Interference from LTE handsets to DTT services

A report for Ofcom

Interference from LTE handsets to DTT services

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ÆGIS spectrum engineering

Table of Contents

1 INTRODUCTION

This report to Ofcom describes modelling undertaken to estimate the degree to which the UK DTT network might experience interference due to emissions from LTE handsets (or 'User Equipment', 'UE') operating in potentially 're-farmed' spectrum above 703 MHz.

The modelling takes an existing set of UK DTT network predictions as a starting point, and evaluates the effect of LTE interference on this DTT network.

The assumptions and parameters were specified by Ofcom and explicitly reflect (i) the spread in receiver performance and (ii) some of the proposed regulatory limits of 700 MHz UE emissions under discussion in the ECC.

2 MODEL FRAMEWORK

Ofcom and the DTT Frequency Planning Group (DFPG) have developed a tentative plan for DTT services in the UK following the potential release of the 700 MHz band (i.e. with DTT transmissions confined to channels 21-48 (470 – 794 MHz)). This planning has involved the use of the 'UK Planning Model (UKPM) which enshrines the propagation models, algorithms and planning criteria agreed between the broadcasters and Ofcom[1].

The UKPM produces a file giving, for each 100m pixel in the UK, a prediction of the median wanted and interfering DTT fields in each pixel, together with their location variabilities; The DTT interfering field includes contributions from all significant sources, each weighted by the angular discrimination of the domestic receive aerial, and by the protection ratio applicable for each specific frequency offset. The location probability of coverage in each pixel can be determined from the relationship between the wanted and unwanted field strength distributions, and this probability is used to determine the number of households served in the pixel, on the basis of census data. In the UK, a pixel is currently assumed to be served where the coverage probability is 70% or greater for 99% of the time.

Software has been written (in C++) which allows these UKPM results to be post-processed to determine possible levels of interference from LTE handsets operating at 700 MHz. The modelling described in this paper has been based on the UKPM output file 'UKPM_7v006_01_dAPSA.csv' for 1% time, as supplied by Ofcom.

The simple assumption is made[2] that the only significant coupling between a UE and the DTT receiver is via an outdoor slant path of 23.6 m (22m horizontal

[1] See: Brown P. G., Tsioumparakis K., Jordan M. S. A., and Chong A., 2002. UK Planning Model for Digital Terrestrial Television Coverage. Proceedings of the International Broadcasting Convention (IBC) 2002. (Also published as BBC Research & Development White Paper, WHP048.)

[2] As in ITU-R contribution 4-5-6-7/91 (November 2012)

separation) to the rooftop antenna. It is further assumed that the UE lies in the same direction as the wanted DTT transmitter so that no discrimination in azimuth is offered to signals from the handset. A small correction (0.45dB) is made to allow for the vertical discrimination of the receive antenna (according to the radiation pattern given in ITU-R BT.419); this correction is shown as *VRP(d, Δh*) in Eq.1 below, where d is the horizontal distance and Δh the differtence between transmit and receive antenna heights*).* Free-space propagation is assumed.

