DTT coverage predictions – how they are made and tested

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Planning of the UK terrestrial digital network was carried out as a Joint Planning Project by the BBC, NTL and ITC. The project was set up to plan the first 81 stations, providing six digital multiplexes. The planning of the network was a very complex operation with many constraints. At each station it was necessary to select the digital channels so as to give the best possible coverage, taking account of possible interference from all other digital and analogue transmitters. At the same time, it was necessary to avoid causing interference to other transmissions, both in the UK and in other countries; in many cases restrictions had to be imposed on the power radiated in some directions. To produce the detailed plans in the tight timescales required, it was essential to use planning methods based on computer predictions of coverage. In this article, then, we will look at how these computer predictions are achieved and how we set about proving their accuracy.

Predicting field strength

At the heart of any computer planning method is propagation prediction – that is the prediction of field strength from a transmitter at a receiving location. For many years, predictions have been made using a set of propagation curves contained in a recommendation of the International Telecommunications Union (ITU-R Rec 370) [1]. In its simplest form this method consists of a set of curves which define field strength versus distance from the transmitter. Different curves are used for paths over land, warm sea, cold sea and for different transmitting antenna heights. However, this method takes no account of terrain. Thus the mountains of Wales are treated in the same way as East Anglia.

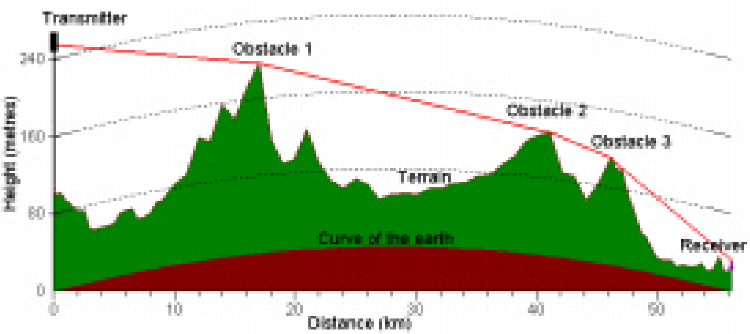
To achieve improved accuracy, DTT planning in the UK uses a sophisticated propagation model, which takes account of terrain. Different organisations within the planning project use their own methods. However, they are all centred on a database, which stores the terrain height for a grid of points covering the whole of the UK. The BBC uses a method developed by BBC R&D. The basic steps involved in predicting the field strength at a receiving location using this method are:

- **Define the direct path between the transmitter and receiver.**
- **Use the database to derive the path profile; a plot of height versus distance along that path.** Note that this also takes account of the curvature of the earth.
- **Determine the major obstacles along the path.** These can be thought of as the points where an ‘imaginary string’ stretched between the transmitter and receiver would touch the ground. Under some circumstances, land which *almost* touches is also considered.
- **Calculate the diffraction loss as signals pass over these obstacles.** This is achieved using mathematical equations derived from diffraction theory. The calculation takes account of the height and position of the obstacle relative to the ‘imaginary string’.
- **Combine these individual diffraction loss components with the free-space loss to calculate predicted field strength at the receiving location.**

Actually, there is a bit more to it than this. Different diffraction calculation methods are used according to how many obstructions are found, and whether the propagation path includes sea. Also, other propagation mechanisms such as tropospheric scattering are taken into account.

Predicting coverage

When generating coverage predictions for digital transmitters, predictions are made for 1 km by 1 km coverage cells. A field strength prediction is carried out to the centre of each cell using the terrain database method. This prediction is taken to represent the average for the cell and the field strengths at individual points within it are assumed to vary about this value. These variations are mathematically modelled using a log-normal distribution with a standard deviation of 5.5 dB. This standard deviation value has been determined by many years of field measurements.



