



Digital Television Project



**Digital Television Action Plan
Spectrum Planning Group**

**DTT Coverage:
Impact of existing installations & mode changes on
reception Coverage**

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The contents of this report include predictions of DTT coverage made by planners working for the ITC, BBC, ntl and Crown Castle. Neither the predictions made or the possible scenarios considered should be taken as representing government policy or a commitment to implement by any of the planning organisations.

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1 Summary

This report has been prepared to aid understanding into the impact that a change in the mode of the digital terrestrial television (DTT) signal (see Annex C for a description of the Modes) may have on the coverage of the DTT services across the UK. This report also identifies how this overall coverage figure may be affected by the type and quality of the domestic reception arrangements in individual households and makes some estimates as to the proportion of UK households which may receive the DTT services without having to make any no further changes to their receiving equipment (aerial, down-lead, distribution amplifiers, etc...), this proportion is referred to as the **Reception Coverage** in the remainder of this report.

The main conclusion reached by this report is that changing the DTT operating mode will change both the Coverage and the Reception Coverage of the DTT service. A change of mode to a lower bit rate (for instance from 24 Mbit/sec to 18 Mbit/sec) will increase both the Coverage and the Reception Coverage of the service. The obvious penalty of such a change is that capacity of the network will be reduced by 25%.

At the time of preparing this report a trial has been carried on the three unused DTT multiplexes in the London area. This trial has carried out tests on the actual performance of the DTT signals using the various modes discussed in this report. Tests were carried out on a variety of commercial set top boxes (STB) and integrated digital televisions (IDTV) in a variety of environments including normal domestic households in the London and Reading areas and test laboratories. In general these tests have confirmed that the improvements in coverage predicted in this report are realistic. However, the results for the Mode 1 operation were significantly worse than predicted, these would indicate that only Modes 2 & 3 should be considered for adoption in the network at this stage.

Lack of time has meant that it has not been possible to consider further options which may be helpful to DTT operators for instance mixed mode operation. Some analysis has though been carried out on core coverage for less than the full six multiplexes. This has indicated that the operation of just three or four multiplexes at full bit-rate will increase the core coverage to a level similar to that predicted for the operation of six multiplexes at a reduced bit-rate.

For instance the Reception Coverage of four multiplexes operating at full bit-rate (Mode 0) on the equalised network at normal resilience is predicted to be 60%.

The Reception Coverage of six multiplexes operating at 18Mbit/sec (Mode 2) on the equalised network at normal resilience is predicted to be 58%.

2 Introduction

The Digital Television Action Plan sets out a series of actions which need to be undertaken to ensure the switchover from analogue to digital television takes place. The Action Plan is being implemented in several parallel streams of activities, carried out through a number of dedicated task groups. The Spectrum Planning Group (SPG) is developing a range of planning options and outline assignment plans. The SPG also provides technical support and analysis to the Government Digital Television Group and Stakeholders Group in matters concerning spectrum policy.

3 Review of current DTT network implementation

The DTT network as currently planned and implemented comprises six multiplex services being broadcast from 80 transmitter sites around the UK. The frequency and power of each service has been planned and agreed by the Joint Planning Project (JPP) and cleared for UK use by the Television Planning Group (TPG). A significant proportion of these assignments have also been agreed and cleared by the UK's international neighbours. Full details of the frequency assignments used for these sites are contained in the "*ITC Note for Applicants on Coverage for Digital Television*" (25 April 2002). The coverage figures used in the ITC Note are reproduced in this report under Table 1. These ITC figures have been taken from the latest Joint Planning Project coverage report.

4 Background & criteria for this report

This special report has been produced by the SPG in order that information relating to the predicted coverage and reception capabilities of the DTT platform using the current modulation mode and several different operating modes can be placed into the public domain. A brief description of these modes can be found in Annex 3 below. The planning predictions contained in this report have been prepared as part of the planning work being undertaken by the SPG in the carrying out of the Tasks 3.1 and 3.2 of the Digital Action Plan.

The common planning model (CPM) has been used for the coverage reviews contained in this report. We are currently refining the CPM to provide predictions at a 50m level rather than a 250m level. When this refined UK planning model (UKPM) is ready (expected August 2002), the coverage figures will be re-calculated. Note that as the UKPM is a refinement of the CPM, it should give more accurate theoretical information about availability of transmitted signals. All coverage figures are quoted in households.

