

## Implementing TV White Spaces Annexes 1 to 12

Statement

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## Annex 1

# **Overview of TVWS calculations**

- A1.1 Under the TVWS framework, a WSD must operate according to EIRP limits that are location and frequency specific. These limits are calculated in a way that meets Ofcom's objective of ensuring there is a low probability of harmful interference to:
  - DTT services in the UK within the UHF TV band;
  - DTT services of the UK's international neighbours within the UHF TV band;
  - PMSE use within the UHF TV band; and
  - Services adjacent to 470 MHz and to 790 MHz.
- A1.2 This Annex provides an overview of the calculations that are necessary to determine the maximum permitted in-block EIRP for a WSD taking account of these various coexistence requirements. It also provides a high level explanation of the main changes compared to the approach proposed in the 2013 Consultation. Annexes 2 to 8 provide the detail of the calculations.
- A1.3 As explained in Section 3, Ofcom is implementing the TVWS framework so that the responsibility for the necessary calculations is split between Ofcom and the WSDBs.
- A1.4 Ofcom will be responsible for:
  - the calculations to determine the limits in WSD EIRPs to take account of UK DTT;
  - the calculations to determine the limits in WSD EIRPs to take account of cross border DTT services;
  - any unscheduled adjustments to the permitted WSD EIRP that may be needed to take account of particular interference issues encountered;
  - the limits in the permitted WSD EIRP needed to take account of PMSE use of Channel 38 (first element of the location agnostic constraints);
  - the limits in the permitted WSD EIRP needed to take account of the services below 470 MHz and above 790 MHz (second element of the location agnostic constraints).
- A1.5 WSDBs will be responsible for:
  - receiving information from the WSD about its location and its technical characteristics – the Device Parameters;
  - the calculations necessary to determine the limits in WSD EIRPs to take account of PMSE;
  - putting together the limits that result from the calculations, in particular taking in to account the uncertainty in the location of the WSD; and

- communicating the limits and other control parameters (together the Operational Parameters) to the WSD.
- A1.6 In practical terms, Ofcom will provide data setting out the limits from all the calculations it is responsible for to the WSDBs, alongside details of the PMSE licences. This is illustrated in Figure A1.1 below.



#### Figure A1.1 - WSD emission limits and their calculation

A1.7 The calculations listed in paragraphs A1.4 and A1.5 are briefly described next.

## **Calculations performed by Ofcom**

## Calculation of emission limits relating to DTT in the UK

- A1.8 In relation to DTT, the derivation of location-specific TVWS availability can be formulated as the following problem.
- A1.9 Calculate the maximum permitted WSD in-block EIRP,  $P_{\text{WSD-UK}}(i, F_{\text{WSD}})$ , for a WSD located in a geographic pixel indexed as *i*, and radiating in channel  $F_{\text{WSD}}$ , subject to a given maximum reduction in DTT location probability in any channel  $F_{\text{DTT}} = 21$  to 60.
- A1.10 The limit  $P_{\text{WSD-UK}}(i, F_{\text{WSD}})$  is measured over 8 MHz, since DTT operates in 8 MHz channels. Also, in line with DTT planning in the UK, we use a spatial resolution that is based on 100 metre × 100 metre geographic squares ("pixels"). The area of the UK is covered by over 20 million pixels.
- A1.11 Annex 2 sets out in detail our approach to this calculation. Ofcom will generate a unique TVWS availability dataset for each combination of five WSD emission classes and seven representative WSD antenna heights.

## Calculation of emission limits relating to Cross Border DTT

- A1.12 In relation to cross border DTT, the derivation of location-specific TVWS availability can be formulated as the following problem.
- A1.13 Calculate the maximum permitted WSD in-block EIRP,  $P_{\text{WSD-XB}}(i, F_{\text{WSD}})$ , for a WSD located in a geographic pixel indexed as *i*, and radiating in channel  $F_{\text{WSD}}$ , subject to the received field strength in neighbouring countries not exceeding relevant international coordination trigger thresholds in channel  $F_{\text{WSD}}$ .
- A1.14 The limit  $P_{\text{WSD-XB}}(i, F_{\text{WSD}})$  is measured over 8 MHz, since DTT operates in 8 MHz channels. Again, in line with DTT planning in the UK, we use a spatial resolution that is based on 100 metre × 100 metre geographic pixels.
- A1.15 Annex 3 sets out in detail our approach to this calculation.

## Calculation of emission limits relating to both UK and Cross Border DTT

A1.16 Of com will take the minimum of the two limits  $P_{\text{WSD-XB}}(i, F_{\text{WSD}})$  and  $P_{\text{WSD-UK}}(i, F_{\text{WSD}})$  to derive  $P_{\text{WSD-DTT}}(i, F_{\text{WSD}})$ . The data set containing these emission limits for the different emission classes and antenna heights will be provided to the WSDBs. Specifically, the dataset will contain the EIRP limit in dBm per 8 MHz channel, for each combination of five WSD emissions classes, seven WSD antenna heights, all DTT channels from 21 to 60, and each of the 20 million 100 metres x 100 metres pixels in the UK.

## Calculation of location-agnostic emission limits

A1.17 There are two elements to the location-agnostic emission limits: those that are required to take account of location-agnostic PMSE use of Channel 38 and those that are required to take account of services below 470 MHz and above 790 MHz.

## Channel 38

A1.18 Annex 5 explains how Ofcom has determined limits for WSD EIRP to take account of location-agnostic PMSE use of Channel 38. These limits are specified for type A and type B devices for different emission classes.

## Above 790 MHz

A1.19 Annex 6 explains how Ofcom has determined limits for WSD EIRP to take account of the use above 790 MHz. The specific limit is to restrict use of channel 60 for WSDs.

## Below 470 MHz

A1.20 Annex 7 explains how Ofcom has determined limits for WSD EIRP to take account of the use below 470 MHz. Specific limits will be imposed in channels 21 to 24. These emission limits vary with device emission class. Table 7.1 in Annex 7 sets out the limits.

## Combination of location agnostic emission limits

A1.21 Ofcom will combine the various location agnostic emission limits for type A and B WSDs for each of the emission classes where relevant. The limits are

communicated to the WSDB as a table – see Table 8.3 in Annex 8. The limit is specified in dBm over 8 MHz.

## **Unscheduled adjustments**

- A1.22 The unscheduled adjustments function allows Ofcom to tell the WSDBs to override the limits that result from the calculations. The unscheduled adjustments are location and frequency specific and can be set on 100 metres by 100 metres pixel granularity. These adjustments may be triggered by an interference management process or by fine tuning of Ofcom's coexistence modelling parameters.
- A1.23 Annex 8 describes in detail how the WSDB must apply these limits.

## **Calculations performed by the WSDBs**

## Calculation of emission limits relating to PMSE (other than for locationagnostic PMSE in Channel 38)

- A1.24 In relation to PMSE, the derivation of location-specific TVWS availability can be formulated as the following problem.
- A1.25 Calculate the maximum permitted WSD in-block EIRP,  $P_{\text{WSD-PMSE}}(j, F_{\text{WSD}})$ , for a WSD located in a geographic location indexed as *j*, and radiating in channel  $F_{\text{WSD}}$ , subject to a given PMSE wanted-to-unwanted power ratio in any channel  $F_{\text{DTT}} = 21$  to 60 and subject to a power restriction in all channels  $F_{\text{DTT}} = 21$  to 60 accounting for intermodulation products.
- A1.26 The limit  $P_{\text{WSD-PMSE}}(j, F_{\text{WSD}})$  is measured over 100 kHz, since the vast majority of PMSE equipment operates in bandwidths of 200 kHz or less, and so a finer resolution than 8 MHz is required.
- A1.27 WSDBs will be responsible for performing the above calculations. The WSDBs will need to account for the WSD spectrum emission class, the reported WSD antenna height, and WSD type (A/B) in performing the calculations. Part 5 of Annex 8 describes the calculations in detail.

## **Dealing with WSD location uncertainty**

- A1.28 As explained in Sections 8 and 9 of this Statement, there will normally be some uncertainty in the location of a WSD. In this regard, our framework requires WSDBs to calculate Operational Parameters according to two scenarios:
  - i) Master or slave devices that provide their location, but with uncertainty.
  - ii) Slave devices that do not provide their location.
- A1.29 A device in the first scenario will provide the WSDB with its location, as a longitude and latitude pair of coordinates, and the uncertainty in its location, as two values in metres that indicate the uncertainty in longitude and latitude. The WSDB will define an area where the device may be located – the area of potential locations – as a rectangle centred in the location and with sides defined by the uncertainty values. The WSDB will calculate the EIRP limits conservatively, under the assumption that the WSD may be anywhere in that area. The detailed procedure for this is described in Parts 2 and 4 in Annex 8.

A1.30 The WSDB will also define an area of potential locations in the second scenario. In this case, the area will be a circle centred at the location of the master serving the slave, with a radius calculated as the coverage range of the master WSD plus the uncertainty in its location. The WSDB will first estimate the coverage range using the transmissions characteristics of the master WSD, and then calculate EIRP limits for the slave WSD under the assumption that it may be anywhere within the circle. This procedure will result in Generic Operational Parameters and is described in detail in Part 3 in Annex 8.

## **Combining of emission limits into Operational Parameters**

- A1.31 The WSDB will provide the EIRP limits to a WSD in the form specified in the ETSI Harmonised Standard EN 301 598. This Standard defines two limits:
  - P1: maximum permitted in-block EIRP in dBm/(8 MHz); and
  - P0: maximum permitted in-block EIRP spectral density in dBm/(100 kHz)
- A1.32 These are calculated as described in the following paragraphs (Annex 8 provides a detailed specification of the procedure).

## Maximum permitted in-block EIRP P1

- A1.33 This limit is calculated to ensure a low probability of harmful interference to DTT and other services with the exception of location-specific PMSE. The procedure can be summarised as follows:
  - i) The WSDB looks up the EIRP limits related to DTT, provided by Ofcom, at all pixels in the area of potential locations and all DTT channels.
  - ii) For each available channel, P<sub>DTT</sub> will be the smallest of the EIRP limit values over the WSD candidate pixels.
  - iii)  $P_1$  at each channel will be calculated as the minimum of: 36 dBm, the EIRP limit looked up,  $P_{DTT}$ , and the location agnostic limit also provided by Ofcom.
  - iv) If the location reported by the WSD is within any of the unscheduled adjustment regions provided by Ofcom to the WSDB, then the unscheduled adjustment limit overrides the value calculated in iii) i.e.  $P_1 = P_{UA}$ .

#### Maximum permitted in-block EIRP spectral density P0

- A1.34 This limit is calculated to ensure a low probability of harmful interference to locationspecific PMSE. The procedure can be summarised as follows:
  - For each PMSE assignment that is active, the WSDB calculates the EIRP limit P<sub>WSD-PMSE</sub> for WSD candidate locations<sup>1</sup> in the area of potential locations and for all channels.
  - ii) For each available channel, P<sub>WSD-PMSE</sub> will be the smallest of the P<sub>WSD-PMSE</sub> values over all WSD candidate locations and over all PMSE assignments.

<sup>&</sup>lt;sup>1</sup> Candidate locations for calculation of  $P_0$  are the points in a 10 metres by 10 metres grid, aligned with the NGR, whose squares totally or partially overlap with the area of potential locations of a WSD (see Annex 8 for a detailed explanation)

iii) P<sub>0</sub> at each channel is then calculated as the minimum of: P<sub>1</sub> (corrected for the different bandwidth), and P<sub>WSD-PMSE</sub>.

## High-level view of changes relative to the 2013 Consultation

- A1.35 The changes relative to the 2013 Consultation fall into six categories:
  - Coexistence with DTT: these changes are explained in Annex 2
  - Coexistence with location-specific PMSE: these changes are explained in Annex 4
  - Coexistence with location-agnostic PMSE in channel 38: these changes are explained in Annex 5
  - Coexistence with services below the UHF TV band: these changes are explained in Annex 7
  - WSD heights assumed where a device does not report its height: these changes are explained below.
  - Calculation of serving master WSD coverage area: these changes are explained below.
- A1.36 There have been no changes to our approach to coexistence with DTT use of spectrum in neighbouring countries or to coexistence with services above the UHF TV band.

## WSD heights

A1.37 There are no substantial changes compared to the 2013 Consultation to the way WSD heights are used in the calculations related to DTT. On the other hand, we have made a number of changes in the calculation of the EIRP restrictions in relation to PMSE, including the adopted default values. These changes are summarised in Table A1.1 below.

## Table A1.1 – WSD antenna heights used in calculation of EIRP restrictions (PMSE)

Change	2013 Consultation	Statement
Rounding of WSD antenna heights	The antenna heights were rounded to the nearest value of 1.5, 5, 10, 15, 20, or 30 metres.	No rounding applied.
Type A WSD	Default value: 30 metres	Default value for a type A master WSD: 20 metres Default value for a type A slave WSD: 5 metres
Type B WSD	Default value: 1.5 metres	Default value for a type B master WSD: 1.5 metres (i.e. no change) Default value for a type B slave WSD: 1.5 metres (i.e. no change)

## Serving master WSD coverage area

- A1.38 As explained above, our approach to dealing with the location uncertainty of a WSD takes account of two considerations:
  - i) the location uncertainty of the reported location of a master WSD or a slave WSD; and
  - ii) when the location of a slave WSD is not known<sup>2</sup>, the radius of the serving master coverage area is taken into account.
- A1.39 This section addresses our changes in relation to how the size of the serving master coverage area is calculated.

## 2013 Consultation Proposals

A1.40 The range of (downlink) coverage between serving master WSD and slave WSD was based on the difference between the reference sensitivity of the slave WSD and the EIRP spectral density of the master WSD. This difference was taken as representative of the "minimum coupling gain", and estimation of the range amounted to determination of the distance for which the median path gain equated to the minimum coupling gain.

## **Statement**

- A1.41 We now take into consideration a number of factors all of which ensure that the calculated coverage area is a more realistic representation of where the slave WSD is likely to lie in relation to its serving master WSD. Given that the generic operational parameters are determined by taking the smallest of the EIRP restrictions across the coverage area, it important that the coverage area is not estimated to be overly large. This could result in unnecessary restrictions on non-geolocated slave WSDs, and on geolocated slave WSDs that use generic operational parameters to set up the initial connection with the master WSD.
- A1.42 A full description of the new calculation is given in Part 6 of Annex 8. The effect of each of the changes is to estimate the size of the serving master coverage area more accurately. The changes we have made are summarised in Table A1.2.

## Table A1.2 – Summary of the changes following the 2013 consultation

Change	2013 Consultation	Statement
Application of an adjustable parameter (margin) to the minimum coupling gain between master WSD and slave WSD.	No	An adjustable parameter (margin) is applied. The adopted value is 10 dB. The net effect is that the minimum median path gain, used to establish the radius of the coverage area, is increased.
Environment type for median path gain calculation	The clutter database categories were mapped to 'urban, 'suburban' and 'open'.	The clutter database categories are mapped to 'urban' and 'suburban'. The mapping to

<sup>&</sup>lt;sup>2</sup> The location of the slave WSD will not be known if the slave is non-geolocated or if it has not yet communicated its location to its serving master WSD.

Change	2013 Consultation	Statement
		'open' no longer applies.
Slave WSD antenna gain	For type A master WSD, the slave WSD antenna gain was 10 dBi. For a type B master WSD, the slave WSD antenna gain was 0 dBi.	For type A master WSD, the slave WSD antenna gain is 0 dBi. For a type B master WSD, the slave WSD antenna gain is 0 dBi.
Slave WSD antenna height	For a type A master, the height of the slave WSD antenna was assumed to be 10 metres. For a type B master, the height of the slave WSD antenna was assumed to be 1.5 metres.	For a type A master, the height of the slave WSD antenna is assumed to be 1.5 metres. For a type B master, the height of the slave WSD antenna is assumed to be 1.5 metres.
Inclusion of WSD body gain	No	Yes. For this calculation the slave WSD is assumed to have a body gain of -6 dB.
Inclusion of building penetration gain	No	Yes. A building penetration gain of -7 dB is applied if the WSD is a type B and its antenna height is greater than 2 metres.

## Inclusion of an adjustable parameter (margin)

A1.43 The difference between reference sensitivity of the slave WSD and the EIRP spectral density is still taken to be representative of the "minimum coupling gain", except that a new adjustment of 10 dB (a margin) is applied. The margin is applied for the following reasons:

## Probability of coverage at cell edge

- i) In cell planning it is usual to establish the cell edge in terms of ensuring a high probability that a mobile station (or, in this case, slave) can "hear" the base station (or master). If we only use the median path gain to establish the distance between cell edge and master there will, to a first approximation, only be a 50% probability of the master being able to communicate with the slave. This is because signals are subject to "location variability" and the median path gain alone only gives the median value of the path gain and does not describe that variability.
- ii) To get a better estimation of the cell area we can define the cell edge as being that where there is a 95% probability of the slave being able to "hear" the master, and to achieve this target it would be usual to apply a margin of around 10 dB.<sup>3</sup> This has the effect of reducing the coverage area. Note also that as the slave

<sup>&</sup>lt;sup>3</sup> For example, the margin will be 10 dB if the planned location probability at cell edge is 95% and the assumed standard deviation associated with the location variability is assumed to be 6 dB, which is a reasonable figure. See the following for examples of assumed standard deviation: ITU-R P.1546-5 <u>http://www.itu.int/dms\_pubrec/itu-r/rec/p/R-REC-P.1546-5-201309-I!!PDF-E.pdf;</u> ECC Rep. 185 <u>http://www.erodocdb.dk/docs/doc98/official/Pdf/ECCRep185.pdf;</u>

SEAMCAT manual http://tractool.seamcat.org/wiki/Manual/PropagationModels/ExtendedHata

gets closer to the master the probability of it being able to "hear" the master is considerably improved.

iii) By application of a margin we are ensuring that we are taking into account on a probabilistic basis where the slave WSDs receiving communications from a serving master WSD are most likely to be located.

## SEAMCAT Extended Hata model and under-prediction of path loss

- iv) The propagation model used for calculation of the median coupling gain between master and slave is the SEAMCAT Extended Hata model. As indicated in the 2013 Consultation, the SEAMCAT Extended Hata model tends to over-estimate the path gain.
- v) The Hata model was originally intended for macro-cellular radio planning, and is valid for base antenna effective heights in the range from 30 to 200 metres coupled with a mobile antenna from 1 to 10 metres. Furthermore, the base antenna height should be clear of local clutter (ground cover, including rooftops). In this framework the antenna heights may fall outside of these ranges, and given that the interference path from WSD to PMSE is relatively low we would expect more additional diffraction loss than is predicted by the SEAMCAT Extended Hata model.
- vi) The Hata model does not account for specific obstacles along the path, and is based upon effective antenna heights above terrain. It is quite usual when planning network coverage that, if Hata is used, an additional term is added to the path loss equation to account for terrain obstacles. The additional term may be accounted for by a standard knife-edge diffraction model or by means of a "terrain correction factor".
- vii) Some recent work published by Ofcom<sup>4</sup> highlights a comparison for residential Wi-Fi networks between a validated ray-tracing model results generated by SIRADEL<sup>5</sup>, the P.1812 model<sup>6</sup> and suburban SEAMCAT Extended Hata for a study area of approximately 300 square km in London and its suburbs. The results suggested that Hata over-estimates interference by differences of up to 15 dB.
- viii) Inclusion of the margin goes some way to offsetting any over-prediction of path gain.

## Environment type

- A1.44 For the calculation of the serving master coverage area, the decision over which particular general environment to use is determined by the clutter code at the master. As in the 2013 Consultation, we apply mapping to establish the general environment. However, instead of mapping to 'urban', 'suburban' and 'open', we are now only using the 'urban' and 'suburban' models, having made a decision to not use the 'open' model.
- A1.45 The reason not to use the 'open' model is based on the following:

<sup>&</sup>lt;sup>4</sup> <u>http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/annexes/Annexes\_7-13.pdf</u> This is not in the same frequency range as the UHF TV band, but the work does nonetheless indicate the potential over-prediction of the gain by SEAMCAT Extended Hata when used in a particular scenario.

<sup>&</sup>lt;sup>5</sup> <u>http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/annexes/Prediction\_Study.pdf</u>

<sup>&</sup>lt;sup>6</sup> http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/annexes/Prediction\_Study.pdf

- As discussed above the SEAMCAT Extended Hata model tends to over-estimate the path gain.
- Additionally, the environment for SEAMCAT Extended Hata is determined by establishing the clutter type at one end of the link only. It is usual to use the clutter type at the lower end of the link to establish clutter type, though we consistently use the clutter type at the master WSD in calculation of the master coverage area. We do this for practical reasons: the coverage area is circular enabling us to characterise the coverage area with one parameter (its radius).
- We accept that in some cases the 'open' variant of the SEAMCAT Extended Hata model gives a reliable answer for the median path gain where the path is truly 'open', but we do not expect that that will be the case for the majority of paths.

## Slave WSD antenna gain

A1.46 An antenna gain of 0 dBi is now assumed for the slave WSD regardless of the type (A/B) of the master WSD.

## Slave WSD antenna height

A1.47 An antenna height of 1.5 metres in now assumed for the slave WSD regardless of the type (A/B) of the master WSD.

## Slave WSD body gain

A1.48 In downlink cell planning it is usual to consider whether the mobile station is likely to be affected by body gain (usually referred to as body loss). In relation to estimating coverage area of the serving master WSD, we have applied a WSD body gain of -6 dB<sup>7</sup>. Many WSDs in the vicinity of PMSE venues will be body worn, or at least shielded by bodies.

## **Building penetration gain**

- A1.49 Type A WSDs will be assumed to be outdoors. Type B WSDs will be assumed to be outdoors, unless they report a height that is greater than 2 metres (AGL) in which case they will be assumed to be indoors.
- A1.50 Accordingly we include a building penetration gain of -7 dB in relation to estimating the size of the coverage area for the case of master type B WSDs with a reported antenna height of greater than 2 metres.

<sup>&</sup>lt;sup>7</sup> CEPT Report 30 Report from CEPT to the European Commission in response to the Mandate on "The identification of common and minimal (least restrictive) technical conditions for 790 - 862 MHz for the digital dividend in the European Union", Final Report on 30 October 2009: http://www.erodocdb.dk/docs/doc98/official/pdf/CEPTRep030.pdf.

## Annex 2

# Approach to determining WSD emission limits taking account of UK DTT

- A2.1 In this annex we present the detailed framework for calculating the maximum permitted in-block EIRP  $P_{WSD-DTT}(i_{WSD}, F_{WSD})$  of a WSD which operates at a given geographic location  $i_{WSD}$  and in a specific DTT channel  $F_{WSD}$ . This emission limit is specified to ensure a low probability of harmful interference to the reception of the DTT service via roof-top aerials. For ease of notation, we refer to the above limit as  $P_{REG}$  in this annex.
- A2.2 Of com will calculate the EIRP limits  $P_{\text{WSD-DTT}}(i_{\text{WSD}}, F_{\text{WSD}})$  at all locations in the UK and all DTT channels 21 to 60, accounting for the five WSD spectrum emission classes, two protection ratio categories ("low" and "high"), and a number of representative WSD antenna heights, all for type A WSDs.
- A2.3 Ofcom will then communicate the calculated EIRP limits for type A WSDs to the WSDB providers. WSDBs can then infer the EIRP limits for type B by adding an appropriate building penetration gain (depending on the WSD height) and body gain (currently assumed to be 0 dB).
- A2.4 We first describe, at a high level, the calculations involved in deriving the WSD EIRP limits. We then describe the details of the calculations of various parameters, including coupling gains, protection ratios, and maximum permitted nuisance powers. We finally explain how various parameter values have changed in comparison with those we proposed in our 2013 Consultation. These changes have been informed by our own recent coexistence tests and stakeholder responses to our 2013 Consultation.
- A2.5 Unless otherwise stated, all equations presented in this Annex are in the linear domain (e.g., with powers in units of mW). Where an equation is expressed in the logarithmic domain, variable names are accompanied with the subscript "dB" or "dBm".

## **Calculation of WSD emission limits**

## High level structure of the calculations

A2.6 The objective is to calculate the regulatory limits for WSD radiation in each of channels 21 to 60, at every 100 metre by 100 metre pixel in the UK. Figure A2.1 illustrates the regulatory EIRP limits at a given location.

## Figure A2.1: An illustration of WSD regulatory EIRP limits at a given location



- A2.7 The following notation is used in this section:
  - *i*<sub>WSD</sub> WSD transmitter location/pixel index.
  - $F_{\text{WSD}}$  WSD channel index, 21 to 60.
  - *i*<sub>DTT</sub> DTT receiver location/pixel index.
  - $F_{\text{DTT}}$  DTT channel index, 21 to 60.
  - $l_{\text{DTT}}$  DTT transmitter index.
- A2.8 We use the terms *location* and *pixel* interchangeably. The spatial resolution of the calculations will be 100 metres. We also use the term *protected* (e.g., a protected channel) simply as short hand for identifying items that need to be included in coexistence calculations.
- A2.9 Table A2.1 describes how we will calculate the maximum permitted WSD EIRPs at a given location  $i_{\text{WSD}}$  and in a given channel  $F_{\text{WSD}}$  in relation to various DTT receiver locations  $i_{\text{DTT}}$ , DTT channels  $F_{\text{DTT}}$ , and DTT transmitters  $l_{\text{DTT}}$ .

## Table A2.1 - High level structure of calculations

For each WSD location $i_{WSD}$ in the UK					
For each WSD channel $F_{WSD} = 2160$					
For each protected location $i_{DTT}$ (relevant to $i_{WSD}$ )					
For each protected DTT transmitter $l_{\text{DTT}}$ (relevant to $i_{\text{WSD}}$ )					
For each protected DTT channel $F_{\text{DTT}}$ (relevant to $l_{\text{DTT}}$ )					
Calculate WSD EIRP: $P_{WSD}(F_{WSD}, F_{DTT}, i_{WSD}, i_{DTT}, l_{DTT})$ in units of (dBm/8MHz) See following sections for details.					
End					

- A2.10 We use the term *protected* to highlight the fact that it is not necessary to examine every element in a parameter set. Specifically:
  - If a DTT pixel is unpopulated, then it is by definition not protected, and we do not include it in our calculations.
  - If a DTT pixel is served by certain protected TV transmitters via a number of protected DTT channels, then we do not include other DTT transmitters and channels in our calculations for that DTT pixel.

- A2.11 At each DTT receiver pixel  $i_{DTT}$  in the UK, Ofcom will specify a list of all serving DTT transmitters  $\{l_{DTT}\}$  and protected DTT channels  $\{F_{DTT}\}$ . Note that while a DTT transmitter may provide service in a given DTT receiver location, it is possible that not all the channels in which it transmits are protected. This might be because for some channels the estimate of location probability (see later for definition) falls below a 70% threshold<sup>8</sup>.
- A2.12 Example: The Hemel Hempstead DTT transmitter broadcasts on channels 41, 44, 47, 50, 55, and 59. Ofcom may specify that in a particular DTT receiver pixel the Hemel Hempstead is the serving DTT transmitter, but only channels 41, 44, 47, 50, and 55 are protected because their respective location probabilities exceed 70% and that for channel 59 does not.
- A2.13 Furthermore, for a given WSD location  $i_{WSD}$  in the UK, it is not necessary to examine all DTT receiver pixels in the UK, since a DTT pixel that is a large distance away would not affect the WSD regulatory limits, and as such is not relevant. For each WSD location  $i_{WSD}$  in the UK, a list of relevant DTT pixel locations { $i_{DTT}$ } can be calculated. Such DTT pixels will be defined as those that are a distance  $R_{REL}$  or less from the WSD location  $i_{WSD}$ , where distance is measured between the pixel centres. The value of  $R_{REL}$  will be 20 km for co-channel, and 2 km for adjacent channel calculations. Example: If  $R_{REL} = 20$  km, then { $i_{DTT}$ } will have 125,664 elements.
- A2.14 The WSD regulatory emission limit  $P_{\text{REG}}$  at location  $i_{\text{WSD}}$  and in channel  $F_{\text{WSD}}$  will be derived as:

$$P_{\text{REG}}(i_{\text{WSD}}, F_{\text{WSD}}) = \min_{i_{\text{DTT}}, l_{\text{DTT}}, F_{\text{DTT}}} \left\{ P_{\text{WSD}}(i_{\text{WSD}}, F_{\text{WSD}}, i_{\text{DTT}}, l_{\text{DTT}}, F_{\text{DTT}}) \right\}$$
(A2.1)

where minimisation is performed over all *protected* DTT receiver pixels, DTT transmitters, and DTT channels.

- A2.15 For the special case of DTT receiver pixels which are the same as or immediately adjacent to a WSD pixel (so-called tier 0/1 pixels), the minimisation over  $i_{DTT}$  is replaced by a combination of averaging and minimisation processes. This will be further described in later sections.
- A2.16 In the following subsections, we will present the approach for deriving the various parameters required for the calculation of  $P_{\text{WSD}}(F_{\text{WSD}}, F_{\text{DTT}}, i_{\text{WSD}}, i_{\text{DTT}}, l_{\text{DTT}})$ .

<sup>&</sup>lt;sup>8</sup> In the planning of the UK network, a pixel is considered served by DTT if the location probability for that pixel exceeds 70%. In calculating this location probability, the wanted received DTT signal power is predicted via 50%-time propagation models, while the unwanted received DTT signal powers are predicted via 1%-time propagation models.

## Parameters required for calculating P<sub>WSD</sub>

A2.17 The WSD EIRP  $P_{\text{WSD}}(F_{\text{WSD}}, F_{\text{DTT}}, i_{\text{WSD}}, i_{\text{DTT}}, l_{\text{DTT}})$  will be calculated as a function of the coupling gain *G*, protection ratio *r*, and maximum permitted *nuisance* power *Z*. Specifically (in the linear domain),

$$P_{\rm WSD} = \frac{Z}{r \, G} \tag{A2.2}$$

A2.18 The parameters *G*, *r* and *Z* are defined next. Their detailed calculation is described in later sections.

## Coupling gain G(F<sub>DTT</sub>, i<sub>WSD</sub>, i<sub>DTT</sub>, l<sub>DTT</sub>)

- A2.19 Coupling gain is the sum (in dB) of propagation gain (path loss) and DTT receiver antenna installation gain. Coupling gain will be calculated a function of
  - a) the DTT channel  $F_{\text{DTT}}$  (path loss is frequency dependent),
  - b) the WSD and DTT receiver antenna locations  $i_{WSD}$  and  $i_{DTT}$  (path loss is a function of the geographic separation between the WSD transmitter and DTT receiver), and
  - c) the protected DTT transmitter (identifies the pointing angle of the household's DTT receiver antenna, and hence the appropriate antenna angular discrimination).

#### <u>Protection ratio $r(F_{WSD}, F_{DTT}, i_{DTT}, l_{DTT})$ </u>

- A2.20 Protection ratio specifies the ratio of received wanted over unwanted power at the point of receiver failure. Protection ratio is defined by the adjacent channel leakage ratio (ACLR) of the interferer and the adjacent channel selectivity (ACS) of the receiver.
- A2.21 Protection ratio is a function of
  - a) the separation between the WSD channel and DTT channel,  $\Delta F = F_{WSD} F_{DTT}$ , since both ACLR and ACS are also functions of  $\Delta F$ , and
  - b) the location of the DTT receiver and the serving TV transmitter, since ACS reduces (protection ratio increases) with increasing levels of DTT signal power as the receiver overloads.

## Maximum permitted nuisance power Z(*i*<sub>DTT</sub>, *F*<sub>DTT</sub>, *l*<sub>DTT</sub>)

- A2.22 The maximum permitted nuisance power relates to the maximum amount of unwanted power a DTT receiver can tolerate. In the linear domain,  $Z = r G P_{WSD}$ .
- A2.23 The maximum permitted nuisance power is a function of
  - a) the DTT receiver location  $i_{\text{DTT}}$ ,
  - b) the DTT channel  $F_{\text{DTT}}$ , and
  - c) the DTT transmitter  $l_{\text{DTT}}$ ,

and its value depends on the quality of DTT coverage, as described by the UK Planning Model (UKPM).

A2.24 The maximum permitted nuisance power will be calculated for every populated pixel in the UK, as described in Table A2.2. A pixel will be considered populated if it contains residential homes and/or postal addresses for commercial properties at which DTT reception might be occurring. These calculations are independent of the calculations described previously.

#### Table A2.2 - Calculation of maximum permitted nuisance power

For each "protected" DTT location <i>i</i> <sub>DTT</sub>
For each "protected" DTT transmitter $l_{\text{DTT}}$
For each "protected" DTT channel $F_{\text{DTT}}$
Calculate: $Z(i_{DTT}, F_{DTT}, l_{DTT})$ See later for details.
End
End
End

A2.25 We next describe the detailed calculations of coupling gains, protection ratios, and maximum permitted nuisance powers.

## Calculating the coupling gain G

## Definition of coupling gain

A2.26 Coupling gain is the ratio of the WSD signal power at the input to the DTT receiver over the power radiated by the WSD. In other words, if  $P_{\text{WSD}}$  is the EIRP of the WSD, and *G* is the coupling gain, then the power at the input to the DTT receiver is  $GP_{\text{WSD}}$  (in the linear domain). This is illustrated in Figure A2.2 below.

# Figure A2.2 - Illustration of coupling gain as the combined effect of propagation, antenna installation gain and angular discrimination



 $G(i_{\text{WSD}}, i_{\text{DTT}}, F_{\text{DTT}}, h_{\text{WSD}}, h_{\text{DTT}}, i_{\text{WSD}}, i_{\text{DTT}}, l_{\text{DTT}})_{(dB)}$   $= G_{\text{Prop}}(i_{\text{WSD}}, i_{\text{DTT}}, F_{\text{DTT}}, h_{\text{WSD}}, h_{\text{DTT}})_{(dB)}$   $+ g(i_{\text{WSD}}, i_{\text{DTT}}, l_{\text{DTT}})_{(dB)}$   $+ G_{\text{Ins}(dB)}$   $+ G_{\text{BP}(dB)}$   $+ G_{\text{B}(dB)}$  (A2.3)

#### where

C	is the coupling gain
G	is the coupling gain,
$G_{\mathrm{Prop}}$	is the propagation gain,
g .	is the DTT receiver antenna angular discrimination.
$G_{\mathrm{Ins}}$	is the installation gain,
$G_{ m BP}$	is the building penetration gain, and
$G_{\rm B}$	is the body gain.

## Propagation gain

- A2.28 We will use extended Hata (as specified by SEAMCAT) to model propagation gain  $G_{\text{Prop}}$  as a function of the locations of the WSD transmitter and DTT receiver antennas. We will also use the centre frequency,  $f_{\text{DTT}}$ , of the DTT channel  $F_{\text{DTT}}$ , as input to extended Hata.
- A2.29 We do not account for terrain; i.e., WSD and DTT antenna heights  $h_{\text{WSD}}$  and  $h_{\text{DTT}}$  will be specified as heights above ground (rather than sea) level as inputs to extended Hata. The height  $h_{\text{DTT}}$  will be a constant set to 10 metres (in accordance with the assumption in DTT planning). The WSD height  $h_{\text{WSD}}$  is a variable (see later for details).
- A2.30 We will use the open, suburban, and urban modes of extended Hata depending on the clutter type at the DTT location  $i_{DTT}$ . The clutter type at each pixel in the UK will be defined according to the Infoterra clutter database.

## Antenna gain

- A2.31 We will consider antenna gain as the combination of two separate elements. The first element is the antenna installation gain  $G_{\text{Ins}}$ , which represents the net gain of the DTT receiver antenna gain including cable loss. The second element is the antenna angular discrimination g, which identifies the angle-dependent gain of a directional antenna.
- A2.32 We will assume a default DTT receiver antenna installation gain of  $G_{\text{Ins}} = 9.15 \text{ dB}^9$ . This represents an antenna gain of 12 dBd, and cable loss of 5 dB.
- A2.33 We will consider angular discrimination  $g(\phi)$  in both the horizontal and vertical directions; i.e., the *cone angle*  $\phi$  is the difference in angle between the line joining

<sup>&</sup>lt;sup>9</sup> Our TVWS-DTT coexistence tests confirmed other studies that have shown that household installation gains are typically lower when close to the transmitter and higher when at the edge of coverage. We will take forward with stakeholders, including the Technical Working Group, how and whether to incorporate a model for varying household installation gains into the WSD availability calculations.

the WSD antenna to the DTT receiver antenna, and the pointing direction of the DTT receiver antenna.

A2.34 We will model  $g(\phi)$  based on the ITU-R BT.419-3 pattern. This pattern is illustrated in Figure A2.3. The angle  $\phi$  accounts for the locations and heights of the WSD transmitter and DTT receiver antennas, and the horizontal orientation of the DTT receiver antenna.



#### Figure A2.3 - ITU-R BT.419-3 pattern for antenna angular discrimination

A2.35 We do not account for any polarisation discrimination at the DTT receiver antenna (i.e. consider coupling as co-polar).

#### **Building penetration**

- A2.36 For type A (fixed outdoor) WSDs, we will use a building penetration gain of  $G_{\rm BP} = 0$  dB in calculating the coupling gains.
- A2.37 For type B (portable/mobile) WSDs, if the WSD height is greater than 2 metres  $(h_{\text{WSD}} > 2)$ , then we will use a building penetration gain of  $G_{\text{BP}} = -7$  dB in calculating the coupling gains. Otherwise, we will use  $G_{\text{BP}} = 0$  dB.

#### Body gain

- A2.38 For type A (fixed outdoor) WSDs, we will use a body gain of  $G_{\rm B} = 0$  dB in calculating the coupling gains.
- A2.39 For type B (portable/mobile) WSDs, we will also use a body gain of  $G_{\rm B} = 0$  dB in calculating the coupling gains.

## Tier 3 pixels and beyond

A2.40 Here, the DTT pixel of interest is among the  $m^{\text{th}}$  tier ( $m \ge 3$ ) of pixels that surround the pixel within which the WSD is located. This is illustrated in Figure A2.4. In such

cases, it is reasonable to use the separation between pixel centres as a proxy for the separation between the WSD and the DTT receiver.



#### Figure A2.4 - Geometry for tier 3 pixels DTT pixels and beyond

- A2.41 We will derive the coupling gain for the WSD-DTT pixel pair  $(i_{\text{WSD}}, i_{\text{DTT}})$  by calculating the propagation gain according to the geographic separation between the centres of the two pixels. The propagation gain will be calculated based on the extended Hata model at the DTT channel  $F_{\text{DTT}}$ , and accounts for the clutter type at the DTT pixel, a specified WSD antenna height  $h_{\text{WSD}}$  (above ground), and a DTT receiver antenna height  $h_{\text{DTT}}$  of 10 metres (above ground).
- A2.42 To derive the coupling gain, we will complement the propagation gain with the addition of a DTT receiver installation gain of  $G_{\text{Ins}} = 9.15$  dB, and an angular discrimination gain  $g(\phi)$ . The angle  $\phi$  is a function of the locations of the WSD and DTT pixel centres, the height  $h_{\text{WSD}}$  of the WSD, and horizontal orientation and height ( $h_{\text{DTT}} = 10$  metres) of the DTT receiver antenna.
- A2.43 If the WSD antenna height  $h_{WSD}$  is reported, then it will be rounded to the nearest of heights 1.5, 5, 10, 15, 20, and 30 metres.
- A2.44 If the antenna height  $h_{WSD}$  of a type A WSD is not reported (is unknown), it will be set to a default value of 30 metres.
- A2.45 If the antenna height  $h_{WSD}$  of a type B WSD is not reported (is unknown), it will be set to a default value of 1.5 metres.

## **Tier 2 pixels**

A2.46 Here, the DTT pixel of interest is among the  $2^{nd}$  tier (m = 2) of pixels that surround the pixel within which the WSD is located. This is shown in Figure A2.5. As can be seen, sixteen distinct coupling gains  $G_n$  n = 1...16 apply in such cases.

# Figure A2.5: Geometry for tier 2 DTT pixels, with three types of WSD/DTT pixel geometries. The coupling gains (excluding antenna angular discrimination) to pixel types a, b, and c are specified as $G_a$ , $G_b$ and $G_c$ , respectively



- A2.47 To generate the 16 values of coupling gain we will calculate three unique *reference* coupling gains  $G_a$ ,  $G_b$ ,  $G_c$ . These three values include the propagation gain between the relevant WSD and DTT pixels, and an antenna installation gain of 9.15 dB. The propagation gain is a function of the separation between the WSD transmitter and DTT receiver, the DTT channel centre frequency, the DTT pixel clutter type, the WSD antenna height, and the DTT receiver antenna height (10 metres).
- A2.48 We then complement  $G_a$ ,  $G_b$ ,  $G_c$  by adding one of 16 angular discrimination gains  $g(\phi_i)$  to account for the horizontal orientation of the DTT receiver antennas in each of the 16 tier 2 DTT pixels.
- A2.49 Specifically, with respect to Figure A2.5 we have:

$G_{1 (dB)} = G_{a (dB)} + g(\theta_1)_{(dB)}$	$G_{9 (dB)} = G_{c (dB)} + g(\theta_9)_{(dB)}$
$G_{2 (\mathrm{dB})} = G_{b (\mathrm{dB})} + g(\theta_2)_{(\mathrm{dB})}$	$G_{10 (dB)} = G_{a (dB)} + g(\theta_{10})_{(dB)}$
$G_{3 (dB)} = G_{c (dB)} + g(\theta_3)_{(dB)}$	$G_{11 (dB)} = G_{b (dB)} + g(\theta_{11})_{(dB)}$
$G_{4 (\mathrm{dB})} = G_{a (\mathrm{dB})} + g(\theta_4)_{(\mathrm{dB})}$	$G_{12 (dB)} = G_{c (dB)} + g(\theta_{12})_{(dB)}$
$G_{5 (\mathrm{dB})} = G_{b (\mathrm{dB})} + g(\theta_5)_{(\mathrm{dB})}$	$G_{13 (dB)} = G_{a (dB)} + g(\theta_{13})_{(dB)}$
$G_{6 (dB)} = G_{c (dB)} + g(\theta_6)_{(dB)}$	$G_{14 (dB)} = G_{b (dB)} + g(\theta_{14})_{(dB)}$
$G_{7 (dB)} = G_{a (dB)} + g(\theta_7)_{(dB)}$	$G_{15 (dB)} = G_{c (dB)} + g(\theta_{15})_{(dB)}$
$G_{8 (\mathrm{dB})} = G_{b (\mathrm{dB})} + g(\theta_8)_{(\mathrm{dB})}$	$G_{16 (dB)} = G_{a (dB)} + g(\theta_{16})_{(dB)}$

A2.50 The values of the reference coupling gains  $G_a$ ,  $G_b$  and  $G_c$  are pre-defined by Ofcom and are presented in Table A2.3 below. These are the 90<sup>th</sup> percentile values derived based on a uniform random distribution of WSD transmitter and DTT receiver locations in the relevant pixels. We use a statistical approach here because the separation between pixel centres is not a very good proxy for the separation between the WSD transmitter and DTT receiver at these closer separation distances. Table A2.3 - Reference coupling gain components for tier 2 DTT receiver pixels. These are based on the 90<sup>th</sup> percentile of propagation gains with uniform random distributions of WSD transmitter and DTT receiver locations. The coupling gains include a 9.15 dB installation gain

	Tier 2: Coupling gain (open, subur					rban, urban)			
	Type "a" pixel			Тур	be "b" p	ixel	Тур	be "c" p	ixel
WSD antenna height	$G_a$ (dB)		$G_b \left( \mathrm{dB}  ight)$		$G_c$ (dB)				
1.5 metres	-65	-82	-91	-67	-85	-93	-71	-89	-97
5 metres	-60	-74	-83	-62	-77	-85	-64	-81	-90
10 metres	-60	-63	-72	-62	-65	-74	-64	-70	-78
15 metres	-60	-60	-68	-62	-62	-70	-64	-66	-75
20 metres	-60	-60	-66	-62	-62	-68	-64	-64	-72
30 metres	-60	-60	-62	-62	-62	-64	-64	-64	-69

- A2.51 The coupling gain values in the above table are quoted at 474 MHz. The corresponding values at a frequency of *f* MHz (centre frequency of DTT channel) can be derived by adding  $20 \log_{10}(474/f)$ .
- A2.52 If the WSD antenna height  $h_{WSD}$  is reported, then it will be rounded to the nearest of heights 1.5, 5, 10, 15, 20, and 30 metres.
- A2.53 If the antenna height  $h_{WSD}$  of a type A WSD is not reported (is unknown), it will be set to a default value of 30 metres.
- A2.54 If the antenna height  $h_{WSD}$  of a type B WSD is not reported (is unknown), it will be set to a default value of 1.5 metres.

## Tier 0/1 pixels

A2.55 Here, the DTT pixel of interest is the same as (tier 0) – or immediately adjacent to (tier 1) – the pixel within which the WSD is located. This is shown in Figure A2.6. Given the uncertainty in the locations of the DTT receiver antennas within a pixel, and the fact that the horizontal coordinates of the WSD itself are only accounted for with a 100 m resolution, we will identify the DTT-WSD coupling gains for the tier 0 DTT receiver pixel and the 8 tier 1 DTT receiver pixels with a single predefined reference coupling gain,  $G_0$ .



## Figure A2.6: Geometry for tier 0 and tier 1 DTT pixels

A2.56 The values of the reference coupling gains  $G_0$  are pre-defined by Ofcom and are presented in Table A2.4 below. These are the 90<sup>th</sup> percentile values derived based on a random distribution of DTT receiver locations around a WSD for a number of WSD antenna heights<sup>10</sup>. The  $G_0$  values include propagation gain, a DTT receiver installation gain of  $G_{Ins} = 9.15$  dB, and DTT receiver angular discrimination  $g(\phi)$ .

# Table A2.4 - Coupling gains for tier 0/1 pixels. These are based on the 90<sup>th</sup> percentile of propagation gains with a random distribution of DTT receiver locations around a WSD. The coupling gains include a 9.15 dB installation gain

WSD antenna height, $h_{ m WSD}$	Coupling gain, $G_0$ (dB) (open, suburban, urban)
1.5 metres	-49
5 metres	-45
10 metres	-43
15 metres	-45
20 metres	-50
30 metres	-56

- A2.57 The coupling gain values in the above table are quoted at 474 MHz. The corresponding values at a frequency of *f* MHz (centre frequency of DTT channel) can be derived by adding  $20 \log_{10}(474/f)$ .
- A2.58 If the WSD antenna height  $h_{WSD}$  is reported, then it will be rounded to the nearest of heights 1.5, 5, 10, 15, 20, and 30 metres.
- A2.59 If the antenna height  $h_{WSD}$  of a type A WSD is not reported (is unknown), it will be set to a default value of 10 metres.
- A2.60 If the antenna height  $h_{WSD}$  of a type B WSD is not reported (is unknown), it will be set to a default value of 1.5 metres.

<sup>&</sup>lt;sup>10</sup> We use statistics of inter-household separations in the UK to model the statistics of geographic separations between households and the WSD, with the separations lower bound of 10 metres. The households are also assumed to be randomly and uniformly distributed in angle surrounding a WSD. For details see the Technical Report which accompanied our 2013 Consultation.

## Calculating the protection ratio r

A2.61 The protection ratio,  $r(\Delta F, m_S)$ , is defined as the ratio of the received *wanted* DTT signal power  $P_S$  to the received *unwanted* WSD interferer power  $P_x = GP_{WSD}$  at the point of *failure* of the DTT receiver. This is illustrated in Figure A2.7 below.

#### Figure A2.7: Wanted and unwanted signals



- A2.62 For the special case of co-channel operation ( $\Delta F = 0$ ) the protection ratio is effectively the signal-to-interference ratio at the point of failure.
- A2.63 For  $\Delta F \neq 0$ , the protection ratio is a function of the adjacent channel leakage ratio (ACLR) of the WSD signal into adjacent DTT channels, as well as the *adjacent channel selectivity* (ACS) of the DTT receiver.
- A2.64 The ACLR of a WSD is characterised by the five *emission classes* which will be specified in the statutory instrument and which are consistent with those set out in the ETSI harmonised standard EN 301 598.
- A2.65 The ACS characterises the overall behaviour of the receiver in response to the adjacent channel interferer, and captures effects ranging from frequency discrimination (i.e., various stages of filtering) to receiver susceptibility to the interferer's signal structure (e.g., inability of the receiver's automatic gain control to respond to large fluctuations in the interferer's power).
- A2.66 The protection ratio broadly decreases with increasing frequency separation,  $\Delta F$ , between the WSD and DTT signals. This is with the exception of the so-called "N+9" effect characteristic of superheterodyne receivers where the protection ratio exhibits an increase for a frequency separation of 72 MHz between the wanted and unwanted signals.
- A2.67 We also model protection ratios as a function of the received median wanted DTT signal power  $m_s$ . This dependency implicitly characterises the non-linear behaviour (including hard overload) of the DTT receiver.
- A2.68 Tables A2.5 to A2.6 describe the "low" and "high" categories of protection ratio which we will use for the five WSD spectrum emission mask classes. These are the 70<sup>th</sup> percentile values derived from laboratory measurements of the ACS of 50 DTT receivers on the UK market. The "low" and "high" categories correspond to a WSD device driven by time-continuous and time-discontinuous (gated) traffic. See

Section 4 and Annex 2 of the DTT Technical Coexistence Test Report<sup>11</sup> for details of the test methodology and how the traffic profiles were generated.

A2.69 Section 7 in the main body of this report gives more detail on how the Technical Working Group will investigate further the potential need for the "high" category of protection ratio and when the "low" and "high" categories of protection ratio will be used.