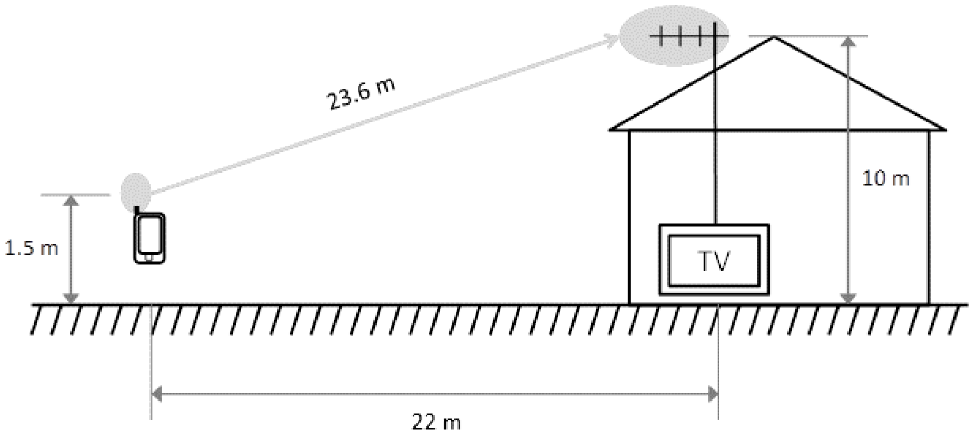

Figure 2.1: Assumed interference geometry

The interference impact is determined by applying the protection ratio appropriate to the specific frequency offset *(Δf*) between the UE interference and the most susceptible (i.e. highest frequency) multiplex in each pixel. If the assumed median field strength is weighted by the protection ratio to give the 'nuisance field strength' (E_{n_LTE}) it can be combined with the DTT intra-system interference to give the overall interference environment (*En*) seen by the receiver.

$$E_{n\_LTE} = E_{LTE} - VRP(d, \Delta h) - PR(\Delta f) \qquad Eq.1$$

$$E_n = \Sigma_{S\&Y}(E_{n\_DTT}, E_{n\_LTE}) \qquad Eq.2$$

The UKPM sums the intra-system interference on the assumption that all signals are log-normally distributed and that their aggregate is also a log-normal variable. The moments of this aggregate cannot be determined in closed-form, but can be approximated in a number of ways or determined by Monte Carlo methods. In the UKPM, and in the Aegis software, the Schwartz-Yeh[3] approximation is applied. This uses numerical integration in an iterative structure to determine the first and second moments of the aggregate interference (shown as $\Sigma_{S\&Y}()$ in Eq.2) .

The Aegis software determines the location coverage in each pixel due to the combination of assumed LTE interference and UKPM-predicted DTT interference:

$$q = 1 - \frac{1}{2} erfc\left[\frac{1}{2} * \frac{Ew - En}{\sqrt{\sigma w^2 + \sigma n^2}}\right] \qquad Eq.3$$

[3] Schwartz S. C. and Yeh Y. S., 1982. On the Distribution Function and Moments of Power Sums with Log-Normal Components. Bell System Technical Journal, September 1982

where E_w and σ_w are the median and standard deviation of the wanted DTT field strength respectively.

The UKPM output includes the number of households in each 100m x 100m pixel, and this figure is weighted by the degradation in coverage to give a model output in terms of the *'number of households lost due to UE interference*' for the particular set of input assumptions.

The predictions made by the software can be displayed graphically, as shown in the figures below.The example given relates to a prediction made (see below) for the case of UEs operating at +23dBm eirp, an OOB emission limit of -42dBm/8 MHz and median DTT receiver performance.

In the left-hand plot, the effect of interference is shown in terms of the reduction in coverage probability in each pixel; the impact is greatest in areas served by transmitters using channel 48, and in the areas of relatively low field strength on the service area edges. In the right-hand plot, the population lost in each pixel is determined, and the few interference 'hotspots' are now concentrated in urban areas.

