DTT COVERAGE – PREDICTIONS AND MEASUREMENT

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Introduction

Digital terrestrial television services began in the UK in November 1998. Unlike previous analogue services, the planning of digital television is based largely on computer coverage predictions. Although this reduces the need for extensive coverage measurements, some field work is 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. This paper discusses the first phase of field work recently undertaken for this purpose by the BBC.

Coverage vs. Prediction

Initial checks

A helicopter measurement system was developed to measure the measure the horizontal and vertical radiation patterns of the DTT transmitting antennas. Field strength measuring equipment was installed in a helicopter, which was flown around the antenna. During the flight, field strength was recorded on a computer along with positional information from a differential GPS system. Subsequent analysis of the data allowed the Horizontal Radiation Pattern (HRP) to be plotted. Also, signals were measured as the helicopter ascended vertically in order to determine the Vertical Radiation Pattern (VRP). Having used this equipment to check that the antennas were performing as intended, valid ground-based measurements could be made to check that the actual coverage was as predicted. It is important to note that the intention is to perform these measurements only in selected areas. It is not intended to survey all DTT transmitters

Coverage measurements

Having verified the transmitting antenna characteristics, 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 dB. 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. The DVB-T receiver was the BBC prototype receiver with a professional front end.

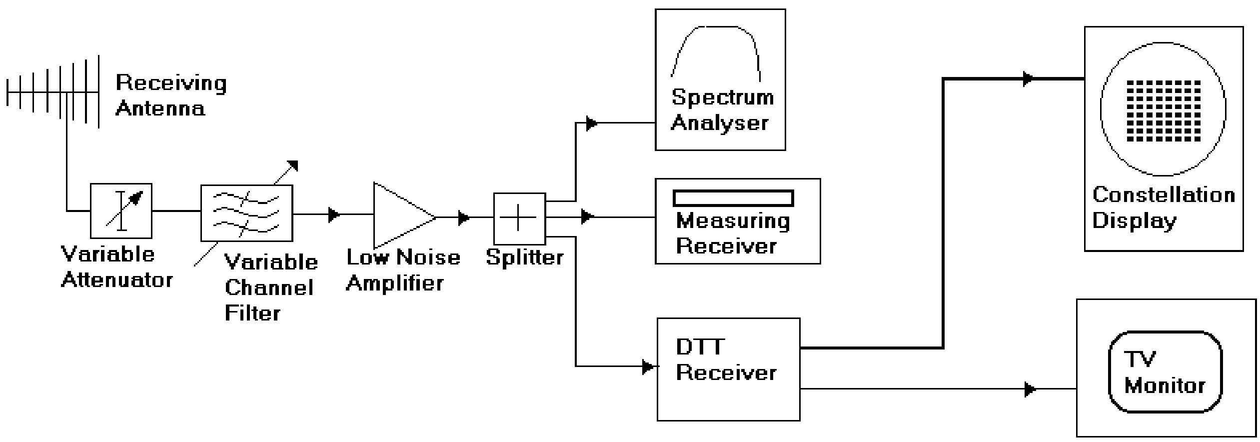

Figure 1. Experimental equipment in survey vehicle

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In order to measure the coverage; a square sampling technique was used. The purpose of this work was to measure the percentage of coverage for a number of 1km squares and compare it 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 coverage for that square.

The squares were mainly chosen in residential town areas, because, these are the areas where most potential viewers live. Rural areas are not suited to this type of survey, since there are generally insufficient roads for a satisfactory sampling of the square to be achieved. Town centre commercial areas, on the other hand, have a dense road network, but it is not usually possible to stop the vehicle.

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 and measurement accuracy. To provide a more accurate coverage figure it would have been necessary to use more points, perhaps up to 100. However, this would have limited the number of squares that could be measured within the time available.

