UK DVB-T NETWORK PLANNING AND COVERAGE VERIFICATION

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ABSTRACT

This paper describes the work that has taken place in the UK to bring about the introduction of DVB-T services in November 1998. First a description is given of the frequency planning work undertaken by the Joint Frequency Planning Project set up in 1995. This work encompassed coverage planning as well as avoidance of interference to existing analogue transmissions and international co-ordination. Following from this, the paper discusses some fieldwork to validate the accuracy of the planning algorithms. Although this work is still ongoing, indications are that the measured coverage levels are at least as good as the predictions. The paper also describes some work to investigate difficult reception conditions. Finally some work to determine the extent of portable indoor reception is presented.

INTRODUCTION

In 1995, the ITC, BBC and NTL set up a Joint Frequency Planning Project to plan UK DVB-T services. This project completed its work in March 1999. In parallel with this, work has been carried out to compare the predicted coverage of the digital stations with measured coverage, and to investigate reception anomalies.

INITIAL ASSUMPTIONS

A total of 81 stations were planned to cover major conurbations and maximise population coverage. 51 of these were main stations, the remaining 30 being relay stations. Existing UHF analogue transmitting sites were selected (to minimise infrastructure costs and to ease reception by existing receiving antennas). Planning was based on the use of Multi-Frequency Networks (MFNs) interleaved with existing analogue services. In the UK, 44 UHF channels were available for DVB-T.

The maximum ERPs of the DVB-T transmitters were typically set 20 dB lower than the maximum ERPs of the analogue transmitters. The intention was to match the analogue and DVB-T service areas as closely as possible, within the constraints of minimising interference to existing and new services.

The original aim of the UK Planning Project was to provide six multiplexes in each area, from each transmitting station. At the award of licences, the multiplexes were allocated as shown in TABLE 1.

Multiplex Operator	Name	Services
BBC	Mux-BBC	BBC1&2, Choice, News 24
Digital ¾	Mux-C3/4	ITV, ITV2, Channel 4, FilmFour
SDN (S4C Digital Networks)	Mux-SDN (or Mux-A)	S4C, Channel 5, others
ONdigital	Mux-B	ONdigital
ONdigital	Mux-C	ONdigital
ONdigital	Mux-D	ONdigital

TABLE 1 - Licence allocations.

Four of the six DVB-T multiplexes were intended to provide national services. The remaining two (Mux-BBC and Mux-C3/4) would have regional variations. There are 13 BBC regions and a similar number of Independent Television regions. The BBC regional requirements are different from those of the independent television services on Mux-C3/4, which means that the programme feed arrangements to the different transmitters are complicated.

POPULATION COVERAGE TARGETS

The original planning targets were for 90% of the UK population to be served by the first two multiplexes, 80% by the next two multiplexes, and 60% by the last two multiplexes.

PLANNING ASSUMPTIONS

The DVB-T COFDM system parameters, selected for use in the UK, were:

Modulation	64 QAM
Error Coding Rate	2/3
Guard Interval	7µs
Carriers	2k
Data Rate	24.13 Mbit/s
System C/N	20.0 dB

An implementation margin of 3 dB was assumed for planning purposes in the UK to allow for multipath conditions. Planning was undertaken for fixed rooftop reception. Domestic receiving antenna directivity and cross-polar discrimination were assumed to be as given in ITU-R Rec. 419-3 (1).

An equivalent receiver noise figure of 5 dB was assumed for planning. Measurements on the first commercially available receivers have shown that the achieved noise figures are currently closer to 7-8 dB. It is hoped that the performance of receivers will improve with time.

A standard deviation of 5.5 dB was assumed for the log-normal distribution of field strengths with location. Addition of a prediction error would result in the value of 8 dB given in ITU-R Rec. 370 (2). The DVB-T services were planned to be protected from interference for 99% of time. Coverage in an area is deemed to be good if more than 90% of the locations are predicted to be served. Note that this criterion for service is less stringent than that subsequently proposed in Chester ’97 (3) for good coverage (namely 95 % of locations).

The wanted and interfering field strengths were predicted using terrain-based computer prediction models. The Schwartz and Yeh method (4) was used for combining the field strengths of a number of different interfering signals, each assumed to have a log-normal distribution. The combined effects of noise, co-channel and adjacent channel interference were taken into account by scaling the equivalent field strengths by the appropriate protection ratios.