Predictions for coverage have been provided for multiplex operation using the current modulation mode (64 QAM R=2/3) as well as the various modes being tested by the DTG mode change trial in May 2002, these being 64 QAM, R=1/2; 16 QAM, R=2/3; 16QAM, R= 3/4. In making the coverage predictions the planners have assumed that

the DTT network has been improved by the full implementation of the equalisation plan (implementing the plans for the Central, North and South-East packages) and that the DTT sites adopt a 3dB increase in power wherever this is permissible (and does not, for example, cause international interference).

In addition to providing predictions of coverage based upon internationally agreed parameters, the report also includes predictions of the **Reception Coverage** of the services. The Reception Coverage figures relate to how many UK households are expected to be able to receive the DTT services without any upgrade to their existing aerial installations. Three factors have been used to calculate these figures, viz.:

1. The majority of domestic aerials used in the UK are designed to work within a specific group of UHF frequencies corresponding to those used for the analogue services (see Annex 2 for further details). A number of the frequencies assigned to the DTT services are outside these aerial groups. At the DTT sites where this applies a correction factor has been used to allow for the loss of gain that the use of the standard aerial would have on the coverage prediction. These correction factors are taken from the “*ITC Note for Applicants on Coverage for Digital Television*” (31 October 1996) and reproduced in Annex 1 to this report for ease of reference.
2. Research has shown that a significant number of household aerial installations are not up to the standard assumed in the international planning models. These assume that aerials are located on the roof of buildings (typically at a height of 10m), that the aerials are in good order and have a gain of 10dB, that the down lead and connection to the television are in good order and use reasonable quality cable. It has been established in a number of studies that households tend to have a installation of just sufficient quality to ensure reasonable reception quality of the analogue services serving that area. This means that the quality of installations near the transmitter are in general worse than assumed by the planning model and those at the edge of the coverage area (furthest from the transmitter) are equal to or better than assumed by the planning model.
3. There has been concern expressed about the relative robustness of the DTT signal to impulse noise in the home. The digital broadcasters and the ITC carried out a series of power increase trials during the second half of 2001 and early 2002 to establish if it was possible to increase the power of the DTT services by 3dB (doubling the power) and to assess what impact this had on DTT reliability in the home. The trials concluded that in general the power of the DTT services could be increased by 3dB with minimal impact on analogue viewers and that the reliability of the DTT service did increase significantly to those homes within the coverage area. The 3dB power increase has been implemented at five sites around the UK (Crystal Palace, Oxford, Sutton Coldfield, Bilsdale and Black Hill). A key issue still to be fully resolved in further trials is whether the 3dB power increase should be reflected as an increase in coverage or should as an increase in the reliability of the DTT

service to those already covered. Accordingly this report treats the 3dB power increases in two different ways:

- a) **Normal Resilience:** The criteria for predicting DTT coverage are not changed and the 3dB power increases these result in a proportionate increase in overall coverage and in the reception coverage for each mode analysed.
- b) **High Resilience:** The criteria for predicting DTT is changed to allow for an increase of 3dB in the implementation margin (This results in an effective increase in the required carrier to noise requirement for reception of DTT services) used by the planners.

5 Current & Equalised DTT Coverage

Table 1: Current Network– Mode 0 (64QAM, R=2/3)

The predicted coverage of the current DTT network (six multiplexes being broadcast from 80 sites) as recorded in the ITC Coverage Note (see 4.1 above). The modulation scheme is set to 64QAM Rate 2/3 operation, corresponding to a net bit-rate of 24.1 Mbit/sec.

Mux	1	2	A	B	C	D	Core 6-mux
Coverage (UK Households)							
Coverage	81	80	78	79	76	74	68
Reception Coverage (% UK Households)							
Current Mode 0 64 QAM, R=2/3	67.4	58.8	60.3	60.1	55.4	47.7	38.6
Mode 1 64 QAM, R=1/2	75.6	66.8	68.7	68.5	65.1	59.6	50.0
Mode 2 16 QAM, R=3/4	73.4	64.5	66.4	66.1	62.4	56.3	46.8
Mode 3 16QAM, R=2/3	77.9	69.7	71.2	71.1	68.4	63.5	54.4

Table 2: Equalised Network – Mode 0 (64QAM, R=2/3)

The predicted coverage of an improved DTT network. This assumes that the remaining equalisation stages (Central, North and South-East) are fully implemented and a 3dB power increase is adopted at most sites. The modulation scheme is as used in (1) above, corresponding to a net bit rate of 24 Mbit/sec.