$r(m_{\rm S}, \Delta F)$ (dB)	m <sub>s</sub> (dBm/8MHz)								
Channel separation	≤ <b>-7</b> 0	-60	-50	-40	-30	-20	-12		
$\Delta F = \pm 1$	-36	-37	-36	-32	-29	-23	-15		
$\Delta F = \pm 2$	-42	-41	-42	-36	-31	-23	-15		
$\Delta F = \pm 3$	-46	-45	-43	-37	-31	-23	-15		
$\Delta F = \pm 4$	-48	-46	-44	-38	-31	-23	-15		
$\Delta F = \pm 8$	-55	-52	-47	-40	-32	-23	-15		
$\Delta F = +9$	-44	-44	-44	-38	-33	-23	-15		
$\Delta F = -9$	-57	-54	-48	-40	-32	-23	-15		
$\Delta F/ \geq \pm 10$	-57	-54	-48	-40	-32	-23	-15		

## Table A2.5(a) - Proposed "low" protection ratios for class 1 WSDs

## Table A2.5(b) - Proposed "low" protection ratios for class 2 WSDs

$r(m_{\rm S}, \Delta F)$ (dB)			ms	, (dBm/8MH	łz)		
Channel separation	≤ <b>-7</b> 0	-60	-50	-40	-30	-20	-12
$\Delta F = \pm 1$	-36	-37	-36	-32	-29	-23	-15
$\Delta F = \pm 2$	-37	-37	-38	-34	-30	-23	-15
$\Delta F = \pm 3$	-38	-37	-37	-34	-30	-23	-15
$\Delta F = \pm 4$	-41	-40	-39	-35	-30	-23	-15
$\Delta F = \pm 8$	-54	-51	-46	-39	-32	-23	-15
$\Delta F = +9$	-44	-44	-44	-38	-33	-23	-15
$\Delta F = -9$	-57	-54	-48	-40	-32	-23	-15
$ \Delta F  \ge \pm 10$	-57	-54	-48	-40	-32	-23	-15

<sup>&</sup>lt;sup>11</sup> <u>http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2014/tvws-coexistence-tests/</u>

$r(m_{\rm S}, \Delta F)$ (dB)	m <sub>s</sub> (dBm/8MHz)							
Channel separation	≤ <b>-7</b> 0	-60	-50	-40	-30	-20	-12	
$\Delta F = \pm 1$	-28	-28	-28	-27	-26	-23	-15	
$\Delta F = \pm 2$	-37	-37	-38	-34	-30	-23	-15	
$\Delta F = \pm 3$	-46	-45	-43	-37	-31	-23	-15	
$\Delta F = \pm 4$	-48	-46	-44	-38	-31	-23	-15	
$\Delta F = \pm 8$	-55	-52	-47	-40	-32	-23	-15	
$\Delta F = +9$	-44	-44	-44	-38	-33	-23	-15	
$\Delta F = -9$	-57	-54	-48	-40	-32	-23	-15	
$ \Delta F  \ge \pm 10$	-57	-54	-48	-40	-32	-23	-15	

## Table A2.5(c) - Proposed "low" protection ratios for class 3 WSDs

## Table A2.5(d) - Proposed "low" protection ratios for class 4 WSDs

$r(m_{\rm S}, \Delta F)$ (dB)	m <sub>s</sub> (dBm/8MHz)							
Channel separation	≤ <b>-7</b> 0	-60	-50	-40	-30	-20	-12	
$\Delta F = \pm 1$	-18	-18	-18	-18	-18	-18	-15	
$\Delta F = \pm 2$	-28	-28	-28	-27	-26	-23	-15	
$\Delta F = \pm 3$	-38	-37	-37	-34	-30	-23	-15	
$\Delta F = \pm 4$	-41	-40	-39	-35	-30	-23	-15	
$\Delta F = \pm 8$	-54	-51	-46	-39	-32	-23	-15	
$\Delta F = +9$	-44	-44	-44	-38	-33	-23	-15	
$\Delta F = -9$	-57	-54	-48	-40	-32	-23	-15	
$ \Delta F  \ge \pm 10$	-57	-54	-48	-40	-32	-23	-15	

## Table A2.5(e) - Proposed "low" protection ratios for class 5 WSDs

$r(m_{\rm S}, \Delta F)$ (dB)	m <sub>s</sub> (dBm/8MHz)							
Channel separation	≤ <b>-</b> 70	-60	-50	-40	-30	-20	-12	
$\Delta F = \pm 1$	-7	-7	-7	-7	-7	-7	-7	
$\Delta F = \pm 2$	-17	-17	-17	-17	-17	-17	-15	
$\Delta F = \pm 3$	-28	-28	-28	-27	-26	-23	-15	
$\Delta F = \pm 4$	-33	-32	-31	-29	-27	-23	-15	
$\Delta F = \pm 8$	-52	-50	-45	-38	-31	-23	-15	
$\Delta F = +9$	-44	-44	-44	-38	-33	-23	-15	
$\Delta F = -9$	-57	-54	-48	-40	-32	-23	-15	
$ \Delta F  \ge \pm 10$	-57	-54	-48	-40	-32	-23	-15	

$r(m_{\rm S}, \Delta F)$ (dB)	m <sub>s</sub> (dBm/8MHz)							
Channel separation	≤ <b>-</b> 70	-60	-50	-40	-30	-20	-12	
$\Delta F = \pm 1$	-23	-22	-16	-15	-13	-12	-11	
$\Delta F = \pm 2$	-36	-33	-28	-26	-23	-20	-12	
$\Delta F = \pm 3$	-38	-37	-31	-27	-23	-19	-12	
$\Delta F = \pm 4$	-40	-38	-33	-29	-24	-20	-12	
$\Delta F = \pm 8$	-46	-44	-41	-35	-29	-20	-12	
$\Delta F = +9$	-43	-43	-43	-35	-27	-19	-12	
$\Delta F = -9$	-47	-45	-43	-36	-30	-20	-12	
$ \Delta F  \ge \pm 10$	-47	-45	-43	-36	-30	-20	-12	

## Table A2.6(a) - Proposed "high" protection ratios for class 1 WSDs

## Table A2.6(b) - Proposed "high" protection ratios for class 2 WSDs

$r(m_{\rm S}, \Delta F)$ (dB)	m <sub>s</sub> (dBm/8MHz)							
Channel separation	≤ <b>-</b> 70	-60	-50	-40	-30	-20	-12	
$\Delta F = \pm 1$	-23	-22	-16	-15	-13	-12	-11	
$\Delta F = \pm 2$	-34	-32	-28	-25	-23	-20	-12	
$\Delta F = \pm 3$	-35	-34	-31	-27	-23	-19	-12	
$\Delta F = \pm 4$	-37	-36	-33	-28	-24	-20	-12	
$\Delta F = \pm 8$	-45	-43	-41	-35	-29	-20	-12	
$\Delta F = +9$	-43	-43	-43	-35	-27	-19	-12	
$\Delta F = -9$	-47	-45	-43	-36	-30	-20	-12	
$ \Delta F  \ge \pm 10$	-47	-45	-43	-36	-30	-20	-12	

## Table A2.6(c) - Proposed "high" protection ratios for class 3 WSDs

$r(m_{\rm S}, \Delta F)$ (dB)	m <sub>s</sub> (dBm/8MHz)							
Channel separation	≤ <b>-7</b> 0	-60	-50	-40	-30	-20	-12	
$\Delta F = \pm 1$	-22	-21	-16	-15	-13	-12	-11	
$\Delta F = \pm 2$	-34	-32	-28	-25	-23	-20	-12	
$\Delta F = \pm 3$	-38	-37	-31	-27	-23	-19	-12	
$\Delta F = \pm 4$	-40	-38	-33	-29	-24	-20	-12	
$\Delta F = \pm 8$	-46	-44	-41	-35	-29	-20	-12	
$\Delta F = +9$	-43	-43	-43	-35	-27	-19	-12	
$\Delta F = -9$	-47	-45	-43	-36	-30	-20	-12	
$ \Delta F  \ge \pm 10$	-47	-45	-43	-36	-30	-20	-12	

$r(m_{\rm S}, \Delta F)$ (dB)	m <sub>s</sub> (dBm/8MHz)							
Channel separation	≤ <b>-</b> 70	-60	-50	-40	-30	-20	-12	
$\Delta F = \pm 1$	-17	-17	-14	-13	-12	-11	-10	
$\Delta F = \pm 2$	-27	-27	-25	-23	-22	-20	-12	
$\Delta F = \pm 3$	-35	-34	-31	-27	-23	-19	-12	
$\Delta F = \pm 4$	-37	-36	-33	-28	-24	-20	-12	
$\Delta F = \pm 8$	-45	-43	-41	-35	-29	-20	-12	
$\Delta F = +9$	-43	-43	-43	-35	-27	-19	-12	
$\Delta F = -9$	-47	-45	-43	-36	-30	-20	-12	
$ \Delta F  \ge \pm 10$	-47	-45	-43	-36	-30	-20	-12	

## Table A2.6(d) - Proposed "high" protection ratios for class 4 WSDs

## Table A2.6(e) - Proposed "high" protection ratios for class 5 WSDs

$r(m_{\rm S}, \Delta F)$ (dB)	m <sub>s</sub> (dBm/8MHz)							
Channel separation	≤ <b>-7</b> 0	-60	-50	-40	-30	-20	-12	
$\Delta F = \pm 1$	-7	-7	-7	-6	-6	-6	-6	
$\Delta F = \pm 2$	-17	-17	-17	-16	-16	-16	-12	
$\Delta F = \pm 3$	-28	-27	-26	-24	-22	-20	-12	
$\Delta F = \pm 4$	-31	-30	-29	-26	-23	-20	-12	
$\Delta F = \pm 8$	-44	-42	-40	-34	-29	-20	-12	
$\Delta F = +9$	-43	-43	-43	-35	-27	-19	-12	
$\Delta F = -9$	-47	-45	-43	-36	-30	-20	-12	
$ \Delta F  \ge \pm 10$	-47	-45	-43	-36	-30	-20	-12	

## Calculating the nuisance power Z

- A2.70 The variable *Z* is the maximum permitted *nuisance* power at the input of a DTT receiver. This relates to the maximum amount of unwanted WSD power a DTT receiver can tolerate. In the linear domain,  $Z = r G P_{WSD}$ , where  $P_{WSD}$  is the maximum permitted WSD EIRP, and *r* and *G* are the protection ratio and coupling gain.
- A2.71 To derive Z, we first need to understand how DTT coverage is quantified in the UK.

## How the DTT network coverage is quantified

A2.72 Consider a DTT service received in pixel  $i_{DTT}$  and channel  $F_{DTT}$ . The DTT coverage at this location and in this channel is quantified via the estimated location probability. This is an estimate of the probability with which the wanted DTT signal is sufficiently large compared to the sum of thermal noise and interference from unwanted DTT signals, such that the minimum required SINR is achieved. Specifically (in the linear domain),

$$q_{1} = \Pr\left\{P_{S} \ge P_{S,\min} + \sum_{k=1}^{K} r_{U,k} P_{U,k}\right\} = \Pr\{P_{S} \ge P_{S,\min} + V\} = \Pr\{P_{S} \ge U\}$$
(A2.4)

- A2.73 where  $Pr{A}$  is the probability of event *A*,  $P_S$  is the received power of the wanted DTT signal,  $P_{S,min}$  is the DTT receiver's (noise-limited) reference sensitivity level<sup>12</sup>,  $P_{U,k}$  is the received power of the  $k^{th}$  unwanted DTT signal, and  $r_{U,k}$  is the DTT-DTT protection ratio (co-channel or adjacent-channel) for the  $k^{th}$  DTT interferer.
- A2.74 Figure A2.8 illustrates the above scenario. Note that all powers are with reference to the input to the DTT receiver.

Figure A2.8 - Illustration of wanted and unwanted DTT signals in a rooftop installation



A2.75 The UK Planning Model (UKPM) models both  $P_{\rm S}$  and U as log-normal random variables, i.e.,  $P_{\rm S~(dBm)} \sim N(m_{\rm S}, \sigma_{\rm S}^{-2})$  and  $U_{\rm (dBm)} \sim N(m_U, \sigma_U^{-2})$ . Then, we can use these values to calculate

$$q_{1} = \Pr\left\{\frac{P_{\rm S}}{U} \ge 1\right\} = \Pr\left\{P_{\rm S\,(dBm)} - U_{\rm (dBm)} \ge 0\right\} = 1 - \frac{1}{2}\operatorname{erfc}\left\{\frac{1}{\sqrt{2}}\frac{m_{\rm S} - m_{U}}{\sqrt{\sigma_{\rm S}^{2} + \sigma_{U}^{2}}}\right\}.$$
 (A2.5)

- A2.76 We consider that a pixel is served in a DTT channel if the estimated location probability for that channel in that pixel exceeds 70% for 99% time. In other words, the location probability is 70% at the edge of DTT coverage (or in weak coverage areas). A pixel that is *not served* by a DTT channel is also *not protected* for that DTT channel.
- A2.77 The UKPM calculates location probability with the DTT wanted and unwanted powers modelled at the *50% time* and *1% time* levels, respectively. That is, the DTT unwanted interferer levels correspond to those which might be experienced during nominally 1% of the time over the period of a year as a result of atmospheric phenomena (anomalous conditions) which cause a significant increase in the received levels of interference. Under normal propagation conditions, the location probability is likely to be considerably greater than predicted by the UKPM.
- A2.78 Where a pixel is predicted to be unserved (location probability less than 70% for 99% time) for a particular multiplex, DTT is considered to provide an unreliable service and therefore that multiplex is unprotected. We will consider in the Technical Working Group any new evidence on whether this definition reflects actual consumer usage of DTT and whether the level of protection of actual DTT usage in marginal reception areas remains appropriate.

<sup>&</sup>lt;sup>12</sup>  $P_{\text{S,min (dBm)}} = -75.42$ . If  $F_{\text{DTT}} \ge 39$ , then  $P_{\text{S,min (dBm)}} \leftarrow P_{\text{S,min (dBm)}} + 1$ .

A2.79 As discussed in the main body of this document, the UKPM was not designed for purposes of analysing coexistence between DTT and other services. This is important context in understanding the role of "reduction in estimated location probability" in our approach. This is not, in itself, an accurate estimate of the number of locations which are likely to suffer harmful interference caused by WSDs (as the name would suggest). It is one parameter that needs to be calibrated in conjunction with several others in order to produce a model that overall results in a real-life low probability" as a shorthand for the model's estimate of location probability.

## What happens when a WSD radiates

A2.80 Again consider a DTT service received with location probability  $q_1$  in pixel  $i_{DTT}$  and channel  $F_{DTT}$ . Now also consider a WSD which is located in pixel  $i_{WSD}$  and operates in DTT channel  $F_{WSD} = F_{DTT} + \Delta F$ , where  $F_{DTT}$  is the index of the DTT channel where the DTT service is received with location probability  $q_1$ . Figure A2.9 illustrates this scenario.

#### Figure A2.9 - Illustration of a WSD signal arriving at the input of a DTT receiver



A2.81 Assume that the WSD radiates with an in-block EIRP of  $P_{WSD}$  over 8 MHz. The presence of the WSD interferer reduces the DTT location probability from  $q_1$  to  $q_2$ . Assuming a coupling gain *G* between the WSD and the DTT receiver, the WSD interferer power at the DTT receiver is given by the product  $GP_{WSD}$ . Following the framework of Equation (A2.4), we may write (again in the linear domain)

$$q_{2} = q_{1} - \Delta q$$

$$= \Pr\left\{P_{s} \ge U + r(\Delta F, m_{s}) G P_{WSD}\right\} = \Pr\left\{P_{s} \ge U + Z\right\}.$$
(A2.6)

- A2.82 For any specific interference scenario/geometry, G,  $r(\Delta F, m_S)$ ,  $P_{WSD}$  and hence Z, are all deterministic variables, whereas  $P_S$  and U are log-normal random variables.
- A2.83 Given a *target* reduction  $\Delta q_{\rm T} = q_1 q_{2\rm T}$  in location probability, using Equation (A2.6) we can calculate the maximum permitted nuisance power  $Z_{\rm T}$ , and then divide by  $\{Gr(\Delta F, m_{\rm S})\}$  to calculate the maximum permitted WSD EIRP.
- A2.84 We will set the target reduction in location probability to seven percentage points. In other words,  $\Delta q_{\rm T} = 0.07$ .

- A2.85 There are no closed-form solutions for calculating Z. Iterative numerical (Monte Carlo) and semi-analytical solutions are possible<sup>13</sup>.
- A2.86 The simplest solution is via a brute force iterative Monte Carlo approach. The algorithm involves selecting a value for Z and calculating the location probability by performing L Monte Carlo trials. Depending on the value of the location probability with respect to the target, Z is then increased or decreased and the process repeated until a sufficiently accurate solution is derived. Table A2.7 describes this more formally.

## Table A2.7 - Iterative Monte Carlo algorithm for calculating maximum nuisance power. All expressions are in the linear domain (powers are in mW)

Initialise:  $Y \leftarrow a \text{ value between } 10^{(-100/10)} \text{ and } 10^{(0/10)};$   $Q_2 \leftarrow \text{ large value;}$ Iterations: Step (1):  $Z \leftarrow Y;$ Step (2): Run *L* Monte Carlo trials; In each trial, generate a random value for  $P_S$  and U;Calculate new  $q_2$  as the proportion of trials in which  $P_S \ge U + Z;$ Step (3): If  $q_2$  is further from  $q_{2T}$  than  $Q_2$  is (i.e.,  $|q_2 - q_{2T}| \ge |Q_2 - q_{2T}|$ ), then STOP; Step (4): If  $q_2 > q_{2T}$ , then  $Y \leftarrow Ye;$ If  $q_2 <= q_{2T}$ , then  $Y \leftarrow Y/e;$ Step (5): Got to (1);



## Uncertainty in the location of WSDs

A2.88 The uncertainty in the location of a WSD shall be accounted for by the WSDBs as described below.

## Uncertainty in the location of master WSDs

- A2.89 If the horizontal location uncertainty reported by a master WSD is nominally zero, then the master WSD shall be associated with the pixel  $i_{DTT}$  within whose boundaries it is located. The maximum permitted WSD in-block EIRP for the said WSD is then  $P_{WSD}(i_{DTT}, F_{WSD})$ .
- A2.90 If the horizontal location uncertainty reported by a master WSD is non-zero, then the WSD shall be associated with multiple pixels. These pixels are those which overlap with the area within which the master WSD might be located; i.e., the master's *area of potential locations*.

<sup>&</sup>lt;sup>13</sup> For an iterative semi-analytical solution see: V.Petrini, H.R.Karimi, "TV white space databases: Algorithms for the calculation of maximum permitted radiated power levels," in *Proc. Dynamic Spectrum Access Networks* (DySPAN), Oct. 2012.

- A2.91 Specifically, for a master WSD with reported Eastings/Northings location ( $x_0$ ,  $y_0$ ) and location uncertainties ( $\pm \Delta x$ ,  $\pm \Delta y$ ), the area of potential locations shall be modelled as a rectangle centred on ( $x_0$ ,  $y_0$ ), and with sides of length  $2\Delta x$  and  $2\Delta y$  aligned with the North-South/East-West directions. If this area of potential locations overlaps (fully or partially) with *N* pixels, then the master WSD shall be associated with those same *N* pixels. This is illustrated in Figure A2.10, where ( $x_0$ ,  $y_0$ ) is in pixel  $i_{DTT}$ .
- A2.92 Let the *N* pixels be indexed as  $n = 1 \dots N$ . Then the maximum permitted WSD EIRP shall be calculated as

$$P_{\text{WSD}}(i_{\text{DTT}}, F_{\text{DTT}}) = \min_{n} P_{\text{WSD}}(n, F_{\text{DTT}}).$$
(A2.7)

## Figure A2.10 - Accounting for location uncertainty of a master WSD. The WSD emission limit shall be the lowest of the emission limits in each of the white pixels



□ Reported location of master (or geolocated slave)

## Uncertainty in the location of slave WSDs

- A2.93 If a slave WSD is geolocated, its location uncertainty shall be accounted for in the same way as it is for a master WSD (see above).
- A2.94 If a slave WSD is not geolocated, then the WSD shall be associated with pixels which overlap with the coverage area of its serving master WSD. The coverage area of the master WSD acts a proxy for the slave's *area of potential locations*.
- A2.95 For a serving master WSD with reported Eastings/Northings location  $(x_0, y_0)$  and location uncertainties  $(\pm \Delta x, \pm \Delta y)$ , the slave's area of potential locations shall be modelled as a circle centred on  $(x_0, y_0)$ , and with radius  $d_0 + \sqrt{(\Delta x^2 + \Delta y^2)}$ , where  $d_0$  is the coverage range of the master WSD. If this area of potential locations overlaps (fully or partially) with *N* pixels, then the slave WSD shall be associated with those same *N* pixels. This is illustrated in Figure A2.11, where  $(x_0, y_0)$  is in pixel  $i_{DTT}$ .
- A2.96 Let the *N* pixels be indexed as  $n = 1 \dots N$ . Then the maximum permitted WSD EIRP shall be calculated as

$$P_{\text{WSD}}(i_{\text{DTT}}, F_{\text{DTT}}) = \min_{n} P_{\text{WSD}}(n, F_{\text{DTT}}).$$
(A2.8)

## Figure A2.11 - Accounting for location uncertainty of a non-geolocated slave WSD. The WSD emission limit shall be the lowest of the emission limits in each of the white pixels



## Averaging for tier 0/1 pixels (important)

A2.97 Earlier we noted that we will calculate the WSD regulatory limit for radiation at a location  $i_{WSD}$  and in channel FWSD as follows:

$$P_{\text{REG}}(i_{\text{WSD}}, F_{\text{WSD}}) = \min_{i_{\text{DTT}}, l_{\text{DTT}}, F_{\text{DTT}}} \left\{ P_{\text{WSD}}(i_{\text{WSD}}, F_{\text{WSD}}, i_{\text{DTT}}, l_{\text{DTT}}, F_{\text{DTT}}) \right\}.$$
(A2.9)

- A2.98 That is to say, a minimisation is performed over each *protected* DTT receiver location/pixel  $i_{DTT}$ , each *protected* DTT transmitter  $l_{DTT}$  serving that pixel, and each *protected* DTT channel  $F_{DTT}$  serving that pixel.
- A2.99 In fact, the above minimisation over DTT receiver pixels  $i_{DTT}$  only applies to tier 2 pixels and beyond. We treat the case of tier 0 and tier 1 DTT receiver pixels somewhat differently. This is for the same reason that we calculate coupling gains differently for tier 0 and tier 1 DTT receiver pixels.
- A2.100 That is, given the uncertainty in the locations of the DTT receiver antennas within a pixel, and the fact that the horizontal coordinates of the WSD itself are only accounted for with a 100 metre resolution, it is not possible to identify a single victim DTT receiver pixel. Basing the WSD emission limits on the most susceptible victim pixel would then be over-cautious, while considering the tier 0 pixel as the only victim pixel might result in an increased risk of harmful interference. The approach is described in this sub-section.
- A2.101 Given a WSD pixel  $i_{WSD}$ , we calculate a single value for the maximum permitted WSD EIRP in channel  $F_{WSD}$  for protecting channel  $F_{DTT}$  in *all* the nine surrounding tier 0/1 pixels. We do this by taking the *average* value (in dBm) of the respective maximum permitted WSD EIRPs for protecting channel  $F_{DTT}$  in *each* of the surrounding nine tier 0/1 DTT receiver pixels. Specifically,

 $\overline{P}_{WSD,0/1}(i_{WSD}, F_{WSD}, l_{DTT}, F_{DTT})_{(dBm)}$ 

$$= \max_{i_{\text{DTT}} \in \text{tier0/1}} \left\{ P_{\text{WSD}}(i_{\text{WSD}}, F_{\text{WSD}}, i_{\text{DTT}}, l_{\text{DTT}}, F_{\text{DTT}})_{(\text{dBm})} \right\}.$$
(A2.10)

- A2.102 In the above equation, averaging is over DTT pixels  $i_{DTT}$ , and the result of averaging has both  $l_{DTT}$  (transmitter) and  $F_{DTT}$  (channel) as arguments. i.e., we get one average result per WSD pixel, per WSD channel, per DTT transmitter, and per DTT channel.
- A2.103 In our 2013 Consultation, we said that we would only take account of the planned transmitter in a given area. We also said that we would also seek to take account of overspill coverage from transmitters in the Republic of Ireland and would seek to take account of UK coverage from transmitters of the correct Nation. We also said we would consider revising the information presented to a WSDB in the light of evidence that the actual transmitter in use was different from that planned to serve the area. We also envisaged that more than one transmitter might be covered in overlap regions where more than one transmitter was actually in use.
- A2.104 Historically, analogue TV coverage was first planned to be delivered by 51 "main stations". Coverage gaps above a certain size were then filled by approximately another 1100 "relay" transmitters.
- A2.105 When the analogue transmitter network was completely converted to DTT operation at the time of digital switchover, the number of main stations (carrying the 3 Public Service Broadcasting - (PSB) - multiplexes and the 3 Commercial - (COM) multiplexes) became 80, and the remainder of the existing transmitter sites were upgraded as relays (carrying 3 PSB multiplexes).
- A2.106 We consider the planned transmitter for a given area to be the DTT main station providing the highest level of coverage (where it provides an acceptable level of coverage) for 6 DTT multiplexes. Where an acceptable level of coverage is not achieved from any main station, we consider the relay station providing the highest level of coverage (where it provides an acceptable level of coverage) for 3 PSB DTT multiplexes to be the planned transmitter.
- A2.107 In addition, we consider a transmitter of the correct Nation serving an area with a lower level of coverage than a transmitter of an incorrect Nation as the planned transmitter provided it still provides an acceptable level of either 6 Mux or 3 PSB coverage as appropriate. Where an additional 600 MHz multiplex or an interleaved multiplex (Local TV or the Northern Ireland Multiplex NI Mux) also provides service from the planned transmitter in a given area, that multiplex will be added to the list of multiplexes (and hence DTT channels) that needs to be included in our calculations. We consider overspill coverage from the Republic of Ireland as being delivered from a planned transmitter (though not situated within the UK).
- A2.108 In considering whether a transmitting station is the planned transmitter for a given area, when assessing the number of multiplexes available, we will consider coverage down to the threshold assumed in normal planning for a full service (i.e. down to 70% locations, 99% time). An individual multiplex from that transmitter will only be included in our calculations when its coverage exceeds the same planning limit for a full service (70% locations, 99% time).

- A2.109 Where a main station is the planned transmitter for a given area, all six of the main multiplexes will be available. We will assign a location to the main station providing a qualifying 3PSB service as well as reception of the three commercial multiplexes (for the threshold of 70% locations, 99% time). A qualifying 3PSB service is one where all three PSB multiplexes have availabilities equal to or better than 70% locations for 99% time. It should be noted that a qualifying 3PSB service may not be the best 3PSB service available at that location. In the event that more than one station is available, we will assign the location to the station with the highest availability from the weakest of the received multiplexes.
- A2.110 Where a main station is not the planned transmitter for a given area but a relay providing the correct 3PSB Nations service is the planned transmitter, the planned transmitter will be the one offering the best 3PSB service (for the threshold of 70% locations, 99% time) of the correct nationality for that location. For example a location in Wales must be served by a Welsh station not an English station and vice versa. In the event of stations having the same coverage, we will assign the location to the station offering the best average coverage and in the event that this is the same, we will allocate the location to the closest station.
- A2.111 Where neither a main station nor a relay providing the correct 3PSB Nation's service is the planned transmitter, the planned transmitter will be the one offering the best 3PSB service (for the threshold of 70% locations, 99% time) for that location. In the event of a 3PSB service being available from more than one station, we will assign the location to the station offering the highest availability for the weakest of the three PSB multiplexes. In the event of stations having the same coverage, we will assign the location to the station offering the best average coverage and in the event that this is the same, we will allocate the location to the closest station.
- A2.112 The sum of the coverages (for 70% locations, 99% time) of each main station will match the overall UK 6Core coverage figure (i.e. the UK-wide coverage figure derived by summing the population coverages of all pixels in the UK predicted to be covered by all 6 multiplexes). The sum of the coverages (for 70% locations, 99% time) for all planned transmitters (whether main stations, ones providing the correct 3PSB Nations service or those providing a 3PSB service only of an incorrect Nation) will match the figure for the overall UK coverage of the 3PSB multiplexes (just over 98.5%). Therefore including the above planned transmitter definitions in our calculations will reflect the overall UK coverage targets as declared by the Digital Frequency Planning Group (DFPG). These definitions are in line with the information supplied in the Digital UK postcode checker for areas marked as served.

A2.113 In summary, the approach that will be taken in determining which is the planned transmitter in a given area (using the above definitions) is:-

If at least one main station provides coverage above 70% locations, 99% time

Which main station provides the best coverage?

If not, and at least one station provides the correct 3PSB Nation's service with coverage above 70% locations, 99% time

Which station provides the best 3PSB Nation's coverage?



If not, and at least one station provides a 3PSB service with coverage above 70% locations, 99% time

Which station provides the best 3PSB coverage?

- A2.114 In addition, we consider a transmitter of the correct Nation serving an area with a lower level of coverage than a transmitter of an incorrect Nation as the planned transmitter provided it still provides an acceptable level of either 6 Mux or 3PSB coverage as appropriate. A multiplex from each planned transmitter will then only be protected when its coverage exceeds the normal planning limit for a full service (70% locations, 99% time).
- A2.115 Our above definition of the planned transmitter for a given area should give the best indication from the output of UKPM of the most likely transmitter in use in a given area. However, experience from the TVWS-DTT coexistence tests has shown that in some instances, the model will not identify the actual transmitter in use and therefore that transmitter would not receive full protection under the framework.
- A2.116 We give more detail in Section 7 of the main body of this document on how we plan to improve information on actual DTT transmitter usage throughout the UK and how we would seek to take that into account in DTT coexistence calculations for the TVWS database.
- A2.117 NOTE In special cases where two (or more) different DTT transmitters serve a pixel using the same channel  $F_{\text{DTT}}$  (characteristic of single frequency networks), we treat each transmitter independently in terms of averaging. For example, if the DTT receiver pixel is served by two transmitters  $l_{\text{DTT},1}$  and  $l_{\text{DTT},2}$ , then we must calculate two averages:

$$\overline{P}_{\text{WSD},0/1}(i_{\text{WSD}}, F_{\text{WSD}}, l_{\text{DTT},1}, F_{\text{DTT}})$$
(A2.11)

and

$$\overline{P}_{\text{WSD},0/1}(i_{\text{WSD}}, F_{\text{WSD}}, l_{\text{DTT},2}, F_{\text{DTT}}).$$
(A2.12)

A2.118 We incorporate the averaged tier 0/1 EIRP values into the overall minimization process as follows:

$$P_{\text{REG}}(i_{\text{WSD}}, F_{\text{WSD}}) = \min(A, B)$$
(A2.13)

where

$$A = \min_{i_{\text{DTT}} \notin \text{ tier } 0/1, \ l_{\text{DTT}}, F_{\text{DTT}}} \left\{ P_{\text{WSD}}(i_{\text{WSD}}, \ F_{\text{WSD}}, i_{\text{DTT}}, \ l_{\text{DTT}}, F_{\text{DTT}}) \right\}$$
(A2.14)
and

$$B = \overline{P}_{\text{WSD},0/1}(i_{\text{WSD}}, F_{\text{WSD}}, l_{\text{DTT}}, F_{\text{DTT}}).$$
(A2.15)

A2.119 Finally we will cap the maximum permissible WSD power for Type A and Type B devices at 36 dBm to limit potential DTT receiver overload.

#### **Changes following our 2013 Consultation**

- A2.120 Our framework for the calculation of WSD regulatory limits in relation to DTT remains unchanged in comparison with what we proposed in our 2013 Consultation. The maximum permitted WSD EIRP is calculated subject to a target maximum reduction in DTT location probability, based on specific values of coupling gain and protection ratio.
- A2.121 However, we have revised some of the assumed parameter values as a result of feedback from stakeholders and the results of our coexistence trials. We discuss these below.

#### **Coupling gains**

- A2.122 In relation to assumed coupling gains, we have revised the values for the tier 0, tier 1, and tier 2 pixel geometries.
- A2.123 In our 2013 Consultation, we performed a statistical analysis of coupling gains, and proposed values which correspond to the 70<sup>th</sup> percentile levels (values that are exceeded with a probability of 0.3). We had proposed the 70<sup>th</sup> percentile values on the basis that we had expected that the UKPM under-estimated the wanted DTT signal strength (i.e. was over-cautious in its prediction of DTT coverage) and that in practice this would result in an overall low probability of harmful interference.
- A2.124 However, the results of our recent coexistence trials have indicated that, at least in the areas tested, the UKPM can, in some cases, over-estimate the wanted DTT signal strength. For this reason, we do not believe that 70<sup>th</sup> percentile coupling gains are appropriate for a low probability of harmful interference. As a result, we have revised up the coupling gain values for tiers 0, 1, and 2, so that they now correspond to the 90<sup>th</sup> percentile level.
- A2.125 Furthermore, in our statistical analysis for our 2013 Consultation, we used household separations as a proxy of the separation between WSD transmitter and DTT receiver antennas in tier 0 and tier 1 geometries. We had also lower-bounded these separations to 5, 10 and 20 metres in urban, suburban, and rural environments, respectively. In their responses, Digital UK and the BBC pointed out that dwellings tend to be clustered in rural areas, and as a result, it is not realistic to assume large separations in rural areas. In our own coexistence trials, we placed WSDs at plausible worst case locations on the street outside some 133 different dwellings. We observed that the clutter type did not have a strong correlation with the separation between the WSDS and DTT antennas.
- A2.126 Given the above, and the fact that the clutter in across 80% of locations in the UK is categorised as suburban, we now propose to use the same tier 0/1 coupling gains in urban, suburban, and rural environments.

A2.127 The revised coupling gains are presented in Tables A2.3 and A2.4. Table A2.8 below shows the changes in the coupling gains for the tier 0/1 geometries. The tier 2 coupling gains have been revised up by 1 to 3 dB.

WSD antenna height, $h_{\rm WSD}$	Change in coupling gain compared to values proposed in the 2013 Consultation, $\Delta G_0$ (dB)			
	open	suburban	urban	
1.5 metres	11	6	4	
5 metres	14	9	6	
10 metres	16	10	4	
15 metres	14	9	6	
20 metres	10	6	4	
30 metres	4	1	-1	

#### Table A2.8 - Changes in coupling gains for tier 0/1 pixels

- A2.128 We have not altered our approach in relation to geometries which involve tier 3 and beyond. We believe that the extended Hata model under-estimates path loss at large separations, and as such, its use for the calculation of propagation gain for tier ≥ 3 geometries will result in a low probability of harmful interference without the need for any additional margins to account for modelling uncertainty.
- A2.129 The limited measurements that we undertook in our TVWS-DTT coexistence technical studies over long-distance paths indicated that path losses, even over unobstructed paths, are typically at least as high as given by the extended Hata model. Also, even over unobstructed paths in open clutter, we found that co-channel interference was only just occurring over path lengths of 2-3 km when operating at the power cap of 36 dBm.
- A2.130 Therefore we intend to continue to use the model with no additional margin built-in, i.e. we intend to continue to model the coupling gain using the extended Hata model but with 0dB standard deviation. Nevertheless we will keep the situation under review within the Technical Working Group if more information becomes available on typical path losses over longer distances when compared with the extended Hata model.
- A2.131 We will continue to use the Infoterra clutter data with the extended Hata model. It should be noted that the clutter data set used in UKPM is an earlier version of the Infoterra data and consideration will be given within the Technical Working Group on the merits of aligning the clutter data to a common set.
- A2.132 Also, as part of our on-going review of the TVWS framework within the Technical Working Group, we will continue to examine more enhanced approaches to modelling path loss which can, for example, account for the impact of terrain and clutter in a more sophisticated way. We will adopt such enhanced models in due course if the increase in operational complexity can be justified in terms of better modelling of the potential interference levels to DTT.
- A2.133 Finally, we will be using a body loss of 0 dB for type B (portable/mobile) WSDs. This is consistent with our approach in relation to PMSE, services above and below the band, and cross-border DTT.

#### **Protection ratios**

- A2.134 In our 2013 Consultation, we proposed class-specific protection ratios which corresponded to the 70<sup>th</sup> percentile levels of the results of laboratory measurements of an available prototype WSD against 50 DTT receivers. We acknowledged in the Consultation that the signals from the tested WSD were likely to be benign, and in our TVWS framework we proposed to use three categories of "high", "medium" and "low" protection ratios, which characterise the propensity of different WSD radio technologies to cause interference to DTT.
- A2.135 Following further laboratory tests, and discussions with stakeholders, we have found that the propensity of a WSD to cause interference to DTT has more to do with the coarse time structure (of the order of seconds) of its signal than with the fine time structure (radio packet duration). Specifically, when the radio signal is discontinuous in time over intervals of the order of seconds, this can result in significantly different protection ratios for some combinations of WSD technology with some makes/models of DTT receivers. Some DTT receivers are not vulnerable to this effect and some WSDs do not exhibit this behaviour.
- A2.136 For this reason, we have performed two sets of new laboratory measurements with a specific prototype WSD (see Section 2 of the TVWS-DTT technical coexistence test report<sup>14</sup> for further details). In the first set, we drove the WSD with a continuous stream of data traffic. In the second set, we drove the WSD with a discontinuous stream of data traffic which switched on and off every 2 seconds. The first and second sets of measurements result in our "low" and "high" categories of protection ratios, respectively.
- A2.137 We have derived from the measurements class-specific protection ratios, using the same approach as described in the 2013 Consultation. Tables A2.9 and A2.10 show how the "low" and "high" protection categories compare with the values we proposed in our 2013 Consultation for class 1 and 5 WSD emission classes.

$\Delta r$ (dB)	m <sub>s</sub> (dBm/8MHz)						
Channel separation	≤ <b>-7</b> 0	-60	-50	-40	-30	-20	-12
$\Delta F = \pm 1$	0	-1	-1	-2	-5	-9	-9
$\Delta F = \pm 2$	0	0	-3	-3	-5	-7	-7
$\Delta F = \pm 3$	-1	-5	-3	-3	-3	-5	-5
$\Delta F = \pm 4$	7	3	0	-1	-2	-4	-4
$\Delta F = \pm 8$	3	5	0	-1	-2	-3	-3
$\Delta F = +9$	3	-1	-5	-3	-5	-5	-5
$\Delta F = -9$	3	4	0	-1	-2	-3	-3
$ \Delta F  \ge \pm 10$	5	4	0	-1	-3	-4	-4

## Table 2.9(a) - Change in "low" protection ratios for class 1 WSDs compared to values proposed in the 2013 Consultation

<sup>&</sup>lt;sup>14</sup> <u>http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2014/tvws-coexistence-tests/</u>

$\Delta r$ (dB)	m <sub>s</sub> (dBm/8MHz)						
Channel separation	≤ <b>-7</b> 0	-60	-50	-40	-30	-20	-12
$\Delta F = \pm 1$	0	-1	-1	0	0	-1	-3
$\Delta F = \pm 2$	0	-1	-1	-1	-1	-4	-8
$\Delta F = \pm 3$	0	-1	-1	-1	-1	-6	-5
$\Delta F = \pm 4$	5	5	5	3	1	-4	-4
$\Delta F = \pm 8$	-4	-3	-1	-1	-1	-3	-3
$\Delta F = +9$	2	-1	-5	-3	-5	-5	-5
$\Delta F = -9$	-2	-1	-2	-2	-2	-3	-3
$\left \Delta F\right  \geq \pm 10$	4	4	0	-1	-3	-4	-4

## Table A2.9(b) - Change in "low" protection ratios for class 5 WSDs compared to values proposed in the 2013 Consultation

## Table A2.10(a) - Comparison of "high" protection ratios for class 1 WSDs with respect to the values proposed in the 2013 Consultation

$\Delta r$ (dB)	m <sub>s</sub> (dBm/8MHz)						
Channel separation	≤ <b>-7</b> 0	-60	-50	-40	-30	-20	-12
$\Delta F = \pm 1$	13	14	19	15	11	2	-5
$\Delta F = \pm 2$	6	8	11	7	3	-4	-4
$\Delta F = \pm 3$	7	3	9	7	5	-1	-2
$\Delta F = \pm 4$	15	11	11	8	5	-1	-1
$\Delta F = \pm 8$	12	13	6	4	1	0	0
$\Delta F = +9$	4	0	-4	0	1	-1	-2
$\Delta F = -9$	13	13	5	3	0	0	0
$ \Delta F  \ge \pm 10$	15	13	5	3	-1	-1	-1

## Table A2.10(b) - Comparison of "high" protection ratios for class 5 WSDs with respect to the values proposed in the 2013 Consultation

$\Delta r$ (dB)	m <sub>s</sub> (dBm/8MHz)						
Channel separation	≤ <b>-7</b> 0	-60	-50	-40	-30	-20	-12
$\Delta F = \pm 1$	0	-1	-1	1	1	0	-2
$\Delta F = \pm 2$	0	-1	-1	0	0	-3	-5
$\Delta F = \pm 3$	0	0	1	2	3	-3	-2
$\Delta F = \pm 4$	7	7	7	6	5	-1	-1
$\Delta F = \pm 8$	4	5	4	3	1	0	0
$\Delta F = +9$	3	0	-4	0	1	-1	-2
$\Delta F = -9$	8	8	3	2	0	0	0
$ \Delta F  \ge \pm 10$	14	13	5	3	-1	-1	-1

- A2.138 Table A2.9 indicates that the "low" category protection ratios are *broadly* similar to the values we had proposed in the 2013 Consultation, larger for some  $(m_S, \Delta F)$  combinations, and smaller for others.
- A2.139 Table A2.10 indicates that the "high" category protection ratios are considerably larger than the values we had proposed in the 2013 Consultation for certain ( $m_s$ ,  $\Delta F$ ) combinations. The difference reduces for large values of  $m_s$  and high WSD spectrum emission classes, where DTT receiver overload and WSD spectral leakage respectively mask the impact of discontinuous traffic.

#### Margin for UKPM prediction errors

- A2.140 Figure A2.12(a) below shows the results of our coexistence tests for four different main DTT transmitting stations (Crystal Palace, Hemel Hempstead, Black Hill and Dover) in three geographical areas (Watford, Glasgow and Thanet). The results are published in a report on the DTT coexistence tests.<sup>15</sup> The curves show the cumulative distribution functions of the margins of the measured WSD powers just prior to DTT picture degradation against the WSD power limits proposed in the Consultation.
- A2.141 The results of our coexistence tests indicate that, at least in the areas tested, an additional margin would be required to allow for the field strength prediction error in UKPM. On average across the UK, UKPM provides a good estimate of the median wanted field strength of DTT services. However there is a random prediction error and UKPM can, in some cases, over-estimate the median wanted DTT signal strength  $m_{\rm S}$ .
- A2.142 An over-estimation of X dB in  $m_{\rm S}$  would approximately translate to a X dB overestimation of the maximum permitted WSD EIRP. We say "approximately" because non-zero unwanted DTT signal powers will mean that the maximum permitted WSD EIRP will typically be mis-predicted by a dB or so more than X dB.
- A2.143 We could not verify whether the UKPM also over-estimates the unwanted DTT signal strengths in these cases. However, this is likely to be the case given that the same methodology is used to estimate both wanted and unwanted DTT signal levels.
- A2.144 In our 2013 Consultation, we proposed to treat co-channel and adjacent channel interference in the same way, and to allow WSDs to operate co-channel with DTT within the coverage area of a DTT transmitter, albeit subject to stringent WSD emission limits.
- A2.145 The results of our coexistence tests have indicated that co-channel WSD operation in the proximity of a DTT receiver may result in interference. Furthermore, in practice the regulatory limits for co-channel operation are very restrictive and could make the co-channel use of TV white spaces impractical for all but extremely shortrange use cases.
- A2.146 Our coexistence tests have also indicated that WSDs which operate co-channel with DTT within the coverage area of a DTT transmitter may themselves be exposed to significant levels of interference from DTT, which might make their operation unreliable in these circumstances. Nevertheless we do not propose to rule out such operation provided that adequate protection of DTT can be delivered.

<sup>&</sup>lt;sup>15</sup> <u>http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2014/tvws-coexistence-tests/</u>

- A2.147 Having allowed for the changes from the Consultation parameters set out above (change from a 70<sup>th</sup> to 90<sup>th</sup> percentile coupling gain for tier 0, 1 and 2 pixels, and the revised protection ratio tables), we determined that an additional 9dB of margin would be required for co-channel operation to result in a low probability of harmful interference. Thus we will reduce the WSD regulatory limits by 9 dB for co-channel operation to account for uncertainties inherent to the UKPM. In practice, the additional 9 dB of margin for co-channel operation can be implemented in the model by adjusting the co-channel protection ratio from 17 dB to 26 dB.
- A2.148 No additional margin is proposed for adjacent channel operation because the Class-based approach to modelling WSD adjacent channel protection ratios builds in additional margin beyond the co-channel case. This is because White Space Devices will typically achieve better adjacent channel protection ratios than assumed in the model (shown in table A2.9). This is because the model protection ratios are based on the assumption that the WSD could radiate at the full power in each channel permitted by the mask when in practice the integrated power in each channel will be lower than that permitted by the mask.
- A2.149 We recognise that the additional margin built-in by the Class-based approach to modelling WSD adjacent channel protection ratios will vary depending on the specific WSD in use. We also recognise that the additional margin built-in may vary from one class to another.
- A2.150 We have insufficient information from our recent measurements of the performances of different WSD technologies to suggest that we should include additional margins for adjacent channel operation to allow for uncertainties in the UKPM at this stage. However we will take further measurements of the out-of-band performances of WSDs as they become available over the coming year and will keep this situation under review within the Technical Working Group. If we were to obtain evidence that further margins needed to be built-in for adjacent channel operation to ensure a low probability of harmful interference to DTT, we would then revise the adjacent channel protection ratio tables to reflect this need.
- A2.151 We will also keep under review within the Technical Working Group whether the Class-based approach to modelling adjacent channel protection ratios remains the most appropriate and effective method both for ensuring a low probability of harmful interference and for maximising the power limits for WSDs. If a more effective or appropriate method became apparent, we would consider how best to implement this.

## Figure A2.12(a) - CDFs of margins against<br/>the Consultation WSD power limitsFigure A2.12(b) - CDFs of margins against<br/>the planned WSD power limits



















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- A2.152 Figure A2.12(b) above shows the combined effects of the changes from the Consultation parameters (change from a 70<sup>th</sup> to 90<sup>th</sup> percentile coupling gain for tier 0, 1 and 2 pixels, the revised protection ratio tables and the 9dB additional margin for co-channel operation) on the recalculated margins against the revised WSD power limits.
- A2.153 Having allowed for these changes from the Consultation parameters, the margins for the measurements from the Crystal Palace, Hemel Hempstead and Black Hill transmitters are predominantly all positive. The four points for the Hemel Hempstead transmitter with a negative margin were all for a single household with a particularly poorly performing DTT receiver.
- A2.154 The margins for the measurements from the Dover transmitter are predominantly all greater than -10dB. The two points with worse negative margins than -10dB were for particularly poorly performing DTT receivers.
- A2.155 The measurements in the Thanet area for the Dover DTT transmitter showed that UKPM particularly over-predicted the wanted field strengths in this area. The mean field strength prediction error was 6dB and also the distribution of the prediction error was not perfectly log-normal. This asymmetry resulted in more measurement points with greater over-predictions than would be expected from a log-normal distribution with a 6dB prediction error and the standard deviation of the errors.
- A2.156 The combined effects of this specific anomaly with the UKPM predictions in the Thanet area results in a requirement for an additional margin of around 10 dB in this area to ensure a low probability of harmful interference.
- A2.157 To ensure a low probability of harmful interference and to make specific allowance for the anomalous behaviour of the UKPM field strength prediction model in the Thanet area, we will apply a 10 dB additional margin to all of the TVWS power limits in the Thanet area, prior to applying the 36 dBm / (8 MHz) cap. Thus for every TVWS power limit calculated by the model, for each pixel and every channel in the Thanet area, we will manually reduce each power limit by 10 dB before provision to the WSDBs.
- A2.158 Note that applying a reduction to every channel in the Thanet area is a cautious approach as some of the channels will have power limits set by a requirement to protect reception of DTT transmitters being received outside the area.
- A2.159 Figure A2.13 below shows the area over which a blanket reduction of 10 dB to the TVWS power limits will be applied in the Thanet area. The area has been defined by enclosing the area where all the field strength prediction errors were in the worst 10 dB of over-prediction and where the margins were less than 0 dB.



## Figure A2.13 - Area in Thanet where a reduction of 10 dB will be applied to TVWS power limits

- A2.160 Section 7 of the main body of this document gives more detail on how the approach adopted for Thanet would be extended to other areas of the UK (expected to be few in number) in response to any evidence of gross over- or under-prediction of mean DTT field strengths by UKPM in those areas.
- A2.161 We will work with broadcasters in the Technical Working Group to prepare a database of DTT field strength measurements across the UK. In parallel, we will work with broadcasters in the Technical Working Group on potential improvements to the accuracy of UKPM field strength predictions in a way that improves it as a tool for coexistence calculations (it was not originally intended for this purpose).
- A2.162 In reaching our decisions on the values for the various parameters described above it is necessary to use software tools that implement the proposed rules for determining coexistence between WSDs and DTT so we can assess what the maximum EIRP for a WSD might be in a given situation and so whether a device operating at such a level would be likely not to meet our objective of ensuring a low probability of harmful interference.
- A2.163 Accordingly, we have used the tools we have available to us including the tool developed by Arqiva for use for the Pilot and our policy development work, and other simpler tools developed by Ofcom. It should be noted that we have not fully verified that these tools exactly implement the rules for determining coexistence with DTT. As part of the implementation work following our policy statement we will further verify the tools to ensure they exactly implement the rules for determining coexistence with DTT.

#### Summary

- A2.164 We have presented the detailed framework for the calculation of the maximum permitted in-block EIRP  $P_{\text{WSD-DTT}}(i_{\text{WSD}}, F_{\text{WSD}})$  of a WSD in relation to DTT. We refer to this as  $P_{\text{REG}}$  in the main body of this annex.
- A2.165 Ofcom will calculate the above limits via computer modelling of the impact of WSD radiation on DTT reception by roof-top aerials. These calculations will be based on assumed values of coupling gain (radio propagation) and protection ratio (susceptibility of DTT receivers to WSD signals), and for a maximum reduction of 7 percentage points in estimated DTT location probability.
- A2.166 A maximum reduction of 7 percentage points in DTT location probability corresponds to a 1 dB rise in the noise floor at the noise-limited edge of DTT coverage and is what we proposed in our 2013 Consultation. In the context of the values we set for other parameters and calibration against test results, we believe this to be an appropriate target for the avoidance of harmful interference.
- A2.167 We have revised (increased) the values of coupling gains for short range geographic separations between WSDs and DTT receivers in comparison with those we proposed in the 2013 Consultation.
- A2.168 We have also introduced two categories of "low" and "high" protection ratios, which replace the single "low" category proposed in the 2013 Consultation.
- A2.169 Based on the results of our recent coexistence tests, we will also include a safety margin of 9 dB for co-channel operation in our calculations in order to account for uncertainty in the predictions of UK-wide DTT coverage.
- A2.170 Ofcom will calculate the limits  $P_{\text{WSD-DTT}}(i_{\text{WSD}}, F_{\text{WSD}})$  based on protection of the single planned transmitter serving each individual pixel. We will update the modelled assumptions on the planned transmitter for a given area in the light of real-world observations of actual transmitter usage patterns.
- A2.171 Ofcom will calculate the limits  $P_{\text{WSD-DTT}}(i_{\text{WSD}}, F_{\text{WSD}})$  based on protection of the single planned transmitter serving each individual pixel. We will update the modelled assumptions on the planned transmitter for a given area in the light of real-world observations of actual transmitter usage patterns.
- A2.172 Ofcom will calculate the limits  $P_{\text{WSD-DTT}}(i_{\text{WSD}}, F_{\text{WSD}})$  for type A (fixed outdoor) WSDs at all locations in the UK and all DTT channels 21 to 60. These will account for the five WSD spectrum emission classes (defined by ETSI), two protection ratio categories (defined by Ofcom), and six representative WSD antenna heights of 1.5, 5, 10, 15, 20 and 30 metres.
- A2.173 Ofcom will also calculate the limits  $P_{\text{WSD-DTT}}(i_{\text{WSD}}, F_{\text{WSD}})$  for the special case where the type A WSD antenna height is unknown. These limits will be based on cautious *default* heights of between 10 to 30 metres depending on the geographic separation between the WSD and the constraining DTT receiver. The dataset for these limits will be labelled as "default height".
- A2.174 Ofcom will then communicate the calculated UK-wide EIRP limits  $P_{\text{WSD-DTT}}(i_{\text{WSD}}, F_{\text{WSD}})$  combined with any location agnostic restrictions for type A WSDs to the WSDB providers. This constitutes a total of  $7 \times 5 \times 2 = 70$  datasets (including the limits for default height).

- A2.175 WSDBs can infer the EIRP limits for type B WSDs by adding to the corresponding type A limits a building penetration gain of 7 dB (if the WSD height exceeds 2 metres) and a body gain of 0 dB.
- A2.176 If the antenna height of a type B WSD is unknown, WSDBs must use the limits for type A WSDs for a height of 1.5 metres, and add a body gain of 0 dB (building penetration gain does not apply as the height is less than 2 metres).
- A2.177 To ensure a low probability of harmful interference and to make specific allowance for the anomalous behaviour of the UKPM field strength prediction model in the Thanet area, we will apply a 10 dB additional margin to all of the TVWS power limits in a proportion of the Thanet area.
- A2.178 The following issues will be taken forward (with other issues) in discussion with stakeholders and within the Technical Working Group:
  - how and whether to incorporate a model for varying household installation gains into the WSD availability calculations;
  - the potential need for the "high" protection ratio category and how devices might be categorised;
  - any new evidence on whether the definition of DTT coverage (70% locations, 99% time) reflects actual consumer usage of DTT and whether the level of protection of actual DTT usage in marginal reception areas remains appropriate;
  - how best to collect new information on actual DTT transmitter usage;
  - the ongoing use of the extended Hata model and the Infoterra clutter data;
  - the out-of-band performances of WSDs and the effectiveness of the Class-based approach to modelling adjacent channel protection ratios;
  - how best to prepare a database of DTT field strength measurements across the UK; and
  - potential improvements to the accuracy of UKPM field strength predictions in a way that improves it as a tool for coexistence calculations.

#### Annex 3

## Approach to determining WSD emission limits taking account of Cross Border DTT

- A3.1 Our coexistence calculations take into account any potential impact of WSD operation into DTT services in neighbouring countries. This section covers:
  - Cross-border DTT co-ordination in the UHF TV band. We describe our international obligations in relation to cross-border coexistence with DTT which impact WSD deployments.
  - The approach for calculation of WSD emission limits. We describe how these international obligations translate into the methodology for calculating TVWS availability.
- A3.2 The UK has international obligations with respect to the development of any services requiring new frequency use, and this includes WSD deployments. Under Article 5 of the ITU Radio Regulations, the primary service allocation in the UHF band (470 to 790MHz) in Region 1 is broadcasting. We consider WSDs to fall within the scope of land mobile services and therefore we consider them as a secondary service as recognised in the ITU Radio Regulations under Article 5.296.
- A3.3 Our technical analysis suggests that unrestricted operation of WSDs near the UK coast line and/or land borders might cause harmful interference to DTT reception in the neighbouring countries. We therefore consider that we should restrict the power of WSDs in these areas.
- A3.4 In this section, we present our decisions on the calculation of location-specific and frequency-specific WSD emission limits in order to mitigate the risk of harmful interference to our neighbours. These limits will be combined by Ofcom with other WSD emission limits in relation to spectrum use by other services in the UK (including DTT and PMSE) and communicated to WSDBs.
- A3.5 We have had a limited amount of engagement with neighbouring countries about the methodology presented here. We received some positive feedback and no material objections. However, the scope of these discussions has been limited, because not all countries have been actively developing TVWS frameworks. Once the neighbouring countries start developing these frameworks, we will cooperate with them to improve the spectrum efficiency implied by these cross-border coexistence calculations.
- A3.6 We have not received any additional evidence which would make us review our approach to setting WSD emission limits in relation to cross-border coexistence as set out in the 2013 Consultation. For this reason, the approach described in this section is the same as in that Consultation.

#### **Cross-border DTT co-ordination in the UHF TV band**

A3.7 The UK signed the Geneva 2006 (GE06) digital broadcasting agreement which sets out the rules of UHF planning and implementation. This includes, where required, restrictions on deployment of new DTT transmitters in UK, for protection of

broadcasting services in neighbouring countries. If a broadcaster in the UK wants to deploy a new DTT transmitter, the GE06 plan requires that the UK seeks new coordination agreements in certain cases. However, this requirement does not apply in every case. GE06 allows deployment of some new transmitters which are lower power or away from the border without international co-ordination. The specific criterion is that their field strength level at the border must be below a specific level (called a co-ordination trigger threshold field strength level).

A3.8 These thresholds are of particular interest in our WSD framework because we do not intend to seek international coordination for deployment of WSDs on a transmitter-by-transmitter basis. The thresholds are listed below<sup>16</sup>:

#### Table A3.1 - GE06 Thresholds which trigger international co-ordination

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

A3.9 If received DTT emissions exceed these threshold levels, official co-ordination is required. Affected administrations analyse each case to determine any incompatibility with registered services and in most cases the bilateral negotiation results in acceptable levels of outgoing/incoming field strengths between both parties.

#### The approach for calculation of WSD emission limits

- A3.10 WSDs have no official internationally recognised frequency plan or treaty to govern their registration, deployment, interference potential or a requirement for co-ordination. The UK is internationally bound by the GE06 Treaties to ensure that neighbouring countries' primary DTT services are not affected by harmful interference from UK secondary services, which as noted above, we consider to include WSDs.
- A3.11 While the trigger levels of Table A3.1 were created for managing DTT to DTT interference, they provide a good reference point for determining WSD emission limits to ensure a low probability of harmful interference to other countries.
- A3.12 We consider this to be a sensible approach on a technical basis because a fixed WSD is very similar to a low power DTT relay in terms of its deployment. Mobile WSDs are likely to operate at lower powers and are therefore less likely to cause cross-border interference. The trigger levels will however apply to all WSDs whether fixed or mobile.
- A3.13 Our approach is therefore to calculate the maximum allowed WSD power at any location and channel such that the GE06 international co-ordination trigger thresholds are not exceeded in our neighbouring countries. We have specified these restrictions for a number of representative WSD antenna heights and will apply them as an overlay on the restrictions relating to DTT in the UK.

