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Joint Frequency Planning Project

Technical Parameters and

Planning Algorithms

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History

Version	Date	Author	Reason
1	1998		Initial Release
2	July 2003		Addition of 16-QAM modes
3	February 2010		Addition of DVB-T2 modes
3.1	April2010		Addition of SFN methodology
3.2	January 2010		Modification to SFN equations in Section 3.9.3.1
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3.5	March 2012		Modifications to Tables 1,2, 4a, 4b & 5b following agreement of revised planning parameters for Mode IV. Mode V follows suit.

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1 Introduction

The purpose of this document is to summarise the planning parameters and algorithms that are being used by the BBC, Arqiva and Ofcom in the joint frequency planning study for digital terrestrial television. Subject to agreement by the clients of the project, the parameters and algorithms described in the document may be updated or modified in the light of new information becoming available in the study.

This update represents the changes that have been made to the parameters and algorithms as a result of the following:

- change in transmission mode by some multiplexes in 2002, and others in 2009;
- adoption of DVB-T2 by one multiplex in 2009;
- adoption of UKPM as the default planning method.

2 Planning Parameters

2.1 DVB-T and DVB-T2 System Parameters

The DVB-T and DVB-T2 systems currently mandated for use in the UK will be considered in the planning study. Other system variants could be investigated if requested by the clients of the project. For the purposes of the study, only the failure C/N and C/I are important. However the following DVB-T and DVB-T2 system parameters form the basis for the values used for planning in the UK:

Table 1: DVB-T System Parameters Currently Used in the UK

Variant	I		II		III	IV	V
UKPM Designator	C2		B3		C3	T2	T3
System	DVB-T		DVB-T		DVB-T	DVB-T2	DVB-T2
Modulation	64 QAM		16 QAM		64-QAM	256-QAM	16-QAM
Error Coding Rate	2/3		3/4		3/4	2/3	1/2
Carriers	2k	8k	2k	8k	8k	32k	32k
Guard Interval Fraction	1/32	1/32	1/32	1/32	1/32	1/128	1/128
Guard Interval (μs)	7	28	7	28	28	28	28
Data rate (Mbit/s)	24.1		18.1		27.1	40.2	7.5
System C/N (dB)	17.1		13		18.6	18.4	6.5
Receiver Implementation Margin (dB)	2.7		2.7		2.7	1.6	1.4
Allowance for 'real' conditions (dB)	3		3		3	1.5	1.5
C/N (dB)	22.8		18.7		24.3	21.5	9.4

The quoted system C/N ratios for DVB-T are taken from Chester 97 [3] and are applicable for fixed reception, assuming a Ricean channel. The quoted receiver implementation margin is extrapolated from the DVB-T specification [9] and other sources [12, 13]. Measurements made using available set-top boxes and professional decoders show that the minimum failure C/N in real conditions is somewhat higher than would be expected by these references, hence the addition of an allowance for 'real' conditions. The figures for 64 QAM are broadly equivalent to those incorporated in former versions of this document; similarly, the figures for 16 QAM are equivalent to those used for the initial prediction of coverage in this mode.

The figures for DVB-T2 are taken from D-Book 6.1, and include a 0.6 dB allowance for a Ricean channel. Additionally, the Receiver Implementation Margin has also been taken from D-Book 6.1. The allowance for real conditions has been reduced to 1.5 dB, as impulsive interference does not affect DVB-T2 but an additional margin has been allowed for the "cliff edge" failure of T2.

2.2 Minimum Wanted Field Strengths

Individual values for minimum wanted field strength are calculated for the centre frequency of each UHF channel. The method given in Chester '97 [3] is used for specifying the minimum field strength in each UHF channel; the method has been adapted to allow for the different receiver noise figures assumed in UK planning for Band IV and Band V. A version of this formula is shown below.

$$FS_{\min} = FS_{base} + 20\log(f / 500)$$

where:

$FS_{\min}$ is the minimum wanted field strength

FS_{base} is the base minimum field strength at 500 MHz (see below)

f is the centre frequency of the channel

The value of f is derived as follows:

$$f = 474 + 8 \cdot (C - 21)$$

Where:

C is the channel number of the transmission

Note that, to allow for the change of receiver noise figure between Bands IV and V, the following statement is also incorporated into this calculation.

