TV white spaces: approach to coexistence

Addendum

Consultation

Publication date: 24 October 2013

Closing Date for Responses: 13 December 2013

Contents

Section 1

Introduction

1.1 On 4 September 2013 Ofcom published its consultation *TV white spaces: approach to coexistence*[1] and a supporting technical report[2].

1.2 Subsequently Ofcom received information from the BBC that suggested there was an error in the Consultation. Ofcom reviewed that information and concluded there was a mathematical error in one of its calculations relating to coexistence with Digital Terrestrial Television (DTT).

1.3 On 10 October, at Ofcom's stakeholder event[3] on the TV white spaces project Ofcom explained the nature of the error and committed to publish a clarification to resolve the inconsistency which the error had created in the documentation. This document provides that clarification.

1.4 In the light of the need to publish this clarification, Ofcom is extending the deadline for responses to the Consultation to **13 December 2013.** Stakeholders should note that as stated in paragraph 2.22(c) of the Consultation, there will be an opportunity to provide further comments after that deadline in the context of the pilot.

[1] http://stakeholders.ofcom.org.uk/consultations/white-space-coexistence/
[2] http://stakeholders.ofcom.org.uk/binaries/consultations/white-space-coexistence/annexes/technical-report.pdf
[3] See the slides presented at that event at the following link: http://stakeholders.ofcom.org.uk/binaries/spectrum/whitespaces/1124340/TVWS_Coex_Workshop_presentation_FINAL.pdf

Section 2

Clarification of proposals for DTT coexistence

2.1 In the Consultation Ofcom set out that our objective was to ensure a low probability of harmful interference to DTT.[4] This remains Ofcom's objective and is unaffected by this clarification.

2.2 We recognised in the Consultation that there was considerable uncertainty surrounding the choices for how to define the approach to coexistence with DTT (see paragraphs 4.2 and 4.3 of the Consultation). We noted that the approach to DTT planning had originally been developed to address a different problem, namely the planning of the DTT network during DSO, and that there was some evidence that using the same approach for coexistence studies overestimates levels of interference. We therefore need to treat with caution the predictions produced by this approach. (See paragraph 5.28 and 5.29 of the Consultation). We consulted on an alternative approach based on desensitisation, on the basis that this is an approach commonly used in coexistence studies (See paragraph 5.30 of the Consultation).

2.3 In paragraph 5.31 of the Consultation Ofcom summarised its proposal for its approach as follows:

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

2.4 The reference to 10% in this paragraph was incorrect and an over simplification as we explain further below in this document.

2.5 However, as also explained below, we do not believe the incorrect reference to 10% is so material as to change our view that the proposals on which we are consulting will meet Ofcom's objective of ensuring a low probability of harmful interference to DTT. Our assessment of the materiality of this reference takes into account that this is one of a number of judgements which we have had to make in our analysis (see paragraph 4.3 of the Consultation), several of which could have an impact comparable to the incorrect reference to 10%. We will be considering responses from stakeholders on these points as part of this consultation process and can then decide, in light of these, what approach we should actually adopt.

[4] This objective reflected the previously taken policy decision to allow WSDs access to the UHF TV band on a licence-exempt basis subject to ensuring that the probability of harmful interference to existing licensed services, including DTT and PMSE, would be low. See paragraphs 2.13-2.17 of the Consultation.

Explanation of the mathematical error

2.6 Ofcom's approach to specifying the emission limits for white space devices (WSDs) was set out in Sections 3 and 4 of the Technical Report. In summary the approach was as follows (see paragraph 3.6 of the Technical Report):

Calculate the maximum permitted WSD in-block EIRP, $P_{\text{WSD-DTT}}(i, F_{\text{WSD}})$, for a WSD located in a geographic pixel indexed as i, and radiating in channel F_{WSD}, subject to a given probability of a target reduction in DTT signal-to-interference-plus-noise ratio in any channel F_{DTT} = 21 to 60.

2.7 In specifying the WSD emission limits, we proposed the following:

- Target rise in the noise-plus-interference floor (desensitisation) at the edge of DTT coverage.
- Target protection ratios, r_{T} (susceptibility of DTT receiver).
- Target coupling gains, G_{T} (radio propagation and receiver antenna gain).