So far detailed surveys have been carried out in six squares, associated with the Crystal Palace transmitting station, since the operational transmitters came on air. The measured and predicted coverage figures are given in Table 1. Reception was achieved at all test points visited, even where coverage was predicted to be less than 100%. 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 a small percentage of time. In cases where measured coverage exceeds predictions, this may not be the case for 100 percent of time. More useful information will be gained when more marginal areas are surveyed.

OS Square	*Location*	*DTT Channel*	*Measured coverage %*	*Predicted coverage %*
TQ3058	Coulsdon	22	100	95
		28	100	98
TQ3157	Old Coulsdon	22	100	98
		28	100	99
TQ3558	Warlingham	22	100	96
		28	100	94
TQ3562	Selsdon	22	100	98
		28	100	98
TQ3965	West Wickam	22	100	100
		25	100	100
		28	100	100
		29	100	98
		32	100	100
		34	100	98
TQ3966	West Wickam	22	100	100
		25	100	100
		28	100	100
		29	100	98
		32	100	100
		34	100	100

Table 1. Measured vs. predicted coverage

Reception anomalies

In some areas, although the field strengths of the DTT 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, multipath propagation and man-made interference.

Adjacent Channel interference from analogue services

In order to avoid causing interference to other analogue and digital transmissions, many digital stations 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 higher that 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 due 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 DTT transmitters.

At Hannington the DTT 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, since 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 the received digital signals.

The village of Overton receives virtually the full ERP of the digital 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 the digital signals, and 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 at one of the test points by intermediate ‘question mark’ indicators.

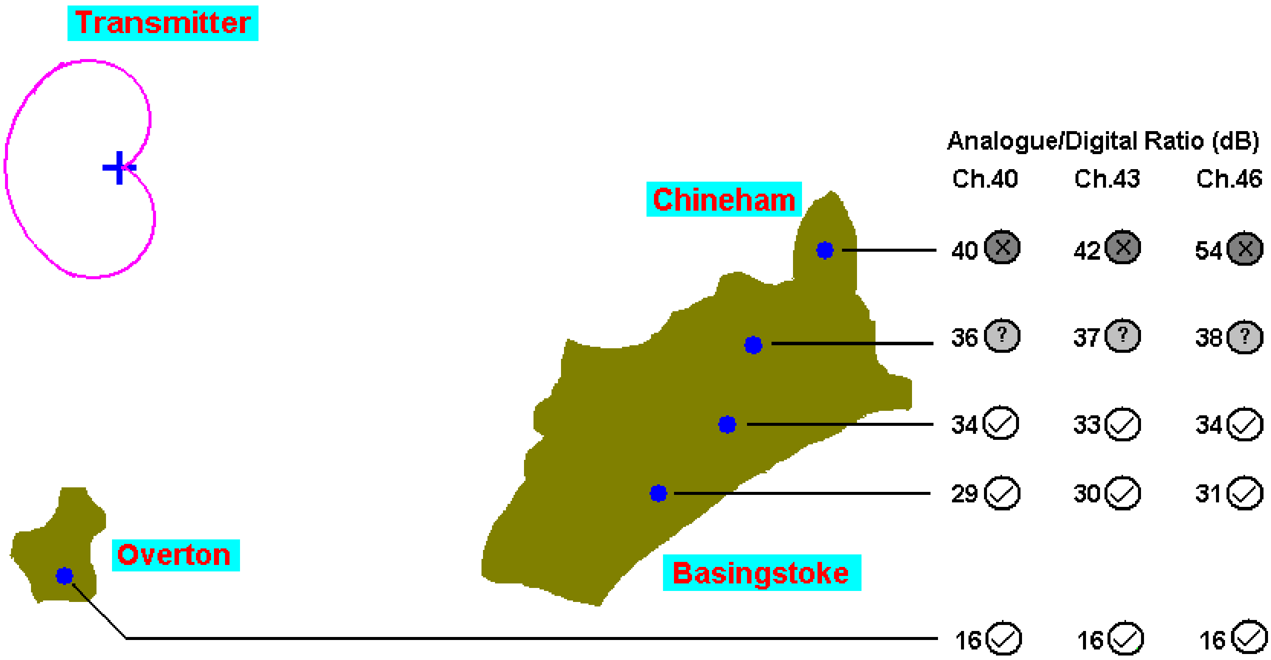

Figure 2. Reception results and analogue/digital ratios for test points in the Basingstoke area

A similar effect was noted in the coverage area of Crystal Palace. In order to avoid causing interference south of the transmitter, the transmitting antenna for the four highest power 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. The two lower power multiplexes are transmitted from the same antenna as the analogue services, which has an omni-directional pattern.