If $C >= 39$ then $FS_{\min} = FS_{\min} + 1$

Tables 2 and 3 show the parameters, for fixed rooftop reception via a directional receiving antenna, which have been calculated for a spot frequency of 500 MHz. This is used as FS_{base} in the formula above.

Table 2: Derivation of minimum field strength at 500 MHz

Variant	**I**	**II**	**III**	**IV**	**V**
UKPM Designator	C2	B3	C3	T2	T3
Noise bandwidth (MHz)	7.5	7.5	7.5	7.9	7.9
Rx input impedance (ohms)	75	75	75	75	75
Thermal noise (dBμV)	3.5	3.5	3.5	3.8	3.8
Minimum C/N (dB)	22.8	18.7	24.3	21.5	9.4
Frequency (MHz)	500	500	500	500	500
Effective receiver noise figure (dB)	7	7	7	7	7
Receiver input voltage (dBμV)	33.3	29.2	34.8	32.3	20.2
Receiving antenna gain (dBd)	10	10	10	10	10
Feeder loss (dB)	3	3	3	3	3
Dipole factor (dB)	20.5	20.5	20.5	20.5	20.5
Minimum Field Strength (dBμV/m)	46.8	42.7	48.3	45.8	33.7

Table 3: Derivation of minimum field strength at 500 MHz for Variant II

DELETED – Data incorporated in Table 2

The effective receiver noise figure is not the same as assumed in Chester '97 [3], which quotes a receiver noise figure of 7 dB across the band. Instead, the figure is based on agreements with receiver manufacturers made at a BBC seminar on DTT receiver performance [2].

These calculations give the minimum equivalent field strengths required at the receiving antenna at each location for the system described in Section 2.1. Further correction factors for location and time variation are required for planning purposes. The resulting minimum median equivalent field strengths for 90% locations served are summarised in Table 4 in section 2.3.

2.3 Location variation

A standard deviation of 5.5 dB is assumed for the log-normal distribution of field strengths with location [3]. When a correction factor for 90% locations served is applied to the minimum equivalent field strengths required at the receiving antenna at each location (given in Tables 2 and 3), the minimum median equivalent field strengths are derived and they are shown in Tables 4a and 4b.

Table 4a: Minimum median equivalent field strengths (dBμV/m) for 90% locations

Variant		**I**	**II**	**III**	**IV**	**V**
Failure C/N (dB)		22.8	18.7	24.3	21.5	9.4
Band IV	(500 MHz)	53.8	49.7	55.3	52.8	40.7
Lower Band V	(700 MHz)	56.8	52.7	58.3	55.8	43.7
Upper Band V	(850 MHz)	58.5	54.4	60.0	57.5	45.4

Table 4b: Minimum median equivalent field strengths (dBμV/m) for 70% locations

Variant		**I**	**II**	**III**	**IV**	**V**
Failure C/N (dB)		22.8	18.7	24.3	21.5	9.4
Band IV	(500 MHz)	49.7	45.6	51.2	48.7	36.6
Lower Band V	(700 MHz)	52.6	48.5	54.1	51.6	39.5
Upper Band V	(850 MHz)	54.3	50.2	55.8	53.3	41.2

Again, the minimum median equivalent field strengths are in practice calculated at the centre frequency of each UHF channel using the method in Chester '97 [3].

An algorithm, given in Section 3, is used to calculate the distribution of the composite field strength that occurs, when more than one interfering signal is present.

2.4 Percentage of Time for Protection from Interference

The interference predictions assume the following time percentage protection:

- 95% time to UK and Irish domestic receiving locations for analogue services.
- 99% time to UK and Irish RBL receiving antennas for analogue services.
- 99% time to Continental analogue transmissions.
- 99% time to UK digital terrestrial television domestic receiving locations.
- 99% time to UK analogue receiving locations when interfered with by continental sources [3]

2.5 Protection Ratios

The protection ratios that will be used for planning are shown in Tables 5a - 5f. All values are subject to review, especially those for adjacent channel interference.