INTERFERENCE TO ANALOGUE SERVICES

One of the main criteria in the selection of channels for DVB-T was to avoid interference to existing analogue services. However in a few geographical areas, the planned DVB-T transmissions could potentially interfere with the off-air reception of analogue services, especially when viewers were watching ‘out-of-area services’ (in the overlap regions between the coverage areas of nearby transmitters). The planning project clearly identified (using computer predictions and vehicle-based survey measurements) the areas liable to interference. Up to 35,000 homes were predicted to be affected.

For every household liable to suffer interference to their analogue services, a solution was identified. In some cases, the channels of the analogue relay station had to be changed. In other cases, new analogue relay stations had to be built to restore analogue services. In the majority of cases, viewers needed their receiving antennas realigning to receive services from an alternative analogue source. The Digital Network (a UK organisation comprising representatives from all multiplex providers) were required to rectify all such problems and to undertake all retuning work prior to full DVB-T services commencing. The Digital Network has commissioned Mentor/Granada to rectify all such problems.

DVB-T can also interfere with the UHF outputs of VCRs, satellite and cable receivers depending on the channel selected for the UHF output (several thousand installations affected). The ITC and Mentor/Granada are offering advice to viewers and cable/satellite operators on how to overcome such problems.

INTERNATIONAL CO-ORDINATION

Compatibility is required between UK and continental DVB-T and analogue services. Chester ’97 (3) set the technical rules for introducing DVB-T in Europe. There were 33 signatories in Europe.

Since the Chester ’97 meeting, a number of countries in Europe have been participating in bilateral co-ordination meetings in an effort to reach agreement on their DVB-T plans. To date, good progress has been made in reaching agreement with neighbouring countries on UK DVB-T plans.

UK DVB-T STATIONS

Restrictions have been required on the radiation patterns of many of the DVB-T stations to protect UK and continental analogue and DVB-T services. In the majority of cases, this has meant that new transmitting antennas have needed to be built.

Station construction has been underway since about June 1998. Approximately 21 stations were on-air at the UK launch of services in November 1998, each having all six multiplexes available. By mid-1999, 40-50 stations will be on-air and all 81 stations are scheduled to be on-air by the end of 1999.

ACHIEVED POPULATION COVERAGE

The achieved population coverages of the six multiplexes from the 81 UK DVB-T stations are predicted to be as shown in TABLE 2.

Multiplex	Population Coverage
BBC	91
Digital 3/4	90
A	88
B	86
C	76
D	70

TABLE 2 - Predicted population coverage.

The above table shows the variation of coverage between the multiplexes. The figures show that 70 % of the UK population will be able to receive all six multiplexes. Roughly 20 % of the UK population will be able to receive between 5 and 1 multiplexes and it is important to be able to inform viewers of what they will be able to receive. The Digital Network have commissioned software for use at the point of sale which gives coverage information in return for the viewer's post (zip) code.

WHY FIELD MEASUREMENTS?

The use of computer prediction methods reduces the need for extensive coverage measurements. However, some field work is still required to validate the predictions for both rooftop and indoor reception. It is also important to investigate situations that may give rise to reception difficulties.

COVERAGE VS. PREDICTION

Having first verified the transmitting antenna characteristics by means of helicopter measurements, coverage measurements were made using the BBC survey vehicle.

FIGURE 1 shows the configuration of test and measurement equipment in the vehicle. Signals were received using a wideband log-periodic antenna mounted on a ten metre pneumatic mast. The antenna had a forward gain of 8 dBd. The signals were fed via a tuneable band-pass filter to a distribution amplifier, which produced feeds to a measuring receiver, a spectrum analyser and a DVB-T receiver.

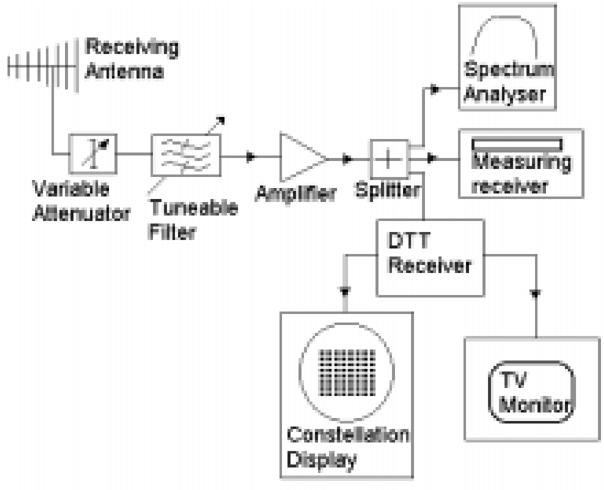

FIGURE 1 - Experimental equipment in survey vehicle.