Typical path profile derived from terrain-height database

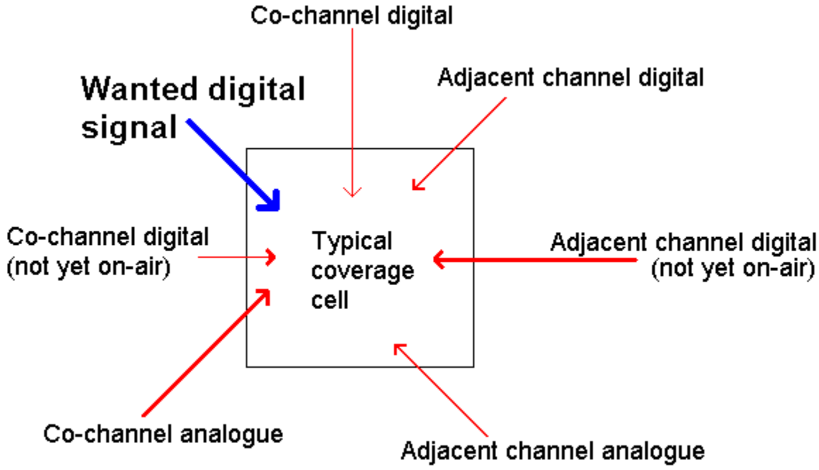
However, the field strength of the wanted digital signal is only one of the factors that determines the coverage. Interference from other transmitters is also vitally important. Therefore similar predictions are performed from all potential co-channel and adjacent-channel interfering transmitters (analogue and digital). In so doing, it is essential to take account of the large distance of some of these interfering transmitters. Propagation over such distances is subject to large variations, so that for short time periods the interfering levels may be much greater than normal. This is because conditions in the atmosphere cause the signals to follow curved paths allowing them to travel well beyond the horizon. To model this effect, when predicting interfering signals, the earth’s radius used to derive the path profile is much greater than the real value. Thus effectively, the earth’s curve (shown in brown in the diagram) is removed and the earth is modelled as being flat. This represents the way the earth appears to radio-waves under these exceptional conditions. The modelling of these effects is based on years of propagation measurements.

Of course, these predicted interference levels are those which only occur under worse case conditions. This often leads to a perception that coverage predictions are pessimistic. However, it must be remembered that the occasional propagation conditions that can give rise to patterning on analogue pictures are likely to result in blank screens in the digital world! Therefore, an area is only considered to be truly served if such effects have been taken into account in the predictions. Before this can be done it is important to set a target for the availability of the service. A figure of 100 percent of time in all areas cannot be achieved. Similarly, 90 percent is far too low. A target of 99 percent of time at the edge of service is considered to be a good compromise.

Having calculated the field strength for all interfering transmitters, they are scaled according to their protection ratio – in other words how damaging they are. This varies according to whether they are co- or adjacent-channel, analogue or digital. The effect of this scaling is to express all interfering signals in terms of an equivalent co-channel noise signal. Since the interfering transmitters will not generally be in the same direction as the wanted transmitter, and may have a different polarisation, a further scaling is performed. This takes account of the direction and polarisation of the interfering signals, based on the performance of a typical receiving antenna as defined by the ITU [2]. As with the wanted signal, these interferers are assumed to be average values and the distribution within the coverage cell is assumed to be log-normal with a standard deviation of 5.5 dB. In addition, the receiver front end-noise is represented by an equivalent interfering field, but since it does not vary across the coverage cell; it is assigned a standard deviation of zero. A receiver noise figure of 7 or 8 dB is assumed depending on the UHF channel number.

The combined effect of all interfering signals can also be approximated to a single interfering signal with a log-normal distribution. A mathematical formula developed by Schwartz and Yeh [3] allows the average and standard deviation of this total interfering field to be calculated from the values for the individual signals.

Having thus derived the averages and standard deviations of both the wanted signal and the total interfering signal, another mathematical formula is used to calculate the average and standard deviation of their ratio. In order for a receiver to work, this ratio in dB must exceed the minimum required carrier to noise ratio for the DTT system (which is assumed to be 23 dB, made up of a system C/N of 20 dB and an allowance of 3 dB for multipath effects). From these average and standard deviation values it is possible to calculate the percentage of locations within the coverage cell for which this would be true. This, then, is the percentage of locations coverage figure from which coverage maps are produced.