Table 5: Protection Ratios (dB)

Table 5a - Co-Channel: Analogue Television (PAL-I) interfered with by DVB-T

Interfering Source	DVB-T Co-channel Interfering Signal (all Variants)	
	Continuous†	Tropospheric†
UK DVB-T	+38	+35
Continental DVB-T	+41	+35

† Continuous interference from UK domestic DVB-T transmissions into analogue services is considered to be acceptable down to an impairment of Grade 3.5 on the ITU 5-point picture impairment scale [10]. Tropospheric interference is considered to be acceptable down to an impairment of Grade 3 on the ITU 5-point picture impairment scale.

Note that in 2002 the BBC and ITC, as clients of this project, allowed a relaxation of the protection ratios for analogue services interfered with by domestic DVB-T by 3 dB; the new figures are reflected in Table 5a above. Protection of UK domestic analogue services from continental DVB-T transmissions remains on the same basis as in previous versions of this document [1]. As tropospheric propagation is the dominant method for most continental interference, the agreed value for co-ordination of DVB-T services from Reference 3 is used throughout.

Table 5b - Co-Channel: DVB interfered with by Analogue Television or DVB-T

Wanted Signal	Interfering Signal	
	Analogue Co-channel	DVB-T Co-channel
DVB-T (Variant I)	+4.0	+19.8
DVB-T (Variant II)	0.0	+15.7
DVB-T (Variant III)	+10.0	+21.3
DVB-T2 (Variant IV)	+8.2	+20.0
DVB-T2 (Variant V)	N/A	+7.9

Note that a Ricean channel (with an appropriate receiver implementation margin incorporated [9]) is assumed in the co-channel protection for DVB-T from DVB-T.

Table 5c – Adjacent Channel: DVB-T interfered with by Analogue Television

Wanted Signal	Interfering Signal								
	Analogue Lower-Adjacent			Analogue Upper-Adjacent					
DVB-T in Channel n	n-1			n+1					
	PAL-I or PAL-I1			PAL-I			PAL-I1		
Frequency Offset of DVB-T	-m*	0	+m*	-m*	0	+m*	-m*	0	+m*
DVB-T & T2 (All variants)	-35	-35	-35	-20	-20	-20	-35	-35	-35

m=1/6 MHz

Table 5d - Adjacent Channel: Analogue Television interfered with by DVB-T

(Non-critical spectrum mask)

Wanted Signal	Interfering Signal											
	DVB-T Lower-adjacent (all Variants)						DVB-T Upper-adjacent (all Variants)					
PAL-I or PAL-I1 in Channel n	n-1						n+1					
	Continuous			Tropospheric			Continuous			Tropospheric		
Frequency Offset of DVB-T	-m*	0	+m*	-m*	0	+m*	-m*	0	+m*	-m*	0	+m*
PAL-I or PAL-I1	-5	-4	0	-9	-8	-4	+8	-6	-7	+4	-10	-11

m=1/6 MHz

Table 5e - Adjacent Channel: Analogue Television interfered with by DVB-T

(No transmitter filtering, assuming a –35 dB shoulder)

Wanted Signal	Interfering Signal											
	DVB-T Lower-adjacent (all Variants)						DVB-T Upper-adjacent (all Variants)					
PAL-I or PAL-I1 in Channel n	n-1						n+1					
	Continuous			Tropospheric			Continuous			Tropospheric		
Frequency Offset of DVB-T	-m *	0	+m *	-m *	0	+m *	-m *	0	+m *	-m *	0	+m *
PAL-I or PAL-I1	+8	+8	+8	+4	+4	+4	+4	+4	+4	0	0	0

m=1/6 MHz

Table A1, in the appendix to this document, shows preliminary adjacent channel protection ratios for DVB-T to DVB-T, where the interfering DVB-T signal is in the upper (n+1) or lower (n-1) adjacent channel. Values are shown for the case of the critical spectrum mask being applied, for the non-critical spectrum mask applied and for no transmitter filtering applied. Note that these values are not consistent with those used in Chester '97 [3] or the previous version of this document [1], because at the time of these documents, measurements had not been available for commercial DVB-T receivers. The values shown are all based on preliminary laboratory measurements on early commercial DVB-T receivers and are subject to review when more measurements have been made.