Figure 3 shows the average of the received analogue to digital power ratios for the four highest power multiplexes measured at points along a radial line centred on the transmitter site. The radial route was chosen to lie in a direction corresponding to one of the ERP restrictions. Also shown is the average analogue to digital power ratio for the two lower power omni-directional multiplexes.

At 5 km from the transmitter, the analogue signals are reduced owing to the VRP of their antenna, whereas the high power digital multiplexes are not. Thus the analogue to digital ratio for the high power multiplexes is considerably smaller than the ratio of the nominal maximum ERPs (20 dB). As distance increases, however, the situation reverses and the ratio becomes greater than the ratio of the nominal maximum ERPs. In the case of the low power multiplexes the ratio remains relatively constant. It can be seen that, beyond 10 km, the ratio for the higher power multiplexes becomes greater than that for the lower power multiplexes. The 18 km point corresponds to the town of Swanley. Detailed surveys around this area revealed some locations where the ratio for the high power multiplexes was great enough to prevent reception. Ironically, the lower power multiplexes, which were not subject to the ERP restriction continued to be received.

Although these interference effects result in reception difficulties in high signal strength areas, the transmitting antenna characteristics that cause them are incorporated into the computer prediction algorithms, and the effects are generally well predicted.

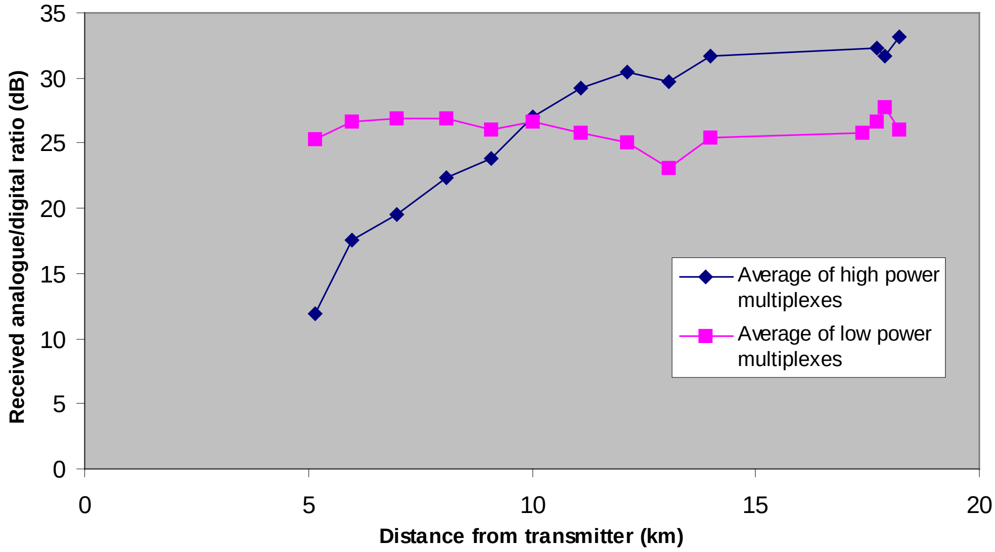

Figure 3. Analogue/digital ratio vs. distance from transmitter in ERP restriction

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, they are 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 DTT transmitter at Crystal Palace. The transmissions had a very directional HRP such that the power radiated to the North was 20 dB higher in level than that radiated to the South. This was found to result in severe multipath in many areas to the South of the transmitter. Figure 4 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. 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 vale 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 service for DTT in the UK. However, although areas of multipath propagation have been found, due to less directional HRPs, no areas have yet been found where reception is prevented by multipath propagation.

