Technical analysis of interference from mobile network base stations in the 800 MHz band to digital terrestrial television

Further modelling

Technical report

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Section 1

Executive summary

1.1 This document reports on the results of further studies undertaken by Ofcom to investigate the impact of interference from future mobile/fixed communication network (MFCN) base stations (BSs) in the 800 MHz band (791-872 MHz) to digital terrestrial television (DTT) services below 790 MHz.

1.2 This report supplements our second consultation on DTT co-existence published in February 2012[1].

1.3 The analysis presented in this report is a revision of the technical modelling published by Ofcom in a technical report[2] along with our first consultation[3] of June 2011. The purpose of this further modelling is

a) to update the modelling methodology and certain technical parameter values in light of new evidence obtained by Ofcom, and based on stakeholder feedback in the responses to our consultation of June 2011;

b) to perform a sensitivity analysis in order to explore the impact of different parameters, particularly relating to the MFCN network deployment and the performance of DTT receiver equipment.

1.4 Table 1 below shows our revised estimates of the number of households in the UK whose DTT reception might be affected[4] as a result of interference from MFCN base stations in the 800 MHz band. These estimates are for a "central" scenario, involving a UK-wide MFCN deployment in each 10 MHz block of the 800 MHz band, with 11,239 base station sites per network, and a base station radiated power of 64 dBm/(10 MHz).

1.5 The estimated total number of households whose DTT reception is affected in the absence of any mitigation measures (case a) is shown to be approximately 2.3 million across the UK. This is a marked increase from the figure of 752,000 households which we had presented in June 2011, and can be accounted for by

a) an increase in the assumed number of base stations (from 8,811 to 11,239 per network),

b) an increase in the assumed base station EIRP (from 59 to 64 dBm/(10 MHz), and

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[1] Ofcom, "Second consultation on coexistence of new services in the 800 MHz band with digital terrestrial television," consultation, 23 February 2012 http://stakeholders.ofcom.org.uk/consultations/second-coexistence-consultation/.

[2] Ofcom, "Technical analysis of interference from mobile network base stations in the 800 MHz band to digital terrestrial television," technical report, 10 June 2011, http://stakeholders.ofcom.org.uk/binaries/consultations/dtt/annexes/Technical-Report.pdf.

[3] Ofcom, "Coexistence of new services in the 800 MHz band with digital terrestrial television," consultation, 2 June 2011, http://stakeholders.ofcom.org.uk/binaries/consultations/dtt/summary/dttcondoc.pdf.

[4] 'Affected' implies a degradation in the margin of reliability of the DTT received service below the planned level of "availability for 99% of the time". This can manifest itself as a degradation of picture and/or audio, or complete loss of one or more DTT multiplexes.

c) updated values of protection ratio (based on further measurements).

Table 1. Summary of revised results for our central scenario.

Mitigation case	Standard domestic installations	Communal aerial systems	Domestic installations with amplifiers	Total
	Number of households affected by interference			
(a) - No mitigation	389,677	952,648	945,238	2,287,563
(b) - Consumer based mitigation	17,710	10,041	10,785	38,536
(c) - Mobile network based mitigation	206,459	647,671	559,900	1,414,030
(d) - Consumer based and mobile network based mitigation	1,551	334	1,428	3,313
(e) - Consumer based mitigation and selective mobile network based mitigation	8,515	3,432	5,058	17,005

1.6 The characteristics of recently commissioned high-performance low-cost DTT receiver filter prototypes have been incorporated into our latest modelling. The results indicate that the installation of DTT receiver filters (case b) reduce the estimated total number of affected households to approximately 38,500.

1.7 Furthermore, the application of network based mitigation (a reduction in base station EIRP to 61 dBm/(10 MHz), and additional base station transmitter filtering) reduces the estimated total number of affected households to approximately 3,300 when used in conjunction with DTT receiver filters (case d). When applied in isolation, network based mitigation alone is not an effective mitigation measure, and only reduces the number of affected households to approximately 1.4 million (case c).

1.8 Results presented in the body of the report also indicate that, in the absence of mitigation measures, the impact of interference is only marginally dominated by the emissions of MFCN base stations in the lower 10 MHz frequency block A, as compared to the middle and upper blocks B and C.

1.9 We have also reported on the results of sensitivity analysis with respect to the base station EIRP, and the number of base station sites. The results indicate that, while it is difficult to derive a precise rule, the estimated numbers of affected households broadly increase linearly with base station EIRP in Watts and number of sites. This relationship is least valid in the case of communal aerial systems, where certain saturation (non-linear) effects are observed with regards to the number of affected households.

1.10 The results for the central scenario and the sensitivity analysis have been used to inform policy proposals outlined in our second consultation on DTT co-existence.

1.11 Note that, unless explicitly stated, the technical parameters used in this report for the modelling of the DTT and mobile networks are identical to those used in our technical report[2] of June 2011.

1.12 Finally, note that in order for the calculations contained herein to be repeatable and transparent, we have presented certain values with up to two decimal places. This should not be construed as an indication of the accuracy of the estimates.

Section 2

Introduction

2.1 In June 2011, Ofcom published a consultation[3] on the co-existence of new services in the 800MHz with DTT. This was accompanied by a separate technical report[2] which presented results of our detailed modelling of the estimated number of households which might be affected due to interference from future MFCN base stations in the 800 MHz band. The headline results presented in June 2011 are summarised in Table 2 below.

Table 2. Headline results reported in June 2011.

	Standard domestic installations	Communal aerial systems	Domestic installations with amplifiers	Total
	Number of households served			
	16,299,699	5,213,819	5,655,629	27,169,147
	Number of households affected by interference			
No mitigation	115,212	521,619	115,058	751,889
Filtering at DTT receiver	32,942	4,128	10,260	47,329
Filtering at DTT receiver & BS transmitter	23,167	44	7,405	30,617

2.2 In their responses to the consultation, certain stakeholders raised concerns with aspects of the methodology adopted by Ofcom. This was in particular with regards to the approach of analysing only a limited number of DTT transmitters, and then extrapolating the results throughout the UK.

2.3 Additionally, some stakeholders were concerned that no sensitivity analysis had been performed as part of the modelling, highlighting that it is crucial to understand how the impact of interference and the costs of mitigation might vary if certain parameters values were changed.

2.4 In particular, questions were raised regarding the sensitivity of the results with respect to the EIRP, total number, and locations of MFCN base stations.

2.5 The wide range in the measured performance of DTT receiver equipment and its impact on the results of the modelling was also raised as a point of concern.

2.6 Since the publication of the June consultation, Ofcom has commissioned further measurements of the performance of amplifiers used in DTT receiver installations, and has commissioned research on alternative receiver filter designs offering better mitigation against interference. The results of the amplifier and filter measurements are published in a separate report[5], and are summarised in Annexes 3 and 4 of this report.

2.7 The rest of this document is structured as follows:

- In Section 3 we re-iterate the background to the technical studies performed in CEPT[6] with regards to the introduction of new services in the 800 MHz band.
- In Section 4 we set out the changes to the modelling methodology, through which we avoid the need for extrapolation of result to derive UK-wide estimates.
- In Section 5 we outline the changes to specific MFCN parameter values, including base station EIRP and site numbers.
- In Section 6 we introduce a revised statistical approach for determining appropriate DTT receiver protection ratio values for use in or modelling tool (Punch).
- In Section 7 we outline revisions to additional DTT parameters, include updates to receiver filter characteristics based on measurements of new filter prototypes.
- In Section 8 the full set of modelling scenarios are summarised, including a central scenario and an additional set of scenarios for the purposes of sensitivity analysis.
- In Section 9 the results for the central scenario are presented.
- In Section 10 the full set of sensitivity analysis results are presented.
- In Section 11 we outline our conclusions derived from the results of the revised modelling.

[5] ERA, "TV Distribution Amplifier performance when interfered with by LTE base station and subsequent mitigation filter testing," technical report, February 2012, to be published in due course at http://stakeholders.ofcom.org.uk/consultations/second-coexistence-consultation/
[6] CEPT: European Conference of Postal and Telecommunications Administrations, www.cept.org

Section 3

Background

3.1 The switchover from analogue to digital terrestrial television (DTT), expected to be completed in Europe by the end of 2012, will free up 72 MHz of spectrum at the top of the UHF TV band. This so-called *Digital Dividend* provides a unique opportunity to meet the demand for spectrum by next generation mobile communications services.

3.2 However, the deployment of mobile networks in frequencies adjacent to those used by DTT networks is inevitably accompanied by a high risk of interference.

3.3 In recognition of this, in 2008 the European Commission (EC) issued a mandate[7] to the European Conference of Postal and Telecommunications Administrations (CEPT) to define technical conditions for use of the 790-862 MHz Digital Dividend spectrum by mobile/fixed communication networks (MFCNs).

3.4 The main objective of this work was to ensure the timely development of the technical conditions required to pave the way for non-mandatory, non-exclusive, and coordinated use of the Digital Dividend in Europe.

3.5 In response to Task 1 of the EC mandate, the ECC[8]/SE42 project team defined a set of least restrictive technical conditions (emission limits) for the use of the Digital Dividend spectrum by MFCN base stations and terminal stations. These accounted for both interference from MFCNs to DTT services, and interference among MFCNs.

3.6 In response to Task 2 of the EC mandate, the ECC/PT1 project team identified appropriate band plans for the use of the Digital Dividend spectrum by MFCNs.

3.7 In October 2009 CEPT adopted ECC Decision 09(03)[9] based on the outcome of the above studies. This work culminated in 2010 with Commission Decision 2010/267/EU[10] which includes most (but not all) of the technical conditions specified in ECC Decision 09(03).

3.8 The technical conditions contained in the Commission Decision are legally binding on all member states of the European Union (EU) who wish to free up the 790-862 MHz band for use by MFCNs.

3.9 These conditions were agreed in the knowledge that adherence to them would not completely remove the risk of interference. The Decision recognised that further measures tailored to fit the specific circumstances of Member States could be applied at a national level to mitigate this risk.

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[7] EC second mandate to CEPT on technical considerations regarding harmonisation options for the digital dividend in the European Union, Apr. 2008.
[8] ECC: European Communications Committee, a sub-committee of CEPT, http://www.cept.org/ecc
[9] ECC Decision (09)03 on harmonised conditions for Mobile/Fixed Communications Networks operating in the band 790-862 MHz, Oct. 2009, www.erodocdb.dk.
[10] Commission Decision 2010/267/EU on harmonised technical conditions of use in the 790-862 MHz frequency band for terrestrial systems capable of providing electronic communications services in the European Union, May 2010.
Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32010D0267:EN:NOT.

3.10 Given the above background, the objective of the present technical report is two-fold:

1) To assess the impact of interference to the DTT service subject to adherence by MFCNs to the technical conditions set out in the Commission Decision.

2) To investigate the technical efficacy of a number of technical measures in mitigating the impact of interference.

3.11 In this section, we outline[11] the relevant band-plans and technical conditions (in-block and out-of-block emission limits) which were specified by the CEPT. For completeness, we include the emission limits for both MFCN base stations and terminal stations. These are used as a basis for the modelling reported in this document.

European harmonised band plans for the 790-862 MHz band

3.12 Figure 1 shows the European preferred harmonized frequency arrangement for MFCNs as specified by ECC/PT1. This consists of a frequency-division duplex (FDD) channelling arrangement of 2×30 MHz, based on a block size of 5 MHz, a duplex gap of 11 MHz, and a duplex spacing of 41 MHz. The FDD downlink starts at 791 MHz and the FDD uplink starts at 832 MHz (reverse duplex). This implies a 1 MHz guard band between MFCN and DTT services.

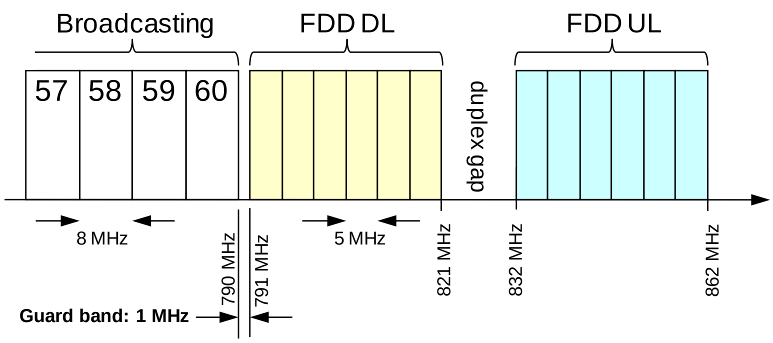


Figure 1. The European preferred (FDD) frequency arrangement.

3.13 ECC/PT1 also considered the possibility of alternative band plans for use by national administrations which do not wish to use the above preferred harmonized frequency arrangement. These alternatives include a) partial implementations of the preferred (FDD) frequency arrangement, b) frequency arrangements for time-division duplex (TDD) operation in all or part of the 790-862 MHz band, and c) frequency arrangements for mixed introduction of TDD and FDD. Specifically, the frequency arrangements for TDD operation consist of a minimum guard band of 7 MHz (from 790 to 797 MHz) for the protection of broadcasting from the MFCN uplink. This is illustrated in Figure 2.

[11] For a concise description of the underlying assumptions made in the derivation of the CEPT band-plans and technical conditions see: H.R.Karimi, M.Fenton, G.Lapierre, E.Fournier, “European harmonized technical conditions and band-plans for broadband wireless access in the 790-862 MHz Digital Dividend spectrum,” in *Proc. Dynamic Spectrum Access Networks* (IEEE-DySPAN), Apr. 2010, Singapore.

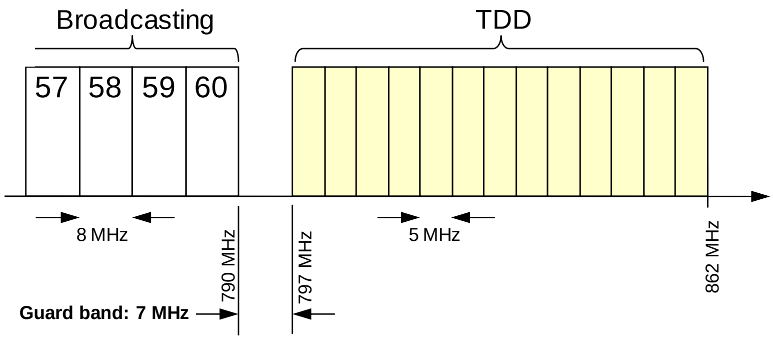


Figure 2. Frequency arrangement for TDD.

3.14 For the specific purposes of this report (and without prejudice to the eventual outcome of the UK auction) only, we consider the FDD frequency arrangement with three MFCN licensees over 791-862 MHz, each with a 10 MHz channel bandwidth. As shown in Figure 3, the 10 MHz blocks will be referred to as “A”, “B”, and “C”, respectively.

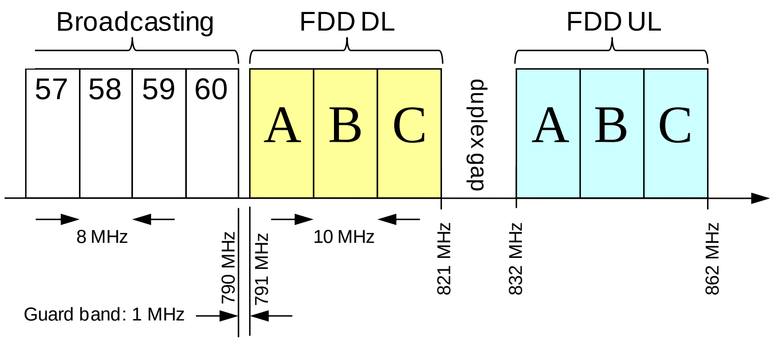


Figure 3. Frequency arrangement used in this study.

European harmonised emission limits for MFCN base stations

In-block limit

3.15 In-block power refers to the power radiated by a transmitter over its channel bandwidth. This power corresponds to that portion of the signal which is intended for reception by a specific receiver.

3.16 ECC/SE42 concluded that there is no need to specify a harmonized regulatory in-block EIRP limit for MFCN base stations. If required, such a limit may be specified by administrations in accordance with national circumstances, and is likely to range from 56 to 64 dBm/(5 MHz).

Out-of-block limits (for protection of broadcasting services)

3.17 Out-of-block power refers to the power radiated by a transmitter outside its channel bandwidth. This power corresponds to a portion of the signal that is not intended for reception by any receivers.

3.18 Table 3 presents the out-of-block *baseline* requirements for MFCN base stations over the spectrum allocated to broadcasting (DTT) services. The relationship between in-block and out-of-block EIRPs is also illustrated in Figure 4.

Table 3. Baseline requirements for base station out-of-block EIRP limits over frequencies occupied by broadcasting.

	Frequency range of out-of-block emissions	Condition on base station in-block EIRP, P dBm/(10 MHz)	Maximum mean out-of-block EIRP dBm/(8 MHz)
A	For DTT frequencies where broadcasting is protected	P ≥ 59	0
		36 ≤ P < 59	(P–59)
		P < 36	–23
B	For DTT frequencies where broadcasting is subject to an intermediate level of protection	P ≥ 59	10
		36 ≤ P < 59	(P–49)
		P < 36	–13
C	For DTT frequencies where broadcasting is not protected	No conditions	22

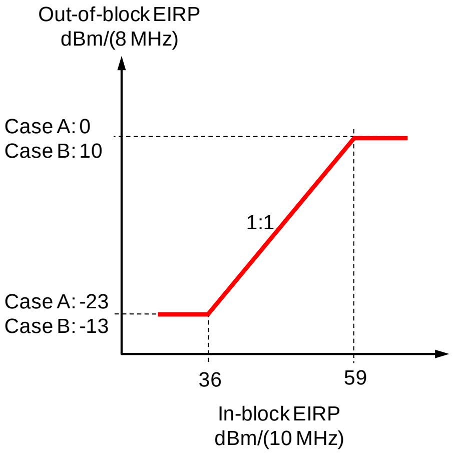


Figure 4. Relationship between base station in-block and out-of-block EIRP limits.

3.19 The three different cases A, B, and C described in Table 3 above can be applied on a per-channel and/or per-region basis. In other words, for the same DTT channel different cases can be applied in different geographic areas (e.g., based on DTT coverage), and different cases can be applied to different channels in the same geographic area.

3.20 Other baseline requirements can be applied in specific circumstances subject to agreements between the broadcasting authority, MFCN operators and the administration if required.

3.21 Given the objectives of this report, we assume that MFCN base stations comply with the out-of-block limits of case A over DTT channel 60. In practice, emission levels reduce with increasing frequency offset from the carrier. As a result, we assume that the base station out-of-block emissions over channels 59 and below are accordingly lower than those specified in Table 3.

European harmonised emission limits for MFCN terminal stations

3.22 The emission limits were specified by ECC/SE42 in terms of EIRP for those terminal stations designed to be fixed or installed, and as total radiated power[12] (TRP) for those terminal stations designed to be mobile or nomadic.

In-block limit

3.23 ECC/SE42 set the maximum value of the in-block emission level for FDD or TDD terminal stations to 23 dBm.

3.24 Administrations may relax this limit in certain situations, for example in the case of fixed terminal stations in rural areas, providing that protection of other services, networks and applications is not compromised and cross-border obligations are fulfilled.

Out-of-band limit (for protection of broadcasting services)

3.25 Table 4 presents the out-of-block baseline requirements for MFCN terminal stations over the spectrum allocated to DTT services.

Table 4. Baseline requirements for terminal station out-of-band emission limits over frequencies occupied by broadcasting.

Frequency range of out-of-band emissions	Maximum mean out-of-band power
Frequencies allocated to broadcasting	–65 dBm/(8 MHz)

[12] TRP is a measure of how much power the antenna actually radiates. The TRP is defined as the integral of the power transmitted in different directions over the entire radiation sphere. For an isotropic antenna radiation pattern, EIRP and TRP are equivalent. For a directional antenna radiation pattern, EIRP in the direction of the main beam is (by definition) greater than the TRP.

Section 4

Methodology

Introduction

4.1 The results of our previous modelling of the estimated number of UK households whose DTT reception might be affected due to interference from MFCN base stations were based on an elaborate methodology[13] which

a) analysed the impact of interference for a number of judiciously selected DTT transmitters, and extrapolated the results across the UK; and

b) quantified the impact on the reception of a *most susceptible* DTT channel uniquely defined for each DTT transmitter.

4.2 The above methodology was adopted in order to manage the significant computational burden of the computer simulations. In this section we describe our proposed changes to the methodology for purposes of further modelling.

UK-wide analysis

4.3 Due to certain constraints in software and hardware, and in order to manage the substantial computational complexity of the modelling, we did not perform a "brute-force" UK-wide analysis in our previous modelling.

4.4 Instead, the number of affected households were analysed in the coverage areas of a selected number of DTT transmitters (15 main and 15 relay) serving the most populated coverage areas in key DTT channels. Subsequently, based on the distribution of UK households across all DTT channels, an elaborate extrapolation process was performed to estimate the total number of households affected in the UK.

4.5 It is difficult to assess the potential inaccuracies introduced by the above extrapolation process, as it could either overestimate or underestimate the impact of interference.

4.6 We now have access to a new version of our modelling software (Punch), and given additionally procured hardware, we are in a position to undertake a "brute-force" UK-wide analysis, without the need to rely on an extrapolation process. We therefore propose to analyse all DTT transmitters in the UK for purposes of further modelling.

Most-susceptible DTT channels per pixel

4.7 As noted above, our previous modelling was based on a selected number of main and relays DTT transmitters. These transmitters were judiciously chosen according to the DTT channels which they serve and the household populations within their serviced coverage areas.

4.8 LTE to DVB-T protection ratios were then used to rank the DTT channels in order of susceptibility to interference (for a specific DTT signal quality). The number of

[13] See Section 8 of the technical report, published 10 June 2011.

affected households was then calculated within the coverage area of each DTT transmitter based on the impact on the reception of the *most-susceptible* DTT channel, with the latter uniquely defined for each of the analysed DTT transmitters.

4.9 In practice, however, the most susceptible DTT channel may actually vary from pixel to pixel within the coverage area of a DTT transmitter. This is due to the varying levels of co-channel and adjacent channel self-interference from other DTT transmitters.

4.10 In our previous modelling, the use of a unique most-susceptible DTT channel per DTT transmitter was necessary in conjunction with the extrapolation methodology we outlined in the previous sub-section.

4.11 For further modelling, we propose to identify the most-susceptible DTT channel for each pixel. In other words, we propose to analyse the impact of MFCN interference on all 3 or 6 DTT channels in use within each pixel according to the relevant preferred DTT server. We can then estimate the number of affected households based on the reception of the most susceptible of the 3 or 6 DTT channels within each pixel.

4.12 Such an approach will provide a more accurate representation of the impact of interference on DTT reception.

Method for counting affected households

4.13 The estimated numbers of affected households published in the June 2011 consultation and technical report were calculated at the level of individual 100 m by 100 m pixels using the "proportional" counting method as opposed to the "cut-off" counting method used in DTT network planning[14].

4.14 To summarise, the proportional method assumes that the reduction in the number of households served within a pixel is proportional to the reduction in the location probability within the said pixel as a result of interference from MFCN base stations. In the cut-off method, all households in a pixel are considered unaffected/affected (i.e., served/not served) if the location probability is above/below 70%.

4.15 We believe that proportional counting is the correct approach for assessing the impact of interference. However, it would be useful to understand how the estimated number of affected households given by the proportional approach differs from those given by the cut-off approach. This would also help to understand the impact on the headline level of national DTT coverage (98.5% of all households) as calculated using the cut-off approach.

4.16 For purposes of comparison, we provide results using both counting methods in our further modelling for certain scenarios.

Preferred service area

4.17 In our previous modelling, we used the analogue preferred service area (APSA) criterion. The APSA identifies the DTT transmitter which households in each pixel receive their analogue service from. We believe that this most accurately represents the current orientation of TV aerials across the UK, and is therefore also appropriate for the purposes of our further modelling.

[14] See Section 4.46 of the technical report, published 10 June 2011.

4.18 For the purposes of comparison, we also examine the impact on the 3PSB and 456COM layers[15] of the digital preferred service area (DPSA) for a single scenario. The 3PSB layer of the DPSA is used to identify the transmitter which offers the best PSB service. The 456COM layer is used to identify the transmitter offering the best 3PSB service and service from one or more commercial multiplexes.

Summary

4.19 The proposed changes to the methodology are summarised as follows:

i) Analysis of the DTT network across the entire UK, as opposed to analysis of a sub-set of DTT transmitters.

ii) Analysis of the most susceptible DTT channel per pixel, as opposed to assuming that there exists a single most susceptible channel per DTT transmitter.

4.20 Other aspects of the methodology are as set out in the technical report of June 2011.

4.21 For the purposes of sensitivity analysis the following effects will also be examined:

i) A comparison of the proportional and "cut-off" methods for counting affected households.

ii) A comparison of results using different assumptions for the preferred DTT transmitter in each pixel. The APSA will be compared with the 3PSB and 456COM layers of the DPSA.

[15] Results for these two layers will be combined at a pixel level with the worst affected multiplex from either layer being considered.

Section 5

MFCN network parameters

Introduction

5.1 In this section we present a number of changes to our assumptions with regards to the MFCN deployments. We discuss the following parameters:

a) MFCN base station EIRP.

b) Numbers and locations of MFCN base stations.

c) MFCN base station out-of-block emissions and transmitter filtering.

d) Radio propagation from MFCN base stations to DTT receivers.

MFCN base station EIRP

5.2 The results of our previous modelling were based on an EIRP of 59 dBm/(10 MHz) for each MFCN base station[16]. This value was derived based on the characteristics of typical commercially available RF equipment; namely a power amplifier with an output rating of 43 dBm, a 3 dB cable loss, and an antenna gain of 15.5 dBi, resulting in a per-antenna EIRP of 55.5 dBm (or 58.5 dBm for dual-antenna transmission). The value of 59 dBm/(10 MHz) was also used as a reference value in the deliberations of ECC/SE42.

5.3 The technical licence conditions proposed by Ofcom for the 800 MHz band specify a maximum in-block EIRP of 61 dBm/(5 MHz), equating to 64 dBm in a 10 MHz channel.

5.4 Evidence[17] from 3G network deployments suggest that large proportions of MFCN base stations radiate at close to the maximum permitted (licensed) EIRP. We therefore propose to use an EIRP of 64 dBm/(10 MHz) at all MFCN base station sites as a worst-case assumption in order to identify the upper-bound on the impact of interference.

5.5 Feedback from stakeholders has indicated that, in typical deployments, the MFCN base station EIRP is usually backed-off from the licensed limit by 3 dB. For this reason, subject to a licensed limit of 64 dBm/(10 MHz), an EIRP of 61 dBm/(10 MHz) would be a more appropriate typical value in the context of modelling (as opposed to 59 dBm).

5.6 We had originally intended to continue using an EIRP of 59 dBm/(10 MHz) as a benchmark for our further modelling, particularly since this would allow comparison with the results of our previous modelling of June 2011. However, given the above feedback, and the fact that our simulation methodology has altered in any case (see Section 4), we will use 64 instead of 59 dBm/(10 MHz).