For the purposes of this study, a single value is used in this case, regardless of the spectrum mask employed and the offset of the interfering signal: this is shown in Table 5f.

Table 5f – Adjacent Channel: DVB-T interfered with by DVB-T

Wanted Signal	Interfering Signal	
	DVB-T in Lower Adjacent Channel	DVB-T in Upper Adjacent Channel
DVB-T/T2 (all variants)	-25	-25

2.6 Receiving antenna discrimination

A domestic antenna directivity (where the front-to-back ratio is 16 dB) and a cross-polar discrimination of 16 dB will be used in accordance with Reference 5.

3 Planning Algorithms

Over the course of three years, the organisations involved in this project have been working together to create a new set of planning algorithms. Together, these are known as the UK Planning Model (UKPM). A full, technical description of the algorithms is expected to be compiled in due course; in the meantime, an outline of the model and its principal features can be found in a paper given to IBC in 2002 [11].

3.1 Field strength calculations from individual transmitters in the UK

A previous version of this document [1] referred to the development of the Common Planning Method and traced its lineage back to the international standards and the BBC and ntl's original prediction models [4, 6]. This method has now been completely superseded by the development of the UKPM.

The UKPM is used to calculate the wanted and interfering field strength distributions to and from each UK transmitting site. These field strengths are calculated for all cases at the centre frequency of the UHF channel in question. Although the frequency of operation was previously not thought to have a significant effect on predicted signal strengths, studies showed that the household counting method could be sensitive to very small changes in the predicted levels linked with a different frequency.

In summary, the main features of the UKPM are:

- the use of a terrain database with a resolution of 50 m (although predictions are currently made at a resolution of 100 m);
- the use of a real clutter database with a minimum resolution of 25 m in dense urban areas and 50 m elsewhere;
- the use of a common database of domestic and continental transmitting stations, administered by the ITC and formed out of the databases of the planning organisations;
- high resolution HRP information for UK DVB-T (and co-sited analogue) stations, extracted from *in situ* measurements made by the BBC using a helicopter-based measuring system;
- regular sampling of the profile between transmitting and receiving locations at twice the prediction resolution;
- radial scanning and re-using of profiles already extracted, in order to increase computation speed.

Out-going co- and adjacent channel interference to UK analogue TV transmitters is also calculated using the above method. The method for calculating the compatibility with non-UK and Irish analogue TV transmitters is that defined in Chester '97 [3], with bi-lateral extensions as appropriate.

3.2 Selection of Interferers

One of the most critical decisions that have to be made when determining the service area of a station, is the identification of the interfering transmitters, as well as the total amount of interference caused by these interferers at each location of interest. The following section is a brief description of how these two tasks are performed in the UKPM.

For a given wanted station, frequency and ERP, we must:

- Determine the bounding box for the wanted station.
- Compile a list of all co-channel and adjacent channel stations.
- Generate bounding boxes for the interfering stations, modifying the ERP as appropriate. The ERP is modified to take into account protection ratio and cross-polar discrimination if appropriate, i.e. don't apply for portable reception.
- Eliminate all interfering stations whose bounding box does not intersect the bounding box of the wanted station.

For each location within the bounding box find the value of the highest interferer, this should include receive antenna HRP discrimination [5] if any. This value should not be lower than the noise level.

For each location within the bounding box carry out a Schwartz and Yeh summation of all interferers at that location, this should include receive antenna HRP discrimination if any. If an interferer is more than 25 dB below the highest value identified above do not include it within the summation. Interferers should be ordered as they appear in the station database, with UK stations first followed by Continental stations.