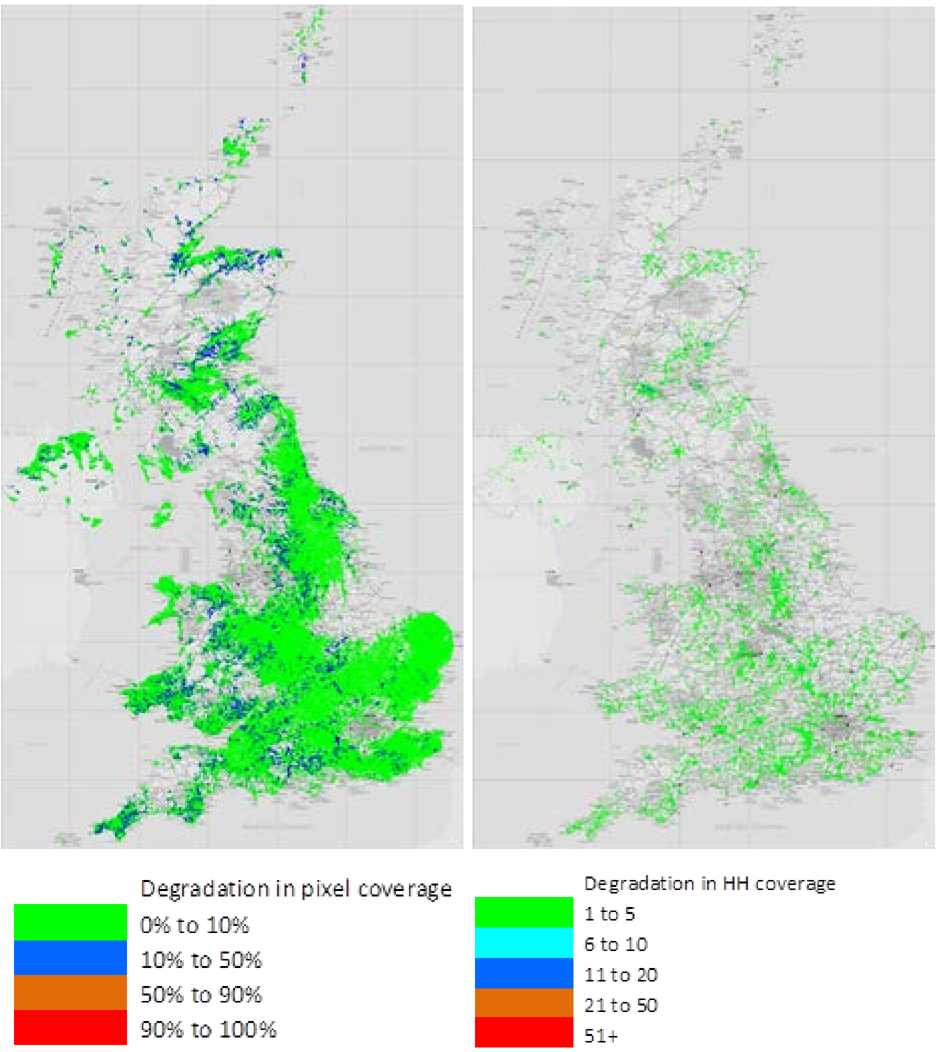

Figure 2.2: Overall interference: Δ-coverage (left), Δ-households (right)

3 INPUT PARAMETERS

The EIRP of the UE was assumed to be either +**16dBm** (representing the quasi-maximum case[4]) or +**2dBm** (the power not exceeded by active UEs for 94% time in measurements made in a typical urban area[5]).

The UE is assumed to lie at 22m horizontal distance from the DTT receive aerial, giving rise to a free-space field strength of 92.9 or 78.9 dBµV/m for EIRPs of +16 or +2dBm respectively). To allow for the variability of antenna gain, body shielding and other shadowing effects, a standard deviation of 5.5dB is associated with the median field strength.

3.1 Protection ratios

The protection ratios used in the modelling have been derived from measured values of receiver selectivity and current or proposed regulatory limits for UE out of band emissions.

3.1.1 Receiver selectivity

The adjacent channel selectivity (ACS) of a selection of DTT receivers has been measured and the statistics tabulated by ITU-R JTG 4-5-6-7.

[4] See JTG document 4-5-6-7/256. The figure assumes 23dBm transmitter power (3GPP 36.101 §6.2.2), antenna gain of -3dBi and a body loss of 4dB.

[5] See Section 3.2 of ITU-R Document 5-6/81 (6 May 2009). A body loss of 4dB and antenna gain of -3dB have been assumed.