Signals arriving at typical coverage cell

In order to avoid causing interference to existing analogue services, at many stations restrictions needed to be imposed on the power radiated in some directions. For, example, at Hannington it was necessary to restrict the power to the east in order to protect analogue services from Guildford. Usually the analogue transmissions from the same mast radiate equal power in all directions. Consequently in the direction of the digital restriction, the ratio of analogue to digital field strength will be significantly greater than the ratio of the nominal transmitter powers. In the case of Hannington, for example, although the ratio of the nominal powers is 17 dB, in parts of Basingstoke field strength ratios have been measured in excess of 40 dB. In cases where the analogue and digital signals are adjacent channel (as at Hannington) this is likely to cause digital reception to fail due to adjacent channel interference. Thus, an additional correction is made to the coverage predictions to take account of such co-sited sources of interference.

Testing the predictions

Although the use of these computer prediction methods reduces the need for extensive coverage measurements, some field-work is still required to validate the predictions. It is also important to investigate situations that may give rise to reception difficulties. To do this a BBC measuring vehicle has been equipped with a DTT receiver and field strength measuring equipment. To receive signals the vehicle is fitted with an antenna mounted on a telescopic mast, which can be raised to a height of 10 metres above ground level.

Survey vehicle

The purpose of the survey work is to measure the coverage within a few coverage cells and compare the results with corresponding predictions. Coverage within a cell is measured by selecting a number of test points evenly distributed throughout the cell. The survey vehicle is positioned at each of these points in order to determine whether or not pictures and sound can be received. The percentage of measured points for which reception is possible is then judged to be the measured percentage of locations coverage for that cell. The coverage cells are mainly chosen in residential areas, because these are the areas where most potential viewers live.

Results so far suggest that coverage is generally at least as good as the predictions suggest. Digital reception is easily achieved in areas predicted to be well served. It may be tempting to say that the predictions are overly pessimistic, but as noted earlier, the predictions are based on worst-case interference levels that only occur under exceptional propagation conditions. Also, in some areas the predictions will include interference from digital transmitters not yet on air.

Multipath effects

There are effects that can, in principle, result in poor digital reception even in strong signal areas. One such effect is adjacent channel interference from co-sited analogue transmissions, as discussed. Another such effect is multipath propagation, which causes the familiar ghosts on analogue pictures. With digital television, multipath can cause higher than expected bit error ratios for a given carrier to noise ratio (C/N). In effect it means that a higher C/N will be required to decode the signals than in a multipath-free situation. In severe cases it can prevent the receiver from working at all. To investigate such situations a multipath analysis tool has been developed by the BBC and others to identify any delayed signals and determine their delay times and levels with respect to the direct signal. So far no locations have been found where multipath propagation represents a serious problem to DTT reception.

Predictions and measurements for the future

Without the use of computer prediction and planning tools it would have been impossible to achieve a detailed 81-station plan in the time for the start of service. Similarly, without real measurements to validate them, there would always be a risk in trusting predictions. However, coverage surveys for the whole of the UK would be an enormous undertaking with little purpose. Field measurements will, therefore, continue to check predictions in a few areas, particularly where particular issues or difficulties are identified. Also, as the transmitter rollout proceeds, small filler transmitters will need to be planned and built. Predicting both the coverage deficiency from the main transmitter and the coverage of the filler will introduce a large margin of error. Thus, measurements will be very important in such a situation. Hand in hand, computers and measuring vehicles will continue to be the major tools in the development of DTT into the next millennium.

References

[1] ITU-R Recommendation 370
[2] ITU-R Recommendation 419
[3] Schwartz, S.C. and Yeh, Y.S., 1982. 'On the distribution function and moments of power sums with log-normal components', Bell Systems Technical Journal, September 1982