In order to measure the coverage, a square sampling technique was used. This was the same technique that had previously been used during pre-operational experimental transmissions – see Nokes, Pullen and Salter (5). The purpose of this work was to measure the percentage of locations coverage for a number of 1km squares and to compare this with the computer prediction. This was achieved by selecting a number of points evenly distributed throughout each square. The survey vehicle was then positioned at each of these points in order to determine whether or not pictures and sound could be received. The percentage of measured points for which reception was possible was then judged to be the measured percentage of locations coverage for that square.

The squares were mainly chosen in residential town areas, because these are the areas where most potential viewers live. As far as possible within the constraints of the road network, the survey points within a square were selected so as to sample the square evenly. In most cases there were about 10 points in a square. This was judged to be a good compromise between time taken and measurement accuracy.

So far, detailed surveys have been carried out in several squares associated with the Crystal Palace and Sutton Coldfield transmitting stations. The measured and predicted coverage figures are given in TABLE 3. This suggests that coverage is at least as good as predicted. However, these are very early results. Furthermore, it is important to remember that the predictions are based on levels of interference that only occur for 1 percent of time. Consequently, where measured coverage exceeds predictions, this may not be the case for 100 percent of time.

OS Square	*Location (transmitter)*	*DTT Channel*	*Measured coverage %*	*Predicted coverage %*
TQ3058	Coulsdon (C. Palace)	22	100	95
		28	100	98
TQ3157	Old Coulsdon (C. Palace)	22	100	98
		28	100	99
TQ3558	Warlingham (C. Palace)	22	100	96
		28	100	94
TQ3562	Selsdon (C. Palace)	22	100	98
		28	100	98
TQ3965	West Wickam (C. Palace)	22	100	100
		25	100	100
		28	100	100
		29	100	98
		32	100	100
		34	100	98
TQ3966	West Wickam (C. Palace)	22	100	100
		25	100	100
		28	100	100
		29	100	98
		32	100	100
		34	100	100
SP3578	Coventry (S. Coldfield)	41	70	37
		44	60	36
		47	50	36
		51	40	34
		52	40	11
		55	40	26
SP2971	Kenilworth (S. Coldfield)	41	90	64
		44	80	53
		47	70	47
		51	80	51
		52	70	13
		55	60	15

TABLE 3 - Measured vs. predicted coverage.

RECEPTION ANOMALIES

In some areas, although the field strengths of the digital signals were significantly greater than the reception threshold, reception was difficult. Possible causes of such anomalies have been investigated. These include adjacent channel interference from analogue services and multipath propagation.

Adjacent Channel Interference From Analogue Services

In order to avoid causing interference to other analogue and digital transmissions, many digital transmitters have been planned so that the radiated power is restricted in some directions. Generally, the analogue services from the same station will not be subject to these restrictions. Consequently, in these directions the ratio of analogue to digital field strengths will be significantly greater than the ratio of the nominal maximum transmitter ERPs. In cases where the analogue and digital signals are on adjacent channels this may result in reception difficulties owing to adjacent channel interference from the analogue signal.

In order to investigate this situation, surveys were carried out in the coverage areas of the Hannington and Crystal Palace DVB-T transmitters.

At Hannington the DVB-T transmissions are subject to an ERP restriction to the east. It was expected that this would result in reception difficulties in the town of Basingstoke, to the south east of the transmitter. Three of the six multiplexes are at risk, because they have adjacent channel analogue services. FIGURE 2 shows the results obtained at a sample of test points in the Basingstoke area. This diagram shows the relative locations of the test points and the transmitter site. The approximate HRP of the transmitting antenna is also indicated. For each test point, figures are given for the analogue to digital power ratios for three of the received digital signals.