Mux	1	2	A	B	C	D	Core 6-mux
Coverage (UK Households)							
Coverage	85.0	85.4	84.3	83.7	81.6	81.2	75.9
Reception Coverage (% UK Households)							
Normal resilience	74.5	67.3	68.3	68.5	64.2	61.3	50.1
High Resilience	70.5	63.0	64.0	64.4	59.2	56.1	44.4

Table 3: Equalised Network - Mode 1 (64QAM, R=1/2)

The predicted coverage of an improved DTT network (see Table 2) but operating at 64QAM Rate 1/2. This corresponds to a net bit-rate of 18 Mbit/sec.

Mux	1	2	A	B	C	D	Core 6-mux
Coverage (UK Households)							
Coverage	90.4	90.7	90.0	89.3	87.9	87.4	83.8
Reception Coverage (% UK Households)							
Normal resilience	81.1	75.3	75.7	75.3	73.0	69.8	61.1
High Resilience	No figures available						

Table 4: Equalised Network - Mode 2 (16QAM, R=3/4)

The predicted coverage of an improved DTT network (see Table 2) but operating at 16QAM Rate 3/4. This corresponds to a net bit-rate of 18 Mbit/sec.

Mux	1	2	A	B	C	D	Core 6-mux
Coverage (UK Households)							
Coverage	88.8	89.2	88.3	87.7	86.2	85.6	81.5
Reception Coverage (% UK Households)							
Normal resilience	79.3	73.0	73.6	73.5	70.6	67.5	58.1
High Resilience	77.3	68.8	70.0	70.5	66.2	63.3	52.2

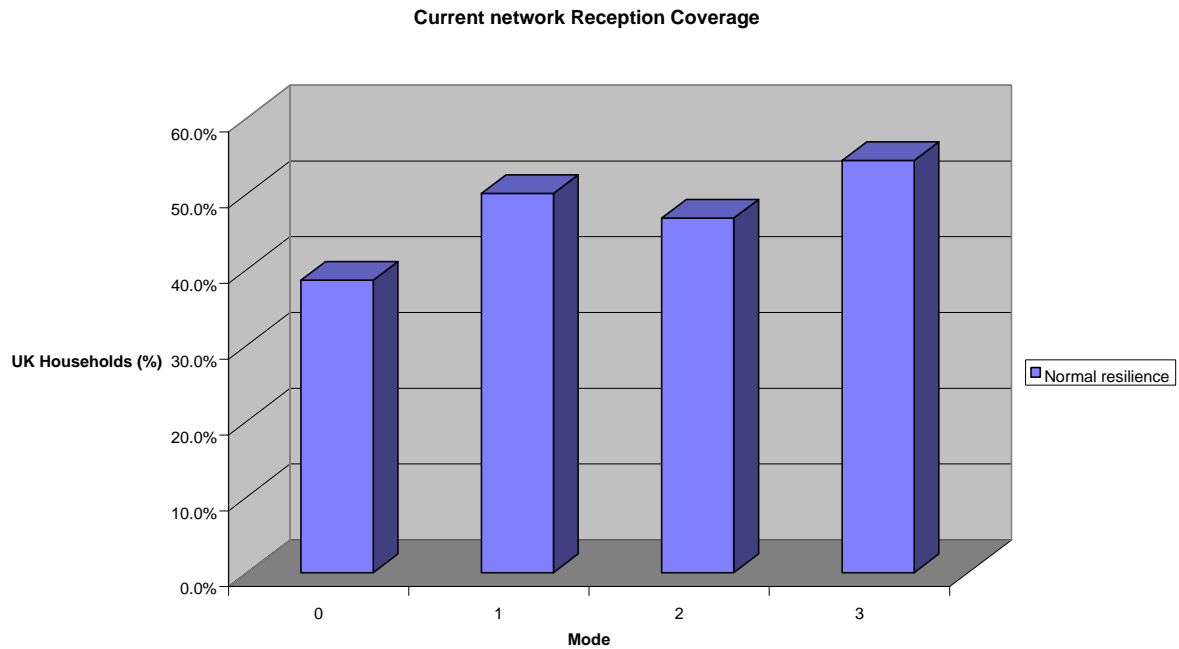
Table 5: Equalised Network - Mode 3 (16QAM, R=2/3)

The predicted coverage of an improved DTT network (see Table 2) but operating at 16QAM Rate 2/3. This corresponds to a net bit-rate of 16 Mbit/sec.