[16] Note that, in all our analysis, a base station EIRP of *P* dBm refers to the total power radiated per sector. For transmissions using N antennas per sector, the EIRP per antenna per sector is then $P - 10\log_{10}(N)$ dBm.
[17] See Section 5.13 of the technical report, published 10 June 2011.

5.7 In order to understand changes with respect to previous results we will additionally simulate a single scenario using an EIRP of 59 dBm/(10 MHz).

5.8 To summarise, we will proceed to use values of 61 and 64 dBm/(10 MHz) to explore the sensitivities of the results with respect to the MFCN base station EIRP.

Number and locations of MFCN base stations

5.9 In our previous modelling we assumed three LTE-800 networks, one in each of blocks A, B, and C. We assumed full site-sharing among the three networks, with each network comprising of 8,811 sites (or 3 × 8,811 BSs) across the UK. The site locations and antenna heights were based on an existing GSM-900 network.

5.10 While we believe it is reasonable to assume that LTE-800 networks would use a similar number of sites to GSM-900 networks, it is possible that an operator might deploy more LTE-800 sites. We therefore propose to also consider larger networks in our further modelling, as indicated in Table 5 below.

Table 5. MFCN network sizes.

Network	Number of sites	Description
1	8,811	Existing GSM-900 deployment
2	11,239	Potential LTE-800 deployment
3	13,000	Hypothetical deployment

5.11 The number of sites refers to the number of base stations in each of MFCN blocks A, B, and C. The total number of sites modelled in the 800 MHz band is then 3 × 8,811, 3 × 11,239 and 3 × 13,000 for network sizes 1, 2, and 3, respectively.

5.12 Network 1 is the network used in our previous modelling, and is based on the number of macro[18] base station sites in an existing GSM-900 deployment. Network 2 is based on a potential LTE-800 deployment at existing base station sites.

5.13 Network 3 is a hypothetical high density deployment. Results for this network are linearly extrapolated from the results for the other two smaller networks. This hypothetical deployment is considered as we do not have access to any information of a network of this size. It should be noted that the extrapolation of results will be performed at the DTT installation category level, which could result in an overall increase in households which is non-linear, and may therefore show useful results despite being a hypothetical scenario.

5.14 Our past studies have indicated that it is possible for MFCN deployments of the same number of base stations but at different site locations to result in significantly different numbers of affected households; i.e., the results are sensitive to the locations (and not just the numbers) of the sites. For this reason, the use of existing MFCN base station sites in modelling the impact of interference is very important.

5.15 Also, as noted above, we have previously assumed site-sharing among the networks at all sites. Sensitivity analysis[19] with respect to this assumption indicates that a departure from the site-sharing could increase the number of affected standard domestic installations by around 10%.

[18] 'Macro' here assumes GSM sites using a per-carrier EIRP ≥ 45 dBm.
[19] See Section 6.85 of the technical report, published 10 June 2011.

5.16 To better understand the impact of the number of sites and site-sharing on a national basis, we propose to perform a comparison of three additional MFCN deployments, using various combinations of Networks 1 and 2 as shown in Table 6 below.

Table 6. Deployment scenarios for examining sensitivity to site-sharing.

Deployment scenario	Number of sites by MFCN block			Description
	A	B	C	
1	8,811	8,811	8,811	Full site-sharing
2	11,239	11,239	11,239	Full site-sharing
3	8,811	11,239	11,239	Partial site-sharing
4	11,239	8,811	11,239	Partial site-sharing
5	11,239	11,239	8,811	Partial site-sharing

MFCN base station out-of-block emissions and filtering

5.17 Absent further evidence, we propose to use the same assumptions relating to base station out-of-block emissions and filtering as those used in our previous modelling[20] (notwithstanding changes required due to the use of different in-block EIRPs). The assumptions in our previous modelling are repeated here in Table 7 below.

Table 7. Assumed MFCN spectral emission characteristics.

Parameter	Value
Base station emission mask (EIRP of 59 dBm/(8 MHz))	Default: ACLR of 59 dB in channel 60 with an increase in ACLR of 10 dB in each DTT channel below channel 60. Here emissions are specified at absolute frequencies. With additional transmitter filtering: ACLR of 76 dB over frequency offsets of 6 to 14 MHz from the MFCN base station carrier, with an increase in ACLR of 10 dB for each additional 8 MHz of frequency offset from the MFCN base station carrier. Here emissions are specified at frequencies relative to the MFCN carrier.

5.18 For clarity, the values in the above table are depicted in Figure 5 and Figure 6 below.

5.19 Note that the ACLR of 59 dB in channel 60 for the "default" case is based on the value specified in EC Decision 09(03), for an in-block EIRP of 59 dBm/(10 MHz).

5.20 We also note that the out-of block emission limits of the EC Decision are specified to be independent of frequency (i.e., flat in frequency). This is the conventional way in

[20] For details, see Section 6.50 of the technical report, published 10 June 2011.

which regulatory block-edge masks are specified and does not mean that the actual out-of-block emissions from equipment are also independent of frequency.

5.21 In practice, the MFCN base station emission levels naturally reduce with increasing frequency separation from the base station carrier. Evidence[21] suggests that a spectral gradient of around 11 dB per 8 MHz is a reasonable model for this spectral roll-off. In the final stages of the SE42 deliberations, Ofcom proposed[22] that such a roll-off be included in the EC Decision block-edge mask. This proposal was considered to be reasonable by the SE42 team, but was ultimately not adopted due to the tight deadlines.

5.22 We have used a roll-off of 10 dB/(8 MHz) in all our previous modeling (first presented to stakeholders in April 2010). Absent evidence to the contrary, we intend to continue using the said roll-off in our further modeling.

5.23 We will investigate the impact of the spectral roll-off on the protection ratio values. This analysis is presented in Annex 5.

5.24 The ACLR of 76 dB over channel 60 assumed for the "additional filtering" case is based on measurements of the actual emissions of a LTE base station equipment. In fact, the aforementioned LTE base station achieved this ACLR without the need for any additional filtering. For this reason, we believe that the ACLR of 76 dB should be readily achievable through the use of additional filtering.

5.25 Finally, the values in Table 7 used in our previous modelling were specified for an EIRP of 59 dBm/(10 MHz). For increased EIRPs of 61 and 64 dBm/(10 MHz),

- the default ACLR would increase by 2 and 5 dB to 61 and 64 dB, respectively. This is because the EC out-of-block emission limit is specified in *absolute* terms as 0 dBm/(8 MHz).

- the ACLR with transmitter filtering would be maintained at 76 dB. This is because the resulting out-of-block emission levels of -15 and -12 dBm/(8 MHz) would still be below the EC limit of 0 dBm/(8 MHz).

[21] This corresponds to the spectral roll-off of typical base station transmitter filters. See contribution ECC PT1(09)048 by Ofcom,"Guard band and duplex gap for the FDD band-plan of the 790-862 MHz band," April 2009.
[22] See, for example, Ofcom, "UK response to the ECC public consultation of the draft Decision ECC/DEC/(09)EE on harmonised conditions for mobile/fixed communications networks operating in the band 790-862 MHz," September 2009.

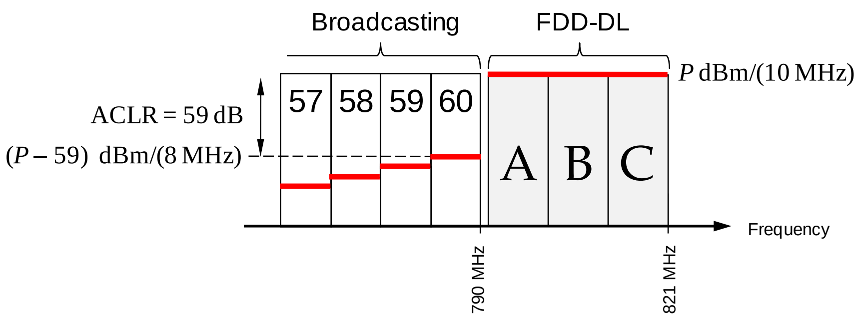


Figure 5. Assumed spectral leakage of the MFCN base stations in the “default” case for an EIRP of 59 dBm/(10 MHz). The emissions comply with the EC Decision block edge mask in channel 60, but with a roll-off of 10 dB/(8 MHz) in lower DTT channels.

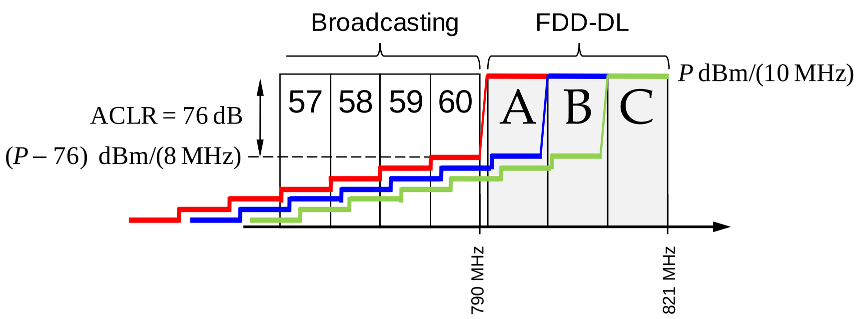


Figure 6. Assumed spectral leakage of the MFCN base stations with “additional filtering”.The emission masks are specified with reference to the carrier frequencies in blocks A, B, and C.

Propagation from MFCN base station to TV aerial

5.26 In our previous modelling we have used the suburban Hata propagation model to determine the median path loss from the MFCN base station to the DTT receiver. The following assumptions were used for the standard deviation of the log-normal shadowing loss based on distance from the MFCN base station:

$\sigma = 1$ dB for separation ≤ 100 m,
$\sigma = 5.5$ dB for separation ≥ 1000 m,

with linear interpolation for intermediate distances.

5.27 The standard deviation of 5.5 dB for large separations is used extensively in broadcast planning to characterise propagation based on roof-top DTT reception. This value, in conjunction with a suburban Hata median path loss appears to be a reasonable model when compared with the results of our field trial measurements (see Figures 49 to 53 in Annex 2 of the technical report, published 10 June 2011).

5.28 For logistic reasons, we were unable to make field measurements of propagation at separations of less than 100 m. However, measurements at separations greater than 100 m suggest that 2-ray propagation is a dominant propagation mechanism. We have shown that if 2-ray propagation is also the dominant mechanism at separations of less than 100 m (and there is no reason to assume otherwise) then a standard deviation of 1 dB is the appropriate value for the purposes of modelling (see Figures 49 to 53 in Annex 2 of the technical report, published 10 June 2011).

Absent evidence to the contrary, we propose to continue to use the above standard deviations in our further modelling.

Summary

5.29 The following changes to the MFCN network parameters will be used in the revised analysis:

i) An increase in base station EIRP from 59 dBm to 64 dBm.

ii) An increase in the number of base station sites from 8,811 to 11,239.

5.30 Assumptions regarding radio propagation and base station out-of-block emissions and transmitter filtering are the same as in the previous modelling.

5.31 We will also perform sensitivity analysis with respect to the number of base station sites, base station EIRP and departure from site sharing.

Section 6

Protection ratios

Introduction

6.1 The impact of interference from LTE emissions on the performance of DTT receiver equipment is quantified through the use of adjacent-channel protection ratios. The protection ratio is equal to the ratio of the received DTT signal power over the received LTE signal power at the point of DTT receiver failure.

6.2 Measurements performed by Ofcom and others have shown that DTT receiver equipment from different manufacturers exhibit a wide range of performance in the presence of adjacent-channel LTE signals. This can correspond to differences in protection ratios of 10 dB or more.

6.3 In our previous modelling (reported in June 2011) we used a unique and cautious set of protection ratios (per receiver installation category) to characterise the performance of all DTT receiver equipment in the UK. These protection ratios were used as an input to Punch, and are a function of the frequency separation between the LTE and DTT signals, as well as the received level of the DTT signal (the latter captures the impact of receiver overload).

6.4 In our further modelling reported in this document, we have developed an approach for selecting more appropriate protection ratios for use with Punch. This is with the aim of better reflecting the full range of performance of DTT receivers available in the UK market.

6.5 In this section, we describe the above approach for the three receiver installation categories. Simulation results for the derivation of appropriate protection ratios are presented in Annex 1. The actual protection ratio values used in Punch are presented in Annexes 2 to 4.

Protection ratios: standard domestic installations

Protection ratios used in previous modelling

6.6 In our previous modelling of June 2011, we adopted a cautious approach[23] in selecting protection ratios for use with Punch. These corresponded to the upper envelope of the protection ratios (poorest immunity) measured by ERA in 2009 for three super-heterodyne receivers and two Silicon tuners. These measurements were all for DVB-T receivers, with *loaded*[24] LTE signals as interferers. An example of the measured protection ratios is illustrated in Figure 7, for DTT reception in channel 60 and a LTE (10 MHz) interferer in block A.

[23] For details, see Annex 3 of the technical report, published 10 June 2011.
[24] The term “loaded” is used to refer to an LTE signal which is continuous in time, and corresponds to the emissions of a heavily loaded LTE base station. The term “idle” is used to refer to an LTE signal which is bursty in time, and corresponds to the emissions of a lightly loaded LTE base station.

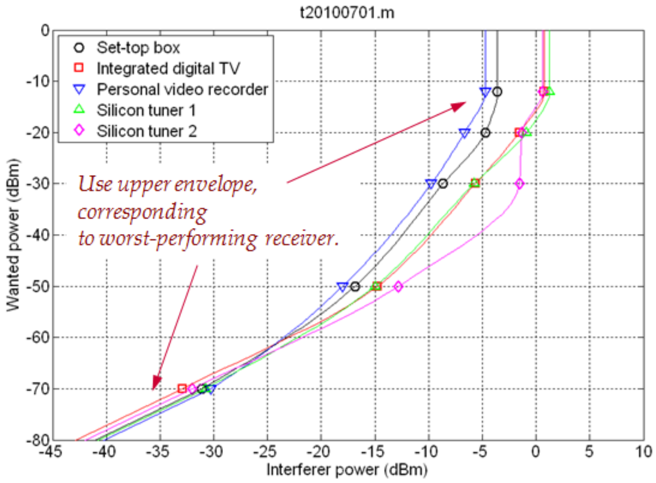


Figure 7. Protection ratios used in our previous modelling for DTT reception in channel 60 and with the LTE signal in block A (ACLR of 59 dB).

6.7 Figure 8 below compares the protection ratios used in our previous modelling (thick black curve) against protection ratios measured by ERA in 2010 for 5 DVB-T and 10 DVB-T2 receivers and for both *loaded* and *idle*[24] LTE interferers[25]. The illustrated examples are again for DTT reception in channel 60 and a LTE (10 MHz) interferer in block A. As can be seen (with the exception of 3 receivers which perform particularly poorly in the presence of idle LTE signals) most of the tested receivers perform better than suggested by the protection ratios used in our previous modelling.

6.8 Also note that adopted protection ratios correspond to a DTT signal power of -43 dBm at a loaded LTE signal power of -15 dBm[26] (idle LTE signal power of -23.3 dBm); i.e., a protection ratio of -28 dB.

6.9 Comparison with measurement results provided[27] by the DTG indicate that only

- ~ 0.5% of the DVB-T receivers in the UK market perform “worse than assumed” (i.e., have protection ratio greater than -28 dB @ -23.3 dBm wanted power);

- ~ 2% of the DVB-T2 receivers the UK market perform “worse than assumed” (i.e., have protection ratio greater than -28 dB @ -23.3 dBm wanted power).

[25] For details, see Annex 6 of the technical report, published 10 June 2011.
[26] This value was used in the DTG measurements.
[27] DTG Testing, “Summary report: LTE interference,” 3rd May 2011.

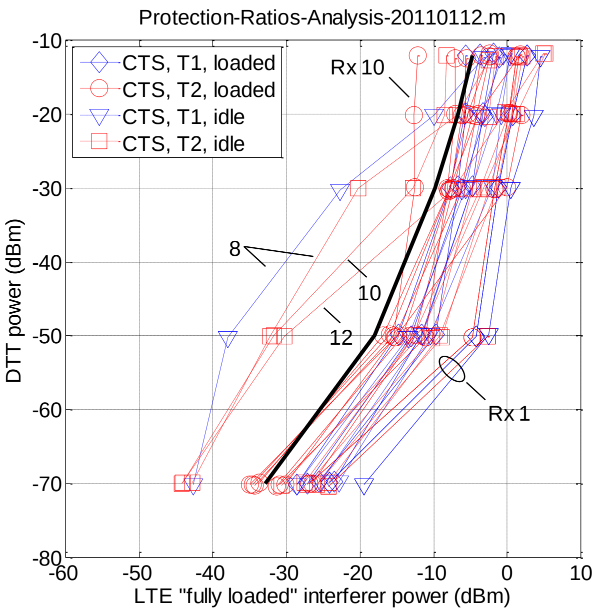


Figure 8. ERA post-processed measurements of DTT receivers for T and T2 mode, and for "loaded" and "idle" LTE signals. DTT reception is in channel 60 with the LTE signals in block A (ACLR of 59 dB). The thick solid black curve represents the protection ratios we have used in our previous modelling (based on measurements conducted in 2009 in T mode and in the presence of "loaded" LTE signals).

Protection ratios used in further modelling

6.10 Clearly, the cautious protection ratios adopted in our earlier study result in an over-estimation of the number of households affected. This is because the use of a single set of cautious protection ratios implies that every DTT receiver in the UK performs as poorly as some of the worst-performing DTT receiver tested.

6.11 It is highly desirable to perform the modelling using a set of protection ratios which more closely capture the range of performance of DTT receivers in the UK market.

6.12 In an ideal world, we would know the actual protection ratio and location of each individual DTT receiver in the UK, and could accordingly model the resulting impact of interference.

6.13 In practice, however, we only know the characteristics of the DTT signals (via the UKPM) to within a resolution of a 100 m × 100 m pixel. For this reason, Punch can only estimate the impact of interference by assuming that all households in a pixel are subject to the same log-normal distribution of wanted and unwanted signal powers.

6.14 Furthermore, we do not know the actual protection ratios of the individual DTT receivers in each pixel. For this reason, Punch was designed to model protection ratios deterministically; i.e., by assuming that every household in the UK is associated with the same protection ratio (for a given a MFCN-DTT frequency separation, and DTT signal power).

6.15 One approach to model protection ratios statistically, is to associate all households within a pixel with a protection ratio that is drawn randomly from a given distribution. We would then aggregate the impacted households in each pixel over the entire UK. We would repeat this UK-wide Monte Carlo experiment a number of times (each time with a different random number generator seed) to derive the statistical distribution of the estimated total number of households affected.

6.16 However, multiple UK-wide Monte Carlo simulations of the type described above are computationally expensive. Furthermore, these would require a significant update of Punch, since, as described earlier, Punch models protection ratios deterministically as a fixed value (for a given MFCN-DTT frequency separation, and DTT signal power).

6.17 So, the question is as follows: What is the fixed deterministic protection ratio (for a given MFCN-DTT frequency separation, and DTT signal power) that we should use in Punch, such that the estimated number, *N*, of households affected is close to the value estimated by multiple UK-wide Monte Carlo simulations?

6.18 To answer the above question, we have estimated the numbers of affected households based on Monte Carlo simulations of protection ratios over the coverage area of the Oxford DTT transmitter. These simulations were performed using MATLAB, since Punch does not have such a capability.

6.19 Before describing the details of our simulation approach, we digress to elaborate on the values of protection ratio used in the simulations.

6.20 The protection ratio values used in this analysis are derived from the distribution of protection ratios of DVB-T receivers in the UK market as reported by the DTG[28]. The corresponding cumulative distribution function is shown in Figure 9 below, adjusted for a LTE ACLR of 64 dB.

[28] These protection ratios were measured for LTE (10 MHz) in block A, in conjunction with DTT in channel 60, at a LTE idle signal power of -23.3 dBm (equivalent to -15 dBm fully loaded), and for an LTE ACLR of 68 dB.

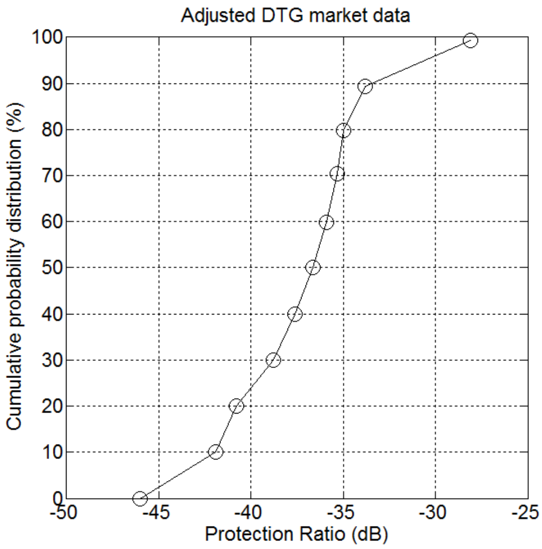


Figure 9. DTG market data on the distribution of DVB-T protection ratios for an idle LTE received signal power of -23.3 dBm (equivalent to -15 dBm fully loaded) and adjusted for an ACLR of 64 dB.

6.21 Based on the distribution shown in Figure 9, we have created a total of 11 *classes* of protection ratio curves, for any given MFCN-DTT frequency separation. An example for DTT in channel 60 and LTE (10 MHz) in block A is given in Figure 10. Here, class-1 corresponds to the lower envelope of the measured DVB-T protection ratios (i.e., corresponding to the 0th percentile in the distribution in Figure 9), and class-11 corresponds to the upper envelope of the DVB-T protection ratios measured by ERA in 2009 and 2010 (corresponding to the 100th percentile in Figure 9).

6.22 The intermediate classes are derived so as to be consistent with the distribution of the protection ratios in Figure 9 as reported by the DTG. Note that these classes are not uniformly spaced.

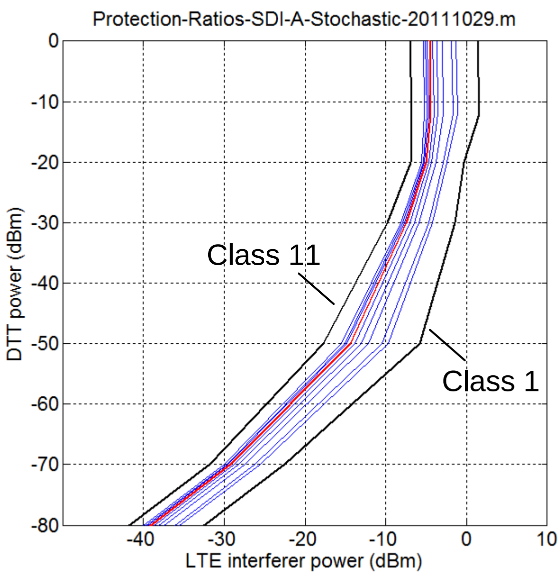


Figure 10. Post-processed LTE to DVB-T protection ratios based on measurements by ERA of DTT receivers. DTT reception is in channel 60 with the LTE signal in block A (ACLR of 64 dB). The thick solid black curves represent the upper and lower envelopes across all measurements. The thin blue lines represent 9 intermediate classes of protection ratio derived from statistics of DVB-T receivers in the UK market. The red curve corresponds to the class-7 values used in the simulations reported in this document.

6.23 Having described the specification of different protection ratio classes, we are in a position to present the details of the simulations.

6.24 In order to derive an appropriate protection ratio class for use in Punch, we have performed the following sets of MATLAB simulations over the coverage area of the Oxford DTT transmitter:

1) Simulations with deterministic protection ratios – here, in each simulation the protection ratio curves belong to a single class. We have performed 11 such simulations, one for each of the 11 classes of protection ratios.

2) Simulations with stochastic protection ratios – Here, the protection ratio in each pixel is drawn randomly (with equal probability) from among the 11 classes. We have performed a handful of such independent simulations. We have found that the total number of affected households varies little from simulation to simulation.

6.25 The above simulations were performed for LTE (10 MHz) in block A and key DTT channels 60, 59, 55, and 51, in order to examine the variations with interferer-victim frequency separation. We also examined various mitigation scenarios, involving the use of filters at the LTE base stations and DTT receivers. The results of these simulations are presented in Annex 1.

6.26 Analysis of the simulation results indicate that the numbers of affected households given by the stochastic simulations are broadly similar to those given by a deterministic simulation with class-6 protection ratios.

6.27 Given the above, and still adopting a cautious approach, we have decided to use class-7 protection ratios for all further Punch modelling of the number of affected standard domestic installations. The values of the class-7 protection ratios are presented in Annex 2.

Protection ratios: amplifiers (domestic & communal)

6.28 Our previous modelling of June 2011 for assessing the impact of interference to communal aerial systems and domestic installations with amplifiers was based on the protection ratios measured for one communal (launch) amplifier and one domestic (mast-head) amplifier. Both sets of measurements were in conjunction with a mid-performing DTT receiver (Silicon tuner).

6.29 Over the second half of 2011, we undertook further measurements of three communal (launch) amplifiers and three domestic (mast-head) amplifiers, and have incorporated these into our further modelling. The results of these measurements are presented in Annexes 3 and 4.

6.30 We have again adopted a statistical approach (as described in 0 for the case of standard domestic installations) for the selection of an appropriate class of protection ratios for use with Punch, and in the context of communal aerial systems and installations with domestic amplifiers.

6.31 In the absence of market data regarding the distribution of different amplifier models in the UK market, we have considered a total of 11 classes of protection ratios, *uniformly* distributed between (and including) the lower and upper envelopes of the measured protection ratio values. Examples of these classes are given in Figure 11 and Figure 12 for LTE (10 MHz) in block A and DTT in channel 60.

6.32 The results of deterministic and stochastic simulations are presented in Annex 1 for LTE (10 MHz) in block A, key DTT channels 60, 59, 55, 51, and various filtering scenarios.

6.33 Analysis of the simulation results indicate that the numbers of affected households given by the stochastic simulations are broadly similar to those given by a deterministic simulation with class-7 protection ratios.

6.34 Given the above, and still adopting a cautious approach, we have decided to use class-8 protection ratios for all further Punch modelling for amplifier installation categories. The values of the class-8 protection ratios are presented in Annexes 3 and 4.

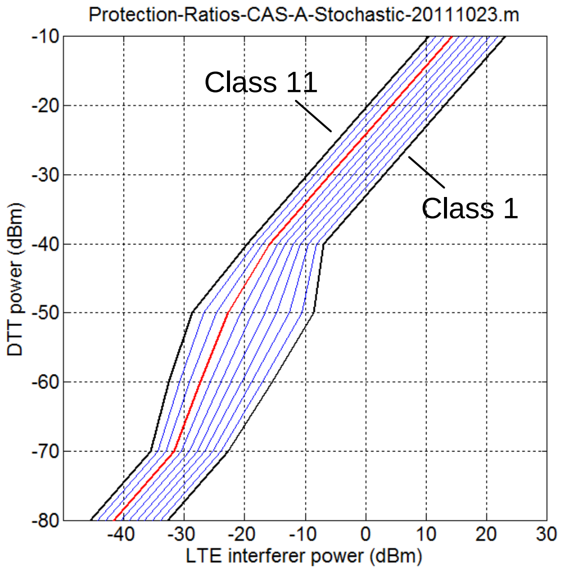


Figure 11. Post-processed LTE to DVB-T protection ratios based on measurements by ERA of DTT receivers in conjunction with communal aerial system amplifiers. DTT reception is in channel 60 with the LTE signal in block A (ACLR of 64 dB). The thick solid black curves represent the upper and lower envelopes across all measurements. The thin blue lines represent 9 intermediate classes of protection ratio derived from statistics of DVB-T receivers in the UK market. The red curve corresponds to the class-8 used in the simulations.

