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UK Planning Model for Digital Terrestrial Television coverage

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Abstract

This paper describes the coverage prediction methods developed for planning DVB-T services in the UK. The method, known as the "UK Planning Model" (UKPM), has been jointly developed by four UK organisations concerned with DVB-T planning. The paper outlines the approach for predicting received field strength with particular discussion of profile extraction, radial prediction and the use of clutter data to take into account the effect of buildings and trees. Transmitter and population databases are also discussed

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UK PLANNING MODEL FOR DIGITAL TERRESTRIAL TELEVISION COVERAGE

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ABSTRACT

This paper describes the coverage prediction methods developed for planning DVB-T services in the UK. The method, known as the "UK Planning Model" (UKPM), has been jointly developed by four UK organisations concerned with DVB-T planning. The paper outlines the approach for predicting received field strength with particular discussion of profile extraction, radial prediction and the use of clutter data to take into account the effect of buildings and trees. Transmitter and population databases are also discussed.

INTRODUCTION

Computer coverage predictions continue to be important for planning digital terrestrial television services. The UK DTT planning organisations (ITC, BBC, Crown Castle and NTL) have jointly developed a coverage prediction and planning model, known as the "UK Planning Model" (UKPM). This paper, jointly produced by the four organisations, discusses the improvements made in developing the UKPM.

UKPM prediction results are primarily used for coverage and interference evaluation to support channel selection and antenna design. This is required for improving and extending the UK DVB-T network plan, Plumb et al (1). The results can also be used as an input to a coverage database to inform retailers and consumers on likely coverage in specific areas.

The purpose of developing the UKPM was to produce consistent prediction results between the UK planning organisations while taking advantage of the availability of terrain and clutter data and improvements in computer power. To obtain this consistency the UKPM must specify the full sequence of processing steps.

FIELD STRENGTH PREDICTION METHOD

The basis of UKPM is the prediction of received field strength at a location, taking into account the environment in between. This is based on the BBC field strength prediction method, the principles of which are described by Causebrook (2) and which has been used and subsequently developed by all UK planning organisations. An overview of the field strength prediction process is shown in Figure 1. Initially a terrain and clutter profile is generated for the path between transmitter and receiver. Terrain heights are then corrected to take into account the curvature of the earth. The effective earth radius used in this calculation is modified according to the time percentage required for the prediction.

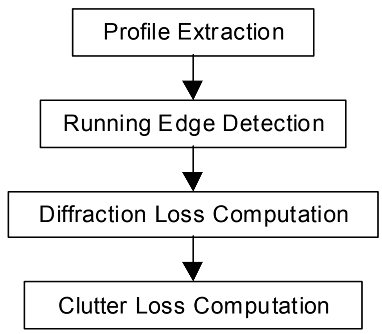

Figure 1 – Overview of the Field Strength prediction method

The terrain profile is processed to select the terrain points which would be touched if a string was stretched between the transmitter and receiver (see Figure 2). These points are termed 'running edges'. Adjacent running edges which are close together may be grouped into a single virtual edge. The terrain diffraction algorithm then models the profile as a canonical object, (wedge, multiple knife edges or a cylinder) and computes the diffraction loss associated with these objects. Clutter losses, due to buildings and trees, are then calculated from the profile. Ducting and troposcatter losses are also taken into account, if the prediction is for a low percentage of time.

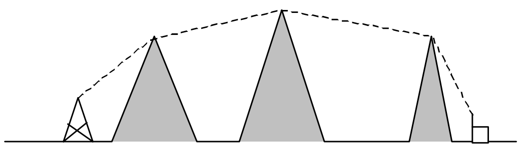

Figure 2 – Definition of the running Edges

In the remainder of this section, some of these procedures are presented in more detail.

Terrain data

The terrain data used for the UK has a 50 metre resolution as supplied by the Ordnance Survey and Ordnance Survey of Northern Ireland. For areas outside the UK, which are important when predicting interference into the UK from other countries, the terrain data used is from the GLOBE 30" dataset (approximately 1 km resolution).