2.8 In the Consultation we proposed the following parameter values:

- Desensitisation of 1 dB (see paragraph 4.56 of the Technical Report).
- Target protection ratios r_{T} that are exceeded with probability of 30% (see paragraphs 4.54 and 4.102 of the Technical Report).
- Target coupling gains G_{T} that are exceeded with probability of 30%. (see paragraph 4.54, 4.76 and 4.81 of the Technical Report)

2.9 We mistakenly stated that the combination of the proposals for the target protection ratios and target coupling gains set out in paragraph 2.8 above implies that a desensitisation of 1 dB or more will occur with a probability of 10% (see for example paragraph 4.64 of the Technical Report and paragraph 5.31 of the Consultation). For this reason, we presented this as splitting the probability of 10% equally into exceedance probabilities of 30% for each of the protection ratio and coupling gain (see paragraph 4.54 of the Technical Report).

2.10 The calculation of the 10% probability figure was incorrect. Following further investigation by Ofcom, we have found that

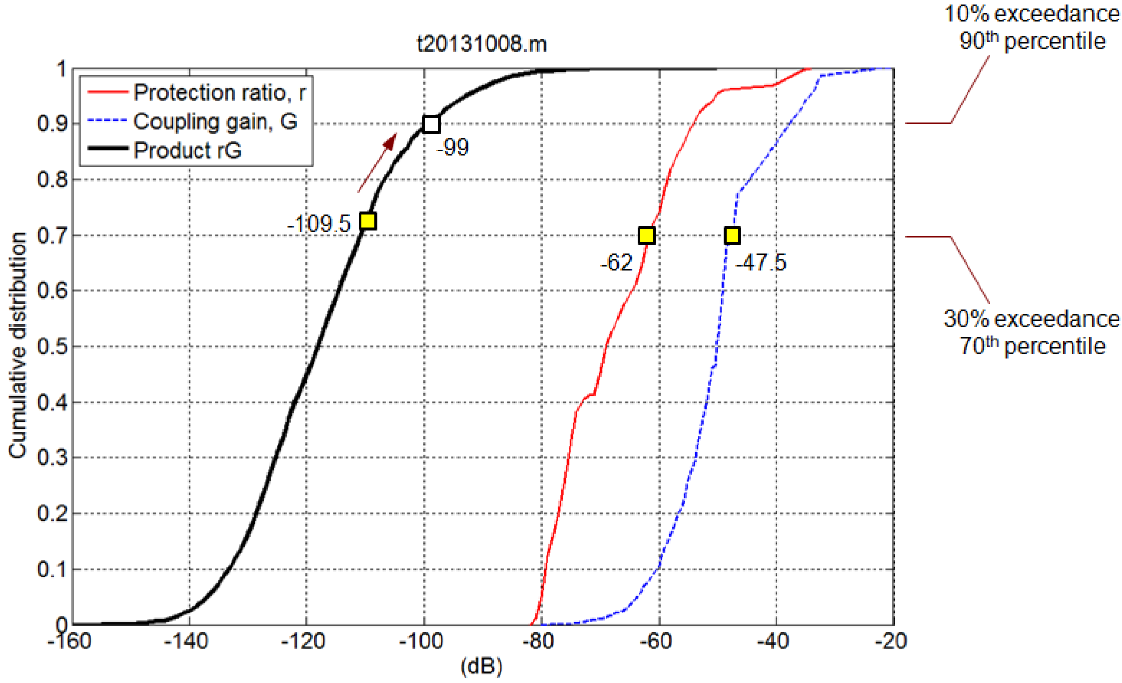
a) there is not a single probability figure that applies in all interference scenarios (i.e. combinations of interferer to victim frequency separation, interferer to victim distance, interferer height and DTT signal power); and

b) in interference scenarios where we mistakenly believed that a probability of 10% applied, the correct probability figures are in fact approximately 30%.

2.11 Figure 1 below provides an example for one specific interference scenario which corresponds to a frequency separation of 10 channels (ΔF = 10), DTT received median wanted power of m_{S} = -70 dBm, a WSD height of 10 m, and with the WSD and DTT receiver located in the same pixel or immediately adjacent pixels. The figure shows that the use of target protection ratio (-62 dB) and coupling gain (-47.5 dB) values which are exceeded with a probability of 30% implies that the product $r_{\text{T}}G_{\text{T}}$

(and hence a 1 dB desensitisation) is exceeded with a probability of roughly 30%, and not 10% as we mistakenly thought).