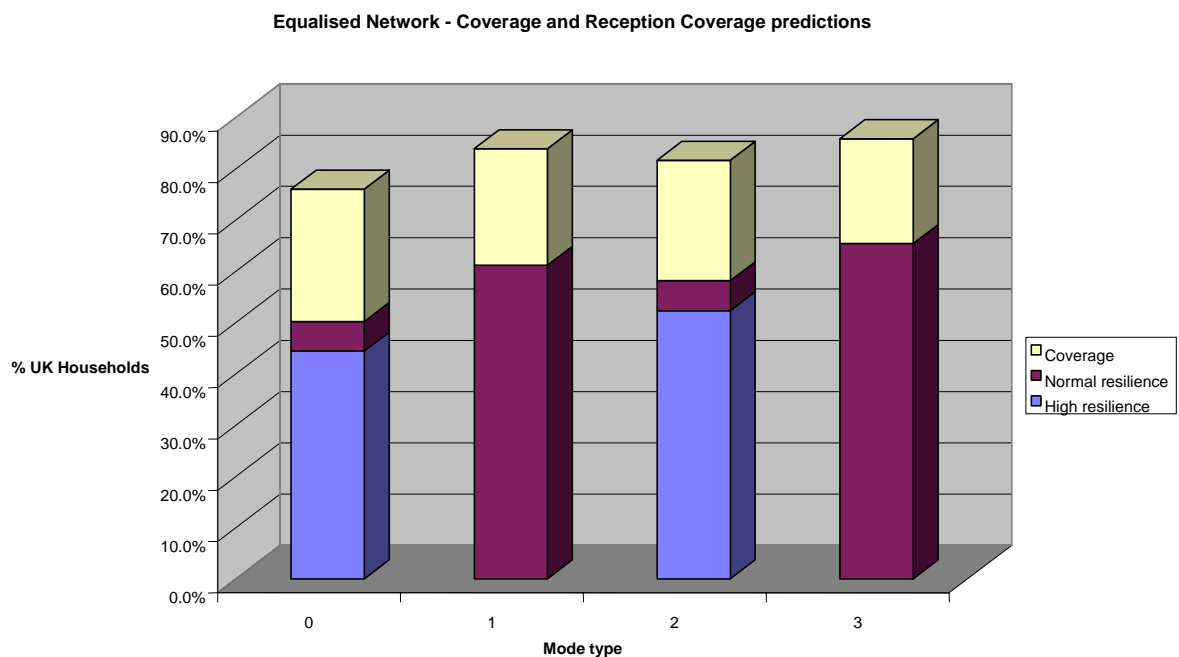
Mux	1	2	A	B	C	D	Core 6-mux
Coverage (UK Households)							
Coverage	91.8	92.0	91.4	90.8	89.6	89.0	85.8
Reception Coverage (% UK Households)							
Normal resilience	83.2	78.2	78.3	77.8	76.2	73.0	65.3
High Resilience	No figures available						

6 Conclusion

The chart below (chart 1) shows how the Coverage Reception for the Current Network varies with the different Modes being used (Mode 0 being the Mode currently used).



The second chart (chart 2) shows how the Coverage and Coverage Reception (for both high and low resilience) for an equalised network varies with the different modes being used (note. No figures were available for Mode 1 & 3 High Resilience).



Annex 1: Aerial Correction Values used in DTV Existing Aerial Calculations

Co-polar correction values (in dB) are shown in the table. Cross-polar values are not included because there are no DTV main stations which are cross-polar to the equivalent analogue services.

Ch	Group A	Group B	Group C/D	Group E
21	0	19	16	14
22	0	17	18	12
23	0	15	20	10
24	0	13	22	8
25	0	11	24	7
26	0	9	25	6
27	0	7	26	5
28	0	5	28	4
29	0	4	29	3
30	0	3	30	2
31	0	3	25	2
32	0	3	20	2
33	0	3	15	2
34	0	3	12	2
35	0	3	9	2
36	0	2	6	2
37	2	2	4	2
38	8	1	3	1
39	15	0	2	1
40	16	0	2	0
41	17	0	2	0
42	18	0	2	0
43	19	0	2	0
44	20	0	2	0
45	21	0	1	0
46	22	0	1	0
47	23	0	1	0
48	23	0	1	0
49	23	0	0	0
50	22	0	0	0
51	22	0	0	0
52	21	0	0	0
53	21	0	0	0
54	20	1	0	0
55	20	2	0	0
56	19	4	0	0

57	19	6	0	0
58	19	8	0	0
59	19	10	0	0
60	19	16	0	0
61	19	17	0	0
62	19	18	0	0
63	19	18	0	0
64	19	19	0	0
65	19	20	0	0
66	19	20	0	0
67	19	21	0	0
68	19	22	0	0

Annex 2: UHF Frequency Channels and Aerial Groups

The following list details the frequency channels used for digital and analogue services in the UK.