Table 3.1: Derived ACS values for silicon tuners from the un-corrected protection ratios (dB) for a DVBT-2 signal interfered with by an LTE UE signal in adjacent channels for silicon tuners *[Table 5 in Appendix 6 to Annex 2 of ITU-R Document 4-5-6-7/242]*

Channel offset N 8 MHz channels/ (centre frequency offset)	1 Mbit/s UE traffic loading Signal generator ACLR = 100 dB all offsets		10 Mbit/s UE traffic loading Signal generator ACLR = 100 dB all offsets		20 Mbit/s UE traffic loading Signal generator ACLR = 67.8 dB (N+1) 80.4 dB (N+2) 100 dB (N+3 to N+9)	
	ACS Percentile dB		ACS Percentile dB		ACS Percentile dB	
	50th	90th	50th	90th	50th	90th
1/(10)	55.0	38.0	60.0	58.0	60.8	58.5
2 (18)	60.0	43.0	66.0	64.0	66.2	62.1
3 (26)	63.0	45.0	67.0	64.0	69.0	63.0
4 (34)	65.0	55.0	67.0	64.0	71.0	64.0
5 (42)	66.0	56.0	67.0	63.0	73.0	65.0
6 (50)	69.0	57.0	68.0	62.0	71.0	64.0
7 (58)	69.0	60.0	68.0	63.0	72.0	63.0
8 (66)	69.0	60.0	68.0	61.0	73.0	64.0
9 (74)	69.0	62.0	68.0	62.0	73.0	66.0

For each level of traffic loading, the selectivity achieved by 50% and 90% of the receivers sampled is given; both figures were used in the modelling.

The values for UE emissions at 1 Mbit/s traffic loading have been used in the present modelling as these represent the worst case.

3.1.2 Transmitter out of band emissions

It is assumed that the UE will have an OOB emission mask that, for a transmitter output power of 23dBm gives rise to the following powers in Channel 48 (all measured in 8 MHz bandwidth):

- -25 dBm *(current 'Band 28' limit*[6])
- -40dBm, -42dBm or -46dBm (*Limits under consideration in ECC as at March 2014*[7])

It is assumed, for the purposes of this exercise only,(i) that the ACLR implied by these values remains constant as the transmit power falls (i.e. OOB emissions are

[6] see 3GPP document 36.101 §6.2.2

[7] see ECC document CPG-PTD(14)099

10dB less for an output power of +13dBm) and (ii) the OOB emission level is constant from channel 48 to channel 41.

3.1.3 Protection ratios

Protection ratios for modelling are derived from the ACLR and ACS values described above using the following approximation:

$$PR(\Delta f) = PR_0 + 10\log(10^{\frac{-ACS}{10}} + 10^{\frac{-ACLR}{10}}) \qquad \textit{Eq.4}$$

An assumed co-channel protection ratio (PR_0) of +19.0 dB, gives the following protection ratio figures:

Table 3.2: Protection ratios used in modelling

		-25dBm		-40dBm		-42dBm		-46dBm	
Dtt channel	**Offset (MHz)**	**-50%**	**-90%**	**-50%**	**-90%**	**-50%**	**-90%**	**-50%**	**-90%**
48	18	-28.7	-22.8	-39.2	-24.0	-39.8	-24.0	-40.5	-24.0
47	26	-28.9	-24.2	-41.0	-25.9	-41.9	-26.0	-43.0	-26.0
46	34	-28.9	-28.2	-41.9	-35.4	-43.0	-35.6	-44.5	-35.8
45	42	-28.9	-28.4	-42.2	-36.2	-43.5	-36.5	-45.2	-36.8
44	50	-29.0	-28.5	-43.0	-37.0	-44.5	-37.4	-47.0	-37.7
43	58	-29.0	-28.7	-43.0	-39.2	-44.5	-39.8	-47.0	-40.5
42	66	-29.0	-28.7	-43.0	-39.2	-44.5	-39.8	-47.0	-40.5
41	74	-29.0	-28.8	-43.0	-40.5	-44.5	-41.2	-47.0	-42.2

These protection ratios are plotted in Figure 3.1, below.

