microphone receiver. In many cases, the receivers are placed on gantries or similar above the stage to ensure good reception of signals from the performers. As a result, it would generally be difficult for a cognitive device to get very close to a receiver. We estimate that, in most cases, minimum separation distances of 10 metres are likely. There are some situations where smaller distances could be envisaged, down to perhaps 1-2 metres. These small distances result in a minimum path loss of around 32 dB. By taking this shortest distance and not allowing for any obstructions in making this calculation, we are being cautious.

5.37 If a cognitive device is operating in a DTT channel adjacent to the one used by a wireless microphone, it will have at least a 4 MHz separation in the worst case that the microphone is operating on the edge of the adjacent channel. At this separation, wireless microphones filter signals to the extent that they can accommodate a signal level 70 dB higher than the wanted level (i.e. C/I = -70). Hence, the maximum transmit power would be -67 (typical receive level) + 70 (filtering) + 32 (path loss) = 35 dBm (in a 200 kHz bandwidth). This is significantly higher than the 13-20 dBm level (in an 8 MHz bandwidth) proposed for DTT, hence the lower DTT level would apply.

5.38 In addition to filtering requirements, high-powered signals in nearby channels can result in “front-end overload” at the receiver, where non-linearities in those parts of the receiver ahead of the filters cause a high-power signal to distort the wanted signal. We are seeking advice from manufacturers of wireless microphones as to whether this is problematic at the transmit-power levels proposed.

Question 9. Do you agree with a maximum transmit power level in line with that for DTT? Are there likely to be any issues associated with front end overload?

Future PMSE devices

5.39 In earlier consultations some respondees advised us that digital microphones and wireless cameras were being developed for PMSE applications in the interleaved bands and should be protected from cognitive devices. We have not been supplied with any information about these devices nor have participants in a range of workshops suggested how we might modify our parameters in order to accommodate them. However, we remain open to examining whether our proposed parameters would offer such devices sufficient protection and varying the parameters if needed.

Protecting mobile television

Introduction

5.40 In addition to the services already identified as using the interleaved spectrum, we might wish to offer protection to mobile television on the basis that this might be offered in the interleaved spectrum. Mobile television is currently not well understood in terms of the technology that might be used or the other deployment characteristics. Hence, a number of assumptions need to be made in completing this assessment.

Sensitivity

5.41 We understand the likely sensitivity of mobile-television receivers to be around -86.5 dBm. We would welcome views on this figure.

Question 10. Do you agree that the sensitivity level for mobile television receivers should be -86.5 dBm?

Additional margin

5.42 A mobile-television receiver is likely to be embedded within a handset that could be used both in the street and in buildings. Cognitive devices are also likely to be in similar locations. Where the cognitive device and the mobile-television receiver are close together (e.g. in the same room or nearby on a street), there will generally be little difference in the signal levels they receive. Problems are perhaps most likely when a mobile-television receiver is outdoors (e.g. on a street) and a cognitive device indoors in a building adjacent to the street. In this case, the cognitive device will see a weaker signal as a result of the building shielding. Values for building penetration vary substantially depending on the construction of the building, the presence of windows and so on but are often quoted in the region of 15 dB. Further shadowing might also apply, perhaps caused by internal structures, resulting in a total margin of the order of 20 dB. This would imply a requirement for cognitive devices to detect mobile-television signals to a level of -106.5 dBm.

Question 11. Do you agree with an additional margin of 20 dB for mobile television?

Adjacent channel issues and transmit power

5.43 As noted above, a cognitive device could be located close to a mobile-television handset. It is difficult to set a minimum distance – situations could be envisaged where the devices were a metre apart, but these might be relatively rare. Also, there may be some form of blocking – perhaps one or both of the users might afford some shielding between the handsets. Also, the interference might be relatively transitory as the devices pass and as cognitive transmissions start and stop. At 1 metre, the free-space path loss is around 26 dB, while at 10 metres, it is around 46 dB. Given the possibilities for blocking and movement, we suggest adopting a value of 35 dB.

5.44 DVB-H devices typically have a C/I ratio of around 40 dB in the adjacent channel and 50 dB in other channels. Considering the adjacent channel, this means that the maximum signal level is -86.5 + 40 = -46.5 dBm. Allowing 35 dB path loss equates to a maximum transmit power of -11.5 dBm. In non-adjacent channels, this rises to -1.5 dBm.

5.45 This leads us to suggest that, if cognitive devices only detect signals in the channel they intend to use, they should be limited to -11.5 dBm, but if they also detect signals in adjacent channels and do not transmit if they detect these, their power levels could be increased to -1.5 dBm.

5.46 These are very low transmit power levels and would substantially impair the functionality of a cognitive device. It appears then that there is a choice to be made between

i) providing full protection to a mobile television service within the interleaved spectrum but effectively preventing cognitive usage, and

ii) providing less than full protection to mobile television within the interleaved spectrum while enabling cognitive access.

5.47 Our current thinking is that mobile television is much more likely to be deployed in the cleared spectrum than the interleaved spectrum and so providing full protection for this service in the interleaved spectrum would be disproportionate.

Question 12. Is it likely that mobile television will be deployed in the interleaved spectrum? If so, would it be proportionate to provide full protection from cognitive access?

Cooperative detection

5.48 A further possibility currently being considered at a research level is for multiple cognitive devices to share information on signal detection. This would improve the probability of detection since if one device were in a shadow of the wanted signal it might receive a signal from another nearby device which was not shadowed warning that the frequency was in use. By this process, researchers suggest that a lower value for the additional margin could be adopted.

5.49 The reduction in any value of the margin is highly dependent on the differences in the signal strength perceived by the cooperating devices. If just one building were providing the shadowing then there would be a very high chance that other devices were not shadowed. However, if a row of contiguous buildings (eg a terraced street) was providing the shadowing then all the cognitive devices which were able to communicate with each other might experience similar levels of shadowing and hence be unable to realise any benefit.

5.50 Cooperative detection would require cognitive devices to exchange information. This might need additional spectrum or alternatively could place a load on the available interleaved spectrum. Protocols would also need to be developed to enable devices to understand each other or any third-party “node” that was collecting sensing information and forwarding it on. There may be security considerations around the authenticity of any reports received. It will likely take some time, perhaps years, before appropriate standards are developed for such behaviour, hence we do not consider it further here. Instead, we propose to monitor this field as it develops further and decide whether to issue further consultations as appropriate.

Question 13. Should we take cooperative detection into account now, or await further developments and consult further as the means for its deployment become clearer?

“Real world” device performance

5.51 We have above proposed a set of sensitivity levels that cognitive devices must be able to achieve to ensure that harmful interference does not occur. This sensitivity needs to be achieved in "real-world" scenarios. In particular, the devices must be able to sense in the presence of strong signals in adjacent channels (or they must choose not to use channels where strong signals are present in adjacent channels). They must also be able to sense adequately in the presence of other cognitive devices using nearby channels.