Clutter data

The main propagation obstacles close to the receiver are likely to be buildings and vegetation. These are identified using a clutter database of the UK. The most detailed data is derived from aerial photography and provides clutter characterisation at a resolution of 25 metres. It has 16 clutter classes and provides information on building and tree heights for major cities and towns. A 50 metre resolution dataset is used for the remainder of the UK. This is derived from Land-sat satellite images and provides 10 clutter classifications and covers the whole of the UK. The two clutter data sets are combined to give the categories listed in Table 1. An example of the clutter map is shown in Figure 3.

	Clutter Class	Building height (m)
1	Water	0
2	Open	0
3	Open in urban	0
4	Light Wood	0
5	Low Suburban	5
6	Embankment	8
7	Suburban	9
8	Wooded Suburban	9
9	Wood	0
10	High Suburban	12
11	High Embankment	15
12	Urban	18
13	Tall Wood	0
14	High Urban	27
15	City	40
16	High City	50

Table 1- Clutter classification scheme

Figure 3 - Building clutter data

Profile Extraction

The objective of the profile extraction algorithm is to compute the shortest path between the transmitter and the receiver terminals, and retrieve terrain and clutter information along this path. Given that the terrain and clutter data we use are projected via a transverse Mercator (TM) projection, if the distance between the two terminals is short, the shortest path between them can be approximated by a straight line (on the map). However, when computing the coverage of a high power broadcasting station, the distance between the receiver and the transmitter can be longer than 100 km, therefore this approximation is no longer valid. In the UKPM we have used an algorithm, described by Ordnance Survey (3), that takes the earth's curvature into account, and therefore accurately traces the correct curve that corresponds to the shortest path.

A common use for the UKPM is for predictions where the transmitter and receiver are in different countries and therefore in different grid systems. This could be dealt with in a number of ways, for example segmenting the profile into sections, each belonging to a single grid system or computing the latitudes and longitudes of the profile points along a great circle and then transforming these coordinates to the appropriate grid coordinates. However both these methods are unacceptably slow. For the UKPM we have adopted a simpler approach based on transforming all source terrain and clutter data to a single grid system. The single grid system used is an extended version of the UK National Grid System, which uses the Transverse Mercator projection (3).

The resulting algorithm is almost as fast as the extraction algorithm of the original BBC model, but is able to trace the path profile much more accurately.

Edge Detection

Given a profile, the goal of the edge detection algorithm is to compute the diffracting edges, as shown in Figure 2. This is achieved in a recursive fashion as illustrated in Figure 4 The execution time of this algorithm is proportional to the number of points in the profile as well as to the number of edges. By moving to higher resolutions, *both* these numbers increase, and as a result, the complexity of the edge detection algorithm is proportional to the *square* of the increase in resolution.

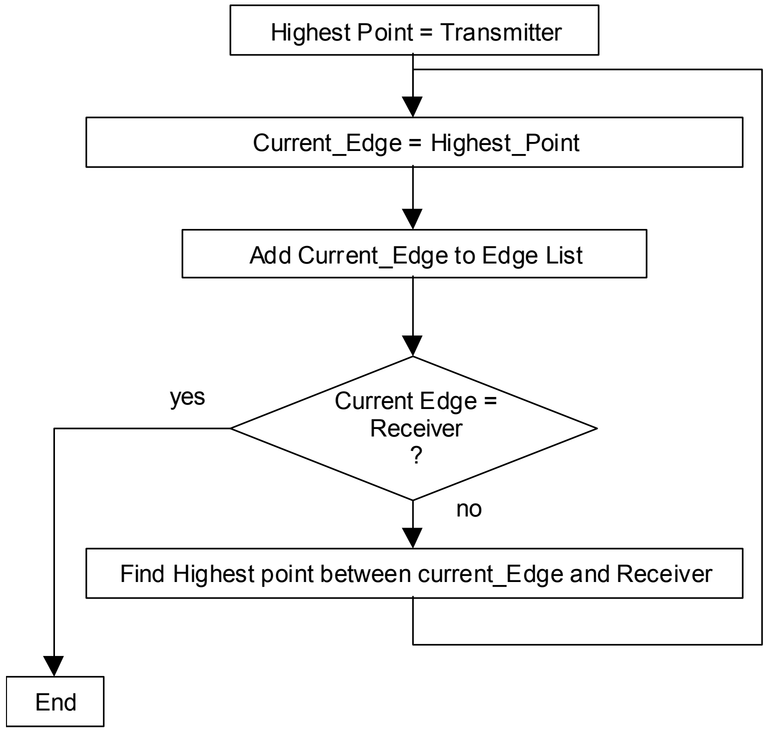

Figure 4 - Description of the edge detection algorithm

Clutter Loss Computation

The clutter loss algorithm is designed to take into account the effect of buildings and trees in the area near to the receiver. Clutter loss is calculated separately for buildings and trees using the terrain and clutter data for the last 5 km of the profile.