Figure 1. Exceedance probabilities



Co-channel protection ratios & coupling gains for tier 3 pixels and beyond

2.12 The proposal for choosing exceedance probabilities of 30% (the 70th percentile) to define the parameter values for protection ratio and coupling gain which Ofcom incorrectly combined to state constituted a 10% probability, only applies to cases where

a) interference is adjacent channel; and

b) the victim is in the same pixel, or tier 1 pixel, or tier 2 pixel with respect to the interferer (close proximity).

2.13 In the cases of co-channel protection ratios and coupling gains for tier 3 pixels and beyond Ofcom did not propose to use the 70th percentile values and nor did it explicitly state the relevant probability was 10%, but we accept that some of our more general statements in the Consultation may have implied this.

2.14 In the case of co-channel protection ratios, we proposed a value of 17 dB (see paragraph 4.102 of the Technical Report). This corresponds to exceedance probabilities of 41% to 9%, depending on the DTT signal power. Although we did not state these probabilities explicitly in the Consultation or Technical Report, the range of measured co-channel protection ratios from which they are derived were presented in Tables A4.7 to A4.10 of the Technical Report. Given that the co-channel protection ratios vary by only 2 dB across the tested DTT receivers, our judgement was that the proposed value of 17 dB was justified and did not merit detailed elaboration.

2.15 In the case of coupling gains for victims in Tier 3 pixel (and beyond) we stated in paragraph 4.92 of the Technical Report that we proposed not to use the 70th percentile but rather to derive the coupling gain from the median of the extended Hata model, which effectively corresponds to a 50th percentile value. Given that the Hata model tends to over-estimate path gain at large separations, our judgement was that the addition of an additional extra margin to the median coupling gain was too cautious (see paragraph 4.92 of the Technical Report).

Published white space availability information

2.16 The white space availability information that was published in and alongside the Consultation and Technical Report does not reflect an overall approach to coexistence with DTT where there was a 10% probability of a 1 dB (or more) rise in the noise-plus-interference floor at the edge of DTT coverage. Rather that information is consistent with: targeting a 1 dB (or more) rise in the noise-plus-interference floor at the edge of DTT coverage with a range of probabilities depending on the particular interference case concerned, and also allowing a greater rise in the noise-plus-interference floor inside DTT coverage areas.

Clarification of Ofcom's proposals

2.17 We set out in paragraph 2.8 above our proposed values for the parameters to be used in the case of adjacent channel protection ratios and close proximity coupling gains gain. We remain of the view that these are appropriate judgements to propose for those values. However, the error that has been identified means that those proposals are not consistent with our stated summary target in the Consultation of a 10% probability. Rather as noted in paragraph 2.10(b) above the correct figure is approximately 30%.

2.18 We also recognise that the statements in paragraph 5.31 and 5.32 of the Consultation were an over simplification of the underlying technical proposals through which we proposed to meet our objective of ensuring a low probability of harmful interference, as they did not reflect the detailed technical proposals for all interference cases.

2.19 In the light of these two points Ofcom has reviewed its proposals and we remain of the view that overall the proposals we have made for coexistence with DTT will ensure a low probability of harmful interference. The error that has been identified related to combining the probabilities and not the underlying judgement about the parameter values. It also only related to some and not all the interference cases we considered. More generally, we recognise that planning for allowing access to TV white spaces is a new and potentially uncertain and difficult area, which is in part addressed by canvassing views on our planning approach in the Consultation. We also intend, to the extent possible, to test our proposals in the planned Pilot. These particular judgements regarding parameter values must be seen within the broader context of firstly all the various modelling assumptions and parameter values used, and secondly the emerging evidence that existing modelling tools, such as that used by Ofcom in this case, may be likely to underestimate the robustness of the DTT reception compared to what will be seen in practice.

TVWS availability information

2.20 The information on TVWS availability that was published in the Consultation and Technical Report and maps which were subsequently published are consistent with proposals as clarified in this document.

Consultation questions

2.21 Question Q1 in the Consultation should be responded to in the light of the clarification provided above.

2.22 Question T4 in the Technical Report is restated as follows:

QT4: Do you have any comments on our proposed target 1 dB rise in the noise-plus-interference floor at the edge of DTT coverage, and our approach for allowing greater rise in the noise plus interference floor in areas inside DTT coverage?

2.23 Question T5 in the Technical Report is restated as follows:

Question T5: Do you have any comments on our proposed approach for calculating coupling gains in relation to DTT calculations, including the use of 70^{th} percentile coupling gain values for same pixel, tier 1 pixel and tier 2 pixel scenarios, and the use of median coupling gains for tier 3 pixel (and beyond) scenarios?