5.52 Hence, we suggest that, as part of the specification and resulting type-approval verification, cognitive devices be tested to ensure that they do not incorrectly declare a channel to be unused regardless of the level of signal in adjacent channels.

Implications for cognitive device design

5.53 If the proposed levels for sensitivity and additional margin are adopted, cognitive devices would need to detect a transmission at very low levels, all in the presence of signals in adjacent channels and fluctuating signal levels. This is an extremely challenging task and will likely require the cognitive device to process repetitive elements of the signals in order to recover them from below the noise.

5.54 Whether this is possible and how it should be achieved is not for us to say. However, we will need to take a view on the value of developing licence-exemption regulations that are unlikely to be exploited. If we decide to move ahead, we would set device specifications, typically in those regulations, and device manufacturers would have to demonstrate in conformity with the Radio and Telecommunications Terminal Equipment (R&TTE) Directive[20] that their devices met the appropriate specifications. Therefore, we do not see it as our role to test prototype devices to establish whether they work correctly, although there may be some merit in performing certain tests to verify that harmful interference is not caused.

5.55 If it is not possible to produce devices with this degree of sensitivity, this might make other approaches, such as geolocation databases, more attractive. Some alternative approaches are explored in subsequent sections.

[20] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1999:091:0010:0028:EN:PDF.

Section 6

Geolocation databases

Introduction

6.1 As mentioned in section 4, an alternative to sensing is for a cognitive device to know its location and to consult a database of which frequencies it is allowed to use at which location. In this section we consider some of the issues associated with such an approach.

6.2 A geolocation-database approach might work well for avoiding DTT transmissions. Transmitter locations and transmission frequencies change relatively infrequently. Moreover, the location of transmitters is well known and the resulting coverage carefully predicted. It would be easy to provide an up-to-date UK-wide database showing which channels were in use for DTT in any given location.

6.3 With wireless-microphone use, the position is less clear. Some use is relatively static over long periods (e.g. in studios or theatres). These locations and the spectrum used could relatively easily be entered into a database. However, other use is shorter term, ranging from sporting events such as the British Formula 1 Grand Prix, which can be predicted, to electronic newsgathering (ENG), which is unpredictable and may see use occurring with an hour's notice or less. The latter application is likely to be most problematic for a database approach, requiring very frequent updates and devices to check the database frequently.

6.4 Many options could be considered. These include:

- The database approach could be adopted with short timescales for updating to accommodate ENG.

- In every location one or more available channels could be marked in the database as “in use”, effectively reserving them for ENG applications.

- The database approach could be coupled with a requirement for sensing such that wireless microphone use (or indeed any other use) not registered in the database would generally be detected by a cognitive device and the channel avoided[21].

Question 14. How could the database approach accommodate ENG and other similar applications?

Determining location

6.5 Clearly, for this approach to work, a cognitive device will need to know its location. How it does so is not a matter of concern to us as regulator, although this will potentially add cost to the handset and may reduce battery life. Most proposals suggest the use of the Global Positioning System, although alternative approaches based on the reception of known transmissions (e.g. from Wi-Fi networks) could be adopted.

[21] This is the approach that the FCC advocated in 2008 for use in the US.

6.6 What is of regulatory concern is the accuracy of position information. If the cognitive device determines its position with substantial error, it may not be able to use spectrum available in the area in which it has concluded it is located. Equally, specifying too precise a requirement for position information could impose unnecessary cost or complexity on the terminal.

6.7 Our view is that position accuracy need not be particularly precise compared to applications such as navigation. DTT transmissions typically cover many square kilometres, and the accuracy to which the edge of coverage can be defined is unlikely to be better than 1 kilometre. PMSE applications might require an exclusion of 1 kilometre or more. As a result, it might be envisaged that any database has a resolution in the region of 1 square kilometre. On this basis, position errors of a few hundreds of metres would have little significant effect.

6.8 We suggest that the requirements for position accuracy be somewhere in the region of 100 metres. We are interested in hearing views as to whether there are any design considerations that would incline us to increase or decrease this value.

Question 15. What positional accuracy should be specified?

Database ownership

6.9 For this approach to work there must be a single "master" database containing the spectrum that can be used in each location in the UK. Licensed spectrum users will need to provide information for the database about the spectrum that they are using in each location, and cognitive devices will need to access this information. There could be multiple copies of the master database located on "mirror" sites and maintained by different organisations, but they will need to ensure that their copies are accurate and up-to-date versions of the original.

6.10 Licensed users (e.g. DTT and PMSE, at least initially in the form of the band manager being created through the DDR) will need to take ownership of providing data concerning the spectrum that they are using in each location. For DTT, this information may be relatively static. For PMSE, it might need updating daily or even more frequently.

6.11 The actual ownership of the servers on which the database resides is less relevant. However, the owner of these servers will need to ensure that:

- The database is updated rapidly upon the provision of information from licence holders, perhaps within 1 hour.
- The database is available for most of the time. We would suggest a minimum of 99.99% availability.
- Database enquiries and downloads use appropriate protocols. We suggest Internet-based protocols and standard enquiry languages.

6.12 There may be commercial issues associated with these arrangements. Licensed users might expect not to bear the costs of providing information for the database, and server owners might expect to be paid for their role. If such funding were needed, it is unclear from where it would be provided.

Question 16. How rapidly should the database be updated? What should its minimum availability be? What protocols should be used for database enquiries?

Question 17. Is funding likely to be needed to enable the database approach to work? If so, where should this funding come from?

Accessing the database

6.13 Cognitive devices will need to send enquiries to the database. They might do so in one of two ways. They might download the entire database (or a part of it relating to their current location) and then perform an internal enquiry, or they might send the enquiry to the master database and await a response. There are advantages to both schemes, and there is no need for us to prefer one over the other.

6.14 If the device downloads the entire database, it will need to update it sufficiently often. It seems appropriate for the updating periodicity to be about the same as the speed with which the master database is changed. The device would not necessarily need to download the entire database each time, only the changes since the last download, although this would require additional functionality within the database server. However, clearly there will be a load on the wireless or wired networks that are used to provide this information.

6.15 Alternatively, the device could send a database request whenever it wishes to transmit, providing its current location and in return receiving information about available spectrum. This requires a radio channel that the cognitive device can use to make this initial request, which might perhaps be via a cellular network or similar.

6.16 It is possible that a device might download information via another, better connected device. So, for example, if there were a cognitive device in the vicinity that had a high data-rate connection to the Internet, it might be possible for mobile cognitive devices to request from this better-connected device the part of the database relating to the local area. This might prevent the need for the mobile device to use alternative spectrum to access the database directly.

Use of the database for spectrum management purposes

6.17 The use of a database would appear to bring spectrum management benefits. For example, all cognitive devices could be deactivated by fully populating the database with “all channels in use in this location”. Alternatively, individual channels could be “turned off” either nationally or in particular geographic areas. If the cognitive device supplied details of its make and model on accessing the database then the control could be tailored to individual devices – for example if a device were known to have a fault that was causing interference it could be turned off via the database.