The village of Overton receives virtually the full ERP of the DVB-T transmitter. Thus the power ratios are in agreement with the ratio of the nominal transmitter ERPs (17 dB). Consequently the digital signal can be decoded easily as denoted by the ‘tick’ indicators in the diagram. In Basingstoke, however, the effect of the ERP restriction can be seen. In the south of the town, the ratio is significantly higher than at Overton, but still not too high for the signals to be decoded. The further north the test point, the closer it is to the centre of the HRP null. Consequently, the more extreme are the analogue to digital power ratios. In the suburb of Chineham, in the extreme north, the analogue signal levels are all at least 40 dB greater than those of the digital signals. In one case the figure is 54 dB. The digital signal levels are sufficient to achieve reception, but the receiver will not operate with these high levels of adjacent channel interference. This is denoted by the ‘cross’ indicators. The protection ratio assumed for planning is 35 dB. When the ratio just exceeds this, the receiver used in these tests could be made to work by careful adjustment of signal levels. However, reception could not be guaranteed. This is denoted by intermediate ‘question mark’ indicators.

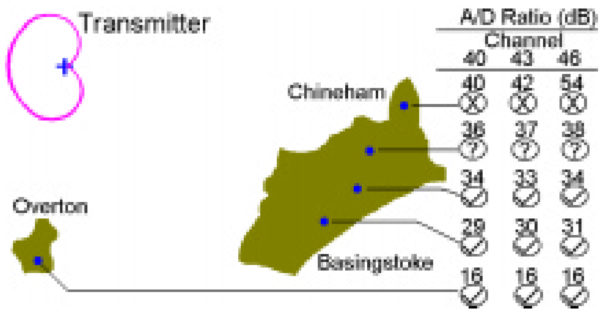

FIGURE 2 - Reception results and analogue/digital ratios for test points in the Basingstoke area.

A similar effect was noted in the coverage area of Crystal Palace, but this time on account of the vertical radiation pattern (VRP). In order to avoid causing interference south of the transmitter, the transmitting antenna used to transmit four of the six multiplexes is arranged so that in some directions the maximum power is directed about 3 degrees below the horizon. Therefore the ERP radiated towards points close to the transmitter is greater than that radiated towards points further away. Consequently, in these directions, the analogue to digital ratio increases with distance from the transmitter. In practice this gives rise to reception difficulties in very few areas. So far the only place where VRP effects have been found to cause reception difficulties is the town of Swanley in Kent, some 18 km from Crystal Palace.

Multipath Propagation (The Capture System)

Reception is sometimes impaired by multipath propagation with relative delays in excess of the guard interval. The effect of this is generally to increase the required Carrier to Noise Ratio (C/N), and hence the field-strength threshold, for the receiver to operate. In extreme cases the receiver will not operate at any signal levels. As with adjacent channel analogue interference, there is an increased likelihood of multipath problems in areas where there is a restriction in the radiation pattern of the transmitting antenna. However unlike adjacent channel interference, it is not easy to predict.

In order to investigate multipath effects, a powerful PC-based analysis tool was developed in association with Pioneer Digital Design Centre Ltd. The system consists of a fast Analogue to Digital Converter to digitise the received COFDM signal, and a digital memory to store a sample of the 'waveform'. Associated software analyses the captured sample to determine the amplitude and delay of any multipath echoes.

This technique was used extensively during field trials between 1996 and 1998 using an experimental pilot DVB-T transmitter at Crystal Palace. The transmission had a very directional HRP such that the power radiated to the North was 20 dB greater than that radiated to the South. This was found to result in severe multipath in many areas to the south of the transmitter.

FIGURE 3 shows three multipath profiles derived from the capture system during this work, along with the associated minimum required C/N. The diagrams show the amplitudes of delayed signals in dB relative to the direct signal, plotted against their delay times.