<sup>&</sup>lt;sup>16</sup> Annex 4 - Final Acts of the Regional Radiocommunication Conference for planning of the digital terrestrial broadcasting service in parts of Regions 1 and 3, in the frequency bands 174 to 230MHz and 470 to 862MHz, RRC-06, Geneva, 15 May - 16 June 2006.

### **Calculation methodology**

- A3.14 The objective here is to calculate the maximum permitted WSD in-block EIRP,  $P_{\text{WSD-XB}}(i, F_{\text{WSD}})$ , at a given location *i* and DTT channel  $F_{\text{WSD}}$  in the UK subject to the requirement that the resulting field strength received at the neighbouring countries does not exceed the GE06 co-ordination trigger threshold levels.
- A3.15 In performing these calculations, we apply the maximum permitted WSD in-block EIRP of 36 dBm/(8 MHz) as set out in Annex 2.
- A3.16 We characterise the locations of WSDs as points in the centres of 1 km × 1 km pixels across the UK. These locations are based on the gridlines contained in the British Ordnance survey map, which provide the co-ordinates of any location in the UK at different resolutions. For example, a pixel near Dover would have the X co-ordinates (Eastings) 629500 and Y co-ordinates (Northings) 140500.
- A3.17 In the future, we will consider moving to higher resolution predictions (100 m  $\times$  100 m), as we gain more experience in performing these calculations and provided the computational complexity remains manageable.
- A3.18 We note that it is not strictly necessary to examine every pixel across the UK for the purpose of calculating the WSD emission limits. Our analysis indicates, for example, that the emissions of a WSD radiating at 36 dBm/(8 MHz) and at a height above ground of 10 metres will not be restricted if the WSD operates more than 20 km in-land from the coast because the thresholds set out in Table A3.1 will not be exceeded.
- A3.19 For this reason, we will only consider WSD pixels in locations which are within a buffer zone along the UK land borders and coastline, including the Isle of Wight, Isles of Scilly, as well as any islands near the coast. The size of these zones is shown below:
- A3.20 Along the coast: 25km. This is illustrated in Figure A3.1. These buffer zones will be extended to include Scotland and Northern Ireland coasts.
- A3.21 In the land border between Northern Ireland and the Republic of Ireland: 25 km.
- A3.22 The size of these buffer zones was set cautiously. For example, our analysis indicates that there is no need to perform calculations for pixels between 20-25km inland from the coast for a WSD height of 10m. Therefore, there may be some computational wastage in the calculations (i.e. in some areas, the calculations may show that no additional restriction would be required to protect DTT services in neighbouring countries). We may seek to reduce this wastage later on, as we gain more experience in performing these calculations.

#### Figure A3.1 - Buffer zone within which calculations are performed



- A3.23 We will also consider both those WSD pixels that are within UK internal waters and those pixels within UK territorial waters. However we expect that the power limits will in practice be very low bearing in mind propagation characteristics over sea. We may seek to reduce the areas over which we calculate for pixels in internal waters and territorial waters later on, as we gain more experience in performing these calculations. We will consider the most appropriate way to authorise use of WSDs at sea and may consult on the technical conditions.
- A3.24 For each WSD location within the buffer zone, the resulting received field strength will be calculated at a set of *M* test points along the coastlines of France, Belgium, the Netherlands, and the Republic of Ireland, as well as the area inside the Republic of Ireland near the land border with Northern Ireland.
- A3.25 Figure A3.2 shows a specific WSD pixel in Dover with its centre at coordinates 629500, 140500 and with lines connecting it to the examined test points along the coasts and borders of neighbouring countries.



#### Figure A3.2 - A WSD pixel in Dover and test point locations in neighbouring countries

A3.26 We use ITU Recommendation1546-4<sup>17</sup> to model radio propagation from each WSD pixel location to each test point location. Specifically, the propagation will be modelled at the three Recommendation1546 reference frequencies of 100, 600 and

<sup>&</sup>lt;sup>17</sup> <u>http://www.itu.int/rec/R-REC-P.1546/en</u>.

2000 MHz. The propagation at intermediate frequencies of DTT channels 21 to 60 will then be derived via the interpolation formula defined in Recommendation 1546.

A3.27 Given a WSD pixel location *i*, the field strengths received at each of the *M* test point locations in the neighbouring countries and each DTT channel will be calculated as  $E_m(i, F_{\text{WSD}})$ , where m = 1...M and  $F_{\text{WSD}} = 21...60$ . We assume that the WSD radiates at 36 dBm/(8 MHz). Let  $E(i, F_{\text{WSD}})$  denote the largest received field strength over the test points at any given channel, i.e.,

$$E(i, F_{\text{wsd}}) = \max_{m} E_{m}(i, F_{\text{wsd}})$$
(A3.1)

- A3.28 These maximum values will then be compared to the relevant GE06 co-ordination trigger threshold levels  $E_{\rm T}(F_{\rm WSD})$  in Table A3.1.
- A3.29 If a WSD at a given pixel location *i* results in received field strengths that do not exceed the GE06 co-ordination trigger thresholds, i.e.,  $E(i, F_{WSD}) \le E_T(F_{WSD})$ , then it will not be subject to restrictions in its emission levels.
- A3.30 If a WSD at a given pixel location *i* results in received field strengths that do exceed the GE06 co-ordination trigger thresholds, i.e.,  $E(i, F_{WSD}) > E_T(F_{WSD})$ , then it will be subject to restrictions in its emission levels. Specifically, if

$$E(i, F_{\rm WSD})_{\rm (dB\mu\nu/m)} = E_{\rm T}(F_{\rm WSD})_{\rm (dB\mu\nu/m)} + x(i, F_{\rm WSD})_{\rm (dB)},$$
(A3.2)

where x > 0, then the maximum permitted in-block EIRP for that WSD is restricted to

$$P_{\text{WSD-XB}}(i, F_{\text{WSD}}) = 36 - x(i, F_{\text{WSD}}) \quad \text{dBm}/(8 \text{ MHz}).$$
 (A3.3)

A3.31 Table A3.2 below shows illustrative examples of the various parameter values for a given channel, with one WSD pixel location and four test points. Based on this example, the maximum permitted WSD EIRP is 36 – 4.9 = 31.1 dBm/(8 MHz).

WSD pixel location, <i>i</i>	Test point index, <i>m</i>	Received field strength at test point $E_m(i,F_{WSD})$ dB $\mu$ V/m	E(i,F <sub>WSD</sub> ) dBμV/m	Threshold $E_{\rm T}(F_{\rm WSD})$ dB $\mu$ V/m	Restriction <i>x</i> (dB)
	F54	25.9			
629500	F55	23.2	25.0	21	4.9
140500	F53	21.4	25.9		
	F56	20.2			

Table A3.2 -	Example of	of received f	ield strength	s and WSI	) EIRP r	estriction
			icia su crigui			Controllori

A3.32 Of com will calculate the emission limits  $P_{\text{WSD-XB}}(i, F_{\text{WSD}})$  for all relevant locations *i* in the UK, all DTT channels  $F_{\text{WSD}} = 21 \dots 60$ , and representative type A WSD antenna heights of 1.5, 5, 10, 15, 20, and 30 metres. Emission limits for type B WSDs can be inferred from the limits for type A WSDs. The limits for type A and type B devices will be the same except for type B WSDs with antenna heights of greater than 2

metres in which case the WSDs will be considered to be indoors and subject to a 7 dB relaxation of the emission limits. Ofcom will then combine the resulting limits with any other limits which might apply (see Annex 1) and communicate these to WSDBs.

#### **Summary and conclusions**

- A3.33 We will implement restrictions on WSD emission limits in order to prevent harmful interference to broadcasting services in neighbouring countries. These restrictions were based on existing thresholds which the GE06 prescribes for preventing DTT-to-DTT interference, in cases where there is no transmitter-by-transmitter international coordination. These limits will be combined with other WSD limits calculated by Ofcom (e.g., in relation to DTT and PMSE in the UK) and communicated to WSDBs.
- A3.34 Our calculations indicate that the restrictions are only significant near Dover and the land border between Northern Ireland and the Republic of Ireland. The extent of these restrictions in the South-East of England can be seen in Figures A3.3 and A3.4.
- A3.35 We have engaged with neighbouring countries to present our technical framework for discussion and feedback, and will continue to do so. These discussions may lead to future improvements in TV white space availability in the UK. For example, we may only select test points at specific frequencies where the relevant DTT channel is actually used by our neighbouring country.

Figure A3.3 - TVWS availability on the Isle of Wight in channel 21, subject to the requirement that the GE06 co-ordination trigger thresholds are not exceeded



## Figure A3.4 - TVWS availability near Folkestone and Dover in channel 21, subject to the requirement that the GE06 co-ordination trigger thresholds are not exceeded



#### Annex 4

# Approach to determining WSD emission limits taking account of PMSE

#### Introduction

- A4.1 In this annex we present the detailed framework for calculating the maximum permitted in-block power  $P_{WSD-PMSE}(i_{WSD}, F_{WSD})$ ) of a WSD which operates at a given geographic location  $i_{WSD}$  and in a specific DTT channel  $F_{WSD}$ . This emission limit is specified to ensure a low probability of harmful interference to PMSE use of the spectrum.
- A4.2 The scope of this annex is restricted to location-specific PMSE usage.<sup>18</sup>
- A4.3 As explained in Section 6 of the main statement, EIRP limits for WSDs will be calculated by the WSDBs, and communicated to the WSDs. The limit will be the lowest of a number of different limits calculated in order to protect different systems.
- A4.4 We first describe the nature of PMSE use in the 470 790 MHz band in the UK. We then set out at a high level, the calculations involved in describing the WSD EIRP limits in order to protect PMSE. Finally we set out how our proposed approach, and specifically, how some parameter values for the coexistence calculations have changed in the light of our measurements<sup>19</sup> compared to those we proposed in the 2013 Consultation.
- A4.5 These parameters include the wanted received signal power at the PMSE receiver, WSD-PMSE protection ratios, WSD-PMSE coupling gains, and a parameter which accounts for the amplitude of intermodulation products that can be generated by wireless microphones.

#### The PMSE services in the UHF TV band

- A4.6 The following are the six main PMSE services<sup>20</sup> which operate in the UHF TV band subject to a licence:
  - Wireless microphones;
  - In-ear monitors (IEMs);
  - Talkback;
  - Programme audio links;
  - Data links; and,

<sup>&</sup>lt;sup>18</sup> This includes some PMSE usage in channel 38 (programme audio links), but in accordance with the locationagnostic restrictions detailed in Annex 5, no WSD transmissions are allowed in channel 38.

<sup>&</sup>lt;sup>19</sup> TV white spaces: PMSE coexistence tests: http://stakeholders.ofcom.org.uk/market-dataresearch/other/technology-research/2014/tyws-pmse-coexistence

research/other/technology-research/2014/tvws-pmse-coexistence <sup>20</sup> Note that, in the future, if other PMSE services are used in the TV band 470-790 MHz, appropriate coexistence criteria will be developed and applied.

- Programme video links.
- A4.7 The transmitter licences issued are location specific; in that they authorise the use of the spectrum at specific venues or locations. Location-agnostic UK-wide licences are also issued for use within channel 38 (606 614 MHz).
- A4.8 Table A4.1 shows the number of assignments associated with the various PMSE equipment types that were registered as active at around 3pm on Monday 25<sup>th</sup> August 2014. Wireless microphones, in-ear monitors and talkback account for a large majority of the assignments at 99.7% of the total.

Equipment type	Number of assignments
Wireless microphone	9,326
In ear monitor	633
Talkback	1,180
Programme audio link	19
Data link	5
Programme video link	5
TOTAL	11,168

#### Table A4.1 - Snapshot of assignments

- A4.9 Wireless microphones and in-ear monitors typically have a nominal channel bandwidth of 200 kHz. Both types of devices can move during use, with the in-ear monitors providing a customised audio link back to the performer. We will treat in-ear monitors in the same way as wireless microphones, because although our measurements show that whilst the protection ratios for both receiver types are not the same, when combined with sensitivity data, the overall protection requirement is similar.
- A4.10 Talkback equipment typically has nominal channel bandwidths of 12.5 kHz, 25 kHz, 100 kHz or 200 kHz, and is designed for the purpose of communicating instructions to the programme-making team including presenters, interviewers, and equipment operators/engineers. Various technologies fall under the talkback category, including professional mobile radio (PMR), in-studio belt-pack systems (of either 12.5 kHz or 25 kHz bandwidth) and intercom systems (200 kHz bandwidth). From our testing of receivers, we consider that intercom systems are likely to be the most vulnerable of these types to WSD interference. Our measurements show that as with the in-ear monitors, the protection requirements are similar, so we have adopted the wireless microphone protection ratios and sensitivity for talkback equipment.
- A4.11 Programme audio links typically have a nominal channel bandwidth of 200 kHz and comprise high-powered wireless microphones and studio transmitter links. Programme audio links are used for the purpose of carrying broadcast-quality mono or stereo music and speech signals. The studio transmitter links use highly directional antennas and are currently only used on a location-specific basis in channel 38. We will also treat programme audio links as wireless microphones, because our measurements show that the protection ratios for both receiver types are similar.

- A4.12 Programme video links are very rare, and we have no evidence of operational use since 2012. We will treat video links in accordance with DTT received wanted signal levels and protection ratios.
- A4.13 Data links are used for remote control of cameras and other equipment and also for signalling. They use the same type of technology as talkback and therefore, as with talkback, we have adopted the wireless microphone protection ratios and sensitivity for data links.
- A4.14 The number of PMSE channels authorised for use in a location depends on the nature of the PMSE event. This can range from a single channel in a small event to up to 40 or more for wireless microphones and IEMs in a major production. The channel frequencies authorised are not based on any specific raster, and are selected to both minimise the impact of inter-modulation products within a venue and to interleave with other PMSE users. Where multiple PMSE channels are authorised for use, these may span a single 8 MHz DTT channel, or multiple (contiguous or non-contiguous) DTT channels.
- A4.15 Table A4.2 describes the PMSE assignments dataset that will be supplied to the WSDBs.

Parameter	Description
Assignment_ID	Unique identifier for the assignment.
Equipment_Type_ID	Type of equipment/service used in the assignment, encodedas follows:1-1-72-Wireless microphone4-Programme audio link8-Programme video link16-Data link64-In ear monitor
X_Coord_metres	Eastings of the PMSE transmitter antenna (expressed to a precision of one metre) referenced to the Ordnance Survey National Grid of Great Britain.
Y_Coord_metres	Northings of the PMSE transmitter antenna (expressed to a precision of one metre) referenced to the Ordnance Survey National Grid of Great Britain.
Antenna_Height_metres	Height above ground level of PMSE receiver antenna in metres. A default value of 5 metres will be assumed in the absence of available information.
Frequency_MHz	Centre frequency of the PMSE assignment in MHz. This is used to determine the DTT channel index of the assignment <sup>21</sup> .
Bandwidth_MHz	Bandwidth of the assignment in MHz. This will usually be the nominal bandwidth of the relevant usage type, for example 0.2 MHz for wireless microphones.
Start	Start date and time of the assignment.
Finish	Finish date and time of the assignment.
Situation_ID	I - Internal (indoor) E - External (outdoor) A - Airborne

#### Table A4.2 - PMSE assignment data

<sup>21</sup> The DTT channel index is given by  $F = 21 + \text{floor}\{(\text{Frequency}_MHz - 470)/8\}$ 

A4.16 We do not propose to account for the specific numbers and frequencies of PMSE channels authorised for use within a given DTT channel. This is because we do not know precisely which frequencies within the DTT channel will be used by WSDs. Therefore, if PMSE equipment and WSDs occupy the same DTT channel, they will be considered co-channel in the context of coexistence calculation.

## Calculation of WSD emission limits for coexistence of TVWS with PMSE

#### High level framework

- A4.17 The algorithm to calculate maximum permitted in-block EIRP  $P_{\text{WSD-PMSE}}(i_{\text{WSD}}, F_{\text{WSD}})$  is defined in Part 5 of Annex 8.
- A4.18 Relative to proposals in the 2013 Consultation, additional restrictions are now included in the expression for the maximum permitted EIRP spectral density, P<sub>WSD-PMSE</sub> in dBm/(100 kHz), to ensure a low probability of harmful interference.
- A4.19 The expression is now the minimum of:
  - a 36 dBm/8 MHz cap i.e. 16.97 dBm/100 kHz, and;
  - a WSD EIRP spectral density restriction, P<sub>WSD-PR-PMSE</sub> in dBm/(100 kHz), to ensure a low probability of spectral leakage from the WSD to the PMSE receiver causing harmful interference

#### and also

• a WSD EIRP spectral density restriction, *P*<sub>WSD-PMSE-PMSE</sub> in dBm/(100 kHz), to ensure a low probability of PMSE transmitter intermodulation interference (generated in response to interference from the WSD) causing harmful interference.

#### **Changes following the 2013 Consultation**

- A4.20 Our framework for calculation of WSD regulatory limits in relation to PMSE has changed compared to our proposals in the 2013 Consultation. These changes are largely based on feedback from stakeholders, results from subsequent coexistence bench tests using a representative sample of equipment, and from functional testing at venues. We have introduced new emission limits associated with PMSE transmitter intermodulation, but otherwise the changes relate to revisions of existing criteria.
- A4.21 We have not included any changes associated with the possibility of WSD transmitter intermodulation between WSDs. However, should the need arise, that additional modification may be included in the framework.
- A4.22 The changes are summarised in Table A4.3 and elaborated in the sections below.

#### Table A4.3 - Summary of changes following 2013 Consultation

Change	2013 Consultation	Statement
Over-arching coexistence criterion	Interference experienced by PMSE from WSDs must not exceed -77 dBm/(200 kHz).	Interference experienced by PMSE from WSDs must not exceed -104 dBm/(200 kHz).
Inclusion of restrictions associated with PMSE (reverse) transmitter intermodulation	No	Yes
Programme video links	Not taken into account.	Taken into account.
PMSE wanted signal power, $P_{\rm S,0}$	-65 dBm/(200 kHz) for wireless microphones	-78 dBm/(200 kHz) for wireless microphones
Ducto stice ratios	Measured based on a SINAD <sup>22</sup> failure criterion	Measured based on a failure criterion related to subjective audio quality
Protection ratios	No WSD EIRP restrictions beyond the 10 <sup>th</sup> adjacent channel.	WSD EIRP restrictions applied beyond the 10 <sup>th</sup> adjacent channel.
WSD body gain	No	Yes, but the value adopted is 0 dB.
PMSE body gain	No	Yes. Used in the PMSE transmit intermodulation equation, but the value adopted in this statement is 0 dB.
Median path gain	The clutter categories mapped to 'urban, 'suburban' and 'open'.	The clutter categories mapped to 'urban' and 'suburban'. The mapping to 'open' no longer applies.
PMSE location uncertainty	Outlined possibility of identifying and recording the boundaries of PMSE venues, in order to derive multiple PMSE candidate locations.	We will include knowledge about boundaries of PMSE venues into the framework, as explained in Section 8.
PMSE assignments straddling several DTT channels	Where a PMSE assignment straddles several DTT channels, we proposed treating PMSE as adjacent-channel to WSDs which occupy any of the DTT channels.	Where a PMSE assignment straddles DTT channels, we treat the relevant DTT channels as co- channel to PMSE.

#### **Over-arching coexistence criterion**

A4.23 We have adopted for wireless microphones a wanted signal power  $P_{\rm S,0}$  of -78 dBm/(200 kHz) and a set of co-channel protection ratios with a co-channel protection ratio of 26 dB (for wanted power and unwanted power over the same bandwidth). In accord with our new proposed figures, this means that the "over-arching coexistence criterion" is given by

<sup>&</sup>lt;sup>22</sup> Signal-to-noise and distortion ratio

#### Co-channel referred interference experienced by PMSE from WSDs must not exceed -78 - 26 = -104 dBm/(200 kHz)

- A4.24 The figure of -104 dBm/(200 kHz) is 10 dB above the receiver noise floor (assuming that a receiver noise figure of 7 dB) and is referred to as "target received interference at PMSE", *P*<sub>I,T</sub>.
- A4.25 The new figure is in contrast to the values assumed in the 2013 Consultation in which a wanted PMSE signal power of -65 dBm/(200 kHz) and a co-channel protection ratio of 12 dB<sup>23</sup> was proposed.
- A4.26 The over-arching coexistence criterion has therefore been tightened by 27 dB.
- A4.27 Please refer to Section 8 for a fuller discussion of the rationale for the over-arching coexistence criterion.

#### Inclusion of restrictions associated with PMSE transmitter intermodulation

- A4.28 A limiting factor in PMSE operation is that of intermodulation components that can be created by a PMSE transmitter due to potentially low reverse isolation between the PMSE antenna and non-linear elements of its output stages.
- A4.29 This situation can arise from any strong emission from a neighbouring system whether from another PMSE transmitter or WSD. This issue is only relevant in venues with multiple PMSE links in operation and is manifest if the intermodulation components fall into the channel of another PMSE link in the same venue and at a sufficient level to cause interference.
- A4.30 This is shown in Figure A4.1. The in-block power  $P_{\text{IB}}$  radiated from a WSD falls upon a wireless microphone transmitter (2), which in response to the received power of  $P_{\text{X}}$  may radiate an unwanted intermodulation product of radiated power  $P_{\text{IM}}$ .

## Figure A4.1 - Illustration of reverse intermodulation interference from a PMSE transmitter to a PMSE receiver in response to interference from a WSD



A4.31 The resulting effect is shown in Figure A4.2 where the WSD radiating at frequency  $f_2$  in combination with the PMSE transmitter (2) radiating at  $f_1$  may lead to

<sup>&</sup>lt;sup>23</sup> For wanted power and unwanted power over the same bandwidth.

intermodulation products at other frequencies, potentially co-channel to another PMSE link (1).





- A4.32 In order to mitigate the potential interference, the maximum power that a WSD may radiate is limited to plan for a level not exceeding -104 dBm/(200 kHz) at the PMSE Receiver (1).
- A4.33 The transmitter intermodulation performance of microphones varies considerably. Microphones that have different power modes perform better when operating at lower power. We observed a variation of around 25 dB in the level of 3<sup>rd</sup> order intermodulation products over the range of microphones and modes tested.
- A4.34 From our laboratory test results<sup>24</sup> we were able to establish a relationship between the WSD power incident at the PMSE transmitter and the EIRP of the intermodulation product as follows:

$$P_{\rm IM (dBm/200kHz)} = P_{X (dBm/8MHz)} + C_{\rm IM1}$$
(A4.1)

where

- *Px* is the incident WSD power upon the PMSE transmitter generating the intermodulation product;
- $P_{\rm IM}$  is the PMSE transmit intermodulation product EIRP; and
- $C_{IM1}$  is the factor relating WSD power incident upon a PMSE transmitter and the power of the third order intermodulation product.
- A4.35 We have chosen a value of  $C_{IMI} = -40$  dB that corresponds roughly to the mid-point between the best and worst results observed during measurements. This figure incorporates the worst case performance of 'MIC2'<sup>25</sup> and an additional 5 dB loss, which corresponds to the variation in  $P_{IM}$  observed when a radio microphone transmitter was rotated about its vertical axis. 'MIC2' is a microphone commonly used in theatres for shows that require a large number of microphones.

<sup>&</sup>lt;sup>24</sup> <u>http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2014/tvws-pmse-coexistence</u>

<sup>&</sup>lt;sup>25</sup> 'MIC2' performance is reported in the PMSE coexistence test report

- A4.36 In the calculation of the coupling gains used to compute the intermodulation calculations we make the following assumptions about geometry:
  - i) The separation distance between the Transmitter (2) "interferer" and Receiver (1),  $d_{\text{PMSE-PMSE}}$ , is 5 metres.
  - ii) The horizontal separation distance between the WSD and interfering PMSE Transmitter (2) is based upon the PMSE assignment location subject to a minimum distance of 10m.
- A4.37 We have to approximate the transmitter position as the PMSE assignment data only provides a location for the PMSE receiver<sup>26</sup>. This is the same geometry as used in the calculation of median path gain to restrict the EIRP  $P_{\text{WSD-PR-PMSE}}$  associated with "direct" transmissions of interference from WSD to PMSE.
- A4.38 Given the positional uncertainty regarding both WSD and PMSE it is impossible to be precise about the separation between the two. We consider it reasonable to assume for our framework that they lie no closer than 10 metres. Sometimes the WSD may be closer than this, but unless that coincides with a number of other worst case scenarios, it should still not lead to harmful interference. Furthermore, the minimum separation distance may be in control of the venue organisers.
- A4.39 Consideration of the coupling gains allows us to calculate the maximum radiated power,  $P_{\text{WSD-PMSE-PMSE}}$ , that the WSD may radiate to ensure that the intermodulation product power received at PMSE transmitter (2) is no greater than  $P_{\text{I,T}}$ .
- A4.40 The expression for calculation of  $P_{WSD-PMSE-PMSE}$  is given in Annex 8.

#### Inclusion of Programme video links

A4.41 These were not taken into account in the 2013 consultation as they were not expected to occur in the UHF TV band and have not been in operational use since 2012. However, we have defined parameter values to ensure a low probability of interference to any video links that may be licensed in the band. These are covered in the sections below.

#### Wanted PMSE signal power, P<sub>S,0</sub>

- A4.42 The WSD radiated EIRP spectral density  $P_{\text{WSD-PR-PMSE}}$  characterised in dBm/(100 kHz), is the limiting power that is calculated to ensure a low probability of "direct" transmissions from the WSD to the PMSE receiver causing harmful interference.
- A4.43 The method to calculate this restriction is unchanged and is based upon a signal-tointerference ratio using tabulated protection ratios and minimum wanted signal for different PMSE equipment types.
- A4.44 The minimum PMSE wanted signal power,  $P_{S,0}$  to be protected for each of the PMSE equipment types, has been reduced to offer greater protection compared to the proposals in the 2013 consultation. The values are discussed by equipment type below:

<sup>&</sup>lt;sup>26</sup> Note that in implementation of the framework PMSE candidate locations may be employed.

#### Wireless microphones

- A4.45 The PMSE wanted signal power  $P_{s,0}$  for wireless microphones is now -78 dBm/(200 kHz), which is 10 dB above the noise-limited sensitivity of the best receiver we measured in the laboratory and 13 dB lower than the value of -65 dBm/(200 kHz) which we proposed in the 2013 Consultation which was based upon protection criteria outlined in the Chester 97 agreement<sup>27</sup>.
- A4.46 Measurements in two London theatres, Wembley Arena and at an outside broadcast event at Calke Abbey confirm the appropriateness of this value. In these tests the wanted signal power  $P_{S,0}$  was measured with reference to a 0 dBi reference antenna (although in practice an installation may have additional gain).
- A4.47 The measurements, summarised in Table A4.4, were averaged over a one second window to remove the effect of deep fades as would be the case with receiver diversity.

Table A4.4 - Percentage of measurements exceeding a particular power level (based on one second moving average data)

Power level (dBm/200 kHz)	Queen's Theatre	New London Theatre	Wembley	Calke Abbey
-88	99.9	100.0	100.0	100.0
-85	99.6	100.0	100.0	100.0
-82	98.7	99.9	100.0	100.0
-78	96.8	99.6	100.0	100.0
-75	94.4	99.1	100.0	99.5

- A4.48 Our laboratory tests measured reference sensitivities of the five common used wireless microphones covering various price points. The sensitivity ranged from -75 dBm/(200 kHz) to -88 dBm/(200 kHz). Taking the lowest reference sensitivity of -88 dBm/(200 kHz), and adding 10 dB margin to account for fading<sup>28</sup> gives the worst case minimum figure of -78 dBm/(200 kHz).
- A4.49 We have therefore adopted a minimum received wanted PMSE signal power of -78 dBm/(200 kHz), which considering the worst measurement location at Queen's Theatre, and factoring in the additional gain of 10 dB in the PMSE receiver antenna/feeder installation at that theatre, would actually mean that 99.9% of signals would exceed the minimum as was the case at the other locations tested.

#### In-ear monitors

A4.50 In the 2013 Consultation, we proposed to treat in-ear monitors in the same way as wireless microphones in terms of the minimum wanted PMSE signal power and protection ratios.

<sup>&</sup>lt;sup>27</sup> "The Chester 1997 Multilateral Coordination Agreement relating to Technical Criteria, Coordination Principles and Procedures for the introduction of Terrestrial Digital Video Broadcasting (DVB-T)," Chester, 25 July 1997, http://www.archive.ero.dk/132D67A4-8815-48CB-B482-903844887DE3?frames=no&.

<sup>&</sup>lt;sup>28</sup> Wireless microphones will not generally be expected to operate in locations experiencing full fading as this does not deliver a useful service.

- A4.51 During our tests, we measured in-ear monitor protection ratios in the laboratory for both mono and stereo modes for a sample device. These tests showed that the reference sensitivity of the in-ear monitor is -75 dBm/(200 kHz) in mono which is as high as the least sensitive of the wireless microphones measured. The reference sensitivity of the in-ear monitor in stereo is -40 dBm/(200 kHz), which is considerably higher. Noting that the in-ear monitor protection ratios are higher than for wireless microphones, the predicted amount of "nuisance power" that can be tolerated at the in-ear monitor receiver, obtained by subtracting the channel offsetdependent protection ratio from the useable PMSE wanted power, consistently results in a higher value of "nuisance power" than would be predicted using our assumed PMSE wanted power of -78 dBm/(200 kHz) and the wireless microphone protection ratios.
- A4.52 We have taken the cautious approach of adopting the wireless microphone PMSE wanted power and the wireless microphone protection ratios for use in relation to IEMs in the framework. This should ensure adequate protection for both mono and stereo.

#### Talkback

A4.53 As proposed in the 2013 Consultation, we treat talkback as wireless microphones in terms of the wanted PMSE signal power and the protection ratios, and we now use the improved values of these. Many talkback systems now operate with a 200 kHz bandwidth rather than narrower bandwidths (to ensure user comfort). The voice quality requirements are not as onerous as for wireless microphones and use of the wireless microphone parameters should ensure low probability of audio interference.

#### Programme audio links

- A4.54 Programme audio links are usually considered to be high-powered wireless microphones or in-ear monitors. As stated in paragraph A4.11 we treat programme audio links as wireless microphones, and adopt the now lower value of -78 dBm/(200 kHz) for the PMSE wanted signal power  $P_{s,0}$ .
- A4.55 Studio transmitter links also fall under the programme audio link equipment type. They can operate anywhere within the UHF TV band including channel 38, where they are assigned frequencies at 606.700 MHz and 607.000 MHz. It is usual to deploy studio transmitter links with directional antennas. This means that off-axis interference is unlikely to be an issue, and, in practice they are generally not susceptible to interference (even though often deployed with high path loss between transmitter and receiver).
- A4.56 The reference sensitivity of a studio transmitter link in analogue mono mode measured in the laboratory was -85 dBm, which is a similar figure to that of the wireless microphones we measured in our PMSE coexistence tests. The co-channel protection ratio was also similar to that of wireless microphones. In addition, we observed that the studio transmitter link was more resistant to interference at large frequency offsets.
- A4.57 The reference sensitivity when operating in stereo or MPX mode will be higher than for analogue mono, by at least 10 dB, with correspondingly higher protection ratios. We would, however, expect that the amount of "nuisance power" that can be tolerated at the receiver would be similar to mono mode operation and also similar to that of wireless microphones.

- A4.58 Note for location-agnostic operation in channel 38, WSDs are not permitted, so cochannel interference to programme audio links will not present an issue.
- A4.59 Within our coexistence framework it is the PMSE receiver location that is specified to the WSDB, so it is important that this is accurately recorded in the PMSE licence<sup>29</sup>.
- Whilst the transmitter location of the programme audio link is not known to the A4.60 WSDB, this should not pose an issue due to transmitter intermodulation products, because other types of PMSE systems in the vicinity of the programme audio link transmitter will be protected as their location will be known. This will cause PMSE transmitter intermodulation restrictions to be applied, and since these intermodulation restrictions are independent of frequency, this should ensure that intermodulation products do not cause harmful audio interference in the vicinity of the programme audio link transmitter.

#### Data links

A4.61 We treat data links, which use a similar technology as some types of talkback, as wireless microphones.

#### Programme video links

A4.62 Programme video links use the DVB-T broadcasting standard. In terms of received wanted PMSE signal power, we have adopted -65 dB/(8 MHz) for the WSD EIRP coexistence calculations. This figure is 10 dB above the reference sensitivity for DTT of -75 dBm/(8 MHz)<sup>30</sup>.

#### **Protection ratios**

- Following publication of the 2013 Consultation, we have revised the protection A4.63 ratios we used for a number of the equipment types, namely wireless microphones, in-ear monitors and programme audio links, by undertaking further measurements in the laboratory. The performance criterion for wireless microphones is given in the PMSE coexistence test report and is based on subjective audio quality rather than a reduction in SINAD as for the protection ratios measured for the 2013 Consultation.
- Previously we had proposed no restriction to WSD emissions beyond the 10<sup>th</sup> A4.64 adjacent channel. We now take the precaution of ensuring that the protection ratios are applied for all adjacent channels within the TV band, not just up to an offset of 10 channels, because whilst spectral leakage from WSD may not be an issue, this approach takes account for the non-linear effects of the PMSE receivers. The values of protection ratios for some of the higher adjacencies are, however, somewhat academic as with an assumed minimum WSD-PMSE separation of 10 metres the 36 dBm/(8 MHz) power cap ensures that the radiated power is limited anyway.

<sup>&</sup>lt;sup>29</sup> Normally in PMSE it is the transmitter that is licenced and that has its location specified, so the receiver is assumed to be at the same location. However, in the case of programme audio links, where the receiver can be up to several miles away from the transmitter, the receiver location is usually recorded separately, and made available to the WSDB in this specific case. <sup>30</sup> See Annex 2.

#### Wireless microphones, in-ear monitors, talkback and programme data links.

- A4.65 We measured the protection ratios of six wireless microphones for various amplitudes of interference to account for any non-linear effects. Taking the 'MIC2' as the most sensitive to interference we then derived the protection ratios for each WSD emission class. Annex 10 details how the protection ratios for each WSD emission class are calculated.
- A4.66 Our adopted values of protection ratio are those of the most sensitive PMSE receiver that we measured. The co-channel protection ratio is 26 dB (wanted power and unwanted power over the PMSE receiver bandwidth).
- A4.67 In the expression used for calculating the WSD radiated EIRP spectral density restriction, *P*<sub>WSD-PR-PMSE</sub> in dBm/(100 kHz), to ensure a low probability of "direct" transmissions from the WSD to the PMSE receiver causing harmful interference the nominal PMSE receiver antenna gain is set to 0 dBi (including all installation gains and losses). In practice, in venue, there may be a gain applied to the received wanted PMSE signal power, and the unwanted WSD power. For example, in Queen's Theatre and New London Theatre the net gain from input to a PMSE receive antenna and the receiver rack is roughly 10 dB.
- A4.68 Our protection ratios implicitly account for non-linear effects at the PMSE receiver, which is why for the higher DTT channel separations the protection ratios as given in Part 5 of Annex 8 reduce as the wanted signal level increases. Furthermore, we account for up to 10dB in installation gain in our protection ratios to ensure that at the higher channel offsets we do not underestimate the impact of WSD interference before audio impairment.
- A4.69 Note that no antenna discrimination between wanted and unwanted signals has been assumed in our model. While antenna discrimination may apply in particular cases, reference to installation set-ups shows that we cannot always assume this to be the case. For example, the wireless microphone antennas may be omnidirectional, and even if the antennas are directional some of their ideal directionality will be lost in a richly scattering environment.

#### Programme video links

A4.70 Programme video links use the DVB-T broadcasting standard. We adopt the "high" DTT protection ratios given in Annex 2 for time-discontinuous (gated) traffic based on a received median wanted DTT signal power of -60 dBm/(8 MHz).

#### WSD body gain

A4.71 For the median coupling gain between WSD and PMSE in the calculation of  $P_{\text{WSD-PR-PMSE}}$  and  $P_{\text{WSD-PRSE-PMSE}}$  we have included a WSD body gain,  $G_{\text{B1,WSD}}$  and  $G_{\text{B2,WSD}}$ . In practice, type B WSDs are likely to experience a non-zero body gain of around -6 dB<sup>31</sup>. However we recognise that in many situations where the WSD-PMSE separation is small the body gain may be not as high as -6 dB, especially if the WSD is held well away from the body/head. We therefore take the cautious approach of assuming a WSD body gain of 0 dB.

<sup>&</sup>lt;sup>31</sup> CEPT Report 30 Report from CEPT to the European Commission in response to the Mandate on "The identification of common and minimal (least restrictive) technical conditions for 790 - 862 MHz for the digital dividend in the European Union", Final Report on 30 October 2009: http://www.erodocdb.dk/docs/doc98/official/pdf/CEPTRep030.pdf

A4.72 We include WSD body gain in this manner so that if it is considered reasonable to adopt a non-zero WSD body gain in the light of experience, it can easily be incorporated in to the calculation.

#### PMSE body gain

- A4.73 For the median coupling gain between the PMSE transmitter and the PMSE receiver for another link (with an assumed 5 metre separation) in calculation of  $P_{\text{WSD-PMSE-PMSE}}$  we have included a PMSE body gain,  $G_{\text{B,PMSE}}$ . In practice, wireless microphone transmitters may experience a non-zero body gain. However we recognise that in many situations where the body gain may be small, especially if the wireless microphone is held well away from the body/head as may happen when using a stick microphone at a concert. We therefore take the cautious approach of assuming a PMSE body gain of 0 dB.
- A4.74 We include PMSE body gain in this manner so that if it is considered reasonable to adopt a non-zero PMSE body gain in the light of experience, it can easily be incorporated in to the calculation.

#### Median path gain

- A4.75 The propagation model used for calculation of the median coupling gain between WSD and PMSE in calculation of the EIRP spectral density restrictions is the Extended Hata in SEAMCAT<sup>32</sup>
- A4.76 For the calculation of the EIRP restrictions, the decision over which particular general environment to use within the SEAMCAT Extended Hata set is determined by the clutter code at the PMSE end.
- A4.77 In the 2013 Consultation we apply mapping to establish the general environment of the PMSE. However, instead of mapping to 'urban', 'suburban' and 'open', we are now only using the 'urban' and 'suburban' models, having made a decision to not use the 'open' model.
- A4.78 We decided not to use the 'open' model for the following reasons:
  - Experimentation has shown that simple application of the Hata 'open' model leads to a gross over-estimate of coupling gains over longer paths;
  - Most PMSE use occurs in urban or suburban areas or at least in an environment adjacent to building clutter, which is handled by the current approach;
  - In the cases where the environment is truly open and the interference paths are significant in length, it is likely that the variability in terrain will cause some shadowing in the interference path leading to an excess loss due to obstacle diffraction, requiring a more comprehensive approach.
- A4.79 A subsequent iteration of the framework is likely to include a terrain based model to better estimate interference path coupling gains over different types of path over irregular terrain, and this may include paths in 'open' environments. This may imply a significant calculation overhead, so we wish to implement having carefully discussed those stakeholders impacted.

<sup>&</sup>lt;sup>32</sup> <u>http://tractool.seamcat.org/attachment/wiki/Manual/PropagationModels/ExtendedHata/Hata-and-Hata-SRD-implementation\_v3.pdf</u>

#### **PMSE** location uncertainty

- A4.80 In the 2013 Consultation we outlined the possibility of identifying and recording the boundaries of PMSE venues, in order to derive multiple PMSE candidate locations.
- A4.81 We will include information about boundaries of PMSE venues into the framework, as explained in Section 8.

#### PMSE assignments straddling several DTT channels

- A4.82 In the 2013 Consultation we proposed to treat PMSE as adjacent-channel to the WSD in those cases where the PMSE assignment overlaps several DTT channels.
- A4.83 We now treat the relevant DTT channels as co-channel to PMSE, which is a much more cautious approach, because when PMSE assignments overlap DTT channel boundaries, the overlap tends to be slight, and WSD power spectra will be much reduced at the channel edges.

#### Annex 5

## Approach to determining WSD emission limits taking account of location-agnostic PMSE use in Channel 38

#### Background

- A5.1 In the UK, channel 38 is allocated exclusively for PMSE use and primarily for use by radio wireless microphones. There are also two 200 kHz channels assigned for programme audio link applications.
- A5.2 The locations of high power programme audio links are known and these are accounted for in the usual way through the WSD emission limits in relation to PMSE as defined in Annex 4.
- A5.3 The locations of PMSE wireless microphone usage in channel 38 are generally not known. They are subject to "shared" licence conditions, which are typically annual/bi-annual and provide spectrum access rights at any location in the UK, and at any time, in an uncoordinated fashion.
- A5.4 The licensing regime in channel 38 is particularly useful for PMSE use cases which are location-agnostic. Examples of such use cases include news gathering, and touring bands.
- A5.5 In this annex we present the restrictions required to ensure a low probability of harmful interference to location-agnostic PMSE use in channel 38.

#### **Co-channel coexistence**

A5.6 In order to remove the risk of co-channel interference to PMSE use in channel 38, WSDs will not be allowed to operate in channel 38.

## Scenarios used to establish the coexistence criteria in channels adjacent to channel 38

- A5.7 In relation to adjacent channel coexistence, we treat PMSE use in channel 38 in a similar way to PMSE use in other channels. However, the coexistence criteria are relaxed in relation to other channels.
- A5.8 As explained in Section 8, we have created four scenarios to depict cases where WSD equipment could conceivably be in close proximity of a channel 38 receiver. Two of these refer to type A WSDs: a theatre scenario and an outside broadcast scenario; and two refer to type B WSDs, again a theatre and an outside broadcast scenario.
- A5.9 We have found that the outside broadcast scenario is the worst case scenario (i.e. the one that required the tightest protection), both for type A and type B WSDs. The criteria are, therefore, derived with reference to two outside broadcast scenarios:
  (A) for type A WSD and (B) for type B WSD. Table A5.1 gives the parameters used in the modelling.

	(A)	(B)
	Outside broadcast	
WSD type	А	В
Horizontal separation between WSD and PMSE receiver <i>d</i>	30 metres	10 metres
Building penetration gain $G_{\rm W}$	0 dB	
WSD antenna height $h_{_{\rm WSD}}$	5 metres	1.5 metres
WSD body gain $G_{\rm B,WSD}$	0 dB	-6 dB
PMSE height $h_{\text{PMSE}}$	5 metres	
PMSE body gain $G_{\rm B,PMSE}$	-6 dB	
PMSE signal level P <sub>S,0</sub>	-78 dBm/(200 kHz)	
Protection ratios $r(\Delta F)$	As given in Annex 8	

#### Table A5.1 - Parameters used in the modelling scenarios for channel 38 use

- A5.10 In the absence of data on the locations of PMSE use in channel 38, we have assumed a "reference" horizontal separation between a WSD and the PMSE equipment. For fixed (type A) WSD equipment we assume the reference separation to be larger than that for portable (type B) equipment.
- A5.11 In the absence of data on the WSD antenna heights, we assume values of 5 metres and 1.5 metres for type A and type B WSDs respectively.
- A5.12 In relation to derivation of WSD emission limits for PMSE use in other channels we assume a PMSE body gain of 0 dB and a WSD body gain of 0 dB. Such assumptions are conservative, but in consideration of PMSE use in channel 38 we assume realistic values of -6 dB for PMSE body gain and -6 dB for type B WSD body gain<sup>33</sup>. For the same geometries, this has the effect of increasing the allowed WSD radiated power for a given channel separation from outdoor PMSE assignments in channel 38 by 0dB and 6dB respectively for type A and type B WSDs compared to assignments in the other channels.
- A5.13 In addition, for the mitigation of harmful intermodulation products in the context of channel 38 we apply restrictions on the immediately adjacent channels 37 and 39 only. This is because WSDs in other channels will result in third-order PMSE-WSD intermodulation products which fall outside of channel 38.
- A5.14 Parameters additional to those listed in Table A5.1 remain the same as stated in Annex 4.

#### **WSD** emission limits

A5.15 Following scenario (A) above, the calculated restrictions for a type A WSDs are as given in Table A5.2.

<sup>&</sup>lt;sup>33</sup> CEPT Report 30 Report from CEPT to the European Commission in response to the Mandate on "The identification of common and minimal (least restrictive) technical conditions for 790 - 862 MHz for the digital dividend in the European Union", Final Report on 30 October 2009: <u>http://www.erodocdb.dk/docs/doc98/official/pdf/CEPTRep030.pdf</u>

## Table A5.2 - Type A WSD: WSD radiated power must not exceed x dBm/8MHz in relation to PMSE usage in channel 38

x	Channel			
(dBm/8MHz)	38 ± 1	$38\pm2$	$38\pm3$	$38\pm4$
Class 1	24	29	33	36
Class 2	24	25	25	34
Class 3	15	25	33	36
Class 4	5	15	25	34
Class 5	-6	4	15	25

A5.16 Following scenario (B) above, the calculated restrictions for a type B WSD are as given in Table A5.3.

## Table A5.3 - Type B WSD: WSD radiated power must not exceed x dBm/8MHz in relation to PMSE usage in channel 38

x	Channel			
(dBm/8MHz)	$38\pm1$	$38\pm2$	$38\pm3$	$38\pm4$
Class 1	21	26	30	36
Class 2	21	22	22	31
Class 3	12	22	30	36
Class 4	2	12	22	31
Class 5	-9	1	12	22

- A5.17 We considered the possible effects only on the four adjacent channels on each side of channel 38 on the basis that in our tests during a live show as described in our PMSE coexistence test report, we were only able to observe audio deterioration due to first adjacent channel interference. This was with a class 3 WSD radiating at an EIRP of 30 dBm/8MHz (and this was when the relevant microphone was judged to be offstage on the basis that it was not picking up show sound material). Under the same conditions, no audio deterioration was observed for second adjacent channel interference.
- A5.18 The calculated restrictions given in Table A5.2 and Table A5.3 are dominated by adjacent channel interference, i.e. the term  $P_{\text{WSD-PR-PMSE}}$  associated with "direct" transmissions from the WSD to the PMSE receiver, rather than PMSE transmitter intermodulation interference due to WSD interference.

#### Changes following our 2013 consultation

- A5.19 In the 2013 Consultation, we proposed that WSDs not be allowed to operate in channel 38. We uphold that decision.
- A5.20 With regard to adjacent channel coexistence, in our 2013 Consultation we proposed that we would treat PMSE use in channel 38 in exactly the same way as PMSE use in all other channels. Given the absence of location data for PMSE use in channel 38 we used a "reference" horizontal separation between the WSD and PMSE receiver of 10 metres. Also, we assumed the WSD and PMSE antennas to be at the same height.
- A5.21 Our current decision based on the above scenarios leads to new restrictions to ensure greater protection to PMSE. The overall effect is a tightening of up to 20 dB

in relation to type B WSD radiated power restrictions and up to 17 dB in relation to type A WSD radiated power restrictions.

A5.22 Section 8 explains how we used the results of our testing programme to ensure that all the changes below, taken together, will result in a low probability of harmful interference to PMSE equipment operating under shared licences in channel 38.

Change	2013 Consultation	Statement
Assumed "reference" separation between WSD and WSD receiver.	10 metres	30 metres for type A WSD. 10 metres for type B WSD.
WSD antenna height	Assumed to be same height as PMSE	5 metres for type A WSD (same as assumed PMSE antenna height). 1.5 metres for type B WSD.
Inclusion of body gain	No	Yes – for type B WSDs. Yes – for PMSE in calculation of restrictions associated with PMSE transmit intermodulation.
Other changes in relation to the modelling.	As detailed in Annex 4.	

#### Table A5.4: Summary of changes following our 2013 consultation.
### Annex 6

# Approach to determining WSD emission limits taking account of mobile services above 790 MHz

### Introduction

A6.1 In this annex we present our detailed analysis to show that our coexistence rules in relation to mobile services at 800 MHz will ensure a low probability of harmful interference. As explained in the main body of this document, we will not allow WSDs to transmit at channel 60, but will not implement any additional restrictions to channel 59 or below.

### Band plan for mobile services in the 800 MHz band

A6.1 Figure A6.1 below shows the UK band allocation following the 4G auction of the 800 MHz band<sup>34</sup>, which follows the preferred European harmonised frequency arrangement<sup>35</sup>.



Figure A6.1 - The UK 800 MHz band plan

- A6.1 In the absence of WSD, base-to-mobile and mobile-to-mobile interference are possible. The calculations in our 2013 consultation concluded that the effects of mobile transmit to mobile receive interference in the FDD band are lower than those of the other interference mechanisms considered. 800 MHz mobile to mobile interference is therefore not considered further.
- A6.2 The remaining sources of interference are shown in Figure A6.2. 800 MHz mobiles operating in the FDD-DL band are potential victims from WSDs operating below 790 MHz and base to mobile interference from mobile base stations operating in adjacent spectrum blocks.

<sup>&</sup>lt;sup>34</sup> http://media.ofcom.org.uk/2013/02/20/ofcom-announces-winners-of-the-4g-mobile-auction/.

<sup>&</sup>lt;sup>35</sup> The European preferred harmonised frequency arrangement for mobile/fixed communication networks (MFCNs) is specified by Annex 1 of ECC/DEC/(09)03. This consists of a frequency division duplex (FDD) channelling arrangements of 2x30 MHz, based on a block size of 5 MHz, a duplex gap of 11 MHz, and a duplex spacing of 41 MHz. The downlink starts at 791 MHz and the uplink starts at 832 MHz (reverse duplex). This implies a 1 MHz guard band between MFCNs and UHF DTT services.

#### Figure A6.2 - Interference from WSDs contrasted with base-to-mobile interference



#### Interference to 800 MHz mobile stations

- A6.1 Our approach is based on comparing the impact of WSD-to-mobile and base-tomobile interference, and demonstrating that additional interference introduced by WSDs is not limiting. In our analysis we assume:
  - b) LTE base stations operating in block  $A_1$  and  $A_2$  may transmit at an in-block EIRP of up to 61 dBm/(5MHz). LTE base stations operating in blocks B and C may transmit at an in-block EIRP of up to 64dBm/(10 MHz). WSDs may transmit (subject to permission from a WSDB) at an in-block EIRP of up to 36 dBm/(8 MHz). These figures are shown in Table A6.1.
  - c) The ACLRs of base stations are derived from the block edge masks in ECC Decision ECC/DEC/(09)03 (and EC Decision 2010/267/EU). These masks were in turn derived from the 3GPP specifications TS 36.105 subject to a 15 dBi antenna gain for comparison with in-block EIRPs.
  - d) The ACLRs of WSDs with respect to the 800 MHz band are derived<sup>36</sup> from the ETSI Harmonised Standard (EN 301 598).
  - e) The ACSs of mobile stations are derived from the selectivity and blocking specifications in 3GPP TS 36.101.
  - The WSD in-block emissions in channels 59 and below<sup>37</sup> will be suppressed due f) to the stop-band attenuation of the duplex filter at the mobile station receiver.
- A6.2 The resulting adjacent channel interference ratios (ACIRs) and the term  $P_{(dBm)} - ACIR_{(dB)}$  for the relevant adjacencies are shown in Table A6.2<sup>38</sup>. In this table the LTE mobile station adjacent channel selectivity from 3GPP TS 36.101 for the relevant adjacencies is supplemented by 50 dB in the case of 800 MHz mobile interference from WSDs operating in channel 59 and below. This additional selectivity accounts for the duplex filtering in the mobile.

<sup>&</sup>lt;sup>36</sup> The WSD emission limit over the band 790-862 MHz is specified at -54 dBm/(100 kHz) in ETSI EN 301 598. For an in-block EIRP of 36 dBm, this corresponds to an ACLR of 36 - (-54+17) = 73 dB.

The WSD in-block emissions in channels 60 would partially fall within the transition band of mobile station duplex filters, and so would not be suppressed as much as those in channels 59 and below.

This table is Table 6.5 from the 2013 Consultation.

A6.3 As the ACLRs of WSDs are significantly more stringent than those of LTE base stations the values of  $P_{(dBm)} - ACIR_{(dB)}$  in Table A6.2 are lower for WSDs than for 800 MHz base stations operating in adjacent blocks.

#### Table A6.1 - Maximum in-block EIRP of LTE base stations and WSDs

	LTE BS (10MHz)	LTE BS (5MHz)	WSD
P (dBm)	64	61	36

#### Table A6.2 - WSD-to-mobile and base-to-mobile interference

Adjacency	ACLR (dB)	ACS (dB)	ACIR (dB)	P – ACIR
$60 \rightarrow A_1$		33	33	3
$59 \rightarrow A_1$	72			
$58 \rightarrow A_1$	/3	98 <sup>+</sup>	73	-37
$57 \rightarrow A_1$				
$A_1 \leftarrow A_2$	39	33	32	29
$A_1 \leftarrow B$	46	36	36	28
$A_1 \leftarrow C$	46	48	44	20

+ Includes 50 dB of added discrimination due to duplex filtering.

- A6.4 However, in future scenarios where WSDs become common, a mobile device may become more likely to be in the close proximity (say, tens of metres) of a WSD than an adjacent channel base station. As a result, a mobile station might occasionally receive significant levels of interference from a WSD in channel 60.
- A6.5 Furthermore, base-to-mobile interference is an issue which affects all mobile network operators (MNOs). For this reason, MNOs have an incentive to coordinate and to mitigate such interference, for example, though a judicious selection of base station sites. Such coordination is not possible between a MNO and users of WSDs.
- A6.6 Given the above, we continue to believe that it would be prudent at this stage to prohibit WSDs from operating in channel 60.
- A6.7 Interference levels from WSDs in channels 59 and below are expected to be much lower than those in channel 60. As such, we do not believe that any restrictions are required for the operation of WSDs in channels 59 and below.
- A6.8 We intend to review our position in light of further studies and evidence in this area, and to explore the possibility of relaxing the proposed restrictions.