6.18 We would not want to make use of such capabilities lightly because they would disadvantage existing users, manufacturers and possibly others. However, there might be good reasons for deploying them, for example, to enabling the introduction of a new and significantly more valuable licensed service in a situation where very few cognitive devices were deployed or alternatively in restricting usage in bands or geographies where interference to licensed services had occurred.

Question 18. Should the capability to use the database for spectrum management purposes be retained? Under what circumstances might its use be appropriate?

Transmitter parameters

6.19 The simplest approach to adopt would be to assume that the same transmit parameters as for the detection case should apply. Alternatively, it could be argued that an intelligent database could return to the device not only the spectrum it could use but also the transmit powers that could be used in each channel. These powers could be calculated depending on how far away the spectrum was in licensed use and, if appropriate, how far away adjacent channels were also used. This might allow higher power levels than those suggested for the sensing approach.

6.20 However, there may also be problems associated with higher power levels. Even if they do not directly lead to harmful interference, they might cause front-end overload on nearby devices. It might also cause increased harmful interference between cognitive devices or result in only a small number being able to access the channel in any given location.

6.21 Allowing the database to return the allowed power levels would seem to provide maximum flexibility and future-proofing. If higher levels were allowed and subsequently appeared to cause harmful interference, they could be reduced as required.

Fixed base stations

6.22 Using a database could potentially allow for fixed base stations operating at relatively high power levels compared to those allowed using detection alone. If a channel was not in use for some distance from the location of the base station, the location database could return a relatively high allowed power level enabling base-station operation.

6.23 Because a base station would typically be at a higher height than a terminal, and hence its signal would propagate further, it might be that the database should return a different power level for base-station operation. Alternatively, the base station itself might be required to reduce the allowed power level as returned by the database according to its height.

6.24 However, a fixed base station would still need to check the database regularly, and it might be that the spectrum it was using became unavailable on occasions, perhaps due to PMSE activity in the area. There could also be harmful interference from other cognitive devices or base stations in the area. Solutions could be found to this but typically only by reducing the amount of spectrum available to others.

Question 19. Should any special measures be taken to facilitate the deployment of cognitive base stations?

Probability of harmful interference

6.25 A geolocation-database approach has the potential to avoid harmful interference altogether assuming it is appropriately specified. As a result, it would appear to offer a higher level of protection to licensed users than detection, albeit at the cost of increased administrative effort.

Section 7

Beacon reception

Introduction

7.1 Beacon reception requires the transmission from some appropriate infrastructure of a signal providing information about which spectrum is available for cognitive use in the vicinity. Cognitive devices tune to this beacon and then use the information provided to select their preferred frequency. They may still need to sense whether these frequencies are in use by other cognitive devices, but this is far less onerous since there is often a lesser need to ensure that cognitive devices do not interfere with each other. If the cognitive device is unable to find a beacon, it is safest for it not to transmit since it may be within the area covered by the beacon but shielded from receiving it. If it were to transmit on a random channel, it could cause harmful interference.

Provision of the beacon signal

7.2 For this approach to work effectively there needs to be a transmission network established across much of the UK providing a beacon signal. Ideally, the signal should be transmitted at a similar frequency to the interleaved spectrum to avoid cognitive devices needing multiple antennas and receivers. The beacon network would ideally have relatively small cells, perhaps covering only a few square kilometres. This is because the same information on spectrum availability will be transmitted across the entire coverage area of the cell. If this is large, it is possible that some spectrum is available in one part of the cell but not another. Because the cognitive devices will not be able to distinguish this, all spectrum that is in use anywhere within the cell must be signalled on the beacon, effectively reducing the amount available. Building a transmission network to cover much of the country with small cells will be costly.

7.3 Many alternative approaches to building such a network could be considered. The network might be dedicated, or it might be overlaid onto an existing (e.g. cellular) network or transmitted from broadcast masts. Regardless, there will be costs associated with its provision, including the cost of spectrum if relevant, hardware investment and ongoing operational costs. Where the funding would come from to cover such costs is unclear.

7.4 The beacon network needs to have a high level of availability. If it were to fail or be taken offline, all cognitive use would cease until it became available again. For this reason, we suggest a reliability of 99.99% in any given location.

Question 20. Where might the funding come from to cover the cost of provision of a beacon frequency?

Question 21. Is a reliability of 99.99% in any one location appropriate? Does reliability need to be specified in any further detail?

Information content

7.5 The beacon will need to provide up-to-date information on the spectrum that can be used in an area. Hence, just as with the geolocation database, it will need to be provided with information on spectrum availability by licensed users. The same database as for the geolocation solution will need to exist, which the beacon operator will need to use as an input to the information it provides. Hence, the same considerations as to the timing of updating information should apply.

7.6 The beacon will need to be provided using an agreed and open standard. Agreements will need to be reached on all aspects, from the physical layer characteristics to the formatting of the information provided. It might be the role of a standards body or alternatively the owner of the beacon network to design these rules and make them openly available to manufacturers of cognitive devices. Clearly, there would be merit in international harmonisation of such rules, where other countries adopt similar schemes, to enable roaming and enhance economies of scale.

Transmitter parameters

7.7 The same parameters as for the detection case would apply.

Probability of harmful interference

7.8 In designing the beacon network, trade-offs will need to be made between enabling access to as much of the spectrum as possible and avoiding harmful interference. Because of the vagaries of propagation, the areas where the beacon signal is received cannot be controlled exactly. Hence, a cognitive device might receive a beacon signal outside of the coverage area for which it was intended and, as a result, transmit in inappropriate spectrum. This can be prevented by reducing the beacon power such that the probability of its being received outside of its area is low, but there will likely be locations within the nominal coverage area where no beacon can be received and hence cognitive access is not permitted.

Section 8

Comparing the different approaches

Introduction

8.1 This section considers the three different approaches to enable the cognitive device to determine the spectrum in which it can transmit. From a regulatory viewpoint, the key parameters of interest are the potential to cause harmful interference and the efficiency of spectrum use. However, we also recognise that it will be important to select an approach that can be practically implemented at the lowest possible cost in order to maximise the benefits to citizens and consumers.

Potential for harmful interference

8.2 We have discussed the interference potential of each of the approaches in sections 5 through 7. In outline we concluded that:

- Detection might result in harmful interference due to the possibility that the cognitive device is shadowed from the signal that it is trying to detect. It is difficult to determine precisely what this probability is, although we have made some estimates based on propagation modelling and shown the inherent trade-off between sensing performance and probability of harmful interference.

- An approach based on geolocation databases is unlikely to result in harmful interference as long as the database is appropriately specified and maintained. The only areas of risk are where licensed users change location unexpectedly and there is possible harmful interference until the database is updated.

- An approach based on beacons has some possibility for harmful interference if the beacon is detected outside the area for which it is intended. The probability of this occurring can be reduced but at the expense of preventing cognitive access altogether in certain areas.