3.3 Signal combination

A method of assessing the combined effects of multiple interferers is needed for computing digital TV coverage. The log-normal location variation of field strength must be taken into account. The combined effect of noise, co-channel and adjacent-channel incoming interference to digital TV signals will be assessed using the following method except in the case where the two sites are within 10 km of each other where the correlation between the signals will be assumed to be 1. This latter case encompasses several complex issues that can only be resolved by further fieldwork.

The distribution of the power sum of a number of log-normally distributed signals can be approximated to a sufficient degree of accuracy by another log-normal distribution function. Various methods have been developed for estimating the mean and standard deviation of this log-normal distribution: the one developed by Schwartz and Yeh [8] is used for field strength combination in this model.

The field strength combination routine will apply the appropriate receiving antenna pattern or polarisation corrections [5] to each mean field strength. This produces an array of mean interfering field strengths. Small interfering field strengths may then be discarded by selecting those more than a user-specified filter range below the wanted field strength. This is done both to speed up the field strength combination and to reduce the possibility of errors arising from the combination of a very large number of individual sources. A suitable filter range is given in Section 3.2, above.

The log-normal method requires a value for the standard deviation of the location variation of each individual signal. The standard deviation of each individual signal is given in Section 2.3. A correlation coefficient of zero is assumed between all signals.

In calculating the interfering fields, 1% of time field strengths will be used to ensure protection for 99% of time. 50% of time fields are used in calculating the contributing fields. This effectively assumes that the fields from all the interfering transmitters are at their 1% of time values for the same 1% of time.

The effect of noise can also be taken into account using this method. The standard deviation of the noise is zero because it is assumed to be constant over all locations. The mean field strength used for the noise is the field strength that would produce the receiver thermal noise voltage. This is given in Table 2. With these values, the effect of noise can be combined with the interfering field strengths using the Schwartz and Yeh method.

Different types of interference will be subject to different protection ratios. The mean field strengths need to be scaled before combination so that a single protection ratio can be used. An offset can be calculated between the minimum C/N and the appropriate protection ratio for the interfering transmitter. The offset should then be added to all the mean field strengths from that transmitter. This will scale all field strengths in the interference power sum to have a protection ratio equal to the minimum C/N.

3.4 Coverage Criteria

Given values for the mean and standard deviation of the wanted and interfering field strengths in a coverage cell, it is possible to calculate the mean and standard deviation of their ratio. The probability of a receiver in the cell being served can then be determined.

The location variation in the ratio of wanted and unwanted power will be log-normally distributed. The mean and standard deviation of this distribution are given by:

$$m_{R_{dB}} = m_{C_{dB}} - m_{(N+I)_{dB}}$$

$$\sigma_{R_{dB}} = \sqrt{\sigma^2_{C_{dB}} + \sigma^2_{(N+I)_{dB}}}$$

where:

$m_{R_{dB}}$ is the mean of the ratio (dB),

$m_{C_{dB}}$ is the mean field strength from the wanted transmitter (dBμV/m),

$m_{(N+I)_{dB}}$ is the mean effective field strength due to noise and interference (dBμV/m),

$\sigma_{R_{dB}}$ is the standard deviation of the location variation in the ratio (dB),

$\sigma_{C_{dB}}$ is the standard deviation of the location variation in the field strength from the wanted transmitter (dB),

$\sigma_{(N+I)_{dB}}$ is the standard deviation of the location variation in the effective field strength due to noise and interference (dB).

The proportional coverage is the proportion of points in this distribution where the ratio is greater than required. This can be calculated using standard methods from the normal distribution for each cell.

3.5 Co-sited Interference

Adjacent channel interference from analogue services that are co-sited with the wanted digital transmitter must be treated differently. The correlation coefficient between the wanted and interference location variation is then assumed to be unity.

The proportion of locations served is calculated taking into account all interferers except the co-sited interferer. The mean wanted power is then compared with a simple power sum of the co-sited interference with the appropriate protection ratio. If this test is passed, then co-sited interference is assumed to have no effect. If the test is failed, then the proportion of locations served is set to zero.