### Sensitivity analysis

- A6.9 Respondents to the consultation suggested some alternative input values for our calculations. We performed some sensitivity analysis and concluded that even using potentially very pessimistic values for these parameters, our conclusions remain the same and there is no need for any restrictions to channel 59 operation.
- A6.10 The fact that we have used these values for sensitivity analysis does not imply that we agree that these are appropriate reference values these were performed to help us assess whether additional work was required; and are here to show the calculations are robust to some worst case scenarios.

- A6.11 We perform our analysis by varying the following variables:
  - a) Duplex filter attenuation of 30 dB (at 9 MHz) rather than 50 dB;
  - b) We performed calculations for when the distance between WSD and handset of 2m.
- A6.12 Table A6.3 shows the results using this revised duplexer attenuation with changed numbers shown in italics. As the main contribution to ACIR is from leakage rather than selectivity the revised assumption the value of  $P_{(dBm)} ACIR_{(dB)}$  in Table A6.3 is increased by less than 1 dB.

## Table A6.3 - WSD-to-mobile and base-to-mobile interference assuming reduced duplex filter attenuation

Adjacency	ACLR (dB)	ACS (dB)	ACIR (dB)	P – ACIR
$60 \rightarrow A_1$		33	33	3
$59 \rightarrow A_1$	72			
$58  ightarrow A_1$	/3	78 <sup>+</sup>	72	-36
$57 \rightarrow A_1$				
$A_1 \leftarrow A_2$	39	33	32	29
$A_1 \leftarrow B$	46	36	36	28
$A_1 \leftarrow C$	46	48	44	20

+ Includes 30 dB of added discrimination due to duplex filtering.

- A6.13 The revised values of P ACIR imply that the levels of interference that a mobile station would receive when in the proximity of a WSD in channel 59 and below are not highly dependent on assumptions about the discrimination of the duplex filter in the mobile as long as this exceeds 30 dB or so at an offset of 9 MHz from the band mobile band edge.
- A6.14 At a spacing of 2m the free-space minimum coupling loss at 790 MHz between the WSD and the mobile would be ~36 dB, excluding any additional losses associated with either the WSD or mobile being worn or resting on a surface. The difference between (P ACIR) for the case  $(A_1 \leftarrow A_2)$  and  $(59 \rightarrow A_1)$  from Table A6.3 is 29 (-36) = 65 dB. The minimum coupling loss to a base station in an adjacent block would have to be greater than 36 + 65 = 101 dB before the WSD interference exceeded that of the adjacent base station<sup>39</sup>. As the actual minimum coupling loss observed in typical macro cellular deployments is less than this even allowing for indoor penetration loss, the conclusion is that the out of band specifications in EN301 598 ensure that interference from a WSD situated 2m from a mobile and transmitting on channels 59 and below is less than that from base stations operating in an adjacent block under a wide range of circumstances.

### **Summary and conclusions**

A6.15 For the reasons above, we will not allow WSDs to operate in channel 60, but will not impose any restrictions related to protection to mobile services above the band in channels 59 or below.

<sup>&</sup>lt;sup>39</sup> Both base stations and WSDs are likely to exceed the relevant leakage specifications by a margin, and if they both do so to a similar extent, these effects will cancel each other out.

### Annex 7

# Approach to determining WSD emission limits taking account of services below the UHF TV band

### Introduction

- A7.1 In this section we examine the issue of interference from WSDs to services operating below the UHF TV band.
- A7.2 In the Section 7 of the technical analysis document accompanying our 2013 consultation we presented proposed WSD emission limits to ensure a low likelihood of harmful interference to breathing apparatus (BA) telemetry equipment as used by the UK Fire and Rescue Service. This service is due to migrate to the sub-band 469.850 to 470MHz by end of 2015 and we consider this to be one of the most vulnerable services for the purpose of establishing WSD emission restrictions in relation to spectrum use below 470 MHz. This is because of the safety of life use of BA telemetry equipment as well as the challenging interference geometries it presents. As such, we consider BA telemetry equipment to be an appropriate representative service for our calculations.
- A7.3 The preferred means of protecting services below the band proposed in our 2013 Consultation was to restrict the level of unwanted WSD emissions below 470 MHz. We proposed to introduce an 8 dB reduction of the WSD emissions limit as set out in the draft harmonised standard EN 301 598<sup>40</sup> over the band 230 to 470MHz from the current value of -36 dBm/(100 kHz) down to a revised value of -44 dBm/(100 kHz).
- A7.4 This reduction was rejected by ETSI on the basis that the proposed reduction was a UK specific requirement since no other jurisdictions within Europe had licensed breathing apparatus in this band.
- A7.5 The material in this annex therefore adopts a refined version of the alternative approach presented in the consultation which is to introduce class-specific restrictions on the in-block EIRPs of WSDs in channels 21 to 24.

# Potential for harmful interference from WSDs to breathing apparatus operating in the band 469.85 to 470 MHz

A7.6 The fire and rescue services have long used self-contained breathing apparatus to undertake operations in hazardous areas such as those filled with smoke or toxic vapour. BA telemetry is essential and provided for safety of life purposes. The potential risk caused by interference from WSDs to BA telemetry equipment is the highest compared to the other services in the UHF 2 band. Furthermore, BA telemetry can pose challenging interference geometries, with the possibility of low separations between the telemetry equipment and WSDs.

<sup>&</sup>lt;sup>40</sup> At the time of our 2013 Consultation, the ETSI standard was in draft (see Draft ETSI EN 301 598, v 1.0.0 (2013-07)). This limit has been adopted in the current version of the ETSI Harmonised Standard as published in the OJEU.

A7.7 For these reasons, we consider BA telemetry to be an appropriate representative of the services in the UHF 2 band for deriving WSD emission limits which ensure a low probability of harmful interference to services below the UHF TV band.



Figure A7.1 - Interference from WSDs operating in channels 21 to 24

- A7.8 Previous studies carried out on behalf of Ofcom by Thales<sup>41</sup> and Aegis,<sup>42</sup> considered the impact of LTE mobile stations in the 800 MHz uplink band (832 to 862MHz) on the BA telemetry equipment at 862.9625 MHz and 869.5 MHz.
- A7.9 We described in Section 7 of the technical analysis document accompanying our 2013 Consultation how the potential for interference from WSDs to planned BA telemetry operating in 469.875 to 470MHz can be compared with the levels of interference which the BA telemetry experience in their current allocation at 869.5 MHz from LTE uplink block C. This analysis concluded that the out-of-band emission levels of WSDs must not exceed -45 5 = -50 dBm/(25 kHz) or -44 dBm/(100 kHz) at 469.9375 MHz<sup>43</sup>.
- A7.10 The ETSI Harmonised Standard (EN 301 598)<sup>44</sup> for WSDs specifies that the level of unwanted emissions from WSD over the 230 to 470MHz band must not exceed -36 dBm/(100kHz). In order to mitigate the interference from WSDs to BA telemetry equipment to -44 dBm/(100kHz) the unwanted emission level below 470 MHz would therefore need to be 8 dB more stringent.
- A7.11 BA telemetry operating in 469.875 to 470MHz has a sensitivity limit of around -107 dBm with a C/I (Carrier Interference ratio) requirement of 10dB in its operating bandwidth of 25 kHz. A typical interference geometry is the approach of a type B (mobile) WSD close to the BA entry control board (ECB) which is typically deployed outside near an incident. Considering free space losses associated with this geometry, BA telemetry operating 10 dB above its sensitivity limit is unconditionally protected from a WSD with an out of band limit of -44 dBm/(100 kHz) if the WSD is located more than 36m from the ECB. This 'exclusion zone' reduces to 18m if the type B WSD is body-worn and therefore subject to 6 dB body losses.

<sup>&</sup>lt;sup>41</sup> Thales Research and Technology (UK), "862-863 MHz breathing apparatus telemetry system interference study," 15 Dec 2010, <u>http://stakeholders.ofcom.org.uk/binaries/consultations/tlc/thales-report.pdf</u>.

 <sup>&</sup>lt;sup>42</sup> Aegis System Limited, "Breathing apparatus telemetry system interference study," 19 Mar 2012, <u>http://stakeholders.ofcom.org.uk/binaries/spectrum/spectrum-awards/spectrum-clearance/Aegis\_Report.pdf</u>.
 <sup>43</sup> 469.9375 MHz is the centre of the potential BA telemetry operating band 469.875-470 MHz.

<sup>&</sup>lt;sup>44</sup> ETSI EN 301 598, v 1.1.1 (2014-04), "White space devices (WSD); Wireless access systems operating in the 470 MHz to 790 MHz frequency band; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

A7.12 In seeking to ensure an out of band limit of -44 dBm/(100 kHz) the technical analysis document accompanying our consultation of September 2013 assumed that the WSD out-of-band emission levels are derived from the more stringent of the class-specific ACLR values given in EN 301 598 and the absolute emission limit of -36 dBm over the 230 to 470MHz band. We also assumed a 10 dB/(8 MHz) roll-off of out-of-band emissions with increasing frequency separation from the band edge. Figure A7.2 illustrates the emissions mask for a class 5 device operating in channel 21 at the highest operating power of 36 dBm/(8 MHz) or 17 dBm/(100 kHz).

# Figure A7.2 - ACLR and out of band emissions for a class 5 WSD in channel 21 coexisting with BA telemetry compared to the limits in EN 301 598 (shown as dashed red lines where higher)



- A7.13 In Section 7 of the technical analysis document accompanying our 2013 Consultation we published a set of class specific power restrictions designed to ensure that the lower emissions limits shown by the solid red lines in Figure A7.2 are met. These limits were proposed with reference to the highest operating power of 36 dBm/(8 MHz).
- A7.14 The limits proposed in the consultation would only be sufficient if they applied relative to the maximum power that the WSD could transmit whilst meeting the emissions mask in EN 301 598. EN 301 598 does not contain device power classes, and no specific assumptions can therefore be made regarding the maximum power of a WSD.
- A7.15 We have therefore decided to tighten the limits for class-specific restrictions in the maximum permitted in-block EIRP of WSDs in DTT channels above the 470 MHz band edge. These restrictions have the effect of reducing the out-of-band emissions below 470 MHz to the required level of -44 dBm/(100 kHz), irrespective of the maximum power of the WSD, under the assumption that WSD out-of-band emission levels are the more stringent of the class-specific ACLR values given in EN 301 598 and the absolute emission limit of -36 dBm. The resulting power restrictions are given in Table A7.1.

# Table A7.1 - WSD in-block EIRP dBm/(8 MHz) must not exceed the following class specific limits in relation to services below 470 MHz. Where no figure is given in this table no specific power limits apply

	DTT channel				
	21	22	23	24	25
Class 1	30	35	-	-	-
Class 2	30	30	30	-	-
Class 3	20	30	-	-	-
Class 4	10	20	30	-	-
Class 5	-1	9	20	30	-

- A7.16 EN 301 598 specifies the ACLR in 100 kHz relative to the full in-band EIRP in 8 MHz. As a result, no further specific restrictions to spectral power density are required in order to meet the out of band emissions objective of -44 dBm/(100 kHz).
- A7.17 In summary:
  - WSDs with class 1 and 3 spectrum emission masks may operate without restriction in channel 23 and above.
  - WSDs with class 2 and 4 spectrum emission masks may operate without restriction in channel 24 and above.
  - WSDs with class 5 spectrum emission mask may operate without restriction in channel 25 and above.

### **Summary and conclusions**

- A7.18 The breathing apparatus (BA) telemetry used by the UK Fire and Rescue Services is due to migrate to the sub-band 469.850 to 470MHz by the end of 2015. As BA telemetry is a life-critical system and can present challenging interference scenarios, we have considered it as representative of other services in the UHF 2 band.
- A7.19 In deriving WSD emission limits to ensure a low probability of harmful interference to the BA telemetry service below 470 MHz, we established a limit for out of band emissions from WSDs with reference to existing operation above the 800 MHz LTE uplink transmissions.
- A7.20 We believe that interference from WSDs to BA telemetry and other services below 470 MHz can be mitigated by restricting the level of unwanted WSD emissions below 470 MHz to -44 dBm/(100 kHz). We therefore intend to propose class-specific EIRP limits on WSDs operating in channels 21 24.

### Annex 8

# **WSDB** calculations

- A8.1 This section explains the detail of how a WSDB must derive the Operational Parameters that it provides to a requesting WSD.
- A8.2 As explained in Annex 1, Ofcom will carry out the calculations of the limits for protection of DTT in the UK, cross border DTT, users below 470 MHz and above 790 MHz, and PMSE users in channel 38. Ofcom will provide WSDBs with the datasets with those limits.
- A8.3 WSDBs will calculate the limits for protection of PMSE users in channels other than channel 38<sup>45</sup>, and then combine the various limits to produce the final EIRP limits that WSDs will have to comply with. The EIRP limits will be part of the Operational Parameters that the WSDB provides to the WSDs. In addition to the EIRP limits, the Operational Parameters include a few other elements that the WSDB will either calculate or simply take the value provided by Ofcom.
- A8.4 This section explains the detail of how a WSDB must derive the Operational Parameters that it provides to a requesting WSD.
- A8.5 We will provide this detailed description of the calculations to the WSDBs as part of the contract that Ofcom and WSDB operators will sign prior to a WSDB being qualified to operate. WSDBs will be required by the contract to follow these calculations (we may introduce changes to these calculation descriptions between now and the signature of the contracts but we do not expect these changes to be material). The rest of this annex is structured as follows:
  - a) Part 1 gives a brief overview of the datasets that a WSDB requires to perform the calculations.
  - b) Part 2 describes the calculation of Specific Operational Parameters for a master WSD. The WSDB derives these on the basis of the device parameters that the master WSD reports in its query, and the information about incumbent use provided by Ofcom.
  - c) Part 3 describes the calculation of Generic Operational Parameters. These parameters could be used by any slave WSD located in the coverage area of a master WSD. In order to calculate generic operational parameters, the WSDB first estimates the coverage area of the master WSD and then makes the assumption that a slave WSD could be anywhere in that area. The WSDB also makes several cautious assumptions about the technical characteristics of the slave WSD.
  - d) Part 4 describes the calculation of Specific Operational Parameters for a slave WSD. This calculation is largely identical to the calculation of Operational Parameters for a master WSD. The changes are certain assumptions about the antenna height.

<sup>&</sup>lt;sup>45</sup> WSDBs will also calculate limits for protection of PMSE users in channel 38 where there is an assignment and the location is known.

- e) Part 5 describes the algorithm for calculation of the EIRP limit for protection of PMSE.
- f) Part 6 describes the algorithm for calculation of the coverage area of a master WSD.
- g) Part 7 describes the calculation of the antenna height of a device.
- h) Part 8 lists the default values that a WSDB will use when certain Device Parameters are not available, and the values provided by Ofcom for for certain Operational Parameters, and the table with the location agnostic limits.

## Part 1 - Overview of calculation datasets

#### Device parameters and operational parameters

A8.6 A master WSD will communicate to a WSDB its device parameters, or the device parameters of a slave that has attached to it, according with the format of ETSI HS 301 598. The WSDB will respond with operational parameters compliant with the format of the ETSI HS. The specific implementation will depend on the protocol that WSDBs and WSDs use to communicate.

#### **EIRP limits for protection of DTT**

- A8.7 Of com will calculate the EIRP limit, in dBm/8 MHz, for all 100 metres x 100 metres pixel in the UK, for all DTT channels from channel 21 to channel 60. We will calculate these limits for all combinations of the following:
  - WSD height above ground: H = 1.5, 5, 10, 15, 20, 30, and "D" metres,

where "D" represents a default height (a mixture of 10 and 30 metres) for Type A WSDs.

• WSD emission class: CL = 1, 2, 3, 4, 5.

#### PMSE assignment data

- A8.8 Ofcom will provide the WSDBs with a list with the details of the PMSE assignments that have been granted. The following information will be made available for each assignment:
  - Unique identifier for the assignment
  - Type of equipment used in the assignment: Talkback, Wireless microphone, Programme link (audio), Programme link (video), Data or In ear monitor
  - Eastings and northings of the PMSE assignment (expressed to a precision of one metre) referenced to the Ordnance Survey National Grid
  - Height above ground level of PMSE antenna in metres. A default value of 5 metres will be assumed in the absence of available information
  - Centre frequency in MHz
  - Bandwidth in MHz
  - Start and finish timestamps
  - Situation of the assignment. Can take the values: indoor, outdoor and airborne

#### Unscheduled adjustments to maximum WSD power (input #6)

A8.9 Ofcom will provide the unscheduled adjustments in a file with a number of rows, each row corresponding to an unscheduled adjustment region specified by the southwest corner, a northings size and an eastings size.

- A8.10 For each unscheduled adjustment, Ofcom may provide values for the following parameters. The WSDB will have to use the values in the adjustment in the Operational Parameters that it communicates to the device.
  - Update timer (T<sub>update</sub>)
  - Location validity value to be included in the operational parameters for devices whose reported location is in the geographical area of the adjustment, in metres. No change if empty
  - Maximum permitted nominal channel bandwidth
  - Maximum permitted total bandwidth
  - Simultaneous channel operation power restriction
  - P<sub>1</sub> EIRP limit, in dBm/8MHz, for any of the channels between channel 21 and channel 60

### Part 2 - METHODOLOGY FOR THE CALCULATION OF MASTER OPERATIONAL PARAMETERS

- A8.11 The Master Operational Parameters shall be calculated using the methodology set out in this Section. Specific protocol implementations may use different terminology to refer to these parameters.
- A8.12 The WSDB shall use the OSTN02 and OSGM02 models for conversion of a location specified using the WGS84 or ETRS89 coordinate reference systems into a location specified using the OSGB36 coordinate reference system, or vice versa. These models are available at: <u>http://www.ordnancesurvey.co.uk/business-and-government/help-and-support/navigation-technology/os-net/formats-for-developers.html</u>
- A8.13 Location conversion accuracy will be specified by Ofcom. The reference is the Ordnance Survey online tool at <a href="http://www.ordnancesurvey.co.uk/gps/transformation">http://www.ordnancesurvey.co.uk/gps/transformation</a>

#### List of available DTT channels

A8.14 These represent the indexes of all DTT channels in the UHF TV band, i.e. channels 21 to 60, that the Master WSD may use. Where Ofcom decides that certain channels are not available for use by WSDs, these will be excluded from the list. Furthermore, a WSDB may choose not to provide Operational Parameters for a certain subset of DTT channels, in which case these may also be excluded from the list of available DTT channels.

#### Maximum permitted in-block EIRP P<sub>1</sub> in dBm/(8 MHz) in each DTT channel

- A8.15 This limit is calculated to ensure a low probability of harmful interference to DTT and other services with the exception of location-specific PMSE, on the basis of the reported horizontal location (x,y) and location uncertainty ( $\Delta x$ ,  $\Delta y$ ) reported by the Master WSD (as well as other Device Parameters).
- A8.16 The WSDB shall use the reported horizontal location and location uncertainty of the Master WSD to define a geographical area within which the Master WSD might be located (the area of potential locations).
- A8.17 The 100 metres x 100 metres pixels which totally or partially overlap with the area of potential locations will be designated as WSD candidate pixels. This is shown in the figure below:

# Figure A8.1 - Candidate pixels for calculation of the maximum permitted in-block EIRP for a Master WSD



- A8.18 For each candidate pixel, *i*, and each channel, *F*, in the list of available DTT channels, the WSDB shall look up the  $P_{DTT}$  value in the datasets provided by Ofcom. The following parameters will also be used for the look up:
  - The Master WSD emission class reported by the device.
  - The height above ground level or above sea level reported by the device
- A8.19 If the WSD does not report its device emissions class, the WSDB shall use the default emissions class specified in table A8.14 in Part 8 for the look up.
- A8.20 If the Master WSD is a type A device, the look up process shall use the emission class and antenna height above ground as follows:
  - Where a Type A WSD reports its height, the antenna height above ground  $h_{\rm WSD}$  shall be calculated first in accordance with Part 7. The WSDB shall then look up  $P_{\rm DTT}$  in the dataset that corresponds to the value of H which is closest to  $h_{\rm WSD}$ . If  $h_{\rm WSD}$  is exactly between two values of H, the dataset for the larger H shall be used.
  - Where a Type A WSD does not report its height, WSDBs shall use the dataset for height D.
- A8.21 Examples for a type A device:

- If a Type A class-3 WSD reports a  $h_{_{\rm WSD}}$  of 7.5 metres, WSDBs shall use the dataset for CL = 3 and H = 10.
- If a Type A class-2 WSD reports a h<sub>WSD</sub> of 7.1 metres, WSDBs shall use the dataset for CL = 2 and H = 5.
- If a Type A class-4 WSD does not reports its height, WSDBs shall use the dataset for CL = 4 and H = D.
- A8.22 If the Master WSD is a type B device, the look up process shall use the emission class and antenna height above ground as follows:
  - Where a Type B WSD reports its height, the antenna height above ground  $h_{\rm WSD}$  shall be calculated first in accordance with Part 7. The WSDB shall then look up  $P_{\rm DTT}$  in the dataset that corresponds to the value of H which is closest to  $h_{\rm WSD}$ . If  $h_{\rm WSD}$  is exactly between two values of H, the dataset for the larger H shall be used. If  $h_{\rm WSD} > 2$  metres, WSDBs shall add 7 dB to the  $P_{\rm DTT}$  value obtained in the look up to account for a wall loss  $L_{\rm W,SECTION2}$  of 7 dB (WSD is assumed to be indoor).
  - Where a Type B WSD does not report its height, WSDBs shall use the dataset for default type B master specified in table A8.14 in Part 8.
- A8.23 In addition, if the Master WSD is a type B device, the WSDB shall add [0] dB to the  $P_{DTT}$  value to account for body gain ( $G_{B,SECTION2}$ )
- A8.24 Examples for a type B device:
  - If a Type B class-3 WSD reports a  $h_{WSD}$  of 2.9 metres, WSDBs shall use the dataset for CL = 3 and H =1.5, and add 7 dB to the WSD emission limits.
  - If a Type B class-4 WSD reports a  $h_{WSD}$  of 2.2 metres, WSDBs shall use the dataset for CL = 4 and H = 1.5, and add 7 dB to the WSD emission limits.
  - If a Type B class-4 WSD reports a h<sub>WSD</sub> of 1.2 metres, WSDBs shall use the dataset for CL = 4 and H = 1.5.
  - If a Type B class-4 WSD does not reports its height, WSDBs shall use the dataset for CL = 4 and H = 1.5.
- A8.25 See Part 1 for the different heights for which Ofcom shall provide datasets.
- A8.26 Repeating the above for each candidate pixel and each available channel, the result will be a number of EIRP values  $P_{\text{DTT}}(i, F)$ .
- A8.27 For an available channel  $F_0$ ,  $P_{DTT}(F_0)$  will be the smallest of the  $P_{DTT}(i, F_0)$  values over the candidate WSD pixels.
- A8.28 The WSDB shall next calculate  $P_1(F_0)$  as the minimum of:
  - 36 dBm
  - $P_{\text{DTT}}(F_0)$  as calculated above

- $P_{LA}(F_0)$ , the location agnostic limit for that channel.  $P_{LA}(F_0)$  accounts for protection of spectrum use above and below the TV band, and for protection of PMSE use in channel 38. The limit is a function of the emission class of the device, the type of the device and the channel. The WSDB shall look up  $P_{LA}(F_0)$  from table A8.16 in Part 8.
- A8.29 If the location reported by the Master WSD is within any of the unscheduled adjustment regions provided by Ofcom, then  $P_1(F_0) = P_{UA}(F_0)$ , where  $P_{UA}(F_0)$  is the limit in the unscheduled adjustment file for that region for that channel. If the location reported by the Master WSD is within more than one unscheduled adjustment regions, then  $P_{UA}(F_0)$  is the minimum of the values in each region.

# Maximum permitted in-block EIRP spectral density $P_0$ in dBm/(100 kHz) in each DTT channel

- A8.30 The value of  $P_0$  at a specific DTT channel is calculated by the WSDB as the minimum of two values, one for protection of DTT derived from  $P_1$  above, and one for protection of PMSE,  $P_{\text{WSD-PMSE}}$ , calculated as described in the following paragraphs.
- A8.31 As above, the WSDB shall use the reported horizontal location and location uncertainty of the Master WSD to define a geographical area within which the WSD might be located (the area of potential locations).
- A8.32 The WSDB shall evaluate  $P_{\text{WSD-PMSE}}$  at a set of candidate locations. The candidate locations shall correspond to those grid points whose squares totally or partially overlap with the area of potential locations of a WSD. The grid itself shall be aligned with the NGR grid and shall have a resolution  $D_{GRID}$  of 10 metres. This shown in the figure below:

# Figure A8.2 - Candidate locations for calculation of the Maximum permitted in-block EIRP spectral density to ensure a low probability of harmful interference to PMSE, $P_{\text{WSD-PMSE}}$



○ Candidate locations of WSD

- A8.33 For each PMSE assignment which is active at any point in time between the Time validity start ( $T_{ValStart}$ ) time and the time validity end ( $T_{ValEnd}$ ) time (for the avoidance of doubt,  $T_{ValStart}$  and  $T_{ValEnd}$  are the start and end times of validity of the operational parameters):
- A8.34 For each candidate location, *i*, and each channel, *F*, in the list of available DTT channels, the WSDB shall calculate *the maxim*um permitted in-block EIRP spectral density according to the procedure in Part 5. The following parameters shall also be used for the calculations in Part 5:
  - The Master WSD emission class; and
  - Master WSD antenna height above ground level, calculated according to Part 7.
- A8.35 If the WSDB does not receive the emission class of the WSD, it shall use the default emissions class specified in table A8.14 in Part 8. If the WSDB does not receive the antenna height, it shall use the height value from table A8.14 in Part 8 that corresponds to the type of the Master WSD.
- A8.36 Repeating the procedure in Part 5 for each candidate Master WSD location and each available channel, the result will be a number of EIRP spectral density values  $P_{WSD-PMSE}(i, F)$  for protection of a specific PMSE assignment.
- A8.37 For an available channel,  $F_0$ , the WSDB shall then derive the maximum permitted EIRP spectral density  $P_{\text{WSD-PMSE}}(F_0)$  as the smallest of the  $P_{\text{WSD-PMSE}}(i, F_0)$  values, over the candidate WSD locations and over the different PMSE assignments.
- A8.38 For each PMSE assignment, it may be possible to identify  $P_{\text{WSD-PMSE}}(F_0)$  without having to exhaustively calculate  $P_{\text{WSD-PMSE}}(i,F_0)$  at all candidate locations – for instance by evaluating  $P_{\text{WSD-PMSE}}(i,F_0)$  at a limited number of candidate locations that are geographically closest to the PMSE victims, in the absence of unscheduled adjustments. The WSDB may optimize its processes in this way provided that the  $P_{\text{WSD-PMSE}}(F_0)$  obtained is equal to the value obtained through the exhaustive procedure.
- A8.39 It may also be possible to identify the PMSE assignments which are close enough to the WSD to be relevant for the calculations in Part 5, and hence limit the PMSE assignments that are evaluated against.
- A8.40 Finally, the EIRP spectral density  $P_0(F_0)$  in dBm/(100 kHz) included in the WSD Operational Parameters will be the minimum of the following two values:
  - i)  $P_{\text{WSD-PMSE}}(F_0)$  as calculated above, and
  - ii)  $P_1(F_0) 10\log_{10}(80)$ , where  $P_1(F_0)$  is the maximum permitted in-block EIRP calculated above.

#### Maximum permitted nominal channel bandwidth and total bandwidth

A8.41 The WSDB shall use the default values communicated by Ofcom, unless the reported location of the device is within an unscheduled adjustment region provided by Ofcom in which case the Max\_nominal\_ch\_BW and the Max\_total\_BW values for the region should be used.

#### Time validity start ( $T_{ValStart}$ ) and time validity end ( $T_{ValEnd}$ )

A8.42 The time validity of the Operational Parameters will normally be defined by changes in the PMSE usage. The WSDB may decide on the start and end times of the validity of a particular operational parameter set. However the WSDB shall ensure that all PMSE assignments that are active during the time interval defined by  $T_{ValStart}$ and  $T_{ValEnd}$  are accounted for and protected.

#### Location validity (L<sub>Val</sub>)

- A8.43 The WSDB shall use the default value communicated by Ofcom, unless the reported location of the device is within an unscheduled adjustment region provided by Ofcom in which case the Location\_validity value for the region should be used.
- A8.44 This parameter is not relevant for Type A WSDs (which are fixed).

#### Update timer (T<sub>Update</sub>)

- A8.45 The WSDB shall use the default value for T<sub>update</sub> communicated by Ofcom, unless the reported location of the device is within an unscheduled adjustment region provided by Ofcom in which case the T\_update value for the region should be used.
- A8.46 Depending on the protocol implementation, the Update Timer information may not be provided as a separate parameter and may be incorporated to the Time validity information.

#### Simultaneous channel operation power restriction

- A8.47 Can take values of 0 or 1.
- A8.48 The WSDB shall use the value communicated by Ofcom, unless the reported location of the device is within an unscheduled adjustment region provided by Ofcom in which case the Simultaneous\_channel value for the region should be used.

# Part 3 - METHODOLOGY FOR THE CALCULATION OF GENERIC OPERATIONAL PARAMETERS FOR SLAVE WSDs

- A8.49 The Generic Operational Parameters shall be calculated using the methodology set out in this Section.
- A8.50 The WSDB shall use the OSTN02 and OSGM02 models for conversion of a location specified using the WGS84 or ETRS89 coordinate reference systems into a location specified using the OSGB36 coordinate reference system, or vice versa. These models are available at: http://www.ordnancesurvey.co.uk/business-and-government/help-and-support/navigation-technology/os-net/formats-for-developers.html
- A8.51 Location conversion accuracy will be specified by Ofcom. The reference is the Ordnance Survey online tool at <u>http://www.ordnancesurvey.co.uk/gps/transformation</u>

#### List of available DTT channels

A8.52 These represent the indexes of all DTT channels in the UHF TV band, i.e. channels 21 to 60, that Slave WSDs may use. Where Ofcom decides that certain channels are not available for use by WSDs, these shall be excluded from the list. Furthermore, a WSDB may choose not to provide Operational Parameters for a certain subset of DTT channels, in which case these may also be excluded from the list of available DTT channels

#### Maximum permitted in-block EIRP P1 in dBm/(8 MHz) in each DTT channel

- A8.53 This limit is calculated to ensure a low probability of harmful interference to DTT and other services with the exception of location-specific PMSE.
- A8.54 The WSDB shall use the reported horizontal location, the location uncertainty and the coverage range of the Master WSD to identify the geographical area within which the Slave WSDs might be located. This is the area of potential locations, and is calculated according to Part 6.
- A8.55 The 100 metres x 100 metres pixels which totally or partially overlap with this area of potential locations will be designated as WSD *candidate* pixels. These are the grey pixels in the figure below:

# Figure A8.3 - Candidate pixels for calculation of the maximum permitted in-block EIRP for Generic Operational Parameters for a Slave WSD



Reported (nominal) location of serving master

- A8.56 For each candidate pixel, *i*, and each channel, *F*, in the list of available DTT channels, the WSDB shall look up the  $P_{DTT}$  value in the datasets provided by Ofcom. The following parameters shall also be used for the look up:
  - Emission class of a generic slave, this will be the default emission class specified in table A8.14 in Part 8.
  - The height of a generic slave WSD specified in table A8.14 in Part 8.
- A8.57 In addition the WSDB shall add [0] dB to the  $P_{DTT}$  value to account for body gain  $(G_{B,SECTION3})$ .
- A8.58 Repeating the above for each candidate pixel and each available channel, the result will be a number of EIRP values  $P_{\text{DTT}}(i, F)$ .
- A8.59 For an available channel  $F_0$ ,  $P_{DTT}(F_0)$  will be the smallest of the  $P_{DTT}(i, F_0)$  values over the candidate WSD pixels in the coverage area of the serving Master WSD.
- A8.60 The WSDB shall next calculate  $P_1(F_0)$  as the minimum of:
  - 36 dBm
  - $P_{\text{DTT}}(F_0)$ , as calculated above
  - *P<sub>LA</sub>(F<sub>0</sub>)*, the location agnostic limit for that channel. *P<sub>LA</sub>(F<sub>0</sub>)* accounts for protection of spectrum use above and below the TV band, and for protection of PMSE use in channel 38. The WSDB shall look up *P<sub>LA</sub>(F<sub>0</sub>)* from table A8.16 in Part 8, with the assumption that the emission class of the device is 5 and that device is type B
- A8.61 If the location reported by the serving Master WSD is within any of the unscheduled adjustment regions provided by Ofcom, then  $P_1(F_0) = P_{UA}(F_0)$ , where  $P_{UA}(F_0)$  is the

limit in the unscheduled adjustment file for that region for that channel. If the location reported by the serving Master WSD is within more than one unscheduled adjustment regions, then  $P_{UA}(F_0)$  is the minimum of the values in each region.

# Maximum permitted in-block EIRP spectral density $P_0$ in dBm/(100 kHz) in each DTT channel

- A8.62 The value of  $P_0$  at a specific DTT channel shall be calculated by the WSDB as the minimum of two values, one for protection of DTT derived from  $P_1$  above, and one for protection of PMSE,  $P_{WSD-PMSE}$ , calculated as described in the following paragraphs.
- A8.63 The WSDB shall use the reported horizontal location, location uncertainty, and coverage radius of the Master WSD to define a geographical area within which the Slave WSDs might be located. This is the area of potential locations calculated according to Part 6.
- A8.64 The WSDB shall evaluate  $P_{\text{WSD-PMSE}}$  at a set of candidate locations. The candidate locations will correspond to those of grid points whose squares totally or partially overlap with the area of potential locations of a WSD. The grid itself will be aligned with the NGR grid and will have a resolution,  $D_{\text{GRID}}$ , of 10 metres. This shown in the figure below:

Figure A8.4 - Candidate locations for calculation of  $P_{\text{WSD-PMSE}}$  for Generic Operational Parameters for a Slave WSD



A8.65 For each PMSE assignment which is active at any point in time between the Time validity start ( $T_{ValStart}$ ) time and the time validity end ( $T_{ValEnd}$ ) time (for the avoidance of doubt,  $T_{ValStart}$  and  $T_{ValEnd}$  are the start and end times of validity of the operational parameters):

- A8.66 For each candidate location, *i*, in the area of potential locations, and each channel, *F*, in the list of available DTT channels, the WSDB shall calculate the maximum permitted in-block EIRP spectral density in dBm/(100 kHz) according to the procedure in Part 5. The following parameters will also be used for the calculations:
  - Emission class of a generic slave, this will be the default emissions class specified in table A8.14 in Part 8.
  - The height of a generic slave WSD specified in table A8.14 in Part 8.
- A8.67 Repeating the above for each candidate location and each available channel, the result will be a number of EIRP spectral density values  $P_{\text{WSD-PMSE}}(i, F)$  in dBm/(100 kHz) for protection of a specific PMSE assignment.
- A8.68 For an available channel,  $F_0$ , the WSDB shall then derive the maximum permitted EIRP  $P_{\text{WSD-PMSE}}(F_0)$ . This will be the smallest of the  $P_{\text{WSD-PMSE}}(i, F_0)$  values, over the candidate locations in coverage area of the serving Master WSD and over the different PMSE assignments.
- A8.69 For each PMSE assignment, it may be possible to identify  $P_{\text{WSD-PMSE}}(F_0)$  without having to exhaustively calculate  $P_{\text{WSD-PMSE}}(i,F_0)$  at all candidate locations – for instance by evaluating  $P_{\text{WSD-PMSE}}(i,F_0)$  at a limited number of candidate locations that are geographically closest to the PMSE victims, in the absence of unscheduled adjustments. The WSDB may optimize its processes in this way provided that the  $P_{\text{WSD-PMSE}}(F_0)$  obtained is equal to the value obtained through the exhaustive procedure.
- A8.70 It may also be possible to identify the PMSE assignments which are close enough to the WSD to be relevant for the calculations in Part 5, and hence limit the PMSE assignments that are evaluated against.
- A8.71 Finally, the EIRP spectral density  $P_0(F_0)$  in dBm/(100 kHz) included in the WSD Operational Parameters will be minimum of:
  - i)  $P_{\text{WSD-PMSE}}(F_0)$  as calculated above
  - ii)  $P_1(F_0) 10\log_{10}(80)$ , where  $P_1(F_0)$  is the Maximum permitted in-block EIRP in the DTT channel calculated above

#### Maximum permitted nominal channel bandwidth and total bandwidth

A8.72 The WSDB shall use the default values communicated by Ofcom, unless the reported location of the serving Master WSD is within an unscheduled adjustment region provided by Ofcom in which case the Max\_nominal\_ch\_BW and the Max\_total\_BW values for the region should be used

#### Time validity start ( $T_{ValStart}$ ) and time validity end ( $T_{ValEnd}$ )

A8.73 The time validity of the parameters will normally be limited by changes in the PMSE usage. The WSDB may decide on the start and end times of the validity of a particular generic operational parameter set. However the WSDB shall ensure that all PMSE assignments that are active during the time interval defined by T<sub>ValStart</sub> and T<sub>ValEnd</sub> are accounted for and protected.

#### Simultaneous channel operation power restriction

- A8.74 Can take values of 0 or 1.
- A8.75 The WSDB shall use the value communicated by Ofcom, unless the reported location of the serving Master WSD is within an unscheduled adjustment region provided by Ofcom in which case the Simultaneous\_channel value for the region should be used.

## Part 4 - METHODOLOGY FOR THE CALCULATION OF SPECIFIC OPERATIONAL PARAMETERS FOR SLAVE WSDs

- A8.76 The Specific Operational Parameters shall be calculated using the methodology set out in this Section. Note that these calculations are the same as those required for the Operational Parameters of a Master WSD.
- A8.77 The WSDB shall use the OSTN02 and OSGM02 models for conversion of a location specified using the WGS84 or ETRS89 coordinate reference systems into a location specified using the OSGB36 coordinate reference system, or vice versa. These models are available at: <u>http://www.ordnancesurvey.co.uk/business-and-government/help-and-support/navigation-technology/os-net/formats-for-developers.html</u>
- A8.78 Location conversion accuracy will be specified by Ofcom. The reference is the Ordnance Survey online tool at http://www.ordnancesurvey.co.uk/gps/transformation

#### List of available DTT channels

A8.79 These represent the indexes of all DTT channels in the UHF TV band, i.e. channels 21 to 60, that the Slave WSD may use. Where Ofcom decides certain channels are not available for use by WSDs, these may be excluded from the list. Furthermore, a WSDB may choose not to provide Operational Parameters for a certain subset of DTT channels, in which case these may also be excluded from the list of available DTT channels.

#### Maximum permitted in-block EIRP P<sub>1</sub> in dBm/(8 MHz) in each DTT channel

- A8.80 This limit is calculated to ensure a low probability of harmful interference to DTT and other services with the exception of location-specific PMSE, and given the reported horizontal location and location uncertainty of the Slave WSD (as well as other Device Parameters).
- A8.81 The WSDB shall use the reported horizontal location (x,y) and location uncertainty  $(\Delta x, \Delta y)$  of the Slave WSD to define a geographical area within which the Slave WSD might be located (the area of potential locations).
- A8.82 The 100 metres x 100 metres pixels which totally or partially overlap with this area of potential locations will be designated as WSD *candidate* pixels. This is shown in figure below:

# Figure A8.5 - Candidate pixels for calculation of the maximum permitted in-block EIRP for a Slave WSD



- A8.83 For each candidate pixel, *i*, and each channel, *F*, in the list of available DTT channels, the WSDB shall look up the  $P_{DTT}$  value in the datasets provided by Ofcom. The following parameters will also be used for the look up:
  - The Slave WSD emission class reported by the device.
  - The height above ground level or above sea level reported by the device
- A8.84 If the WSD does not report its device emissions class, the WSDB shall use the default emissions class specified in table A8.14 in Part 8 for the look up.
- A8.85 If the Slave WSD is a type A device, the look up process shall use the emission class and antenna height above ground as follows:
  - Where a Type A WSD reports its height, the antenna height above ground  $h_{\rm WSD}$  shall be calculated first in accordance with Part 7. The WSDB shall then look up  $P_{\rm DTT}$  in the dataset that corresponds to the value of H which is closest to  $h_{\rm WSD}$ . If  $h_{\rm WSD}$  is exactly between two values of H, the dataset for the larger H shall be used.
  - Where a Type A WSD does not report its height, WSDBs shall use the dataset for height [D].
- A8.86 If the Slave WSD is a type B device, the look up process shall use the emission class and antenna height above ground as follows:

- Where a Type B WSD reports its height, the antenna height above ground  $h_{\rm WSD}$  shall be calculated first in accordance with Part 7. The WSDB shall then look up  $P_{\rm DTT}$  in the dataset that corresponds to the value of H which is closest to  $h_{\rm WSD}$ . If  $h_{\rm WSD}$  is exactly between two values of H, the dataset for the larger H shall be used. If  $h_{\rm WSD} > 2$  metres, WSDBs shall add 7 dB to the  $P_{\rm DTT}$  value obtained in the look up to account for a wall loss  $L_{\rm W,SECTION4}$  of 7 dB (WSD is assumed to be indoor).
- Where a Type B slave WSD does not report its height, WSDBs shall use the dataset default type B slave specified in table A8.14 in Part 8.
- A8.87 In addition, if the Master WSD is a type B device, the WSDB shall add [0] dB to the  $P_{DTT}$  value to account for body gain ( $G_{B,SECTION4}$ )
- A8.88 Repeating the above for each candidate pixel and each available channel, the result will be a number of EIRP values  $P_{\text{DTT}}(i, F)$ .
- A8.89 For an available channel  $F_0$ ,  $P_{DTT}(F_0)$  will be the smallest of the  $P_{DTT}(i, F_0)$  values over the candidate WSD pixels.
- A8.90 The WSDB shall next calculate  $P_1(F_0)$  as the minimum of:
  - 36 dBm
  - $P_{\text{DTT}}(F_0)$ , as calculated above
- A8.91  $P_{LA}(F_0)$ , the location agnostic limit for that channel.  $P_{LA}(F_0)$  accounts for protection of spectrum use above and below the TV band, and for protection of PMSE use in channel 38. The limit is a function of the emission class of the device, the type of the device and the channel. The WSDB shall look up  $P_{LA}(F_0)$  from table A8.16 in Part 8.
- A8.92 If the location reported by the slave WSD is within any of the unscheduled adjustment regions provided by Ofcom, then  $P_1(F_0) = P_{UA}(F_0)$ , where  $P_{UA}(F_0)$  is the limit in the unscheduled adjustment file for that region for that channel. If the location reported by the slave WSD is within more than one unscheduled adjustment regions, then  $P_{UA}(F_0)$  is the minimum of the values in each region.

# Maximum permitted in-block EIRP spectral density $P_0$ in dBm/(100 kHz) in each DTT channel

- A8.93 The value of  $P_0$  at a specific DTT channel is calculated by the WSDB as the minimum of two values, one for protection of DTT derived from  $P_1$  above, and one for protection of PMSE,  $P_{WSD-PMSE}$ , calculated as described in the following paragraphs.
- A8.94 As above, the WSDB shall use the reported horizontal location and location uncertainty of the Slave WSD to define a geographical area within which the Slave WSD might be located (the area of potential locations).
- A8.95 The WSDB shall evaluate  $P_{WSD-PMSE}$  at a set of candidate locations. The candidate locations will correspond to those of grid points whose squares totally or partially overlap with the area of potential locations of a WSD. The grid itself will be aligned

with the NGR grid and will have a resolution  $D_{GRID}$  of 10 metres. This shown in the figure below:

Figure A8.6 - Candidate locations for calculation of the Maximum permitted in-block EIRP spectral density to ensure a low probability of harmful interference to PMSE,  $P_{\text{WSD-PMSE}}$ 



- Candidate locations of WSD
- A8.96 For each PMSE assignment which is active at any point in time between the Time validity start ( $T_{ValStart}$ ) time and the time validity end ( $T_{ValEnd}$ ) time (for the avoidance of doubt,  $T_{ValStart}$  and  $T_{ValEnd}$  are the start and end times of validity of the operational parameters):
- A8.97 For each candidate location, *i*, and each channel, *F*, in the list of available DTT channels, the WSDB will calculate the maximum permitted in-block EIRP spectral density in dBm/(100 kHz) according to the procedure in Part 5. The following parameters shall also be used for the calculations:
  - Slave WSD emission class; and
  - Slave WSD antenna height above ground level, which shall be calculated in accordance with Part 7.
- A8.98 If the WSDB does not receive the emission class of the WSD, it shall use the default emissions class specified in table A8.14 in Part 8. If the WSDB does not receive the antenna height, it shall use the height value from table A8.14 in Part 8 that corresponds to the type of the slave device.
- A8.99 Repeating the procedure in Part 5 for each candidate Slave WSD location and each available channel, the result will be a number of EIRP spectral density values  $P_{WSD-}_{PMSE}$  (*i*,*F*) for protection of a specific PMSE assignment.
- A8.100 For an available channel,  $F_0$ , the WSDB shall then derive the maximum permitted EIRP spectral density  $P_{\text{WSD-PMSE}}(F_0)$  as the smallest of the  $P_{\text{WSD-PMSE}}(i, F_0)$  values, over candidate WSD locations and over the different PMSE assignments.

- A8.101 For each PMSE assignment, it may be possible to identify  $P_{\text{WSD-PMSE}}(F_0)$  without having to exhaustively calculate  $P_{\text{WSD-PMSE}}(i,F_0)$  at all candidate locations – for instance by evaluating  $P_{\text{WSD-PMSE}}(i,F_0)$  at a limited number of candidate locations that are geographically closest to the PMSE victims, in the absence of unscheduled adjustments. The WSDB may optimize its processes in this way provided that the  $P_{\text{WSD-PMSE}}(F_0)$  obtained is equal to the value obtained through the exhaustive procedure.
- A8.102 It may also be possible to identify the PMSE assignments which are close enough to the WSD to be relevant for the calculations in Part 5, and hence limit the PMSE assignments that are evaluated against.
- A8.103 Finally, the EIRP spectral density  $P_0(F_0)$  in dBm/(100 kHz) included in the WSD Operational Parameters will be the minimum of the following two values
  - $P_{\text{WSD-PMSE}}(F_0)$  as calculated above, and
  - $P_1(F_0) 10\log_{10}(80)$ , where  $P_1(F_0)$  is the maximum permitted in-block EIRP calculated above.

#### Maximum permitted nominal channel bandwidth and total bandwidth

A8.104 The WSDB shall use the default values communicated by Ofcom, unless the reported location of the device is within an unscheduled adjustment region provided by Ofcom in which case the Max\_nominal\_ch\_BW and the Max\_total\_BW values for the region should be used.

#### Time validity start ( $T_{ValStart}$ ) and time validity end ( $T_{ValEnd}$ )

A8.105 The time validity of the Specific Operational Parameters will normally be defined by changes in the PMSE usage. The WSDB may decide on the duration of the validity of a particular operational parameter set. However the WSDB shall ensure that all PMSE assignments that are active during the time interval defined by  $T_{ValStart}$  and  $T_{ValEnd}$  are accounted for and protected.

#### Location validity (L<sub>Val</sub>)

- A8.106 The WSDB shall use the default value communicated by Ofcom, unless the reported location of the device is within an unscheduled adjustment region provided by Ofcom in which case the Location\_validity value for the region should be used.
- A8.107 This parameter is not relevant for Type A WSDs (which are fixed).

#### Simultaneous channel operation power restriction

- A8.108 Can take values of 0 or 1.
- A8.109 The WSDB shall use the value communicated by Ofcom, unless the reported location of the device is within an unscheduled adjustment region provided by Ofcom in which case the Simultaneous\_channel value for the region should be used

## Part 5 - ALGORITHM FOR THE CALCULATION OF MAXIMUM IN-BLOCK EIRP SPECTRAL DENSITY TO ENSURE A LOW PROBABILITY OF HARMFUL INTERFERENCE TO PMSE

- A8.110 This section specifies the WSDB calculations for deriving the maximum permitted WSD in-block EIRP spectral density, *P*<sub>WSD-PMSE</sub> in dBm/(100 kHz), to ensure a low probability of harmful interference to a specific PMSE assignment.
- A8.111  $P_{\text{WSD-PMSE}}$  is limited to avoid "direct" interference from the WSD to the PMSE receiver. This is illustrated in Figure A8.7.  $P_{\text{WSD-PMSE}}$  is also limited to avoid intermodulation interference caused by a PMSE transmitter into a second PMSE receiver in the presence of a WSD signal. This is illustrated in Figure A8.8, where PMSE transmit intermodulation interference from the PMSE transmitter (2) has the potential to cause co-channel interference to reception of signals from another PMSE transmitter (1).



Figure A8.7 - Illustration of interference from a WSD to a PMSE receiver

Figure A8.8 - Illustration of reverse intermodulation interference from a PMSE transmitter to a PMSE receiver in response to interference from a WSD



#### EXPRESSION FOR THE MAXIMUM PERMITTED WSD EIRP SPECTRAL DENSITY

- A8.112 The maximum permitted EIRP spectral density,  $P_{\text{WSD-PMSE}}$  in dBm/(100 kHz), is the minimum of the following restrictions:
  - a WSD radiated EIRP spectral density restriction, P<sub>WSD-PR-PMSE</sub>, in dBm/(100 kHz), to ensure a low probability of "direct" transmissions from the WSD to the PMSE receiver causing harmful interference; and
  - a WSD radiated EIRP spectral density restriction, P<sub>WSD-PMSE-PMSE</sub>, in dBm/(100 kHz), to ensure a low probability of "PMSE transmit intermodulation" interference (generated in response to interference from the WSD) causing harmful interference; and
  - a 36 dBm/8 MHz cap i.e. 16.97 dBm/100 kHz.
- A8.113 Therefore, the maximum permitted EIRP spectral density,  $P_{\text{WSD-PMSE}}$ , shall be calculated according to:

$$P_{\text{WSD-PMSE}(\text{dBm}/(100\text{kHz})} = \min(P_{\text{WSD-PR-PMSE}}, P_{\text{WSD-PMSE-PMSE}}, 16.97)$$
(5.1)

A8.114 P<sub>WSD-PR-PMSE</sub> in a specific DTT channel and at a specific WSD candidate location shall be calculated according to:

$$P_{\text{WSD-PR-PMSE}} = P_{\text{S},0 (dBm/B)} - r(\Delta F)_{(dB)} - m_{G1(dB)} - \gamma_{(dB)} - 10\log_{10}(80)$$
(5.2)

where

$P_{S,0}$	is the wanted PMSE received signal power (over bandwidth <i>B</i> ),
В	is the nominal channel bandwidth of the PMSE device,
$m_{G1}$	is the WSD-to-PMSE median coupling gain,
$r(\Delta F)$	is the WSD-to-PMSE protection ratio defined as the ratio of PMSE
	received wanted signal power (in dBm/( <i>B</i> kHz)) over WSD received unwanted signal power (in dBm/(8 MHz)) at the point of PMSE receiver failure,
$\Delta F$	is the WSD-to-PMSE DTT channel separation (in units of 8 MHz),
γ	is a margin ( $\geq$ 0 dB),
10log <sub>10</sub> (80)	converts the calculated EIRP from a bandwidth of 8 MHz to a bandwidth
	of 100 kHz

A8.115 The WSD radiated EIRP spectral density restriction,  $P_{\text{WSD-PMSE-PMSE}}$  in dBm/(100 kHz), shall be calculated according to:

$$P_{\text{WSD-PMSE-PMSE}} = P_{\text{I},\text{T}(\text{dBm/B})} - m_{G2(\text{dB})} - m_{G3(\text{dB})} - C_{\text{IM1}} - 10\log_{10}(80)$$
(5.3)

where

$P_{I,T}$	is the target received interference at PMSE (over bandwidth 200 kHz),
$m_{G2}$	is the median coupling gain between WSD and the PMSE transmitter
	which is generating the PMSE transmit intermodulation interference,
$m_{G3}$	is the median coupling gain between PMSE transmitter which is
	generating the PMSE transmit intermodulation interference and the
	victim PMSE receiver,
C <sub>IM1</sub>	is an adjustable parameter for intermodulation product,

# 10log<sub>10</sub>(80) converts the calculated EIRP from a bandwidth of 8 MHz to a bandwidth of 100 kHz

A8.116 The values for the various parameters to be used in Equations 5.1 to 5.3 are presented next.

#### PARAMETER VALUES AND PARAMETER CALCULATION

# PMSE wanted signal power ( $P_{S,0}$ ) and nominal channel bandwidth of the PMSE device (B)

A8.117 The values of wanted PMSE received signal power  $P_{S,0}$  and of channel bandwith described in Table A8.1 below shall be used in Equation 5.2. These are given for various PMSE use cases.

#### Table A8.1 - P<sub>S,0</sub> and B for each PMSE use case

PMSE use case	P <sub>S,0</sub> (dBm/ <i>B</i> )	Nominal PMSE channel bandwidth, <i>B</i>
Wireless microphones	-78	200 kHz
In-ear monitors	-78	200 kHz
Talkback	-78	200 kHz
Programme audio links	-78	200 kHz
Data links	-78	200 kHz
Programme video links	-65	8 MHz

A8.118 If the PMSE equipment type identifier provided in the PMSE assignment information does not correspond to any of the types in table 5.1 then the value of  $P_{S,0}$  and *B* for wireless microphones shall be used.

#### Margin (γ)

A8.119 In Equation 5.2 the value of the margin,  $\gamma$ , is 0 dB.

#### Target received interference at PMSE (P<sub>I,T</sub>)

A8.120 In Equation 5.3 the value of the target received interference,  $P_{I,T}$ , is -104 dBm/(200 kHz).