Buildings

The algorithm for the computation of path loss due to the presence of buildings is based on the multiple edge diffraction method followed in the BBC model. However, when computing diffraction from buildings, the clutter height, as presented in table 1, is added to the terrain height, for all profile points whose clutter class indicates that they contain buildings. This method is essentially a modified Deygout method (4), but up to three edges are considered, the main one and another edge on either side of it. The Causebrook correction (2) is applied, to compensate for the fact that if two edges are close, the Deygout method overestimates losses.

Additionally, there is a limit to the maximum loss due to buildings. This is to compensate for the fact that if buildings are tall, thus introducing a large diffraction loss, the main signal path will be *around* them rather than *over* them.

Trees

Unlike buildings, trees allow a proportion of the electromagnetic energy to pass through them. The path loss due to trees can be computed by multiplying the length of the profile that is covered by trees by a predetermined loss rate factor, expressed in dB/m, Saxton and Lane (5). The portion of the profile that is covered by trees, is computed by scanning through profile, and identifying the points whose clutter type indicates that they contain trees. The contribution of each point to the tree cover depends on the probability of trees blocking the first Fresnel zone.

On the other hand, part of the electromagnetic energy is diffracted and propagates above the tree canopy. This propagation mechanism is decribed by Head (6) and introduces almost a fixed loss. As a result the amount of attenuation that is introduced by vegetation is bounded by the magnitude of this loss, which is an empirical factor that needs to be optimised.

Raster vs Radial scanning

The traditional method, followed by the UK planning organisations, to compute the field strength of a transmitter over a wide area, is to superimpose a regular grid over this area and then perform a point-to-point prediction between the transmitter and each vertex of the grid. This is known as raster scanning. The advantage of this approach is simplicity, however it can be time consuming when the number of grid points is large.

When specifying the requirements of the UKPM, it became evident that performing a prediction over a wide area using 50 m or even 100 m grid resolution would be prohibitively slow. For example the area for which the Crystal Palace transmitter can be a significant interferer is a square with a side of about 700 km. (or 490,000 km^2). Assuming a 100 m grid resolution, then the field strength at 49 million points needs to be computed, and if raster scanning was applied it would take many days.

In order to improve execution speed, the UKPM model uses a technique known as radial scanning. Terrain and clutter profiles are generated from the transmitter location to successive points along the edge of the target area. Field strengths are calculated for all the pixels along each profile, thus allowing the reuse of intermediate results.

The most obvious gain is realised at profile extraction. If the grid is a square with N points per side, then up to 4N profiles need to be extracted, rather than N^2 required for the raster scanning method. Furthermore, the time consuming edge detection algorithm was adapted so as to work in a marching fashion along a profile.

As a result, the benefit of radial scanning is a dramatic reduction in execution time. Performing the aforementioned area coverage prediction can take 2 to 3 hours rather than many days. On the other hand one may argue that we do not compute exactly at the grid vertices. But if the grid resolution is as high as 50 or 100 m, this is not a significant problem.

Another potential disadvantage is that the precise radial paths depend on the target area which is to be calculated. This could lead to different predictions results for the same pixel, if the target area is altered. To avoid this problem we have standardised prediction target areas between organisations.

TRANSMITTER DATA

A common database is used by all planning organisations to ensure consistent transmitter data. The format of the database is based on the CEPT format (7) but the antenna pattern resolution in this format is low so where available a separate antenna pattern file is used. This file can contain the pattern either in the form of two planes, a horizontal plane at 1 degree resolution and a vertical plane at 0.1 degree resolution, or in a 3D format giving the vertical plane pattern at different azimuths. The 3D format is necessary to enable predictions to be performed for antenna systems that exhibit varying vertical pattern with azimuth.