2.24 Question T6 in the Technical Report is restated as follows:

Question T6: Do you have any comments on our proposed protection ratios in relation to DTT calculations, including the use of 17 dB for co-channel protection ratio, and 70^{th} percentile values for adjacent channel protection ratios?

Section 3

Table of clarifications

3.1 The two tables below lists the various places in the Consultation and Technical Report where the existing text became unclear as a result of the error and provides new text to clarify Ofcom's position.

Table 1 Consultation

Paragraph number	Existing text	Revised text / Clarification
5.30	While location probability is a key parameter in quantifying the quality of DTT coverage, its calculated value is very much dependent on assumptions regarding the statistical distributions of received signals[20]. We consider that it is more appropriate to use a target rise in the noise-plus-interference floor (rather than a reduction in location probability) as the technical criterion for setting WSD emission limits. Furthermore, we also consider that it is important to specify the probability with which a target rise in the noise-plus-interference floor might be exceeded.	While location probability is a key parameter in quantifying the quality of DTT coverage, its calculated value is very much dependent on assumptions regarding the statistical distributions of received signals[20]. We consider that it is more appropriate to use a target rise in the noise-plus-interference floor (rather than a reduction in location probability) as the technical criterion for setting WSD emission limits.
5.31	We consider that we can meet the objective of a low probability of harmful interference to DTT by setting emission limits for WSDs such that there is only a 10% likelihood that the rise in the noise-plus-interference floor exceeds 1 dB at the edge of DTT coverage. The overall probability of harmful interference combines the 10% likelihood of an increase of 1 dB in the noise-plus-interference floor with the likelihood that that increase prevents a DTT receiver from operating normally.	We consider that we can meet the objective of a low probability of harmful interference to DTT in practice by setting the WSD emission limits based on a target 1 dB rise in the noise-plus-interference floor at the edge of DTT coverage, combined with appropriate selected values of target coupling gains and protection ratios.
5.32	A 1 dB rise in the noise-plus-interference floor at the edge of coverage is a common technical	A 1 dB rise in the noise-plus-interference floor at the edge of coverage is a common technical

Paragraph number	Existing text	Revised text / Clarification
	assumption in coexistence studies. This is because wireless systems are usually engineered to operate at a safe margin above expected levels of noise-plus-interference, and as a result, a 1 dB rise is not considered to result in perceptible interference in practice. Hence we would expect that only a small proportion of the 10% of households predicted to experience a 1 dB rise or more in the noise-plus-interference floor would suffer harmful interference.	assumption in coexistence studies. This is because wireless systems are usually engineered to operate at a safe margin above expected levels of noise-plus-interference, and as a result, a 1 dB rise is not considered to result in perceptible interference in practice. Hence we would expect that only a small proportion of the households predicted to experience a 1 dB rise or more in the noise-plus-interference floor would suffer harmful interference.
5.35	In order to ensure that there is no more than a 10% likelihood of degradation in location probability exceeding 7 percentage points, we need to make assumptions about the statistics of radio propagation from WSDs to DTT receivers (WSD-DTT coupling gains) and the statistics of DTT receiver performance (WSD-DTT protection ratios).	In deriving WSD emission limits, in addition to specifying a target 7 percentage point degradation in location probability, we need to make assumptions about the statistics and target values for radio propagation from WSDs to DTT receivers (WSD-DTT coupling gains) and the statistics of DTT receiver performance (WSD-DTT protection ratios).
5.36	We have modelled coupling gains by using the statistics of nearest neighbour household separations for urban, suburban and rural environments.	We have modelled coupling gains for short WSD-DTT separations (two pixels or less) based on the statistics of household separations for urban, suburban and rural environments, and then using the 70th percentile coupling gain values as targets. For greater WSD-DTT separations, we have modelled coupling gains based on median path loss, which effectively imply 50th percentile coupling gain target values.
Annex A4.1 Question T4	Do you have any comments on our proposed target of a 10% likelihood of a 1 dB rise in the noise-plus-interference floor at the edge of DTT coverage?	Do you have any comments on our proposed target 1 dB rise in the noise-plus-interference floor at the edge of DTT coverage, and our approach for allowing greater rise in the noise plus interference floor in areas inside DTT coverage?
Annex A4.1 Question T5	Do you have any comments on our proposed approach for calculating coupling gains in relation to DTT calculations?	Do you have any comments on our proposed approach for calculating coupling gains in relation to DTT calculations, including the use of 70th percentile coupling gain values for