#### Adjustable parameter ( $C_{IM1}$ )

A8.121 In Equation 5.3 the default value for the constant  $C_{IMI}$  is -40 dB.

### Median coupling gains ( $m_{G1}$ , $m_{G2}$ , $m_{G3}$ )

A8.122 The median coupling gains between the WSD and PMSE equipment shall be calculated according to:

$$m_{G1(dB)} = m_{p(dB)} + G_{W(dB)} + G_{A,PMSE(dB)} + G_{B1,WSD(dB)},$$
(5.4)

$$m_{G2(dB)} = m_{p(dB)} + G_{W(dB)} + G_{B2,WSD(dB)}$$
 (5.5)

 $m_{G3(dB)} = 27.56 - 20\log_{10}(d_{PMSE-PMSE}) - 20\log_{10}(f) + G_{B,PMSE(dB)} + G_{A,PMSE(dB)}$  (5.6)

where:

$m_{ m p}$	is the median path gain between WSD and both PMSE transmitter and
	receiver (< 0 dB),
$G_{ m W}$	is the building penetration (wall) gain ( $\leq 0 \text{ dB}$ ), and
$G_{ m A,PMSE}$	is the PMSE receiver antenna gain <sup>46</sup> ,
$G_{\text{B1,WSD}}$	is the default WSD body gain used in Equation 5.4,
G <sub>B2,WSD</sub>	is the default WSD body gain used in Equation 5.5,
$G_{B,PMSE}$	is the default PMSE body gain of the PMSE transmitter creating the
	PMSE transmit intermodulation interference.
d <sub>PMSE-PMSE</sub>	is the assumed separation between the PMSE intermodulation product
	generating transmitter and the victim PSME receiver (metres), and
f	is the centre frequency (in MHz) of the DTT channel used by the PMSE
	assignment.

- A8.123 Note that the median path gain  $m_p$  in Equation 5.4 is the same as the median path gain  $m_p$  in Equation 5.5. For the purposes of calculation of the median path gain in Equation 5.5 it is assumed that the PMSE transmitter generating the PMSE transmit intermodulation interference is at the same location as the PMSE receiver. This means that for a particular PMSE-WSD pair, the values of  $m_{p(dB)}$  in Equations 5.4 and 5.5 are the same.
- A8.124 The values described in Table A8.2 below shall be used in Equations 5.4 to 5.6.

Parameter	Value
<i>m<sub>P</sub></i>	Median path gain.
	For terrestrial PMSE services (those categorised as indoor or outdoor), the median path gain will be based on the SEAMCAT Extended Hata path loss model <sup>47</sup> .
	For airborne services, the free space path loss model will be used.
	Note that path gain is the negative of path loss (both in dB).
G <sub>W</sub>	Building penetration gain. We propose to use one of three values dependent upon the rules given below: 0 dB (no wall) -7 dB (one wall) -14 dB (two walls)
	If the horizontal separation between the WSD and PMSE receiver antenna is less than or equal to $d_{\text{DEF}}$ metres then a building penetration gain of 0 dB applies.
	<ul> <li>If the PMSE-WSD horizontal separation is greater than d<sub>DEF</sub> metres, the building penetration gain will be applied as follows:</li> <li>0 dB for outdoor PMSE assignments / outdoor WSD,</li> <li>-7 dB for indoor PMSE assignments / outdoor WSD,</li> <li>-7 dB for outdoor PMSE assignments / indoor WSD, and</li> </ul>

#### Table A8.2 - Parameters for the median coupling gain calculations

<sup>&</sup>lt;sup>46</sup> We keep the same terminology as the [Sept 2013 condoc]. The PMSE antenna gain is assumed to include all components of the PMSE installation.

<sup>&</sup>lt;sup>47</sup> See the SEAMCAT manual at <u>http://tractool.seamcat.org/wiki/Manual</u>.

	• -14 dB for indoor PMSE assignments / indoor WSD.	
	The indoor ("internal") / outdoor ("external") situation of the PMSE assignment is provided in the PMSE data.	
	Airborne PMSE assignments are assumed to be outdoor.	
	<ul> <li>For calculation of specific operating parameters for a master WSD or specific operational parameters for a slave WSD, the indoor/outdoor characteristic of the WSD is determined as follows:</li> <li>Type A WSDs will be assumed to be outdoors.</li> </ul>	
	• Type B WSDs will be assumed to be outdoors, unless they report a height that is greater than 2 metres (AGL) in which case they will be assumed to be indoors.	
	For calculation of generic operational parameter EIRP restrictions for a slave WSD in accordance with Part 3 the slave WSD will be assumed to be outdoor.	
	The definition of horizontal separation, d, is in Table A8.3.	
$G_{ m A,PMSE}$	PMSE antenna gain. 0 dBi for all PMSE usage types.	
$G_{ m B1,WSD}$	<ul> <li>WSD body gain for use in Equation 5.4</li> <li>For type A WSDs, a default body gain of 0 dB applies.</li> <li>For type B WSDs, a default body gain of 0 dB applies</li> </ul>	
$G_{ m B2,WSD}$	<ul> <li>WSD body gain for use in Equation 5.5</li> <li>For type A WSDs, a default body gain of 0 dB applies.</li> <li>For type B WSDs, a default body gain of 0 dB applies</li> </ul>	
$G_{ m B,PMSE}$	<ul><li>PMSE body gain for use in Equation 5.6</li><li>a default body gain of 0 dB applies in all cases.</li></ul>	
$d_{\mathrm{PMSE-PMSE}}$	The assumed separation between the PMSE transmitter which is generating the intermodulation interference and the victim PMSE receiver (metres). The value of $d_{\text{PMSE-PMSE}}$ is 5 metres.	
d <sub>DEF</sub>	A default separation used in the determination of building penetration gain. Currently $d_{\text{DEF}}$ is 10 metres.	

A8.125 The median path gain  $m_P$  is a function of WSD transmitter antenna height  $h_{WSD}$ , PMSE receiver antenna height  $h_{PMSE}$ , horizontal separation d between WSD transmitter and PMSE receiver antennas, frequency f, and clutter type (for SEAMCAT Extended Hata). Table A8.3 below lists the values for calculation of median path gain.

Parameter	Value
h <sub>wsd</sub>	Height of WSD antenna above ground level, determined as specified in Part 2, Part 3 or Part 4.
h <sub>PMSE</sub>	Height of PMSE receiver antenna above ground level. This will be provided as part of the PMSE assignment data. A default value $h_{\text{PMSE-DEFAULT}}$ of 5 metres will be assumed in the absence of this information.
d <sub>WSD-PMSE</sub>	Horizontal separation between the candidate location of the WSD and the location of the PMSE assignment.
	If the horizontal separation between the candidate location of the Slave WSD and the location of the PMSE receiver is less than or equal to $d_{\rm MIN}$ metres, then the WSDB shall use a WSD-PMSE horizontal separation of $d_{\rm MIN}$ metres. $d_{\rm MIN} = 10$ metres.
f	Centre frequency of the DTT channel used by PMSE. This will be derived from the frequency of the PMSE assignment as provided by Ofcom to the WSDBs.
	In the case that the PMSE assignment extends over more than one DTT channel, the WSDB shall use the DTT channel which contains the centre frequency of the PMSE assignment. If the PMSE centre frequency sits exactly at the boundary between two DTT channels, then the lower DTT channel shall be used.
Clutter type	This is the clutter type at the location of the PMSE assignment.
	The WSDB shall use clutter information from a clutter dataset for the median path gain calculation.
	The clutter information from the dataset will be mapped on to urban, and suburban clutter designations as defined by Ofcom. An illustrative example is given in Table A8.4 below.
	If clutter information is not available for the location of the PMSE assignment, then the WSDB shall use clutter type "suburban".

#### Table A8.3 - Parameters for the median path gain calculation

#### Table A8.4 - Illustrative clutter mapping

Clutter class number	Extended Hata clutter profile
classes 1 to 21:	Suburban
class 22:	Urban
class 23:	Suburban
Undefined	Suburban

A8.126 The clutter mapping shall consider the west and south boundary as part of each clutter pixel. If a query point is on the west (or south) boundary or southwest corner, we consider the clutter type in east / north clutter pixel or northeast clutter pixel. As it is illustrated in Figure A8.9 below, the red clutter pixel will be used if WSD / PMSE is located at the three points (boundaries and corners).





- A8.127 The SEAMCAT Extended Hata model with the parameters in Table A8.4 shall be used for the median path gain calculation between WSD and PMSE receiver.
- A8.128 Note that in accordance with specification of the SEAMCAT Extended Hata model, the parameters  $H_b$  and  $H_m$  within that model are defined as follows:

$$H_b = \max(h_{\text{WSD}}, h_{\text{PMSE}})$$
(5.7)

$$H_m = \min(h_{\rm WSD}, h_{\rm PMSE}) \tag{5.8}$$

#### Protection ratios ( $r(\Delta F)$ )

- A8.129 The values of protection ratio  $r(\Delta F)$  described in Tables A8.5 to A8.10 below shall be used in Equation 5.2. These are given for various PMSE use cases and WSD emission classes. Note that the protection ratios in the tables are for a wanted signal in 200 kHz and an unwanted signal in 8 MHz.
- A8.130 Determination of the DTT channel a particular PMSE assignment is using is made using the centre frequency of the PMSE assignment (*Frequency\_MHz*) and the bandwidth of the PMSE assignment (*Bandwidth\_MHz*), which are provided as part of the PMSE assignment data. Specifically, a PMSE assignment is assumed to use a particular DTT channel *K* if the frequency range *Frequency\_MHz* – (*Bandwidth\_MHz*/2) to *Frequency\_MHz* + (*Bandwidth\_MHz*/2) extends over DTT channel *K*. For the avoidance of doubt, the bandwidth of the assignment to be used here must be *Bandwidth\_MHz*, not the nominal PMSE channel bandwidth, *B*, as given in Table A8.1.
- A8.131 A PMSE assignment may use more than one DTT channel. If a PMSE device is using DTT channels  $K = \underline{K}_{min} \dots K_{max}$ , the relevant protection ratio for a particular DTT channel F is that given by the channel separation  $\Delta F$  with the smallest absolute value, where  $\Delta F = (F K)$ . If the PMSE assignment extends over more than one DTT channel, all DTT channels over which the PMSE assignment extends shall be protected as co-channel, i.e. the protection ratio for  $\Delta F = 0$  applies.

$r(\Delta F)$ (dB)								
Frequency Adjacency (DTT channels)	WSD Class 1	WSD Class 2	WSD Class 3	WSD Class 4	WSD Class 5			
$\Delta F = 0$	10							
$\Delta F = \pm 1$	-44	-44	-35	-25	-14			
$\Delta F = \pm 2$	-49	-45	-45	-35	-24			
$\Delta F = \pm 3$	-53	-45	-53	-45	-35			
$\Delta F = \pm 4$	-59	-54	-59	-54	-45			
$\Delta F = \pm 5$	-62	-61	-62	-61	-54			
$\Delta F = \pm 6$	-65	-64	-65	-64	-62			
$\Delta F = \pm 7$	-66	-66	-66	-66	-65			
$\Delta F = \pm 8$	-67	-67	-67	-67	-67			
$\Delta F = \pm 9$	-68	-68	-68	-68	-68			
$\Delta F = \pm 10$	-69	-69	-69	-69	-69			
$\Delta F = \pm 11$	-69	-69	-69	-69	-69			
$\Delta F = \pm 12$	-70	-70	-70	-70	-70			
$\Delta F = \pm 13$	-70	-70	-70	-70	-70			
$\Delta F = \pm 14$	-71	-71	-71	-71	-71			
$\Delta F = \pm 15$	-72	-72	-72	-72	-72			
$\Delta F = \pm 16$	-72	-72	-72	-72	-72			
$\Delta F = \pm 17$	-73	-73	-73	-73	-73			
$\Delta F = \pm 18$	-73	-73	-73	-73	-73			
$\Delta F = \pm 19$	-74	-74	-74	-74	-74			
∆ <i>F</i>   ≥ 20	-74	-74	-74	-74	-74			

### Table A8.5 - WSD-PMSE protection ratios: Wireless microphones

#### Table A8.6 - WSD-PMSE protection ratios: In-ear monitors

<i>r</i> (∆ <i>F</i> ) (dB)							
Frequency Adjacency (DTT channels)	WSD Class 1	WSD Class 2	WSD Class 3	WSD Class 4	WSD Class 5		
$\Delta F = 0$	10						
$\Delta F = \pm 1$	-44	-44	-35	-25	-14		
$\Delta F = \pm 2$	-49	-45	-45	-35	-24		
$\Delta F = \pm 3$	-53	-45	-53	-45	-35		
$\Delta F = \pm 4$	-59	-54	-59	-54	-45		
$\Delta F = \pm 5$	-62	-61	-62	-61	-54		
$\Delta F = \pm 6$	-65	-64	-65	-64	-62		
$\Delta F = \pm 7$	-66	-66	-66	-66	-65		
$\Delta F = \pm 8$	-67	-67	-67	-67	-67		
$\Delta F = \pm 9$	-68	-68	-68	-68	-68		
$\Delta F = \pm 10$	-69	-69	-69	-69	-69		
$\Delta F = \pm 11$	-69	-69	-69	-69	-69		
$\Delta F = \pm 12$	-70	-70	-70	-70	-70		
$\Delta F = \pm 13$	-70	-70	-70	-70	-70		
---------------------	-----	-----	-----	-----	-----		
$\Delta F = \pm 14$	-71	-71	-71	-71	-71		
$\Delta F = \pm 15$	-72	-72	-72	-72	-72		
$\Delta F = \pm 16$	-72	-72	-72	-72	-72		
$\Delta F = \pm 17$	-73	-73	-73	-73	-73		
$\Delta F = \pm 18$	-73	-73	-73	-73	-73		
$\Delta F = \pm 19$	-74	-74	-74	-74	-74		
∆ <i>F</i>   ≥ 20	-74	-74	-74	-74	-74		

## Table A8.7 - WSD-PMSE protection ratios: Talkback

<i>r</i> (∆ <i>F</i> ) (dB)					
Frequency Adjacency (DTT channels)	WSD Class 1	WSD Class 2	WSD Class 3	WSD Class 4	WSD Class 5
$\Delta F = 0$			10		
$\Delta F = \pm 1$	-44	-44	-35	-25	-14
$\Delta F = \pm 2$	-49	-45	-45	-35	-24
$\Delta F = \pm 3$	-53	-45	-53	-45	-35
$\Delta F = \pm 4$	-59	-54	-59	-54	-45
$\Delta F = \pm 5$	-62	-61	-62	-61	-54
$\Delta F = \pm 6$	-65	-64	-65	-64	-62
$\Delta F = \pm 7$	-66	-66	-66	-66	-65
$\Delta F = \pm 8$	-67	-67	-67	-67	-67
$\Delta F = \pm 9$	-68	-68	-68	-68	-68
$\Delta F = \pm 10$	-69	-69	-69	-69	-69
$\Delta F = \pm 11$	-69	-69	-69	-69	-69
$\Delta F = \pm 12$	-70	-70	-70	-70	-70
$\Delta F = \pm 13$	-70	-70	-70	-70	-70
$\Delta F = \pm 14$	-71	-71	-71	-71	-71
$\Delta F = \pm 15$	-72	-72	-72	-72	-72
$\Delta F = \pm 16$	-72	-72	-72	-72	-72
$\Delta F = \pm 17$	-73	-73	-73	-73	-73
$\Delta F = \pm 18$	-73	-73	-73	-73	-73
$\Delta F = \pm 19$	-74	-74	-74	-74	-74
$ \Delta F  \ge 20$	-74	-74	-74	-74	-74

## Table A8.8 - WSD-PMSE protection ratios: Programme audio links

$r(\Delta F)$ (dB)					
Frequency Adjacency (DTT channels)	WSD Class 1	WSD Class 2	WSD Class 3	WSD Class 4	WSD Class 5
$\Delta F = 0$	10				
$\Delta F = \pm 1$	-44	-44	-35	-25	-14
$\Delta F = \pm 2$	-49	-45	-45	-35	-24
$\Delta F = \pm 3$	-53	-45	-53	-45	-35

$\Delta F = \pm 4$	-59	-54	-59	-54	-45
$\Delta F = \pm 5$	-62	-61	-62	-61	-54
$\Delta F = \pm 6$	-65	-64	-65	-64	-62
$\Delta F = \pm 7$	-66	-66	-66	-66	-65
$\Delta F = \pm 8$	-67	-67	-67	-67	-67
$\Delta F = \pm 9$	-68	-68	-68	-68	-68
$\Delta F = \pm 10$	-69	-69	-69	-69	-69
$\Delta F = \pm 11$	-69	-69	-69	-69	-69
$\Delta F = \pm 12$	-70	-70	-70	-70	-70
$\Delta F = \pm 13$	-70	-70	-70	-70	-70
$\Delta F = \pm 14$	-71	-71	-71	-71	-71
$\Delta F = \pm 15$	-72	-72	-72	-72	-72
$\Delta F = \pm 16$	-72	-72	-72	-72	-72
$\Delta F = \pm 17$	-73	-73	-73	-73	-73
$\Delta F = \pm 18$	-73	-73	-73	-73	-73
$\Delta F = \pm 19$	-74	-74	-74	-74	-74
∆ <i>F </i> ≥ 20	-74	-74	-74	-74	-74

## Table A8.9 - WSD-PMSE protection ratios: data links

$r(\Delta F)$ (dB)					
Frequency Adjacency (DTT channels)	WSD Class 1	WSD Class 2	WSD Class 3	WSD Class 4	WSD Class 5
$\Delta F = 0$			10		
$\Delta F = \pm 1$	-44	-44	-35	-25	-14
$\Delta F = \pm 2$	-49	-45	-45	-35	-24
$\Delta F = \pm 3$	-53	-45	-53	-45	-35
$\Delta F = \pm 4$	-59	-54	-59	-54	-45
$\Delta F = \pm 5$	-62	-61	-62	-61	-54
$\Delta F = \pm 6$	-65	-64	-65	-64	-62
$\Delta F = \pm 7$	-66	-66	-66	-66	-65
$\Delta F = \pm 8$	-67	-67	-67	-67	-67
$\Delta F = \pm 9$	-68	-68	-68	-68	-68
$\Delta F = \pm 10$	-69	-69	-69	-69	-69
$\Delta F = \pm 11$	-69	-69	-69	-69	-69
$\Delta F = \pm 12$	-70	-70	-70	-70	-70
$\Delta F = \pm 13$	-70	-70	-70	-70	-70
$\Delta F = \pm 14$	-71	-71	-71	-71	-71
$\Delta F = \pm 15$	-72	-72	-72	-72	-72
$\Delta F = \pm 16$	-72	-72	-72	-72	-72
$\Delta F = \pm 17$	-73	-73	-73	-73	-73
$\Delta F = \pm 18$	-73	-73	-73	-73	-73
$\Delta F = \pm 19$	-74	-74	-74	-74	-74
$ \Delta F  \ge 20$	-74	-74	-74	-74	-74

<i>r</i> (∆ <i>F</i> ) (dB)					
Frequency Adjacency (DTT channels)	WSD Class 1	WSD Class 2	WSD Class 3	WSD Class 4	WSD Class 5
$\Delta F = 0$			17		
$\Delta F = \pm 1$	-22	-22	-21	-17	-7
$\Delta F = \pm 2$	-33	-32	-32	-27	-17
$\Delta F = \pm 3$	-37	-34	-37	-34	-27
$\Delta F = \pm 4$	-38	-36	-38	-36	-30
$\Delta F = \pm 5$	-39	-38	-39	-38	-33
$\Delta F = \pm 6$	-41	-40	-41	-40	-36
$\Delta F = \pm 7$	-42	-41	-42	-41	-39
$\Delta F = \pm 8$	-44	-43	-44	-43	-42
$\Delta F = \pm 9$	-43	-43	-43	-43	-43
$\Delta F = \pm 10$	-45	-45	-45	-45	-45
$\Delta F = \pm 11$	-45	-45	-45	-45	-45
$\Delta F = \pm 12$	-45	-45	-45	-45	-45
$\Delta F = \pm 13$	-45	-45	-45	-45	-45
$\Delta F = \pm 14$	-45	-45	-45	-45	-45
$\Delta F = \pm 15$	-45	-45	-45	-45	-45
$\Delta F = \pm 16$	-45	-45	-45	-45	-45
$\Delta F = \pm 17$	-45	-45	-45	-45	-45
$\Delta F = \pm 18$	-45	-45	-45	-45	-45
$\Delta F = \pm 19$	-45	-45	-45	-45	-45
$ \Delta F  \ge 20$	-45	-45	-45	-45	-45

#### Table A8.10 - WSD-PMSE protection ratios: Programme video links

- A8.132 Note: the values for the protection ratios for wireless microphones are also used for talkback, programme audio links and data link equipment.
- A8.133 If the PMSE equipment type identifier provided in the PMSE assignment information does not correspond to any of the types identified in tables A8.5 to A8.10 the protection ratios for wireless microphones shall be used.

# Part 6 THE ALGORITHM FOR THE CALCULATION OF THE COVERAGE AREA OF A MASTER WSD

- A8.134 The WSDB calculations for deriving the coverage area of a Master WSD whose location is uncertain are set out in this Part. This coverage area is used to calculate Generic Operational Parameters for Slave WSDs, as an indication of the possible locations of Slave WSDs that could be served by the Master WSD.
- A8.135 This area is based on the location uncertainty and the coverage range of a Master WSD. For a Master WSD that reported nominal horizontal coordinates (x, y), and reported horizontal location uncertainties ( $\pm \Delta x, \pm \Delta y$ ), the coverage area will be modelled as a circle centred on (x, y), and with radius d<sub>0</sub> +  $\sqrt{(\Delta x^2 + \Delta y^2)}$ . Here, d<sub>0</sub> is the coverage range of the Master WSD. In short, the area of potential locations for Slave WSDs is the area of potential locations for the Master WSD, extended by d<sub>0</sub>.

#### Figure A8.10 - Coverage area of Master WSD



A8.136 A WSDB shall calculate the coverage range, d<sub>0</sub>, of a Master WSD by first estimating the minimum coupling gain between the Master WSD and its Slave WSDs, and then using a path loss model to estimate the range. These calculations are specified next.

#### MINIMUM COUPLING GAIN

A8.137 A WSDB shall calculate the minimum coupling gain,  $m_{G,min}$ , as

$$m_{G,min(dB)} = P_{\text{REFSENS (dBm/100 kHz)}} - P_{(dBm/100 kHz)} + C_{\text{PL1}}$$
(6.1)

where

Р	is the EIRP spectral density of the Master WSD, and
$P_{\text{REFSENS}}$	is the minimum receiver (reference) sensitivity at the antenna
	connector of the Slave WSD, defined by the equipment technology
	specifications.

- C<sub>PL1</sub> Adjustable parameters for coupling gain, default value is 10.
- A8.138 We next present the proposed values for the various parameters to be used in Equation 6.1.

## EIRP spectral density of the Master WSD (P) and frequency of the Master WSD broadcasts ( $f_0$ )

- A8.139 Note: the frequency of the Master WSD broadcasts is used in table 6.2 below.
- A8.140 If the Master WSD reports one channel only in its Channel Usage Parameters, or if it reports explicitly the channel and power used for broadcasting generic operational parameter information, then *P* is equal to the EIRP spectral density reported, and f<sub>0</sub> is the centre frequency of the reported channel.
- A8.141 Else if the Master WSD reports more than one channel in its Channel Usage Parameters then let  $p_0(F)$  be the reported EIRP spectral density in DTT channel *F*, and let  $f_{chF}$  be the centre frequency of the DTT channel *F*. *P* is equal to the value of the EIRP spectral density  $p_0(F)$  that corresponds to the maximum value of

$$p_0(F) - 20\log_{10}(f_{chF}) \tag{6.2}$$

i.e., that which results in the largest coverage range accounting for a square-law frequency dependence of radio propagation.

 $f_0 \, \text{is equal to the} \, f_{\text{chF}} \, \text{of the channel where the maximum value occurs}$ 

#### Slave WSD reference sensitivity

A8.142 The WSDB shall use the reference sensitivity level of the Slave WSD as quoted in the specifications of the WSD technology. Where multiple reference sensitivity levels are quoted for different modulation and coding schemes, the WSDB shall select the minimum value quoted. The WSDB shall identify the WSD technology through the reported technology ID of the Master WSD. If the technology ID of the Master WSD is not available, the WSDB shall use the default reference sensitivity value in Table A8.14 in Part 8 for the Slave WSD reference sensitivity.

### **MEDIAN PATH GAIN**

- A8.143 The WSDB shall use the minimum coupling gain  $m_{G,min}$  found above, and an assumption about the antenna gain of the Slave WSD to calculate the median path gain  $m_{\rm P}(d_0)$ . It shall then use the SEAMCAT Extended Hata propagation model to find the separation distance  $d_0$  that corresponds to the calculated median path gain.
- A8.144 The median path gain between the Master WSD and Slave WSD shall be calculated according to

$$m_{\rm P}(d_0) = m_{G,min} - G_{\rm A,Slave} - G_{B,Slave} - G_W$$
(6.2)

where

$m_{G,min}$	is the minimum coupling gain from Equation (6.1), and
$m_{\rm P}({\rm d}_0)$	is the median path gain (< 0 dB), and
$G_{A,Slave}$	is the Slave WSD receiver antenna gain ( $\geq 0 \text{ dB}$ ).
$G_{B,Slave}$	is the body gain of the Slave WSD
$G_W$	is the building penetration gain

A8.145 The values described in Table A8.11 below will be used in Equation 6.2.

Parameter	Value
m	Median path gain
г	Path gain is the negative of path loss (both in dB).
G <sub>A Slava</sub>	Slave WSD antenna gain
A,Slave	WSDBs shall use the following value:
	$G_{A,Slave} = 0$ dBi if the Master WSD is Type A,
	$G_{A Slave} = 0$ dBi if the Master WSD is Type B
G <sub>B,Slave</sub>	Body gain of the Slave WSD: -6 dBm
,	
G <sub>W</sub>	Building penetration gain
	If the master WSD is type B and its antenna height is above
	2 metres, then
	$G_W = -7 \text{ dBm}$
	else
	$G_W = 0 \text{ dBm}$

 Table A8.11 - Parameters for the median path gain calculation

A8.146 The coverage range,  $d_0$ , is calculated applying the inverse of the SEAMCAT Extended Hata model<sup>48</sup> to the value of  $m_P(d_0)$  that results from equation 6.2. The parameters in table A8.12 below shall be used in the inverser SEAMCAT Extended Hata.

#### Table A8.12 - Parameters for the SEAMCAT Extended Hata model

Parameter	Value
$h_{_{ m Master}}$	Height of the Master WSD above ground level, which shall be calculated in accordance with Part 7.
	If the height is not reported or cannot be calculated, then WSDBs will use the default values from table A8.14 in Part 8
h <sub>Slave</sub>	Height of the Slave WSD , The height of a generic slave WSD in table A8.14 in Part 8 shall be used
$d_0$	Horizontal separation between transmitter at the master WSD and receiver at the slave WSD. This is the unknown to be determined.
fo	frequency of the Master WSD broadcasts as specified in paragraphs 7 and 8.
Clutter type	This is the clutter type at the reported location of the Master WSD (location uncertainty shall not be taken into account)

<sup>&</sup>lt;sup>48</sup> See the SEAMCAT manual at <u>http://tractool.seamcat.org/wiki/Manual</u>.

The WSDB shall use clutter information from a clutter dataset for the Hata model calculation.
The clutter type shall be established by using the clutter information at the nearest grid point of the clutter dataset. The clutter information from the dataset shall be mapped on to urban, and suburban clutter designations as defined by Ofcom. An illustrative example is given in Table 6.3 below. If clutter information is not available for the location of the Master WSD, then the WSDB shall use clutter type "suburban"

- A8.147 If the value of  $m_P(d_0)$  that results from equation 6.2 is greater than the path gain given by the SEAMCAT Extended Hata model for a distance d=1 metre and the parameters in table 6.2, then  $d_0=0$  (See note <sup>49</sup>).
- A8.148 Note that the extended Hata model shall be used so that the Master WSD is the base station and the Slave WSD is the terminal.
- A8.149 Note also that although the Hata model recommends using clutter at the terminal end, this section requires using it at the base station end. The clutter classes shall be mapped to clutter categories urban and suburban for use in the SEAMCAT Extended Hata propagation model using the mapping defined in Table A8.13.

#### Table A8.13 - Illustrative clutter mapping

Database clutter class	Extended Hata	
	clutter profile	
classes 1 to 21:	Suburban	
class 22:	Urban	
class 23:	Suburban	

A8.150 The radius of the Master WSD coverage area is d<sub>0</sub>.

<sup>&</sup>lt;sup>49</sup> This situation may appear if the EIRP of the master is very low. In this case, a slave WSD will have to be very close to the master to receive its transmissions.

# Part 7 - CALCULATION OF WSD ANTENNA HEIGHT ABOVE GROUND LEVEL $h_{\rm WSD}$

A8.151 A WSD may report height above ground level hWSD directly to a WSDB. Alternatively, if it is the altitude, h, that is reported, then hWSD will be calculated as:

 $h_{\rm wsp} = \max(h - h_{\rm T}, 1.5)$  metres

- A8.152 where h<sub>T</sub> is the local terrain height at the reported horizontal location of the WSD. WSDBs shall calculate the local terrain height by using the bi-linear interpolation method described in Rec. ITU-R P.1144<sup>50</sup>. Ordnance Survey OS Terrain 50 as the source for the local terrain height.
- A8.153 Note that when
  - a. the WSD reports altitude, and
  - b. there is uncertainty in the horizontal location of a WSD, i.e. the WSD reports horizontal location (x,y) and location uncertainty ( $\Delta x$ ,  $\Delta y$ )
- A8.154 then the WSDB shall evaluate hWSD only once, using the value of  $h_T$  at the reported horizontal location (x,y)

<sup>&</sup>lt;sup>50</sup> <u>http://www.itu.int/rec/R-REC-P.1144/en</u>

## Part 8 – DEFAULT VALUES AND PLA LIMITS

#### Table A8.14 - Default values for Device Parameters

Parameter	Value
Device Emissions Class	Class 5 according to EN 301 598
Height of type A master WSD	20 metres
Height of type B master WSD	1.5 metres
Height of a type A slave WSD	5 metres
Height of a type B slave WSD	1.5 metres
Height of a generic slave WSD	1.5 metres
Height uncertainty	0 metres, i.e. no uncertainty
Technology Identifier	"Generic"
Reference sensitivity of a Slave WSD for the	-114 dBm/100kHz
purpose of calculating the Master WSD's	
coverage area (P <sub>REFSENS)</sub>	

## Table A8.15 - Default values for Operational Parameters

Parameter	Value
Maximum permitted nominal channel	8 MHz
bandwidth	
Maximum permitted total bandwidth	8 MHz
Location validity (L <sub>Val</sub> )	50 metres
Update timer (T <sub>Update</sub> )	15 minutes

	Туре А			Туре В						
Limit in	Class	Class	Class	Class	Class	Class	Class	Class	Class	Class
dBm	1	2	3	4	5	1	2	3	4	5
Channel 21	30	30	20	10	-1	30	30	20	10	-1
Channel 22	35	30	30	20	9	35	30	30	20	9
Channel 23	36	30	36	30	20	36	30	36	30	20
Channel 24	36	36	36	36	30	36	36	36	36	30
Channel 25	36	36	36	36	36	36	36	36	36	36
Channel 26	36	36	36	36	36	36	36	36	36	36
Channel 27	36	36	36	36	36	36	36	36	36	36
Channel 28	36	36	36	36	36	36	36	36	36	36
Channel 29	36	36	36	36	36	36	36	36	36	36
Channel 30	36	36	36	36	36	36	36	36	36	36
Channel 31	36	36	36	36	36	36	36	36	36	36
Channel 32	36	36	36	36	36	36	36	36	36	36
Channel 33	36	36	36	36	36	36	36	36	36	36
Channel 34	36	34	36	34	25	36	31	36	31	22
Channel 35	33	25	33	25	15	30	22	30	22	12
Channel 36	29	25	25	15	4	26	22	22	12	1
Channel 37	24	24	15	5	-6	21	21	12	2	-9
Channel 38	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Channel 39	24	24	15	5	-6	21	21	12	2	-9
Channel 40	29	25	25	15	4	26	22	22	12	1
Channel 41	33	25	33	25	15	30	22	30	22	12
Channel 42	36	34	36	34	25	36	31	36	31	22
Channel 43	36	36	36	36	36	36	36	36	36	36
Channel 44	36	36	36	36	36	36	36	36	36	36
Channel 45	36	36	36	36	36	36	36	36	36	36
Channel 46	36	36	36	36	36	36	36	36	36	36
Channel 47	36	36	36	36	36	36	36	36	36	36
Channel 48	36	36	36	36	36	36	36	36	36	36
Channel 49	36	36	36	36	36	36	36	36	36	36
Channel 50	36	36	36	36	36	36	36	36	36	36
Channel 51	36	36	36	36	36	36	36	36	36	36
Channel 52	36	36	36	36	36	36	36	36	36	36
Channel 53	36	36	36	36	36	36	36	36	36	36
Channel 54	36	36	36	36	36	36	36	36	36	36
Channel 55	36	36	36	36	36	36	36	36	36	36
Channel 56	30	36	36	36	36	36	36	36	36	36
Channel 57	36	36	36	36	36	36	36	36	36	36
Channel 58	30	30	30	30	30	30	30	30	30	36
Channel 59	30	30	30	30	30	30	30	30	30	30
	-333	-333	-333	-333	-333	-333	-333	-333	-333	-333

## Table A8.16 - P<sub>LA</sub> limits

Note:  $P_{LA}$  limits can take values between 36 and -100, and value -999

## Annex 9

# WSD to DTT protection ratios

- A9.1 In this annex we describe the procedures for deriving WSD-DTT protection ratios corresponding to five WSD spectrum emission classes as defined in the ETSI European harmonised standard EN 301 598<sup>51</sup>.
- A9.2 These protection ratios are for use by Ofcom for the purpose of calculating the maximum permitted WSD in-block EIRPs in relation to DTT use.
- A9.3 We have derived these protection ratios by first measuring the co-channel and adjacent-channel protection ratios of DTT receivers in the presence of continuous and discontinuous WSD test signals.
- A9.4 The test WSD signals were generated using WSD master and slave devices supplied by one vendor. We commissioned the Digital TV Group (DTG) to perform measurements on fifty DTT (DVB-T and DVB-T2) receivers. The details of the measurements are explained in the DTG report<sup>52</sup>.
- A9.5 We have used these measurements to derive the adjacent channel selectivity (ACS) of the DTT receivers for continuous and discontinuous WSD signals. The derived ACS values were then combined with sales data for the fifty tested receivers to generate the cumulative distribution of ACS values and their 30<sup>th</sup> percentile values (values exceeded by 70% of receivers). Finally, we have combined the 30<sup>th</sup> percentile ACS values with the adjacent channel leakage ratios (ACLRs) for the five WSD spectrum emission classes to calculate the class-specific 70<sup>th</sup> percentile WSD-DTT protection ratios.
- A9.6 Unless otherwise stated, we use the term 'channel' to refer to an 8 MHz DTT channel. Furthermore, we use  $P_{\rm S}$  (or *C*), and  $P_{\rm X}$  to refer to wanted DTT and unwanted WSD in-block powers respectively. Finally, we use the subscript "M" to denote measured parameters.

## **DTT signal**

A9.7 The wanted DTT signal was generated using a Rohde & Schwarz Test System (BTC). The DVB-T signal parameters were set as shown in Table A9.1.

<sup>&</sup>lt;sup>51</sup> ETSI EN 301 598 V1.1.1 (2014-04), "White space devices (WSD); Wireless access systems operating in the 470 MHz to 790 MHz frequency band; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

<sup>&</sup>lt;sup>52</sup> http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2014/Protection\_Ratio\_Testing.pdf

Standard	DVB-T
Modulation scheme	COFDM
Modulation	64-QAM
Forward error correction	2/3
FFT points	8k
Guard Interval (µs)	7(1/32)
Data rate (Mbit/s)	24.1
Channel bandwidth (MHz)	8

### Table A9.1 – DVB-T signal parameters.

## **WSD** signals

- A9.8 Two types of WSD signal were used during the protection ratio testing. We refer to these as 'continuous' and 'discontinuous' signals. A continuous WSD signal operates on constant throughput of data and a discontinuous WSD signal operates on a four second loop providing bursts of data in the first two seconds with the signal being transmitted at full power followed by a further two seconds with no data being transmitted.
- A9.9 For the continuous WSD signal, the data traffic between the two WSDs was maintained at a constant bit rate of around 4.1 Mbps generating a signal of almost constant power from a master WSD. For the discontinuous WSD signal, the data traffic was switched on and off every two seconds which resulted in the RF signal from a slave WSD being transmitted every two seconds, with no data during the off periods.
- A9.10 The spectrum emission mask of the WSD signal in Figure A9.1 was captured with a 10 kHz resolution (note that the discrete spectral line in block is actually a feature of the emission). The power level on the Y axis represents dBm/10 kHz. In this case, the total in-block power over 8 MHz input to the spectrum analyser is around 11.9 dBm.



Figure A9.1 - Spectrum emission mask of the tested WSD signal

A9.11 The adjacent channel leakage ratio (ACLR) of the WSD test signal is a key element in the derivation of the DTT receiver selectivity. The ACLR is measured as

$$ACLR_{M} = \frac{P_{X (8 \text{ MHz})}}{P_{OOB (8 \text{ MHz})}}$$
(A9.1)

where  $P_{\rm X}$  is the in-block power over 8 MHz, and  $P_{\rm OOB}$  is the out-of-block power over 8 MHz. Note that the out-of-block power is measured by adding up 10 kHz samples over 8 MHz to reflect the bandwidth of the DTT receiver.

A9.12 Table A9.2 shows the measured ACLR values of the WSD test signal. The ACLR of the test signal determines the upper limit of the DTT receiver ACS that can be reliably measured in these tests. If the adjacent channel selectivity exceeds the ACLR quoted in Table A9.2, the measured result will reflect the ACLR of the source rather than the ACS of the DTT receiver.

Channel separation ( $\Delta F$ )	+9	+3	+2	+1	-1	-2	-3	-9
ACLR	76.2	74.3	74.3	63.3	63.3	73.2	73.2	77.1

## **Measurement of protection ratios**

- A9.13 The following is the procedure used to measure the WSD-DTT protection ratios for the tested DTT receivers:
  - 1) The DTT receiver was initially tuned to an appropriate channel in an interferencefree environment with sufficient DTT signal power to verify video operation.

- 2) The wanted DTT signal power was adjusted via a variable attenuator. The power level at the input to the DTT receiver was recorded as  $C_{(dBm)}$ . It is worth to note that a +7 dB DTT signal at 10 channels away is also added to simulate the presence of another 5 multiplexes.
- Without switching off the DTT signal, the unwanted WSD signal was applied to the DTT receiver with its carrier frequency adjusted for the required channel separation.
- 4) The maximum level of WSD signal was measured using a spectrum analyser in zero span mode. The analyser was connected to the 8-way tap at the same point as the input to the receivers so that whatever was measured was the equivalent to the signal at the input to the receivers.
- 5) The WSD signal was then turned back to zero for the start of the tests. The interfering signal was then gradually increased until the receiver reached the failure point.
- 6) The level of WSD signal at the last point of successful reception was then recorded for the protection ratio,  $r_{M}(C, \Delta F)$ , calculations in dB.
- A9.14 The DTT receivers were tested at wanted power levels of C = -70, -60, -50 and -30 dBm, and channel separations  $\Delta F = 0, \pm 1, \pm 2, \pm 3$ , and  $\pm 9$ . A positive channel separation means that the WSD signal is at the higher frequency.
- A9.15 Figures A9.2 to A9.9 illustrate the measured protection ratios  $r_{\rm M}(C, \Delta F)$  for the fifty tested DTT receivers at various channel separations,  $\Delta F$ , and wanted DTT signal powers, *C*. Protection ratios are presented for both continuous and discontinuous WSD signals. These are also presented in Figures A1.1 to A2.4 in the DTG's measurement report.

Figure A9.2 - Measured protection ratios for 50 DTT receivers. Continuous WSD interferer signal, C = -70 dBm.



Figure A9.3 - Measured protection ratios for 50 DTT receivers. Continuous WSD interferer signal, C = -60 dBm



Figure A9.4 - Measured protection ratios for 50 DTT receivers. Continuous WSD interferer signal, C = -50 dBm



Figure A9.5 - Measured protection ratios for 50 DTT receivers. Continuous WSD interferer signal, C = -30 dBm



Figure A9.6 - Measured protection ratios for 50 DTT receivers. Discontinuous WSD interferer signal, C = -70 dBm



Figure A9.7 - Measured protection ratios for 50 DTT receivers. Discontinuous WSD interferer signal, C = -60 dBm



Figure A9.8 - Measured protection ratios for 50 DTT receivers. Discontinuous WSD interferer signal, C = -50 dBm



Figure A9.9 – Measured protection ratios for 50 DTT receivers. Discontinuous WSD interferer signal, C = -30 dBm



## **Derivation of adjacent channel selectivity**

A9.16 In this subsection, we describe the derivation of the adjacent channel selectivity of a DTT receiver from laboratory measurements of the protection ratio and the adjacent channel leakage ratio of the WSD interferer.

A9.17 The adjacent channel selectivity  $ACS(C, \Delta F)$  of a tested DTT receiver can be derived from the measured co-channel and adjacent-channel protection ratios. From the definition of ACS we have (in the linear domain),

$$P_{I(8 \text{ MHz})} = P_{\text{OOB}(8 \text{ MHz})} + \frac{P_{X(8 \text{ MHz})}}{\text{ACS}(C, \Delta F)},$$
(A9.2)

where  $P_X$  is the received in-block power of the unwanted signal,  $P_{OOB}$  is the received out-of-block power of the unwanted signal, and  $P_I$  is the experienced interference power.

A9.18 From the definition of adjacent-channel interference ratio (ACIR) we also have (in the linear domain),

$$ACIR_{M}(C,\Delta F) = \frac{P_{X(8 \text{ MHz})}}{P_{I(8 \text{ MHz})}},$$
(A9.3)

at the point of receiver failure. Combining (A9.2) and (A9.3) we have

$$\frac{1}{\operatorname{ACIR}_{M}(C,\Delta F)} = \frac{P_{\operatorname{OOB}(8\,\operatorname{MHz})}}{P_{X(8\,\operatorname{MHz})}} + \frac{1}{\operatorname{ACS}(C,\Delta F)}$$

$$= \frac{1}{\operatorname{ACLR}_{M}(\Delta F)} + \frac{1}{\operatorname{ACS}(C,\Delta F)},$$
(A9.4)
$$\operatorname{ACS}(C,\Delta F) = \left\{\operatorname{ACIR}_{M}^{-1}(C,\Delta F) - \operatorname{ACLR}_{M}^{-1}(\Delta F)\right\}^{-1},$$
(A9.5)

or

where  $ACLR_M(\Delta F)$  is the measured adjacent channel leakage ratio<sup>53</sup> of the 8 MHz WSD test signal with spectral leakage over the 8 MHz DTT channel (see Table A9.2).

#### A9.19 Finally, from the definition of ACIR we have (in the linear domain),

$$ACIR_{M}(C, \Delta F) = \frac{P_{X (8 \text{ MHz})}}{P_{I (8 \text{ MHz})}} = \frac{P_{X (8 \text{ MHz})}}{P_{S (8 \text{ MHz})}} \times \frac{P_{S (8 \text{ MHz})}}{P_{I (8 \text{ MHz})}}$$

$$= \frac{1}{r_{M}(C, \Delta F)} \times SIR \equiv \frac{1}{r_{M}(C, \Delta F)} \times r_{M}(0),$$
(A9.6)

where  $r_{\rm M}(C, \Delta F)$  is the measured adjacent channel protection ratio, SIR is the signalto-interference ratio at the point of failure, and  $r_{\rm M}(0)$  is the measured co-channel protection ratio. Note that we use  $r_{\rm M}(0)$  as a proxy for the signal-to-interference ratio at the point of receiver failure. Specifically, if  $P_{\rm X}$  is the power of a co-channel unwanted signal over 8 MHz,

<sup>&</sup>lt;sup>53</sup> By definition, ACLR is greater than ACIR (ACS being a positive number). Occasionally, the measured ACLR<sub>M</sub> is lower than ACIR<sub>M</sub> as derived from the measured protection ratios  $r_M(C, \Delta F)$  and  $r_M(0)$ . This is a result of model/measurement error and it is not possible to derive a valid ACS in such circumstances. We have excluded DTG measurements where ACLR<sub>M</sub> is lower than ACIR<sub>M</sub>.

$$r_{\rm M}(0) = \frac{P_{\rm S\,(8\,MHz)}}{P_{\rm X\,(8\,MHz)}} \equiv \frac{P_{\rm S\,(8\,MHz)}}{P_{\rm I\,(8\,MHz)}}.$$
 (A9.7)

A9.20 Combining Equation (A9.6) and (A9.5) we have

$$ACS(C,\Delta F) = \left\{ \frac{r_{M}(C,\Delta F)}{r_{M}(0)} - ACLR_{M}^{-1}(\Delta F) \right\}^{-1}.$$
(A9.8)

A9.21 Figures A9.10 to A9.17 illustrate the derived values of  $ACS(C, \Delta F)$  for the fifty tested DTT receivers at various channel separations,  $\Delta F$ , and wanted DTT signal powers, *C*. These ACS values are presented for both continuous and discontinuous WSD signals at *C* = -70, -60, -50 and -30 dBm, and channel separations  $\Delta F = \pm 1, \pm 2, \pm 3,$  and  $\pm 9$ .



Figure A9.10 - Derived ACS for 50 DTT receivers. Continuous WSD signal, C = -70 dBm  $\,$ 















Figure A9.14 - Derived ACS for 50 DTT receivers. Discontinuous WSD signal, C = -70 dBm

Figure A9.15 - Derived ACS for 50 DTT receivers. Discontinuous WSD signal, C = -60 dBm  $\,$ 





Figure A9.16 - Derived ACS for 50 DTT receivers. Discontinuous WSD signal, C = -50 dBm  $\,$ 





## Statistics of adjacent channel selectivity based on sales figures

A9.22 In this subsection, we describe the calculation of the 70<sup>th</sup> percentile values of ACS values. We do this by generating cumulative distribution functions of  $ACS(C, \Delta F)$ , based on the sales figures of the fifty receivers tested.

- A9.23 The tested DTT receivers were chosen initially based upon receivers that were encountered in consumers' homes during Ofcom TVWS coexistence tests<sup>54</sup>. This accounted for 35 out of the 50 test samples with the remaining 15 chosen as the highest selling receivers between 2007 and 2013. The sales figure for each tested receiver is shown in Table A9.3.
- A9.24 Note that the sales data for DTT receivers 27, 28 and 50 are not available, and we did not include these three receivers in the ACS statistical analysis.
- A9.25 For each combination of *C*,  $\Delta F$  and WSD signal type, we compiled the 47 calculated values of  $ACS(C, \Delta F)$  for the receivers, and counted them according to their respective sales figures. We then generated the cumulative distribution function of the ACS values for each combination. Consequently, the *n*th percentile protection ratio can be read off the distributions.
- A9.26 Figures A9.18 to A9.25 illustrate the cumulative distributions of  $ACS(C, \Delta F)$  for C = -70, -60, -50, and -30 dBm and  $\Delta F = \pm 1, \pm 2, \pm 3, \text{ and } \pm 9$  for continuous and discontinuous WSD signals.

<sup>&</sup>lt;sup>54</sup> Reference for Ofcom TVWS field trials.

Receiver ID	Receiver type	Total chassis sales units	Receiver ID	Receiver type	Total chassis sales units	
1	DVB-T2	190572	26	DVB-T2	11115	
2	DVB-T	1125901	27	DVB-T2	N/A	
3	DVB-T	729580	28	DVB-T	N/A	
4	DVB-T2	698732	29	DVB-T	991916	
5	DVB-T2	566642	30	DVB-T	637306	
6	DVB-T	557322	31	DVB-T2	481352	
7	DVB-T	549012	32	DVB-T	421543	
8	DVB-T	541321	33	DVB-T	420611	
9	DVB-T	399115	34	DVB-T	380175	
10	DVB-T	393551	35	DVB-T	375054	
11	DVB-T	360387	36	DVB-T	360387	
12	DVB-T	344346	37	DVB-S/T2	336409	
13	DVB-T	298194	38	DVB-T2	333747	
14	DVB-T	286074	39	DVB-T2	213426	
15	DVB-T	255296	40	DVB-T	201098	
16	DVB-T2	213966	41	DVB-T2	160558	
17	DVB-S/T	144989	42	DVB-T	159425	
18	DVB-T	132227	43	DVB-T	153917	
19	DVB-T	104310	44	DVB-T	815024	
20	DVB-T	59502	45	DVB-T2	73974	
21	DVB-T	48386	46	DVB-T2	59459	
22	DVB-T2	36591	47	DVB-T2	32853	
23	DVB-T2	35085	48	DVB-T2	32477	
24	DVB-T2	26873	49	DVB-T	8843	
25	DVB-T	24938	50	DVB-T	N/A	

## Table A9.3 – DTT receiver sales figures between 2007 and 2013





























Figure A9.25 – Cumulative distribution functions of ACS for discontinuous WSD interferer signal,  $\Delta F = \pm 1$ 



## **Calculation of class-specific protection ratios**

- A9.27 In this subsection, we describe the calculation of 70<sup>th</sup> percentile protection ratios for each of the five WSD spectrum emission classes based on continuous and discontinuous WSD signals.
- A9.28 A class-specific 70<sup>th</sup> percentile,  $r(C, \Delta F)$ , at a particular wanted signal power *C*, and channel separation  $\Delta F$ , can be calculated from the corresponding 30<sup>th</sup> percentile ACS(*C*,  $\Delta F$ ) and the class-specific WSD ACLR ( $\Delta F$ ) as defined in EN 301 598.
- A9.29 Note that we derive class-specific protection ratios by using the class-specific ACLR of a WSD with an in-block bandwidth of 8 MHz.
- A9.30 By definition (in the linear domain),

$$r(C, \Delta F) = \frac{P_{S(8 \text{ MHz})}}{P_{X(8 \text{ MHz})}} = \frac{P_{S(8 \text{ MHz})}}{P_{I(8 \text{ MHz})}} \times \frac{P_{I(8 \text{ MHz})}}{P_{X(8 \text{ MHz})}}$$
  
=  $r_{M}(0) \times \frac{1}{\text{ACIR}(C, \Delta F)}$   
=  $r_{M}(0) \times \left(\text{ACLR}^{-1}(\Delta F) + \text{ACS}^{-1}(C, \Delta F)\right),$  (A9.9)

where  $P_{\rm S}$  is the in-block power of the wanted signal,  $P_{\rm X}$  is the in-block power of the unwanted signal, and  $P_{\rm I}$  is the experienced interference power. We have used the definition of ACIR to derive the last line which describes the relationship with the class-specific ACLR and the derived ACS.

- A9.31 Class-specific protection ratios can be calculated via Equation (A9.9) from the measured co-channel protection ratio, the derived ACS, and the WSD class-specific ACLR.
- A9.32 Table A9.4 shows the values of ACLR( $\Delta F$ ) for the five WSD spectrum emission classes. For channel separations  $\Delta F = \pm 1, \pm 2$  and  $\pm 3$ , the values of ACLR( $\Delta F$ ) are as defined in ETSI EN 301 598 (for greater channel separations, the limits in EN 301 598 remain at their values for  $\Delta F = \pm 3$ ). To account for practical spectrum masks, we have assumed a roll off (increase in ACLR) of 10 dB per 8 MHz for  $|\Delta F| > 3$  until  $|\Delta F| = 9$ . We have assumed the spectrum mask is flat for  $|\Delta F| > 9$ .

$ACLR(\Delta F)$	WSD spectrum emission class						
Channel separation, $\Delta F$	Class 1	Class 2	Class 3	Class 4	Class 5		
±1	55	55	45	35	24		
±2	60	55	55	45	34		
±3	65	55	65	55	45		
±9	125	115	125	115	105		
±10	125	115	125	115	105		

#### Table A9.4 – Class-specific ACLRs

- A9.33 As mentioned earlier, protection ratios were measured for C = -70, -60, -50, and -30 dBm at  $\Delta F = \pm 1, \pm 2, \pm 3$  and  $\pm 9$ . In order to derive protection ratios for C = -40, -20, and -12 dBm, and frequency offsets  $\Delta F = \pm 4, \pm 5, \pm 6, \pm 7$ , and  $\pm 8$  for use in the coexistence studies, we have used interpolation and extrapolation as follows:
  - a) Protection ratios for C = -40 dBm were derived via linear interpolation of the protection ratios C = -50 and -30 dBm.
  - b) Protection ratios for C = -20 and -12 dBm were derived by assuming that all the receivers suffer from hard overload at the maximum tested interferer power  $I_{max}$  at C = -30 dBm. The values of interferer power I for C = -20 and -12 dBm were derived via linear extrapolation of I values at C = -30 dBm. This is shown in Figures A9.26 and A9.27 below.
  - c) Protection ratios for channel separation  $\Delta F = \pm 4, \pm 5, \pm 6, \pm 7, \text{ and } \pm 8$  are defined via linear interpolation between protection ratio values at  $\Delta F = \pm 3$  and  $-9^{55}$ . We calculate the average of protection ratios at  $\Delta F = -3$  and +3 for  $\Delta F = \pm 3$ . The same approach to averaging applies to  $\Delta F = \pm 1$  and  $\pm 2$ .
  - d) Protection ratios for  $\Delta F \ge \pm 10$  are the same as protection ratios at  $\Delta F = -9$ .

<sup>&</sup>lt;sup>55</sup> The reason that we use  $\Delta F = -9$  for linear interpolation is because the large protection ratios that occur at  $\Delta F = +9$  for a proportion of the receivers tested are as a result of the so-called "N+9" effect characteristic related to mixer image rejection in some super-heterodyne receivers.