8.3 Hence, an approach based on geolocation databases appears to offer the lowest potential for harmful interference.

Efficiency of spectrum use

8.4 By efficiency of use, we mean the ability of cognitive devices to use as much unused spectrum as possible in any given location. Considering each of the approaches:

- Detection would generally be able to make efficient use of the spectrum as long as the devices did not generate “false positives” (i.e. conclude that spectrum was used when it was not). This might occur if they detected noise or spurious emissions within the spectrum and could not distinguish this from an intentional signal. As the sensing level is reduced to reduce the potential for harmful interference, the likelihood of false positives increases. However, advances in technology or novel approaches to detection might improve this over time.

- An approach based on geolocation databases is likely to make efficient use of the spectrum. Since the cognitive device is accurately informed of all available spectrum, there should be no inefficient operation.

- An approach based on beacons may be inefficient for various reasons. If the cell size of the beacon is larger than the area of licensed use, cognitive access will be sterilised unnecessarily. As described above, reducing the probability of harmful interference is also likely to result in inefficient use of spectrum.

8.5 Hence, an approach based on geolocation databases would appear to offer the most efficient use of the spectrum and does not require any trade-off between harmful interference and efficiency, unlike the other two approaches.

Practicality

8.6 It is generally more appropriate for stakeholders to provide insight on the practicality of different approaches as they will have more information available to them than we do. Our initial assessment is that:

- Detection requires neither standardisation nor any coordinated activity (e.g. to build a database). No funding is needed to establish databases or beacons. Hence, this approach could likely be implemented most quickly. However, sensing reliably at the levels proposed has so far proved to be difficult, and it is not yet clear whether it can be practically achieved in consumer devices.

- The geolocation-database approach does require coordinated activity to build and maintain the database, to specify its parameters and to ensure appropriate availability. It also requires cognitive devices to be able to determine their position and communicate with the database regularly, perhaps via alternative wireless mechanisms. All of this can be achieved with current technology but will add cost to cognitive devices and administrative burdens to licensed users.

- Beacons require substantial activity to build and maintain a network. Access to spectrum must be achieved and standards developed, likely on an international basis. It is unclear how a network of beacons would be funded or who would build and maintain them. It seems likely that it would take many years to design and deploy such a network.

8.7 Hence, detection is likely to be the most practical approach to implement, providing compliant devices can be economically developed, while beacons could be expensive and time-consuming to deploy.

Conclusions

8.8 Of the three approaches considered, we conclude that beacons are unlikely to be deployed in the medium term and do not have any compelling advantages over the other two approaches. Hence, we do not see the need to proceed with the regulatory activity needed to enable them at present.

8.9 We see advantages and disadvantages to both detection and geolocation databases. From a spectrum-management viewpoint, geolocation databases appear to bring some advantages in terms of reducing the probability of harmful interference while enabling efficient use of spectrum, but we fully recognise the practical difficulties associated with this approach. Hence, at this point, our inclination is to enable both detection and geolocation databases and allow stakeholders to determine which approach they prefer. Indeed, both approaches could even be amalgamated.

Question 22. Do you agree with our proposal to enable both detection and geolocation as alternative approaches to cognitive access?

Section 9

Other important parameters

Introduction

9.1 In addition to sensitivity and transmit power there are other parameters that need to be set appropriately. These include bandwidth, time between sensing, out-of-band performance and politeness of use. Each of these is considered separately below.

Spectrum available

9.2 If we proceed with our proposals to clear the 800 MHz band, the available spectrum will be 470-550 MHz and 614-790 MHz. There might be some merit in excluding cognitive access at the edge of these bands to provide additional protection to licensed services operating in the adjacent spectrum.

Question 23. Should we restrict cognitive use of the interleaved spectrum at the edge of these bands? If so, what form should these restrictions take?

Bandwidth

9.3 We see no need to place any particular restrictions on device bandwidth other than that the emissions must fit within the spectrum identified above (a maximum of 176 MHz). While there is a default bandwidth of 8 MHz in use by DTT transmissions in the interleaved spectrum, there seems no reason why a cognitive device should not transmit across more than one DTT channel as long as it correctly measures all the channels used and any appropriate adjacent channels as empty. Equally, there is no reason why devices should not transmit with a bandwidth less than 8 MHz.

9.4 In practice, using bandwidths that spread across multiple channels will be difficult because the probability of finding multiple contiguous free channels in a given area will be substantially lower than finding a single free channel. Hence, we do not expect to see extremely broadband devices being widely used, but we do not wish to prevent this occurring if appropriate.

Question 24. Do you agree that there should be no limits on bandwidth?

Signal characteristics

9.5 A signal structure that is “bursty” could cause greater interference than one that is continuous. For example, a mobile cognitive device might transmit for 100 milliseconds and then stay silent for 900 milliseconds. The average power level when averaged over one second or greater would then appear relatively low, but the peak would be 10 dB higher. We suggest that the power levels be averaged over a “burst” where a burst is a period of continuous transmission at a relatively constant power level.

Time between checking for channel usage (where sensing is used)

9.6 Cognitive devices which use sensing to determine whether a channel is available should periodically check to detect whether, perhaps as a result of their movement or a change in the licensed use, the channel they previously identified as usable is no longer available to them. The time between checking is a trade off – too long and they could move into a materially different situation before changing channel, too short and they could spend so much time checking that there is little opportunity for them to transmit.

9.7 We envisage that cognitive devices will be relatively slow-moving or stationary. This is because the low power levels we are proposing will likely only allow a range of a few hundred metres. A fast-moving device would move out of communications range with another device too quickly to be able to handover or perform useful data transfer.

9.8 We expect DTT signals to be relatively static. The transmitters will not turn on or off rapidly, nor will they change their transmit powers. The received signal level at a cognitive device will not fluctuate substantively under most usage scenarios.

9.9 Wireless microphone signals are less likely to be static over a period of minutes. Microphones can be switched on and off in a venue as an actor enters or leaves the stage and the signal level at a cognitive device could fluctuate, for example, as the device was moved along a street adjacent to a theatre.

9.10 One case might be a device moving at a slow walking pace past a theatre. Simple modelling suggests that the signal strength will vary by 10 dB in about 100m distance when directly approaching the theatre. At 2m/s this would take around 50s. However, a more demanding case would be when an actor turned on their microphone and then moved onto the stage. This might happen in just a few seconds resulting in a channel suddenly coming into licensed use.

9.11 Hence, it seems appropriate that the rescan time on the channel that the cognitive device is using should be of the order of a second or two. We suggest 1s in order to be conservative.

Question 25. Do you agree that a maximum time between checks for channel availability should be 1s?

Out-of-band performance

9.12 We can understand the required out-of-band performance using the same argument as for adjacent channel performance. From the ERA report we have that a DTT receiver needs about 20 dB C/I ratio co-channel. Hence, for a DTT receiver on the edge of coverage, any in-band signals need to be below -92 dBm if they are not to degrade performance. With a 55 dB path loss the maximum transmitted signal would be -92 + 55 = -37 dBm. (For example, with a 20 dBm transmitter power this corresponds to a filtering requirement of 57 dB.)