Paragraph number	Existing text	Revised text / Clarification
		same pixel, tier 1 pixel and tier 2 pixel scenarios, and the use of median coupling gains for tier 3 pixel (and beyond) scenarios?
Annex A4.1 Question T6	Do you have any comments on our proposed protection ratios in relation to DTT calculations?	Do you have any comments on our proposed protection ratios in relation to DTT calculations, including the use of 17 dB for co-channel protection ratio, and 70th percentile values for adjacent channel protection ratios?

Table 2 Technical Report

Paragraph number	Existing text	Revised text
3.6	Calculate the maximum permitted WSD in-block EIRP, $P_{WSD\text{-}DTT}(i, F_{WSD})$, for a WSD located in a geographic pixel indexed as i, and radiating in channel F_{WSD}, subject to a given probability of a target reduction in DTT signal-to-interference-plus-noise ratio in any channel F_{DTT} = 21 to 60.	Calculate the maximum permitted WSD in-block EIRP, $P_{WSD\text{-}DTT}(i, F_{WSD})$, for a WSD located in a geographic pixel indexed as i, and radiating in channel F_{WSD}, subject to a given target reduction in DTT signal-to-interference-plus-noise ratio in any channel F_{DTT} = 21 to 60.
4.5	Subsequently, we set out our proposals for the parameter values to be used in calculating the maximum permitted WSD in-block EIRPs. Specifically, we specify values for the: • probability of a target reduction in DTT SINR; • WSD-DTT coupling gains; and • WSD-DTT protection ratios.	Subsequently, we set out our proposals for the parameter values to be used in calculating the maximum permitted WSD in-block EIRPs. Specifically, we specify values for the: • target reduction in DTT SINR; • WSD-DTT coupling gains; and • WSD-DTT protection ratios.
4.51	The parameter values to be specified are as follows: • A maximum (target) reduction in location probability, Δq_T • The protection ratio, r_T • The coupling gain, G_T	The parameter values to be specified are as follows: • A target reduction in location probability, Δq_T • A target protection ratio, r_T • A target coupling gain, G_T

Paragraph number	Existing text	Revised text
4.52	In defining the above parameter values, it is important to account for another key parameter. This is the likelihood, L, that the reduction in location probability exceeds the target Δq_T, given the selected values G_T and r_T for the protection ratio and coupling gain, respectively. In short, $L = \Pr\{\Delta q > \Delta q_T\} = \Pr\{r\,G > r_T G_T\}$ $= \Pr\{r > r_T\}\Pr\{G > G_T\}$ where the coupling gain and protection ratio are assumed to be independent random variables.	In defining the above parameter values, it is important to account for another key parameter. This is the likelihood, L, that the reduction in location probability exceeds the target Δq_T, given the selected target values G_T and r_T for the protection ratio and coupling gain, respectively. In short, $L = \Pr\{\Delta q > \Delta q_T\} = \Pr\{r\,G > r_T G_T\}$ where the coupling gain and protection ratio are assumed to be independent random variables.
4.53	We propose a likelihood of L = 0.1 (or 10%). That is to say, once a WSD radiates, we expect a 10% likelihood that the resulting reduction in location probability, Δq, at a DTT receiver exceeds the intended target, Δq_T.	That is to say, once a WSD radiates, the model suggests that the resulting reduction in location probability, Δq, at a DTT receiver exceeds the intended target, Δq_T, with a likelihood L. The value of the likelihood L is a function of the distributions of the random variables r and G, and the selected target values r_T and G_T.
4.54	We further propose to split this likelihood equally into exceedance likelihoods of roughly 30% for each of the protection ratio and coupling gain, i.e., $\Pr\{r > r_T\} = \Pr\{G > G_T\} = 0.3.$	The values of r_T and G_T are selected based on our engineering judgement as to what constitutes a low probability of harmful interference in practice. As a result, our criteria for selecting values of r_T and G_T (and consequently, the resulting value of likelihood L) will vary in different interference scenarios. For example, for the case of adjacent channel interference in same pixel, 1st tier pixel, and 2nd tier pixel geometries, we propose to use (see later in this section) 70th percentile values of r_T and G_T , i.e., $\Pr\{r > r_T\} = \Pr\{G > G_T\} = 0.3.$
4.55	An exceedance likelihood of 10% might appear too high in the context of ensuring a low probability of harmful	The above combination would imply a value of approximately L = 0.3 (or 30%). An exceedance likelihood of