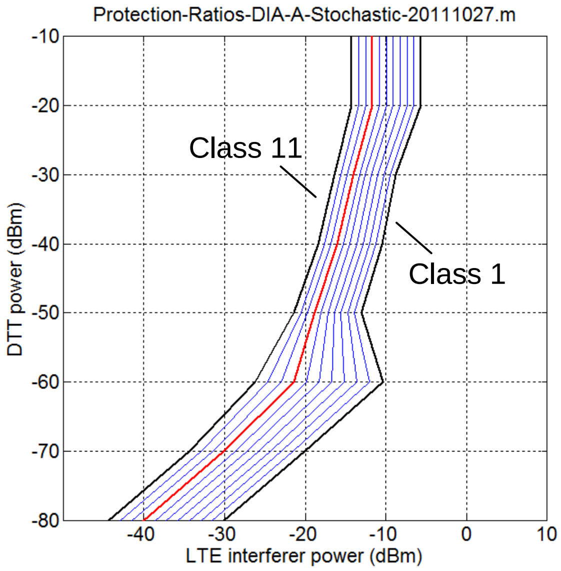


Figure 12. Post-processed LTE to DVB-T protection ratios based on measurements by ERA of DTT receivers in conjunction with domestic amplifiers. DTT reception is in channel 60 with the LTE signal in block A (ACLR of 64 dB). The thick solid black curves represent the upper and lower envelopes across all measurements. The thin blue lines represent 9 intermediate classes of protection ratio derived from statistics of DVB-T receivers in the UK market. The red curve corresponds to the class-8 used in the simulations.

Summary

6.35 The revised analysis will consider a new set of protection ratio values which are based on a stochastic analysis of market data and new measurements of amplifiers.

6.36 We believe that these revised values represent the most accurate view of the range of performance of both DTT receivers and amplifiers in existence in the UK market.

6.37 The changes in protection ratios as compared to the values used in the previous modelling are not uniform across installation categories and frequency offsets – i.e., both increases and decreases are observed. The effects of these variations are examined in the sensitivity analysis.

Section 7

DTT parameters

Introduction

7.1 In this section we present proposed revisions to assumptions relating to certain DTT network parameters and receiver installations. These include UKPM updates, number of domestic installations with amplifiers and DTT receiver filters.

Updates to UKPM data

7.2 Recent updates of the modelling software (Punch) include updates to the UKPM dataset underlying the analysis, according to the v6.14 of the DSO/Clearance plan. These will introduce some minor differences in results when compared with previous analysis, which used v5.9.3.

Number of domestic amplifiers

7.3 Based on market data we have estimated there to be approximately 5 million 'indoor'[29] amplifiers in use in the UK. In our previous modelling it was assumed that 1/3 of these were in use with primary DTT sets. This ratio was based on the relative proportion of the total numbers of primary and secondary DTT sets[30].

7.4 In the July 5th stakeholder workshop, concerns were raised with regards to the validity of the above assumption, based on the argument that the majority of such indoor amplifiers feed primary DTT receivers (e.g., in the form of indoor distribution systems).

7.5 In further modelling, all 5 million indoor amplifiers will be included in the analysis as feeding into primary sets. This results in a total of 9 million served households with domestic amplifiers. See Table 8. We expect that this would increase the number of affected households with domestic amplifiers. This will be offset to some extent by a reduction in the number of served and affected households with standard installations.

Table 8. Total number of served households in the UK for each installation category.

	Standard domestic installations	Communal aerial systems	Domestic installations with amplifiers	Total
Original	16,299,699	5,213,819	5,655,629	27,169,147
Revised	12,969,605	5,609,491	9,000,000	27,579,096

DTT receiver filtering

7.6 Since the publication of our consultation in June 2011, we have identified the possibility of improved DTT receiver filters as a mitigation measure in domestic

[29] 'Indoor' here refers to all types of amplifiers installed either in the loft or at the back of the DTT set. Note that mast-head amplifiers are considered separately.
[30] See Section 7.15 of the technical report published 10 June 2011.

installations. These filters offer significantly better stop-band rejection than the low-pass filters[31] we had assumed in our earlier modelling, with little or no increase in the filter price.

7.7 Figure 13 and Figure 14 illustrate the frequency response of the improved filters for standard domestic installations (and domestically installed amplifiers) and communal aerial systems.

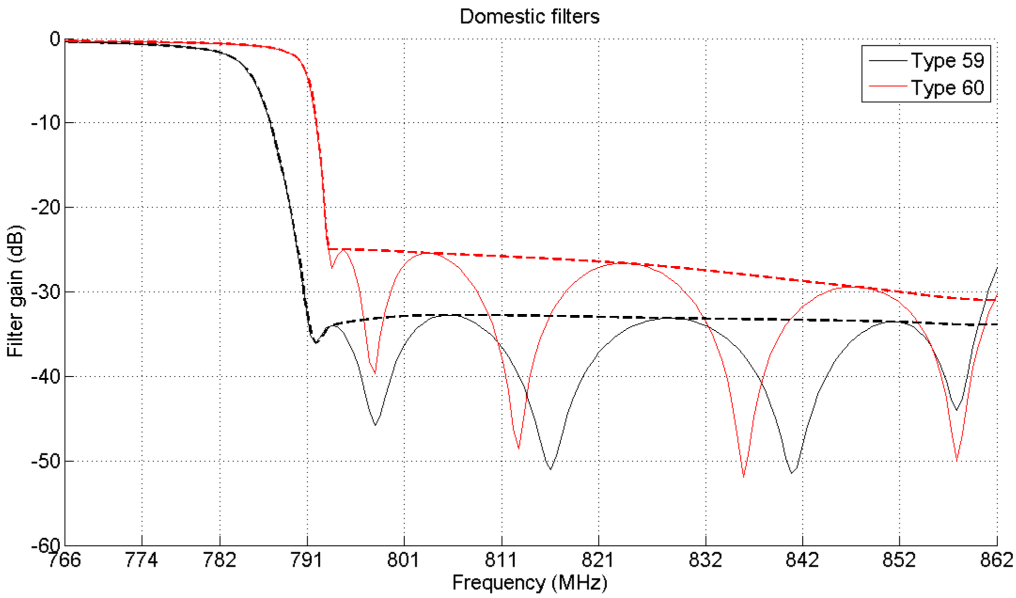


Figure 13. Frequency discrimination gain for type-60 and type-59 filters used for modelling the impact of interference on DTT reception for the cases of standard domestic installations and domestic installations with amplifiers.

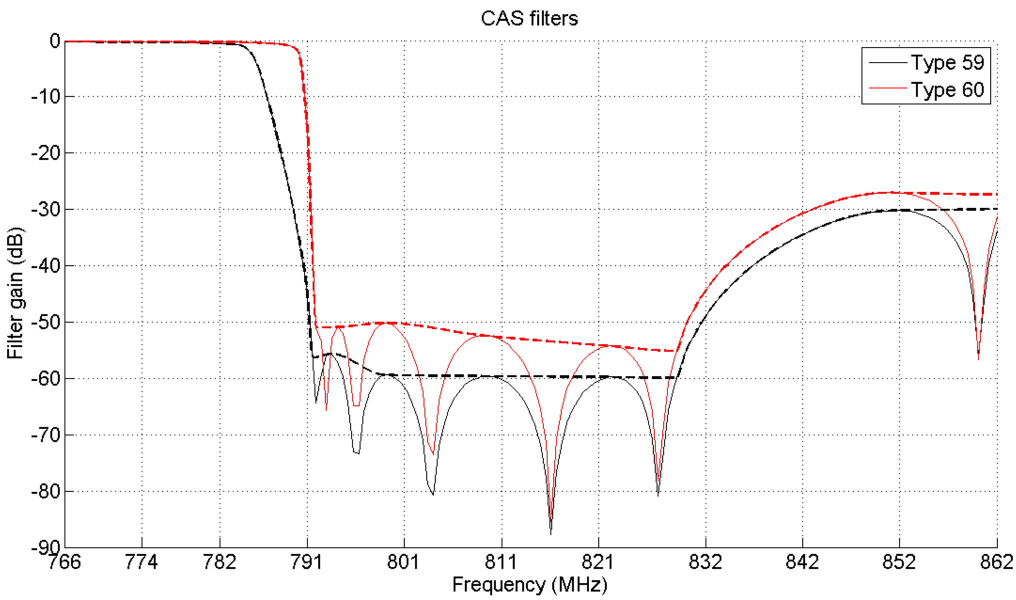


Figure 14. Frequency discrimination gain for type-60 and type-59 filters used for modelling the impact of interference on DTT reception for the case of communal aerial systems.

[31] See Section 6.27 and A3.15 of the technical report published 10 June 2011.

7.8 Table 9 and Table 10 below illustrate examples of the band-reject filter frequency response over MFCN blocks A, B, and C, for the protection of DTT channels 60 and 59.

Table 9. Frequency discrimination gains used for modelling the impact of interference on DTT reception for the cases of standard domestic installations and domestic installations with amplifiers.

		Frequency discrimination gain in MFCN block (dB)			Frequency discrimination gain in DTT channel (dB)		
Filter type	Nominal cut-off (MHz)	A	B	C	DTT channel 60	DTT channel 59	Approximate size (mm)
60	790	-14.3	-24.5	-25.0	-1.1	-0.5	13 × 62 × 25
59	782	-32.6	-31.7	-31.8	-5.4	-1.1	9 × 42 × 25

Table 10. Frequency discrimination gains used for modelling the impact of interference on DTT reception for the case of communal aerial systems.

		Frequency discrimination gain in MFCN block (dB)			Frequency discrimination gain in DTT channel (dB)		
Filter type	Nominal cut-off (MHz)	A	B	C	DTT channel 60	DTT channel 59	Approximate size (mm)
60	790	-32.2	-51.0	-52.9	-0.5	-0.2	250 × 120 × 70
59	782	-55.4	-59.2	-59.3	-4.0	-0.4	250 × 120 × 70

7.9 We propose to use the above frequency responses in our further modelling of standard installations and domestic installations with amplifiers.

7.10 Note that the above values do not represent measured responses, but are design values expected to be readily achievable. We have commissioned the manufacture of a number of filter prototypes. Measurements of these prototypes confirm that the predicted rejection capabilities are broadly feasible.

Summary

7.11 Based on feedback from stakeholders we have revised our assumptions on the total number of domestic installations with amplifiers considered in the modelling. This figure has increased from 5.65 million to 9 million.

7.12 The revised analysis will consider new DTT receiver filters as outlined above. These offer better mitigation against interference when compared to the filters used in the previous modelling.

Section 8

Summary of simulation scenarios

Introduction

8.1 In the previous sections we described the changes to our modelling methodology and technical parameter values for the purpose of further modelling and sensitivity analysis of the estimated number of households whose DTT service might be affected due to emissions from MFCN base stations in the 800 MHz band.

8.2 We propose to use a “brute-force” approach in our analysis by modelling the impact of interference in the coverage area of every DTT transmitter in the UK, thereby avoiding the use of elaborate extrapolation techniques as used in our previous modelling of June 2011.

8.3 In this section we present a summary of the scenarios which we have modelled. Specifically, we describe a “central” scenario, along with a number of scenarios used for purposes of sensitivity analysis. The corresponding estimates of the number of affected households for the central and sensitivity scenarios are presented in Sections 9 and 10, respectively.

8.4 All scenarios account for the following three DTT installation categories:

a. Standard domestic installations (SDI).
b. Communal aerial systems (CAS).
c. Domestic installations with amplifiers (DIA).

8.5 The estimated total number of affected households is then calculated as the summation of the numbers of affected households for each of the three installation categories.

Central scenario

8.6 The central scenario involves a UK-wide MFCN deployed in each of the 10 MHz blocks A, B, and C, where each network consists of 11,239 base stations. Table 11 describes the 5 cases of different mitigation measures we have investigated in the context of the central scenario.

Table 11. Description of mitigation cases in the central scenario.

Mitigation case	Description	EIRP dBm/(10 MHz)	Filtering
(a)	No mitigation	64	None
(b)	Consumer based mitigation	64	DTT Rx
(c)	Mobile network based mitigation	61	Base station Tx
(d)	Consumer based and mobile network based mitigation	61	DTT Rx and base station Tx
(e)	Consumer based mitigation and selective mobile network based mitigation	61/64	DTT Rx and selective base station Tx

8.7 Case (a) refers to the situation where no mitigation measures are applied. Case (b) refers to the situation where a DTT receiver filter is installed (prior to the amplifier, where appropriate) at every household. In case (c), transmit filters are installed at every MFCN base station, and the base station EIRP is reduced from 64 to 61 dBm/(10 MHz). In case (d), the mitigation measures in cases (b) and (c) are applied simultaneously.

8.8 Case (e) is a special case where base station mitigation (i.e., EIRP reduction of 3 dB in conjunction with transmit filtering) is applied to a selected subset of 150 base station sites which have been identified as causing the most *costly* interference under case (a). The full cost analysis for selecting these base station sites is explained in detail in Section 6 of the main consultation document.

8.9 In Section 9 we present the estimated numbers of affected households in the central scenario for cases (a) to (e).

Scenarios for sensitivity analysis

8.10 Table 12 below sets out 6 proposed scenarios for sensitivity analysis in relation to the number of base station sites per LTE network, and LTE base station EIRP. These parameters are two of the key factors which influence the estimated number of affected households, and are used on our modelling for purposes of sensitivity analysis.

Table 12. Sensitivity analysis scenarios.

Scenario number	Number of base station sites per LTE network*	BS EIRP dBm/(10 MHz)
1.1	8,811	61
1.2		64
2.1	11,239	61
2.2		64
3.1	13,000**	61
3.2		64

* Three LTE networks are modelled, one in each of the 10 MHz blocks A, B, and C, respectively.

** Results here are linearly extrapolated from the results for the smaller networks.

8.11 In the context of filtering at the DTT receiver and at the MFCN base station, the following four configurations will be considered in each of the above 6 scenarios:

i. No filtering.
ii. DTT receiver filtering only.
iii. MFCN base station filtering only.
iv. DTT T receiver filtering and MFCN base station filtering.

8.12 Table 13 shows the way in which cases (a) to (d) of the central scenario relate to the scenarios used for purposes of sensitivity analysis. Case (e) is not applicable to the sensitivity analysis as it applies to the specific number of sites and EIRP values used in the central scenario.

Table 13. Relationship between mitigation cases in the central scenario and the scenarios used for sensitivity analysis.

Mitigation case from central scenario	Equivalent scenario number in sensitivity analysis	Description
(a)	2.2.i	No mitigation
(b)	2.2.ii	Consumer based mitigation
(c)	2.1.iii	Mobile network based mitigation
(d)	2.i.iv	Consumer based and mobile network based mitigation

8.13 The estimated numbers of affected households for the various sensitivity scenarios are presented in Section 10. An additional set of single scenarios will be considered which take into account sensitivities to other parameters.

Summary

8.14 In this section we have outlined a central scenario, along with a number of mitigation cases, for the purpose of modelling the impact of interference from MFCN base stations in the 800 MHz band to DTT reception.

8.15 In addition, we have described a number of alternative scenarios for the purposes of sensitivity analysis, and investigating the influence of different parameter values.

8.16 Complete sets of results regarding the number of affected households for both the central scenario and sensitivity analysis scenarios are presented in Sections 9 and 10, respectively.

Section 9

Modelling results: Central scenario

Introduction

9.1 In this section we present the estimated number of affect households for the central scenario described in Section 8, covering the mitigation cases (a) to (e) outlined in Table 11.

9.2 We first present the estimated numbers of affected households due to the impact of interference from the combined emissions of base stations in blocks A, B and C.

9.3 Subsequently, for mitigation cases (a) to (d)[32], we present a breakdown of the number of affected households due to base station emissions from blocks A, B and C in isolation, as well as combined emissions from blocks B and C.

9.4 We then present results which show the impact of interference on the headline DTT coverage figures for both PSB and COM services. In order to be consistent with DTT network planning assumptions, these results are based on the cut-off counting method[33] and assume that all households are associated with standard domestic installations.

9.5 Finally, we present a breakdown of the number of affected households based on DTT channel, and DTT transmitter.

Main results

9.6 Table 14 depicts the estimated total number of households affected in the UK for the central scenario and mitigation cases (a) to (e), with a breakdown across different DTT receiver installation categories.

[32] Case (e) is not applicable here as it relies on contributions from all 3 blocks.
[33] See Section 4.46 of the original technical report published in June 2011.

Table 14. Estimated numbers of affected households for different mitigation combinations and three MFCN networks of 11,239 sites (one network in each of blocks A, B, and C).

Mitigation case	Standard domestic installations	Communal aerial systems	Domestic installations with amplifiers	Total
	Number of households affected by interference			
(a) - No mitigation	389,677	952,648	945,238	2,287,563
(b) - Consumer based mitigation	17,710	10,041	10,785	38,536
(c) - Mobile network based mitigation	206,459	647,671	559,900	1,414,030
(d) - Consumer based and mobile network based mitigation	1,551	334	1,428	3,313
(e) - Consumer based mitigation and selective mobile network based mitigation	8,515	3,432	5,058	17,005

9.7 As can be seen from Table 14, the estimated numbers of affected households in the absence of any mitigation measures are greater than the values we presented in June 2011 (see Table 2 in Section 2). This could be expected, given the increased value of base station EIRP (from 59 to 64 dBm/(10MHz)) and the increased number of MFCN base stations (from 8,811 to 11,239 per network) assumed in our updated analysis.

9.8 It should be noted that the protection ratio values have also been revised in our updated analysis, as outlined in Section 6. The changes in protection ratio values are non-uniform across installation categories and frequency offsets, i.e., both increases and decreases are observed when compared with the previous set of protection ratio values. This is explored in further detail in the sensitivity analysis presented in Section 10.

9.9 Finally, we note that the revised filter characteristics result in a significant reduction in the number of affected households with standard domestic installations, and domestically installed amplifiers. Note that the characteristics of the receiver filter used for communal aerial systems are similar to those used in the June 2011 technical report.

Impact by MFCN block

9.10 The results presented above account for the impact of interference due to combined emissions from all three MFCN blocks.

9.11 The results in the following tables show the impact that would be observed if the interference from each of blocks A, B and C were examined in isolation. The impact of interference from combined emissions from blocks B and C (i.e., with the exclusion of emissions from block A) is also presented, in order to quantify the incremental impact of emissions from blocks A and B.

9.12 Note that the estimated numbers of affected households due to combined emissions from blocks A, B and C are not equal to the sum of the estimated numbers of affected households due to emissions from each of the blocks individually.

Table 15(a). Impact by MFCN block: Standard domestic installations.

Mitigation case	MFCN block				
	ABC	BC	C	B	A
	Number of households affected by interference				
(a)	389,677	267,503	141,424	145,173	170,154
(b)	17,710	11,954	6,766	6,746	8,866
(c)	206,459	136,989	69,862	73,346	88,492
(d)	1,551	81	31	47	1,479

Table 15(b). Impact by MFCN block: Communal aerial systems.

Mitigation case	MFCN block				
	ABC	BC	C	B	A
	Number of households affected by interference				
(a)	952,648	745,906	464,826	470,472	503,403
(b)	10,041	7,326	4,157	4,143	4,346
(c)	647,671	490,381	290,740	296,122	321,706
(d)	334	17	0	17	318

Table 15(c). Impact by MFCN block: Domestic installations with amplifiers.

Mitigation case	MFCN block				
	ABC	BC	C	B	A
	Number of households affected by interference				
(a)	945,238	693,790	373,769	371,906	389,515
(b)	10,785	5,879	3,050	3,039	5,699
(c)	559,900	399,057	204,416	204,548	215,075
(d)	1,428	52	17	22	1,298

Table 15(d). Impact by MFCN block: All DTT receiver installation categories.

Mitigation case	MFCN block				
	ABC	BC	C	B	A
	Number of households affected by interference				
(a)	2,287,563	1,707,199	980,019	987,551	1,063,072
(b)	38,536	25,159	13,973	13,928	18,911
(c)	1,414,030	1,026,427	565,018	574,016	625,273
(d)	3,313	150	48	86	3,095

9.13 The above results indicate that, in the absence of mitigation measures, all MFCN blocks contribute significantly to the number of affected households. As might be expected, in all cases the impact of interference from block A is somewhat higher than that from blocks B or C, due to the lower interferer-victim frequency separations.

9.14 However, it should be noted that the relative impacts of interference from each of blocks A, B, and C are more similar than suggested by our previous analysis, where block A was shown to dominate, particularly in the case of standard domestic installations. This change suggests that the dominant interference mechanism in standard domestic installations is now receiver overload and not SINR degradation[34]. Overload is also expected to be the dominant effect for interference to amplifiers.

9.15 This effect is further evident in the breakdown of results by DTT channel below in Table 17.

9.16 The results in Table 15 for cases (b) to (d) also indicate that DTT receiver filtering and base station transmitter filtering are more effective in mitigating the impact of interference from blocks B and C than from block A. This is expected, and is due to the increased filter rejection that can be achieved as a result of the greater interferer-victim separations.

Impact on headline DTT coverage

9.17 Table 16 shows the impact of interference in the context of national DTT coverage figures. In order to be consistent with the approach and assumptions used in DTT network planning, the following results are derived using the cut-off counting method, and by assuming that all households are associated with standard domestic installations.

[34] Receiver overload is somewhat less dependent on the frequency separation between the victim and interferer. Refer to Section 6 of the original technical report, published 10 June 2011, for details on the difference between these two interference mechanisms.

Table 16. Impact on headline DTT coverage figures, based on current PSB and COM coverage of 98.47% and 90.57%, respectively.

Mitigation case	No. of households losing ≥ 1 PSB mux	No. of households losing ≥ 1 COM mux	Reduction in PSB coverage as % of total population	PSB coverage figure after reduction	Reduction in COM coverage as % of total population	COM coverage figure after reduction
(a)	1,099,230	1,053,401	3.99%	94.48%	3.82%	86.75%
(b)	29,877	31,924	0.11%	98.36%	0.12%	90.45%
(c)	540,721	534,862	1.96%	96.51%	1.94%	88.63%
(d)	2,271	3,377	0.01%	98.46%	0.01%	90.55%
(e)	13,133	12,258	0.05%	98.42%	0.04%	90.52%

9.18 Note that in the absence of mitigation measures (case (a)), the headline PSB coverage reduces by 3.99% (from 98.47%) of total population, while the headline COM coverage reduces by 3.82% (from 90.57%) of total population. The addition of filters at the DTT receivers and MFCN base stations transmitters reduces the degradation in coverage to negligible levels.

Impact by DTT channel

9.19 Table 17 shows the breakdown of impact by the worst affected DTT channel per pixel. It should be noted that in practice more than one channel within a pixel can be affected, but the highest impact is considered here in order to avoid double counting.

Table 17. Breakdown of impact by worst affected DTT channel per pixel.

	Case (a)		Case (b)		Case (c)		Case (d)	
Rank	DTT Channel	Number of affected households	DTT Channel	Number of affected households	DTT Channel	Number of affected households	DTT Channel	Number of affected households
1	22	236,284	60	31,745	22	159,107	60	3,052
2	23	230,545	59	6,180	23	149,021	59	89
3	30	214,657	58	404	30	133,612	58	70
4	59	175,957	21	32	59	105,949	21	23
5	60	175,449	22	19	60	100,400	57	15
6	21	122,796	25	15	21	78,653	56	12
7	41	89,161	23	14	41	54,058	22	7
8	50	85,903	28	12	50	50,277	29	5
9	40	73,644	57	11	25	46,921	30	4
10	29	73,233	40	11	40	45,635	28	4
11	25	73,084	26	10	29	45,553	52	3
12	28	69,668	56	9	28	43,174	47	3
13	26	63,741	47	8	58	39,427	41	3
14	58	61,837	30	7	26	39,328	25	3
15	47	59,738	41	6	39	37,097	55	2
16	39	58,510	29	6	47	34,606	54	2
17	46	51,336	24	6	46	28,318	51	2
18	44	42,525	51	5	44	25,958	40	2
19	27	41,844	39	5	27	24,766	26	2
20	49	40,202	27	5	24	24,022	24	2
21	52	39,562	52	4	49	24,015	23	2
22	24	39,145	48	4	52	22,207	49	1
23	45	35,996	44	3	45	21,471	46	1
24	42	33,972	43	3	42	20,267	44	1
25	43	28,860	42	3	43	17,017	43	1
26	48	19,656	54	2	48	12,142	42	1
27	51	12,718	46	2	51	7,940	39	1
28	54	11,385	45	2	54	6,359	53	0
29	57	7,995	53	1	57	5,509	50	0
30	53	7,626	50	1	53	4,675	48	0
31	55	5,638	49	1	55	3,485	45	0
32	56	4,896	55	0	56	3,061	27	0

9.20 Somewhat surprisingly, the most affected channels in case (a) are much lower in frequency than might be expected. However, these results should be viewed in the context of the breakdown by DTT transmitter outlined in the following section. Specifically, it should be noted that the three worst affected channels (22, 23 and 30) are used by the Crystal Palace transmitter, which serves the highest population in the UK (covering the Greater London area).

9.21 Additionally, the high impacts to lower channels under case (a) support the hypothesis outlined previously that the overload effect is the dominant interference mechanism, as it is largely independent of frequency offset.

9.22 Use of DTT receiver filtering in cases (b) and (d) shows a negligible number of affected households for channels 58 and below. Mitigation is not as effective in channels 59 and 60 when compared with lower channels.

9.23 Comparing cases (a) and (c) shows that the inclusion of base station filtering does not significantly change the rank order of affected channels.

Impact by transmitter

9.24 Table 18 to Table 21 show the breakdown of affected households for the 20 most affected DTT transmitters in order of estimated number of affected households. The total number of served households per transmitter and a list of the channels used are also provided for context.

Table 18. Breakdown of impact by the 20 most affected DTT transmitters in case (a).

Rank	DTT Transmitter	Total number of households served	Number of affected households	DTT channels used					
				PSB1	PSB2	PSB3	COM4	COM5	COM6
1	Crystal Palace	4,527,376	657,300	23	26	30	25	22	28
2	Winter Hill	2,716,124	188,609	50	59	54	58	49	55
3	Sutton Coldfield	1,872,348	117,821	43	46	40	42	45	39
4	Black Hill	941,963	104,790	46	43	40	41	44	47
5	Emley Moor	1,555,462	89,202	47	44	41	51	52	48
6	Sandy Heath	932,194	70,734	27	24	21	51	52	48
7	Belmont	726,877	67,803	22	25	28	30	53	60
8	Waltham	783,931	65,802	49	54	58	29	56	57
9	Craigkelly	434,461	57,811	27	24	21	42	45	39
10	Rowridge	640,974	47,954	24	27	21	25	22	28
11	Pontop Pike	698,309	46,555	58	54	49	50	59	55
12	Sudbury	464,772	40,066	44	41	47	58	60	56
13	Bilsdale	574,766	38,766	26	29	23	43	46	40
14	Mendip	723,325	32,136	49	54	58	48	52	56
15	Hannington	539,513	31,328	45	42	39	41	44	47
16	Oxford	421,341	28,760	53	60	57	50	59	55
17	Divis	440,257	26,380	27	21	24	23	26	29
18	Durris	177,189	22,873	28	25	22	23	26	29
19	Wenvoe	367,514	20,522	41	44	47	42	45	39
20	The Wrekin	283,544	18,595	26	23	30	41	44	47

Table 19. Breakdown of impact by the 20 most affected DTT transmitters in case (b).