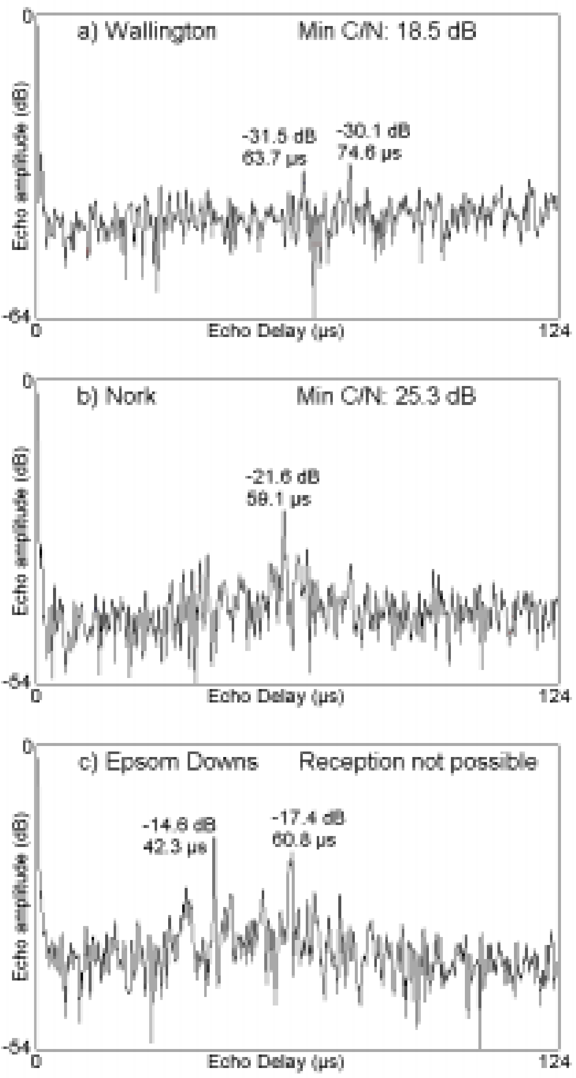

FIGURE 3 - Delay/amplitude plots for multipath echoes.

At the Wallington test point, the echoes were relatively low in level. Consequently reception was possible with a C/N of 18.5 dB (about the lowest value normally encountered). At Nork, there was a higher level echo, resulting in an increased C/N requirement of 25.3 dB. At Epsom Downs the multipath was even more severe and reception was not possible at all.

This measuring technique has continued to be used since the beginning of the DVB-T services in the UK. However, although multipath propagation has been found in some areas, no cases have yet been found where reception is inhibited by multipath propagation. This is thought to be because the directional characteristics of the transmitting antennas are generally less extreme than those used for the pilot transmission.

INDOOR RECEPTION

An important aspect of terrestrial transmission is indoor portable reception. Work has, therefore, been carried out to determine the limit of coverage to indoor antennas.

Measurements were made in a total of 33 residential buildings in the coverage area of the pre-operational experimental DVB-T transmissions from Crystal Palace. At each building, measurements were made in various rooms on different floors to quantify the loss of field strength compared to that measured outside at a height of 10 metres above ground level. Measurements were also made to determine the standard deviation of field strength within rooms.

From these results it was possible to calculate the minimum field strength required at 10 metres outside to provide various levels of indoor coverage. The results are summarised in TABLE 4. Although the UK network is not planned on the basis of indoor reception, a useful level of such reception is obtained in many areas.

	50% of rooms		All rooms	
Room category	50% of locations within room	90% of locations within room	50% of locations within room	90% of locations within room
Ground Floor	74	79	86	91
First Floor	69	74	81	86
Second Floor	68	74	79	84

TABLE 4 - Minimum field strength at 10 metres for various levels of indoor coverage.

CONCLUSIONS AND FUTURE PLANS

The work of the UK Joint Frequency Planning Project is now complete. The first 81 stations have been planned on the basis of a Multi-Frequency Network interleaved with existing analogue services. In doing this much attention needed to be paid to avoiding interference to these analogue services and providing solutions where interference was caused.

The roll-out of the DVB-T network in the UK is progressing well. Measurements in a few areas have confirmed that the coverage is generally in line with expectations. In some areas, coverage is limited by HRP restrictions in the transmitting antennas. This can give rise to difficulties caused by effects such as multipath propagation and adjacent channel interference from analogue transmissions. Indoor set-top reception of DVB-T services has been demonstrated. Although perfect indoor reception can only be expected very close to the transmitter, a useful level of such reception can be expected in many more areas.

As the transmitter rollout proceeds, more measurements will be required and, if necessary, solutions to new problems will be developed.

A new planning project was started in April ‘99 with contributions from the ITC, BBC, NTL and CTI. The intention is to improve and extend the UK DVB-T network over the next 3 years. This will be done by improving the coverage of the existing 81 stations where possible (by increasing the radiated power or the use of infill transmissions). Also, the possibilities for new stations will be investigated. Emphasis will be given to improving the coverages of the lower coverage multiplexes in order to equalise the coverages of the six multiplexes.

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