Treating co-sited interference separately in this way assumes that co-sited adjacent channel interference does not add with other interference sources and that there is perfect correlation between the wanted and co-sited interference location variation.

3.6 Calculation of Gross Coverages

This section outlines the method for calculation of gross coverages for each multiplex from each transmitter.

Gross household coverage assessments are currently based on the predicted wanted and interfering field strength level in each 100 m square. Gross coverage counts all households within pixels where at least 70% of the locations are predicted to be served.

When counting the number of households served by a transmitter, it is very important that a sufficiently large area is selected over which to perform the calculation. Otherwise, not all of the coverage area will be included and some of the households will not be counted. In practice, the coverage of a transmitter is calculated over an area defined in a way similar to those areas defined as the bounding boxes of interferers. The method for this is given in Section 3.2.1, assuming an unmodified ERP and that the wanted system is DTT.

With access to the common transmitter, terrain, clutter and population databases, it is not impossible for all of the UK planning organisations to produce identical coverage predictions using the UKPM. Any minor differences that might arise are likely to be due to the individual implementations and computing platforms chosen by the organisation.

3.7 Calculation of Apportioned Coverages

This section outlines the method for calculation of apportioned coverages for each multiplex from each transmitter and the rationale used in the selection of the proposed method.

3.7.1 Conditions

The method meets the following conditions:

The sum of the apportioned coverages equals the total coverage.

Division of coverage in these overlap areas is biased towards the dominant transmitter.

The method is simple to implement.

The method is quick to calculate.

3.7.2 Calculation Method

The following simple apportioned coverage calculation method satisfies the above conditions.

A small square is taken to be served if at least one transmitter has coverage of greater than or equal to 90% locations in that square. The total coverage probability in each such small square is then taken to be unity ($p_c=1$). Otherwise the total coverage probability in that square is taken to be zero ($p_c=0$).

The total coverage for each square is then apportioned between all of the transmitters serving the square to at least 90% locations to give the apportioned coverage for each transmitter as follows:

$$p_{ni} = p_c \frac{p_i^2}{\sum_{j=1}^{n} p_j^2}$$

where:

p_i , p_j is the coverage probability from transmitter *i, j*

n is the number of transmitters serving the square to at least 90% locations.

p_c is the total coverage probability in the square

(=1.0 if any transmitter serves the square for at least 90 % of locations

=0.0 if no transmitter serves the square for at least 90 % of locations)

Taking squares in the fraction causes more weight to be given to the dominant transmitter or transmitters, to satisfy condition (2). The sum of all the apportioned coverages in the square will be equal to the total coverage in the square, thus satisfying condition (1).

3.7.3 Overall Apportioned Coverages

The overall apportioned coverage of a transmitter is the sum of the apportioned coverages in each square. Note that the household counting rules are not applied in calculating this sum, as they have already been applied to the total coverage in each square.

Note that the apportioned coverage of a transmitter will be affected by the selection of transmitters to be included in the set of transmitters for which the calculation is to be performed. As transmitters are added to the set, the apportioned coverage of the transmitters already in the set will reduce slightly due to the presence of overlaps.

3.7.4 Illustrative Example

Consider a square served by two transmitters. Transmitter 1 serves 90% of the square $(p_1 = 0.9)$ and transmitter 2 serves 95% $(p_2 = 0.95)$. The total coverage p_s in the square is then $1-(1-0.9)(1-0.95) = 0.995$. Applying the household counting rules gives p_c = 1.0. The apportioned coverages are then as shown in Table 6.

Table 6: Apportioned Coverage Calculations

p_1	p_2	p_c	Appt. p_1	Appt. p_2	Sum of Apportioned
0.9	0.95	1.0	0.473	0.527	1.0

3.8 'Core Coverage Area'

The 'gross core coverage area' of a single transmitting station is the area in which all six multiplexes are predicted to be available for 90% locations and 99% time, using a single receiving antenna.