Rank	DTT Transmitter	Total number of households served	Number of affected households	DTT channels used					
				PSB1	PSB2	PSB3	COM4	COM5	COM6
1	Belmont	726,877	9,027	22	25	28	30	53	60
2	Sudbury	464,772	6,780	44	41	47	58	60	56
3	Oxford	421,341	4,842	53	60	57	50	59	55
4	Winter Hill	2,716,124	3,420	50	59	54	58	49	55
5	Angus	133,653	1,606	60	53	57	54	58	49
6	Beacon Hill	89,866	1,343	60	53	57	42	45	51
7	Malvern	59,120	1,195	53	57	60	50	59	55
8	Thornhill	18,037	977	57	60	53	-	-	-
9	Pontop Pike	698,309	817	58	54	49	50	59	55
10	Alton	5,617	690	57	60	53	-	-	-
11	Whitehawk Hill	106,357	510	60	53	51	57	56	48
12	Reigate	69,958	477	60	57	53	21	24	27
13	Brierley Hill	84,226	455	60	57	53	50	59	55
14	Cannongate VP	2,576	388	55	50	59	-	-	-
15	Knockmore	32,729	387	26	23	29	53	57	60
16	Llanddona	59,167	262	57	60	53	43	46	40
17	Stranraer	6,577	262	57	60	53	-	-	-
18	Hasland	3,815	253	57	60	53	-	-	-
19	Rosneath VP	40,755	252	49	58	54	53	57	60
20	Poole	32,671	242	57	60	53	-	-	-

Table 20. Breakdown of impact by the 20 most affected DTT transmitters in case (c).

Rank	DTT Transmitter	Total number of households served	Number of affected households	DTT channels used					
				PSB1	PSB2	PSB3	COM4	COM5	COM6
1	Crystal Palace	4,527,376	427,244	23	26	30	25	22	28
2	Winter Hill	2,716,124	113,023	50	59	54	58	49	55
3	Sutton Coldfield	1,872,348	68,972	43	46	40	42	45	39
4	Black Hill	941,963	64,883	46	43	40	41	44	47
5	Emley Moor	1,555,462	52,183	47	44	41	51	52	48
6	Sandy Heath	932,194	42,737	27	24	21	51	52	48
7	Waltham	783,931	40,893	49	54	58	29	56	57
8	Belmont	726,877	39,676	22	25	28	30	53	60
9	Craigkelly	434,461	37,121	27	24	21	42	45	39
10	Rowridge	640,974	29,083	24	27	21	25	22	28
11	Pontop Pike	698,309	27,577	58	54	49	50	59	55
12	Sudbury	464,772	23,694	44	41	47	58	60	56
13	Bilsdale	574,766	22,771	26	29	23	43	46	40
14	Mendip	723,325	19,740	49	54	58	48	52	56
15	Hannington	539,513	19,145	45	42	39	41	44	47
16	Oxford	421,341	17,072	53	60	57	50	59	55
17	Divis	440,257	15,694	27	21	24	23	26	29
18	Durris	177,189	14,889	28	25	22	23	26	29
19	Wenvoe	367,514	12,071	41	44	47	42	45	39
20	The Wrekin	283,544	11,569	26	23	30	41	44	47

Table 21. Breakdown of impact by the 20 most affected DTT transmitters in case (d).

Rank	DTT Transmitter	Total number of households served	Number of affected households	DTT channels used					
				PSB1	PSB2	PSB3	COM4	COM5	COM6
1	Belmont	726,877	870	22	25	28	30	53	60
2	Sudbury	464,772	724	44	41	47	58	60	56
3	Oxford	421,341	483	53	60	57	50	59	55
4	Malvern	59,120	135	53	57	60	50	59	55
5	Angus	133,653	120	60	53	57	54	58	49
6	Beacon Hill	89,866	101	60	53	57	42	45	51
7	Alton	5,617	92	57	60	53	-	-	-
8	Thornhill	18,037	84	57	60	53	-	-	-
9	Reigate	69,958	71	60	57	53	21	24	27
10	Brierley Hill	84,226	63	60	57	53	50	59	55
11	Knockmore	32,729	48	26	23	29	53	57	60
12	Whitehawk Hill	106,357	45	60	53	51	57	56	48
13	Poole	32,671	36	57	60	53	-	-	-
14	Blaenau Gwent	1,742	29	60	57	53	-	-	-
15	Winter Hill	2,716,124	27	50	59	54	58	49	55
16	Hasland	3,815	25	57	60	53	-	-	-
17	Cannongate VP	2,576	22	55	50	59	-	-	-
18	Stranraer	6,577	22	57	60	53	-	-	-
19	Selkirk	24,543	21	50	59	55	57	53	60
20	Carmel	72,101	19	60	53	57	54	58	49

9.25 In Table 18 it can seen that for case (a) the most affected DTT transmitters are those which also serve the largest population. The 3 transmitters with the highest impacts are also the 3 transmitters which serve the highest number of households in the UK. The remaining transmitters in the list also broadly follow this trend, with a few exceptions.

The channels used by the most affected transmitters can be compared with the impacts by impacts by channel presented in Table 17.

9.26 Table 19 shows that for case (b) (DTT receiver filtering) the most affected DTT transmitters are the larger channel 59 and 60 transmitters, which is as expected given the breakdown of results by channel outlined in Table 17.

9.27 In Table 20 for case (c) the order is broadly similar to that for case (a) presented in Table 18.

9.28 Similarly, the order for case (d) (as shown in Table 21) is similar to that for case (b). This could be expected when viewed in the context of the breakdown of impacts by channel as presented in Table 17, where it was shown that base station filtering does not significantly change the order of affected channels.

Conclusions

9.29 In this section we have presented results relating to the impact of interference to DTT reception for a central scenario involving three MFCNs of 11,239 base station sites each, and a base station EIRP of 64 dBm/(10 MHz).

9.30 The estimated total number of households whose DTT reception is affected in the absence of any mitigation measures is shown to be approximately 2.3 million across the UK. This is a marked increase from the figure of 752,000 households which we had presented in June 2011, and can be accounted for by an increase in the assumed number of base stations (from 8,811 to 11,239 per network), an increase in the assumed base station EIRP (from 59 to 64 dBm/(10 MHz), and updated values of protection ratio.

9.31 The installation of DTT receiver filters (prior to any amplifiers, where appropriate) reduces the estimated total number of affected households to approximately 38,500.

9.32 Mobile network based mitigation alone (a reduction in base station EIRP to 59 dBm/(10 MHz), and installation of base station transmitter filtering) reduces the estimated total number of affected households to approximately 1.4 million.

9.33 Combining both DTT receiver filtering and MFCN base station transmitter filtering results in a residual figure of approximately 3,000 affected households across the UK.

9.34 The results also indicate that, in the absence of mitigation measures, the impact of interference is only marginally dominated by the emissions of MFCN base stations in block A as compared to blocks B and C.

9.35 The sensitivity of these results to various parameter values is explored in the following section.

Section 10

Modelling results: Sensitivity analysis

Introduction

10.1 In this section we present the estimated number of affected households for the full range of sensitivity analysis scenarios described in Section 8.

10.2 We first investigate the sensitivity of the results with respect to the EIRP of the MFCN base stations, and the number of base station sites per MFCN network.

10.3 We then explore the influence of site sharing on the number of affected households. We also consider the viability of installing high performance (in the context of adjacent channel interference rejection) DTT receiver equipment as a means of interference mitigation.

10.4 For purposes of comparison only, the estimated numbers of affected households in the central scenario are presented based on the cut-off method of counting and contrasted with the values based on the proportional method of counting.

10.5 We also present a number of results which quantify the impact of our revised modelling methodology in isolation, as compared to the methodology we have used in the technical report of June 2011.

10.6 Finally, we present estimated numbers of affected households based on the 3PSB and 456COM layers of DPSA, and compare these with the results derived based on APSA.

10.7 The impact of the spectral roll-off of MFCN base station emissions on the protection ratios is considered separately in Annex 5.

Main sensitivity analysis: Base station EIRP and site numbers

10.8 Here we explore the sensitivity of the estimated numbers of affected households to the value of the base station EIRP, and the number of base stations sites deployed in each of the three MFCN networks.

10.9 The results are presented in Table 22. As described in Section 8, scenarios 1.x.x and 2.x.x correspond to 8,811 and 11,239 sites per network respectively, and scenarios x.1.x and x.2.x correspond to base station EIRPs of 61 and 64 dBm/(10 MHz) respectively.

Table 22(i). Sensitivity analysis: no mitigation.

Scenario number	Standard domestic installations	Communal aerial systems	Domestic installations with amplifiers	Total
	Number of households affected by interference			
1.1.i	180,720	626,364	463,440	1,270,524
1.2.i	319,157	897,927	771,002	1,988,086
2.1.i	220,143	653,501	566,993	1,440,637
2.2.i	389,677	952,648	945,238	2,287,563
3.1.i	248,736	673,183	642,099	1,564,018
3.2.i	440,824	992,337	1,071,609	2,504,770

Table 22(ii). Sensitivity analysis – DTT receiver filtering.

Scenario number	Standard domestic installations	Communal aerial systems	Domestic installations with amplifiers	Total
	Number of households affected by interference			
1.1.ii	12,655	8,465	6,767	27,887
1.2.ii	13,374	8,541	7,824	29,739
2.1.ii	16,755	9,939	9,329	36,023
2.2.ii	17,710	10,041	10,785	38,536
3.1.ii	19,729	11,008	11,187	41,924
3.2.ii	20,855	11,129	12,933	44,917

Table 22(iii). Sensitivity analysis – Base station transmitter filtering.

Scenario number	Standard domestic installations	Communal aerial systems	Domestic installations with amplifiers	Total
	Number of households affected by interference			
1.1.iii	170,468	621,268	457,601	1,249,337
1.2.iii	310,202	894,229	765,963	1,970,394
2.1.iii	206,459	647,671	559,900	1,414,030
2.2.iii	377,857	948,678	939,290	2,265,825
3.1.iii	232,563	666,821	634,096	1,533,480
3.2.iii	426,926	988,169	1,065,002	2,480,097

Tale 22(iv) Sensitivity analysis: DTT receiver filtering and base station transmitter filtering.

Scenario number	Standard domestic installations	Communal aerial systems	Domestic installations with amplifiers	Total
	Number of households affected by interference			
1.1.iv	1,237	313	1,063	2,613
1.2.iv	2,364	613	2,245	5,222
2.1.iv	1,551	334	1,428	3,313
2.2.iv	3,044	668	3,156	6,868
3.1.iv	1,779	349	1,693	3,821
3.2.iv	3,537	708	3,817	8,062

10.10 One might expect (notwithstanding any saturation effects) that the number of affected households would broadly increase linearly with an increase in the number of MFCN base stations; i.e., with an increase in the number of holes punched in the DTT coverage area[35].

10.11 One might then expect that an increase in the number of MFCN base stations from 8,811 to 11,239 would increase the numbers of affected households by a factor of around ×1.3. A comparison of the results in Table 22 indicates an increase by factors of between ×1.2 and ×1.4 in the case of standard domestic installations and domestic installations with amplifiers. The increase for communal aerial systems is somewhat lower, indicating a saturation effect in the number of affected households.

10.12 Furthermore, previous studies[36] have indicated that (again notwithstanding any saturation effects) the number of affected households with standard domestic installations receiving channel 60 broadly increases linearly with the EIRP of the MFCN base stations when the latter is expressed in units of Watts. This would suggest than an EIRP increase of 3 dB from 61 to 64 dBm would increase the number of affected households by a factor of around ×2. A comparison of the results in Table 22 indicates an increase by factors of between ×1.7 and ×2.2 in the case of standard domestic installations and domestic installations with amplifiers.

10.13 This is with the exception of cases in which DTT receiver filtering is deployed, where the increase is by factors of between ×1.1 and 1.2. The increase for communal aerial systems is somewhat lower at factors of between ×1.4 and ×2. Again, this is with the exception of cases in which DTT receiver filtering is deployed, where very little increase is observed.

10.14 Comparing the results in Table 22(i) and (iii) shows that base station transmitter filtering is somewhat ineffective when used in isolation, and an EIRP reduction offers a more effective method of base station based mitigation. This can be explained by the fact that the results are dominated by receiver overload rather than SINR degradation. As the overload effect is a function of the interferer's in-band EIRP,

[35] The implicit assumption being that the punched holes do not overlap significantly, and so the intensities of the punched holes remain broadly unchanged.
[36] See Section 6 of the technical report, published 10 June 2011.

base station transmitter filtering alone does not offer significant reductions in the number of households affected.

10.15 However, when combined with DTT receiver filtering (see Table 22(iv)) base station transmitter filtering is shown to offer some significant improvement when compared with receiver filtering in isolation (see Table 22(ii)). This is because while DTT receiver filtering can resolve interference due to overload, SINR degradation may still occur due to the out-of-band emissions of the base station, and these are reduced with the use of base station transmitter filtering.

Base station site sharing

10.16 Here, we explore the impact of site sharing among the MFCN networks on the estimated number of affected households.

10.17 To this end, we model a total of five network deployment scenarios, as originally outlined in Table 6 of Section 5, and repeated in Table 23 below. Deployment scenarios 1 and 2 consist of 8,811 and 11,239 sites per network, respectively. In deployment scenarios 3 to 5, two networks consist of 11,239 sites each, whereas the third network consists of only 8,811 sites.

Table 23. Impact of site sharing.

Deployment scenario	Number of sites per MFCN block (1,000s)			Standard domestic installations	Communal aerial systems	Domestic installations with amplifiers	Total
	A	B	C	Number of households affected by interference			
1	9	9	9	319,157	897,927	771,002	1,988,086
2	11	11	11	389,677	952,648	945,238	2,287,563
3	9	11	11	393,870	999,553	972,356	2,365,779
4	11	9	11	397,320	1,002,242	973,697	2,373,259
5	11	11	9	398,471	1,005,103	976,219	2,379,793

10.18 As expected, the estimated numbers of affected households in deployment scenario 2 are greater than those in deployment scenario 1. The results for deployment scenarios 3 to 5 are somewhat less obvious.

10.19 It should be noted that there are a number of different forces in play, namely, a) the number of base station sites (contributes primarily to the number of DTT coverage holes), b) the specific locations of the base station sites (some sites can be in particularly susceptible DTT coverage areas), and c) the impact of a departure from site-sharing (contributes to the size and intensity of the DTT coverage holes).

10.20 In Section 6 of the technical report of June 2011 we showed that a departure from site sharing is likely to result in an approximately 10% increase in the estimated number of affected households.

10.21 Interestingly, the results of Table 23 indicate that the greatest increase of around 4% in the estimated number of affected households is observed when the network with the smaller number of sites is deployed in block C. This 4% increase is the net result of a decrease in the number of affected households due to fewer sites in block C, and a likely increase in the number of affected households due to a departure from site sharing.

10.22 As explained in Section 5, it has not been possible to model a scenario using three independent network topologies based on existing (and hence realistic) site locations. It is reasonable to assume that in practice some degree of site sharing among the mobile network operators will exist. It should be understood that the precise number of affected households will depend on the specific details of actual network deployments.

Improved receiver performance

10.23 Here we investigate the impact on the number of affected households as a result of the use of DTT receiver systems (including amplifiers) which exhibit robust performance in the presence of adjacent channel interferers.

10.24 Specifically, we address two scenarios. In the first scenario, referred to as “nominal”, we assume the same protection ratios used in deriving the earlier results for case (b). In the second scenario, referred to as “high performance”, we assume the very best protection ratios that we have measured for each installation category (see Annexes 2 to 4 for these values). A DTT receiver filter is assumed in both scenarios.

10.25 Table 24 shows the estimated number of affected households for each of the two receiver performance scenarios. All other parameter values correspond to case (b) of the central scenario (i.e., scenario 2.2.ii).

Table 24. Estimated number of affected households with nominal and high performance receivers.

Receiver performance	Standard domestic installations	Communal aerial systems	Domestic installations with amplifiers	Total
	Number of households affected by interference			
Nominal	17,710	10,041	10,785	38,536
High performance	8,007	5,738	4,880	18,625

10.26 These results show that using high performance DTT receiver equipment and amplifiers (in terms of resilience to adjacent channel interference) can significantly reduce the number of affected households, and as such, can be considered as a secondary form of mitigation in cases where receiver filtering alone proves ineffective.

Cut-off counting

10.27 The results in Table 25 present the estimated number of affected households as calculated using the “cut-off” method of counting (see Section 4), as opposed to the proportional method which is used elsewhere. Results are presented for cases (a) to (d) of the central scenario.

Table 25. Estimated number of affected households for the central scenario derived via cut-off counting.

Mitigation case	Sensitivity analysis scenario number	Standard domestic installations	Communal aerial systems	Domestic installations with amplifiers	Total
		Number of households affected by interference			
(a)	2.2.i	457,155	1,359,329	1,303,945	3,120,429
(b)	2.2.ii	24,513	14,383	18,380	57,276
(c)	2.1.i	236,723	917,919	761,058	1,915,700
(d)	2.i.iv	2,216	508	2,922	5,646

10.28 A comparison of the results of Table 25 and Table 14 of Section 9 indicates that the use of cut-off counting implies a significant increase in the estimated number of affected households. As discussed previously, we believe proportional counting is a more appropriate method for determining the impact of interference to DTT reception and the various installation categories. As such, Table 25 is presented for information only.

10.29 Please refer to Table 16 presented earlier, for a detailed view of the impact on headline DTT coverage based on calculations which are consistent with those used in DTT network planning and the UKPM (including the use of cut-off counting).

Modelling methodology

10.30 Here we explore the impact on the estimated number of households affected as a result of our revised modelling methodology (see Section 4) as compared to the methodology we used in June 2011.

10.31 Scenario O in Table 26 shows the results of the June 2011 model in the absence of mitigation measures. These correspond to a scenario which involves three MFCN networks of 8,811 sites each (network 1 in Table 5) and a base station EIRP of 59 dBm/(10 MHz). Furthermore, the results in scenario O are associated with the protection ratios outlined in Annexes 3 to 6 of the June 2011 technical report, and a 16.3m/5.2m/5.65m split between the households with standard domestic installations, communal aerial systems, and domestic installations with amplifiers respectively.

10.32 Scenario R1 in Table 26 shows the results provided by our revised modelling methodology, but for all the same parameters which were used to derive the results of Scenario O.

10.33 Scenario R2 in Table 26 shows the results provided by our revised modelling methodology, but based on revised protection ratios (see Section 6), and a 13m/5.6m/9m split between the served households with standard domestic installations, communal aerial systems, and domestic installations with amplifiers. Note that with the exception of the EIRP, Scenario R2 is identical to Scenario 1.2.i as set out in Table 12 in Section 8.

Table 26. Impact of revised methodology and parameter values.

Scenario	Standard domestic installations	Communal aerial systems	Domestic installations with amplifiers	Total
	Number of households affected by interference			
O: June 2011	115,212	521,619	115,058	751,889
R1: Revised methodology	157,144	661,912	197,599	1,016,655
R2: Revised methodology, protection ratios, & installation categories	122,759	479,155	321,912	923,826

10.34 A comparison of the results for scenarios O and R1 shows that the revised modelling methodology in isolation (namely, the brute-force UK-wide analysis, and accounting for the most susceptible channel per pixel) implies an increase in the estimated number of affected households.

A comparison of the results for scenarios R1 and R2 shows that the revised protection ratios, and splits in served installation categories imply roughly similar reductions in the number of affected standard and communal installations, but a significant increase in the number of affected domestic installations with amplifiers.

10.35 These changes can be broadly explained by the changes in the protection ratios, which for SDI and DIA categories are greater than previously assumed, and for the CAS category are lower than previously assumed. In addition, the total number of served households within the DIA category has increased from 5.65 million to 9 million (which results in an equivalent decrease in the total number of served households in the SDI category).

DTT preferred service area

10.36 Table 27 shows the result of modelling for scenario 2.2.i (equivalent to the central scenario, case (a); i.e., in the absence of mitigation measures) for the APSA, the 3PSB layer of the DPSA, and a combination of the 3PSB and 456COM layers of DPSA.

10.37 The number of affected households for the PSB and COM layers are derived as follows:

i) For a pixel where only PSB coverage is available (i.e. 3 PSB multiplexes), the number of affected households in that pixel is set equal to the maximum number of affected households in that pixel among the 3 PSB multiplexes.

ii) For a pixel where both PSB and COM coverage is available (i.e., 3 PSB and 3 COM multiplexes), the number of affected households in that pixel is set equal to the maximum number of affected households in that pixel among the 6 DTT multiplexes across both layers.

Table 27. Modelling results for the central scenario, case (a), and different preferred service area assumptions.

Preferred service area	Standard domestic installations	Communal aerial systems	Domestic installations with amplifiers	Total
	Number of households affected by interference			
APSA	389,677	952,648	945,238	2,287,563
3PSB DPSA	391,578	987,370	977,625	2,356,573
3PSB DPSA & 456COM DPSA	453,655	1,050,747	1,021,284	2,525,686

10.38 As can be seen, the estimated number of affected households calculated based on the 3PSB layer of the DPSA definition is approximately 3% greater than that calculated based on the APSA definition.

10.39 When the results for the 3PSB and 456COM layers of the DPSA are combined, the estimated number of affected households is around 10% greater than that calculated based on the APSA definition. This large increase is not unexpected, since the combination of the two layers assumes the most susceptible orientation of TV aerials at every individual pixel.

10.40 It should be noted that the APSA represents the current orientation of TV aerials across the UK, and as such, offers an appropriate approach for the purposes of modelling.

Conclusions

10.41 In this section we have presented the results of a sensitivity analysis which indicates how the estimated number of affected households varies as a function of key parameters such as the MFCN base station EIRP, and the density of MFCN base station deployments.

10.42 The results indicate that it is difficult to extract a precise rule for relating the estimated number of affected households to the base station EIRP and the number of sites. Having said that, the results do indicate that a linear relationship with base station EIRP in Watts and with the number of sites can be used as a rough guide in most circumstances.

10.43 The results for the full range of mitigation options highlight the fact that base station transmitter filtering in isolation is not very effective in reducing the number of affected households. In fact, a 3 dB reduction in base station EIRP is far more effective as a mitigation measure. However, base station transmitter filtering is highly effective in reducing the residual number of affected households when it is used in combination with DTT receiver filtering.

10.44 Our modelling based on a smaller network size in one of the three MFCN blocks indicates a net 4% increase in the number of affected households in the absence of mitigation measures. This net increase is a result of a departure from full site sharing (offset by fewer base stations). This is consistent with our assertion in the technical report of June 2012 that a departure from site sharing can result in an increase of around 10% in the number of affected households.

10.45 The use of combined DSPA layers instead of APSA shows a 10% increase in the estimated number of affected households.

10.46 Results also indicate that the use of high performance DTT receiver equipment and amplifiers significantly reduce the number of affected households, and can be considered as a secondary form of mitigation in cases where receiver filtering alone proves ineffective.

Section 11

Conclusions

11.1 In this report we have presented an updated set of technical modelling results in relation to the impact of interference from MFCN base stations in the 800 MHz band (790 – 862MHz) to DTT reception in the adjacent band (470 – 790 MHz). The material presented here supplement those presented in our previous technical report published in June 2011.

11.2 We have outlined how our modelling methodology has been revised, whereby we use a brute-force approach to quantify the impact of interference on the coverage area of each and every DTT transmitter in the UK, accounting for the most susceptible DTT channel in each pixel.

11.3 We have also described the changes in various modelling parameter values, both in response to issues raised by respondents to our consultation of June 2011 with regards to base station EIRP and MFCN base station site numbers, and in light of newly obtained information relating to improved DTT receiver filters, and measurements of additional DTT amplifiers.

11.4 The estimated total number of households whose DTT reception is affected in the absence of any mitigation measures is shown to be approximately 2.3 million across the UK. This is a marked increase from the figure of 752,000 households which we had presented in June 2011, and can be accounted for by an increase in the assumed number of base stations (from 8,811 to 11,239 per network), an increase in the assumed base station EIRP (from 59 to 64 dBm/(10 MHz), and updated values of protection ratio.

11.5 The characteristics of recently commissioned high-performance low-cost DTT receiver filter prototypes have been incorporated into our latest modelling. The results indicate that the installation of DTT receiver filters (case (b)) reduces the estimated total number of affected households to approximately 38,500.

11.6 Furthermore, the application of network based mitigation (a reduction in base station EIRP to 61 dBm/(10 MHz), and additional base station transmitter filtering) reduces the estimated total number of affected households to approximately 3,300 when used in conjunction with DTT receiver filters (case (d)). When applied in isolation, network based mitigation alone is not an effective mitigation measure, and only reduces the number of affected households to approximately 1.4 million (case (c)).

11.7 The results also indicate that, in the absence of mitigation measures, the impact of interference is only marginally dominated by the emissions of MFCN base stations in the lower 10 MHz frequency block A, as compared to the middle and upper blocks B and C.

11.8 We have also reported on the results of sensitivity analysis with respect to the base station EIRP, and the number of base station sites. The results indicate that, while it is difficult to derive a precise rule, the estimated numbers of affected households broadly increase linearly with base station EIRP in Watts and number of sites. This relationship is least valid in the case of communal aerial systems, where certain saturation (non-linear) effects are observed with regards to the number of affected households.

Annex 1

Monte Carlo approach for the calculation of appropriate protection ratios for use in Punch

Introduction

A1.1 In Section 6 we described our approach for deriving appropriate protection ratio (PR) values for use with the Punch modelling tool. The objective of this approach is to effectively capture the impact of the range of PRs observed among various DTT receivers.

A1.2 Specifically, we explained that the approach involves two types (deterministic and stochastic) of simulations and the use of multiple classes of PRs. We examine a total of 11 classes, with class-1 representing the smallest PRs measured (most robust receivers), and class 11 representing the greatest PRs measured (least robust receivers).

A1.3 For standard domestic installations, the intermediate classes 2 to 10 are derived based on market statistics of the PRs of DVB-T receivers in the UK (see Figure 9 and Figure 10 for an illustration). For communal aerial systems and domestic installations with amplifiers, the intermediate classes 2 to 10 are chosen to correspond to equi-spaced PR values between those of classes 1 and 11 (see Figure 11 and Figure 12 for illustrations).

A1.4 In the first (deterministic) type of simulation, all DTT receivers are assumed to be associated with a single class of PRs. In the second (stochastic) type of simulation, the PR associated with each pixel is drawn randomly from among the 11 classes.