Man-made Noise

In town centres, man-made noise can be a problem if the field strength does not exceed the reception threshold by a sufficient margin. So far this problem has been identified at one location in Basingstoke. This location was near to the commercial centre of the town and suffered from low field strengths because of the transmitter HRP.

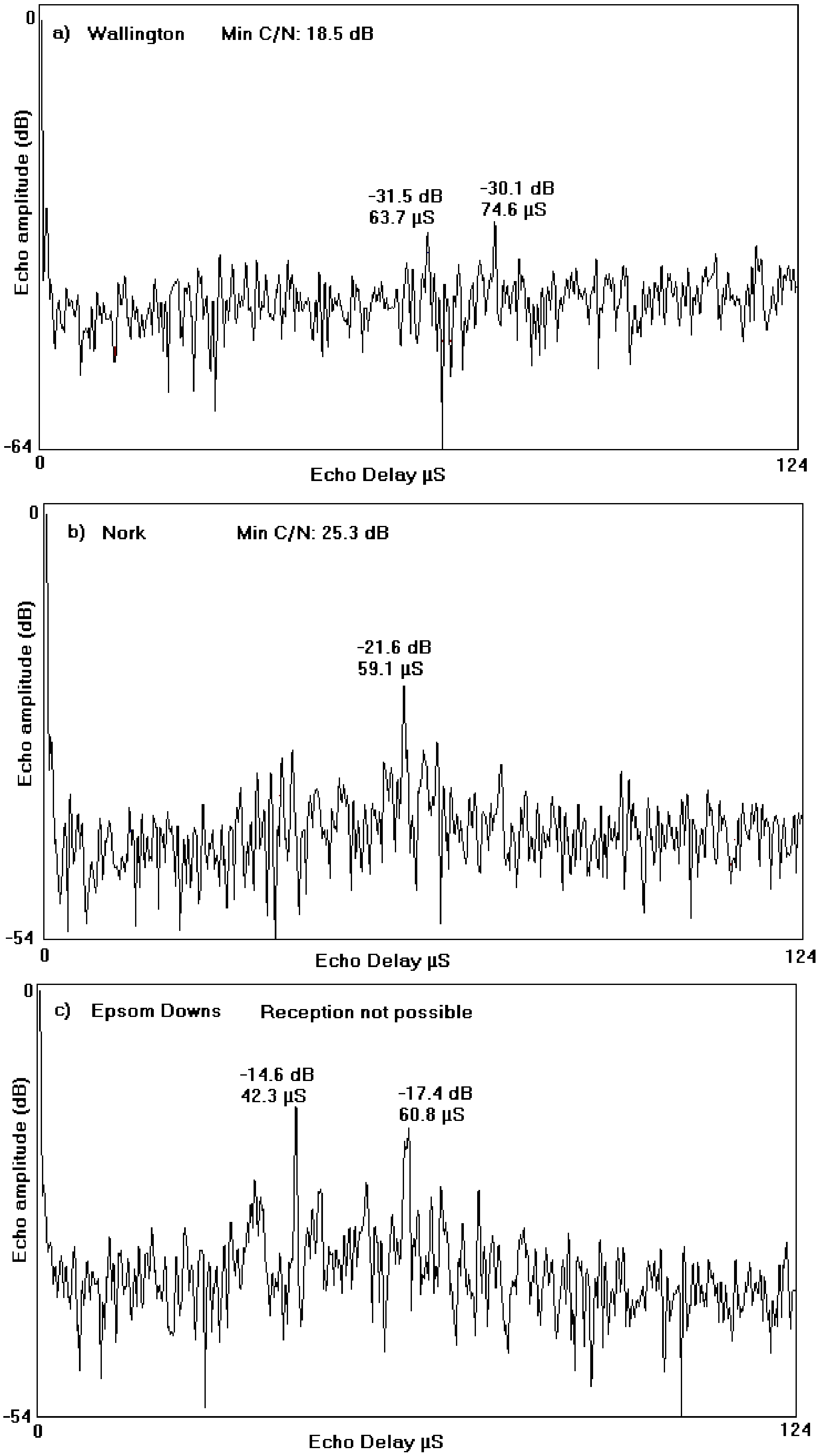

Figure 4. Delay/amplitude plots for multipath echoes

Indoor Reception

An important aspect of terrestrial transmission is indoor portable reception. Work has been carried out to determine the limit of coverage to indoor antennas and how it might be improved.

Measurements were made in a total of 33 residential buildings in the coverage area of the pre-operational experimental DTT transmissions from Crystal Palace. At each building, measurements were made of the loss of field strength associated with various rooms on different floors of the building. To do this a small indoor antenna was moved around the room at a typical ‘set-top’ height of about one metre above floor level. The signals from the antenna were fed to a measuring receiver interfaced to a computer, which recorded the measurements as the antenna was moved around the room. Analysis of the resulting data produced values for the median and standard deviation of the field strength within the room. A reference field strength was also measured outside the building at a height of 10 metres using the survey vehicle. The building loss of a room was defined as the ratio in dB of the outdoor field strength to the median value inside the room. Further tests were carried out to determine the minimum field strength required inside the rooms for the digital signals to be decoded. By adding the building loss, it was possible to calculate the minimum outdoor field-strength required at 10 metres to provide indoor coverage.

In practice, there was a considerable spread of values of building loss. A statistical approach was therefore adopted with measured rooms grouped according to floor level – ground, first and second. The results are summarised in Table 2. The first column gives the median value of the minimum outdoor 10 metre field strength corresponding to each floor level. However, since the building loss values themselves relate to the median field strength in a room, this value would only provide coverage to 50% of locations within the worst rooms. This level of coverage is considered to be just acceptable. Good coverage, with 90% of locations within a room served, requires an additional field strength equal to 1.3 times the standard deviation of the field strength variation within the rooms (see Column 2).