For each small square in the gross core coverage area of a transmitter, the core coverage in that square can be taken as the lowest percentage coverage of the six multiplexes. When two or more transmitters provide core coverage in a square, the core coverage in the square (and hence the households served) can be apportioned between the contributing transmitters using the method described above in section 3.7.2. This results in the apportioned core coverage for each square. The apportioned core coverage for a transmitter is the sum of the apportioned core coverages for each square.

For example:

Tx	Coverage Probability (%)							
	Mux 1	Mux 2	Mux 3	Mux 4	Mux 5	Mux 6	Core	Core Appt.
1	98	98	96	95	92	90	90	47
2	99	97	96	96	95	95	95	53

3.9 Single Frequency Networks

Although the UK plan is based on multi-frequency network topology, there are occasions where single-frequency networks (SFNs) are planned to overcome local frequency scarcity. In such cases, the following algorithms are used to calculate coverage.

3.9.1 Receiving aerial pointing

As the UK DTT network is based upon reception to fixed directional antennas the station that a viewer's receive aerial points at may affect the coverage. Within an SFN if two or more stations serve a location, the UKPM assumes that the receiving aerial at that location will be aligned with the station providing the highest availability.

3.9.2 Receiver Synchronisation Strategy

In considering the receiver synchronisation strategy it is assumed that the FFT and equalisation windows are aligned. The receiver is assumed to lock (align the start of the FFT window) to the first signal above the receiver noise threshold (thermal noise + receiver noise figure) after taking into account receive aerial directivity and/or polarisation.

3.9.3 Out of Guard Interval Performance

3.9.3.1 DVB-T

The UKPM assumes the characteristics of DVB-T receivers are as described in the EBU Technical Review July 2003 – ‘OFDM receivers impact on coverage of inter symbol interference and FFT window positioning’, with one slight modification, the addition of a factor G_{eff} to allow the effective guard interval to be modeled.

$$w_i = \begin{cases} 0 & if \quad t < 0 \\ 1 & if \quad 0 \le t \le G_{eff}\,\Delta \\ \left(\dfrac{(T_u + G_{eff}\,\Delta) - t}{T_u}\right)^2 & if \quad G_{eff}\,\Delta < t \le T_{Pstop} \\ 0 & if \quad T_{Pstop} < t \end{cases}$$

$$C = \sum_i w_i C_i$$

$$I = \sum_i (1 - W_i) C_i$$

where:

C_i	=the power contribution from the i-th signal at the receiver input
C	= the total power of the effective useful signal
I	= the total effective interfering power
w_i	= the weighting coefficient for the i-th component
T_u	= the useful symbol length
Δ	= the guard interval length
G_{eff}	= Effective length of the guard interval (0 to 1)
t	= the signal arrival time
T_{Pstop}	= the interval after the guard during which signals usefully contribute

The effective length of the guard interval G_{eff} is set to 0.9 in the UKPM

The length of the period T_p is set to $7/24T_u$ in the UKPM

Guard interval and symbol period are specified by the mode.

3.9.3.2 DVB-T2

DVB-T2 receivers can work in one of two modes: time interpolation, or frequency interpolation. Frequency interpolation improves performance in channels with substantial Doppler characteristics, while time interpolation improves performance in the presence of long-delay echoes such as might be found in an SFN.

Tests show that early DVB-T2 receivers work predominantly in time interpolation mode, and as that is the more suitable mode for fixed reception, that mode will be described here and implemented in the UKPM.

It is possible that future receivers will be hybrid in that they may be able to switch between the two modes as required for the channel in which they are operating.

For UKPM, the following values of T_{pstart} and T_{pstop} are used, in the same functions as used for DVB-T:

For time-interpolation, $T_{pstart} = T_{pstop} = 1/24T_u$.

For receivers using frequency interpolation, $T_{pstart} = T_{pstop} = 1/96T_u$.

3.9.4 Power Sum

Wanted stations are power summed using the Schwarz and Yeh methodology. Following the summation coverage for a station in an SFN is calculated on the basis of the unmodified wanted signal level and the modified standard deviation, i.e. the modified signal resulting from the Schwarz and Yeh calculation is discarded. The process is summarised in Figure 1.