Figure A9.27 – C vs I plot for 70% DTT receiver based on class 4, continuous WSD signal



A9.34 Figures A9.28 to A9.37 show the resulting class-specific 70<sup>th</sup> percentile protection ratios for ETSI emission classes 1 to 5, for C = -70, -60, -50 and -30 dBm, and channel separations  $\Delta F = \pm 1$  to  $\pm 10$  for both continuous and discontinuous WSD

signals. The values of protection ratios are presented in tabular form in Tables A9.5 to A9.14.





Figure A9.29 - Class-specific 70th percentile protection ratios. Continuous WSD signal, emission - class 2



## Figure A9.30 - Class-specific 70th percentile protection ratios. Continuous WSD signal, emission class 3











Figure A9.33 - Class-specific 70th percentile protection ratios. Discontinuous WSD signal, emission- class 1


# Figure A9.34 - Class-specific 70th percentile protection ratios. Discontinuous WSD signal, emission class 2



Figure A9.35 - Class-specific 70th percentile protection ratios. Discontinuous WSD signal, emission class 3







Figure A9.37 - Class-specific 70th percentile protection ratios. Discontinuous WSD signal, emission class 5



A9.35 Tables A9.5 to A9.9 show the resulting values of class-specific protections ratios based on continuous WSD signals. The class specific protection ratios will be met by 70% of the DTT receivers from ACS statistics calculations. Each table contains the protection ratios for one ETSI class, C = -70, -60, -50, -30, -20 and -12 dBm, and channel separations  $\Delta F = \pm 1$  to  $\pm 10$ . It should be noted that where a class has a different value of C than that shown for class 1 for a given channel separation, the higher quoted protection ratio results from the WSD leakage dominating the ACS for that particular result. The higher of the class-specific protection ratios will therefore be met by most, if not all, of the receivers tested.

Class 1, 70%		C (dBm/8 MHz)							
Channel separation, $\Delta F$	-70	-60	-50	-40	-30	-20	-12		
$\Delta F = \pm 1$	-36	-37	-36	-32	-29	-23	-15		
$\Delta F = \pm 2$	-42	-41	-42	-36	-31	-23	-15		
$\Delta F = \pm 3$	-46	-45	-43	-37	-31	-23	-15		
$\Delta F = \pm 4$	-48	-46	-44	-38	-31	-23	-15		
$\Delta F = \pm 5$	-49	-48	-45	-38	-31	-23	-15		
$\Delta F = \pm 6$	-51	-49	-46	-39	-31	-23	-15		
$\Delta F = \pm 7$	-53	-51	-46	-39	-32	-23	-15		
$\Delta F = \pm 8$	-55	-52	-47	-40	-32	-23	-15		
$\Delta F = -9$	-57	-54	-48	-40	-32	-23	-15		
$\Delta F = +9$	-44	-44	-44	-38	-33	-23	-15		
$ \Delta F  \ge 10$	-57	-54	-48	-40	-32	-23	-15		

# Table A9.5 – Protection ratios (dB) for 70th percentile DTT receivers based on continuous WSD signal, class 1

# Table A9.6 - Protection ratios (dB) for 70th percentile DTT receivers based on continuous WSD signal, class 2

Class 2, 70%		C (dBm/8 MHz)							
Channel separation, $\Delta F$	-70	-60	-50	-40	-30	-20	-12		
$\Delta F = \pm 1$	-36	-37	-36	-32	-29	-23	-15		
$\Delta F = \pm 2$	-37	-37	-38	-34	-30	-23	-15		
$\Delta F = \pm 3$	-38	-37	-37	-34	-30	-23	-15		
$\Delta F = \pm 4$	-41	-40	-39	-35	-30	-23	-15		
$\Delta F = \pm 5$	-44	-43	-41	-36	-31	-23	-15		
$\Delta F = \pm 6$	-47	-46	-43	-37	-31	-23	-15		
$\Delta F = \pm 7$	-51	-48	-44	-38	-31	-23	-15		
$\Delta F = \pm 8$	-54	-51	-46	-39	-32	-23	-15		
$\Delta F = -9$	-57	-54	-48	-40	-32	-23	-15		
$\Delta F = +9$	-44	-44	-44	-38	-33	-23	-15		
$ \Delta F  \ge 10$	-57	-54	-48	-40	-32	-23	-15		

Class 3, 70%		C (dBm/8 MHz)							
Channel separation, $\Delta F$	-70	-60	-50	-40	-30	-20	-12		
$\Delta F = \pm 1$	-28	-28	-28	-27	-26	-23	-15		
$\Delta F = \pm 2$	-37	-37	-38	-34	-30	-23	-15		
$\Delta F = \pm 3$	-46	-45	-43	-37	-31	-23	-15		
$\Delta F = \pm 4$	-48	-46	-44	-38	-31	-23	-15		
$\Delta F = \pm 5$	-49	-48	-45	-38	-31	-23	-15		
$\Delta F = \pm 6$	-51	-49	-46	-39	-31	-23	-15		
$\Delta F = \pm 7$	-53	-51	-46	-39	-32	-23	-15		
$\Delta F = \pm 8$	-55	-52	-47	-40	-32	-23	-15		
$\Delta F = -9$	-57	-54	-48	-40	-32	-23	-15		
$\Delta F = +9$	-44	-44	-44	-38	-33	-23	-15		
$ \Delta F  \ge 10$	-57	-54	-48	-40	-32	-23	-15		

# Table A9.7 – Protection ratios (dB) for 70th percentile DTT receivers based on continuous WSD signal, class 3

# Table A9.8 – Protection ratios (dB) for 70th percentile DTT receivers based on continuous WSD signal, class 4

Class 4, 70%		C (dBm/8 MHz)							
Channel	70	60	FO	40	20	20	10		
separation, $\Delta F$	-70	-00	-30	-40	-50	-20	-12		
$\Delta F = \pm 1$	-18	-18	-18	-18	-18	-18	-15		
$\Delta F = \pm 2$	-28	-28	-28	-27	-26	-23	-15		
$\Delta F = \pm 3$	-38	-37	-37	-34	-30	-23	-15		
$\Delta F = \pm 4$	-41	-40	-39	-35	-30	-23	-15		
$\Delta F = \pm 5$	-44	-43	-41	-36	-31	-23	-15		
$\Delta F = \pm 6$	-47	-46	-43	-37	-31	-23	-15		
$\Delta F = \pm 7$	-51	-48	-44	-38	-31	-23	-15		
$\Delta F = \pm 8$	-54	-51	-46	-39	-32	-23	-15		
$\Delta F = -9$	-57	-54	-48	-40	-32	-23	-15		
$\Delta F = +9$	-44	-44	-44	-38	-33	-23	-15		
$ \Delta F  \ge 10$	-57	-54	-48	-40	-32	-23	-15		

Class 5, 70%		C (dBm/8 MHz)						
Channel separation, $\Delta F$	-70	-60	-50	-40	-30	-20	-12	
$\Delta F = \pm 1$	-7	-7	-7	-7	-7	-7	-7	
$\Delta F = \pm 2$	-17	-17	-17	-17	-17	-17	-15	
$\Delta F = \pm 3$	-28	-28	-28	-27	-26	-23	-15	
$\Delta F = \pm 4$	-33	-32	-31	-29	-27	-23	-15	
$\Delta F = \pm 5$	-38	-37	-35	-31	-28	-23	-15	
$\Delta F = \pm 6$	-42	-41	-38	-34	-29	-23	-15	
$\Delta F = \pm 7$	-47	-45	-41	-36	-30	-23	-15	
$\Delta F = \pm 8$	-52	-50	-45	-38	-31	-23	-15	
$\Delta F = -9$	-57	-54	-48	-40	-32	-23	-15	
$\Delta F = +9$	-44	-44	-44	-38	-33	-23	-15	
$ \Delta F  \ge 10$	-57	-54	-48	-40	-32	-23	-15	

# Table A9.9 - Protection ratios (dB) for 70th percentile DTT receivers based on continuous WSD signal, class 5

A9.36 Tables A9.10 to A9.14 show the values of resulting class-specific protection ratios based on discontinuous WSD signals ('high' protection ratios). The class-specific protection ratios will be met by 70% of the DTT receivers from ACS statistics calculations. Each table contains the protection ratios for one ETSI class, C = -70, -60, -50, -30, -20 and -12 dBm, and channel separations  $\Delta F = \pm 1$  to  $\pm 10$ .

# Table A9.10 – Protection ratios (dB) for 70th percentile DTT receivers based on discontinuous WSD signal, class 1

Class 1, 70%		C (dBm/8 MHz)							
Channel separation, $\Delta F$	-70	-60	-50	-40	-30	-20	-12		
$\Delta F = \pm 1$	-23	-22	-16	-15	-13	-12	-11		
$\Delta F = \pm 2$	-36	-33	-28	-26	-23	-20	-12		
$\Delta F = \pm 3$	-38	-37	-31	-27	-23	-19	-12		
$\Delta F = \pm 4$	-40	-38	-33	-29	-24	-20	-12		
$\Delta F = \pm 5$	-41	-39	-35	-30	-25	-20	-12		
$\Delta F = \pm 6$	-43	-41	-37	-32	-26	-20	-12		
$\Delta F = \pm 7$	-44	-42	-39	-33	-28	-20	-12		
$\Delta F = \pm 8$	-46	-44	-41	-35	-29	-20	-12		
$\Delta F = -9$	-47	-45	-43	-36	-30	-20	-12		
$\Delta F = +9$	-43	-43	-43	-35	-27	-19	-12		
$ \Delta F  \ge 10$	-47	-45	-43	-36	-30	-20	-12		

Class 2, 70%		C (dBm/8 MHz)							
Channel separation, $\Delta F$	-70	-60	-50	-40	-30	-20	-12		
$\Delta F = \pm 1$	-23	-22	-16	-15	-13	-12	-11		
$\Delta F = \pm 2$	-34	-32	-28	-25	-23	-20	-12		
$\Delta F = \pm 3$	-35	-34	-31	-27	-23	-19	-12		
$\Delta F = \pm 4$	-37	-36	-33	-28	-24	-20	-12		
$\Delta F = \pm 5$	-39	-38	-35	-30	-25	-20	-12		
$\Delta F = \pm 6$	-41	-40	-37	-32	-26	-20	-12		
$\Delta F = \pm 7$	-43	-41	-39	-33	-28	-20	-12		
$\Delta F = \pm 8$	-45	-43	-41	-35	-29	-20	-12		
$\Delta F = -9$	-47	-45	-43	-36	-30	-20	-12		
$\Delta F = +9$	-43	-43	-43	-35	-27	-19	-12		
$ \Delta F  \ge 10$	-47	-45	-43	-36	-30	-20	-12		

# Table A9.11 - Protection ratios (dB) for 70th percentile DTT receivers based on discontinuous WSD signal, class 2

# Table A9.12 – Protection ratios (dB) for 70<sup>th</sup> percentile DTT receivers based on discontinuous WSD signal, class 3

Class 3, 70%		C (dBm/8 MHz)							
Channel	-70	-60	-50	-40	-30	-20	-12		
separation, $\Delta F$	-70	-00	50	40	-30	-20	-12		
$\Delta F = \pm 1$	-22	-21	-16	-15	-13	-12	-11		
$\Delta F = \pm 2$	-34	-32	-28	-25	-23	-20	-12		
$\Delta F = \pm 3$	-38	-37	-31	-27	-23	-19	-12		
$\Delta F = \pm 4$	-40	-38	-33	-29	-24	-20	-12		
$\Delta F = \pm 5$	-41	-39	-35	-30	-25	-20	-12		
$\Delta F = \pm 6$	-43	-41	-37	-32	-26	-20	-12		
$\Delta F = \pm 7$	-44	-42	-39	-33	-28	-20	-12		
$\Delta F = \pm 8$	-46	-44	-41	-35	-29	-20	-12		
$\Delta F = -9$	-47	-45	-43	-36	-30	-20	-12		
$\Delta F = +9$	-43	-43	-43	-35	-27	-19	-12		
$ \Delta F  \ge 10$	-47	-45	-43	-36	-30	-20	-12		

Class 4, 70%		C (dBm/8 MHz)							
Channel separation, $\Delta F$	-70	-60	-50	-40	-30	-20	-12		
$\Delta F = \pm 1$	-17	-17	-14	-13	-12	-11	-10		
$\Delta F = \pm 2$	-27	-27	-25	-23	-22	-20	-12		
$\Delta F = \pm 3$	-35	-34	-31	-27	-23	-19	-12		
$\Delta F = \pm 4$	-37	-36	-33	-28	-24	-20	-12		
$\Delta F = \pm 5$	-39	-38	-35	-30	-25	-20	-12		
$\Delta F = \pm 6$	-41	-40	-37	-32	-26	-20	-12		
$\Delta F = \pm 7$	-43	-41	-39	-33	-28	-20	-12		
$\Delta F = \pm 8$	-45	-43	-41	-35	-29	-20	-12		
$\Delta F = -9$	-47	-45	-43	-36	-30	-20	-12		
$\Delta F = +9$	-43	-43	-43	-35	-27	-19	-12		
$ \Delta F  \ge 10$	-47	-45	-43	-36	-30	-20	-12		

# Table A9.13 – Protection ratios (dB) for 70th percentile DTT receivers based on discontinuous WSD signal, class 4

# Table A9.14 – Protection ratios (dB) for 70th percentile DTT receivers based on discontinuous WSD signal, class 5

Class 5, 70%		C (dBm/8 MHz)								
Channel	-70	-60	-50	-40	-30	-20	_12			
separation, $\Delta F$	-70	-00	-30	40	-30	-20	-12			
$\Delta F = \pm 1$	-7	-7	-7	-6	-6	-6	-6			
$\Delta F = \pm 2$	-17	-17	-17	-16	-16	-16	-12			
$\Delta F = \pm 3$	-28	-27	-26	-24	-22	-20	-12			
$\Delta F = \pm 4$	-31	-30	-29	-26	-23	-20	-12			
$\Delta F = \pm 5$	-34	-33	-32	-28	-25	-20	-12			
$\Delta F = \pm 6$	-37	-36	-35	-30	-26	-20	-12			
$\Delta F = \pm 7$	-41	-39	-37	-32	-27	-20	-12			
$\Delta F = \pm 8$	-44	-42	-40	-34	-29	-20	-12			
$\Delta F = -9$	-47	-45	-43	-36	-30	-20	-12			
$\Delta F = +9$	-43	-43	-43	-35	-27	-19	-12			
$ \Delta F  \ge 10$	-47	-45	-43	-36	-30	-20	-12			

### Annex 10

# WSD to PMSE protection ratios

- A10.1 In this annex we describe the procedures for deriving WSD-PMSE protection ratios corresponding to five WSD spectrum emission classes as defined in the ETSI European harmonised standard EN 301 598<sup>56</sup>.
- A10.2 These protection ratios are intended for use by WSDBs for purposes of calculating the maximum permitted WSD in-block EIRPs in relation to PMSE use.
- A10.3 We have derived these protection ratios by using laboratory tests of measuring the co-channel and adjacent-channel protection ratios of a selection of wireless microphones in the presence of a WSD *test* signal.
- A10.4 We have used these measurements to derive the adjacent channel selectivity (ACS) of the PMSE receivers. The derived ACS values were then combined with the adjacent channel leakage ratios (ACLRs) for the five WSD spectrum emission classes to calculate the class-specific WSD-PMSE protection ratios.
- A10.5 Unless otherwise stated, we use the term 'channel' to refer to an 8 MHz DTT channel. Furthermore, we use  $P_s$  and C, and  $P_x$  and I interchangeably to refer to wanted PMSE and unwanted WSD in-block powers, respectively. Finally, we use the subscript "M" to denote measured parameters.

### Measurement set up

- A10.6 An illustration of the high level set up for the conductive (non-radiating) measurements is shown in Figure A10.1. Conductive measurements are preferred to radiating tests where possible since they give repeatable and stable results and minimise uncertainty of RF levels throughout the measurement system.
- A10.7 In the measurement setup, a 3dB 4-port coupler is used to combine the PMSE signal and the WSD interferer. We use an audio analyser to generate the test audio signal which is a constant tone for the purposes of protection ratio tests. More details about PMSE measurements are contained in Section 6 of the PMSE coexistence test report published in November 2014<sup>57.</sup>
- A10.8 In the context of PMSE use, we have defined the point of 'failure' to be one where although the audio quality is still good, subjective listeners are just able to perceive some degradation.

<sup>&</sup>lt;sup>56</sup> ETSI EN 301 598 V1.1.1(2014-04), "White space devices (WSD); Wireless access systems operating in the 470 MHz to 790 MHz frequency band; Harmonized EN covering the essential requirements of article 3.2 of the <u>R</u>&TTE Directive".

<sup>&</sup>lt;sup>57</sup> <u>http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2014/tvws-pmse-</u> coexistence

![](_page_152_Figure_0.jpeg)

#### Figure A10.1 – Conductive protection ratio measurements for wireless microphones

# **PMSE Equipment**

- A10.9 PMSE equipment was chosen through stakeholder engagement and supplied by vendors. The results were anonymised for presentation in the PMSE coexistence test report. Equipment from a number of price points within the vendors' product ranges was tested. All equipment supplied was analogue PMSE equipment. Although digital wireless microphone transmitters and IEMs are available, use of analogue equipment is much more common.
- A10.10 Compared to digital equipment, analogue equipment suffers from more graceful quality reduction at lower levels of interference. Protection ratios derived from measurements on analogue equipment are therefore expected to provide more than adequate protection for digital equipment. We measured the performance of six wireless microphones. The wireless microphone selected for our adopted values of wireless microphone protection ratios was the most sensitive of the set, with a -88 dBm reference sensitivity. It is considered typical for production-quality audio in theatres.

### **Interferer signal**

- A10.11 The actual protection ratio measured is a combination of effects of ACLR of the WSD and ACS of the PMSE equipment. In order to understand the impact of PMSE's adjacent channel selectivity (ACS), an interferer signal with very high ACLR is preferred so that the effect of ACLR does not dominate protection ratio measurement results.
- A10.12 On the other hand, we have observed that the fine structure of the WSD signal modulation and bandwidth is less important than its duty cycle to the reduction in PMSE audio quality. We have therefore used an AWGN (additive white Gaussian noise) signal from a signal generator (with a duty cycle of 100%) as a proxy for the WSD signal.
- A10.13 We used a band-pass filter to suppress adjacent channel leakage from the signal generator, and achieve higher ACLR. Table A10.1 shows the measured ACLR values of the AWGN test signal. The ACLR of the AWGN test signal is measured as

$$ACLR_{M} = \frac{P_{X(5 \text{ MHz})}}{P_{OOB(200 \text{ kHz})}},$$
(A10.1)

where  $P_{\rm X}$  is in-block power of AWGN over 5 MHz<sup>58</sup>, and  $P_{\rm OOB}$  is the out-of-block power of the AWGN signal over 200 kHz. Note that the out-of-block power is measured over 200 kHz<sup>59</sup> to reflect the bandwidth of the PMSE receiver. The process of generating the AWGN signal and the detailed filter configuration can be found in the PMSE coexistence test report.

Centre-to-centre (MHz)	Channel separation, $\Delta F$	Measured ACLR <sup>60</sup>
0	0	14.4
4.1	±1	77.8
12.1	±2	96
20.1	±3	108
28.1	±4	118
36.1	±5	125
44.1	±6	132
52.1	±7	135
76.1	±10	140
116.1	±15	145
172.1	±22	150

#### Table A10.1 – Measured ACLR values of the AWGN test signal

### **Measurement of protection ratios**

- A10.14 As we explained in the PMSE coexistence test report, it is necessary to assess performance of a PMSE device when it is operating with audio quality similar to that during actual use in venues. For this reason, we adopt an approach based on scoring audio quality via subjective listening.
- A10.15 In the subjective tests, we developed an Instrumented Audio Metric (IAM) method for rating the reduction in sound quality of audio recordings related to a known 'reference' recording. Quality reduction was assessed on a 5 point scale: 5.0 imperceptible, 4.0 perceptible but not annoying, 3.0 slightly annoying, 2.0 annoying, and 1.0 very annoying. This methodology is explained in Annex 1 of PMSE coexistence test report.
- A10.16 In the context of characterising the performance of PMSE receivers in the presence of WSD radiation we have defined the 'point of failure' to be one where although the audio quality is still good, listeners are only just able to perceive some reduction in quality as associated with a score of 4.5 on the subjective audio quality scale.

 $P_{X(5 \text{ MHz})} = P_{X(8 \text{ MHz})}$ 

<sup>&</sup>lt;sup>59</sup> In EN 301 598, out of block power is specified in 100 kHz.

<sup>&</sup>lt;sup>60</sup> ACLR is measured indirectly for channel offset > 1 by characterising the signal generator and the filter separately.

- A10.17 We measured protection ratios for WSD-PMSE channel separations of  $\Delta F = 0, +1, +2, +3, +4, +5, +6, +7, +10, +15$  and +22. A positive channel separation means that the WSD signal is at the higher frequency. We assumed similar protection ratios for negative channel separations.
- A10.18 Table A10.2 show the measured protection ratios  $r_{M}(C, \Delta F)$  of the PMSE receiver (wireless microphone) at specific PMSE wanted signal powers and for a range of WSD-PMSE channel separations.

	Measured protec	tion ratio of	MIC2 ( $C, \Delta I$	F) (dB)					
Channel	Edge-to-edge	V	Vanted signa	l power leve	el,				
separation,	separation,		<i>C</i> (dBm/	200kHz)					
$\Delta F$	$\Delta f$ (MHz)	-75	-65	-55	-40				
±1	1.5	-49.1	-47.1	-40.1	-29.1				
±2	9.5	-62.1	-54.1	-46.1	-35.1				
±3	17.5	-65.1	-58.1	-50.1	-35.6				
±4	25.5	-67.6	-59.6	-52.6	-42.6				
±5	33.5	-69.6	-62.6	-55.6	-45.6				
±6	41.5	-70.6	-64.6	-57.6	-48.6				
±7	49.5	-71.6	-65.6	-59.6	-49.6				
±10	73.5	-74.6	-68.6	-63.6	-54.6				
±15	113.5	-77.6	-71.6	-64.6	-54.6				
±22	169.5	-81.6	-75.6	-69.6	-62.6				

#### Table A10.2 – Measured protection ratios of MIC2

### **Derivation of adjacent channel selectivity**

- A10.19 In this subsection, we describe the derivation of the adjacent channel selectivity of a PMSE receiver.
- A10.20 The adjacent channel selectivity,  $ACS(C, \Delta F)$  of a tested PMSE receiver can be derived from the measured co-channel and adjacent-channel protection ratios, and the measured adjacent channel leakage ratio of the unwanted signal used in the tests. From the definition of ACS we have (in the linear domain),

$$P_{I(200 \text{ kHz})} = P_{OOB(200 \text{ kHz})} + \frac{P_{X(5 \text{ MHz})}}{ACS(C, \Delta F)},$$
(A10.2)

where  $P_X$  is the in-block power of the unwanted signal,  $P_{OOB}$  is the out-of-block power of the unwanted signal, and  $P_I$  is the experienced interference power.

A10.21 From the definition of adjacent-channel interference ratio (ACIR) we also have (in the linear domain),

ACIR<sub>M</sub>(C, 
$$\Delta F$$
) =  $\frac{P_{X(5 \text{ MHz})}}{P_{I(200 \text{ kHz})}}$ , (A10.3)

at the point of receiver failure. Combining Equations (A10.2) and (A10.3) we have

$$\frac{1}{\operatorname{ACIR}_{M}(C,\Delta F)} = \frac{P_{\operatorname{OOB}(200 \text{ kHz})}}{P_{X(5 \text{ MHz})}} + \frac{1}{\operatorname{ACS}(C,\Delta F)}$$

$$= \frac{1}{\operatorname{ACLR}_{M}(\Delta F)} + \frac{1}{\operatorname{ACS}(C,\Delta F)},$$
(A10.4)
$$\operatorname{ACS}(C,\Delta F) = \left\{\operatorname{ACIR}_{M}^{-1}(C,\Delta F) - \operatorname{ACLR}_{M}^{-1}(\Delta F)\right\}^{-1},$$
(A10.5)

or

where  $ACLR_M(\Delta F)$  is the measured adjacent channel leakage ratio of the 5 MHz WSD test signal with spectral leakage over the 200 kHz PMSE channel (see Table A10.1).

A10.22 Finally, from the definition of ACIR we have (in the linear domain),

$$ACIR_{M}(C, \Delta F) = \frac{P_{X}(5 \text{ MHz})}{P_{I}(200 \text{ kHz})} = \frac{P_{X}(5 \text{ MHz})}{P_{S}(200 \text{ kHz})} \times \frac{P_{S}(200 \text{ kHz})}{P_{I}(200 \text{ kHz})}$$

$$= \frac{1}{r_{M}(C, \Delta F)} \times SIR \equiv \frac{1}{r_{M}(C, \Delta F)} \times r'_{M}(0) , \qquad (A10.6)$$

where  $r_{\rm M}(C, \Delta F)$  is the measured adjacent channel protection ratio, and SIR is the signal-to-interference ratio at the point of failure. Note that  $r'_{\rm M}(0)$  is the measured bandwidth adjusted co-channel protection ratio over the 200 kHz PMSE channel. We can derive its value from the measured co-channel protection ratio r(0). Specifically, if  $P_{\rm X}$  is the power of a co-channel unwanted signal over 5 MHz,

$$r'_{\rm M}(0) = \frac{P_{\rm S\,(200\,\,kHz)}}{P_{\rm X\,(200\,\,kHz)}} = \frac{P_{\rm S\,(200\,\,kHz)}}{P_{\rm I\,(200\,\,kHz)}} = \frac{P_{\rm S\,(200\,\,kHz)}}{\frac{0.2}{5}} P_{\rm X\,(5\,\,MHz)}$$

$$= \frac{5}{0.2} \frac{P_{\rm S\,(200\,\,kHz)}}{P_{\rm X\,(5\,\,MHz)}} = \frac{5}{0.2} r_{\rm M}(0).$$
(A10.7)

#### A10.23 Combining Equations (A10.5) to (A10.7) we have

ACS
$$(C, \Delta F) = \left\{ \frac{0.2}{5} \frac{r_{\rm M}(C, \Delta F)}{r_{\rm M}(0)} - \text{ACLR}_{\rm M}^{-1}(\Delta F) \right\}^{-1}$$
. (A10.8)

- A10.24 The measured co-channel protection ratio  $r_{\rm M}(0)$ , and the bandwidth adjusted cochannel protection ratio  $r'_{\rm M}(0)$ , for the tested PMSE receiver are 11.9 dB and 25.9 dB respectively.
- A10.25 Table A10.3 shows the derived values of ACS for MIC2.

ACS $(C, \Delta F)$ (dB)							
Channel	Edge-to-edge	Wanted	Wanted signal power level of Radio Mic 2,				
separation,	separation,		<i>C</i> (dBm/	'200kHz)			
$\Delta F$	$\Delta f$ (MHz)	-75	-65	-55	-40		
±1	1.5	78.0	74.7	66.3	55.0		
±2	9.5	88.7	80.1	72.0	61.0		
±3	17.5	91.1	84.0	76.0	61.5		
±4	25.5	93.5	85.5	78.5	68.5		
±5	33.5	95.5	88.5	81.5	71.5		
±6	41.5	96.5	90.5	83.5	74.5		
±7	49.5	97.5	91.5	85.5	75.5		
±10	73.5	100.5	94.5	89.5	80.5		
±15	113.5	103.5	97.5	90.5	80.5		
±22	169.5	107.5	101.5	95.5	88.5		

#### Table A10.3 – Derived values of ACS, MIC2

### **Calculating class-specific protection ratios**

- A10.26 In this subsection, we describe the calculation of protection ratios for the tested PMSE device, for each of the five WSD spectrum emission classes.
- A10.27 A class-specific protection ratio,  $r(C, \Delta F)$ , at a particular wanted signal power C, and channel separation  $\Delta F$ , can be calculated by taking account of derived PMSE receiver selectivity ACS( $C, \Delta F$ ), and the class-specific WSD ACLR ( $\Delta F$ ) as defined in ETSI EN 301 598.
- A10.28 Note that we derive class-specific protection ratios by using the class-specific ACLR of a WSD with an in-block bandwidth of 8 MHz.
- A10.29 By definition (in the linear domain),

$$r(C, \Delta F) = \frac{P_{S(200 \text{ kHz})}}{P_{X(8 \text{ MHz})}} = \frac{P_{S(200 \text{ kHz})}}{P_{I(200 \text{ kHz})}} \times \frac{P_{I(200 \text{ kHz})}}{P_{X(8 \text{ MHz})}}$$
  
=  $r'_{M}(0) \times \frac{1}{\text{ACIR}(C, \Delta F)}$   
=  $r'_{M}(0) \times \left(\text{ACLR}^{-1}(\Delta F) + \text{ACS}^{-1}(C, \Delta F)\right),$  (A10.9)

where  $P_{\rm S}$  is the in-block power of the wanted signal,  $P_{\rm X}$  is the in-block power of the unwanted signal, and  $P_{\rm I}$  is the experienced interference power. We have used the definition of ACIR to derive the last line which describes the relationship with the class-specific ACLR, and the derived ACS. Note that  $r'_{\rm M}(0)$  is the bandwidth adjusted co-channel protection ratio. We can derive its value from the measured co-channel protection ratio  $r_{\rm M}(0)$  as described earlier. Specifically,

$$r'_{\rm M}(0) = \frac{5}{0.2} \times r_{\rm M}(0).$$
 (A10.10)

- A10.30 So class-specific protection ratios can be calculated via Equation (A10.9) from the measured co-channel protection ratio, the measured ACS, and the WSD class-specific ACLR.
- A10.31 Table A10.4 shows the values of ACLR( $\Delta F$ ) for the five WSD spectrum emission classes. For channel separations  $\Delta F = \pm 1, \pm 2$  and  $\pm 3$ , the values of ACLR( $\Delta F$ ) are as defined in EN 301 598<sup>61</sup> (for greater channel separations the limits in EN 301 598 remain at their values for  $\Delta F = \pm 3$ ). To account for practical spectrum masks, we have assumed a roll off (increase in ACLR) of 10 dB per 8 MHz for  $|\Delta F| > 3$ . We have assumed the spectrum mask is flat for  $|\Delta F| > 9$ .
- A10.32 Tables A10.5 to A10.8 show the calculated values of  $r(C, \Delta F)$  as given by Equation A10.9.
- A10.33 We use the same protection ratio for some other types of PMSE, i.e. in ear monitor, talkback, programme audio link and data link. The reasoning behind this decision is given in Annex 4.

$ACLR(\Delta F)$			WSD spec	ctrum emis	sion class	
Channel separation, $\Delta F$	Edge-to-edge separation, $\Delta f$ (MHz)	WSD class 1	WSD class 2	WSD class 3	WSD class 4	WSD class 5
$\Delta F = \pm 1$	1.5	71	71	61	51	40
$\Delta F = \pm 2$	9.5	76	71	71	61	50
$\Delta F = \pm 3$	17.5	81	71	81	71	61
$\Delta F = \pm 9$	65.5	141	131	141	131	121
$ \Delta F  \ge 10$	73.5	151	141	151	141	131

#### Table A10.4 – Class-specific ACLRs

Table A10.5 – Class-specif	ic protection	ratios, wireless	microphone	, C = -75dBm
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<i>r(C,∆F), C</i> = -75 dBm			Wireles	ss microph	ones 2	
Channel separation, $\Delta F$	Edge-to-edge separation, $\Delta f$ (MHz)	WSD class 1	WSD class 2	WSD class 3	WSD class 4	WSD class 5
$\Delta F = \pm 1$	1.5	-44.3	-44.3	-35.0	-25.1	-14.1
$\Delta F = \pm 2$	9.5	-49.9	-45.0	-45.0	-35.1	-24.1
$\Delta F = \pm 3$	17.5	-54.7	-45.1	-54.7	-45.1	-35.1
$\Delta F = \pm 4$	25.5	-63.2	-54.9	-63.2	-54.9	-45.1
$\Delta F = \pm 5$	33.5	-68.5	-63.8	-68.5	-63.8	-55.0
$\Delta F = \pm 6$	41.5	-70.5	-69.3	-70.5	-69.3	-64.0
$\Delta F = \pm 7$	49.5	-71.6	-71.4	-71.6	-71.4	-70.0
$\Delta F = \pm 8$	57.5	-72.6	-72.6	-72.6	-72.6	-72.4
$\Delta F = \pm 9$	65.5	-73.6	-73.6	-73.6	-73.6	-73.6
$\Delta F = \pm 10$	73.5	-74.6	-74.6	-74.6	-74.6	-74.6
$\Delta F = \pm 15$	113.5	-77.6	-77.6	-77.6	-77.6	-77.6
$\Delta F = \pm 22$	169.5	-81.6	-81.6	-81.6	-81.6	-81.6

<sup>&</sup>lt;sup>61</sup> Note that the out-of-block powers in EN 301 598 are spectral densities in dBm/(100 kHz). Here we have adjusted the values by 3 dB to reflect that we are working with out-of-block powers in 200 kHz.

$r(C,\Delta F),$		Wireles	s microph	ones 2		
Channel separation, $\Delta F$	Edge-to-edge separation, $\Delta f$ (MHz)	WSD class 1	WSD class 2	WSD class 3	WSD class 4	WSD class 5
$\Delta F = \pm 1$	1.5	-43.6	-43.6	-34.9	-25.1	-14.1
$\Delta F = \pm 2$	9.5	-48.7	-44.6	-44.6	-35.1	-24.1
$\Delta F = \pm 3$	17.5	-53.4	-44.9	-53.4	-44.9	-35.1
$\Delta F = \pm 4$	25.5	-58.5	-53.8	-58.5	-53.8	-45.0
$\Delta F = \pm 5$	33.5	-62.4	-60.7	-62.4	-60.7	-54.4
$\Delta F = \pm 6$	41.5	-64.6	-64.2	-64.6	-64.2	-61.8
$\Delta F = \pm 7$	49.5	-65.6	-65.6	-65.6	-65.6	-65.1
$\Delta F = \pm 8$	57.5	-66.6	-66.6	-66.6	-66.6	-66.5
$\Delta F = \pm 9$	65.5	-67.6	-67.6	-67.6	-67.6	-67.6
$\Delta F = \pm 10$	73.5	-68.6	-68.6	-68.6	-68.6	-68.6
$\Delta F = \pm 15$	113.5	-71.6	-71.6	-71.6	-71.6	-71.6
$\Delta F = \pm 22$	169.5	-75.6	-75.6	-75.6	-75.6	-75.6

#### Table A10.6 – Class-specific protection ratios, wireless microphone, C = -65dBm

#### Table A10.7 – Class-specific protection ratios, wireless microphone, C = -55dBm

<i>r(C,∆F), C</i> = -55 dBm			Wireles	ss microph	ones 2	
Channel separation, $\Delta F$	Edge-to-edge separation, $\Delta f$ (MHz)	WSD class 1	WSD class 2	WSD class 3	WSD class 4	WSD class 5
$\Delta F = \pm 1$	1.5	-39.1	-39.1	-34.0	-25.0	-14.1
$\Delta F = \pm 2$	9.5	-44.7	-42.6	-42.6	-34.8	-24.1
$\Delta F = \pm 3$	17.5	-48.9	-43.9	-48.9	-43.9	-35.0
$\Delta F = \pm 4$	25.5	-52.4	-50.7	-52.4	-50.7	-44.4
$\Delta F = \pm 5$	33.5	-55.6	-55.1	-55.6	-55.1	-52.3
$\Delta F = \pm 6$	41.5	-57.6	-57.5	-57.6	-57.5	-56.9
$\Delta F = \pm 7$	49.5	-59.6	-59.6	-59.6	-59.6	-59.5
$\Delta F = \pm 8$	57.5	-60.9	-60.9	-60.9	-60.9	-60.9
$\Delta F = \pm 9$	65.5	-62.3	-62.3	-62.3	-62.3	-62.3
$\Delta F = \pm 10$	73.5	-63.6	-63.6	-63.6	-63.6	-63.6
$\Delta F = \pm 15$	113.5	-64.6	-64.6	-64.6	-64.6	-64.6
$\Delta F = \pm 22$	169.5	-69.6	-69.6	-69.6	-69.6	-69.6

# Table A10.8 – Class-specific protection ratios, wireless microphone, C = -40dBm

r(C,ΔF),		Wireles	ss microph	ones 2		
Channel separation, $\Delta F$	Edge-to-edge separation, $\Delta f$ (MHz)	WSD class 1	WSD class 2	WSD class 3	WSD class 4	WSD class 5
$\Delta F = \pm 1$	1.5	-29.0	-29.0	-28.1	-23.7	-14.0
$\Delta F = \pm 2$	9.5	-35.0	-34.7	-34.7	-32.1	-23.8
$\Delta F = \pm 3$	17.5	-35.6	-35.1	-35.6	-35.1	-32.3
$\Delta F = \pm 4$	25.5	-42.6	-42.4	-42.6	-42.4	-40.7
$\Delta F = \pm 5$	33.5	-45.6	-45.6	-45.6	-45.6	-45.1
$\Delta F = \pm 6$	41.5	-48.6	-48.6	-48.6	-48.6	-48.5
$\Delta F = \pm 7$	49.5	-49.6	-49.6	-49.6	-49.6	-49.6
$\Delta F = \pm 8$	57.5	-51.3	-51.3	-51.3	-51.3	-51.3
$\Delta F = \pm 9$	65.5	-52.9	-52.9	-52.9	-52.9	-52.9
$\Delta F = \pm 10$	73.5	-54.6	-54.6	-54.6	-54.6	-54.6
$\Delta F = \pm 15$	113.5	-54.6	-54.6	-54.6	-54.6	-54.6
$\Delta F = \pm 22$	169.5	-62.6	-62.6	-62.6	-62.6	-62.6

### Annex 11

# Summary of responses to our consultations and Ofcom's comments

### Introduction

- A11.1 This Annex sets out a summary of the responses to the coexistence proposals in our 2013 Consultation and the device requirements proposals in the 2012 Consultation. Our decisions on coexistence and device authorisation, as set out in the main body of this document, took these responses into account.
- A11.2 We received 27 responses to the 2012 Consultation, 1 of which was confidential. For the 2013 Consultation, we received 31 responses, 4 of which were confidential. The non-confidential responses to these consultations are publicly available on our website.

Section 1	Responses relating to the TVWS framework
Section 2	Responses relating to DTT
Section 3	Responses relating to PMSE
Section 4	Responses relating to mobile services above the UHF TV band
Section 5	Responses relating to users below the band
Section 6	Responses relating to cable

#### **List of Sections**

### Section 1

### **Responses relating to the TVWS framework**

#### Our goal to ensure a low probability of harmful interference

#### Summary of our position in the 2013 Consultation

A11.3 In our 2013 Consultation we reiterated<sup>62</sup> our objective of ensuring that there is a low probability of harmful interference to other services in and adjacent to the UHF TV band.

- A11.4 The majority of respondents from the broadcast and PMSE sectors were concerned that the proposals in the 2013 consultation would not achieve the goal of ensuring a low probability of harmful interference, with some suggesting that further coexistence tests and trials were needed.
- A11.5 Other respondents supported our approach to setting coexistence parameters. Sky thought that Ofcom had taken a proportionate approach to coexistence based on the available evidence. The Dynamic Spectrum Alliance thought that Ofcom's proposed approach "is practical and strikes a sensible balance between ensuring that there is a low probability of harmful interference to DTT services and enabling new TVWS applications and services". Neul thought that the proposed approach was a fair judgement of the real likelihood of interference with DTT and PMSE receivers, but noted some parameters where they thought Ofcom had been too conservative.
- A11.6 The BBC said that the current proposals represent a significant risk to both DTT and PMSE services. It noted that it was difficult to have an informed view on the objective to ensure there is a low probability of harmful interference in the absence of knowing precisely what Ofcom means by this terminology.
- A11.7 Two respondents referred to section 8 of the Wireless Telegraphy Act 2006 (WTA 2006), which describes the legal basis for licence exemption, and questioned whether TVWS could be introduced as a licence exempt service based on current proposals. Digital UK said that there is no precedent for knowingly permitting interference from a licence-exempt service into a licensed service, which is contrary to the spirit, if not the letter, of the WT Act. Digital UK also said that, where interference does occur, "it is always on a "polluter pays" basis, which is not presented as the case here".
- A11.8 A respondent said that the WSD testing regime should make it clear that, in the event of any interference with DTT, the WSD provider is responsible for reducing power or installing interference mitigation measures and the costs of doing so.
- A11.9 The British Entertainment Industry Radio Group (BEIRG)<sup>63</sup> urged Ofcom to ensure that there would be no possibility of 'harmful interference' to PMSE operators. They

 <sup>&</sup>lt;sup>62</sup> Previously stated in our 2011 Statement on Implementing Geolocation (<u>http://stakeholders.ofcom.org.uk/consultations/geolocation/statement/</u>)
 <sup>63</sup> A number of responses to our 2013 Consultation were from stakeholders who supported the response from

<sup>&</sup>lt;sup>63</sup> A number of responses to our 2013 Consultation were from stakeholders who supported the response from BEIRG and most of these included a copy of BEIRG's response in their submission. These respondents were as follows: Association of Motion Picture Sound, Institute of Professional Sound, Production Services Association, Sound Technology UK, Terry Tew Sound & Light Ltd and Visual Impact UK Ltd.

note that any interference is harmful for the PMSE industry and has the ability to cause serious problems within the sector and beyond.

A11.10 Highfield Church said that PMSE users pay licence fees to Ofcom to protect a suitable quality of service. It said the damage of interference would accrue to performers, producers, broadcasters and the licence-fee paying audience and, potentially, the nation. It suggested that there should be a "registration fee for every WSD sold" and that the "revenue shall be used to properly manage and police WSDs for the protection of DTT and PMSE licensees". It also said that "there appears to be no incentive for WSDBs to ensure that the issued Operating Parameters are correct or suitable".

#### Ofcom's response

- A11.11 Ofcom has, since the 2013 Consultation, undertaken an extensive programme of coexistence testing looking at both PMSE and DTT coexistence scenarios and published test reports on the Ofcom website. We have used this further evidence to inform our decisions on coexistence described in the main body of this Statement. We believe that these decisions will result in a low probability of harmful interference to both DTT and PMSE users, as well as to users above and below the UHF TV band.
- A11.12 We have expressed our goal as a "low" probability of harmful interference as opposed to "no" harmful interference in recognition that, in general, achieving zero probability of interference between services that coexist is not feasible. The approach we have taken in setting our regulatory criteria for white spaces is not intended to define or identify at what point interference from white space (or any other) device would be harmful we have instead set limits that we are confident will offer the protection needed to secure a low likelihood of harmful interference to users.
- A11.13 In relation to comments on Section 8 of the WTA 2006, we note that section 8(4) and (5) require that Ofcom <u>must</u> grant a licence exemption (as opposed to a licence) where Ofcom is satisfied, amongst other things, that the use of stations or apparatus of a particular description "is not likely to involve undue interference with wireless telegraphy". These provisions do not guarantee that licensed services have an absolute right to protection from interference from licence exempt services. For the reasons explained in paragraphs 5.5 to 5.9 of this Statement, we consider that granting a licence exemption permitting WSDs to access the UHF TV band is appropriate and consistent with the WT Act.
- A11.14 In respect of the argument that WSD users, manufacturers or retailers should be held liable for causing interference or should contribute to the costs of mitigating interference (for example, through licence fees or registration fees), we do not consider that there is any need to put in place specific measures to require WSD users, manufacturers or retailers to contribute to the costs of interference management. We have explained in section 5 of the Statement that we consider licence exempt authorisation, rather than a licensing regime, is appropriate in this case and we are not able to charge fees for licence exempt use. We do not have a general policy of holding spectrum users accountable for interference caused when they operate within the scope of their authorisation.
- A11.15 Some respondents mentioned the example of coexistence between mobile services at 800 MHz and DTT. In that case, licences were issued with requirements that make the mobile operators responsible for providing consumer assistance to DTT

viewers affected by interference from mobile networks. This was a policy adopted to fit the particular circumstances of that case, and not a general policy applicable to all spectrum bands and uses. An important distinction is that WSDs will only be allowed to operate at powers and channels that are set at a level which should result in a low probability of harmful interference from the outset, which was not the case in 800 MHz coexistence. For 800 MHz, consumer mitigation is part of the package of measures designed in conjunction with Government to manage the risk of harmful interference.

- A11.16 We consider that the framework we are putting in place will ensure that WSDBs have appropriate incentives to calculate Operational Parameters correctly for the WSDs that they serve. WSDBs will enter into a contract with Ofcom which will place certain obligations on them, including the following:
  - They will not be permitted under that contract to provide WSDB services, nor will they appear on the list of qualifying WSDBs that WSDs are required to use, until they have passed a qualification assessment;
  - The contract will impose detailed technical requirements on them as to how they should calculate the operational parameters to be provided to WSDs; and
  - The contract will provide Ofcom with a range of mechanisms to address both WSDB non-compliance and interference (regardless of whether that interference was caused by the WSDB, the WSD or otherwise), including the ability to require a WSDB to cease providing WSDB services and remove it from the list of qualifying WSDBs.
- A11.17 Finally, we note that we will have the ability to switch off a device within a short period of time where required for interference management purposes, as explained in Section 5 of the statement. In addition, where appropriate, Ofcom would be able to take enforcement action using its powers under the WT Act for unauthorised use (e.g. where a user does not comply with the terms of the licence exemption) or causing deliberate interference.

#### **Impact Assessment**

#### Summary of our position in the 2013 Consultation

A11.18 In paragraph 2.30 of the 2013 Consultation we explained that "the impact assessment in the consultation is about demonstrating why we consider that our proposed approach to spectrum planning should achieve the objective of ensuring a low probability of harmful interference. Against this background, sections 4 to 7 constitute our assessment of the impact of the coexistence proposals".

- A11.19 Several respondents argued for a separate Impact Assessment or Cost Benefit Analysis (CBA). Some of the arguments were that:
  - A respondent said that Ofcom should undertake a thorough impact assessment to demonstrate that these proposals minimise disruption to incumbent licensed services. In its view, this was particularly the case for consultations of this type which involve highly technical and complex analysis that renders the consultation accessible to only a limited number of stakeholders;

- The same respondent noted that Ofcom acknowledged the importance of impact assessments particularly when their proposals have the potential to have a significant effect on businesses or the general public, or when there is a major change in Ofcom's activities. Ofcom has not attempted to define the potential impact of its proposals to incumbent licensed users on which the majority of UK consumers depend for access to audiovisual content.
- Brian Copsey noted Ofcom's own statement<sup>64</sup> that impact assessments are "a key part of best practice policy making, which is reflected in our statutory duty to carry them out";
- Voice of the Listener & Viewer said that sharing of spectrum between lightly regulated commercial services and public broadcasting is unprecedented, and it would have been expected that evaluation by means of a dedicated cost benefit analysis would have been appropriate;
- The BBC said that an Impact Assessment "may have led to a fuller understanding of the likely impacts of some of its proposals than appears to be present".

#### Ofcom's response

- A11.20 As noted, rather than presenting a separate impact assessment (which we have sometimes done in other cases, where appropriate), the impact assessment for the 2013 Consultation was integrated into the main body of the document in sections 4 to 7. We also noted that the 2013 Consultation followed earlier decisions relating to authorising use of white space in the UHF TV band (as summarised in Section 2 of this Statement) and set out proposals for implementing those decisions. We consider that it should be viewed in the context of the previous consultation processes that have been undertaken and the impact assessments that were carried out as part of that process.
- A11.21 Moreover, we have conducted a large amount of additional work since the 2013 Consultation with a view to examining the impact of our proposals and whether our proposals were appropriate to ensure there would be a low probability of harmful interference to other spectrum users, and have subsequently amended our proposals where relevant to ensure that this goal is met. This work included running a White Space pilot and an extensive coexistence testing programme. Two reports documenting the results of the coexistence testing have been published on the Ofcom website and these reports supplement the impact assessment included in the 2013 Consultation.

#### Aggregation issues with multiple devices and use of multiple databases

#### Summary of our position in the 2013 Consultation

A11.22 We published a technical report alongside the September 2013 consultation, in which we considered the possibility of multiple WSDs deployed in the same geographic area using the same DTT channels causing an aggregation of interferer signal powers.

<sup>&</sup>lt;sup>64</sup> In our policy "Better Policy Making – Ofcom's approach to Impact Assessment", published on our website at: <u>http://www.ofcom.org.uk/about/policies-and-guidelines/better-policy-making-ofcoms-approach-to-impact-assessment/</u>

- A11.23 We noted that in our framework for the calculation of WSD emission limits we had implicitly assumed that at any one time only one WSD would radiate per location and per DTT channel. However, we noted it was possible that in practice deployment of multiple WSDs in the same location could increase the probability of harmful interference to the incumbent users of the band.
- A11.24 We set out in the document our view that such interference aggregation would be unlikely to be problematic in the early stages of implementation of the TVWS framework. We gave a number of reasons for our assessment. We considered that:
  - Our approach for the calculation of WSD emission limits was sufficiently cautious, including implicit margins providing some *ex ante* mitigation of interference aggregation;
  - WSDs were likely to implement polite protocols, such as listen-before-talk collision avoidance or frequency hopping, to coexist with other WSDs;
  - Databases were likely to perform radio resource management for congestion avoidance and instruct WSDs to avoid congregating in the same channels in the same geographic area; and
  - If WSDs did transmit simultaneously and at the same frequencies, the composite signal would increasingly appear noise-like and this would render the time-frequency structure of the composite signal more benign in the context of interference to existing services.
- A11.25 For these reasons, we judged that we did not need to address interference aggregation in the short term. We recognised that there was a possibility that interference aggregation could increase the probability of harmful interference in the long term and set out high-level options for mitigating this. We noted that we would develop more detailed proposals if and when interference aggregation arises.

- A11.26 A number of respondents commented on our assessment that interference aggregation did not increase the probability of harmful interference in the short term.
- A11.27 BEIRG and Sony both raised concerns about the risk of interference aggregation. BEIRG sought reassurances that Ofcom would be able to protect the PMSE industry from problems caused by aggregate interference, such as increased intermodulation, while Sony submitted detailed calculations supporting its view that aggregation may cause unacceptable interference to receivers even during the introductory phase.
- A11.28 The BBC also raised concerns that we had concluded that interference aggregation was unlikely. It submitted that aggregated interference may be caused if devices are using independent channels adjacent to the DTT service. The BBC considered that our approach did not take account for transmissions at different frequencies or the aggregation of noise-like interference from WSDs in far pixels. It suggested that Ofcom should include an appropriate interference margin in initial deployment.
- A11.29 techUK considered that Ofcom should use the aggregation of all interferers over the band (including WSD interferers), taking account of the appropriate frequency separations of interferers, to calculate the maximum transmit power of WSDs. It

also suggested that databases should gather statistics of the number of WSDs in a particular area of time, so that Ofcom could learn more about the effects of interference aggregation.

A11.30 In contrast, the Dynamic Spectrum Alliance (DSA) agreed with our conclusion that aggregated interference is not a significant issue in the short term and cited a study<sup>65</sup> in support of its view.

#### Ofcom's response

- A11.31 We remain of the view that our framework will lead to a low probability of harmful interference even taking into account the possibility of aggregation of power between devices. The rationale for this is explained in Section 6, paragraphs 6.22-6.24. In particular, we consider that aggregation of interference is unlikely to be problematic in the short term, for the following reasons:
  - a) Evidence suggests that devices (in particular mobile devices) rarely transmit at the full power they are capable to transmit, to conserve battery among other reasons. This can make a large difference: as an illustration, one study of behaviour of mobile handsets suggests one may need between 25 and 2,000 mobile handsets transmitting at typical power to generate the maximum power that a single handset is allowed.<sup>66</sup>
  - b) Received power reduces rapidly with increasing geographic and frequency separation from a transmitter, and as such, experienced interference tends to be dominated by one interferer; additional interferers which are physically further away, and/or further away in frequency quickly become irrelevant in comparison.
  - c) In order for WSDs to coexist successfully with each other, many will implement polite protocols, such as "listen-before talk" used in Wi-Fi, or frequency hopping used in Bluetooth. In such cases, it is unlikely that WSDs will transmit at the same time and at the same frequencies when in close proximity.
  - d) Our approach for the calculation of WSD emission limits is cautious. The emission limits include implicit margins which will provide some mitigation of interference aggregation.
- A11.32 We also intend to continue to monitor this issue as the market develops, and if required we may adapt the framework to further reduce the probability of interference caused by aggregation effects.

#### Use of power caps

#### Summary of our position in the 2013 Consultation

A11.33 We proposed to set a maximum power level of 36 dBm/(8 MHz). No WSD at any location is permitted to operate at a power level above this cap.

<sup>66</sup> Based on ITU document 5-6/81-E "Additional System Characteristics of an operational IMT network deployed in Australia in the 800 MHz band". Although handsets can transmit at up to 24 dBm, the study found they spend 90% of the time transmitting at 8 dBm or below in an urban cell, and on average the transmission level was -9 dBm. The difference between 24 dBm and 8 dBm is a factor of 25; between -9dBm and 24 dBm there is a

<sup>&</sup>lt;sup>65</sup> Controlling Aggregate Interference under Adjacent Channel Interference Constraint in TV White Spaces.

was -9 dBm. The difference between 24 dBm and 8 dBm is a factor of 25; between -9dBm and 24 dBm there is a factor of 1,995.

A11.34 We noted that this limit is very similar to that adopted by the Federal Communications Commission (FCC) for the deployment of WSDs in the US. The limit adopted by the FCC is 36dBm/(6 MHz), which is slightly higher in power density than our maximum power limit, but identical in total power per channel.