Paragraph number	Existing text	Revised text
	interference from licence exempt WSDs to licensed services. However, the 10% figure needs to be considered in conjunction with the target reduction in location probability (see below).	30% might appear too high in the context of ensuring a low probability of harmful interference from licence exempt WSDs to licensed services. However, the 30% figure needs to be considered in conjunction with the target reduction in location probability or desensitisation (see below). Finally, it should be noted that the value of L is a result of a range of assumptions that we have made within our model-based framework, and must be treated primarily as a comparative (rather than absolute) measure of the likelihood of harmful interference.
4.59	We consider, therefore, that a 1 dB desensitisation is a reasonable criterion in the context of our model-based framework and a 10% likelihood that this might be exceeded.	We consider, therefore, that a 1 dB desensitisation is a reasonable criterion in the context of our model-based framework.
4.64	Taken together, we believe that a 10% probability of a 1 dB rise in the edge of coverage noise-plus-interference floor (or a 7 percentage point reduction in location probability), implies a low probability of harmful interference to DTT in practice. In reaching this conclusion, we have given due consideration to recent evidence from LTE base station deployments in the 800 MHz band. These indicate that the observed cases of interference to DTT are substantially fewer than predicted by a similar modelling of the impact of interference on DTT location probability.	Considered in the context of our model-based framework, we believe that a 1 dB target rise in the edge of coverage noise-plus-interference floor (or a 7 percentage point reduction in location probability), implies a low probability of harmful interference to DTT in practice. In reaching this conclusion, we have given due consideration to recent evidence from LTE base station deployments in the 800 MHz band. These indicate that the observed cases of interference to DTT are substantially fewer than predicted by a similar modelling of the impact of interference on DTT location probability.
4.64 Question T4	Do you have any comments on our proposed target of a 10% likelihood of a 1 dB rise in the noise-plus-interference floor at the edge of DTT coverage?	Do you have any comments on our proposed target 1 dB rise in the noise-plus-interference floor at the edge of DTT coverage, and our approach for allowing greater rise in the noise plus interference floor in areas inside DTT coverage?
4.94 Question	Do you have any comments on our proposed approach for calculating coupling gains in relation to DTT	Do you have any comments on our proposed approach for calculating coupling gains in relation to DTT calculations, including the use of 70th

Paragraph number	Existing text	Revised text
T5	calculations?	percentile coupling gain values for same pixel, tier 1 pixel and tier 2 pixel scenarios, and the use of median coupling gains for tier 3 pixel (and beyond) scenarios?
4.108 Question T6	Do you have any comments on our proposed protection ratios in relation to DTT calculations?	Do you have any comments on our proposed protection ratios in relation to DTT calculations, including the use of 17 dB for co-channel protection ratio, and 70th percentile values for adjacent channel protection ratios?
4.125	These results are for same-pixel or tier-1 pixel scenarios, and for a L = 10% likelihood that the reduction Δq in location probability exceeds 7 percentage points. They also correspond to a noise-limited DTT coverage; i.e., where the DTT self-interference term V in Equation (4.1) is zero. The coupling gain and protection ratio values are as proposed earlier in this section.	These results are for same-pixel or tier 1 pixel scenarios, and a target reduction Δq in location probability of 7 percentage points. They also correspond to a noise-limited DTT coverage; i.e., where the DTT self-interference term V in Equation (4.1) is zero. The target coupling gain and protection ratio values G_T and r_T are as proposed earlier in this section and correspond to individual exceedance probabilities of 30% (70th percentile values).
4.145 first bullet	The proposed WSD emission limits are calculated subject to a 10% probability that the radiations by a WSD would result in a rise in the noise-plus-interference floor which exceeds 1 dB at the edge of DTT coverage in any given channel. The approach permits increasing WSD emission levels in accordance with increasing DTT received power levels deep within the coverage area of a DTT transmitter.	The proposed WSD emission limits are calculated subject to appropriately selected target coupling gain and protection ratio values, and a target 1 dB rise in the noise-plus-interference floor at the edge of DTT coverage in any given channel. The approach permits increasing WSD emission levels in accordance with increasing DTT received power levels deep within the coverage area of a DTT transmitter.