A1.5 The appropriate protection ratio class for use in Punch is that which, when used in a deterministic simulation, results in an estimated number of affected households which is similar to the estimate provided by the stochastic simulation.

A1.6 In principle, it is required to perform large numbers of independent stochastic simulations in order to explore the statistics of the estimated number of affected households. In practice, we have found that independent stochastic simulations result in broadly similar estimates, and so a handful of simulations are sufficient for the purposes of this analysis.

A1.7 In this annex, we present the results of deterministic and stochastic simulations in the coverage area of the Oxford DTT transmitter. The central scenario mitigation cases examined are outlined in Table 11 in Section 8, with the estimated numbers of affected households presented in Table 14 in Section 9.

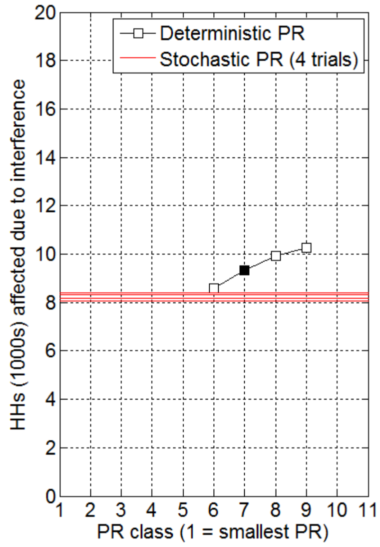
A1.8 Note that in each simulation, all households are assumed to belong to a single DTT receiver installation category. Furthermore, due to the high computational complexity, we have only performed the deterministic simulations for those classes of protection ratio for which the estimated number of affected households is greater than the corresponding number affected as indicated by the stochastic simulations.

Table 28. Scenarios simulated for purposes of deriving appropriate protection ratios for use in Punch.

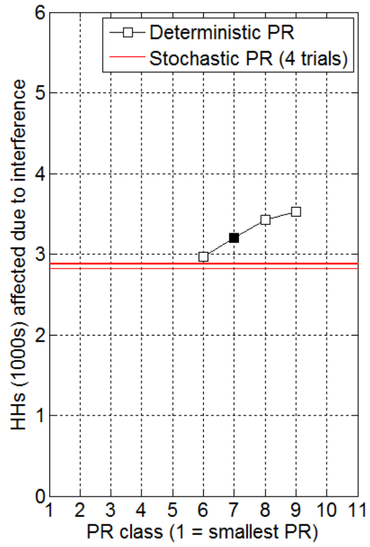
Mitigation case	BS EIRP (dBm)	BS ACLR (dB)	Filtering	Simulated LTE block	Simulated DTT channels
(a)	64	64	None	A	60, 59, 55, 51
(b)	64	64	DTT Rx		60, 59, 55, 51
(c)	61	76	Base station Tx		60, 59, 55, 51
(d)	61	76	DTT Rx and base station Tx		60, 59, 55, 51

Standard domestic installations

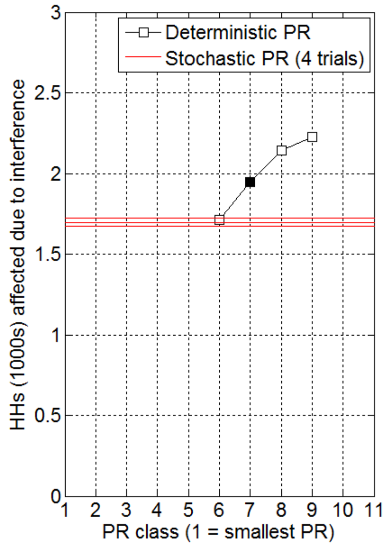
<u>Case (a)</u>



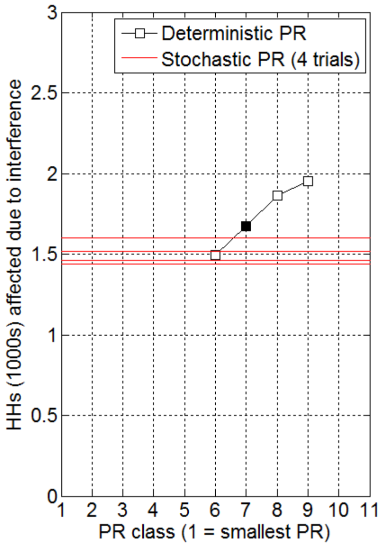
a) DTT channel 60



b) DTT channel 59



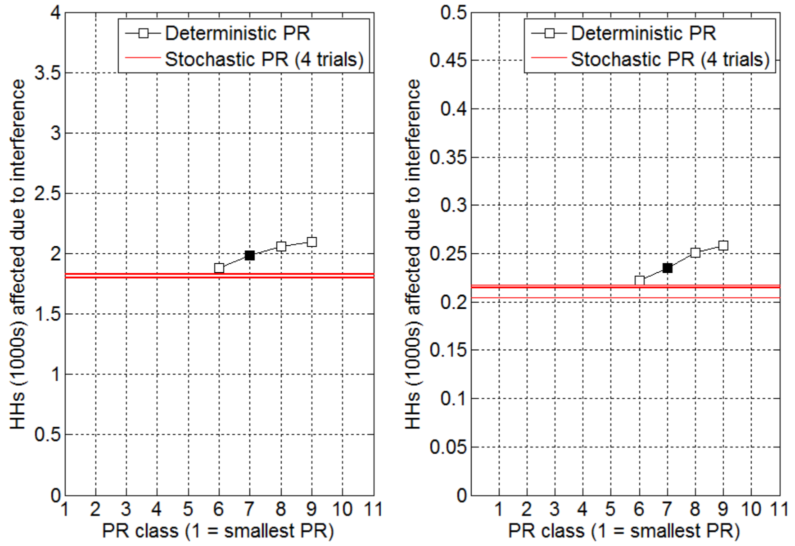
c) DTT channel 55



d) DTT channel 51

Figure 15. Estimated number of affected households in the coverage area of the Oxford transmitter, derived via simulations using deterministic PRs and stochastic PRs. Protection ratios are for standard domestic installations. Each point on the black curve corresponds to the case where a single protection ratio *class* is used in <u>all pixels</u>. As expected, the numbers of affected households increases as the values of the PRs increase from class-1 to class-11. The horizontal red lines correspond to the results of 4 Monte Carlo trials, where in each trial the protection ratio in each pixel is selected randomly from the 11 PR classes. The results with stochastic PRs are close to the results with deterministic class-6 PRs. As a cautious measure, we use class-7 PRs in Punch.

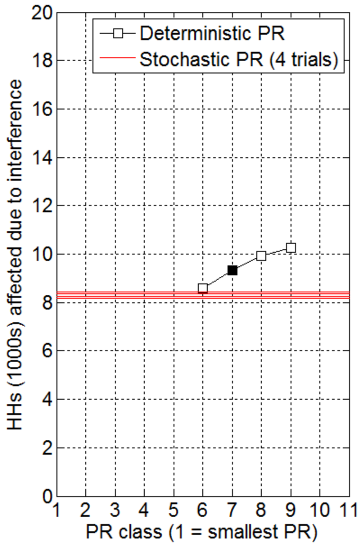
Case (b)

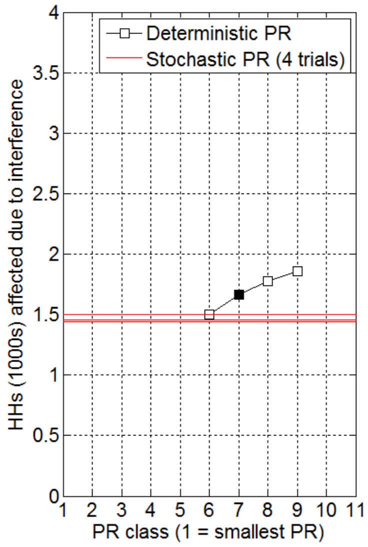


a) DTT channel 60 b) DTT channel 59

Figure 16. Estimated number of affected households in the coverage area of the Oxford transmitter, derived via simulations using deterministic PRs and stochastic PRs. Protection ratios are for standard domestic installations. Each point on the black curve corresponds to the case where a single protection ratio *class* is used in <u>all pixels</u>. We confine our analysis to DTT channels 60 and 59, because the use of a filter at the input to the DTT receiver in scenario II nominally eliminates the impact of interference below channel 59. The results with stochastic PRs are close to the results with deterministic class-6 PRs. As a cautious measure, we use class-7 PRs in Punch.

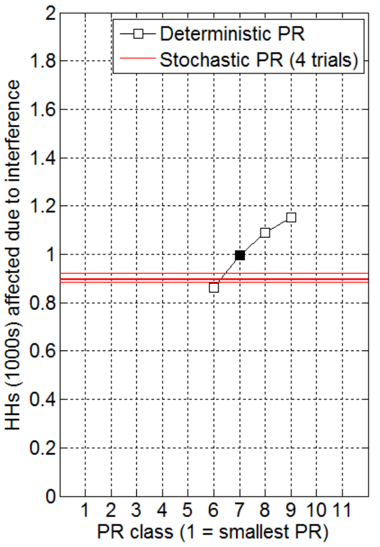
Case (c)

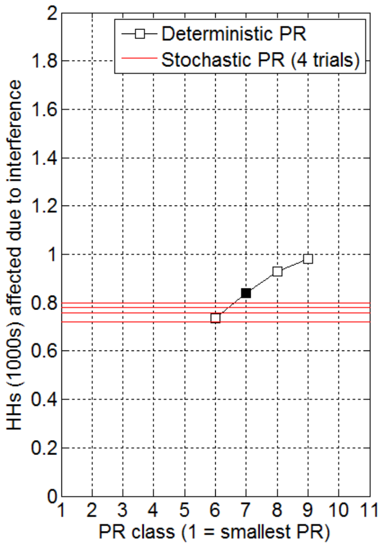




a) DTT channel 60

b) DTT channel 59



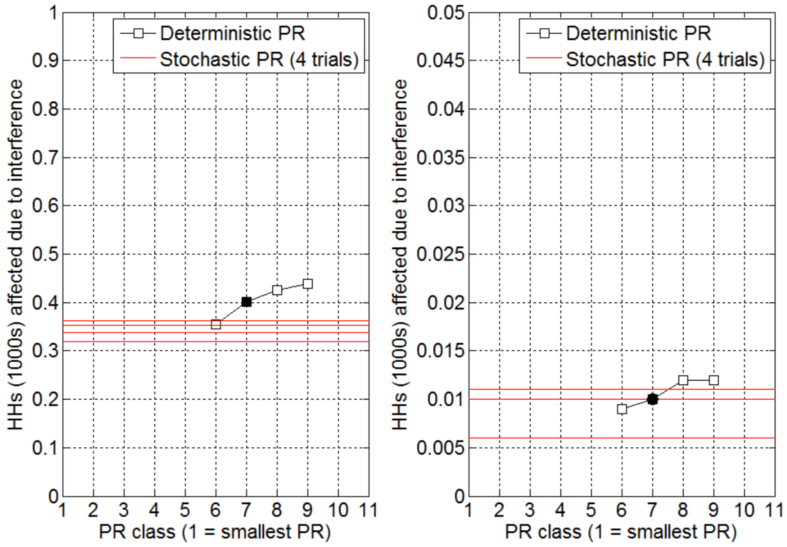


a) DTT channel 55

b) DTT channel 51

Figure 17. Estimated number of affected households in the coverage area of the Oxford transmitter, derived via simulations using deterministic PRs and stochastic PRs. Protection ratios are for standard domestic installations. Each point on the black curve corresponds to the case where a single protection ratio *class* is used in <u>all pixels</u>. As expected, the numbers of affected households increases as the values of the PRs increase from class-1 to class-11. The horizontal red lines correspond to the results of 4 Monte Carlo trials, where in each trial the protection ratio in each pixel is selected randomly from the 11 PR classes. The results with stochastic PRs are close to the results with deterministic class-6 PRs. As a cautious measure, we use class-7 PRs in Punch.

Case (d)

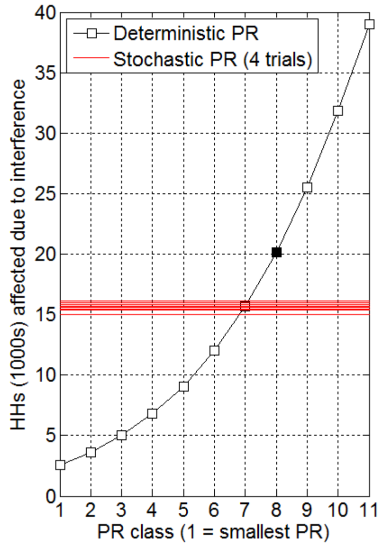


a) DTT channel 60 b) DTT channel 59

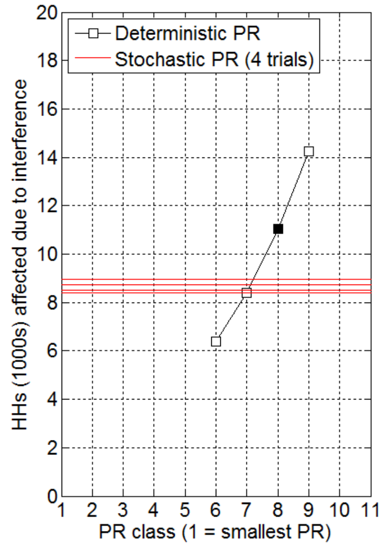
Figure 18. Estimated number of affected households in the coverage area of the Oxford transmitter, derived via simulations using deterministic PRs and stochastic PRs. Protection ratios are for standard domestic installations. Each point on the black curve corresponds to the case where a single protection ratio *class* is used in all pixels. We confine our analysis to DTT channels 60 and 59, because the use of a filter at the input to the DTT receiver in scenario IV nominally eliminates the impact of interference below channel 59. The results with stochastic PRs are close to the results with deterministic class-6 PRs. As a cautious measure, we use class-7 PRs in Punch.

Communal aerial systems

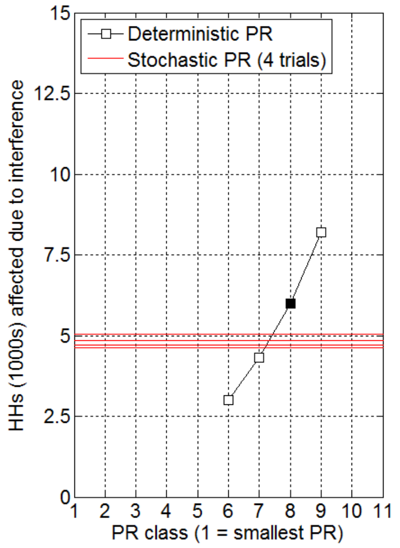
<u>Case (a)</u>



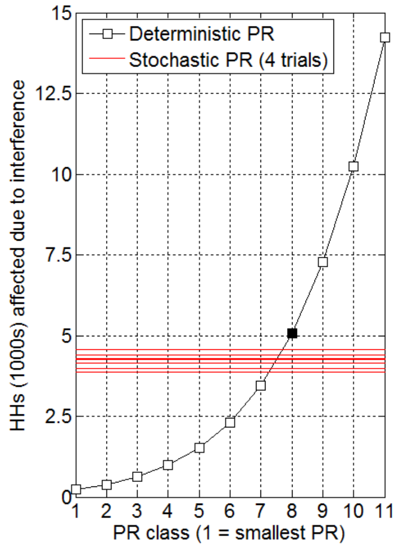
a) DTT channel 60



b) DTT channel 59



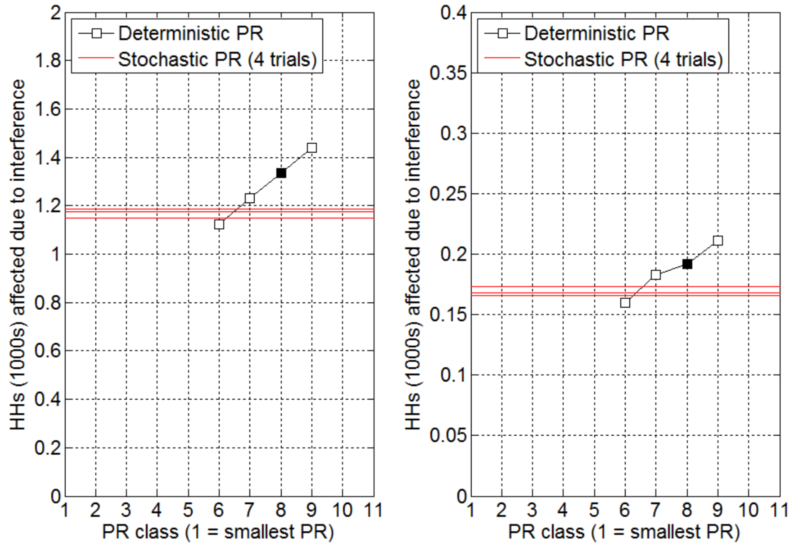
a) DTT channel 55



b) DTT channel 51

Figure 19. Estimated number of affected households in the coverage area of the Oxford transmitter, derived via simulations using deterministic PRs and stochastic PRs. Protection ratios are for communal aerial systems. Each point on the black curve corresponds to the case where a single protection ratio *class* is used in <u>all pixels</u>. As expected, the numbers of affected households increases as the values of the PRs increase from class-1 to class-11. The horizontal red lines correspond to the results of 4 Monte Carlo trials, where in each trial the protection ratio in each pixel is selected randomly from the 11 PR classes. The results with stochastic PRs are close to the results with deterministic class-7 PRs. As a cautious measure, we use class-8 PRs in Punch.

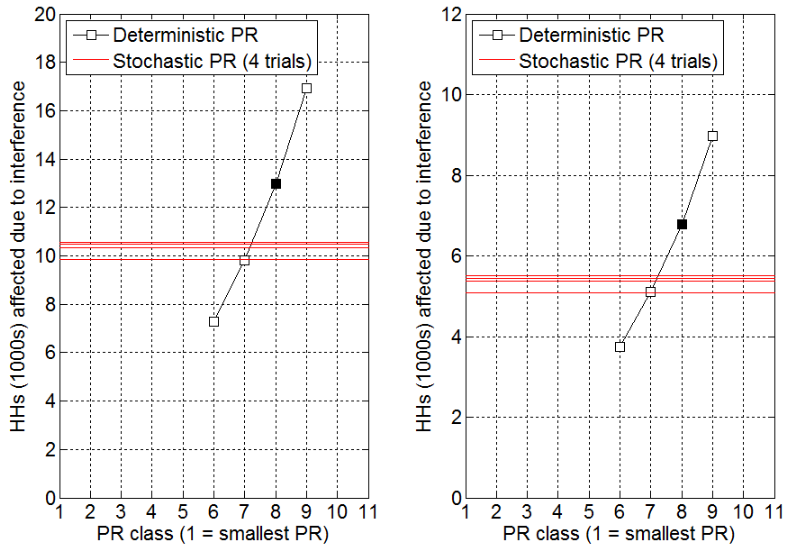
Case (b)



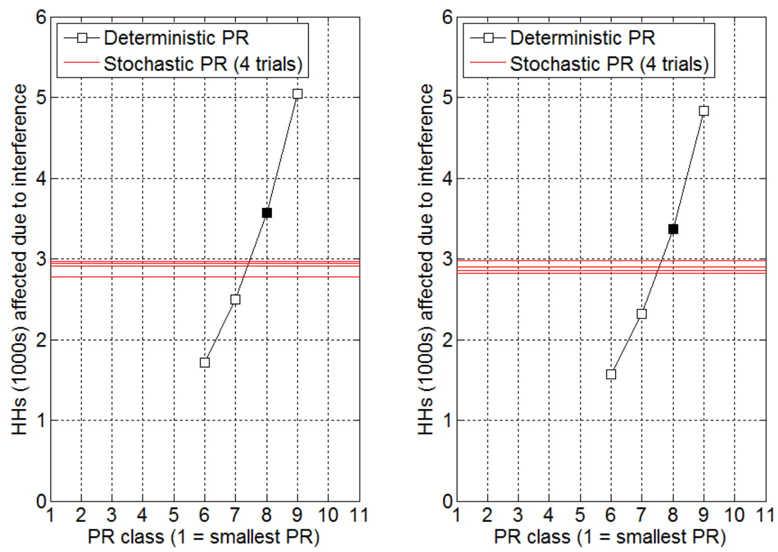
a) DTT channel 60 b) DTT channel 59

Figure 20. Estimated number of affected households in the coverage area of the Oxford transmitter, derived via simulations using deterministic PRs and stochastic PRs. Protection ratios are for communal aerial systems. Each point on the black curve corresponds to the case where a single protection ratio *class* is used in all pixels. We confine our analysis to DTT channels 60 and 59, because the use of a filter at the input to the DTT receiver in scenario II nominally eliminates the impact of interference below channel 59. The results with stochastic PRs are close to the results with deterministic class-7 PRs. As a cautious measure, we use class-8 PRs in Punch.

Case (c)



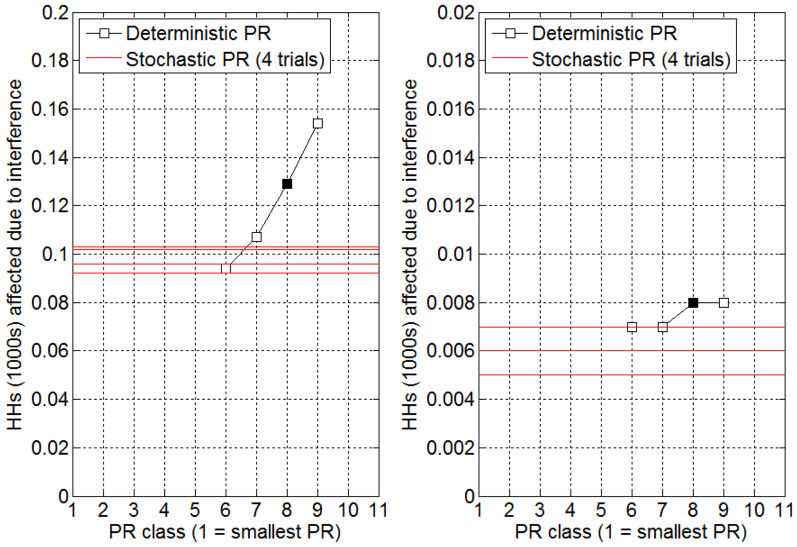
a) DTT channel 60 b) DTT channel 59



a) DTT channel 55 b) DTT channel 51

Figure 21. Estimated number of affected households in the coverage area of the Oxford transmitter, derived via simulations using deterministic PRs and stochastic PRs. Protection ratios are for communal aerial systems. Each point on the black curve corresponds to the case where a single protection ratio *class* is used in all pixels. As expected, the numbers of affected households increases as the values of the PRs increase from class-1 to class-11. The horizontal red lines correspond to the results of 4 Monte Carlo trials, where in each trial the protection ratio in each pixel is selected randomly from the 11 PR classes. The results with stochastic PRs are close to the results with deterministic class-7 PRs. As a cautious measure, we use class-8 PRs in Punch.

Case (d)

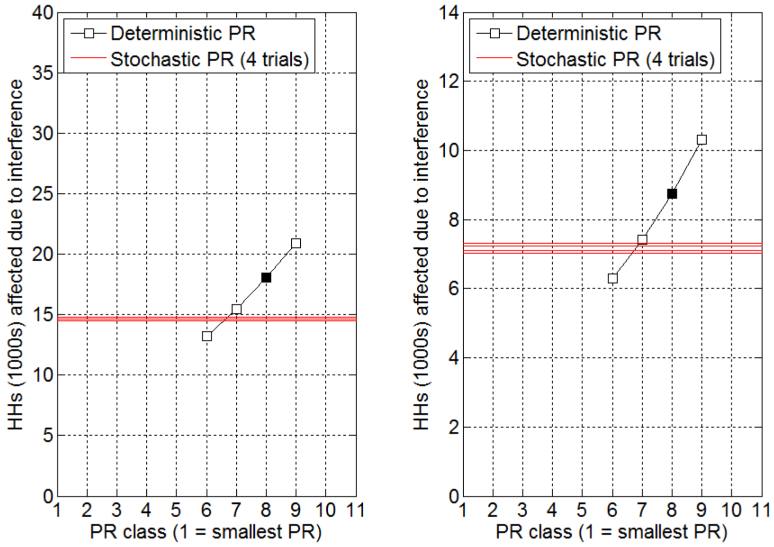


a) DTT channel 60 b) DTT channel 59

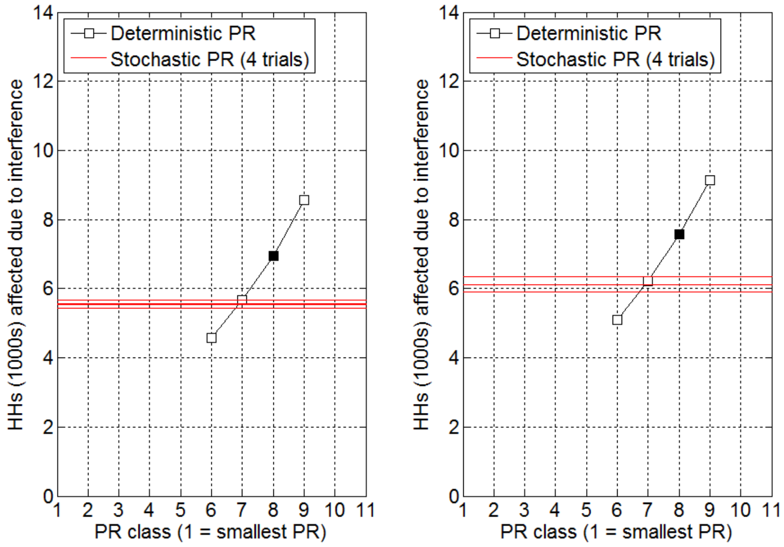
Figure 22. Estimated number of affected households in the coverage area of the Oxford transmitter, derived via simulations using deterministic PRs and stochastic PRs. Protection ratios are for communal aerial systems. Each point on the black curve corresponds to the case where a single protection ratio *class* is used in all pixels. We confine our analysis to DTT channels 60 and 59, because the use of a filter at the input to the DTT receiver in scenario IV nominally eliminates the impact of interference below channel 59. The results with stochastic PRs are close to the results with deterministic class-7 PRs. As a cautious measure, we use class-8 PRs in Punch.