- A11.35 Several respondents disagreed with our proposed maximum power limit of 36 dBm/(8 MHz). Some respondents stated that the limit should be higher, while others suggested that our proposed limit was too low.
- A11.36 The DTT broadcasters and other groups with an interest in DTT broadcasting tended to consider that our proposed power limit was too high. Many of these respondents suggested that our proposed maximum power level created a likelihood of harmful interference to the incumbent users of the band. The BBC suggested that our proposed power limit appeared inconsistent with our stated aim to take a conservative approach to implementing TVWS.
- A11.37 The BBC suggested that the power limit would be too high for portable devices, on health and safety grounds, based on guidelines for exposure to electromagnetic fields by the International Commission on Non-Ionizing Radiation Protection (ICNIRP)<sup>67</sup>. They mentioned that the FCC has implemented a lower cap for portable devices.
- A11.38 A number of DTT broadcasters voiced concerns about the effect of our proposed power limit in cases where amplifiers are deployed. The BBC considered that, while the limit may be sufficient to prevent overloading of standard domestic installations, it is likely to cause overloading of amplified installations. In support of its argument, the BBC referred to the Isle of Bute TVWS trial, which resulted in the blocking of TV reception and was remedied by reducing amplifier gain. Digital UK and Freeview were both concerned that the proposed power limit would increase the risk of overload for receivers or aerial amplifiers, as well as cause disruption to the reception of indoor aerials. Both Digital UK and Freeview considered that a limit of not more than 30 dBm/(8 MHz) would be more appropriate.
- A11.39 In addition to the DTT broadcasters, a number of other respondents considered that our proposed power limit was too high. BEIRG, supported by several other respondents in the PMSE sector, recommended that WSDs should not be allowed to operate using high powers (up to 4 Watts) from the beginning of their introduction. Brian Copsey, a communications consultant, submitted that our proposed maximum power level was too high and suggested that a limit of 2 Watts would be more appropriate. Vodafone noted that the proposed limit was substantially higher than any other licence exempt device operating in shared spectrum, and raised concerns regarding the possibility of TV receiver overload and interference between WSDs.
- A11.40 In contrast, respondents in the WSD industry and interest groups tended to consider WSDs should be permitted to operate at higher powers than allowed under our proposed limit, given the low probability of harmful interference to incumbent users of the band. Google and Wi-Fi Alliance submitted that, in rural areas where there are fewer broadcasters, broadband providers using WSDs may be able to

<sup>&</sup>lt;sup>67</sup> ICNIRP is a charitable body of independent scientific experts established by the International Radiation Protection Association whose principal aim is to disseminate information and advice on the potential health hazard of exposure to non-ionising radiation including electromagnetic fields. For more information, see <u>http://www.hse.gov.uk/radiation/nonionising/faqs.htm</u>

reach more end users if they are permitted to increase the power of their operations. Both Wi-Fi Alliance and Google suggested that we should reconsider our maximum power limit, with Google submitting that we should consider increasing the cap to 40 dBm/(8 MHz) and remain flexible as to increasing the limit in the future. Dynamic Spectrum Alliance submitted that there is no reason to limit the maximum power at which WSDs can transmit as our geolocation implementation approach already prevents interference to other spectrum users.

- A11.41 Other respondents were more cautious. Sony agreed that a higher power limit may be reasonable provided it could be guaranteed that no DTT homes are nearby that might be overloaded by higher powers, but raised concerns about the possibility of someone moving into a house that was previously served by satellite TV who installed DTT and experienced DTT receiver overload from a high power WSD nearby. techUK noted that views within its organisation were divided: while some of its members saw no reason to impose a limit, given our geolocation database approach, others encouraged Ofcom to adopt a precautionary approach.
- A11.42 BT and Weightless accepted our proposed limit on maximum power levels as a provisional measure, while both encouraged Ofcom to increase maximum allowed power levels as deployment of WSDs becomes more established.

#### Ofcom's response

- A11.43 We remain of the view that a 36 dBm / (8 MHz) cap is appropriate to avoid overloading DTT receivers. Our in-home DTT coexistence technical studies, and those of BBC/Arqiva, did not produce any evidence of overload of aerial amplifiers. However we did see some evidence of some variation in receiver protection ratio with DTT signal level.
- A11.44 The framework takes account of the variation in receiver protection ratio with DTT signal level. However, the framework currently models the signal level presented to the DTT receiver as being provided by a standard receiving installation with a gain of 9.15 dBi. The BBC/Arqiva studies did demonstrate that the presence of aerial amplifiers would increase the signal levels presented to DTT receivers and this could worsen the point of onset of perceptible interference by up to 3 dB.
- A11.45 This worsening of apparent protection ratio with DTT signal levels will have been one of the factors that affected the point of onset of perceptible interference in the Ofcom in-home DTT coexistence testing i.e. it is one of the factors that will have contributed to the overall margin observed.
- A11.46 Observations made of the range of typical household installation gains and the signal levels actually encountered in home at the DTT receiver suggest that the 36 dBm / (8 MHz) cap should neither be relaxed (as this would increase the risk of DTT receiver overload) nor tightened (as there was no receiver hard overload identified, albeit that there was the normal worsening of protection ratios typically observed at higher signal levels). Therefore we remain of the view that a 36 dBm / (8 MHz) cap is appropriate to avoid overloading DTT receivers.
- A11.47 The above conclusions on the 36 dBm / (8 MHz) cap apply at the typical minimum separation distances expected between a WSD and a DTT aerial. As deployment of WSDs becomes more established, we may in the future consider a relaxation of this limit in rural areas where we can be certain of the separation distance between the WSD and any DTT receiving aerials being significantly greater than typical minimum separation distances and there being no harmful impact on PMSE.

- A11.48 We will cap the maximum permissible WSD power for both Type A and Type B devices at 36 dBm to avoid DTT receiver overload.
- A11.49 We recognise that Type B portable/handheld devices may need to operate with maximum powers significantly lower than the 36 dBm / (8 MHz) limit to comply with ICNIRP recommendations. We have not set a lower power cap for Type B devices as:
  - The power limits in the WSD database are intended to protect DTT, PMSE and other services and not to comply with ICNIRP limits or any other non WSDspecific constraint. The WSD limits represent the maximum powers under the WSD framework but they should not be taken as in any way authorising or encouraging the use of powers that would not be permitted or recommended for other reasons.
  - The maximum power at which a Type B device could radiate, whilst complying with ICNIRP limits, would depend on the technology adopted.
  - Type B devices such as fixed installations on boats or in cars, or those not intended for use by members of the public, would be subject to different limits, based on the ICNIRP guidelines.
- A11.50 In addition, portable/handheld devices typically have significant power restrictions due to battery life, often more stringent than health and safety considerations. For example, there is evidence that suggests that mobile handsets spend 90% of their time operating below 8 dBm, despite being able to operate up to 24dBm<sup>68</sup>
- A11.51 Portable/handheld devices will typically manage power consumption by using power control, whereby the device will transmit no more power than it needs to retain a reliable connection. This has the added advantage of managing interference with other White Space Devices and maximising spectrum utilisation. Although the framework is not proscriptive on the technologies to be adopted by White Space Devices, we strongly recommend the adoption of power control and politeness protocols to make the most efficient use of spectrum available to WSDs.
- A11.52 We do not consider that the evidence we have gathered indicates that a lower power cap for 36 dBm is required for Type B WSDs in order to ensure there would be a low probability of harmful interference. However, we would expect that manufacturers would comply with relevant ICNIRP limits. A side-effect of complying with ICNIRP limits would be that additional safety margins would be built in for protection of DTT, PMSE and other services than had the ICNIRP limits not been in place.

#### Calculation of master coverage area

#### Summary of our position in the 2013 Consultation

A11.53 While the location of master WSDs will typically be known to a high degree of accuracy through geo-location, slave WSDs are not required to report their location. Master WSDs will not know the location of a slave WSD, even if the slave WSD is capable of geolocating, until the point where the slave first reports its location to the master. There will be some communication before this point (not least so that the

<sup>&</sup>lt;sup>68</sup> ITU document 5-6/81-E "Additional System Characteristics of an operational IMT network deployed in Australia in the 800 MHz band".

slave can report its location), and this phase of communications will happen as if the slave was not geolocated.<sup>69</sup>

- A11.54 We proposed that, if a slave WSD is not geolocated, databases would need to calculate the coverage area of its serving master WSD. This is the area within which the master WSD is able to communicate with the slave WSD and it would act as an indication of the area of potential locations of non-geolocating slave WSDs.
- A11.55 The technical report accompanying the 2013 Consultation set out in detail proposals about the database calculations that would be used to derive the coverage area of a master WSD. We noted that the coverage area of a master WSD would be modelled as a circle.

#### Summary of responses

- A11.56 A number of respondents disagreed with our proposed calculations for the coverage area of master WSDs.
- A11.57 The PMSE respondents tended to consider that our calculations increased the probability of harmful interference to the incumbent users of the band. BEIRG submitted that our approach had not considered the effect of slave WSDs transmitting at or near the edge of a master WSD's coverage area. It submitted that a slave in these circumstances transmitting at the same power as its master would double the radius of the master alone. Similarly, Highfield Church was concerned that the Generic Operational Parameters might be too generous for slave WSDs operating at their full permitted EIRP at any point on the perimeter of the coverage area. It considered that the assumptions underlying our calculations were too crude for practical use.
- A11.58 In contrast, WSD groups considered that our calculations were too restrictive. Neul considered that the calculations were relatively conservative and would result in Generic Operational Parameters that are much more constraining than the specific operating limits. It submitted that our calculations would have a detrimental impact on operators deploying an M2M communications system in TVWS. Google and Wi-Fi Alliance both raised concerns that our proposed approach did not maximise spectrum utilisation. They submitted that absolute limits on the power levels for non-geolocated slaves could result in significant overprotection and diminished use of available spectrum. Google suggested that Ofcom should compute the maximum allowable power level for the slave WSD in a probabilistic way and allow TVWS operations where the likelihood of interference is below a threshold level of 5%.

#### Ofcom's response

A11.59 We do not agree that the calculations we intend to put in place would lead to an increased risk of harmful interference to incumbent users. The database will generate generic operational parameters on the assumption that a slave device could be anywhere in the coverage area of the master. Locations at the edge of the coverage area will be evaluated, and the operational parameters restrictions applicable to those locations will be taken into account. We also disagree with Highfield Church that the generic operational parameters will be too generous. A slave WSD will only be authorised to operate at full EIRP in a given channel if there

<sup>&</sup>lt;sup>69</sup> It is possible that a geolocated slave reports its location to a master WSD through means other than wireless communications over the UHF TV band (e.g. wireless communications in other bands). In such cases the location of the slave may be known by the master prior to master-slave communications over the UHF TV band.

are no incumbents that could be affected by a WSD at full power at any of the locations in the coverage area.

- A11.60 The practical experience from the pilot has shown that the proposed calculation produces an unrealistically large radius for the coverage area. Some of the triallists have reported scenarios where the database calculation had resulted in a radius of a few kilometres, but in the field they could not set up a master to slave link of more than a few hundred metres. This is a concern because an unrealistically large coverage area results in a very low generic operational parameters allowance, and this has the effect that the slave device cannot operate with enough power to reach the master.
- A11.61 We have modified the calculation so that it results in coverage areas that better match what actual devices achieve in real life deployments. However this is an area where we recognise that more work needs to be done and we intend to continue to work with industry to discuss how to improve this part of the framework.

#### Accuracy of information databases will hold about height of WSDs

#### Summary of our position in the 2013 Consultation

- A11.62 In our technical report published alongside the 2013 Consultation, we stated that we would generate TVWS availability datasets for WSD heights of 1.5, 5, 10, 15, 20 and 30 metres and would communicate these to databases.
- A11.63 We proposed that, where WSDs report their height, databases should select the TVWS availability dataset corresponding to the nearest height among that list. Where WSDs do not report their height, we proposed that databases should select the dataset calculated by Ofcom based on specific default heights.

#### Summary of responses

A11.64 A respondent raised a number of concerns about the accuracy of WSDs' antenna heights as reported to the databases. The respondent identified two potential sources of inaccuracies: where the reliability of the reported height is unclear and the device does not report the accuracy; and terrain heights from a terrain database are subject to inaccuracy due to the resolution of the database. The respondent submitted that these inaccuracies could lead to significant differences in the calculated coupling gain and recommended that Ofcom undertake further studies to test the practical accuracy of reported heights and locations and to estimate the impact on DTT interference.

#### Ofcom's response

- A11.65 We recognise that devices may not report their antenna height. We have set out an initial set of rules for the databases to incorporate height information when available, and we will monitor to what extent height devices provide height and height accuracy. We have taken default values, for the cases when height is not provided, that are conservative.
- A11.66 Secondly, our rules require databases to use a terrain dataset with a 50 metres resolution. We think this provides a good trade-off between accuracy and data storage and computation requirements.

### **Security requirements**

#### Summary of our position in the 2012 Consultation and the 2013 Consultation

- A11.67 The 2013 Consultation focused on our proposed approach for the coexistence of WSDs operating alongside the incumbent users of the band. As such, it did not focus on security requirements for WSDs or databases.
- A11.68 We discussed WSD security in our 2012 Consultation,<sup>70</sup> which focused on device requirements for WSDs. In the 2012 Consultation, we stated that communications between a master WSD and the website that contains Ofcom's list of qualifying databases should be performed using secure protocols that avoid malicious corruption or unauthorised modification of the data, and ensure WSDs communicate with the correct website. For this reason, we proposed that the website be accessed using the HTTPS protocol.
- A11.69 We noted that we expected communications between master WSDs and databases to be performed using security protocols addressed by technology standardisation organisations. We also noted that we expected communications between master WSDs and slave WSDs for the purposes of relaying database-related instructions and parameters to be performed using secure protocols specified within wireless technology standards.

- A11.70 In their responses to the 2012 Consultation, several stakeholders expressed concern regarding security measures for TVWS operation. Channel 4 had concerns over potential fraudulent devices, and wanted to understand what security measures could be put in place, for example to prevent a device using or replicating an existing unique device identifier. Other respondents were concerned about the security in the Master WSD to WSDB channel and the Master WSD to Ofcom website channel.
- A11.71 Respondents to the 2013 Consultation also raised a number of concerns regarding the security of white space devices. BEIRG, supported by several other respondents in the PMSE sector, and Brian Copsey, a communications consultant, both voiced concerns about the possibility of the "jailbreaking" of WSDs occurring. In this case, jailbreaking refers to removing some of the limitations on the operation of a WSD, which may result in an increased risk of a WSD causing harmful interference. Both BEIRG and Mr Copsey referred to a recent R&TTE report<sup>71</sup> which found that in some cases end users were able to switch off the Dynamic Frequency Selection (DFS) requirements of wireless local area network (WLAN) devices. This was not in line with the ETSI standard. Both BEIRG and Mr Copsey suggested similar modifications to WSD software would result in harmful interference for the incumbent users of the band.
- A11.72 Similarly, the Voice of the Listener and Viewer considered that it must be clear beyond all reasonable doubt that all WSDs that claim to be compliant with our requirements are compliant.

 <sup>&</sup>lt;sup>70</sup> TV white spaces: A consultation of white space device requirements, 22 November 2012, <a href="http://stakeholders.ofcom.org.uk/binaries/consultations/whitespaces/summary/condoc.pdf">http://stakeholders.ofcom.org.uk/binaries/consultations/whitespaces/summary/condoc.pdf</a>
 <sup>71</sup> Report on the 5<sup>th</sup> Joint Cross-Border R&TTE Market Surveillance Campaign WLAN 5 GHz, 2013: <a href="http://ec.europa.eu/enterprise/sectors/rtte/files/5th-rttems-report\_en.pdf">http://ec.europa.eu/enterprise/sectors/rtte/files/5th-rttems-report\_en.pdf</a>

A11.73 techUK and one other respondent were concerned about the possibility of cyber attacks. techUK considered that, in particular, the interface between WSDs and Ofcom's list of qualifying databases is particularly vulnerable to attack because it must use an open protocol, while the other stakeholder sought reassurances that Ofcom was satisfied that protections were in place to ensure the security of the databases.

#### Ofcom's response

- A11.74 As discussed in Section 5 of the Statement, we intend to require that in order to benefit from licence exempt operation devices would need to be designed such that it must not be possible for a user to modify or tamper with the hardware or software settings of the device related to the exchange of parameters with the database, or the parameters themselves.
- A11.75 We expect most if not all device manufacturers to follow the ETSI Harmonised Standard EN 301 598 as the means of showing compliance with the requirements of the R&TTE Directive. The ETSI standard includes strict requirements for the security of the communications between the master, the slave, the WSDB and the list of databases hosted by the regulator (in this case, Ofcom). Communications protocols must ensure integrity, and the master must authenticate the database and the list servers. In addition, manufacturers must ensure that the user does not have access or can alter the parameters used for operation in TVWS..
- A11.76 We recognise that, despite precautions, a residual risk of devices being tampered with will remain. However, we note that unauthorised use of any radio equipment, including use which is not in accordance with the terms of a licence exemption, poses a risk of interference in any band and Ofcom has powers to bring enforcement action under WT Act for unauthorised use or for use causing deliberate interference.
- A11.77 We have considered how to obtain assurances that communications between WSDs and databases are secure. As part of the qualification process, any organisation wishing to operate a white space database will need to complete a self-declaration, declaring compliance with the requirements in the contract, which will include provisions requiring databases ensure that communications between a database and WSDs will use a protocol that includes appropriate security features, and providing relevant information about how they will ensure this. This approach allows Ofcom to gain some assurances that the database operator has in place security protocols that are robust enough to meet our expectations.
- A11.78 The ETSI Harmonised Standard does not have a requirement that slaves must authenticate master devices. We will not require this in our regulations either. We think that such a requirement would introduce a huge burden in the system as it would require issuing and maintaining certificates for all master devices. If this becomes an issue, we expect to deal with it via the enforcement route.

#### WSD performance / roll-off assumption

#### Summary of our position in the 2013 Consultation

A11.79 In the technical report published alongside the 2013 Consultation we set out our proposed protection ratios for DTT calculations.

- A11.80 We outlined a number of assumptions that we made in relation to the measured protection ratios and the calculated class-specific protection ratios. Among these was an assumed roll off (increase in adjacent channel leakage ratio (ACLR)) of 10 dB per 8 MHz in the calculation of class-specific ratios.
- A11.81 The assumed roll off was to account for the experience that in practice the emissions of radio devices roll off with frequency separations beyond the first few adjacent channels. We noted that the roll off is in line with the slopes of the class 3, 4 and 5 masks over the first three adjacent channels, meaning that at large frequency separations the protection ratios are lower bounded due to the selectivity of the DTT receiver.

#### Summary of responses

- A11.82 The BBC disagreed with our assumption that WSD out-of-band emissions will roll off at 10 dB per 8 MHz at offsets beyond N3. It considered that, while our assumption was appropriate for a narrow band base station with a high–Q band pass filter, it was not valid for a broadband WSD. Submitted that ACLR characteristics at higher offsets will be dominated by amplifier noise.
- A11.83 Brian Copsey queried how the statement in paragraph 5.74 of the Technical Report, i.e., *"WSDs will readily meet and exceed the EN 301 598 spectrum emission masks"*, was justified.
- A11.84 Sony and techUK argued that there is nothing to prevent a WSD manufacturer from using a different design technique (such as envelope tracking) that might not conform to Ofcom's assumption of 10dB/8MHz roll-off, whilst still conforming to the less demanding ETSI specification mask. techUK recommended that our planning assumptions follow the ETSI mask.

#### Ofcom's response

- A11.85 We have decided to maintain the roll off in the assumed out of band emissions (increase in AFLR) of 10 dB per 8 MHz beyond the third adjacent channel.
- A11.86 We acknowledge stakeholders' arguments that there may be some devices which do not meet our assumed out of band emissions. However, based on the evidence we have gathered thus far, we maintain our view that in the majority of cases we are likely to observe better out of band spectrum emissions than those only just complying with the masks in the ETSI Harmonised Standard EN 301 598 for channel offsets greater than three.
- A11.87 We have also looked at the variation in the impact on effective protection for DTT and PMSE under different assumptions about the roll off in the assumed out of band emissions. We have found that the DTT protection ratios are not particularly sensitive to the assumed roll off at channel separations greater than the third adjacent channel. We have found that the required protection distances<sup>72</sup> between PMSE and WSDs are materially the same, using the 10 dB/8 MHz roll-off, or an alternative roll-off profile based on measurements. Similarly, in relation to coexistence with services below the band we do not consider that any deviation in

<sup>&</sup>lt;sup>72</sup> Required separation distances are a function of on WSD power, class, height and other factors as explained in Section 8 of this Statement. The database will actually implement the inverse function: given a distance from a PMSE user, it will cap powers that can be used. These are two equivalent ways of expressing the same concept: that at shorter distances (in either geography or frequency), less power is allowed, and at longer distances, more power is allowed.

real WSD performance from our assumption of 10dB / 8 MHz roll off of WSD emissions will significantly increase the risk of WSD interference.

A11.88 We believe our approach is a reasonable assumption as to the future rollout of WSDs. We are of the view that it strikes the right balance between being appropriately cautious, i.e. fulfilling our goal of a low probability of harmful interference, and avoiding making a compounded series of worst case assumptions.

#### Split of responsibilities between Ofcom and databases

#### Summary of our position in the 2012 and 2013 Consultations

- A11.89 In our 2012 Consultation, we noted that our previous proposal was that the databases would calculate TVWS availability, using the DTT and PMSE data as input. We noted that we were reconsidering this and would address this issue in the co-existence consultation.
- A11.90 In our 2013 Consultation we explained that Ofcom would now run the DTT calculations in house, and we proposed that the database would run its own model using the PMSE database and would combine the outputs of this model with the outputs from the Ofcom DTT calculations to determine the TVWS availability. We also explained that, when running its PMSE calculations, the database would be required under the terms of a contract with Ofcom to use a specific set of algorithms and parameters. This was to ensure a low probability of harmful interference to PMSE services.
- A11.91 Our approach to qualifying databases, as noted in our September 2011 statement,<sup>73</sup> is intended to be designed to be flexible to allow multiple third party database providers to emerge. We noted in the September 2011 statement that we expected third parties in a competitive marketplace to be incentivised to provide the best database service to consumers, encouraging innovation in functions and services in addition to the minimum database functionality we will specify.

- A11.92 A number of respondents to the 2012 Consultation noted that the availability calculations are complex and require detailed data and thought that Ofcom should run them in house.
- A11.93 As noted above, we set out revised proposals on this in the 2013 Consultation. In response to the 2013 Consultation, some respondents considered that our TVWS framework should give more control to the databases to calculate TVWS availability. Google submitted that, in order to facilitate innovation and enable users to take advantage of the latest technological advances, Ofcom should set interference protection criteria and let databases calculate TVWS availability. It considered that Ofcom could effectively manage interference through the database certification process and through enforcement, without the need to prescribe a specific set of algorithms for calculating TVWS availability. Wi-Fi Alliance agreed that, to allow database developers to innovate, Ofcom should not lay out detailed or prescriptive algorithms.

<sup>&</sup>lt;sup>73</sup> Implementing geolocation: Summary of consultation responses and next steps, 1 September 2011 <u>http://stakeholders.ofcom.org.uk/binaries/consultations/geolocation/statement/statement.pdf</u>

- A11.94 Both Google and Wi-Fi Alliance suggested that Ofcom should move away from a protection model that requires knowing the locations of television receivers. The two organisations considered that this method relied on a non-transparent, proprietary dataset and so limited innovation on the part of the database operators, who would be unable to effectively suggest improvements to the model without access to the raw data.
- A11.95 Dynamic Spectrum Alliance (DSA) suggested a number of ways in which Ofcom could take advantage of the geolocation database approach to maximise the utility of licence exempt use of spectrum. It submitted that, as a further development, the geolocation database may be augmented with sensing information, so that the database can incorporate real world feedback experienced by a WSD. The DSA suggested that we could use geolocation databases in the future to manage other opportunistic services and other bands. For example, it suggested we could require PMSE devices to automatically register their location with the database to make management of the spectrum more efficient.
- A11.96 Sky stressed the need for the regulatory framework to be flexible, given the nascent nature of white space technology, in order to encourage innovation.

#### Ofcom's response

- A11.97 We remain of the view that it is appropriate for Ofcom to carry out the DTT coexistence calculations in house (and to provide this information to databases) and for the databases to carry out the further calculations taking account of information about PMSE assignments and the characteristics of the WSDs they serve in order to provide the WSDs with TVWS availability information and the powers and frequencies at which they may operate. As noted above, databases will need to go through a qualification process, during which they must demonstrate they are able to implement the required calculations correctly, before they will be included in the list of designated white space databases in the statutory instrument and can start providing availability information to WSDs. We consider that this process will be sufficient to ensure these calculations should be carried out accurately, Our experience during the pilot supports this view.
- A11.98 We have taken a cautious approach to the way these calculations are carried out. We are prescriptive about the database calculations in order to protect the incumbent users, but we do not constrain the databases if they want to provide additional information or services to devices. Database operators are also allowed to improve the algorithm implementation, provided that their results always match those of our reference database.
- A11.99 Looking forward, we recognise that there could be ways in which the calculation rules can be improved to increase the TVWS availability without increasing the risk of interference to incumbents. We would like to hear from stakeholders about ideas for improvement, notably from databases as they will be best placed to innovate in this area but from other participants as well. We agree with the DSA on the suggested areas of improvement, in particular WSD feedback looks promising although probably not in feasible the immediate term.

#### Need for an interference management process

#### Summary of our position in the 2013 Consultation

- A11.100 We recognised in the 2013 Consultation that WSDs will introduce a new source of interference and we stated our intention to develop processes for reacting to cases where WSDs cause interference to the incumbent users of the band.
- A11.101 We broadly outlined our intended processes for dealing with interference. In summary, these involved:
  - Ensuring that organisations that operate existing helplines dealing with interference to DTT complaints are aware of the possibility of WSD-related interference;
  - Obtaining information from databases to check for the presence of WSDs at the location of any interference complaints;
  - Developing tests to establish whether WSDs are likely to be the source of a case of interference, such as reducing the maximum power levels or changing the allowed frequencies of WSDs operating in the vicinity of the reported interference or preventing their transmitting altogether; and
  - Making permanent, localised adjustments to white space availability.
- A11.102 We also set out our intention to work closely with other organisations that have related roles in dealing with interference to DTT and PMSE services to continue to develop our processes to manage cases of interference from WSDs.
- A11.103 We restated our view that our geolocation database approach to implementation meant that the probability of harmful interference from WSDs was low, and that consequently we expected only a few cases requiring specific interference management.

- A11.104 The DTT broadcasters considered that our proposals for interference management, as set out in the 2013 Consultation, were unclear and required further clarification on the detail of our processes.
- A11.105 The BBC said that one of its key areas of concern was the lack of detail as to how any interference events will be managed. It submitted that Ofcom had not developed any proposals on how interference should be monitored and that existing processes for managing interference may be inadequate. Another respondent agreed that Ofcom had not provided sufficient detail on what our processes for interference management might be. Similarly, Freeview and Digital UK asked Ofcom to develop proposals on how interference will be managed and share the details of these proposals with stakeholders.
- A11.106 The Voice of the Listener and Viewer (VLV) and another respondent stressed the importance of promptly dealing with complaints of interference to DTT viewers. The VLV noted that the nature of WSD interference is such that it will be difficult, if not impossible, to trace.

- A11.107 Vodafone and another respondent noted that, unlike previous experience with the 800 MHz band, there is no obvious body or organisation like at800 to be responsible for identifying and remedying cases of interference as WSD use of the spectrum will be licence exempt.
- A11.108 techUK considered that Ofcom should work with the Consumer Electronics industry to ensure all parties are able to properly address any consumer calls. It submitted that it is well-placed to work with Ofcom on refinements to the interference management framework if necessary, given the wide range of its membership covering DTT, PMSE, mobile and TVWS proponents.
- A11.109 Google suggested that it is important that PMSE manufacturers and regulators help to solve the interference and deployment issues by upgrading to improved processes and technology. It considered that Ofcom should identify and eliminate unlicensed use of PMSE equipment and encourage PMSE users to update their equipment. Google submitted that Ofcom's protection criteria ought to be based on the performance of state-of-the-art PMSE equipment, rather than older equipment.

#### Ofcom's response

- A11.110 Our primary focus in developing and implementing the TVWS framework has been on the prevention of interference occurring from the deployment of WSDs rather than on remedying interference once it has been caused. We remain confident that our coexistence rules are sufficiently conservative to ensure a low probability of harmful interference to the incumbent users of the band. However, we have also been developing processes for interference management in relation to WSDs.
- A11.111 The trials that took place under our Pilot from mid-2014 allowed us to set up and test processes for interference management. Although our focus remains on preventing cases of interference, we learnt a number of lessons from our experience of the trials and have developed our interference management processes appropriately in response.
- A11.112 Our interference management processes will include:
  - Ensuring that Ofcom has access to an information system held by databases for the purposes of carrying out an initial triage of interference cases;
  - Having the ability to instruct databases to require a particular WSD to cease transmissions;
  - Having the ability to adjust the maximum power at which WSDs can operate in a certain area; and
  - Having the ability to instruct a database to cease providing some or all database services.
- A11.113 Our interference management processes are discussed in more detail in Section 3 of the Statement.

### Whether Ofcom should allow WSDs into mobile spectrum

#### Summary of our position in the 2013 Consultation

A11.114 Ofcom has identified the UHF TV band, currently allocated for DTT and PMSE use, as suitable for spectrum sharing. We have not considered allowing WSDs to operate in spectrum bands currently allocated for mobile use.

#### Summary of responses

A11.115 The BBC submitted that a more flexible approach to ensuring a low probability to 4G services about the UHF TV band might allow WSDs to operate in the band 790 to 868 MHz in areas where mobile services are not available, such as rural locations. The BBC noted that this would allow for local self-provision of broadband services using LTE-800 equipment, which could represent a significant benefit for rural communities.

#### Ofcom's response

A11.116 Allowing WSDs into mobile spectrum would raise an additional set of issues that we have not considered to date since the work we have undertaken so far has focused on implementing access to white space in the UHF TV band. For this reason, this proposal is outside of the scope of this Statement. However, our spectrum management strategy includes pro-actively exploring new forms of spectrum sharing, and, in the course of implementing this strategy there may be further opportunities to consider this suggestion.<sup>74</sup>

#### A guard band channel was proposed for mobile but not DTT or PMSE

#### Summary of our position in the 2013 Consultation

A11.117 We proposed to prevent WSDs from operating in channel 60, the channel at the top of the UHF TV band, and the one closest to 4G services, in order to ensure a low probability of harmful interference from the deployment of WSDs to 4G services operating in the 800 MHz band.

- A11.118 The BBC noted Ofcom's proposal that WSDs should not be allowed to operate adjacent to the primary service (mobile). They say this contrasts starkly with DTT where both adjacent and co-channel operation would be allowed.
- A11.119 A respondent argued that affording the 4G licensed service an 8 MHz guard band (in addition to the existing 1 MHz) is an inequitable protection approach for the two primary licensed services. The respondent was concerned that Ofcom is setting a precedent that is not robust from a regulatory point of view and is hence not legally sound. The respondent also stated that all primary licensed users should be afforded the same protection and hence the exclusion of TVWS devices from channel 60 should be applied to terrestrial broadcast use of spectrum, i.e. the adjacent channels should be excluded from TVWS use.

<sup>&</sup>lt;sup>74</sup> Spectrum management strategy, Ofcom's approach to and priorities for spectrum management over the next ten years, Statement, 30 April 2014 <u>http://stakeholders.ofcom.org.uk/binaries/consultations/spectrummanagement-strategy/statement/statement.pdf</u>
A11.120 Highfield Church called for the same level of protection to be afforded to other licensees. Brian Copsey said that 4G appeared to be better protected than broadcasting and PMSE.

#### Ofcom's response

- A11.121 The spectrum management decisions that we are taking for the purposes of coexistence aim to give effect to our policy of allowing WSDs to access the UHF TV band subject to ensuring a low probability of harmful interference to incumbent services. However, in order to achieve that objective, our spectrum management decisions will differ according to the particular circumstances.
- A11.122 For DTT and PMSE, we know the locations of DTT transmitters and PMSE receivers which enables us to determine maximum WSD powers by reference to them, as well as by reference to the locations of WSDs relative to the locations of incumbent services. By contrast, under our framework, WSDBs will not know the locations of mobile handsets and therefore will not be able to take them into account in their calculations of operational parameters.

#### Affordable basic access

#### Summary of responses to the 2012 Consultation

A11.123 A combined industry response<sup>75</sup> to the 2012 Consultation recommended that there should be more than one affordable public (open) database, to ensure that spectrum access remains affordable to all comers. They thought this might arise naturally, but could also be achieved, for example, by requiring major database service providers to offer at least an affordable basic public interface, as well as any closed (private) access mode(s).

- A11.124 As we explained in our 2010 statement "Implementing Geo-location",<sup>76</sup> we decided that we should adopt a flexible approach, which favours neither closed nor open database systems, but instead enables the appropriate solutions to be decided by the market which emerges and not the regulator. Our framework aims to incentivise an innovative approach to the use of spectrum which will require investment by WSDB providers in new infrastructure, and they will need to be able to recover the costs of their investment in some way. We also expect third party WSDB providers to seek to design services which attract and offer value to their customers. We do not consider that it is appropriate for the regulator to seek to become involved with the commercial arrangements between WSDB providers and their customers unless there is a regulatory need to do so and would be concerned that imposing a requirement to provide "affordable" public access may risk discouraging entrants in the early stages of development. However, we will monitor how the market develops and consider regulatory options if we think that consumers are having difficulties in accessing white spaces.
- A11.125 Finally, we have seen in our pilot that there are many organisations interested in becoming a WSDB provider.

<sup>&</sup>lt;sup>75</sup> Joint industry response from Adaptrum, Broadcom, CSR, Google, Jaguar Land Rover, Microsoft, Neul, Sky and Spectrum Bridge <sup>76</sup>

<sup>&</sup>lt;sup>76</sup> http://stakeholders.ofcom.org.uk/binaries/consultations/geolocation/statement/statement.pdf

# Support for third party manager of a network with a large number of WSDs

#### Summary of responses to the 2012 Consultation

A11.126 In their response to the 2012 Consultation, BT expressed their support for the use of management systems for networks with large numbers of WSDs. It said that, in the case of a large network of devices (with many master WSDs) operated by a single organisation, there could be significant benefits if a management system is permitted, acting on behalf of many master WSDs. Such a management system would come between the master WSDs and the WSDB, and would hold all of the information about all of the devices (both master and slave) within the network (or part of the network). The management system would interface with the WSDB on behalf of the master WSDs, and would convey the relevant operational parameters back from the WSDB to the master WSDs. Such a management system would be configured so that it would appear to the WSDB to be like a master WSD, in order to conform to the requirements, although it would actually be making requests to the WSDB on behalf of more than one master WSD. For the purposes of device testing (to the European Harmonised Standard) the management system would be tested in conjunction with the master WSD, to ensure that they work together in the appropriate manner.

#### Ofcom's response

A11.127 We note stakeholder comments that they see some potential benefits in allowing a network management system to act as an interface between the database and the master WSDs. Such an arrangement would not fit within the terms of the proposed licence exemption, which would require master WSDs to report their device parameters to a WSDB and obtain operational parameters from a WSDB. However, we intend to consult on authorising access to TVWS by manually configured devices under a licensed regime and we consider that such a management system arrangement could potentially fit within such a licensing regime.

#### Device may have simultaneous master/slave operation

#### Summary of responses to the 2012 Consultation

A11.128 Spectrum Bridge noted that some devices could operate in either master or slave mode and some could be operating in both modes simultaneously.

- A11.129 The device must report whether it is a master or a slave device when it requests operational parameters. However, the framework does not currently allow a device to report itself simultaneously as both a master device and a slave device, since different requirements will apply depending on whether a device is acting as a master or a slave device.
- A11.130 This suggestion may have in mind a situation where a master device loses direct connection with a database, but is in the coverage area of another master and is able to attach to it as a slave. In such a case, we think that the device would have to request a new set of operational parameters after having reported itself to that master device as a slave.

# The process to enable new emissions classes

#### Summary of responses to the 2012 Consultation

A11.131 Neul and Weightless commented that there should be a simple and clear process for enabling new device emission classes. In particular, the method of testing a new device and the list of TV receivers that it will be tested against need to be defined and published as soon as possible.

#### Ofcom's response

- A11.132 The ETSI Harmonised Standard sets out five emission classes specified by their ACLR masks.<sup>77</sup> An updated version of the ETSI Harmonised Standard would need to be developed in order to introduce a new device class. ETSI has an established process for this.
- A11.133 The ETSI Harmonised Standard does not require testing against specific receivers to determine the emissions class. Testing with TV receivers is related to the technology ID, which we have not yet incorporated in our calculations. We will discuss at the Technical Working Group how to move this functionality forward.

#### Definition of types, in particular with regards to the integral antenna

#### Summary of responses to the 2012 Consultation

- A11.134 Neul, BEIRG, Weightless, Arqiva, BT, Digital UK, Vodafone, Intellect and Channel 4 commented that the requirement for an integral antenna should be clarified. They reasoned that in some applications it will not be appropriate or possible to mount the antenna on/in the radio unit perhaps because it is inside an appliance with a metal skin. Some type B devices might be, for example, modules within vehicles where the antenna is part of the vehicle itself and hence not integral to the radio.
- A11.135 A better definition should convey that they are permanently connected to the WSD, without necessarily being within the same box as the radio equipment. Also, it should be clear that it is designed as a fixed part of the equipment, without the use of an external connector, and as such, cannot be disconnected by a user.

#### Ofcom's response

A11.136 We agree that the definition proposed in the 2012 Consultation was not clear. Our regulations, which are consistent with the requirements of the ETSI Harmonised Standard EN 301 598 regarding Type A and Type B devices, now set three types of antennas: integral, dedicated and external (see Section 5 of the statement which explains the proposed classifications). Our requirements are that type A devices may have any type of antenna and type B devices may have dedicated or integral antennas.

<sup>&</sup>lt;sup>77</sup> It is worth noting that under the technical and operational requirements which we intend to put in place, it will not be mandatory for devices to report their emission class to databases, but where they do so this will be taken into account by the database in calculating operational parameters for that device.

# Unclear how a manufacturer may declare the device type

#### Summary of responses to the 2012 Consultation

A11.137 Arqiva, BT and Vodafone commented that it is not clear how the device manufacturer can declare the device type, since it cannot know if the device will be used indoors or outdoors, or on a non-moving platform.

#### Ofcom's response

A11.138 We agree that the manufacturer cannot know the location where the user in fact puts the equipment and whether or not the user chooses to mount the equipment on a moving or non-moving platform. However, what we envisage, which is in line with the requirements of the ETSI Harmonised Standard, is that the manufacturer will declare its intended use. For instance, manufacturers will design certain equipment for outdoor use – with a ruggedized enclosure and points for attaching to a wall. The manufacturer will in this case declare that the intended use is outdoors.

#### Class 4 WSDs may become orphaned

#### Summary of responses to the 2012 Consultation

A11.139 Weightless was concerned that devices with high adjacent frequency leakage, e.g. Class 4 devices, may become orphaned from the initial allocation of devices. Weightless reasoned that, if primary use of the spectrum changes, it may result in a previously installed Class 4 device producing unacceptable levels of interference. The WSDB would have no option but to bar the Class 4 device from the network.

#### Ofcom's response

A11.140 We do not expect that the primary use of the band below 694 MHz will change for some time to come<sup>78</sup>. Ofcom has made the decision to change the use of the upper part of the band (700 MHz band) to mobile services. When this change materialises, DTT, PMSE and WS devices will no longer have access to that part of the band. This will not result in Class 4 devices being barred from the rest of the TV band.

#### **Receive only devices**

#### Summary of responses to the 2012 Consultation

A11.141 Both DTG and Intellect requested that we confirm that a receive-only device configuration can also be used in addition to the currently defined master and slave configurations.

#### Ofcom's response

A11.142 Receive only slave devices are not precluded by our regulations or the ETSI Harmonised Standard.

<sup>&</sup>lt;sup>78</sup> As explained in our discussion document "The future of free to view TV" of May 2014, "our base case view remains that DTT will continue to be an important delivery technology for free to view TV over the next decade. We do not currently expect a full switch-off of DTT until post 2030, unless there was significant policy intervention to support a more aggressive timetable for change. " (paragraph 2.19) http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/discussion/ftv.pdf

# Type C - high speed mobile devices

# Summary of responses to the 2012 Consultation

A11.143 Jaguar Land Rover requested that we consider adopting a third type, a type C device, which is used in high speed mobility (above walking speeds) as well as static scenarios. This would involve downloading operational parameters for a number of pixels at a time, to "reserve" channel(s) before getting to the location.

# Ofcom's response

A11.144 We consider this a possible future enhancement. Moving forward, we expect that if industry has an interest in new device type, then this would be proposed and discussed in ETSI and, if agreed, introduced in a future version of the ETSI Harmonised Standard. Ofcom would then consider incorporating the new type into our regulations.

# Kill switch

# Summary of responses to the 2012 Consultation

- A11.145 Several respondents had concerns with the kill switch functionality that we presented in the device requirements consultation, which was that a master WSD (and its served slave WSDs) must cease transmission within 60 seconds of receiving instructions to do so by the WSDB. Stakeholders also commented at a more general level on the process that Ofcom would follow to deal with interference cases. Some stakeholders argued that it was not quick enough to deal with interference in particular to PMSE, while others said that it was too much of a burden for databases and devices to support. The main issues raised were:
  - A combined industry response<sup>79</sup>, Spectrum Bridge and the BBC commented that pushing information from the WSDB to the devices raises practical difficulties. In their view, it would require a database to keep track of a potentially large numbers of devices, and their addresses, raising challenges of scale. They said that reaching white space devices could be difficult, given that they might be located behind firewalls. They also considered that this raises security concerns, for the correct operation of the white space devices and the safety of other devices and data present on end-user networks.
  - The combined industry response added that it is not clear how the switch would be triggered, and the information passed on to the WSDB and eventually to the WSD. They considered that 60 seconds would be an acceptable time period for the device to switch of after receiving the message, but identifying the WSD and then getting the request to it would take significantly longer.
  - Brian Copsey, Samsung, CAI and BEIRG considered that a one to two hour time period to resolve an issue of interference to PMSE was not acceptable because PMSE deals with time critical events. In their view, to be truly useful in protecting PMSE, the process must able to operate, from reported interference to PMSE or DTT to the ceasing of any and all WSD transmission, in the space of 3-5 minutes.
  - Samsung noted that cooperation between the Ofcom monitoring and clearing of interference and at800 (the organisation overseeing the introduction of mobile

<sup>&</sup>lt;sup>79</sup> Adaptrum, Broadcom, CSR, Google, Jaguar Land Rover, Microsoft, Neul, Sky and Spectrum Bridge.

services in the 800 MHz band) may be necessary, so that affected DTT viewers can reach the proper organization to resolve the problem.

- The School of Informatics, University of Edinburgh noted that requiring the slave WSDs to cease transmission within one second when instructed to do so by the serving master WSD could lead to energy efficiency issues.
- The Open Rights Group considered that more information was needed from Ofcom on what 'appropriate circumstances' for the kill switch would be. They recommended that the circumstances in which Ofcom stipulates the "kill switch" could be deployed should be limited to managing interference.

# Ofcom's response

- A11.146 Following discussions with industry, the kill switch functionality has changed in our regulations and in the ETSI Harmonised Standard. We require a master WSD to verify with the serving WSDB that the Operational Parameters it is using are valid, within a time period (T<sub>Update</sub>) indicated by the WSDB. If a master WSD is not able to verify that the operational parameters it is using are still valid or if a WSDB instructs the master WSD that the operational parameters are not valid, then the master WSD must stop transmitting and instruct all slave WSDs that it controls to stop transmissions. This aligns with the requirement in the ETSI Harmonised Standard, now called "WSD update function". We consider that the revised approach will be a more practicable way to ensure that WSDs are switched off quickly where necessary for interference management reasons.
- A11.147 Our intention is only to require databases to instruct devices to cease transmitting where necessary in order to deal with cases of interference.
- A11.148 The value of T<sub>Update</sub> will initially be set at 15 minutes. We note that currently the response time for Safety of Life incidents is 8 hours our highest priority. It is unlikely that we can provide resolution to PMSE interference problems within the time periods requested by stakeholders. However, we are setting up processes to deal with interference to PMSE in the most efficient way.
- A11.149 We would anticipate liaising with at800 in order to make sure that they are able to give consumers who may contact them about interference to their DTT services appropriate advice on what to do about suspected cases of WSD interference.
- A11.150 Although we are not including any specific provision in our regulations to deal with sleep mode, we note that the ETSI Harmonised Standard does include a set of requirements dealing with the case of devices in sleep mode, i.e. the WSD is inactive but not powered-down, to avoid unnecessary energy consumption.

#### **Technical requirements in the VNS**

#### Summary of responses to the 2012 Consultation

A11.151 A number of stakeholders commented on the detailed technical device requirements as set out in the proposed specification in the VNS and consultation including on: the definition of certain device parameters and channel usage parameters, specification of the sequence of exchange of information between devices and databases, specification of how a database should respond if the information from a device was missing or in the incorrect form, specification of time validity for operational parameters, the need for simplification of the approach to a device checking the validity of its parameters, the correct behaviour of slaves if a master device loses contact with a database, and the geo-location requirements.

#### Ofcom's response

- A11.152 Following the 2012 Consultation, an ETSI Harmonised Standard for White Space Devices has now been developed<sup>80</sup> and it is no longer necessary to put in place a VNS as suggested in our 2012 proposals. We therefore do not discuss further in our Statement any of the requirements set out in the draft VNS.<sup>1</sup> During 2013 and 2014 we were involved through ETSI in developing the ETSI Harmonised Standard. The standard making process in ETSI is contribution driven, so any UK stakeholder with an interest in the device requirements had an opportunity to contribute. As part of this process, we discussed the proposals we had developed for the purposes of the draft VNS and many of the requirements under the ETSI Harmonised Standard are similar to those outlined in the draft VNS, although there are a certain number of differences and refinements to the processes and requirements originally envisaged in the draft VNS.
- A11.153 We note that devices that meet the requirements of the ETSI Harmonised Standard benefit from a presumption of conformity with the essential requirements of the R&TTE Directive.<sup>81</sup> For the purposes of our TVWS framework, we consider that compliance with the requirements in the ETSI Harmonised Standard is one way of ensuring compliance with the regulatory requirements for licence exempt authorisation of WSDs set out below. In practice, we would expect that the majority of devices would meet the ETSI Harmonised Standard or would otherwise follow similar standards that ensure compliance with the essential requirements of the R&TTE Directive.

# Manual input of device parameters and user access to device settings

#### Summary of responses to the 2012 Consultation

A11.154 Spectrum Bridge, BT and the combined industry responses suggested we should allow the installer / user of a WSD to be able to manually input and configure the device parameters. BEIRG said that device parameters must be beyond the control of the user. The BBC felt that manually entered data should only be used if the WSD is operated by a professional communications provider.

#### Ofcom's response

A11.155 As explained in Section 5 of the Statement, we do not think that it is appropriate to authorise WSDs that can be manually configured on a licence exempt basis. This is because we would be concerned if it was possible for end-users (who would be unlikely to have the expertise needed to accurately configure a device) to input or modify the device parameters, in particular in relation to the location of a device. If

<sup>&</sup>lt;sup>80</sup> During 2013 and 2014 we were involved through ETSI in developing the ETSI standard. The standard making process in ETSI is contribution driven, so any UK stakeholder with an interest in the device requirements had an opportunity to contribute. As part of this process, we discussed the proposals we had developed for the purposes of the draft VNS and many of the requirements under the ETSI Harmonised Standard are similar to those outlined in the draft VNS, although there are a certain number of differences and refinements to the processes and requirements originally envisaged in the draft VNS.
<sup>81</sup> This Directive establishes the regulatory framework for the placing of radio equipment on the market within the

<sup>&</sup>lt;sup>81</sup> This Directive establishes the regulatory framework for the placing of radio equipment on the market within the EU. It is implemented in the UK by the by the Radio Equipment and Telecommunications Terminal Equipment Regulations 2000 (SI 2000/730). However, meeting the requirements of the ETSI Harmonised Standard is not the only route to demonstrating compliance with the essential requirements under the R&TTE Directive, and manufacturers can choose to demonstrate compliance by other means.

the WSD reports inaccurate device parameters to a WSDB, the WSDB may provide operational parameters that could result in interference to other spectrum users in the proximity of that WSD.

A11.156 As a result, for licence exempt operation devices would need to be designed such that it must not be possible for a user to modify or tamper with the hardware or software settings of the device related to the exchange of parameters with the database, or the parameters themselves. However, Ofcom intends to consult separately on whether to authorise devices which require manual configuration on a licensed basis.

# **Directional antennas**

# Summary of responses to the 2012 Consultation

A11.157 TTP and Neul noted that our proposals did not allow the directionality of antennas to be taken into account. TTP commented that this led to over protection of existing users of the band.

#### Ofcom's response

A11.158 It is correct that the Framework at present does not take account of the directionality of antennas. We believe this is appropriate for licence exempt devices where the assumed user of the device could be a consumer and not someone who has expertise in the installation of radio equipment. We intend to consult on whether to introduce a licensing regime for devices that can be manually configured and in principle it might be possible for directionality of antennas to be part of that regime.

# **Alignment with IETF PAWS**

#### Summary of responses to the 2012 Consultation

A11.159 The combined industry response commented that it was important to maintain a close alignment with IETF PAWS, to maximise the harmonisation benefits.

#### Ofcom's response

A11.160 We agree that consistency will be important to the successful deployment of WSDs. We believe that the PAWS specification supports the UK and ETSI requirements. However, the PAWS specification is an industry-led process and we expect industry to ensure the PAWS specification meets the UK's requirements as set out in the licence exemption and database contract.

# **Section 2**

# **Responses relating to DTT**

# Approach for protecting DTT

#### Summary of our position in the 2013 Consultation

A11.161 As also described in section 7 of this Statement, at high level, our approach is based on a calculation used in DTT planning known as *location probability*. We allow WSD transmit power up to the point at which it would reduce location probability by seven percentage points.

#### Summary of responses

- A11.162 A respondent said that a loss in location probability of 7% across the entire coverage area is not acceptable and is inconsistent with Ofcom's aim of minimising the risk of harmful interference, and recommended that a more appropriate target would be an interference-to-noise ratio of -10dB.
- A11.163 The BBC made a number of comments on this point. It said that there is no precedent for considering self-interference in co-existence studies and that it seemed inappropriate to use the interferer-to-noise (I/N) criterion to calculate the acceptable loss of coverage at the very edge of service and apply this loss of coverage throughout the DTT cell. It also commented on the erosion in margin both at the edge of reception and in strong signal areas. It thought that it was inappropriate to apply 1dB erosion to a 'marginal' coverage margin. It noted that the margin will be limited to 8.1dB in strong signal areas even though the errors in the underlying planning model can exceed this value. It noted that significant investments have been made by broadcasters during digital switchover to improve reception reliability and said that these proposals could undermine this investment.
- A11.164 Google and WiFi Alliance suggested Ofcom should adopt a coexistence framework that allows database developers to innovate. They thought Ofcom should set interference protection thresholds and recommend propagation models, but it should not lay out algorithms in chapter and verse. They also suggested moving away from a protection model that requires knowing the locations of television receivers as this method relies on a proprietary dataset and will require much more frequent updating. They commented that this would not scale well to the rest of Europe because, in other jurisdictions, similar datasets may not be available or may have very different characteristics.

- A11.165 We have considered a number of previous case-studies where actual levels of interference to DTT reception can be compared with theoretical reductions in location probability predicted by the UKPM. These case-studies include the predicted losses as a consequence of the roll-out of LTE services in the 800 MHz band and the predicted changes in coverage as a consequence of the clearance of UHF channels 61 and 62.
- A11.166 In both these cases, the number of households that reported interference were significantly lower than estimates derived by a simple scaling of household densities by the predicted reduction in location probability predicted by the UKPM. There are a number of factors that contribute to this difference, including the fact that aerial

installers typically check that any installation has a good margin against noise (both receiver noise and impulsive noise within the house) and network interference, and that receiving installations often have somewhat different performances than the assumptions made in the planning model. So for example, in the planning model, it is assumed that the household installation gain is 9.15 dBi. This value is typical of a good installation at the edge of coverage, but often the gains may be lower closer-in to the transmitter.

- A11.167 Our DTT coexistence tests were undertaken in three geographical locations across the UK, to cover a range of factors that affect reception (weak/strong DTT signal areas, different clutter types, different separation distances from the transmitter, different housing types and different types/qualities of receiving installation etc.). We adjusted the main inputs to the coexistence model (i.e. the coupling gains and the protection ratios) and made additional allowances for the prediction error in the UKPM in the light of the findings from our coexistence tests and those of BBC/Arqiva. We believe that the combination of these measures should result in a low probability of harmful interference to DTT.
- A11.168 We want to implement a framework that enables database providers to innovate. However, Ofcom also needs to ensure that the framework will result in a low probability of harmful interference to DTT. Therefore we consider that it is appropriate for Ofcom to carry out these calculations and provide the data to the databases. We do not intend to offer flexibility to databases as to the calculations that will provide for co-existence with DTT.
- A11.169 The locations of households in the UK that might be making use of DTT are determined from the Address Base data available from Ordnance Survey. The calculations of TVWS availability are undertaken by Ofcom with reference to this data and it is not necessary for WSDB providers to have access to the Address Base data to implement databases.
- A11.170 Other approaches based on not knowing the locations of UK households might increase the risk of interference to DTT or risk reducing the overall spectrum availability for TVWS. We consider our proposed approach will make most effective use of spectrum in the UK although we recognise that other simpler approaches may be appropriate for other countries in Europe.

