MEASUREMENT BASED SOFTWARE DESIGN FOR DVB-T AND T-DAB SINGLE FREQUENCY NETWORK PLANNING AND COVERAGE PREDICTION

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Abstract

This paper suggests an architecture design for a single frequency network (SFN) planning software. These software tools are going to be very useful during the planning stages in order to optimize the network design and implementation process. The new digital broadcasting services DVB-T (digital terrestrial video broadcasting) and T-DAB (digital terrestrial audio broadcasting) have been already tested in many countries over the world and commercial emissions have already begun in some European and Asian countries. The design described here includes an optimization module that allows evaluating the coverage estimation values obtained when some field measurements are available.

INTRODUCTION

The present moment is the starting point of a transition period in which traditional analogue broadcast services will coexist with the new digital broadcasting standards: digital terrestrial television (DVB-T) and digital audio broadcasting (T-DAB) Among many other features of these new systems, one of the most appealing aspects of those services is the possibility to work by means of single frequency networks (SFN).

The aim of this paper is to suggest a possible architecture design for SFN planning software implementation. This type of tools will be very useful in order to predict electric field strength values on the service area and also to make an estimation of the percentage of locations covered. The major innovation of this work is based on the error estimation module with field measurement data and the inclusion of signal combination methods that have been already proposed to calculate real coverage percentages on SFN service areas.

SFN PLANNING

SFN planning requires a much more detailed coverage estimation if compared to conventional analogue planning due to the abrupt behavior of digital receivers and the adding effect of signals from different transmitters of the same network. The immediate consequence of this need of accuracy is the size of each analysis cell where coverage is estimated (100x100 m). Predicted field strength values have to be statistically combined to obtain the C/N ratios present inside that small area.

The parameters that have been taken into account to calculate the coverage probability inside the service area of a SFN are the following:

- **Minimum C/N** ratios required by the digital receiver. These values have to be determined by field measurement data and depend on the receiving environment type. The ones usually considered are gaussian, ricean and rayleigh environments, according to rural, suburban and urban areas each **[1]**.

- **Coverage definition.** The coverage area is the result of all the 100 x 100 m areas where the 98% of the locations inside have a C/N ratio higher than the minimum required by the service being planned.

- **Guard Interval.** This parameter is a special feature of the modulation schemes used by DVB-T and T-DAB. The signals from different transmitters will be classified into contributing or interfering depending upon this parameter.

- **Standard deviation** of the spatial distribution of the received signal in order to evaluate coverage probabilities from the predicted median electric field. Measurement campaigns inside several DVB-T and T-DAB networks have estimated some reference values **[2][3].**

Figure 1 shows the complete coverage probability estimation process.