In an SFN when more than one station contributes to the wanted signal at a location summation using the Schwarz and Yeh method results in an modified wanted signal higher than the highest wanted and a reduced standard deviation. Tests [in Holland] have shown that this over estimates actual coverage. Whilst there is an increase in the power available to the receiver, it has been found that channel distortion – in the case where there are a limited number of sources of comparable magnitude - offsets any benefit. The benefit to be had from multiple sources comes from site diversity rather than an increase in signal level.

3.10 Allocation of Channels to Multiplexes

NB: This section no longer applies

3.10.1 Original 80 site plan

For the original 80 site plan, channels were allocated to multiplexes according to the algorithm published in the ITC note for applicants on coverage for digital television. The gross coverage of the six channels was considered. In general, the highest gross coverage was assigned to mux 1, the next highest to mux 2 and so on down to the lowest gross coverage being assigned to mux D. The algorithm took account of factors such as existing aerials and adjacency to co-located analogue channels. Exceptions could be made where the algorithm produced technically unsound results.

The general idea behind the algorithm was to assign channels with the best coverage to the public service multiplexes.

3.10.2 New DTT sites (if any)

It is understood that if any further new DTT sites are planned, the coverage of the six multiplexes should be planned to be as close as possible from the outset. However, this may not always be possible, since interference on each channel can differ even if all muxes are planned with the same transmission characteristics. Also not all channels available may be within the local aerial group.

In general, channels that are in or closest to existing analogue aerial group and with the highest coverage will be allocated to the public service multiplexes.

4 References

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Appendix: Adjacent Channel Protection Ratios

Table A1 – Adjacent Channel: DVB-T interfered with by DVB-T

Wanted Signal	DVB-T Interfering Signal in Channel n+1				
	Critical Spectrum Mask				
	Frequency Offset of Interfering Signal Relative to Channel Centre				
Channel n	-2*m**	-m*	0	+m*	+2*m**
DVB-T	-13	-15	-26	-30	-30

Wanted Signal	DVB-T Interfering Signal in Channel n-1				
	Critical Spectrum Mask				
	Frequency Offset of Interfering Signal Relative to Channel Centre				
Channel n	-2*m**	-m*	0	+m*	+2*m**
DVB-T	-30	-30	-30	-23	-18

Wanted Signal	DVB-T Interfering Signal in Channel n+1				
	Non-Critical Spectrum Mask				
	Frequency Offset of Interfering Signal Relative to Channel Centre				
Channel n	-2*m**	-m*	0	+m*	+2*m**
DVB-T	-13	-14	-25	-28	-28

Wanted Signal	DVB-T Interfering Signal in Channel n-1				
	Non-Critical Spectrum Mask				
	Frequency Offset of Interfering Signal Relative to Channel Centre				
Channel n	-2*m**	-m*	0	+m*	+2*m**
DVB-T	-28	-28	-28	-22	-17

Wanted Signal	DVB-T Interfering Signal in Channel n+1				
	No Transmitter Filtering – assuming a –35 dB shoulder				
	Frequency Offset of Interfering Signal Relative to Channel Centre				
Channel n	-2*m**	-m*	0	+m*	+2*m**
DVB-T	-13	-14	-21	-22	-22

Wanted Signal	DVB-T Interfering Signal in Channel n-1				
	No Transmitter Filtering – assuming a –35 dB shoulder				
	Frequency Offset of Interfering Signal Relative to Channel Centre				
Channel n	-2*m**	-m*	0	+m*	+2*m**
DVB-T	-22	-22	-22	-18	-16

m=1/6 MHz

Note that the protection ratio for the wanted signal having a ‘+m’ offset and the interfering signal having a ‘0’ offset is the same as for the wanted signal having a ‘0’ offset and the interfering signal having a ‘-m’ offset. In practice, the wanted or interfering signal will never have a ‘+2m’ or ‘-2m’ offset. This situation only arises when both the wanted and interfering signals have a single ‘m’ offset in opposite directions.