# **DTT coverage**

# Summary of responses to the 2013 Consultation

A11.171 Digital UK and Freeview both commented on the impact of the proposals on DTT coverage. They considered that Ofcom was only seeking to protect the headline 98.5% PSB coverage, plus circa 90% commercial multiplex coverage, and said that in reality virtually every household in the UK currently has access to terrestrial television. Digital UK expressed its concern that the proposals contribute to an ongoing erosion of what constitutes a DTT "service", with each change seeming insignificant compared to the previous position, but which cumulatively constitute a significant move. It pointed to previous Ofcom statements relating to households which fall outside of the official core coverage areas and expressed concern that Ofcom was entertaining further reductions in coverage.

# Ofcom's response

A11.172 Ofcom has decided that the TVWS power limits specified by the framework should be calculated based on the best available information as to actual DTT transmitter usage. Although actual DTT transmitter usage is currently estimated from the predictions from UKPM, we have proposed that this information should be adjusted by reference to a new database containing information on actual usage of different transmitters across the UK. In this way, actual DTT transmitter usage would be accounted for in the TVWS calculations in addition to the headline coverage figures obtained from UKPM.

# Coupling gain, uncertainty in DTT coverage predictions and use of amplifiers

# Summary of responses to the 2013 Consultation

- A11.173 A number of respondents made detailed comments on coupling gain, uncertainty in DTT coverage predictions and use of amplifiers in the 2013 Consultation. The BBC and Arqiva subsequently carried out a detailed testing programme<sup>82</sup> at the Building Research Establishment (BRE) which provided further evidence on these points.
- A11.174 We highlight a number of the key points from the testing below:
  - The measured coupling gains exceeded the Ofcom proposed threshold by as much as 7 dB when considering the 70th percentile of the cumulative distribution;
  - Peak coupling gains up to 10 dB higher than the Ofcom proposed threshold were observed; this is particularly likely for antennas installed below 10m height;
  - The combination of higher coupling gains and DTT signals lower than the predicted value led to interference events at WSD powers below those proposed by Ofcom;
  - The extensive implementation of amplifiers in DTT systems may lead to additional risk of interference from the WSD, the BRE work indicates an additional margin of up to 3 dB may be needed. Further studies would be desirable;
  - A margin of 6 dB would be desirable to take account of the uncertainty in DTT coverage predictions.

- A11.175 In the light of evidence from the BBC/Arqiva studies, we have decided to change from the use of the 70<sup>th</sup> to 90<sup>th</sup> percentiles of the cumulative distribution. We also propose to use the same tier 0/1 coupling gains in urban, suburban, and rural environments. This will increase the tier 0/1 coupling gains by the values given in table A2.8 in annex 2 and will increase the tier 2 coupling gains by 1 to 3 dB.
- A11.176 The changes we have decided on are based on the ITU-R BT. 419-3 pattern for antenna angular discrimination and the theoretical cumulative distributions. We note that the BBC/Arqiva recommendations are based on real world measurements with two types of DTT receiving aerial and walk tests outside a small number of

<sup>&</sup>lt;sup>82</sup> WSD Coexistence Testing at the Building Research Establishment: An experimental validation of Ofcom Regulatory Proposals, Jan 2015 <u>http://www.bbc.co.uk/rd/publications/whitepaper288</u>

households at the Building Research Establishment. In the future we will consider whether our proposed changes might need any further small adjustments in either direction in the light of any further evidence on the cumulative distributions of coupling gains, real world antenna performances and the installed base of different antenna types in the UK.

- A11.177 We have made an allowance for DTT signal levels being lower than the predicted values and for the real world impact of amplifiers in DTT systems by adjusting the co-channel protection ratios assumed in the model by 9 dB. For adjacent channel operation, we have not proposed any additional allowance for these effects because the current class-based approach in the model builds in additional margin. We will keep under review with the TWG whether this approach will continue to provide the appropriate degree of protection across different types of WSD and across different classes of WSD.
- A11.178 We believe that our coexistence studies have shown that the combination of the above measures would ensure a low risk of harmful interference to DTT.

# Indoor aerials

#### Summary of our position in the 2013 Consultation

A11.179 In our 2013 Consultation, we said that the possibility of DTT reception via indoor aerials is an incidental consequence and not an objective of the current approach to DTT planning. We therefore have not developed algorithms or parameters designed specifically to ensure a low probability of harmful interference to indoor aerials for receiving DTT.

#### Summary of responses

- A11.180 Eight respondents said that, given their widespread use, we should also ensure a low probability of harmful interference to indoor aerials receiving DTT. For example:
  - The BBC said that as many as 7.5 million TVs rely on indoor aerials and that interference from WSDs to indoor aerials is unlikely to be solvable using a simple filter unlike in the 4G scenario.
  - Another respondent said that internal aerials are used by around 15% of primary sets and 30% of secondary sets, some 25% of the entire DTT receiver population.

- A11.181 Despite the DTT network being planned on the basis of reception using a rooftop aerial, some viewers use an indoor aerial to receive DTT broadcasts. Loft aerials, as well as aerials positioned next to TV sets, are classed as indoor aerials. These aerials are typically less effective at receiving DTT broadcasts given their indoor location and technical characteristics, and are more likely to be affected by interference from other sources.
- A11.182 When making other spectrum management decisions and interference management decisions, we, and Government, have made clear that the DTT network is not planned for indoor aerials such as set-top aerials and we have not taken any extra measures to minimise the risk of interference to indoor aerial reception. For example:

- In 2003, a consultation by the Government stated that "current planning methodology is based on providing reception to television sets with a good quality roof-top aerial. This, fortuitously, also allows a certain level of reception by televisions using set-top aerials"<sup>83</sup>. This was used as a principle for DSO, where we required PSB multiplexes to replicate analogue reception as received by rooftop aerials, but not reception as received by indoor aerials.
- In 2004, we said that, following Digital Switchover "some disruption would be inevitable: a small proportion of existing roof-top aerials and many more existing portable aerials would be unlikely to be able to receive an acceptable digital terrestrial signal"84.
- In our 2009 consultation on licence exemption for White Space Devices, we said that the protection of indoor reception is not conferred under our current interference policy or any decisions we have made in relation to DSO<sup>85</sup>.
- In our 2010 consultation on implementation of a framework for White Space Devices, we said that indoor antennas are not specifically protected under current DTT planning guidelines and that in our consultations we have not considered explicitly protecting such reception<sup>86</sup>.
- In 2012, in the context of 4G/DTT coexistence, government decided that there should be no support for interference issues that result from problems with settop aerials<sup>87</sup>.
- In our 2014 Consultation on the Future of the 700 MHz band<sup>88</sup>, we said "In any event, we attach very little weight to any potential coexistence issues caused to set top aerials in our analysis because the DTT network is not planned and designed for TV reception by way of set top aerials. Ofcom and other organisations (e.g. BBC RTIS, CAI, Freeview and at800) advise consumers that set top aerials are much less effective. Consistent with this advice, consumers tend to adjust their expectations from this means of reception that is less reliable than that by way of rooftop aerials, because it is more prone to interference from a range of sources".
- A11.183 Planning a network for reception via indoor aerials would be significantly more challenging, financially expensive and less efficient in spectrum usage terms. For example, as we do not know the locations of the minority of viewers attempting reception through indoor aerials at any given time, specific measures to reduce the probability of interference into indoor areas would require widespread sterilisation of spectrum in all locations where reception could be taking place, which we do not consider justified or consistent with existing practice.

<sup>&</sup>lt;sup>83</sup> Digital Television: the principles for spectrum planning,

http://www.digitaltelevision.gov.uk/pdf\_documents/publications/digtv\_spectrum\_planning.pdf

Driving digital switchover, a report to the Secretary of State, http://stakeholders.ofcom.org.uk/market-datasearch/other/tv-research/dsoind/dso\_report/

<sup>&</sup>lt;sup>85</sup> Digital dividend: cognitive access – Consultation on licence-exempting cognitive devices using interleaved spectrum, 16 February 2009

Implementing geolocation: Consultation, 9 November 2010, http://stakeholders.ofcom.org.uk/consultations/geolocation/

Letter from Ed Vaizey to Ed Richards, 10 July 2012 http://old.culture.gov.uk/images/publications/letter-dcmsofcom-10072012.pdf

Consultation on future use of the 700 MHz band, 28 May 2014

http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/summary/main.pdf

- A11.184 We continue to consider that the possibility of reception via indoor aerials such as set-top aerials is an incidental consequence of main planning goals. Therefore, we consider that the approach outlined in our 2013 Consultation is appropriate, and we have not developed algorithms or parameters designed specifically to ensure a low probability of interference into indoor aerials.
- A11.185 As explained earlier in Annex 2, our proposals for ensuring a low probability of harmful interference into reception via rooftop aerials will heavily restrict (but not prevent) WSD operation in channels that are used by DTT in any given area, and restrict power in channels close to those in order to protect rooftop aerial reception. This will also have the effect of lowering the probability of interference into indoor aerials.
- A11.186 In addition, we note that some indoor aerials are large aerials in loft spaces ("loft aerials"), and their performance is closer to that of rooftop aerials. Therefore the proposals designed for rooftop aerials will be more effective for this type of indoor installation despite the losses introduced by the roof itself.

# Instances where DTT modelling does not reflect usage on the ground

#### Summary of our position in the 2013 Consultation

- A11.187 In our 2013 Consultation, we said that, with the exceptions of the overspill from the Republic of Ireland and viewers whose main transmitter is in a different nation, our approach to spectrum planning has typically not sought to minimise the risk of harmful interference to alternative transmitters. Accordingly, we proposed that, save for these two exceptions, white space availability should in general be calculated taking into account only the main transmitter.
- A11.188 We added that, if we observe material evidence showing a significant impact on DTT viewers as a consequence of this proposal, we will consider the need to change the data provided to WSDBs.

#### Summary of responses

- A11.189 Several respondents argued that the current approach would not afford adequate protection and that further work or adjustments in WSDB calculations are necessary:
  - The BBC argued that we should allow protection of more than a single DTT transmitter, using existing datasets (DPSA layers). It argued that, otherwise, our current approach would lead to a loss of DTT service in situations where a 3-multiplex relay station provides the preferred service and a significant number of viewers opt for an enhanced receiving installation pointing at the lower signal level 6-multiplex main station. Further, it said that where coverage overlaps at the edges, use of the "Next Best" DPSA would be appropriate.
  - Digital UK and Freeview believed not all transmitters had been included in Ofcom's planning English regional correction transmitters and alternative transmitters in overlap areas had been omitted.
  - Digital UK commented that the entire family of DPSA layers are a suitable tool which should be used in assessing which transmitters should be afforded protection in any particular area.

- Sony suggested we carry out a study of the number of antennas that are not pointing to the preferred transmitter to estimate the extent of the issue rather than let users complain about interference before adjusting the database.
- techUK also noted that, given the difference of coverage between commercial multiplexes and public services multiplexes, viewers may align their aerial to an alternative transmitter in order to receive the 6 multiplexes.
- BT proposed that (occupied) pixels which are identified as not being served (i.e. not within primary layer coverage) by any DTT transmitter, but which are still receiving an adequate DTT signal, should still be considered for protection, albeit to a lesser degree reflecting an assumption that additional engineering has been used to boost the signal.

- A11.190 We remain of the view set out in the 2013 Consultation that our approach to calculating white space availability should take account of the single planned transmitter in a given area. However, in the light of evidence gained in our DTT coexistence tests and through a recent audit of aerial usage across the UK<sup>89</sup>, we have refined the choice of transmitter in use from the planning model to more closely reflect typical usage.
- A11.191 Our approach will be first to take account of coverage from a transmitting station where it provides the best coverage from 6 Multiplexes in a given area, and where this is not the case, to take account of coverage from a station providing the best coverage of 3 PSB multiplexes of the correct Nation, and where this is not the case to take account of coverage from a station providing the best coverage of 3 PSB multiplexes from any Nation. This approach will reflect the overall UK coverage targets as declared by the Digital Frequency Planning Group (DFPG).
- A11.192 The evidence from our DTT coexistence tests and the aerial audit suggests that relying solely on the planning model to determine actual transmitter usage is imprecise where services from more than one transmitter are receivable in practice. In a proportion of cases, the actual transmitter in use was not contained in any of the DPSA layers and so relying on that data would mean that we would not be taking into account the relevant transmitter as needed to ensure a low probability of interference to DTT reception in those areas. In a proportion of other cases, there was only one transmitter in use but the different DPSA layers contained different transmitters (so relying on that data would mean taking account of more transmitters than needed to ensure a low probability of interference to DTT services in those areas and unnecessarily limiting the spectrum available for WSDs).
- A11.193 We believe that making adjustments to the algorithms used in the planning model and the DPSA layers will only have a limited effect in overcoming these problems with the DTT modelling approach. Therefore we intend to investigate ways of collecting available data to populate a new database of actual transmitter usage on rooftop aerials throughout the UK. We will use this database to make adjustments to the output from the planning model to ensure that our DTT coexistence calculations take account of real-world usage of DTT transmitters<sup>90</sup>. We will also

<sup>&</sup>lt;sup>89</sup> <u>http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/annexes/20</u> Consumer aerial survey.pdf

<sup>&</sup>lt;sup>90</sup> As an example, in our coexistence tests in Thanet, we found that most viewers were receiving services from the Dover DTT main transmitting station rather than the Margate relay (which provides stronger signals). We

use this data to refine our understanding on how the minimum thresholds defined within the planning model for delivering a DTT service (99% time and 70% locations) relate to actual transmitting station usage in weak signal areas. More detail on our proposed next steps is included in Annex 2.

# Other DTT coding/modes

#### Summary of responses to the 2013 Consultation

A11.194 Sony noted that our consultation proposals were based on one DTT mode and queried how other modes would be taken into account. They asked whether WSDBs would check all the applicable DTT modes in the receive area, and base the allowed power of the WSD on the least robust of these modes. Similarly techUK sought clarification from Ofcom as to whether the database check will include all the applicable DTT modes in the receive area.

#### Ofcom's response

- A11.195 The framework is based on one (default) DTT mode (that for PSB multiplexes PSB1 and PSB2). The High Definition multiplexes (PSB3 and the 600 MHz multiplexes) use a DVB-T2 mode that has very similar protection ratio requirements to the default mode. The Local TV multiplex and the Northern Ireland Multiplex (NI Mux) use more robust modes than the other multiplexes and these will be afforded a higher level of protection under the framework than had they used the default mode.
- A11.196 The three Commercial Multiplexes use a transmission mode that is slightly less robust than the default mode (protection ratios are poorer by around 3 dB). Nevertheless, the DTT coexistence tests that were used to calibrate the framework were based on measurements on all of the multiplexes available from each of the transmitters in the areas tested. The additional margins that will be built in to the coupling gains and the protection ratios in the model will ensure that the model would produce TVWS power limits that will take account of the Commercial Multiplexes (having the least robust transmission mode).
- A11.197 We do not currently propose to modify the calculations to take account of the different protection ratios delivered by different DTT modes, as this would entail a significant increase in calculation complexity within the model. Such a change would probably not materially affect overall TVWS spectrum availability and the differences are in any case within the likely margins of error within the prediction model. Nevertheless we will keep this position under review in the future.

# **Co-channel operation**

#### Summary of responses to the 2013 Consultation

A11.198 The BBC and one other respondent expressed concerns regarding the co-channel coexistence parameters for WSDs and DTT. The BBC said that it would prefer to see a prohibition of WSD access to co-channel frequencies to prevent such a risk of harmful interference

would propose to ensure that TVWS calculations in this area were based on the knowledge that the Dover transmitter was in use.

- A11.199 As set out in Annex 2, we propose to increase the protection provided for cochannel operation of WSDs with DTT, both through the increase in the coupling gains from the 70<sup>th</sup> to 90<sup>th</sup> percentile for tier 0/1/2 pixels, and by the addition of a further margin of 9dB. Our coexistence tests have shown that this would afford sufficient protection to co-channel operation of DTT.
- A11.200 We recognise that the power limits for WSDs within the service area of a DTT transmitter may be so low as to make WSD operation unviable on these frequencies in most cases (except in very strong DTT signal areas when in any case the WSD would be vulnerable to interference from the DTT service). We will explore in the future whether it would be beneficial for DTT field strengths to be provided to WSDBs to enable them to prioritise use of frequencies not subject to incoming co-channel DTT interference.
- A11.201 We do not propose to further reduce the power limits for co-channel operation as that would produce an unnecessary restriction on WSD spectrum usage. Also, doing so would unnecessarily restrict availability of spectrum for WSDs because of the significant distances (20 km) over which co-channel WSD coexistence calculations are undertaken in the model.

# Section 3

# **Responses relating to PMSE**

# Our proposed high level approach

# Summary of our position in the 2013 Consultation

A11.202 In the 2013 Consultation we set out our proposed approach to ensuring a low probability of harmful interference to PMSE services. Our approach was based on ensuring an adequate protection ratio between the wanted PMSE signal and any potential interfering white space signal at the PMSE receiver (i.e the WSD interfering signal should be sufficiently far below the PMSE signal at the same frequencies<sup>91</sup> so as not to cause audio degradation). This required us to set parameters for assumed wanted signal power at the PMSE receiver and for protection ratios.

#### Summary of responses

- A11.203 The BBC called for a different approach, where we control the WSD interfering signal so that it is 6dB lower than thermal noise, which is present everywhere. This would provide additional certainty that interference would not be caused in a variety of situations.
- A11.204 BT commented that our approach seemed reasonable.

#### Ofcom's response

A11.205 As described in Section 8, we have adjusted the values of parameters in our approach, and in particular reduced wanted signal levels and increased protection ratios, without changing the basic methodology. Our empirical evidence shows that, after adjustments, our chosen methodology should achieve our goal of ensuring a low probability of harmful interference to PMSE services. Therefore we do not consider that it is necessary to adopt a different methodology as suggested by the BBC.

#### Intermodulation

# Summary of our position in the 2013 Consultation

A11.206 Intermodulation is an interference mechanism that may occur when some very specific circumstances arise, normally when devices operate very close to each other. Our proposals in the 2013 Consultation did not take account of this mechanism.

#### Summary of responses

A11.207 A number of respondents commented that PMSE receivers would be vulnerable to intermodulation products, particularly in situations where WSDs and PMSE equipment are in close proximity.

<sup>&</sup>lt;sup>91</sup> Protection ratios are also calculated for the case where WSD and PMSE are at different frequencies. In this case, the WSD signal level at the PMSE receiver does not necessarily need to be lower than the PMSE wanted signal level.

- A11.208 The BBC argued that, because Ofcom's proposals did not take into account intermodulation, it would need to, instead, prohibit WSD spectrum access anywhere within the boundary of a PMSE event, as a way to avoid the close proximity conditions that could give rise to intermodulation products.
- A11.209 BEIRG stated that multiple WSDs operating close to each other could give rise to intermodulation products, creating a risk for other services. In particular, they noted that WSDs operating in or within PMSE venues could give rise to intermodulation products. Brian Copsey also supported the need to take account of intermodulation in our analysis.

#### Ofcom's response

A11.210 We agree with the suggestion that we should take intermodulation into account, and as explained in Section 8 and Annex 4 we have now included this in our framework.

# **Exclusion zones**

#### Summary of our position in the 2013 Consultation

- A11.211 In our 2013 Consultation, we proposed not to allow WSDs to operate immediately outside the boundaries of a PMSE venue and we noted this could extend up to 14 metres outside the boundaries.
- A11.212 We added that, in instances where slave WSDs are non-geolocated and the coverage area of their serving master WSD overlaps with a PMSE venue, we would additionally assume that the PMSE receiver is always a distance of 10 metres away from the slave WSD.

#### Summary of responses

- A11.213 BEIRG argued that the proposed 14m is inadequate and urged that we implement 400m zone, or 600m if testing were to show that coexistence between WSDs and PMSE were not possible. The main rationale provided was the potential for intermodulation. There was a suggestion that these zones should apply at all frequencies.
- A11.214 Similarly, Brian Copsey requested that, due to lack of real life testing of WSDs in reasonable numbers and the uncertain nature of the modulation schemes and applications to be used, we apply 400m exclusion zones around PMSE use.
- A11.215 Highfield Church proposed an exclusion zone of 3km radius around geolocated PMSE licensees until further work is done that justifies any relaxation.

#### Ofcom's response

A11.216 In Section 8 of the Statement we explain how the adjustments we have made to our framework will result in increased separation distances between PMSE and WSDs. The distances are variable, depending on the WSD required power and other factors, but are not dissimilar to some of the sizes suggested for exclusion zones. The required separation distances do not apply equally to all frequencies. Distances are greatest for the co-channel case and reduce with separation distance, as explained in more detail in Section 8.

# Channel 38

# Summary of our position in the 2013 Consultation

A11.217 In our 2013 Consultation, we proposed not to allow WSDs to use channel 38 in any location and to impose restrictions nationwide in neighbouring channels.

#### Summary of responses

- A11.218 Three respondents argued that our proposal may be insufficient to ensure a low probability of harmful interference to PMSE use in channel 38:
  - The BBC felt it may be necessary to reduce the emission levels from WSDs by up to 40 dB to ensure there was not harmful interference to PMSE operating in channel 38;
  - BEIRG said that, whilst controlling the emission limits in the channels adjacent to channel 38 is a positive step, it would not be completely successful in eliminating harmful interference to those services from WSDs. BEIRG also believed that due to intermodulation, it would not be possible to fully protect PMSE operations in channel 38 from WSD interference;
  - Brian Copsey argued that the method proposed by us requires complex calculations which have a possibility of going wrong. He believed that a simple exclusion of WSDs from channels 37 to 39 would be a more practical solution and would give confidence to PMSE users.
- A11.219 Three respondents argued that our proposal may in some cases be overly restrictive:
  - Dynamic Spectrum Alliance (DSA) and Google argued that the nationwide restrictions in channels adjacent to channel 38 should be tested during the pilot to determine whether they can be moderated to reflect a lower risk of interference, for example, in certain rural areas where the population density is much lower;
  - Similarly, techUK believed that, in exceptional circumstances, such as in rural areas where there is a lower risk of interference, it may be feasible to moderate nationwide restrictions in channels adjacent to channel 38.
- A11.220 Two respondents, BT and Highfield Church believed that our proposals for channel 38 were reasonable.
- A11.221 Weightless commented that, at least for the moment, it would be prudent not to allow WSD emissions in channel 38.

#### Ofcom's response

A11.222 Our policy decisions with regards to channel 38 and the adjacent channels and our reasons for them are set out in Section 8 and Annex 5 to this Statement. We continue to consider that it is appropriate to prevent any WSD use in channel 38 in order to mitigate the risk of co-channel interference to PMSE use in channel 38. In relation to adjacent channel coexistence, we adopt limits to adjacent channels which are more restrictive than those proposed in our 2013 Consultation. We note that some of the resulting restrictions are similar to those suggested by the BBC; we

will allow a maximum of 24 or 22 dBm/(8MHz)<sup>92</sup> in the first adjacent channels (for a type A or type B device respectively). The BBC suggested a 22 dBm limit for class 1 devices in the first adjacent channel.

# Approach to uncertainty in locations of WSDs in relation to PMSE

# Summary of our position in the 2013 Consultation

A11.223 In the Technical Report accompanying our 2013 Consultation, we proposed that, for a slave WSD whose horizontal location is unknown (i.e. where it is not geolocated), the area of potential locations would be the coverage area of its serving master WSD.

# Summary of responses

- A11.224 The BBC, BT, the Dynamic Spectrum Alliance (DSA) and Google believed that our proposals were reasonable. The BBC and the DSA made additional comments:
  - The BBC said that our approach appeared to be acceptable. However, they cautioned that if this approach is followed carefully, Fig. 5.4 (of the 2013 Consultation) appeared to show some locations that should be treated as potential WSD locations have not been correctly marked;
  - The DSA believed that, in general, Ofcom had taken a reasonable approach and commented that the uncertainty of WSDs' locations to wireless microphones and other types of PMSE may be improved in the future by complementing the database with sensing information.

A11.225 Three respondents expressed concerns with our proposals:

- BEIRG did not believe that the proposed approach took into account the extended interference footprint of slave WSDs operating at or near the edge of a master's coverage area. BEIRG argued that slaves operating at the same power level as their master would extend the interference footprint to double the radius of the master alone;
- Brian Copsey said that the proposed approach presumed conformity with standardised receiver and transmitter parameters and did not consider a safety factor for production variations;
- Highfield Church commented that the proposals were too crude for practical use.

- A11.226 We remain of the view that, the high level approach set out in our 2013 Consultation is appropriate; we have adjusted some of the parameters for calculating the coverage area of the master, as explained in Annex 1.
- A11.227 BEIRG's comment about slaves potentially doubling the interference footprint of the master is correct, and this is taken into account by the framework, which assumes a non-geolocated slave is in the worst possible location with respect to interference to a PMSE receiver. This is explained in Section 8.

<sup>&</sup>lt;sup>92</sup> For a wideband device. The restrictions are applied per 100 kHz, maintaining an equivalent power density.

A11.228 We consider that the assumptions used in calculating the coverage area of the master are still conservative and therefore appropriate for this purpose.

# Approach to uncertainty in locations of PMSE receivers

#### Summary of our position in the 2013 Consultation

A11.229 In the Technical Report to our 2013 Consultation, we proposed to select the candidate PMSE locations so that they coincide with locations of grid points which fall within the boundary of the PMSE venue, or whose associated grid squares overlap with the boundary of the PMSE venue. We proposed to align the grid with the NGR and give it a resolution of 10 metres.

#### Summary of responses

- A11.230 The BBC noted that the location of antennas within TV studios may not be known to 10m accuracy. Furthermore, in ear monitors (IEM) and electronic news gathering (ENG) applications are highly mobile over large areas. The BBC therefore argued that it would be necessary to describe PMSE venues by a polygon and accept that the receivers may be deployed anywhere within that polygon.
- A11.231 Brian Copsey noted that antenna locations can be changed at short notice and in many cases vary with each performance or activity or even during a performance. Brian Copsey added that, in the case of outdoor events, this system could not be used as the location of PMSE antenna varies in position and height. Brian Copsey suggested imposing a 400m exclusion zone from the edge of the PMSE venue.
- A11.232 Three respondents, BT, the DSA and Google, said that they thought our proposals were reasonable.

#### Ofcom's response

- A11.233 We intend to adopt an approach that allows for PMSE receivers being placed anywhere within a venue, as suggested by some responses. We therefore intend to include data about venue boundaries into the framework, as explained in Section 8. We agree that the polygon approach proposed by the BBC appears to have advantages over our original proposals. This is currently our preferred approach for implementing boundaries, but we will confirm this when we have evaluated the practical implementation consequences further.
- A11.234 Our intention is to include information about venue boundaries, where appropriate, in the framework from the time when it becomes operationally active. However, if it becomes clear that it would be impractical to achieve this we will consider at the time how to proceed, including for example by adopting some additional interim restrictions.

# Parameter values - Reference distance of 10m

#### Summary of our position in the 2013 Consultation

A11.235 In the Technical Report to our 2013 Consultation, for non-geolocated slave WSDs, we proposed that if the coverage area of a master WSD overlaps with the location of a PMSE receiver, we would assume that irrespective of the location of a slave WSD, it is always a distance of 10 metres away from the said PMSE receiver.

# Summary of responses

A11.236 A number of respondents argued that a reference distance of 10m would not provide sufficient protection for PMSE users. For example:

- BEIRG argued that WSD and PMSE users could be as close as, effectively, zero metres from each other;
- Brian Copsey argued that we should assume a distance of 5 metres until such time more information becomes available;
- A11.237 BT and Weightless agreed with our proposals.
- A11.238 Both Google and DSA stated that the proposals are too strict. They both argue that WSD masters will have very large coverage areas, and the probability that WSDs will be less than 10m away from a given PMSE user in the same area will be very small.

#### Ofcom's response

- A11.239 As explained in Section 8 of this document, it is the aggregate effect of all parameters and calculations which is important, and even if a particular set-up breaches the reference value for one parameter, this does not mean that interference will occur. While it is obviously possible that a PMSE and WSD could be closer than 10m of each other, based on the co-existence testing we have undertaken, we do not consider that it is likely that harmful interference would occur. This was shown for instance in tests we performed at 9m distance and where the allowed maximum WSD power was much below the point at which any audio degradation would be heard.
- A11.240 We acknowledge the concerns that our approach may be too strict and therefore sterilise too much White Space. However, we have adopted an initially cautious approach, as explained in section 6. We anticipate that, given our initially cautious approach, we may be able to relax some rules as we understand more about actual deployments of WSDs and those devices improve. However, we will also be ready to tighten our approach if experience shows this is necessary.

#### Parameter values - wanted signal level

#### Summary of our position in the 2013 Consultation

A11.241 In our 2013 Consultation, we proposed to use a value of -65dBm/(200kHz) (except for Programme audio links, where we used -73dBm/(200kHz). This was based on a multilateral coordination agreement, Chester 97<sup>93</sup>.

#### Summary of responses

- A11.242 Several respondents disagreed with our proposed values.
  - BBC and BEIRG argued that this value did not take fading into account (i.e. that, as equipment such as wireless microphones and actors move around a stage,

<sup>&</sup>lt;sup>93</sup> The Chester 1997 Multilateral Coordination Agreement relating to Technical Criteria, Coordination Principles and Procedures for the introduction of Terrestrial Digital Video Broadcasting (DVB-T), Chester, 25 July 1997

the propagation environment changes, making the wanted signal levels vary, often dropping in power (fading);

- BEIRG considered that we should protect PMSE down to the sensitivity of the receivers;
- Sony supported Ofcom's proposed overall framework to ensure a low probability of harmful interference to PMSE services, however considered that the received wanted signal power, P<sub>S,0</sub>, for wireless microphones should be -95dBm/(200 kHz) and not -65dBm/(200 kHz), referring to ECC report 186 section 5.3 which specifies -114dBm (worst case PMSE receiving level);
- Brian Copsey suggested -97 dBm/(200 kHz), quoting a report by Cambridge Silicon Radio Limited (CSR)<sup>94</sup>;
- techUK said the PMSE wanted signal power level should be -95dBm/(200kHz);
- A11.243 Some respondents agreed with our proposed values, including BT, the Wi-Fi Alliance, the Dynamic Spectrum Alliance and Google.

#### Ofcom's response

A11.244 Following our own testing programme, we have revised down the wanted signal levels to -78dBm/(200 kHz). We explain how we used the evidence from tests to make this adjustment in Section 8 and Annex 4.

#### Parameter values - protection ratios

#### Summary of our position in the 2013 Consultation

A11.245 We set out our proposed WSD-PMSE protection ratios for wireless microphones, talkback, data link equipment, in-ear monitors and programme audio links.

#### Summary of responses

A11.246 Some respondents argued for additional measurements on protection ratios to be conducted. The BBC argued that we should use the worst-case traffic loads for the tests.

A11.247 Four respondents agreed with our proposed values:

- BT said that it considered that our approach appeared to be reasonable.
- Google and the Wi-Fi Alliance considered that the proposed protection ratios were adequate. However, Google argued that Ofcom's analysis at the time of the 2013 Consultation has assumed that all white space signals look similar to those emitted by Weightless devices. In its view, Ofcom may need to adjust protection ratios in the future as it collects more information regarding the characteristics of other WSDs.
- Neul believed that the proposed approach was a fair judgement of the real likelihood of interference with DTT and PMSE receivers. Neul added that any

<sup>&</sup>lt;sup>94</sup> TV White Spaces – PMSE Trials Report <u>http://www.csr.com/assets/documents/Cambridge\_TV\_White\_Spaces\_PMSE\_Trials\_Report\_21.pdf</u>

subsequent tightening of protection ratios would be very detrimental to the commercial use of TV White Space.

#### Ofcom's response

A11.248 We have performed additional tests and increased the protection ratios applied to the framework as explained in Annexes 9 and 10. We have addressed the potential for intermodulation products separately, as explained in Annex 4.

#### Parameter values - building penetration loss

#### Summary of our position in the 2013 Consultation

A11.249 In our 2013 Consultation, we proposed a nominal building penetration loss of 7 dB for WSDs located indoors. We also said that where a type B (portable) device height is reported and its height is greater than 2 metres, the WSD will be assumed to be located indoors. Where the WSD height is not reported, we proposed that a default height of 1.5 metres is used, and the device is assumed to be outdoors.

#### Summary of responses

A11.250 Some respondents argued this approach was not sufficiently protective of PMSE:

- The BBC believed it would be incorrect to assume a building will always provide 7dB screening. The BBC argued that building entry loss should be modelled as a lognormal random variable with 8dB loss and 5.5dB standard deviation, based on a document published by ITU.
- Brian Copsey said that the default height of 1.5 metres was an unsafe assumption and should be the same as for type A devices, i.e. 30 metres.

A11.251 Some respondents argued this approach was excessively protective of PMSE:

- The Dynamic Spectrum Alliance believed that the penalty (losing the 7dB indoor to outdoor factor and assuming that a type B device is outdoors at a height of 1.5 meters) of not reporting the height for portables/mobiles is pessimistic especially since most portables or mobiles do not currently have the capability to report height.
- Similarly, Wi-Fi Alliance thought that losing the building penetration loss when antenna height is not reported seemed too pessimistic. Wi-Fi Alliance stated that the building penetration loss of 7dB seemed to be overly conservative. Wi-Fi Alliance presented links to eight research papers to show that building penetration loss had been found to be in the range from 6dB to 27dB for frequencies below 1GHz. Wi-Fi Alliance believed the value should be changed from 7dB to 10dB, based on the measurement results reported in the open literature.
- Google considered that, for most structures, the exterior wall of a building causes signal loss in the range of 10 to 15 dB on average and that Ofcom should raise the 7 dB parameter accordingly.
- Neul noted that there are many M2M devices that will be at lower heights than 2 metres but are known to be indoors. Therefore, Neul proposed that whether a type B device is indoors or outdoors should be included in the device parameters.

Neul also proposed that generic operational parameters for both indoor and outdoor slaves are calculated (and broadcast) by the master, such that an indoor slave can use the indoor generic operating parameters. This inclusion of the indoor status of a slave within its device parameters would only be allowed for type B devices that cannot reasonably be moved into an outdoor location, either as a result of physical attachment to the indoor location, or through a trusted installation process.

A11.252 Sony suggested that Ofcom should make a survey of building penetration losses on a representative selection of UK building types as part of our pilot.

#### Ofcom's response

- A11.253 In most cases, portable wireless equipment used outdoors are normally carried by people (such as mobile phones), or vehicles (such as GPS), and therefore are not normally much above shoulder height (around 1.5m). Portable devices that achieve greater heights normally do so if they are inside a building. There may be exceptions (such a mobile phone carried by a crane operator).
- A11.254 As explained in Section 8, we ensured that values of individual parameters each represent a reasonably cautious choice as opposed to an absolute worst case that covers every exception and in aggregate they represent a cautious reference set of values. The emphasis is on the aggregate effect of these choices: if a particular set-up exceeds the reference value for one or even several parameters, this does not mean that interference will occur.
- A11.255 Some stakeholders (such as the BBC) believe the value we used for building penetration gain (7 dB) is too high, and some (such as Google and the Wi-Fi Alliance) believe it is too low. Both BBC and Google, though, accept this is below average for building entry. We note that inside a building there is normally additional clutter and additional walls, and therefore we consider that our 7dB reference value is suitably cautious.
- A11.256 We note Neul's suggestion for devices to report whether they are indoor or outdoor. We could consider this as a possible enhancement in a future review.

#### **Propagation model**

#### Summary of our position in the 2013 Consultation

- A11.257 We proposed to use the open, suburban, and urban profiles of the extended Hata model depending on the clutter type of the PMSE receiver's location.
- A11.258 We did not account for any angular or polarisation discrimination at the transmitter or receiver antennas.

#### Summary of responses

A11.259 Four respondents disagreed with the proposed approach:

• The BBC argued that our proposal for a 0dB margin was unacceptable as WSD deployments on hills would give rise to coupling gains that approach free space and exceed the values calculated using Hata.

- BEIRG said it was not in favour of the proposed approach as "anything which reduces the levels of protection to PMSE is unacceptable".
- Brian Copsey believed that the proposed approach needed further discussion and trial.
- Highfield Church said: "The issue of polarisation coupling gain is not relevant. Multi-path propagation inherent in the function of PMSE with moving transmitters in a complex, built environment is naturally accompanied by shifts in polarisation. The polarisation coupling between transmitter and receiver antennas should be assumed random and thus often less than unity".
- A11.260 BT, the DSA, techUK, Weightless and Wi-Fi Alliance agreed with the proposed approach, and that additional margins were not necessary.

#### Ofcom's response

A11.261 We have revised our propagation model to exclude the "open" category, for the reasons given in Annex 4. We have not added additional margins in the propagation model. However, we note that in general our framework, after the proposed adjustments is significantly more conservative (i.e. results in a lower probability of harmful interference) than it was before the adjustments. This is explained in Section 8. As previously stated, we ensured that values of individual parameters represent each a reasonably cautious choice, and in aggregate they represent a cautious reference set of values. The emphasis is on the aggregate effect of these choices: if a particular set-up exceeds the reference value for one or even several parameters, this does not mean that interference will occur.

# PMSE assignments straddling two DTT channels

#### Summary of our position in the 2013 Consultation

A11.262 In the Technical Report to our 2013 Consultation, we proposed that, in the cases where a PMSE assignment straddles two DTT channels, PMSE should be treated as adjacent-channel to WSDs which occupy either of the two DTT channels. We considered this to be a reasonable approach given that PMSE channel bandwidths are much less than 8 MHz, and WSD signals tend to use internal guard bands in order to meet out-of-block emission limits.

#### Summary of responses

A11.263 The BBC disagreed with our proposal. It argued that a PMSE assignment straddling two DTT channels should be treated as co-channel. It reasoned that our co-channel protection ratios used WiMAX recording of 5MHz bandwidth, implying a guard-band between the edge of the WSD signal and the PMSE of 5.5MHz for the adjacent channel measurements. This, BBC noted, tends to underestimate the WSD interference when a PMSE is operated on the edge of an 8MHz-wide WSD signal.

#### Ofcom's response

A11.264 We have decided to treat PMSE assignments straddling two DTT channels as cochannel to WSDs which occupy either of the two DTT channels, thereby providing additional protection. A11.265 This is part of our initially cautious approach. As explained in Annex 4, when PMSE assignments overlap DTT channel boundaries, the overlap tends to be slight, and WSD power spectra will be much reduced at the channel edges. However, we recognise that there may be exceptions where the overlap may be larger.

# **Section 4**

# Responses relating to mobile services above the UHF TV band

# Summary of our position in the 2013 Consultation

- A11.266 In our 2013 Consultation, we proposed to prevent WSDs from operating in channel 60 in order to ensure a low probability of harmful interference to 800 MHz band mobile devices operating near to the edge of coverage of the serving base station and in proximity to WSDs.
- A11.267 We explained that, as the impact of interference on mobile devices operating in the 800 MHz band from WSDs operating in channels 59 and below is expected to be much lower than that form WSDs operating in channel 60, we did not consider that any restrictions were required below channel 60 to ensure a low probability of harmful interference.

#### Summary of responses

- A11.268 Four respondents thought that refinements could be made to the framework which may allow some use of channel 60:
  - Three respondents commented that there are some indications that our proposals may be excessively cautious: The DSA thought that WSD operations should not be restricted in channel 60. It said that current high-powered incumbents using channel 60 (i.e. DTT Freeview ) will most likely cause more significant interference issues to 4G networks than low power WSDs. The WiFi Alliance questioned the need to reserve channel 60 as a guard band and suggested some other ways to mitigate the interference risk. Both the DSA and the Wi-Fi alliance observed that the WSD power levels are significantly lower than the levels of an adjacent base station in the reference scenario;
  - Google said that, rather than employing a total ban on channel 60, we should prescribe the out-of-band emission limit for devices in channel 60 and leave it to WSD manufacturers to determine how those requirements can best be met.;
  - The BBC said that geolocation could allow some use of channel 60 especially where licence A LTE-800 services are not deployed. It reasoned that a more flexible approach might allow WSDs in the band 790-862 MHz in areas where LTE services are not available (e.g. rural locations). However they also suggested that operation of "type B" devices at 36dBm could overload 4G mobile devices in close proximity, and that the existing out of band limits would imply a noise rise of 22dB<sup>95</sup> for a WSD operating 5m away from a LTE-UE receiver.
- A11.269 Two respondents noted that the proposal to exclude WSDs from channel 60 may be insufficient to ensure a low probability of harmful interference to mobile devices operating in the 800 MHz band:
  - Vodafone believed the achievable stop-band attenuation of a duplex filter in a terminal is substantially less than the value of 50dB we had used in that report.

<sup>&</sup>lt;sup>95</sup> These figures imply a coupling gain of -45dB (5m at 872MHz with no body loss), a receiver bandwidth of 5 MHz and a receiver noise figure of 3dB.

- EE supported the principle of a guard band to protect services above 791MHz but believed that a guard band consisting only of channel 60 would be inadequate and that greater frequency separation is required to fully protect 4G services.
- EE also said that we need to consider the scenario where mobile devices are indoor, at cell edge and operating close to 5MHz carrier QPSK device sensitivity of -100dBm. EE suggested a deterministic approach to physical separation protecting the -100dBm device sensitivity would be appropriate. EE believed Ofcom should protect LTE device sensitivity allowing only minimal desensitisation (< 0.4dB) at WSD/device separation distance of 2 metres.</li>

- A11.270 As explained in Section 9, having assessed base station to mobile station interference as a benchmark for assessing the impact from WSDs to mobile devices, we have decided to adopt the proposals set out in the 2013 Consultation.
- A11.271 We will therefore adopt a guard band at channel 60, meaning that no WSD could operate using that channel. We note that some respondents believe that there is potential for some use to be made of channel 60. We do not consider that this would be appropriate for the early stages of implementation. In particular, as explained in Section 9, a mobile device may be sufficiently near to a WSD in channel 60 that it experiences higher levels of interference than it would experience from adjacent channel base stations, and this level of interference may cause a degradation in the service. However, as stated in Annex 6, we intend to review our position in light of further studies and evidence in this area, and to explore the possibility of relaxing the proposed restrictions.
- A11.272 We note that some respondents suggested we should be more cautious in our approach and suggested changes to some input parameters in our calculations. For the reasons set out in Section 9 and Annex 6, we do not consider that any additional restrictions are required below channel 60 to ensure a low probability of harmful interference to 4G services. In particular, we performed some sensitivity analysis and concluded that even using potentially very pessimistic values for these parameters, our conclusions remain the same and there is no need for any restrictions to channel 59 operation.

# **Section 5**

# Responses relating to users below the band

# Summary of our position in the 2013 Consultation

- A11.273 In our 2013 Consultation, we proposed WSD emission limits to ensure a low likelihood of harmful interference to services below the band. We based our proposals on protecting breathing apparatus (BA) telemetry equipment as used by the UK Fire and Rescue Service, on the basis that this is one of the most vulnerable services below the band. We considered that by using this as a representative service, other less vulnerable services would also be protected.
- A11.274 The preferred means of protecting services below the band proposed in our 2013 Consultation was to restrict the level of unwanted WSD emissions below 470 MHz via a fixed limit, to be implemented in specifications for devices. We proposed to introduce an 8 dB reduction of the WSD emissions limit specified in EN 301 598 over the band 230-470 MHz from the current value of -36 dBm/(100 kHz) down to a revised value of -44dBm/(100 kHz).
- A11.275 A reduction of this nature was not adopted as part of the ETSI Harmonised Standard.<sup>96</sup>
- A11.276 We have therefore developed the alternative approach presented in the consultation which is to introduce class-specific restrictions on the in-block EIRPs of WSDs in channels 21 to 24. Detailed calculations of the revised approach are contained in Annex 7.

# Summary of responses

- A11.277 A number of respondents agreed with Ofcom's proposal and others did not comment specifically on this issue.
- A11.278 The BBC thought that the limits may not be sufficiently restrictive:
  - It noted that they were not aware of any coexistence studies addressing compatibility of WSD with services below 470MHz and that the background for our proposal to tighten the emissions from WSD into the band below 470MHz by 8dB appeared to be based on protection of breathing apparatus alone and said that other potentially more susceptible applications below 470MHz appeared not to have been included.
  - It also noted that our proposal to tighten the OOB emissions of WSDs to -44dBm / 100 kHz required a coupling loss of 74dB for an I/N of 0dB<sup>97</sup>. It said that this corresponded to a separation between WSD and a victim receiver in the UHF1/2 band of 250m when using a free space model. It commented that at typical separations of WSD to victim, perhaps 20m, the link budget of victim receivers could be eroded significantly.
  - It noted that our suggested power restrictions make an assumption that the out of block emissions will decrease pro-rata with the in block emissions. In practice,

<sup>&</sup>lt;sup>96</sup> It was considered that proposed reduction was a UK specific requirement since no other jurisdictions within Europe had licensed breathing apparatus in this band.

<sup>&</sup>lt;sup>97</sup> The figure quoted by the BBC assumes a receiver noise figure of 6dB.

many WSDs implement power control in the digital domain by reducing the signal into the modulator DAC. In this case, the out of block emissions are dominated by amplifier noise and quantisation noise and would not decrease pro-rata with the in-block emission.

A11.279 BT suggested that if the European harmonised unwanted emission limits do not provide sufficient protection to the BA equipment, consideration should be given to moving them to a more appropriate frequency band.

- A11.280 The BBC suggested that we should have considered "other potentially more susceptible applications" in our analysis, but did not explain what it considered those applications to be or why it considered them to be more vulnerable to interference than breathing apparatus. We remain of the view that BA telemetry is one of the most vulnerable services below the band, in particular due to its safety of life requirements; and the possibility of operation in close proximity to WSDs. It will also be operating immediately adjacent to the UHF TV band 469.850-470 MHz. Additional frequency separation reduces risk of interference for other services, since out of band emissions will be suppressed by filtering within WSDs.
- A11.281 Whilst we do not disagree with the coupling loss calculations presented by the BBC in their consultation response, the impact of the calculated noise rise depends on the extent to which the apparatus is operated close to its noise limit. We have aligned our assessment of interference in Annex 7 to previous assessments of the operation of breathing apparatus in the presence of interference<sup>98</sup>. On the basis of the findings of those previous theoretical and practical studies we are confident that under operational conditions the current proposals will allow coexistence with services below the UHF TV band with a low probability of harmful interference. We therefore do not think it is necessary to implement BT's suggestion and consider moving BA equipment to a different frequency band.
- A11.282 Our analysis assumes that a WSD meets its ACLR class specific performance requirements. These performance requirements are given in terms of a relative mask which is combined with a very low absolute limit for out of band emissions. We have assumed that this relative performance is met irrespective of WSD power. Under this assumption, WSD interference is reduced if WSD power is reduced. If a WSD implemented some part of its power control range in the digital domain, some components of out of band performance (such as those identified by the BBC) would not reduce whilst other components (such as those related to non-linearity in the output stages) would reduce significantly. For the purposes of conformance testing there is a requirement to operate the WSD in the 'worst case operational mode'. We consider in the light of this that that our assumptions are reasonable and will achieve a low probability of harmful interference.

<sup>&</sup>lt;sup>98</sup> Thales Research and Technology (UK), "862-863MHz breathing apparatus telemetry system interference study," 15 Dec 2010, <u>http://stakeholders.ofcom.org.uk/binaries/consultations/tlc/thales-report.pdf</u>. Aegis System Limited, "Breathing apparatus telemetry system interference study," 19 Mar 2012, <u>http://stakeholders.ofcom.org.uk/binaries/spectrum-awards/spectrum-clearance/Aegis Report.pdf</u>

# **Section 6**

# **Responses relating to cable**

# Summary of our position in the 2013 Consultation

- A11.283 In our 2013 Consultation, we noted that, since cable networks do not use wireless spectrum, we do not take them into account in our spectrum planning decisions.
- A11.284 We also observed that, in any event, deployment of WSDs is unlikely to cause harmful interference to cable services. This is because the lack of purpose-built antennas reduces the potential for interfering signals entering receivers. Consequently, any ingress of radio signals occurs incidentally due to the absence of robust shielding of cable equipment.

#### Summary of responses

- A11.285 Some respondents suggested there might currently be insufficient evidence that interference to cable networks would occur and that further consideration should be given to the potential risk of interference with cable systems. For example:
  - The BBC commented in its response that it is unclear whether WSDs operating at 4W (ca. 36dBm) would be compatible with cable TV. The BBC reasoned that this is because, whilst cable operators have improved screening of set top boxes and cable modems to address potential interference from mobile devices operating at a lower power of up to 20dBm, these improvements may be insufficient to protect against potential interference from WSDs operating at higher powers;
  - Sony queried in its response whether Ofcom had, given proximity of WSDs to cable receivers, conducted interference tests on cable receivers using white space signals.

# Ofcom's response

A11.286 As noted in the 2013 Consultation, since cable networks do not use wireless spectrum, we do not typically take them into account in our spectrum planning decisions. For this reason, we have not undertaken additional analysis on potential coexistence issues. We also note that no respondent provided additional evidence about the actual possibility of harmful interference into cable services.

# Annex 12

# Glossary

**2012 Consultation:** Ofcom consultation "TV white spaces - A consultation on white space device requirements" published on 22 November 2012. <u>http://stakeholders.ofcom.org.uk/binaries/consultations/whitespaces/summary/condoc.pdf</u>

**2013 Consultation:** Ofcom consultation "TV white spaces: approach to coexistence" published on 4 September 2013. <u>http://stakeholders.ofcom.org.uk/binaries/consultations/white-space-</u> <u>coexistence/summary/white-spaces.pdf</u>

**4G:** Fourth generation mobile standards and technology.

ACLR (Adjacent Channel Leakage Ratio): The ratio of in band transmitted power to out-ofband power in the adjacent channel (or for a specified frequency offset).

ACS (Adjacent Channel Selectivity): A measure of how susceptible a receiver is to unwanted signals in adjacent spectrum.

**Channel Usage Parameters:** The specific channel(s) and power level(s) used by a WSD and reported to a WSDB.

dB: A decibel.

**dBm:** Decibels (dB) of power referenced to one milliwatt (mW). The milliwatt is equal to one thousandth (10<sup>-3</sup>) of a watt.

dBµV/m: Signal strength expressed in dB-microvolts per metre.

**Device Parameters:** Parameters which identify specific characteristics of a WSD such as its location.

**DTT:** Digital Terrestrial Television. The terrestrial platform for the delivery of TV content via broadcasting in the UHF TV band (UHF Channels 21 – 60 (470 - 790 MHz)).

DTT channel: An 8 MHz frequency channel within the UHF TV band.

**DSA (Dynamic Spectrum Access):** Technique of sharing the same spectrum band by dynamically selecting a frequency and/or time slot to use whilst avoiding causing interference to other nearby devices.

EIRP: Equivalent Isotropically Radiated Power.

**ETSI:** The European Telecommunications Standards Institute.

FCC: The Federal Communications Commission of the United States.

**Generic Operational Parameters (GOPs):** Operational parameters that can be used by all slave devices operating in the area in which transmissions from the master device can be received.

**Geolocation:** The determination by a white space device of the latitude and longitude coordinates of its antenna and the level of uncertainty in the accuracy of its antenna latitude and longitude coordinates, specified as  $\pm\Delta x$  and  $\pm\Delta y$  metres respectively, corresponding to a ninety-five per cent confidence level.

**GHz (Gigahertz):** Giga is 10<sup>9</sup> and Hertz (or cycles/second) is a measure of frequency (in this document, in relation to the frequency of oscillation of radio frequency transmissions).

**GPS (Global Positioning System):** A system that enables a device to determine its geographical location by reference to signals transmitted by multiple satellites.

**ITU (International Telecommunications Union):** The United Nations specialised agency for information and communications technologies. http://www.itu.int/en/about/Pages/default.aspx

**kHz (Kilohertz):** Kilo is 10<sup>3</sup> and Hertz (or cycles/second) is a measure of frequency (in this document, in relation to the frequency of oscillation of Radio Frequency transmissions).

**MHz (Megahertz):** Mega is 10<sup>6</sup> and Hertz (or cycles/second) is a measure of frequency (in this document, in relation to the frequency of oscillation of Radio Frequency transmissions).

**Master Device:** A white space device that is able to communicate with and which obtains operational parameters from a designated white space database.

**Multiplex:** A combination of multiple signals or streams of information at the same time into a single, complex signal. A multiplexer (or "mux") is a device that performs this task. The separate signals are then recovered at the receiving end using a demultiplexer (or "demux"). Multiplexers are used in telecommunications to combine different information streams into a single signal, often to use transmission capacity more efficiently. For DTT, a number of TV services are combined together in a mux for transmission in a single UHF channel.

**Operational Parameters:** A set of parameters calculated by a WSDB (on the basis of device parameters together with information provided to it by Ofcom) to determine what frequencies are available for that particular device and at what powers it is able to transmit in those frequencies.

**PMSE (Programme Making and Special Events):** A class of radio applications that supports a wide range of activities in entertainment, broadcasting, news gathering and community events.

**Slave Device:** A white space device that is only able to transmit in TV white spaces when under the control of a master device.

**Specific Operational Parameters (SOPs):** The operational parameters that are specific to a particular slave device.

**TV White Spaces:** The frequencies within the UHF TV band which have been identified by a qualified white space database as available for use by white space devices.

**UHF (Ultra High Frequency):** The ITU designation for radio frequencies in the range between 300 MHz and 3 GHz.

**UHF TV band:** In this Statement, the 470 - 790 MHz band, but recognising that once 694 - 790 MHz is cleared for mobile data use, this part of the band will no longer be available for white space use. See Ofcom's "Decision to make the 700 MHz band available for mobile

data – statement" published on 19/11/14. (http://stakeholders.ofcom.org.uk/consultations/700MHz/statement/)

**UKPM (UK Planning Model):** An industry planning tool for DTT coverage prediction.

**WSDB (White Space Database):** A database which is able to provide information on the availability of TV white spaces to white space devices.

**WSD (White Space Device):** Wireless telegraphy stations or wireless telegraphy apparatus which is able to operate in TV white spaces.

WSDIS (White Space Device Information System): An information system that provides information on the frequencies and powers used by WSDs for the purposes of carrying out an initial triage of interference cases.