Domestic installations with amplifiers

<u>Case (a)</u>



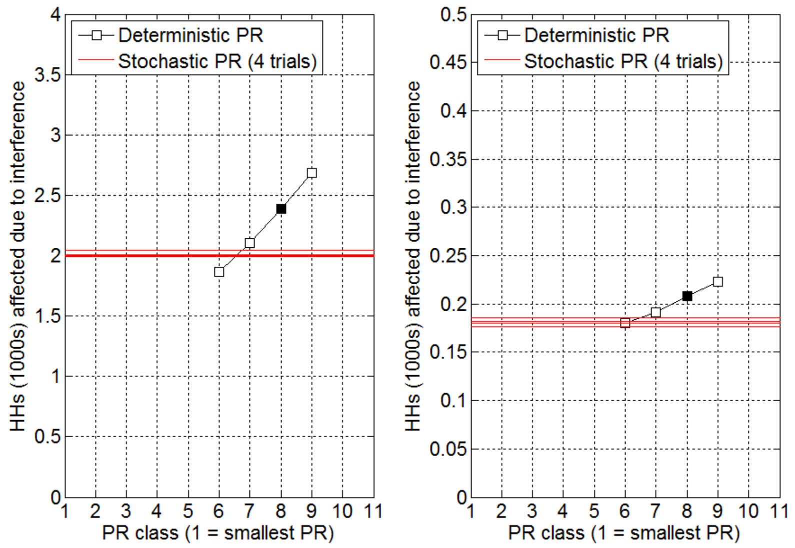
a) DTT channel 60 b) DTT channel 59



a) DTT channel 55 b) DTT channel 51

Figure 23. Estimated number of affected households in the coverage area of the Oxford transmitter, derived via simulations using deterministic PRs and stochastic PRs. Protection ratios are for domestic installations with amplifiers. Each point on the black curve corresponds to the case where a single protection ratio *class* is used in <u>all pixels</u>. As expected, the numbers of affected households increases as the values of the PRs increase from class-1 to class-11. The horizontal red lines correspond to the results of 4 Monte Carlo trials, where in each trial the protection ratio in each pixel is selected randomly from the 11 PR classes. The results with stochastic PRs are close to the results with deterministic class-7 PRs. As a cautious measure, we use class-8 PRs in Punch.

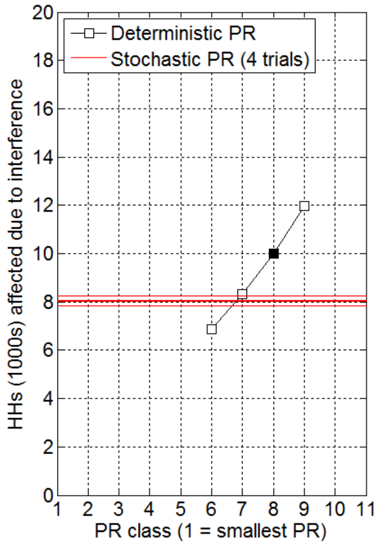
Case (b)

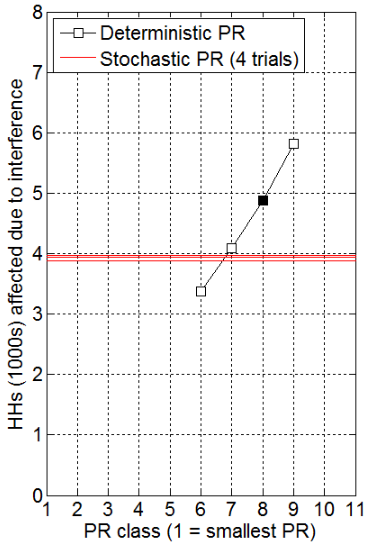


a) DTT channel 60 b) DTT channel 59

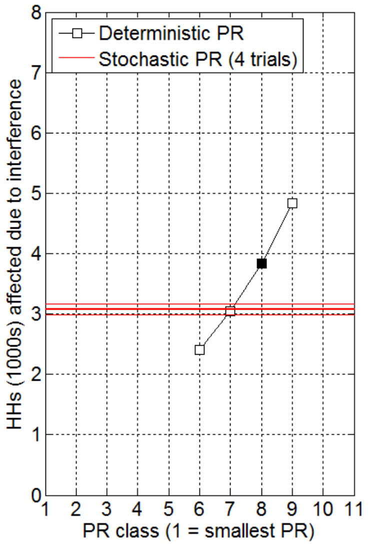
Figure 24. Estimated number of affected households in the coverage area of the Oxford transmitter, derived via simulations using deterministic PRs and stochastic PRs. Protection ratios are for domestic installations with amplifiers. Each point on the black curve corresponds to the case where a single protection ratio *class* is used in <u>all pixels</u>. We confine our analysis to DTT channels 60 and 59, because the use of a filter at the input to the DTT receiver in scenario II nominally eliminates the impact of interference below channel 59. The results with stochastic PRs are close to the results with deterministic class-7 PRs. As a cautious measure, we use class-8 PRs in Punch.

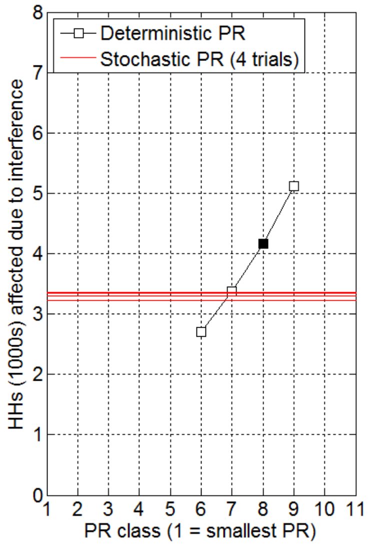
Case (c)





a) DTT channel 60 b) DTT channel 59

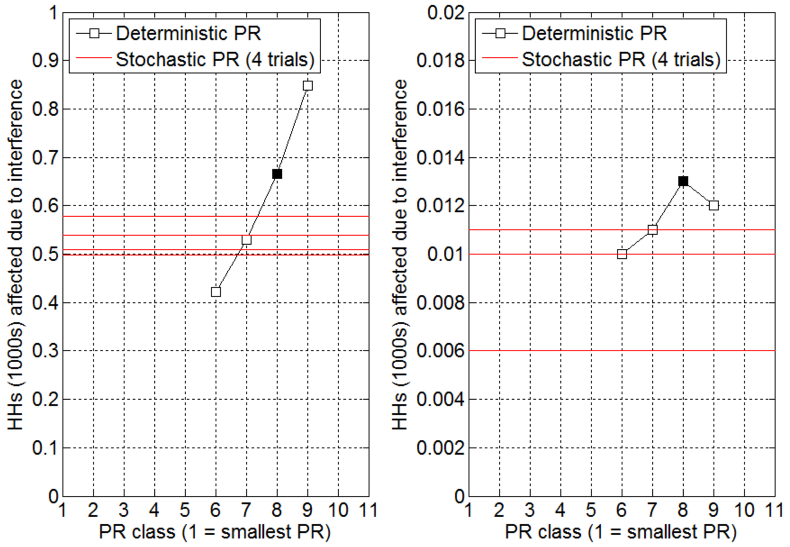




a) DTT channel 55 b) DTT channel 51

Figure 25. Estimated number of affected households in the coverage area of the Oxford transmitter, derived via simulations using deterministic PRs and stochastic PRs. Protection ratios are for domestic installations with amplifiers. Each point on the black curve corresponds to the case where a single protection ratio *class* is used in all pixels. As expected, the numbers of affected households increases as the values of the PRs increase from class-1 to class-11. The horizontal red lines correspond to the results of 4 Monte Carlo trials, where in each trial the protection ratio in each pixel is selected randomly from the 11 PR classes. The results with stochastic PRs are close to the results with deterministic class-7 PRs. As a cautious measure, we use class-8 PRs in Punch.

Case (d)



a) DTT channel 60 b) DTT channel 59

Figure 26. Estimated number of affected households in the coverage area of the Oxford transmitter, derived via simulations using deterministic PRs and stochastic PRs. Protection ratios are for communal aerial systems. Each point on the black curve corresponds to the case where a single protection ratio *class* is used in <u>all pixels</u>. We confine our analysis to DTT channels 60 and 59, because the use of a filter at the input to the DTT receiver in scenario IV nominally eliminates the impact of interference below channel 59. The results with stochastic PRs are close to the results with deterministic class-7 PRs. As a cautious measure, we use class-8 PRs in Punch.

Annex 2

Protection ratios: Standard domestic installations

Introduction

A2.1 In this annex we present the MFCN to DTT protection ratios (class 7) used in this report for the modelling of the impact of interference on households with standard domestic installations (SDI).

A2.2 We first present the raw protection ratio measurements of a number of DTT receivers. We subsequently present the post-processed class-7 protection ratios.

A2.3 Note that a change in base station EIRP, or the use of filtering at the base station, result in a change in the MFCN signal's adjacent-channel leakage ratio (ACLR), and hence a change in the MFCN to DTT protection ratio. Furthermore, the use of filtering at a DTT receiver alters the receiver's adjacent-channel selectivity (ACS), and hence also changes the protection ratio. Post-processing is therefore required to adjust the measured protection ratios based on the prevailing interferer ACLR and receiver filter parameters.

A2.4 The presented post-processed protection ratios are associated with interference from MFCN blocks A, B, and C, into DTT channels 60 down to 51, for different values, *C*, of received DTT signal power. The protection ratios for channel 51 are used as proxies for channels 50 and below. Linear interpolation is used to derive protection ratios for intermediate values of *C*. The protection ratios for $C = -12$ dBm are used as proxies for $C \geq -12$ dBm. Where required, linear interpolation is used to derive protection ratios for appropriate interferer-victim frequency separations.

Measured SDI protection ratios

A2.5 In this section we present two sets of protection ratio measurements.

A2.6 The first set of protection ratios, outlined in Table 29 to Table 33, consists of measurements performed in 2009 by ERA Technology. These relate to the performance of five DVB-T receivers (three super-heterodyne receivers and two Silicon tuners) in the presence of time-continuous adjacent channel LTE signals. The tested LTE interferer has a 10 MHz bandwidth centred at 796 MHz. The ACLRs of the tested LTE signal can be found in Annex 3 of our technical report published in June 2011.

A2.7 The second set of protection ratios, outlined in Table 34 to Table 43 consists of measurements performed in 2011 by ERA Technology. These relate to the performance of a further five DVB-T receivers in the presence of both time-continuous (so-called "fully loaded") and time-discontinuous (so-called "idle") adjacent channel LTE interferers. The ACLRs of the tested LTE signal are the same as those described in Annex 3 of our technical report published in June 2011.

A2.8 Note that certain cells in Table 34 to Table 43 are empty (denoted with a hyphen). This is because the equipment used in the test set up was unable to generate sufficient interferer in-block powers (for the required ACLR) to affect the operation of the DTT receiver.

A2.9 Measured values are quoted to two decimal places for transparency of further calculations. Measurement uncertainty is of the order of 1 dB.

Table 29. Measured protection ratios for super-heterodyne receiver #1 and "fully loaded" LTE interferer (ERA 2009).

r_M (dB)	DTT signal power, *C* (dBm)				
Carrier separation Δf (MHz)	-70	-50	-30	-20	-12
0	16.88	16.13	15.12	15.96	16.39
10	-41.55	-34.55	-22.44	-16.36	-9.51
15	-49.45	-43.09	-28.41	-18.13	-10.89
20	-50.09	-45.73	-29.12	-19.53	-12.26
25	-56.38	-48.82	-31.52	-20.53	-12.75
30	-59.56	-47.01	-32.41	-21.55	-13.09
35	-63.55	-44.26	-33.41	-22.38	-13.87
46	-64.94	-46.99	-33.97	-22.85	-14.86
51	-65.43	-47.47	-34.22	-23.08	-15.09
56	-68.78	-48.61	-34.56	-23.4	-15.42
61	-69.43	-49.04	-34.92	-22.87	-16.17
66	-64.06	-48.97	-34.69	-23.52	-15.32
71	-53.08	-48.72	-34.59	-23.44	-16.22
76	-56.04	-49.04	-34.88	-23.52	-15.82
81	-70.75	-49.49	-35.59	-24.25	-15.63

Table 30. Measured protection ratios for super-heterodyne receiver #2 and “fully loaded” LTE interferer (ERA 2009).

r_M (dB)	DTT signal power, C (dBm)				
Carrier separation Δf (MHz)	-70	-50	-30	-20	-12
0	15.15	13.83	14	14.27	15.49
10	-38.82	-36.63	-25.47	-19.54	-13.88
15	-45.13	-44.31	-30.92	-22.02	-14.6
20	-52.06	-49.82	-31.64	-21.73	-14.45
25	-52.52	-49.54	-32.43	-22.34	-14.78
30	-58.48	-42.81	-34.47	-22.68	-15.16
35	-60.29	-43.56	-34.54	-23.54	-15.63
46	-66.89	-49.29	-36.01	-25.05	-17.12
51	-68.24	-50.52	-36.18	-25.2	-17.59
56	-70.02	-50.84	-36.61	-25.66	-17.02
61	-69.39	-51.57	-36.09	-25.28	-17.62
66	-54.18	-50.03	-35.86	-25.97	-17.31
71	-41.83	-40.84	-35.72	-25.72	-17.12
76	-47.18	-48.19	-35.92	-25.92	-17.18
81	-71.63	-53.58	-36.56	-25.62	-17.69

Table 31. Measured protection ratios for super-heterodyne DTT receiver #3 and “fully loaded” LTE interferer (ERA 2009).

r_M (dB)	DTT signal power, C (dBm)				
Carrier separation Δf (MHz)	-70	-50	-30	-20	-12
0	12.97	14.21	14.18	15.41	15.55
10	-41.54	-33.24	-21.34	-14.44	-8.36
15	-52.22	-42.64	-26.76	-20.03	-12.03
20	-45.51	-44.5	-30.47	-19.74	-12.68
25	-50.93	-37.16	-31.78	-22.08	-13.91
30	-60.91	-42.87	-33.09	-22.77	-14.81
35	-59.35	-41.19	-31.18	-22.04	-14.13
46	-69.02	-51.87	-33.79	-23.99	-16.61
51	-69.48	-53.16	-34.31	-24.51	-16.32
56	-70.08	-53.96	-34.93	-24.99	-16.94
61	-70.56	-54.52	-34.58	-24.63	-17.67
66	-69.41	-54.32	-35.23	-25.43	-17.36
71	-58.31	-54.28	-35.11	-25.18	-17.17
76	-61.29	-54.26	-36.15	-25.23	-17.23
81	-73.04	-54.92	-35.81	-25.58	-17.61

Table 32. Measured protection ratios for Silicon tuner DTT receiver #1 and “fully loaded” LTE interferer (ERA 2009).

r_M (dB)	DTT signal power, *C* (dBm)				
Carrier separation Δf (MHz)	-70	-50	-30	-20	-12
0	15.66	14.29	14.33	14.49	15.73
10	-41.53	-36.41	-25.34	-20.23	-14.36
15	-48.97	-42.74	-30.76	-22.61	-16.88
20	-51.66	-45.43	-32.42	-24.22	-17.38
25	-51.29	-47.02	-33.96	-24.89	-16.77
30	-51.73	-49.46	-34.4	-24.13	-16.72
35	-52.73	-50.3	-33.37	-23.26	-14.95
46	-53.46	-51.18	-32.39	-22.14	-14.74
51	-54.95	-51.61	-31.73	-22.48	-14.41
56	-54.46	-50.96	-31.16	-22.05	-14.02
61	-54.97	-50.56	-30.86	-20.75	-12.76
66	-55.68	-49.49	-30.62	-20.55	-12.32
71	-56.43	-49.29	-29.43	-19.35	-12.06
76	-57.28	-49.31	-29.33	-19.28	-12.28
81	-57.52	-48.55	-29.6	-19.44	-12.65

Table 33. Measured protection ratios for Silicon tuner DTT receiver #2 and “fully loaded” LTE interferer (ERA 2009).

r_M (dB)	DTT signal power, *C* (dBm)				
Carrier separation Δf (MHz)	-70	-50	-30	-20	-12
0	14.49	14.16	14.18	14.74	15.47
10	-39.78	-38.79	-29.61	-19.79	-13.69
15	-47.43	-44.35	-30.21	-22.59	-16.36
20	-47.87	-45.87	-31.74	-24.28	-17.95
25	-48.29	-48.27	-33.06	-25.55	-20.24
30	-48.45	-48.49	-34.29	-26.29	-20.28
35	-49.2	-49.22	-35.19	-26.06	-17.98
46	-49.96	-48.92	-34.95	-24.69	-16.83
51	-50.45	-50.37	-34.34	-24.32	-16.15
56	-50.85	-50.52	-34.02	-23.75	-16.68
61	-51.38	-50.31	-34.51	-24.38	-16.42
66	-53.23	-50.08	-34.44	-24.15	-16.24
71	-53.04	-49.83	-34.42	-23.92	-15.94
76	-53.15	-51	-34.08	-24.07	-16.14
81	-53.07	-50.55	-34.4	-23.75	-15.71

Table 34. Measured protection ratios for receiver #1 and "fully loaded" LTE interferer (ERA 2011).

r_M (dB)	DTT signal power, C (dBm)				
Carrier separation Δf (MHz)	-70	-50	-30	-20	-12
0	15.46	15.28	15.56	15.24	14.98
10	-45.79	-45.82	-28.71	-20.84	-14.71
18	-52.81	-48.81	-33.76	-24.68	-16.6
26	-53.64	-51.65	-34.58	-24.49	-16.93
34	-55.62	-53.69	-	-	-
42	-56.47	-54.44	-	-	-
50	-58.17	-	-	-	-
58	-58.45	-	-	-	-
66	-59.55	-	-	-	-
74	-62.51	-	-	-	-
82	-64.5	-	-	-	-
90	-66.27	-	-	-	-
98	-67.49	-	-	-	-
106	-68.27	-	-	-	-
186	-71.33	-	-	-	-

Table 35. Measured protection ratios for receiver #2 and "fully loaded" LTE interferer (ERA 2011).

r_M (dB)	DTT signal power, C (dBm)				
Carrier separation Δf (MHz)	-70	-50	-30	-20	-12
0	14.63	15.76	14.92	16.05	15.11
10	-41.54	-35.09	-22.13	-14.2	-8.17
18	-44.21	-42.16	-27.15	-18.2	-9.85
26	-50.53	-39.51	-28.41	-18.12	-10.24
34	-52.46	-38.03	-28.04	-18.01	-10.49
42	-60.39	-45.39	-29.08	-19.09	-11.24
50	-63.02	-47.1	-28.98	-19.29	-11.39
58	-64.96	-47.08	-29.06	-19.01	-11.14
66	-57.07	-47.1	-29	-20.02	-12.33
74	-45.31	-44.19	-30.17	-20.17	-12.46
82	-68.34	-49.49	-30.31	-20.27	-12.31
90	-69.44	-49.44	-30.45	-20.28	-12.15
98	-69.97	-50.14	-30.03	-20.24	-12.18
106	-69.09	-50.17	-30.12	-20	-12.27
186	-70.4	-50.5	-30.5	-20.52	-12.24

Table 36. Measured protection ratios for receiver #3 and "fully loaded" LTE interferer (ERA 2011).

r_M (dB)	DTT signal power, *C* (dBm)				
Carrier separation Δf (MHz)	-70	-50	-30	-20	-12
0	18.17	15.93	15.14	15.2	16.22
10	-42.98	-36.96	-24.03	-17.07	-11.11
18	-54.87	-47.55	-29.63	-20.08	-12.75
26	-56.05	-49.09	-31.08	-21.14	-14.06
34	-68.23	-49.72	-32.23	-22.02	-14.84
42	-69.85	-51.83	-32.78	-23.81	-
50	-71.17	-52.66	-34.03	-23.77	-
58	-71.8	-53.77	-33.87	-	-
66	-71.95	-53.98	-33.82	-	-
74	-70.85	-53.77	-	-	-
82	-72.75	-	-	-	-
90	-73.57	-	-	-	-
98	-73.66	-	-	-	-
106	-73.98	-	-	-	-
186	-	-	-	-	-

Table 37. Measured protection ratios for receiver #4 and "fully loaded" LTE interferer (ERA 2011).

r_M (dB)	DTT signal power, *C* (dBm)				
Carrier separation Δf (MHz)	-70	-50	-30	-20	-12
0	15.53	15.37	15.14	16.04	15.88
10	-44.14	-40.09	-23.08	-14.12	-6.29
18	-45.94	-42.92	-24.78	-14.43	-6.61
26	-46.65	-42.84	-24.76	-14.66	-6.8
34	-47.81	-43.84	-24.78	-14.68	-6.58
42	-49.42	-43.43	-24.15	-14.44	-6.33
50	-50.94	-43.89	-24.51	-14.12	-6.28
58	-52.2	-44.28	-24.28	-15.07	-6.24
66	-53.16	-44.23	-24.4	-15.35	-7.39
74	-53.44	-44.52	-24.46	-15.51	-7.22
82	-54.64	-44.55	-24.58	-15.43	-7.64
90	-56.46	-44.52	-24.6	-15.52	-7.32
98	-57.27	-44.54	-24.37	-15.27	-7.1
106	-58.15	-44.38	-24.25	-15.27	-7.3
186	-63.38	-45.54	-25.47	-15.53	-7.58

Table 38. Measured protection ratios for receiver #5 and “fully loaded” LTE interferer (ERA 2011).

r_M (dB)	DTT signal power, *C* (dBm)				
Carrier separation Δf (MHz)	-70	-50	-30	-20	-12
0	12.93	16.39	16.61	16.57	16.39
10	-46.25	-38.19	-25.09	-16.53	-9.91
18	-46	-43.43	-30.1	-20.17	-12.01
26	-53.32	-45.24	-	-	-
34	-63.36	-44.06	-	-	-
42	-66.54	-46.65	-	-	-
50	-66.38	-48.32	-	-	-
58	-68.8	-48.9	-	-	-
66	-58.08	-48.97	-	-	-
74	-52.98	-50.21	-	-	-
82	-69.78	-	-	-	-
90	-	-	-	-	-
98	-	-	-	-	-
106	-	-	-	-	-
186	-	-	-	-	-

Table 39. Measured protection ratios for receiver #1 and “idle” LTE interferer (ERA 2011).

r_M (dB)	DTT signal power, *C* (dBm)				
Carrier separation Δf (MHz)	-70	-50	-30	-20	-12
0	18.89	19.21	19.5	19.38	19.5
10	-42.37	-39.02	-22.16	-15.58	-8.4
18	-46	-42.32	-	-	-
26	-46.96	-45.39	-	-	-
34	-48.19	-	-	-	-
42	-50.23	-	-	-	-
50	-51.04	-	-	-	-
58	-52.02	-	-	-	-
66	-52.78	-	-	-	-
74	-55.18	-	-	-	-
82	-57.89	-	-	-	-
90	-58.99	-	-	-	-
98	-61.67	-	-	-	-
106	-61.12	-	-	-	-
186	-65.21	-	-	-	-

Table 40. Measured protection ratios for receiver #2 and “idle” LTE interferer (ERA 2011).

r_M (dB)	DTT signal power, *C* (dBm)				
Carrier separation Δ*f* (MHz)	-70	-50	-30	-20	-12
0	18.18	19.78	20.19	19.97	21.05
10	-33.27	-28.43	-16.17	-8.29	-2.94
18	-40.01	-36.09	-21.18	-11.04	-3.83
26	-43.95	-33.17	-22.01	-12.06	-4.94
34	-49.97	-35.99	-21.83	-11.92	-3.86
42	-53.91	-39.13	-21.95	-11.95	-3.93
50	-57.14	-41.5	-21.8	-11.84	-4.14
58	-60.31	-41.87	-21.79	-12.82	-4.98
66	-54.01	-41.21	-23.04	-13.02	-5.08
74	-41.12	-39.87	-23.23	-13.25	-5.08
82	-61.94	-42.94	-23.05	-13.09	-4.94
90	-62.88	-42.98	-22.96	-13.04	-4.78
98	-63.04	-43.14	-23.1	-12.91	-4.69
106	-62.82	-42.92	-22.92	-12.88	-4.86
186	-63.86	-42.88	-23.77	-13.75	-6.66

Table 41. Measured protection ratios for receiver #3 and “idle” LTE interferer (ERA 2011).

r_M (dB)	DTT signal power, *C* (dBm)				
Carrier separation Δ*f* (MHz)	-70	-50	-30	-20	-12
0	20.64	19.75	20.56	20.32	20.27
10	-38.68	-31.08	-19.55	-10.84	-4.16
18	-48.42	-41.4	-23.2	-13.92	-7.4
26	-50.58	-40.25	-24.08	-15.84	-7.88
34	-61	-43.02	-26.05	-	-
42	-62.32	-45.56	-	-	-
50	-64.25	-	-	-	-
58	-65.2	-	-	-	-
66	-65.24	-	-	-	-
74	-65.56	-	-	-	-
82	-	-	-	-	-
90	-	-	-	-	-
98	-	-	-	-	-
106	-	-	-	-	-
186	-	-	-	-	-

Table 42. Measured protection ratios for receiver #4 and “idle” LTE interferer (ERA 2011).

r_M (dB)	DTT signal power, C (dBm)				
Carrier separation Δf (MHz)	-70	-50	-30	-20	-12
0	19.35	19.79	20.05	20.01	20.51
10	-19.13	-3.84	0.8	-1.9	-0.84
18	-21.08	-7.37	-1.23	-3.01	-1.19
26	-21.81	-9.56	0.43	-3.67	-1.52
34	-24.97	-11.93	-1.11	-3.46	-1.31
42	-26.2	-12.1	-3.66	-4.3	-0.5
50	-25.15	-11.96	-2.98	-6.16	-1.33
58	-29.6	-14.48	-4.06	-6.44	-1.2
66	-30.52	-15.8	-5.47	-7.2	-1.44
74	-31.71	-15.72	-7.19	-8.51	-1.24
82	-31.93	-17.3	-7.23	-8.51	-1.36
90	-33.24	-17.31	-8.35	-8.58	-1.15
98	-34.44	-17.12	-9.79	-8.48	-1.24
106	-35.69	-16.92	-11.49	-9.12	-1.3
186	-39.92	-21.16	-16.23	-9.69	-1.32

Table 43. Measured protection ratios for receiver #5 and “idle” LTE interferer (ERA 2011).

r_M (dB)	DTT signal power, C (dBm)				
Carrier separation Δf (MHz)	-70	-50	-30	-20	-12
0	22.67	20.17	20.8	20.33	20.09
10	-36.12	-30	-16.77	-10.06	-3.87
18	-42.21	-39.71	-23.94	-14.43	-7.13
26	-45.21	-37.97	-24.24	-	-
34	-59.5	-39.26	-	-	-
42	-61.74	-40.95	-	-	-
50	-59.21	-41.15	-	-	-
58	-64.02	-43.1	-	-	-
66	-53.28	-44.06	-	-	-
74	-45.54	-44.23	-	-	-
82	-64.85	-44.25	-	-	-
90	-65.23	-45.03	-	-	-
98	-	-	-	-	-
106	-	-	-	-	-
186	-	-	-	-	-

Post-processed SDI protection ratios

A2.10 Table 44 to Table 47 show the post-processed (class 7) protection ratio values used for purposes of modelling in this document.

A2.11 Details of the post-processing procedure can be found in Annex 3 of our technical report published in June 2011. The term post-processing refers to the mathematical adjustment of the measured protection ratios in order to account for the required ACLR values of the LTE interferer (which are not necessarily the same as those used in the measurement process), and any improvements in receiver selectivity due to the use of filtering.

A2.12 For each interferer-victim frequency offset and DTT signal power, the gap between the highest and lowest post-processed protection ratios is filled with nine classes of protection ratios (implying a total of 11 classes) whose spacings are consistent with 10^{th} percentile intervals of available market data provided by the DTG (see Figure 9. DTG market data on the distribution of DVB-T protection ratios for an idle LTE received signal power of -23.3 dBm (equivalent to -15 dBm fully loaded) and adjusted for an ACLR of 64 dB.Figure 9 and Figure 10 and the description in Section 6

A2.13 For brevity, post-processed protection ratios are presented only for specific base station ACLRs (and hence EIRPs) which apply to the central scenario described in Section 8.