UHF Band IV

Channel No.	Lower Freq (MHz)	Upper Freq (MHz)	Channel No.	Lower Freq (MHz)	Upper Freq (MHz)
21	470	478	30	542	550
22	478	486	31	550	558
23	486	494	32	558	566
24	494	502	33	566	574
25	502	510	34	574	582
26	510	518	35	582	590
27	518	526	36	590	598
28	526	534	37	598	606
29	534	542	38	606	614

(note. Channels 36 & 38 are not used for broadcasting in the UK)

UHF Band IV

Channel No.	Lower Freq (MHz)	Upper Freq (MHz)	Channel No.	Lower Freq (MHz)	Upper Freq (MHz)
39	614	622	54	734	742
40	622	630	55	742	750
41	630	638	56	750	758
42	638	646	57	758	766
43	646	654	58	766	774
44	654	662	59	774	782
45	662	670	60	782	790
46	670	678	61	790	798
47	678	686	62	798	806
48	686	694	63	806	814
49	694	702	64	814	822
50	702	710	65	822	830
51	710	718	66	830	838
52	718	726	67	838	846
53	726	734	68	846	854

UHF Receiving Aerial Groups and Colour Codes

Channels	21 - 37	35 - 53	48 - 68	35 - 68	21 -48	21 – 68
Group	A	B	C/D	E	K	W
Colour	Red	Yellow	Green	Brown	Grey	Black

Annex 3: DTT Mode changes

Number of carriers

The DTT multiplexes are broadcast using a transmission standard called DVB-T. This spreads the content of the multiplex (digital television signals) across a large number of carriers simultaneously. The system used in the UK uses 1,705 carriers (of which 1,504 actually carry data) within the same frequency range as normally used by a single analogue video service (that is an 8MHz channel).

Modulation

A modulation scheme determines how much data a single carrier can carry, in general the more information carried by a carrier the more susceptible that carrier will be to noise and interference.

- The simplest modulation scheme used is called QPSK and this is capable of carrying 2 bits of data per carrier.
- The next most complex scheme is called 16 QAM and this is capable of carrying 4 bits of data per carrier.
- The most complex modulation scheme is called 64 QAM and this is capable of carrying 6 bits of data per carrier.

Therefore depending upon which modulation scheme is used each of the 1,504 usable carriers can carry between 2 and 6 bits of data.

There are a total of 4,329 symbols per second of which 31/32 are used for data (the remainder are used as a guard interval to protect against transmission echoes) meaning that a total of 4194 symbols carry data per second.

So for each modulation scheme used the DTT signal will carry the following pay load:

QPSK = 3,008 bits per symbol and 12.6 Mbit/sec in total

16 QAM = 6,016 bits per symbol and 25.2 Mbit/sec in total

64 QAM = 9,024 bits per symbol and 37.8 Mbit/sec in total

Error Protection

The digital signal is also protected against interference by the use of error protection codes. These use some of the available capacity to add the ability to detect and correct errors that the signal may have suffered as a result of interference or noise between the transmitter and receiver. The proportion of the available signal capacity that is used to protect the wanted signal is called the coding rate and is normally recorded as $R=1/2, 2/3, 3/4, 5/6, 7/8$. Where the number refers to the proportion of the data that is used for the wanted information.

Operating Modes

The operating mode referred to in the rest of this paper refers to a combination of modulation and coding rate. The choice of operating mode reflects a trade off between the wanted data-rate and the signal robustness.

Of the four modes considered in this paper and tested in the trial Mode 0 is the least robust but has the highest capacity and Mode 3 is the most robust and has the lowest capacity. A summary of each mode is provided below:

Mode	Modulation	Coding	Net data capacity	Robustness	Comments
0	64 QAM	2/3	24 Mbit/sec	Low	Used for current services. Can carry up to six television services
1	64 QAM	1/2	18 Mbit/sec	Medium	Capable of carrying up to 4 television services
2	16 QAM	3/4	18 Mbit/sec	Medium	Capable of carrying up to four television services
3	16 QAM	2/3	16 Mbit/sec	High	Capable of carrying 3 television services (possibly 4 at lower quality)