SIGNAL COMBINATION

The proportion of locations in each prediction pixel which will be served with interference limited coverage depends on the effect of the sum of multiple interferers whose field strength has a log-normal distribution. The Schwartz and Yeh method (8) is used to sum multiple log-normally distributed field strengths with the standard deviation assumed to be 5.5 dB (7).

POPULATION COVERAGE CALCULATIONS

An important output of the prediction process is the predicted number of households in the coverage area. Previously this has been estimated using a list of addresses per postal code but the accuracy of this is limited because the area covered by a single postcode can be bigger than a prediction pixel. We can now use data which gives locations for individual addresses. This gives a more accurate estimation of the number of households in each prediction pixel.

COMPARISON WITH MEASUREMENTS

Description of measurements data

In order to measure the performance of the UKPM prediction model, a procedure also known as validation, we used a collection of measurements that were performed by the BBC in previous years. The measurements set is quite extensive, comprising of more than 9000 points. No averaging has been applied to these data. A large number of transmitters was measured (mostly main, analogue stations), and the path length range varies between a few and more than a hundred kilometres.

Some of these measurements are quite old and the clutter database, which is based on images taken after 1999, may not describe accurately the local obstruction at the time of the measurement. Furthermore, the receiver location was not extracted electronically, but was taken from a paper map with an accuracy of 100 m. As a result, we believe that the quality of these data is not good enough to validate the performance of a high-resolution model. Therefore all the results presented in this section must be considered preliminary.

To overcome this problem we have initiated a large scale campaign to collect more measurement data. We have taken more than 50,000 measurements but the processing phase had not been completed by the submission date of this paper.

The validation metrics

The validation of the UKPM model has been performed against the mean error, and the standard deviation of the error. Another useful metric is the excess loss as described in (2). The basis of this approach is the elimination of the free space loss component from both measurements and predictions. In other words, both measurements and predictions are expressed in terms of the excess loss over the free space loss. When the measured excess loss is plotted against the predicted excess loss, we have a visual indication of the performance of the model, which can help us identify any systematic errors, as well as areas where the model misbehaves.

Ideally all points should fall on the 45 degree diagonal (also expressed as the x=y line), indicating a match between predictions and measurements. The performance of the model is inversely proportional to the scattering of the points.

Results

The mean error and standard deviation for the BBC model assuming 500 m profile sampling resolution and the UKPM model assuming 500 m and 50 m resolution are presented in Table 2.

The better performance of the UKPM model is clearly illustrated by these results. It is also apparent that most of the performance gain is achieved by the inclusion of the clutter loss prediction algorithm rather that the increased resolution.

The corresponding excess loss graphs are presented in Figure 5 and Figure 6. The relatively small scattering of the points in the UKPM model are a clear indication for its superior performance.

	Mean error	Standard Deviation
BBC model 500 m resolution	5 dB	9.4
UKPM model 500 m resolution	- 5 dB	8.3
UKPM model 50 m resolution	-2 dB	7.7

Table 2 - Preliminary prediction error statistics

CONCLUSION

The UK Planning Method for Digital Terrestrial Television coverage predictions has been discussed. Initial results have shown that the newly developed propagation model is more accurate than the original BBC model or other empirical models such as that described in ITU-R Recommendation 370. Furthermore, the radial scanning technique that has been adopted and refined in the UKPM ensures that the increased accuracy will be achieved without the expense of greater computation speed. As a result we believe that UKPM will greatly enhance our capability to plan and optimise the Digital Terrestrial Television network in the UK.