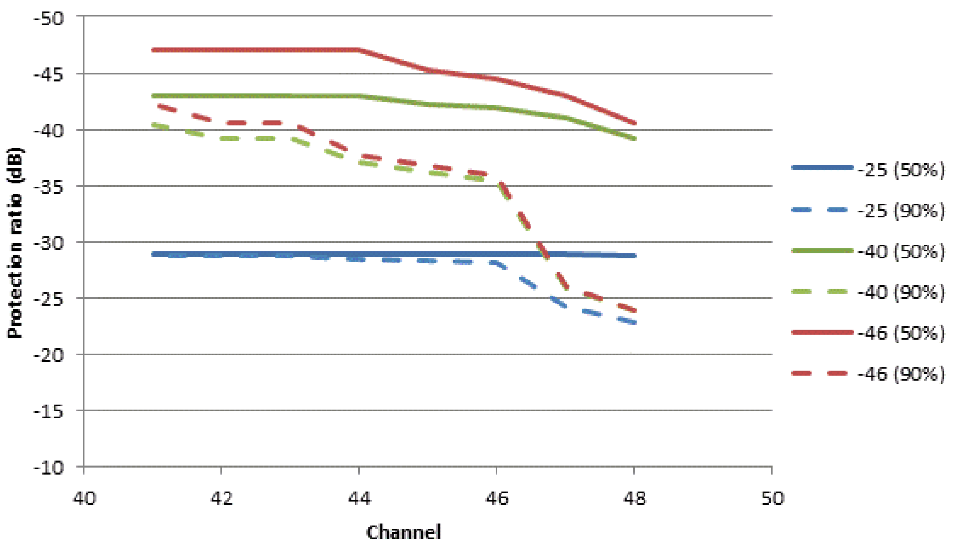

Figure 3.1: Protection ratios used in modelling

In the present modelling, it has been assumed that UE interference has no impact on DTT transmissions below channel 41.

The model was also exercised for the case where an external filter is fitted to the DTT receiver to improve selectivity with respect to signals above 703 MHz. It is assumed that this filter adds 20dB to the ACS values tabulated in Table 3.1, and has zero dB insertion loss.

.Table 3.2: Protection ratios used in modelling

Filtered		-25dBm		-40dBm		-42dBm		-46dBm	
Dtt channel	Offset (MHz)	-50%	-90%	-50%	-90%	-50%	-90%	-50%	-90%
48	18	-29.0	-28.9	-43.9	-41.0	-45.9	-41.9	-49.7	-43.0
47	26	-29.0	-28.9	-44.0	-41.9	-45.9	-43.0	-49.8	-44.5
46	34	-29.0	-29.0	-44.0	-43.7	-46.0	-45.6	-49.9	-49.0
45	42	-29.0	-29.0	-44.0	-43.8	-46.0	-45.7	-49.9	-49.2
44	50	-29.0	-29.0	-44.0	-43.8	-46.0	-45.7	-50.0	-49.4
43	58	-29.0	-29.0	-44.0	-43.9	-46.0	-45.9	-50.0	-49.7
42	66	-29.0	-29.0	-44.0	-43.9	-46.0	-45.9	-50.0	-49.7
41	74	-29.0	-29.0	-44.0	-43.9	-46.0	-45.9	-50.0	-49.8

4 RESULTS

The number of DTT households in the UK liable to interference from LTE UE under this model is tabulated below for each combination of handset EIRP, receiver selectivity, and ACLR.

Table 4.1: Model results (DTT households lost)

eirp	% rx	OOB		HH with interference	HH with interference (filter)
16	50	-25		673,352	656,972
16	50	-40		78,054	38,642
16	50	-42		65,486	25,328
16	50	-46		52,857	11,151
16	90	-25		1,163,376	663,185
16	90	-40		819,982	56,794
16	90	-42		812,408	43,896
16	90	-46		809,439	30,586
2	50	-25		49,305	47,688
2	50	-40		4,383	2,685
2	50	-42		3,853	2,164
2	50	-46		3,335	1,688
2	90	-25		114,472	48,293
2	90	-40		74,868	3,466
2	90	-42		74,107	2,940
2	90	-46		73,919	2,417