Table 44. Protection ratios (class 7) for SDI: no mitigation, EIRP of 64 dBm/(10 MHz).

Block A r_B (dB)		*C* (dBm)					
		-70	-50	-30	-20	≥-12	
DTT channel	60	-41	-36	-23	-15	-8	
	59	-47	-43	-26	-16	-9	
	58	-49	-41	-27	-17	-10	
	57	-53	-42	-27	-17	-9	
	56	-55	-46	-26	-17	-8	
	55	-56	-46	-27	-16	-8	
	54	-56	-46	-27	-17	-8	
	53	-58	-46	-27	-17	-9	
	52	-52	-46	-27	-18	-9	
	≤ 51	-58	-47	-27	-17	-9	

Block B r_B (dB)		*C* (dBm)					
		-70	-50	-30	-20	≥-12	
DTT channel	60	-45	-42	-26	-16	-9	
	59	-49	-41	-27	-17	-10	
	58	-53	-42	-27	-17	-9	
	57	-55	-45	-27	-16	-8	
	56	-56	-46	-27	-16	-8	
	55	-57	-46	-27	-17	-9	
	54	-54	-46	-27	-17	-9	
	53	-53	-46	-27	-18	-9	
	52	-58	-47	-27	-17	-9	
	≤ 51	-58	-47	-27	-17	-9	

Block C r_C (dB)		*C* (dBm)					
		-70	-50	-30	-20	≥-12	
DTT channel	60	-45	-40	-27	-17	-10	
	59	-51	-44	-27	-17	-9	
	58	-54	-45	-27	-16	-8	
	57	-56	-46	-27	-17	-8	
	56	-57	-46	-27	-17	-9	
	55	-50	-44	-27	-17	-9	
	54	-57	-46	-27	-17	-9	
	53	-58	-47	-27	-17	-9	
	52	-58	-47	-27	-17	-9	
	≤ 51	-58	-47	-27	-17	-9	

Table 45. Protection ratios (class 7) for SDI:
DTT Rx filtering, EIRP = 64 dBm/(10 MHz).

Block A r_B (dB)		C (dBm)					
		-70	-50	-30	-20	≥-12	
DTT channel	60	-46	-45	-36	-29	-22	
	59	-56	-57	-55	-48	-41	
	58	-66	-67	-58	-49	-42	
	57	-76	-72	-59	-50	-41	
	56	-83	-78	-59	-49	-41	
	55	-87	-78	-59	-49	-41	
	54	-89	-79	-59	-50	-41	
	53	-91	-79	-59	-50	-42	
	52	-84	-79	-59	-50	-42	
	≤ 51	-90	-79	-60	-50	-42	

Block B r_B (dB)		C (dBm)					
		-70	-50	-30	-20	≥-12	
DTT channel	60	-46	-47	-46	-40	-33	
	59	-56	-57	-55	-48	-41	
	58	-66	-67	-58	-49	-40	
	57	-76	-74	-58	-48	-40	
	56	-83	-77	-59	-48	-40	
	55	-87	-78	-59	-49	-40	
	54	-86	-78	-58	-49	-41	
	53	-85	-78	-59	-49	-41	
	52	-90	-78	-59	-49	-41	
	≤ 51	-90	-78	-59	-49	-41	

Block C r_C (dB)		C (dBm)					
		-70	-50	-30	-20	≥-12	
DTT channel	60	-46	-47	-46	-40	-34	
	59	-56	-57	-54	-48	-40	
	58	-66	-67	-58	-48	-40	
	57	-76	-74	-59	-49	-40	
	56	-84	-77	-59	-49	-41	
	55	-81	-76	-59	-49	-41	
	54	-88	-78	-59	-49	-41	
	53	-90	-78	-59	-49	-41	
	52	-90	-78	-59	-49	-41	
	≤ 51	-90	-78	-59	-49	-41	

Table 46. Protection ratios (class 7) for SDI:
BS Tx filtering, BS EIRP = 61 dBm/(10 MHz).

Block A r_B (dB)		C (dBm)					
		-70	-50	-30	-20	≥-12	
DTT channel	60	-42	-37	-23	-15	-8	
	59	-48	-44	-26	-16	-9	
	58	-49	-41	-27	-17	-10	
	57	-53	-42	-27	-17	-9	
	56	-55	-46	-26	-17	-8	
	55	-56	-46	-27	-16	-8	
	54	-56	-46	-27	-17	-8	
	53	-58	-46	-27	-17	-9	
	52	-52	-46	-27	-18	-9	
	≤ 51	-58	-47	-27	-17	-9	

Block B r_B (dB)		C (dBm)					
		-70	-50	-30	-20	≥-12	
DTT channel	60	-48	-43	-27	-16	-9	
	59	-50	-42	-27	-17	-10	
	58	-53	-42	-27	-17	-9	
	57	-55	-45	-27	-16	-8	
	56	-56	-46	-27	-16	-8	
	55	-57	-46	-27	-17	-9	
	54	-54	-46	-27	-17	-9	
	53	-53	-46	-27	-18	-9	
	52	-58	-47	-27	-17	-9	
	≤ 51	-58	-47	-27	-17	-9	

Block C r_C (dB)		C (dBm)					
		-70	-50	-30	-20	≥-12	
DTT channel	60	-51	-42	-27	-17	-10	
	59	-54	-44	-27	-17	-9	
	58	-55	-45	-27	-16	-8	
	57	-56	-46	-27	-17	-8	
	56	-57	-46	-27	-17	-9	
	55	-50	-44	-27	-17	-9	
	54	-57	-46	-27	-17	-9	
	53	-58	-47	-27	-17	-9	
	52	-58	-47	-27	-17	-9	
	≤ 51	-58	-47	-27	-17	-9	

Table 47. Protection ratios (class 7) for SDI:
DTT Rx filtering, BS Tx filtering, and BS EIRP = 61 dBm/(10 MHz).

Block A r_B (dB)		C (dBm)					
		-70	-50	-30	-20	≥-12	
DTT channel	60	-55	-50	-37	-29	-22	
	59	-68	-69	-58	-49	-41	
	58	-77	-72	-59	-49	-42	
	57	-83	-74	-59	-50	-41	
	56	-86	-78	-59	-49	-41	
	55	-88	-78	-59	-49	-41	
	54	-89	-79	-59	-50	-41	
	53	-91	-79	-59	-50	-42	
	52	-84	-79	-59	-50	-42	
	≤ 51	-90	-79	-60	-50	-42	

Block B r_B (dB)		C (dBm)					
		-70	-50	-30	-20	≥-12	
DTT channel	60	-68	-66	-51	-41	-33	
	59	-78	-72	-58	-49	-41	
	58	-83	-74	-58	-49	-40	
	57	-86	-77	-58	-48	-40	
	56	-88	-78	-59	-48	-40	
	55	-88	-78	-59	-49	-40	
	54	-86	-78	-58	-49	-41	
	53	-85	-78	-59	-49	-41	
	52	-90	-78	-59	-49	-41	
	≤ 51	-90	-78	-59	-49	-41	

Block C r_C (dB)		C (dBm)					
		-70	-50	-30	-20	≥-12	
DTT channel	60	-74	-66	-52	-42	-35	
	59	-83	-76	-58	-49	-40	
	58	-86	-77	-59	-48	-40	
	57	-88	-78	-59	-49	-40	
	56	-89	-78	-59	-49	-41	
	55	-82	-76	-59	-49	-41	
	54	-89	-78	-59	-49	-41	
	53	-90	-78	-59	-49	-41	
	52	-90	-78	-59	-49	-41	
	≤ 51	-90	-78	-59	-49	-41	

Annex 3

Protection ratios: Communal aerial systems

Introduction

A3.1 In this annex we present the MFCN to DTT protection ratios (class 8) used in this report for the modelling of the impact of interference on households in communal aerial systems (CAS).

A3.2 We first present the raw protection ratio measurements corresponding to a number of communal DTT amplifiers. We subsequently present the post-processed class-8 protection ratios.

A3.3 Note that a change in base station EIRP, or the use of filtering at the base station, result in a change in the MFCN signal's adjacent-channel leakage ratio (ACLR), and hence a change in the MFCN to DTT protection ratio. Furthermore, the use of filtering at the input to a DTT amplifier alters the receiver's overall adjacent-channel selectivity (ACS), and hence also changes the protection ratio. Post-processing is therefore required to adjust the measured protection ratios based on the prevailing interferer ACLR and receiver filter parameters.

A3.4 The presented post-processed protection ratios are associated with interference from MFCN blocks A, B, and C, into DTT channels 60 down to 51, for different values, *C*, of received DTT signal power. The protection ratios for channel 51 are used as proxies for channels 50 and below. Linear interpolation is used to derive protection ratios for intermediate values of *C*. The protection ratios for $C = -30$ dBm are used as proxies[37] for $C \geq -30$ dBm. Where required, linear interpolation is used to derive protection ratios for appropriate interferer-victim frequency separations.

Measured CAS protection ratios

A3.5 Table 48 to Table 60 show the protection ratios measured[38] in 2011 by ERA Technology for four CAS amplifiers feeding a DTT receiver. These relate to the performance of the receiver systems in the presence of both time-continuous (so-called "fully loaded") and time-discontinuous (so-called "idle") adjacent channel LTE interferers. The LTE test interferer has a 10 MHz bandwidth centred at 796 MHz. The ACLRs of the tested LTE signal are 59 dB over channel 60, and 69 dB over the lower DTT channels. The test set up is described in Annex 4 of our technical report published in June 2011.

A3.6 Measurements were performed in conjunction with 2 different DTT receivers in order to explore the impact of the DTT receiver itself on the measured protection ratios for the overall receiver system. The selected receivers were receiver #1 and receiver #4, as indicated in Annex 2 for standard domestic installations.

[37] This is in line with the assumed criterion for CAS amplifier back-off described in Annex 4 of our technical report published in June 2011.
[38] ERA, "TV Distribution Amplifier performance when interfered with by LTE base station and subsequent mitigation filter testing," technical report, February 2012, to be published in due course at http://stakeholders.ofcom.org.uk/consultations/second-coexistence-consultation/

A3.7 Note that CAS amplifier #1 is the device which was analysed in our technical report of June 2011[39]. CAS amplifiers #2, #3 and #4 are additional devices that have been measured since, in order to better account for the range of performance of CAS amplifiers in the UK market.

A3.8 Measure protection ratios are quoted to two decimal places for transparency of further calculations. Measurement uncertainty is of the order of 1 dB.

Table 48. Measured protection ratios for CAS amplifier #1, receiver #1, and "fully loaded" LTE interferer.

Block A r_A (dB)	*C* (dBm)				
	-70	-60	-50	-40	-30
co-channel	15.3	15.42	15.44	14.92	15.12
60	-36.95	-29.82	-22.09	-22.42	-22.45
59	-41.57	-35.01	-26.38	-26.22	-25.56
58	-44.11	-36.08	-27.33	-26.67	-26.47
57	-45.95	-37.13	-28.48	-27.21	-26.32
51	-46.86	-37.19	-28.11	-28.07	-26.85

Table 49. Measured protection ratios for CAS amplifier #2, receiver #1, and "fully loaded" LTE interferer.

Block A r_A (dB)	*C* (dBm)				
	-70	-60	-50	-40	-30
co-channel	15.46	15.71	15.47	15.3	15.3
60	-42.76	-41.7	-39.14	-32.54	-32.54
59	-50.9	-48.55	-43.92	-37.45	-37.45
58	-50.8	-50.57	-46.63	-39.2	-39.2
57	-51.77	-51.64	-47.62	-41.16	-41.16
51	-52.23	-52.13	-47.92	-41.1	-41.1

Table 50. Measured protection ratios for CAS amplifier #2, receiver #1, and "idle" LTE interferer.

Block A r_A (dB)	*C* (dBm)				
	-70	-60	-50	-40	-30
co-channel	12.56	11.12	11.62	11.7	11.7
60	-44.84	-43.99	-41.5	-34	-34
59	-52.92	-50.7	-46.13	-38.62	-38.62
58	-53.43	-53.95	-47.95	-39.44	-39.44
57	-54.13	-54	-50.01	-40.01	-40.01
51	-54.84	-54.32	-49.97	-40.85	-40.85

[39] At the time, this amplifier had been only measured in conjunction with receiver #1 and fully loaded LTE signals.

Table 51. Measured protection ratios for CAS amplifier #2, receiver #4, and “fully loaded” LTE interferer.

Block A r_A (dB)	*C* (dBm)				
	-70	-60	-50	-40	-30
co-channel	15.72	15.64	15.49	15.28	15.28
60	-39.09	-34.64	-36.16	-30.59	-30.59
59	-48.76	-42.6	-43.93	-36.53	-36.53
58	-41.77	-39.65	-39.66	-38.26	-38.26
57	-42.69	-37.78	-37.7	-38.26	-38.26
51	-51.65	-47.67	-49.46	-41.06	-41.06

Table 52. Measured protection ratios for CAS amplifier #2, receiver #4, and “idle” LTE interferer.

Block A r_A (dB)	*C* (dBm)				
	-70	-60	-50	-40	-30
co-channel	12.6	11.37	11.67	11.75	11.75
60	-38.49	-36	-37.76	-31.78	-31.78
59	-47.33	-43.63	-43.23	-37.98	-37.98
58	-44.14	-40.17	-40.92	-39.43	-39.43
57	-47.84	-44.17	-43.82	-40.27	-40.27
51	-54.99	-49.94	-49.86	-40.71	-40.71

Table 53. Measured protection ratios for CAS amplifier #3, receiver #1, and fully loaded LTE interferer.

Block A r_A (dB)	*C* (dBm)				
	-70	-60	-50	-40	-30
co-channel	15.94	15.91	15.62	15.91	15.91
60	-36.07	-28.02	-20.36	-21.1	-21.1
59	-41.43	-33.33	-25.29	-23.89	-23.89
58	-44.22	-35.34	-26.31	-26.01	-26.01
57	-45.13	-36.26	-27.23	-28.68	-28.68
51	-47.11	-37.25	-28.24	-24.57	-24.57

Table 54. Measured protection ratios for CAS amplifier #3, receiver #1, and “idle” LTE interferer.

Block A r_A (dB)	*C* (dBm)				
	-70	-60	-50	-40	-30
co-channel	12.64	11.41	12.14	11.44	11.44
60	-38.14	-29.03	-23.02	-22.5	-22.5
59	-43.86	-35.69	-27.65	-25.4	-25.4
58	-45.49	-36.88	-28.61	-27.27	-27.27
57	-47.42	-38.21	-29	-28.16	-28.16
51	-49.33	-39.25	-29.85	-25.08	-25.08

Table 55. Measured protection ratios for CAS amplifier #3, receiver #4, and "fully loaded" LTE interferer.

Block A r_A (dB)	*C* (dBm)				
	-70	-60	-50	-40	-30
co-channel	15.98	15.82	15.59	15.85	15.85
60	-33.76	-26.74	-20.34	-20.14	-20.14
59	-41.45	-32.34	-25.22	-22.92	-22.92
58	-37.26	-33.28	-26.3	-26.06	-26.06
57	-36.26	-34.35	-27.26	-27.77	-27.77
51	-46.12	-37.21	-28.29	-24.54	-24.54

Table 56. Measured protection ratios for CAS amplifier #3, receiver #4, and "idle" LTE interferer.

Block A r_A (dB)	*C* (dBm)				
	-70	-60	-50	-40	-30
co-channel	12.42	12.62	12.45	11.42	11.42
60	-34.99	-28.39	-21.72	-21.74	-21.74
59	-41.65	-34.67	-26.76	-25.35	-25.35
58	-38.64	-35.59	-28.65	-27.38	-27.38
57	-42.39	-37.31	-29.57	-29.14	-29.14
51	-48.36	-39.84	-29.68	-26.02	-26.02

Table 57. Measured protection ratios for CAS amplifier #4, receiver #1, and "fully loaded" LTE interferer.

Block A r_A (dB)	*C* (dBm)				
	-70	-60	-50	-40	-30
co-channel	15.73	15.66	15.64	15.64	15.64
60	-38.84	-31.15	-23.1	-23.1	-23.1
59	-42.85	-34.74	-26.11	-26.11	-26.11
58	-45.82	-36.6	-27.09	-27.09	-27.09
57	-46.8	-37.62	-28.1	-28.1	-28.1
51	-47.75	-38.44	-28.11	-28.11	-28.11

Table 58. Measured protection ratios for CAS amplifier #4, receiver #1, and "idle" LTE interferer.

Block A r_A (dB)	*C* (dBm)				
	-70	-60	-50	-40	-30
co-channel	12.49	12.31	12.4	12.4	12.4
60	-41.68	-33.41	-24.32	-24.32	-24.32
59	-45.35	-37.24	-28.39	-28.39	-28.39
58	-47.36	-38.96	-29.24	-29.24	-29.24
57	-49.26	-40.13	-30.47	-30.47	-30.47
51	-50.29	-40.38	-30.49	-30.49	-30.49

Table 59. Measured protection ratios for CAS amplifier #4, receiver #4, and “fully loaded” LTE interferer.

Block A r_A (dB)	*C* (dBm)				
	-70	-60	-50	-40	-30
co-channel	15.15	14.57	15.06	15.06	15.06
60	-34.84	-31.88	-23.28	-23.28	-23.28
59	-42.85	-34.89	-25.8	-25.8	-25.8
58	-40	-35.75	-27.85	-27.85	-27.85
57	-39.23	-36.74	-27.82	-27.82	-27.82
51	-46.97	-38.78	-28.89	-28.89	-28.89

Table 60. Measured protection ratios for CAS amplifier #4, receiver #4, and “idle” LTE interferer.

Block A r_A (dB)	*C* (dBm)				
	-70	-60	-50	-40	-30
co-channel	12.06	12.09	11.92	11.92	11.92
60	-35.76	-33.99	-24.63	-24.63	-24.63
59	-43.85	-36.61	-28.59	-28.59	-28.59
58	-41.51	-38.66	-29.56	-29.56	-29.56
57	-43.45	-39.35	-30.73	-30.73	-30.73
51	-49.47	-40.62	-30.34	-30.34	-30.34

Post-processed CAS protection ratios

A3.9 Table 61 to Table 64 show the post-processed (class 8) protection ratio values used for purposes of modelling in this document. These are based on the measured values presented above, which have been adjusted for the appropriate ACLR value in each case, and linearly interpolated for intermediate frequency offsets.

A3.10 Details of the post-processing procedure can be found in Annexes 3 and 4 of our technical report published in June 2011. The term post-processing refers to the mathematical adjustment of the measured protection ratios in order to account for the required ACLR values of the LTE interferer (which are not necessarily the same as those used in the measurement process), and any improvements in receiver selectivity due to the use of filtering.

A3.11 For each interferer-victim frequency offset and DTT signal power, the gap between the highest and lowest post-processed protection ratios is filled with nine classes of protection ratios (implying a total of 11 classes) with uniform spacing (see Figure 11 and the description in Section 6.

A3.12 For brevity, post-processed protection ratios are presented only for specific base station ACLRs (and hence EIRPs) which apply to the central scenario described in Section 8.

Table 61. Protection ratios (class 8) for CAS:
no mitigation, EIRP = 64 dBm/(10 MHz).

Block A r_A (dB)		*C* (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-37	-31	-26	-23	-23	-23
	59	-45	-37	-30	-27	-27	-27
	58	-42	-39	-32	-29	-29	-29
	57	-42	-41	-33	-30	-30	-30
	56	-43	-41	-34	-31	-30	-30
	55	-44	-42	-34	-30	-30	-30
	54	-46	-43	-34	-30	-30	-30
	53	-48	-43	-34	-29	-29	-29
	52	-50	-44	-34	-29	-29	-29
	≤ 51	-51	-44	-34	-29	-29	-29

Block B r_B (dB)		*C* (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-42	-37	-31	-27	-27	-27
	59	-42	-39	-32	-30	-29	-29
	58	-42	-41	-33	-30	-30	-30
	57	-43	-42	-34	-31	-30	-30
	56	-45	-42	-34	-30	-30	-30
	55	-47	-43	-34	-30	-30	-30
	54	-49	-43	-34	-29	-29	-29
	53	-50	-44	-34	-29	-29	-29
	52	-51	-44	-34	-29	-29	-29
	≤ 51	-51	-44	-34	-29	-29	-29

Block C r_C (dB)		*C* (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-39	-38	-32	-30	-29	-29
	59	-42	-40	-33	-30	-30	-30
	58	-43	-42	-34	-30	-30	-30
	57	-45	-42	-34	-30	-30	-30
	56	-47	-43	-34	-29	-29	-29
	55	-49	-44	-34	-29	-29	-29
	54	-51	-44	-34	-29	-29	-29
	53	-51	-44	-34	-29	-29	-29
	52	-51	-44	-34	-29	-29	-29
	≤ 51	-51	-44	-34	-29	-29	-29

Table 62. Protection ratios (class 8) for CAS: DTT Rx filtering, EIRP = 64 dBm/(10 MHz).

	Block A r_A (dB)	C (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-47	-48	-47	-47	-47	-47
	59	-57	-58	-58	-58	-58	-58
	58	-67	-68	-68	-67	-67	-67
	57	-77	-78	-77	-77	-77	-77
	56	-86	-86	-83	-83	-82	-82
	55	-94	-92	-87	-84	-84	-84
	54	-99	-95	-88	-84	-84	-84
	53	-103	-97	-89	-84	-84	-84
	52	-105	-98	-89	-83	-83	-83
	≤ 51	-106	-98	-89	-83	-83	-83

	Block B r_B (dB)	C (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-47	-48	-48	-48	-48	-48
	59	-57	-58	-58	-58	-58	-58
	58	-67	-68	-68	-68	-68	-68
	57	-77	-78	-77	-77	-77	-77
	56	-87	-87	-85	-84	-84	-84
	55	-96	-95	-90	-87	-87	-87
	54	-103	-99	-92	-87	-87	-87
	53	-108	-101	-92	-87	-87	-87
	52	-109	-102	-93	-87	-87	-87
	≤ 51	-110	-102	-93	-87	-87	-87

	Block C r_C (dB)	C (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-47	-48	-48	-48	-48	-48
	59	-57	-58	-58	-58	-58	-58
	58	-67	-68	-68	-68	-68	-68
	57	-77	-78	-77	-77	-77	-77
	56	-87	-87	-85	-84	-84	-84
	55	-97	-95	-90	-87	-87	-87
	54	-104	-99	-92	-87	-87	-87
	53	-108	-101	-93	-87	-87	-87
	52	-110	-102	-93	-87	-87	-87
	≤ 51	-110	-102	-93	-87	-87	-87

Table 63. Protection ratios (class 8) for CAS:
BS Tx filtering, BS EIRP = 61 dBm/(10 MHz).

Block A r_A (dB)		*C* (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-40	-32	-26	-23	-23	-23
	59	-45	-37	-31	-27	-27	-27
	58	-42	-39	-32	-29	-29	-29
	57	-42	-41	-33	-30	-30	-30
	56	-43	-41	-34	-31	-30	-30
	55	-44	-42	-34	-30	-30	-30
	54	-46	-43	-34	-30	-30	-30
	53	-48	-43	-34	-29	-29	-29
	52	-50	-44	-34	-29	-29	-29
	≤ 51	-51	-44	-34	-29	-29	-29

Block B r_B (dB)		*C* (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-45	-38	-31	-27	-27	-27
	59	-42	-39	-32	-30	-29	-29
	58	-42	-41	-33	-30	-30	-30
	57	-43	-42	-34	-31	-30	-30
	56	-45	-42	-34	-30	-30	-30
	55	-47	-43	-34	-30	-30	-30
	54	-49	-43	-34	-29	-29	-29
	53	-50	-44	-34	-29	-29	-29
	52	-51	-44	-34	-29	-29	-29
	≤ 51	-51	-44	-34	-29	-29	-29

Block C r_C (dB)		*C* (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-42	-40	-33	-30	-30	-30
	59	-42	-41	-33	-30	-30	-30
	58	-44	-42	-34	-30	-30	-30
	57	-45	-43	-34	-30	-30	-30
	56	-47	-43	-34	-29	-29	-29
	55	-49	-44	-34	-29	-29	-29
	54	-51	-44	-34	-29	-29	-29
	53	-51	-44	-34	-29	-29	-29
	52	-51	-44	-34	-29	-29	-29
	≤ 51	-51	-44	-34	-29	-29	-29

Table 64. Protection ratios (class 8) for CAS:
DTT Rx filtering, BS Tx filtering, and BS EIRP = 61 dBm/(10 MHz).

Block A r_A (dB)		*C* (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-59	-57	-54	-53	-53	-53
	59	-69	-70	-69	-69	-69	-69
	58	-79	-79	-78	-78	-78	-78
	57	-88	-88	-84	-83	-83	-83
	56	-93	-93	-87	-85	-84	-84
	55	-98	-95	-88	-85	-85	-85
	54	-101	-97	-89	-84	-84	-84
	53	-103	-98	-89	-84	-84	-84
	52	-105	-98	-89	-83	-83	-83
	≤ 51	-106	-98	-89	-83	-83	-83

Block B r_B (dB)		*C* (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-70	-71	-70	-70	-70	-70
	59	-80	-81	-80	-80	-80	-80
	58	-89	-90	-87	-86	-86	-86
	57	-96	-95	-90	-88	-88	-88
	56	-101	-99	-92	-89	-88	-88
	55	-105	-101	-92	-88	-88	-88
	54	-107	-102	-92	-88	-88	-88
	53	-109	-102	-93	-87	-87	-87
	52	-110	-102	-93	-87	-87	-87
	≤ 51	-110	-102	-93	-87	-87	-87

Block C r_C (dB)		*C* (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-81	-81	-79	-79	-79	-79
	59	-91	-91	-87	-87	-86	-86
	58	-97	-96	-91	-89	-88	-88
	57	-102	-99	-92	-89	-89	-89
	56	-106	-101	-93	-88	-88	-88
	55	-108	-102	-93	-88	-88	-88
	54	-109	-102	-93	-87	-87	-87
	53	-110	-102	-93	-87	-87	-87
	52	-110	-102	-93	-87	-87	-87
	≤ 51	-110	-102	-93	-87	-87	-87

Annex 4

Protection ratios: Domestic installations with amplifiers

Introduction

A4.1 In this annex we present the MFCN to DTT protection ratios (class 8) used in this report for the modelling of the impact of interference on households with domestically installed amplifiers (DIA).

A4.2 We first present the raw protection ratio measurements corresponding to a number of domestic DTT amplifiers. We subsequently present the post-processed class-8 protection ratios.

A4.3 Note that a change in base station EIRP, or the use of filtering at the base station, result in a change in the MFCN signal's adjacent-channel leakage ratio (ACLR), and hence a change in the MFCN to DTT protection ratio. Furthermore, the use of filtering at the input to a DTT amplifier alters the receiver's overall adjacent-channel selectivity (ACS), and hence also changes the protection ratio. Post-processing is therefore required to adjust the measured protection ratios based on the prevailing interferer ACLR and receiver filter parameters.