9.13 For a wireless microphone operating at 67 dBm there is a requirement for 25 dB C/I. This means any interfering signal must be below -67 - 25 = -92 dBm. With a 32 dB minimum path loss this results in a transmitter level of -60 dBm in a 200 kHz bandwidth. This is equivalent to -44 dBm in an 8MHz bandwidth. Hence, this is the more demanding requirement.

9.14 We propose that the signal level for a cognitive device should fall to -44 dBm or lower in adjacent 8MHz channels.

Question 26. Do you agree that the out-of-band performance should be -44 dBm?

Politeness

9.15 As we set out in our statement on the Licence-Exemption Framework Review (LEFR), published on 4 December 2007,[22] we believe that licence-exempt devices should behave in a polite manner. By this we mean that the available resource should be shared fairly between all those attempting to use it.

9.16 In the case of cognitive access, we believe that there will inherently be an element of fairness in that when a cognitive device scans spectrum to see whether it is in use, it will automatically detect another nearby cognitive device already using that spectrum and so refrain from using it itself. By this means, we expect that one device will not force another out of spectrum that it is already using.

9.17 However, this raises the possibility of a device acquiring spectrum that is free and then staying in that spectrum for a prolonged period, preventing others having an opportunity to access it. This would be unreasonable. One way to avoid this is to cease transmitting periodically, allowing others a chance to access the spectrum. The periodicity and length of this period of silence is not critical other than that the silence period should be sufficiently long to allow another device to recognise that the spectrum is free and start transmission and it should occur with sufficient regularity that applications are not prevented due to the time taken to access the spectrum.

9.18 Since we do not have any information on the time that should be allowed to scan the spectrum nor the applications that are most likely, we are seeking stakeholders' views. We note that the White Spaces Coalition has proposed in the US that the maximum time for using spectrum be 400 milliseconds followed by at least 100 milliseconds of silence. This would seem to fit well with a requirement to rescan the spectrum at least once a second as the rescan could be performed during the silence period.

Question 27. Is a maximum transmission time of 400ms and a minimum silence time of 100ms appropriate?

Making use of sensing or location in other devices

9.19 If a cognitive device (termed the "slave") communicates with another nearby cognitive device (termed the "master") that has already established that the spectrum is free using sensing or location, it might not be necessary for the slave to also establish that the spectrum is free. It could simply make use of the searching performed by the master. This could allow much simpler cognitive devices working in, say, a home environment where the home hub had undertaken the necessary spectrum checks. Alternatively, it could allow simpler devices communicating with base stations.

9.20 However, there is a risk of harmful interference if the slave is some distance from the master and possibly in a location where the spectrum is in licensed use. This risk clearly increases with the range of the slave. For the home application, there would appear to be little risk, whereas for the base-station application, the risk is much greater. Quantifying the degree of risk is difficult.

9.21 Given that the geolocation database tends to offer a higher level of protection than sensing, we propose that the use of slave-device operation only be allowed where the master has performed database location.

[22] www.ofcom.org.uk/consult/condocs/lefr/lefr_statement/lefr_statement.pdf.

Question 28. Is it appropriate to allow “slave” operation where a “master” device has used a geolocation database to verify spectrum availability?

Future-proofing

9.22 It is generally not possible to design a cognitive device to be able to detect and avoid any technology that might be deployed in the spectrum in the future. Indeed, as explained in this consultation document, parameters typically need to be set depending on the technologies and services that the cognitive device is trying to detect. Hence, there is a risk that cognitive access to the interleaved spectrum might reduce the value of subsequent licensed deployment of different technologies.

9.23 We considered this in the DDR statement and concluded that the likelihood of the introduction of such technologies in this spectrum was low in the foreseeable future given its likely continued use for DTT and PMSE. If it became clear, in due course, that there was a valuable new licensed use of the spectrum that could not be deployed as a result of cognitive use, we would carefully review the situation, taking all relevant factors into account, including the expected economic value of continued cognitive use and the predicted value of the new licensed use.

9.24 If we came to the view that there was good reason to take action, we might require all cognitive devices sold after some future date to be able to detect and avoid this new licensed use. It is typically not possible (nor necessarily desirable) to require devices already sold to be recalled or for their use to be prevented. However, over time, the number of such devices, and hence their potential for harmful interference, will fall. It often takes more than five years to introduce a new technology from the time that it is first identified. Many consumer electronics products have a lifetime of this order, and hence we might expect that many of the existing cognitive devices would have been replaced by the time that the new technology was deployed.

9.25 If a database approach is adopted, this substantially eases the future-proofing problem. If it were judged appropriate and proportionate, all devices could be “turned off” simply by ensuring that the database registers all spectrum as in use. A transition period can be implemented by gradually increasing the spectrum registered as in use in the database. This is clearly a significant advantage of utilising databases.

Section 10

International harmonisation

Introduction

10.1 This section outlines the path we plan to follow to maximise the probability of achieving international harmonisation around an acceptable standard.

10.2 In our statement of 4 December 2007 on our Licence-Exemption Framework Review,[23] we set out the reasons why regulators have a role to play in ensuring harmonisation of the terms of spectrum access for licence-exempt devices. These include the greater economies of scale in equipment manufacture that can be achieved with international harmonisation, benefiting citizens and consumers. Moreover, cognitive devices may be small and easily transported across borders and so may cause harmful interference in different countries if key parameters differ substantively.

Harmonisation in Europe

10.3 European alignment can occur through informal, semi-formal or mandatory processes. An informal route would entail all countries individually selecting the same standard. A semi-formal route might be via a CEPT recommendation that was widely adopted. A mandatory process might be via EU legislation, such as was adopted for ultra wideband (UWB).

Harmonisation with the US

10.4 There are no formal mechanisms for ensuring alignment with the US. The FCC has developed its own views on an appropriate set of device parameters, as we have been doing in this document. Nevertheless, there are many informal opportunities to work together, sharing evidence and thinking and we will make the most of these opportunities.

10.5 As we have noted in many parts of this consultation, there is good agreement between the parameters put forward in the US and those that we propose here. Equally, there are some differences. The channel plan for television transmissions in the US differs from the UK, being based around 6MHz rather than 8MHz channels. Also, the technical standard for DTT transmission is different; with the result that sensing mechanisms designed to allow cognitive devices to detect DTT signals at low levels in the US may not work in the UK. As a result, it seems unlikely that a device made for the US market would be able to work in the UK even with alignment of parameters. However, it may be that manufacturers are able to make devices that can detect which environment they are in, perhaps based on characteristics of local television signals, and modify their behaviour accordingly. Even if this is not possible, relatively similar parameter values might allow economies of scale for some components and chipsets.

10.6 The key point of difference between our proposals and the US is that we suggest that sensing alone could be allowed without detailed device tests (although devices would have to operate in conformity with the R&TTE Directive).

[23] www.ofcom.org.uk/consult/condocs/lefr/lefr_statement/lefr_statement.pdf.