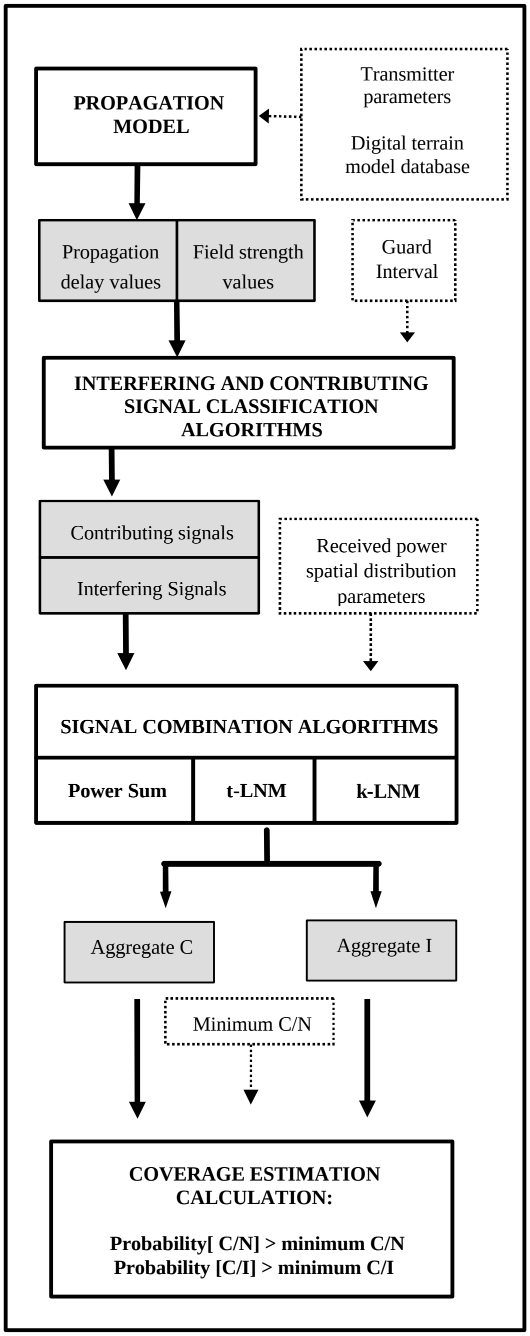

Figure 1. SFN coverage calculation method

The process of calculating the coverage probability in a SFN can be summarized in four steps.

The first one consists in estimating the field strength matrix for each transmitter of the SFN as the received power at every point of the analysis grid inside the service planning area. This calculation can be based upon theoretical, empirical or semi-empirical propagation models. A comparison between the error values given by some methods was shown in **[4]** and **[5]**.

These authors demonstrated that there is not a suitable method appropriate over the whole frequency range assigned to DVB-T and T-DAB services. Moreover, the accuracy of those models strongly depends on the geographical features of the coverage area. During this calculation step the propagation delays from the different transmitters at each point of the coverage area are also obtained.

The second step consists in classifying the field strength matrices into interfering signals and contributing ones. The transmitters having a propagation delay higher than the guard interval will be considered interfering ones and those having a delay smaller than that guard interval will be treated as a contribution to the useful signal.

Once the contributing and interfering transmitters have been determined, the aggregate C and I have to be calculated. Some methods have been proposed in **[6]** to obtain the aggregate C and I. Excluding the *power sum method*, those methods are based on statistic algorithms that assume a log-normal distribution of the field strength variation. The final combination of those fields is another log-normally distributed field strength.

The last step would be to calculate the probability of having an aggregate useful power to noise and interference ratio higher than the required minimum C/N and C/I ratios of the system being studied.

PLANNING SOFTWARE DESIGN

The SFN planning software functions have been structured into four independent modules:

- Geographical analysis and representation
- Field strength prediction models
- Error estimation
- Coverage percentages estimation

The geographical analysis and representation module manages the digital terrain database. This module provides the information that some of the propagation models use to predict field strength values. It also gives geographical representation of the results.

Field strength predicting algorithms

This module contains all the algorithms that estimate the received field strength inside the area that is being studied. These calculations are based on several theoretical, empirical and semi-empirical propagation models. The theoretical algorithms include the Deygout, Epstein & Peterson, Giovaneli, Meeks and Bullington multiple knife edge diffraction formulae. The empirical methods considered are the ITU-R Recommendation 370, and Oukumura-Hata. The FZT and Longley-Rice semi-empirical methods have also been implemented inside this module.

The selection of the propagation model is directly related to each service and the frequency used to broadcast it. As an example, Spain has the Band III of the UHF band assigned to T-DAB and the DVB-T is being allocated on the Band V. As a consequence, it is not easy to recommend a valid model that provides reasonable accuracy for both services. Different prediction methods should be also used depending upon the geographical features of the SFN service area (flat, hilly or mountainous)

Several simulations were carried out and the results were compared to some field data from a measurement campaign in an experimental DVB-T network in Madrid **[7]**. Table I shows the mean error between simulations and field data.

Method	Mean Error (dB)
Deygout	-2.53
Giovanelli	-2.46
Epstein & Peterson	-4.51
Meeks	-3.69
Bullington	-6.62
Rec. 370 UIT-R	2.58
Oukumura-Hata	-4.49
FTZ	0.54
Longley-Rice	-8.38

Table I. Mean error between simulations and measurements.