A4.4 The presented post-processed protection ratios are associated with interference from MFCN blocks A, B, and C, into DTT channels 60 down to 51, for different values, *C*, of received DTT signal power. The protection ratios for channel 51 are used as proxies for channels 50 and below. Linear interpolation is used to derive protection ratios for intermediate values of *C*. The protection ratios for $C = -20$ dBm are used as proxies[40] for $C \geq -20$ dBm. Where required, linear interpolation is used to derive protection ratios for appropriate interferer-victim frequency separations.

Measured DIA protection ratios

A4.5 Table 65 to Table 77 show the protection ratios measured[41] in 2011 by ERA Technology for four domestic amplifiers feeding a DTT receiver. These relate to the performance of the receiver systems in the presence of both time-continuous (so-called "fully loaded") and time-discontinuous (so-called "idle") adjacent channel LTE interferers. The LTE test interferer has a 10 MHz bandwidth centred at 796 MHz. The ACLRs of the tested LTE signal are 59 dB over channel 60, and 69 dB over the lower DTT channels. The test set up is described in Annex 5 of our technical report published in June 2011.

A4.6 Measurements were performed in conjunction with 2 different DTT receivers in order to explore the impact of the DTT receiver itself on the measured protection ratios for the overall receiver system. The selected receivers were receiver #1 and receiver #4, as indicated in Annex 2 for standard domestic installations.

[40] This is in line with the arguments described in Annex 5 of our technical report published in June 2011.

[41] ERA, "TV Distribution Amplifier performance when interfered with by LTE base station and subsequent mitigation filter testing," technical report, February 2012, to be published in due course at http://stakeholders.ofcom.org.uk/consultations/second-coexistence-consultation/

A4.7 Note that domestic amplifier #1 is the device which was analysed in our technical report of June 2011[42]. Domestic amplifiers #2, #3 and #4 are additional devices that have been measured since, in order to better account for the range of performance of domestic amplifiers in the UK market.

A4.8 Measured protection ratios are quoted to two decimal places for transparency of further calculations. Measurement uncertainty is of the order of 1 dB.

Table 65. Measured protection ratios for domestic amplifier #1, receiver #1, and "fully loaded" LTE interferer.

Block A *r* (dB)	*C* (dBm)					
	-70	-60	-50	-40	-30	-20
co-channel	14.54	14.86	15.01	15.05	14.98	14.86
60	-42.33	-40.23	-33.14	-24.97	-18.11	-9.87
59	-50.26	-46.21	-39.17	-30.89	-21	-11.72
58	-50.3	-48.13	-40.7	-30.93	-21.79	-11.6
57	-51.47	-49.14	-41.38	-31.03	-20.84	-11.7
51	-52.99	-50.06	-41.22	-31.21	-20.86	-11.61

Table 66. Measured protection ratios for domestic amplifier #2, receiver #1, and "fully loaded" LTE interferer.

Block A *r* (dB)	*C* (dBm)					
	-70	-60	-50	-40	-30	-20
co-channel	15.77	15.84	15.93	15.89	15.9	15.89
60	-41.55	-41.75	-35.65	-29.05	-21.02	-13
59	-49.33	-48.61	-40.59	-33	-24.04	-14.71
58	-50.27	-50.57	-42.48	-33.94	-25.05	-14.84
57	-51.35	-51.65	-44.45	-34.95	-25.01	-14.92
51	-53.17	-52.51	-43.54	-34.01	-24.07	-13.93

Table 67. Measured protection ratios for domestic amplifier #2, receiver #1, and "idle" LTE interferer.

Block A *r* (dB)	*C* (dBm)					
	-70	-60	-50	-40	-30	-20
co-channel	11.71	11.75	11.71	11.71	11.89	11.98
60	-48.96	-46.25	-37.65	-30.6	-22.37	-15.3
59	-51.86	-51.58	-43.11	-35.4	-26.66	-15.52
58	-55.7	-53.03	-44.87	-36.23	-26.71	-17.04
57	-57.5	-55.37	-45.73	-36.44	-26.64	-17.19
51	-60.29	-55.61	-45.95	-36.34	-26.6	-16.26

[42] At the time, this amplifier had been only measured in conjunction with receiver #1 and fully loaded LTE signals.

Table 68. Measured protection ratios for domestic amplifier #2, receiver #4, and “fully loaded” LTE interferer.

Block A r (dB)	C (dBm)					
	-70	-60	-50	-40	-30	-20
co-channel	15.89	15.83	15.92	15.89	15.87	15.93
60	-35.41	-35.72	-33.65	-28.07	-21.05	-12.97
59	-44.29	-46.62	-40.68	-32.98	-24.14	-14.84
58	-38.36	-38.68	-37.48	-33.95	-25.04	-14.85
57	-36.29	-37.73	-35.53	-32.93	-25.08	-14.93
51	-49.25	-50.52	-43.54	-33.99	-24	-13.9

Table 69. Measured protection ratios for domestic amplifier #2, receiver #4, and “idle” LTE interferer.

Block A r (dB)	C (dBm)					
	-70	-60	-50	-40	-30	-20
co-channel	11.76	11.72	11.97	12.1	11.83	11.91
60	-35.7	-36.82	-35	-29.38	-22.12	-15.45
59	-41.79	-42.71	-41.07	-34.03	-26.49	-16.35
58	-39.8	-39.72	-38.91	-35.37	-26.28	-17.13
57	-42.01	-43.71	-41.88	-36.18	-27.18	-17.56
51	-52.98	-53.95	-44.92	-36.56	-26.71	-16.49

Table 70. Measured protection ratios for domestic amplifier #3, receiver #1, and “fully loaded” LTE interferer.

Block A r (dB)	C (dBm)					
	-70	-60	-50	-40	-30	-20
co-channel	15.89	15.97	15.99	15.94	15.95	15.32
60	-41.62	-36.75	-28.89	-21.86	-14	-6.03
59	-49.09	-42.82	-34.63	-25.75	-16.01	-7.03
58	-50.99	-44.73	-36.83	-27.76	-17.03	-8.04
57	-51.78	-46.79	-37.7	-27.83	-18.06	-8.07
51	-52.26	-45.68	-35.72	-25.75	-15.99	-5.95

Table 71. Measured protection ratios for domestic amplifier #3, receiver #1, and “idle” LTE interferer.

Block A r (dB)	C (dBm)					
	-70	-60	-50	-40	-30	-20
co-channel	11.73	11.96	11.81	11.84	11.89	11.95
60	-45.44	-38.92	-31.56	-23.83	-15.35	-7.64
59	-51.25	-44.74	-36.94	-28.11	-17.35	-7.31
58	-53.95	-47	-38.17	-28.04	-18.29	-8.44
57	-56.35	-48.9	-38.85	-29.33	-19.36	-9.13
51	-56.44	-47.9	-37.25	-27.11	-17	-7.67

Table 72. Measured protection ratios for domestic amplifier #3, receiver #4, and "fully loaded" LTE interferer.

Block A *r* (dB)	*C* (dBm)					
	-70	-60	-50	-40	-30	-20
co-channel	15.83	15.94	15.95	15.9	15.98	15.32
60	-36.5	-33.7	-28.8	-21.85	-14.03	-6.05
59	-46.12	-41.84	-34.62	-25.72	-16.02	-7.06
58	-40.03	-39.82	-34.73	-26.81	-17.09	-8.08
57	-38.72	-38.91	-34.75	-27.79	-18.1	-8.09
51	-48.61	-45.7	-35.72	-25.78	-16.05	-5.99

Table 73. Measured protection ratios for domestic amplifier #3, receiver #4, and "idle" LTE interferer.

Block A *r* (dB)	*C* (dBm)					
	-70	-60	-50	-40	-30	-20
co-channel	12.05	11.96	11.87	12.06	12.34	12.14
60	-38.08	-35.48	-30.52	-22.82	-15.28	-7.61
59	-45.75	-42.45	-35.92	-27.2	-17.24	-8.57
58	-39.58	-41.57	-36.69	-28.39	-18.38	-8.5
57	-46.04	-45.12	-38.01	-29.12	-19.26	-9.45
51	-53.87	-47.8	-37.16	-26.97	-17.24	-7.27

Table 74. Measured protection ratios for domestic amplifier #4, receiver #1, and "fully loaded" LTE interferer.

Block A *r* (dB)	*C* (dBm)					
	-70	-60	-50	-40	-30	-20
co-channel	15.43	15.48	15.9	15.92	15.53	15.09
60	-41.93	-39.03	-33.05	-26.05	-17.96	-9.41
59	-47.23	-46.15	-39.11	-30.12	-20.7	-11.46
58	-49.31	-48.2	-40.13	-31.11	-20.55	-11.4
57	-50.08	-49.03	-41.17	-31.1	-20.48	-11.4
51	-52.24	-51.09	-41.16	-31.15	-20.48	-11.37

Table 75. Measured protection ratios for domestic amplifier #4, receiver #1, and "idle" LTE interferer.

Block A *r* (dB)	*C* (dBm)					
	-70	-60	-50	-40	-30	-20
co-channel	11.9	12.31	11.92	11.85	11.92	11.84
60	-46.26	-41.33	-34.43	-27.31	-20.34	-12.22
59	-49.34	-45.51	-41.45	-32.32	-23.34	-12.71
58	-52.78	-50.24	-42.68	-32.38	-23.21	-12.86
57	-54.4	-51.37	-42.7	-32.39	-23.08	-12.81
51	-56.31	-52.34	-42.68	-32.46	-23.18	-12.67

Table 76. Measured protection ratios for domestic amplifier #4, receiver #4, and “fully loaded” LTE interferer.

Block A *r* (dB)	*C* (dBm)					
	-70	-60	-50	-40	-30	-20
co-channel	15.38	15.35	15.77	15.91	15.53	15.07
60	-34.84	-33.03	-32.22	-25.06	-17.97	-9.42
59	-44.2	-42.25	-39.18	-30.08	-20.69	-11.48
58	-38.28	-38.25	-38.11	-30.05	-20.57	-11.43
57	-37.16	-37.2	-37.14	-30.18	-20.42	-11.43
51	-49.22	-46.11	-41.16	-31.13	-20.47	-11.42

Table 77. Measured protection ratios for domestic amplifier #4, receiver #4, and “idle” LTE interferer.

Block A *r* (dB)	*C* (dBm)					
	-70	-60	-50	-40	-30	-20
co-channel	11.89	11.96	12.09	11.74	11.96	11.93
60	-36.23	-34.11	-32.78	-26.47	-19.5	-11.76
59	-42.59	-43.14	-39.55	-31.6	-21.85	-12.86
58	-39.31	-39.77	-39.52	-32.44	-22.99	-12.84
57	-43.76	-42.64	-41.53	-32.52	-23.03	-12.78
51	-52.31	-48.57	-43.58	-32.38	-22.79	-12.64

Post-processed DIA protection ratios

A4.9 Table 78 to Table 81 show the post-processed (class 8) protection ratio values used for purposes of modelling in this document. These are based on the measured values presented above, which have been adjusted for the appropriate ACLR value in each case, and linearly interpolated for intermediate frequency offsets.

A4.10 Details of the post-processing procedure can be found in Annexes 3 and 5 of our technical report published in June 2011. The term post-processing refers to the mathematical adjustment of the measured protection ratios in order to account for the required ACLR values of the LTE interferer (which are not necessarily the same as those used in the measurement process), and any improvements in receiver selectivity due to the use of filtering.

A4.11 For each interferer-victim frequency offset and DTT signal power, the gap between the highest and lowest post-processed protection ratios is filled with nine classes of protection ratios (implying a total of 11 classes) with uniform spacing (see Figure 12 and the description in Section 6.

A4.12 For brevity, post-processed protection ratios are presented only for specific base station ACLRs (and hence EIRPs) which apply to the central scenario described in Section 8.

Table 78. Protection ratios (class 8) for DIA: no mitigation, EIRP of 64 dBm/(10 MHz).

Block A	r_A (dB)	*C* (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-39	-37	-31	-23	-15	-8
	59	-44	-44	-36	-28	-18	-9
	58	-45	-42	-37	-29	-19	-10
	57	-45	-44	-37	-29	-20	-10
	56	-46	-44	-37	-29	-20	-10
	55	-48	-46	-37	-29	-19	-9
	54	-51	-49	-38	-29	-19	-9
	53	-54	-54	-38	-28	-19	-8
	52	-56	-50	-38	-28	-18	-8
	≤ 51	-57	-50	-38	-28	-18	-8

Block B	r_B (dB)	*C* (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-43	-42	-36	-28	-18	-9
	59	-44	-42	-37	-29	-19	-10
	58	-45	-43	-37	-29	-20	-10
	57	-47	-44	-37	-29	-20	-10
	56	-49	-47	-37	-29	-19	-9
	55	-52	-50	-38	-29	-19	-9
	54	-54	-49	-38	-28	-18	-8
	53	-56	-50	-38	-28	-18	-8
	52	-57	-50	-38	-28	-18	-8
	≤ 51	-57	-50	-38	-28	-18	-8

Block C	r_C (dB)	*C* (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-40	-40	-37	-29	-19	-10
	59	-43	-43	-37	-29	-20	-10
	58	-46	-45	-37	-29	-19	-10
	57	-51	-47	-37	-29	-19	-9
	56	-52	-51	-38	-28	-19	-9
	55	-55	-50	-38	-28	-18	-8
	54	-57	-50	-38	-28	-18	-8
	53	-57	-50	-38	-28	-18	-8
	52	-57	-50	-38	-28	-18	-8
	≤ 51	-57	-50	-38	-28	-18	-8

Table 79. Protection ratios (class 8) for DIA:
DTT Rx filtering, EIRP = 64 dBm/(10 MHz).

Block A r_A (dB)		*C* (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-46	-46	-43	-37	-30	-22
	59	-58	-57	-57	-55	-50	-41
	58	-66	-67	-65	-60	-51	-42
	57	-71	-72	-69	-62	-52	-42
	56	-75	-75	-70	-62	-52	-42
	55	-80	-78	-70	-62	-52	-42
	54	-83	-81	-70	-61	-52	-42
	53	-86	-87	-70	-61	-51	-41
	52	-88	-83	-70	-61	-51	-41
	≤ 51	-90	-83	-70	-61	-51	-41

Block B r_B (dB)		*C* (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-48	-47	-47	-46	-41	-33
	59	-57	-57	-57	-56	-50	-41
	58	-66	-66	-65	-60	-51	-42
	57	-72	-72	-68	-61	-51	-41
	56	-77	-76	-69	-61	-51	-41
	55	-82	-80	-69	-60	-51	-41
	54	-86	-81	-70	-60	-50	-40
	53	-88	-82	-70	-60	-50	-40
	52	-89	-82	-70	-60	-50	-40
	≤ 51	-89	-82	-70	-60	-50	-40

Block C r_C (dB)		*C* (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-47	-47	-47	-47	-43	-35
	59	-57	-57	-57	-56	-50	-42
	58	-66	-67	-65	-60	-51	-41
	57	-74	-73	-69	-61	-51	-41
	56	-80	-78	-69	-60	-51	-41
	55	-85	-81	-70	-60	-50	-40
	54	-88	-82	-70	-60	-50	-40
	53	-89	-82	-70	-60	-50	-40
	52	-89	-82	-70	-60	-50	-40
	≤ 51	-89	-82	-70	-60	-50	-40

Table 80. Protection ratios (class 8) for DIA:
BS Tx filtering, BS EIRP = 61 dBm/(10 MHz).

	Block A r_A (dB)	*C* (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-42	-40	-31	-23	-15	-8
	59	-44	-44	-36	-28	-18	-9
	58	-45	-42	-37	-29	-19	-10
	57	-45	-44	-37	-29	-20	-10
	56	-46	-44	-37	-29	-20	-10
	55	-48	-46	-37	-29	-19	-9
	54	-51	-49	-38	-29	-19	-9
	53	-54	-54	-38	-28	-19	-8
	52	-56	-50	-38	-28	-18	-8
	≤ 51	-57	-50	-38	-28	-18	-8

	Block B r_B (dB)	*C* (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-45	-44	-36	-28	-18	-9
	59	-46	-43	-37	-29	-19	-10
	58	-45	-44	-37	-29	-20	-10
	57	-47	-44	-37	-29	-20	-10
	56	-49	-47	-37	-29	-19	-9
	55	-52	-50	-38	-29	-19	-9
	54	-54	-49	-38	-28	-18	-8
	53	-56	-50	-38	-28	-18	-8
	52	-57	-50	-38	-28	-18	-8
	≤ 51	-57	-50	-38	-28	-18	-8

	Block C r_C (dB)	*C* (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-44	-43	-37	-29	-19	-10
	59	-46	-44	-37	-29	-20	-10
	58	-47	-45	-37	-29	-19	-10
	57	-56	-47	-37	-29	-19	-9
	56	-52	-51	-38	-28	-19	-9
	55	-55	-50	-38	-28	-18	-8
	54	-57	-50	-38	-28	-18	-8
	53	-57	-50	-38	-28	-18	-8
	52	-57	-50	-38	-28	-18	-8
	≤ 51	-57	-50	-38	-28	-18	-8

Table 81. Protection ratios (class 8) for DIA:
DTT Rx filtering, BS Tx filtering, and BS EIRP = 61 dBm/(10 MHz).

Block A	r_A (dB)	C (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-52	-51	-45	-38	-30	-22
	59	-69	-69	-66	-60	-51	-41
	58	-73	-73	-69	-61	-51	-42
	57	-75	-75	-70	-62	-52	-42
	56	-78	-77	-70	-62	-52	-42
	55	-81	-78	-70	-62	-52	-42
	54	-83	-81	-70	-61	-52	-42
	53	-86	-87	-70	-61	-51	-41
	52	-88	-83	-70	-61	-51	-41
	≤ 51	-90	-83	-70	-61	-51	-41

Block B	r_B (dB)	C (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-67	-66	-60	-52	-43	-34
	59	-73	-72	-68	-61	-51	-41
	58	-75	-75	-69	-61	-51	-42
	57	-78	-76	-69	-61	-51	-41
	56	-81	-78	-69	-61	-51	-41
	55	-83	-81	-69	-60	-51	-41
	54	-86	-81	-70	-60	-50	-40
	53	-88	-82	-70	-60	-50	-40
	52	-89	-82	-70	-60	-50	-40
	≤ 51	-89	-82	-70	-60	-50	-40

Block C	r_C (dB)	C (dBm)					
		-70	-60	-50	-40	-30	≥ -20
DTT channel	60	-68	-67	-62	-54	-44	-35
	59	-75	-75	-69	-61	-52	-42
	58	-79	-77	-69	-61	-51	-41
	57	-84	-79	-69	-61	-51	-41
	56	-84	-82	-69	-60	-51	-41
	55	-87	-81	-70	-60	-50	-40
	54	-88	-82	-70	-60	-50	-40
	53	-89	-82	-70	-60	-50	-40
	52	-89	-82	-70	-60	-50	-40
	≤ 51	-89	-82	-70	-60	-50	-40

Annex 5

ACLR sensitivity analysis

Introduction

A5.1 In this section we consider the effect of varying the ACLR (adjacent channel leakage ratio) of the interfering signal, in order to understand the impact that this may have on the protection ratio values.

A5.2 As outlined in Section 5, we have assumed in our modelling that the out-of-band emissions of MFCN base stations “roll off” (i.e. absolute emissions decrease, and ACLR increases) with increasing frequency separation. Specifically, in case (a) (an EIRP of 64 dBm/(10 MHz) and no base station filtering) we assume an ACLR of 64 dB in DTT channel 60, and an increase in ACLR of 10 dB for each lower DTT channel. This is illustrated in Figure 5 in Section 5.

A5.3 In this annex we consider an ACLR value of 64 dB across all DTT channels (i.e. frequency independent) This is expected to cause an increase to the protection ratio values.

Results

A5.4 In Table 82 to Table 84 values for *delta* (*Δ*) for the 3 installation categories are presented, where *delta* is defined as the increase in protection ratio values if a frequency indepent ACLR is assumed, when compared with the protection ratios for case (a) presented in Annexes 2 to 4, which assume a frequency dependent ACLR.

Table 82: Increase in protection ratios for SDI case (a) if a frequency independent ACLR is assumed

Block A Δ(dB)		C (dBm)				
		-70	-50	-30	-20	≥-12
DTT channel	60	0	0	0	0	0
	59	2.64	1.26	0	0	0
	58	4.16	1.49	0	0	0
	57	7.12	1.72	0	0	0
	56	8.51	2.22	0	0	0
	55	9.48	2.58	0	0	0
	54	10.19	2.74	0	0	0
	53	11.89	2.62	0	0	0
	52	7.59	2.66	0	0	0
	≤ 51	11.54	2.84	0	0	0

Block B Δ (dB)		C (dBm)				
		-70	-50	-30	-20	-12
DTT channel	60	0	0	0	0	0
	59	3.73	1.48	0	0	0
	58	6.78	1.74	0	0	0
	57	8.61	2.26	0	0	0
	56	9.67	2.68	0	0	0
	55	10.35	2.76	0	0	0
	54	8.24	2.61	0	0	0
	53	7.85	2.65	0	0	0
	52	11.58	2.83	0	0	0
	≤ 51	11.58	3.05	0	0	0

Block C Δ (dB)		C (dBm)				
		-70	-50	-30	-20	-12
DTT channel	60	0	0	0	0	0
	59	4.73	1.52	0	0	0
	58	7.97	2.29	0	0	0
	57	9.67	2.71	0	0	0
	56	10.67	2.72	0	0	0
	55	7.28	1.97	0	0	0
	54	11.31	2.72	0	0	0
	53	11.61	2.8	0	0	0
	52	11.58	3.04	0	0	0
	≤ 51	11.63	3.03	0	0	0

Table 83: Increase in protection ratios for CAS case (a) if a frequency independent ACLR is assumed

Block A Δ(dB)		*C* (dBm)					
		-70	-60	-50	-40	-30	-20
DTT channel	60	0	0	0	0	0	0
	59	2.24	0.82	0	0	0	0
	58	2.48	1.85	0.54	0	0	0
	57	2.97	2.51	0.85	0	0	0
	56	3.23	2.84	0.85	0	0	0
	55	3.56	3.12	0.85	0	0	0
	54	4.02	3.36	0.85	0	0	0
	53	4.65	3.54	0.85	0	0	0
	52	5.33	3.65	0.85	0	0	0
	≤ 51	6	3.66	1.19	0	0	0

Block B Δ (dB)		*C* (dBm)					
		-70	-60	-50	-40	-30	-20
DTT channel	60	0	0	0	0	0	0
	59	2.06	1.56	0.54	0	0	0
	58	2.94	2.43	0.84	0	0	0
	57	3.29	2.89	0.85	0	0	0
	56	3.66	3.18	0.85	0	0	0
	55	4.17	3.41	0.85	0	0	0
	54	4.82	3.57	0.85	0	0	0
	53	5.56	3.67	0.92	0	0	0
	52	6	3.66	1.19	0	0	0
	≤ 51	6	3.66	1.19	0	0	0

Block C Δ (dB)		*C* (dBm)					
		-70	-60	-50	-40	-30	-20
DTT channel	60	0	0	0	0	0	0
	59	2.31	1.61	0.74	0	0	0
	58	3.26	2.76	0.84	0	0	0
	57	3.76	3.22	0.85	0	0	0
	56	4.32	3.45	0.85	0	0	0
	55	5	3.6	0.85	0	0	0
	54	5.79	3.68	1.07	0	0	0
	53	6	3.66	1.19	0	0	0
	52	6	3.66	1.19	0	0	0
	≤ 51	6	3.66	1.19	0	0	0

Table 84: Increase in protection ratios for DIA case (a) if a frequency independent ACLR is assumed

Block A	Δ(dB)	C (dBm)					
		-70	-60	-50	-40	-30	-20
DTT channel	60	0	0	0	0	0	0
	59	1.34	1.74	0	0	0	0
	58	3.71	1.94	0	0	0	0
	57	5.71	3.41	0	0	0	0
	56	6.1	3.58	0.5	0	0	0
	55	6.54	4.32	0.51	0	0	0
	54	7.21	5.74	0.53	0	0	0
	53	8.31	10.21	0.54	0	0	0
	52	9.41	5.2	0.55	0	0	0
	≤ 51	10.6	5.41	0.55	0	0	0

Block B	Δ (dB)	C (dBm)					
		-70	-60	-50	-40	-30	-20
DTT channel	60	0	0	0	0	0	0
	59	3.06	1.81	0	0	0	0
	58	5.14	3.32	0	0	0	0
	57	6.09	3.61	0.5	0	0	0
	56	6.67	4.61	0.52	0	0	0
	55	7.44	6.26	0.53	0	0	0
	54	8.63	4.79	0.54	0	0	0
	53	9.73	5.28	0.55	0	0	0
	52	10.6	5.41	0.55	0	0	0
	≤ 51	10.6	5.41	0.55	0	0	0

Block C	Δ (dB)	C (dBm)					
		-70	-60	-50	-40	-30	-20
DTT channel	60	0	0	0	0	0	0
	59	3.08	2.5	0	0	0	0
	58	5.44	3.53	0.5	0	0	0
	57	8.47	4.85	0.52	0	0	0
	56	7.68	6.89	0.53	0	0	0
	55	8.89	4.98	0.54	0	0	0
	54	10.18	5.35	0.55	0	0	0
	53	10.6	5.41	0.55	0	0	0
	52	10.6	5.41	0.55	0	0	0
	≤ 51	10.6	5.41	0.55	0	0	0

A5.5 As expected, use of a flat ACLR can cause an increase in protection ratio when compared with a roll-off of 10 dB per DTT channel. This increase (*delta*) varies with installation category, DTT channel and DTT signal strength, with maximum increases of 11 – 12 dB in extreme cases.

A5.6 Higher values of *delta* are seen for lower DTT channels – this is as expected as the difference in ACLR is greatest for channel 51. For SDI, delta is lower for 'n+9' offsets (e.g. block A into channel 52) when compared with surrounding offsets. This can be explained by the fact that for these offsets ACS is expected to contribute to interference as well as ACLR, whereas ACLR will be the dominant mechanism for other offsets.

A5.7 Values of *delta* for channel 60 are always zero as the ACLR is unchanged for this channel.

A5.8 It is clear that the variation is heavily dependent on the value of DTT signal strength, *C*. For intermediate and high values of signal strength (C ≥ -50dBm) *delta* is zero or negligible in all cases. The highest values of *delta* correspond to low values of DTT signal strength (C = -70dBm). This can be explained by the fact that for higher values of DTT signal strength the overload interference mechanism is expected to be the dominant effect. As overload is a function of the interferer's in-block EIRP and not the out-of-band emissions, any changes in ACLR will not affect the protection ratio values.

A5.9 The highest values of *delta* (11 – 12 dB) are seen for SDI and DIA, for larger frequency offsets and low values of DTT signal strength.

Conclusions

A5.10 The analysis presented in this Annex shows the effect of a flat ACLR on the protection ratio values used in the modelling. It has been shown that the maximum increase in protection ratio is of the order of 11 – 12dB.

A5.11 While the increases may seem large for the extreme cases in lower DTT channels, it should be noted that a frequency independent ACLR is highly unrealistic and unlikely to exist in practice.