10.7 Table 4 provides a comparison of some of the key parameters we are proposing and those put forward by the FCC.

Table 4. Comparison of UK and US proposals

Parameter	UK value	US value
DTT sensing	-114 dBm	-114 dBm
Wireless-microphone sensing	-126 dBm	-114 dBm
Location accuracy	100 metres	50 metres
Transmit power – adjacent channels	20 mW	40 mW
Transmit power – non-adjacent channels	100 mW	100 mW
Out-of-band powers	< -44 dBm	55 dBc[24]
Time between sensing	1 second	1 minute

10.8 As we did with UWB, we intend to consult within the UK first and after appropriate dialogue and consideration to then develop an evidence-based and widely supported position that we can use to influence other specifications, such as those in Europe. Our hope is that harmonisation in Europe and the US will be on as similar a basis as possible. However, we will not support any form of harmonisation unless we are satisfied that it will not result in harmful interference to licensed users of the interleaved spectrum in the UK. Also, different DTT standards (e.g. between the US and Europe) make full worldwide harmonisation unlikely.

[24] For a transmit power of 100 mW, this corresponds to 20 - 55 = -35 dBm.

Section 11

Conclusions and next steps

Conclusions

11.1 This consultation document has considered licence-exempt cognitive access to the interleaved spectrum and noted that there are three mechanisms that might be used to select channels, namely sensing, geolocation and beacons. Of these, we conclude that the beacon approach is some way off but that sensing and location might be implemented more quickly. We have also proposed device parameters for each of these approaches such that the probability of harmful interference is acceptably low.

11.2 If sensing is to be used, the key parameters we propose are as set out in table 5.

Table 5. Key parameters for sensing

Cognitive parameter	Value
Sensitivity assuming a 0 dBi antenna	-114 dBm in 8 MHz channel (DTT) -126 dBm in 200 kHz channel (wireless microphones)
Transmit power	13 dBm (adjacent channels) to 20 dBm
Transmit-power control	Required
Bandwidth	Unlimited
Out-of-band performance	< -44 dBm
Time between sensing	< 1 second
Maximum continuous transmission	400 milliseconds
Minimum pause after transmission	100 milliseconds

11.3 If geolocation is to be used, the key parameters we propose are as set out in table 6.

Table 2. Key parameters for geolocation

Cognitive parameter	Value
Locational accuracy	100 metres
Frequency of database access	(to be determined)
Transmit power	As specified by the database
Transmit-power control	Required
Bandwidth	Unlimited
Out-of-band performance	< -44 dBm
Maximum continuous transmission	400 milliseconds
Minimum pause after transmission	100 milliseconds

Next steps

11.4 This consultation closes on 1 May. We will give due consideration to all responses in determining the most appropriate course of action.

11.5 If we decide to work internationally to achieve harmonisation, it may take some time, perhaps years, for all the necessary processes to be concluded. At present, the key points of interaction are with the FCC and the White Spaces Coalition in the US and within CEPT and the European Union in Europe.

11.6 Once we are satisfied that we have taken all relevant factors into account (possibly including further consultation) and done all that we can to ensure appropriate international harmonisation, we will proceed with the necessary steps to licence-exempt cognitive access to interleaved spectrum in the UK. This will involve consulting on draft regulations and then, in the light of responses, making those regulations. Because we do not yet know whether and in what form international harmonisation might be achieved, we cannot give guidance as to how long it might take to reach this stage.

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 1 May 2009.

A1.2 We strongly prefer to receive responses using the online web form at http://www.ofcom.org.uk/consult/condocs/cognitive/howtorespond/form 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 consultation responses – particularly those with supporting charts, tables or other data – please email william.webb@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 intend to publish a statement later in 2009.

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 We seek to ensure that responding to a consultation is as easy as possible. For more information, please see our consultation principles in annex 2.

A1.14 If you have any comments or suggestions on how 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.

A1.15 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

Our consultation principles

A2.1 We have published the following seven principles that we will follow for each public written consultation.

Before the consultation

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

During the consultation

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

A2.4 We will make the consultation document as short and simple as possible. We will try to make it as easy as possible to give us a written response. If the consultation is complicated, we may provide a shortened Plain English Guide for smaller organisations or individuals who would otherwise not be able to spare the time to share their views.

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

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

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

After the consultation

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

Annex 3

Consultation response cover sheet

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

A3.2 We have produced a 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.

A3.3 The quality of consultation can be enhanced by publishing responses before the consultation period closes. In particular, this can help those individuals and organisations with limited resources or familiarity with the issues to respond in a more informed way. Therefore, 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 consultation period has ended.

A3.4 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/.

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

Cover sheet for response to an Ofcom consultation

BASIC DETAILS

Consultation title:

To (Ofcom contact):

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

CONFIDENTIALITY

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

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Annex 4

Consultation questions

Executive summary

Question 1. The executive summary sets out our proposals for licence-exempting cognitive devices using interleaved spectrum. Do you agree with these proposals?

Detection

Question 2. Do you agree that the sensitivity level for DTT should be -72 dBm?

Question 3. Do you agree with an additional margin of 35 dB resulting in a sensitivity requirement for cognitive devices of -114 dBm?

Question 4. Do you agree with a maximum transmit power level of 13 dBm EIRP on adjacent channels and 20 dBm on non-adjacent channels?

Question 5. Would it be appropriate to expect DTT equipment manufacturers to improve their receiver specifications over time? If so, what is the best mechanism to influence this?

Question 6. Do you agree that the reference receive level for wireless microphones should be -67 dBm?

Question 7. Do you agree with an additional margin of 59 dB for wireless microphones?

Question 8. Do you agree with a sensitivity requirement for -126 dB (in a 200 kHz channel) for wireless microphones?

Question 9. Do you agree with a maximum transmit power level in line with that for DTT? Are there likely to be any issues associated with front end overload?

Question 10. Do you agree that the sensitivity level for mobile television receivers should be -86.5 dBm?

Question 11. Do you agree with an additional margin of 20 dB for mobile television?

Question 12. Is it likely that mobile television will be deployed in the interleaved spectrum? If so, would it be proportionate to provide full protection from cognitive access?

Question 13. Should we take cooperative detection into account now, or await further developments and consult further as the means for its deployment become clearer?

Geolocation databases

Question 14. How could the database approach accommodate ENG and other similar applications?

Question 15. What positional accuracy should be specified?

Question 16. How rapidly should the database be updated? What should its minimum availability be? What protocols should be used for database enquiries?

Question 17. Is funding likely to be needed to enable the database approach to work? If so, where should this funding come from?

Question 18. Should the capability to use the database for spectrum management purposes be retained? Under what circumstances might its use be appropriate?

Question 19. Should any special measures be taken to facilitate the deployment of cognitive base stations?

Beacon reception

Question 20. Where might the funding come from to cover the cost of provision of a beacon frequency?

Question 21. Is a reliability of 99.99% in any one location appropriate? Does reliability need to be specified in any further detail?