Columns 3 and 4 of Table 2 give the maximum values of the 50% and 90% field strengths for each floor level. These represent the field strength values required to cover *all* measured rooms. When compared to the minimum field strength required for outdoor reception at 10 metres (45 dB μV/m for the channel used in the tests), it becomes clear that blanket coverage to all buildings can only be achieved in high field strength areas close to the transmitter. However, an acceptable level of indoor reception, particularly in upstairs rooms, may be expected in a relatively large proportion of the coverage area of a transmitter.

Room category	50% of rooms		All rooms	
	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 2. Minimum field strength required at 10 metres to achieve various levels of indoor coverage

Clearly, there will be many areas where the field strength is too low for any useful level of indoor reception. In order to provide the flexibility of indoor reception in such areas, work was carried out within the ACTS VALIDATE project to determine the viability of a small domestic ‘gap-filler’. Such a device would amplify the DTT signals from an outdoor antenna and re-radiate them within the building. A prototype was developed by Televes, one of the partners within the VALIDATE project. Although there are still a number of issues to be resolved, initial trials were promising. An output power of less than 1 mW was found to provide good coverage in all houses tested.

Conclusions and future plans

The roll-out of the DTT 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 such as multipath propagation and adjacent channel interference from analogue transmissions. In addition, at some locations the digital signals have been found to suffer from man-made interference. Some preliminary work has been directed at quantifying these issues. As the transmitter rollout proceeds, more measurements will be required and, if necessary, solutions to any problems will be developed. However, it is not the intention of the BBC to survey the coverage areas of all DTT transmitters. Indoor set-top reception of DTT 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. Even if reception is only possible with an outdoor antenna, set-top reception could, in principle, be achieved using a domestic gap-filler device. Future work will be directed at the issue of reception with commercial receivers using both outdoor and indoor antennas.