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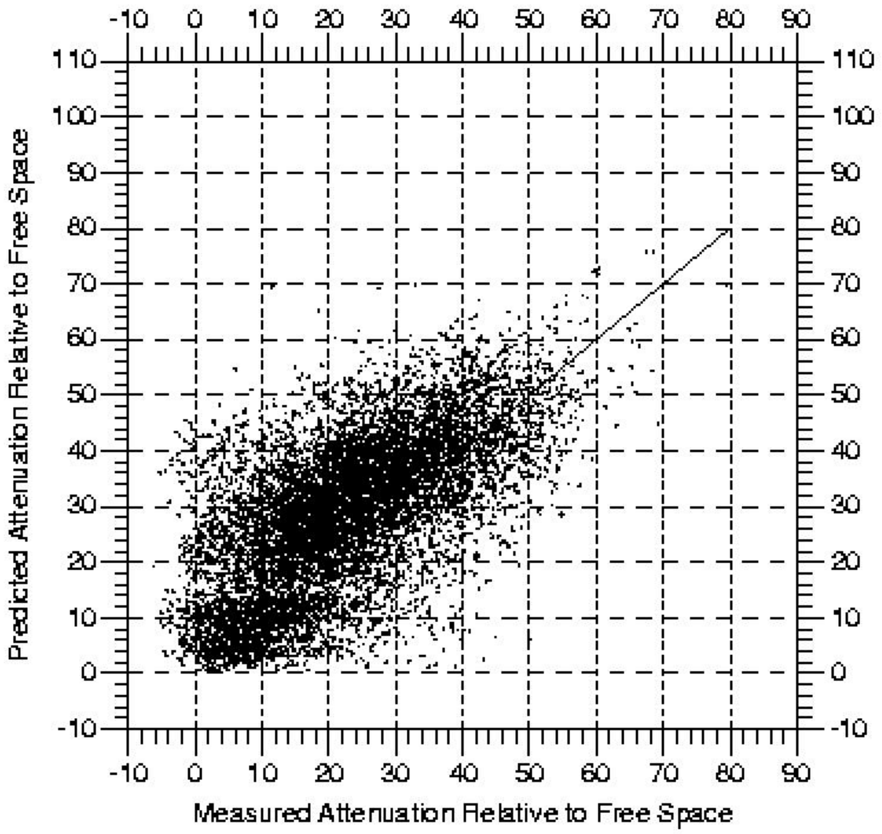

Figure 5 - The excess Loss for the BBC model assuming 500 m resolution

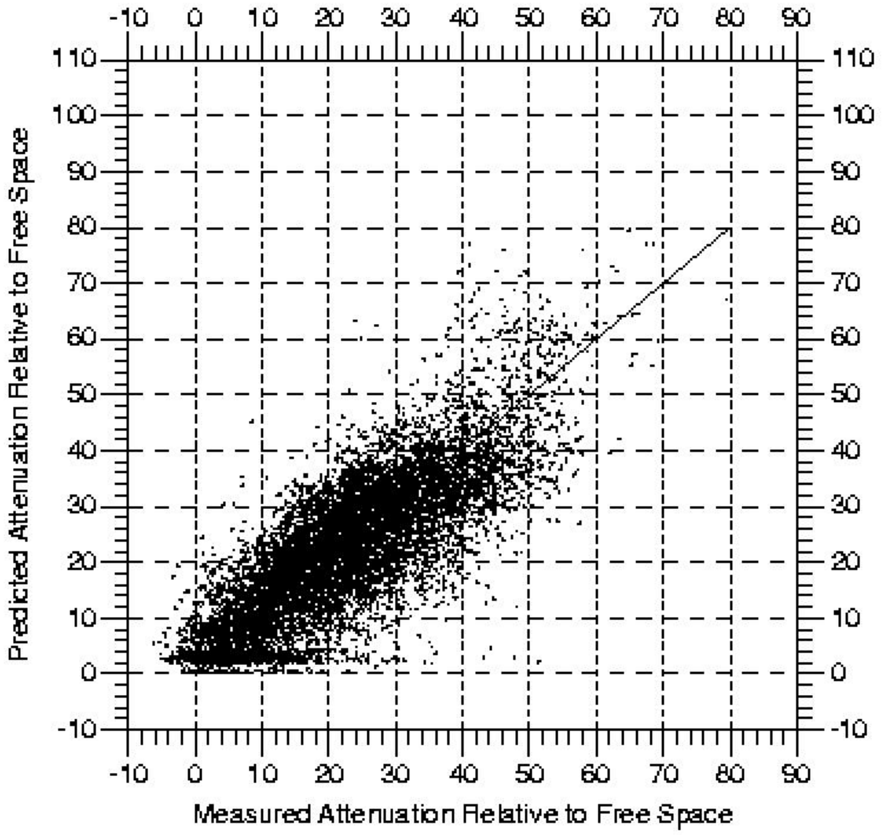

Figure 6 - The excess loss of the UKPM model assuming 50 m resolution