Comparing the different options

Question 22. Do you agree with our proposal to enable both detection and geolocation as alternative approaches to cognitive access?

Other important parameters

Question 23. Should we restrict cognitive use of the interleaved spectrum at the edge of these bands? If so, what form should these restrictions take?

Question 24. Do you agree that there should be no limits on bandwidth?

Question 25. Do you agree that a maximum time between checks for channel availability should be 1s?

Question 26. Do you agree that the out-of-band performance should be -44 dBm?

Question 27. Is a maximum transmission time of 400ms and a minimum silence time of 100ms appropriate?

Question 28. Is it appropriate to allow "slave" operation where a "master" device has used a geolocation database to verify spectrum availability?

Annex 5

Impact assessment

Introduction

A5.1 The analysis presented in this annex represents an impact assessment, as defined in section 7 of the Communications Act 2003.[25]

A5.2 You should send any comments on this impact assessment to us by 1 May 2009. We will consider all comments before deciding whether to implement our proposals.

A5.3 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

A5.4 If cognitive access is allowed, we expect there to be citizen and consumer benefits. Cognitive 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.

A5.5 However, if cognitive 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 this consultation document, we intend to licence-exempt cognitive access only if the risk of harmful interference to licensed services is acceptably low.

A5.6 It seems unlikely that cognitive access would affect different groups of citizens and consumers in different ways. Since we do not know the applications for which cognitive devices 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 cognitive access to favour one group of citizens or consumers over another, regardless of the detailed technical choices made.

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

Our policy objective

A5.7 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 cognitive 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.

A5.8 We do not know how long it will take to introduce the necessary regulations to licence-exempt cognitive access since this depends in part on the actions of other countries and international organisations. We expect that it might take between one and three years, depending on the degree of international activity needed. If cognitive 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 cognitive access

The value of cognitive access

A5.9 Cognitive access might bring significant economic benefits. The use of cognitive devices might enable new applications or make existing applications less expensive, which could bring significant benefits to consumers.

A5.10 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. In part, this is because the choice between detection and geolocation (see below) could affect which basic types of application are developed for use in the UK (e.g. because it can be difficult to establish location indoors).

A5.11 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**

A5.12 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.

A5.13 In addition to these direct benefits, cognitive 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 cognitive 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).

A5.14 The benefits of cognitive 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 cognitive devices using interleaved spectrum compared to the assumed environment of “non-cognitive” licence-exempt devices using cleared spectrum. However, estimating how much less is difficult until more information on cognitive device costs becomes available.

Potential impacts on licensed users

A5.15 Cognitive 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.

Impacts on existing licensed uses

A5.16 As noted above, geolocation might effectively remove the risk of harmful interference to licensed uses, provided the requisite database could be developed and maintained to the standards required. The commercial feasibility of doing this is unproven. For the purposes of this assessment, therefore, we have examined the potential impacts of the alternative option of relying on sensing, using the parameters we have proposed in this consultation document.

A5.17 There will be some risk to existing licensed uses of increased harmful interference associated with any set of cognitive-device parameters. The costs associated with these risks might be manifested in terms of:

- lower-reliability reception experienced by DTT viewers and/or additional transmission costs for broadcasters to mitigate this;
- additional risks of harmful interference for PMSE users and/or the costs of additional or modified equipment to mitigate this; and
- potentially some harmful interference to users of the nearby cleared spectrum depending on restrictions placed on cognitive devices near the edge of the interleaved spectrum.

A5.18 Our assessment of the economic value of DTT and PMSE use of the interleaved spectrum is of the order of £80bn (NPV). This is dominated by the value of the six DTT multiplexes that will operate after DSO. However, it is not certain that these would be the only licensed uses of this spectrum over the whole 20-year period or that the same terms for licence-exempt access would persist throughout if a need to adapt them (e.g. to move to an approach based on geolocation) arose in the longer term. We have therefore examined the potential impacts over a shorter, 10-year period, when the corresponding economic value of licensed use would be lower – potentially of the order of £50bn (NPV).

A5.19 DTT transmission planning standards are based on viewers receiving adequate reception on average around 99% of the time. Some levels of propagation interference (due to combinations of various external factors, including foreign transmissions and the weather) are therefore already to be expected by DTT viewers. In some parts of the UK, these levels of interference can be expected to be higher, and accordingly a lower, 95% planning standard is adopted in some locations.

A5.20 The advent of sensing cognitive devices would imply a very small risk that some viewers and PMSE users could be affected by additional harmful interference. However, the affected users would be concentrated in specific parts of the UK. This is because such interference from cognitive devices would occur when the actual "hidden-node margin" is larger than the assumed maximum we have proposed for the cognitive-device parameters. In such locations, the cognitive devices might not detect a DTT signal or wireless microphone and as a result could transmit erroneously.

A5.21 The specific locations where such a risk could crystallise would be those where the local terrain and building environment caused a particularly high hidden-node margin to occur. Hence, any such harmful interference would only occur in a few specific locations. However, in those locations, harmful interference could occur frequently, depending on the density and use of cognitive devices. The modelling performed by ERA suggests these locations are most likely to be in suburban areas.

A5.22 We have carefully considered the parameters we have proposed in this consultation document in order to result in a very low likelihood of such additional harmful interference. For sensing, we believe that the likelihood of noticeable harmful interference occurring to DTT viewers is less than 0.04%. (For geolocation, we expect it to be effectively zero.) We have not quantified the levels for PMSE but expect this to be similarly low. If this harmful interference were to occur, it would therefore affect, as a first approximation, no more than 0.04% of existing DTT viewers and PMSE users in specific locations. In the limit, if all such viewers and PMSE users were forced to use alternative reception routes, up to 0.04% of existing total benefits would be lost – around £20m (NPV over 10 years).

A5.23 However, because of the uncertainties attached to the potential rollout of the cognitive devices concerned, it may not in practice be possible to predict with confidence in advance which specific locations, and hence which DTT viewers and PMSE users, might be adversely affected in this way over the longer term. Accordingly, an additional effect might be, on average, to reduce the perceived reliability of licensed uses for those who would in practice be unaffected but who were uncertain of the future impacts of cognitive devices.

A5.24 Assuming that an expected reliability at the 95% level would constitute a floor for the average DTT viewer (below which platform switching would occur), a very small reduction in reliability would translate to an additional loss in value from the platform relative to the value associated with current reliability expectations. For example, if 80% of any adverse interference could be identified to specific locations and hence viewers but the remainder was sufficiently difficult to predict that it reduced the perceived overall reliability of the DTT platform for the average viewer, the perceived reliability reduction would be no more than 0.008% (20% of 0.04%). Assuming all the value of DTT reception resides in the difference between 100% and 95% availability this corresponds to a loss of value of 0.008% ÷ (100% -95%) = 0.2%. This would represent a £100m loss in the expected economic value of DTT (NPV).