Inside the surveyed area, where many terrain profiles have knife edge obstacles, the theoretical methods show an optimistic behavior. Among all those methods the best results were obtained using the FZT method, which takes into account empiric data as well as the terrain profiles to predict the field strength. Nevertheless, it should be noted that at some points the error value is about 12 dB. Considering the abrupt behavior of a digital receiver, such values would lead to a very inaccurate coverage prediction. The empirical methods have an acceptable median error but some points show values higher than 15 dB.

Error estimation

This module estimates the error by means of a comparison between the simulated values of each method and the data from real measurements. The functions of this module provide both graphical and numerical relationships between the parameters used by each method and the magnitude of the error. This approach allows optimizing the values of those parameters to improve the accuracy of simulations carried out in a specific country.

It is essential to be aware of the accuracy of the simulations when planning digital broadcasting systems because the difference between error free reception and decoding failure can be in a range of some decibels if the location is near to the coverage threshold.

As an example of the capabilities offered by this module, figure 2 shows the behavior of the error for the UIT-R Rec. 370 related to the distance between transmitter and receiver. The vertical axis shows error values and the horizontal axis the distance in kilometers.

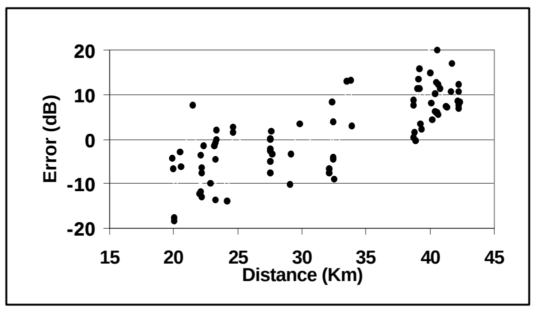

Figure 2. Relationship between simulation error and transmitter-receiver distance (UIT-R Rec. 370)

Coverage estimation

This module is composed by the functions that carry out the calculations made to take into account the specific features of the SFN. There are three different tasks to be done:

- Contributing and interfering matrix classification
- Statistical combination of received signals
- Coverage probability calculation

The classification process of the field strength into contributing and interfering matrices is done by comparing the propagation delays to the guard interval of the SFN. At this stage, the effect of a standard receiver equalization algorithm can be included by means of a coefficient **W**. Each value of each matrix will be multiplied by **W**, being this parameter a function of the propagation delay from the transmitter to the receiver and taking the reference time value the delay of the main signal received at each point.

$$\begin{aligned} W &= F_{PRE}(t) && \text{if } t < 0 \\ W &= 1 && \text{if } 0 < t < Tg \\ W &= F_{POST}(t) && \text{if } t > Tg \end{aligned}$$

t propagation delay related to the main signal
Tg guard interval
F_{PRE}(t) Equalizer response to pre-echoes
F_{POST}(t) Equalizer response to post-echoes

The matrices that result from this classification process are combined. The software presented uses three possible methods: Power Sum, t-LNM and k-LNM. The power sum method shows a poor accuracy if compared to the other two. Coverage estimations appear to be quite optimistic. In spite of that optimistic behavior and due to its small computational requirements it is suitable for the first stages of the planning process. The k-LNM method shows a certain amount of error when applied to those areas where the coverage probability is high. Nevertheless, this method can be optimized by adjusting the parameter *K* by means of field measurements and coverage simulations. This process needs to be done carefully because the coverage probability is strongly affected by small variations on *K.* The t-LNM algorithm is the one that offers the highest accuracy but at the same time consumes a considerably computational resources. As well as the k-LNM, this method has some parameters to be optimized.

The third set of functions included in the coverage probability module calculate the percentage of covered locations at each 100 x 100 m area. The input variables for those functions are the aggregate C, the I and the minimum C/N and C/I ratios of the service being planned.

CONCLUSIONS

This paper suggests a software architecture to estimate the percentage of covered locations inside a single frequency network service area with a high degree of accuracy. A wide range of propagation models should be included in this type of planning tools if it is going to be used to plan both T-DAB and DVB-T networks and if its scope is intended for a wide range of different geographic environments.

The fact of adding an error estimation and parameter optimization module allows to improve the results as far as new data from real measurement campaigns become available.

ACKNOWLEDGEMENT

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