A5.25 In practice, we would expect the impact to be much less than this because it is unlikely that any harmful interference, which would be transitory, would remove all economic value from DTT (or using wireless microphones). Further, it is likely that any problems occurring would be identified to specific locations so that the overall perceived reliability of the DTT platform would not be adversely affected in the longer term. Accordingly, we do not expect any adverse impacts to be as high as the above estimates would imply. However, even on the basis of the above estimates, the cost of any harmful interference would be much lower than the expected value to society generated by cognitive access. It is also worth noting that if the benefits from cognitive devices happen to be lower than expected, because their viable deployment is less widespread than anticipated or is delayed for some time, there will be a resultant decrease in the harmful interference caused and hence its cost.

Impacts on future licensed uses

A5.26 The advent of cognitive access might also prevent changes in the licensed use of the interleaved spectrum at some future point due to the cognitive devices being less able to detect and avoid a proposed new licensed application with higher value than the existing applications. It is very difficult to predict the value that might be lost due to the delayed deployment of such new applications as a result of possible harmful interference from cognitive devices. This is because we do not know what these applications might be, when they might emerge, the impact of cognitive-device interference to them in future or the mitigating measures that could be taken at the time.

A5.27 Despite these uncertainties, we are inclined to believe that 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 developed so as to be able to work within the protection being offered to existing DTT and wireless microphones;

- if geolocation is used, new licensed applications could be introduced without risk of harmful interference through their appropriate inclusion in the geolocation database; and

- ultimately, it would be possible to change or remove the licence-exemption conditions themselves. While it may take some years for cognitive devices already in use to be gradually retired, it often takes similar periods of time for new licensed users to acquire spectrum and to design and deploy networks to use it efficiently.

A5.28 For these reasons, we believe that the value of new licensed applications put at risk by the introduction of cognitive devices on a licence-exempt basis will be very low relative to the estimated economic benefits that might arise from their deployment.

Assessment of alternative approaches to cognitive access

A5.29 This consultation document has considered three approaches to cognitive access: detection, geolocation and beacons. We have calculated the most appropriate parameters for each.

A5.30 Briefly summarised below is our assessment of these three approaches against three criteria that, in line with our objective for the DDR, each focus on a key component of the total social-value impacts of introducing cognitive access (relative to the base case of doing nothing):

- the risk of harmful interference to licensed use;
- efficiency of spectrum use; and
- the practicality of introduction.

Risk of harmful interference

A5.31 We discussed the potential for harmful interference of each of the three approaches in sections 4 through 6. In outline, we conclude that:

- detection might result in harmful interference due to the possibility that the cognitive device is shadowed from the signal that it is trying to detect. It is difficult to determine precisely what this probability is, although we have made some estimates based on propagation modelling and shown the inherent trade-off between sensing performance and probability of harmful interference;
- an approach based on geolocation databases is unlikely to result in harmful interference as long as the database is appropriately specified and maintained. The only areas of risk are where licensed users change location unexpectedly and there is possible harmful interference until the database is updated; and
- an approach based on beacons has some possibility for harmful interference if the beacon is detected outside the area for which it is intended. The probability of this occurring can be reduced but at the expense of preventing cognitive access altogether in certain areas.

A5.32 Hence, an approach based on geolocation databases appears to offer the lowest potential for harmful interference.

Efficiency of spectrum use

A5.33 We also considered which approach would enable cognitive devices use spectrum most efficiently, in the sense of using as much unused spectrum as possible in any given location. Considering each approach:

- detection would generally be able to make efficient use of the spectrum as long as the devices did not generate “false positives” (i.e. conclude that spectrum was used when it was not). This might occur if they detected noise or spurious emissions within the spectrum and could not distinguish this from an intentional signal. As the sensing level is reduced to reduce the potential for harmful interference, the likelihood of false positives increases. However, advances in technology or novel approaches to detection might improve this over time;

- an approach based on geolocation databases is likely to make efficient use of the spectrum. Since the cognitive device is accurately informed of all available spectrum, there should be no inefficient operation; and

- an approach based on beacons may be inefficient for various reasons. If the cell size of the beacon is larger than the area of licensed use, cognitive access will be sterilised unnecessarily. As described above, reducing the probability of harmful interference is also likely to result in inefficient use of spectrum.

A5.34 Hence, an approach based on geolocation databases would appear to offer the most efficient use of the spectrum and does not require any trade-off between harmful interference and efficiency, unlike the other two approaches.

Practicality of introduction

A5.35 Finally, we briefly considered the practicality of each approach, albeit that it is generally more appropriate for stakeholders to provide insight on the practicality of different approaches as they will have more information available to them than we do. Our initial assessment is that:

- detection requires neither standardisation nor any coordinated activity (e.g. to build a database). No funding is needed to establish databases or beacons. Hence, this approach could likely be implemented most quickly. However, sensing reliably at the levels proposed has so far proved to be difficult, and it is not yet clear whether it can be practically achieved in consumer devices;

- the geolocation-database approach does require coordinated activity to build and maintain the database, to specify its parameters and to ensure appropriate availability. It also requires cognitive devices to be able to determine their position and communicate with the database regularly, perhaps via alternative wireless mechanisms. All of this can be achieved with current technology but will add cost to cognitive devices and administrative burdens to licensed users including broadcasters and potentially the PMSE band manager; and

- beacons require substantial activity to build and maintain a network. Access to spectrum must be achieved and standards developed, likely on an international basis. It is unclear how a network of beacons would be funded or who would build and maintain them. It seems likely that it would take many years to design and deploy such a network.

A5.36 Hence, detection is likely to be the most practical approach to implement, providing compliant devices can be economically developed, while beacons could be expensive and time-consuming to deploy.

The preferred option

A5.37 Overall, while we see advantages and disadvantages with each approach, at this point it appears to us that the practical difficulties associated with beacons are such that their deployment, at least in the medium term, is unlikely.

A5.38 Hence, at this point, our inclination is to enable both detection and geolocation databases and allow stakeholders to determine which approach they prefer. Indeed, both approaches could even be amalgamated.

Annex 6

Glossary of abbreviations

3G	Third-generation mobile-phone standards and technology
CEPT	European Conference of Postal and Telecommunications Administrations
C/I	Carrier to interference
dB	Decibel
dBc	Decibels relative to carrier
dBi	Decibels relative to an isotropic antenna
dBm	Decibels relative to milliwatts
DDR	Digital Dividend Review
DSO	Digital switchover
DTT	Digital terrestrial television
DVB-H	Digital Video Broadcast – Handheld
DVB-T	Digital Video Broadcast – Terrestrial
EIRP	Effective isotropic radiated power
ENG	Electronic newsgathering
EU	European Union
FCC	Federal Communications Commission
GHz	Gigahertz
kHz	Kilohertz
LEFR	Licence-Exemption Framework Review
MHz	Megahertz
mW	Milliwatt
NPV	Net present value
PMSE	Programme-making and special events
PSB	Public-service broadcasting

R&TTE	Radio and telecommunications terminal equipment
TPC	Transmit-power control
UHF	Ultra-High Frequency
UWB	Ultra-wideband
WLAN	Wireless local-area network