GROUND PROFILE ANALYSIS ALGORITHM TO IMPROVE MULTIPLE DIFFRACTION LOSS ESTIMATION

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Abstract
This paper suggests an optimized algorithm for computer based field strength and coverage predicting tools. This algorithm is intended for network planning software and focuses on the calculation stages of the diffraction loss caused by multiple edge-knife obstruction of the first Fresnel ellipsoid. The results presented here have been obtained by comparison between former software implementations of the Deygout[1] method and some field strength measurements.

1. INTRODUCTION

The selection of a propagation model that provides the highest accuracy for the estimated values of the received field strength inside the coverage area is essential for a correct network planning. Many factors have to be taken into account during the selection process. Such factors include the terrain characteristics, frequency band, special features of the service that is being planned and so on. During the last decades some studies have been carried out in order to survey the behavior of the different propagation models by means of comparison between computer simulated values and data obtained in field measurement campaigns**[2]**. Those studies have been focused on analogue broadcast services. The result of those surveys has lead to a reasonable accuracy of the field strength prediction process when applied to analogue planning.

The recently developed standards for digital broadcast services like digital terrestrial television (DVB-T) and digital terrestrial audio broadcasting (T-DAB) are now being put into practice in some European and Asian countries. The first network planning has already begun in countries like Spain, and the availability of accurate network planning tools is essential to take advantage of all the technical benefits that those new technologies provide.

The study presented in this paper has surveyed the behavior of some propagation models that estimate the equivalent field strength values over the service area of the DVB-T experimental network in Madrid (Spain). As result of this work an algorithm is proposed for digital terrain data based models that use Deygout and derived methods to predict the diffraction loss caused by multiple knife-edge obstacles. First in this paper, a very brief description of the measurement data is given. Afterwards, a comparison between those values and simulations made based upon the original prediction models is shown, and finally, the new algorithm is detailed along with a comparison between the results obtained with and without this modification.

2. FIELD STRENGTH MEASUREMENT DATA

The field strength measurement data were obtained during the field trials of the experimental DVB-T network set up in Madrid under the scope of the VIDITER project **[3]**. The whole measurement set is composed by the data acquired at 79 locations inside the network coverage area. The transmitter is located at the north border of the region at the top of a high mountain range. The coverage area of the transmitter has two different types of locations. Certain areas show a regular geographical features with no abrupt height changes but with small rounded hills. Those small irregularities at some locations arise high and close enough to the receiver to partially obstruct the first Fresnel ellipsoid as shown in figure 1a. Other areas have irregular ground profiles between transmitter and receiver and depending on the azimuth of the measurement location one or more peaks near the transmitter partially obstruct the first Fresnel ellipsoid as shown in figure 1b.

3. ALGORITHM DESCRIPTION

Previous to the measurement campaign, several simulations were made with a digital terrain database of the service area of the experimental DVB-T network. Those simulations were compared to the measurements. The methods used in the simulation tools were both theoretical (Deygout, Meeks, Giovanelli)**[4][5]**, empirical (Rec 370 UIT-R, Oukumura) and semiempirical (Longley-Rice, FZT). Table 1 shows a summary of the overall errors between simulations and measurements. The error shown is the difference between the measured and predicted values.

	Mean Error	Standard Deviation
DEYGOUT	-4,2804	5,7747
GIOVANELLI	-4.4360	6,7509
MEEKS	-4,43253	6,6333
Rec 370 UIT-R	1,8788	8,9603
OUKUMURA	-4,4954	10,6549
FTZ	0,5404	5,7169
LONGLEY	-8,3857	7,8395

Table 1. Comparison between measurement data and simulations

As the number of measurements was not very extensive the methods that include statistically obtained parameters were not taken into account. The three diffraction methods (Deygout, Meeks and Giovanelli) led to a reasonable accuracy at most profiles. However, the error at some points was found to be near -20 dB. A deeper inspection of the ground profiles showed that no multiple edge knife obstacles were present at those points. The cause of such optimistic behavior of the diffraction methods was due to small terrain irregularities near the receiver that were not considered as knife-edges by the profile analysis algorithms. Figure 1 shows one of these ground profiles and the Fresnel ellipsoid obstruction near the receiver.

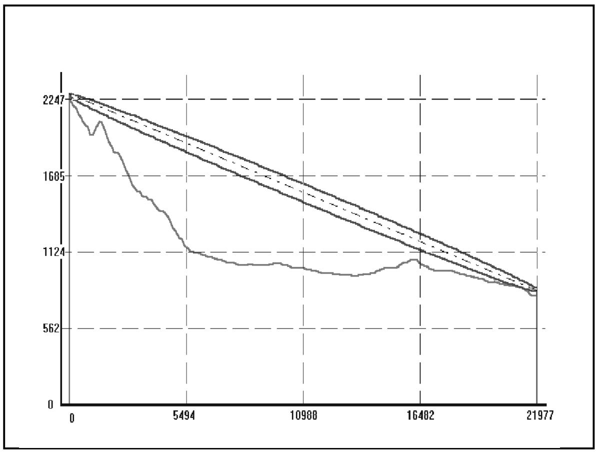

Figure 1a. Obstruction near the receiver at one of the measured locations

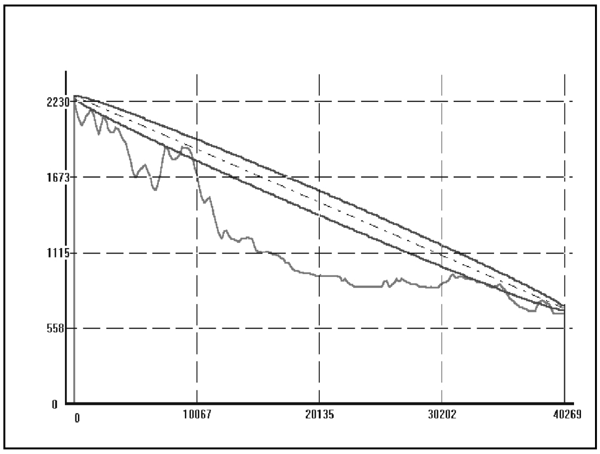

Figure 1b. Irregular profile with multiple obstacles at one of the measured locations

The multiple edge diffraction estimation methods are based on the combination of the loss caused by simple edges that obstruct the first Fresnel ellipsoid on each transmitter-receiver ground profile. The first step that those methods follow in order to estimate the diffraction loss consists on identifying the main knife-edge obstacles. All the points of the profile obstructing the Fresnel first ellipsoid and being surrounded by lower heights are considered as knife-edge obstacles.

At locations like the one shown in figure 1a, the partial obstruction near the receiver was not identified as a knife-edge obstacle and the result was an optimistic estimation of the field strength value. The implementation of those three algorithm used the same terrain analysis functions to identify knife-edges so the error was similar in Deygout, Giovanelli and Meeks.

In order to improve the profile analysis and to avoid the specific situation that arises when small rounded hills obstruct the first Fresnel ellipsoid near the receiver the following steps are suggested.

1.Any point of the ground profile obstructing the Fresnel ellipsoid (either being a knife-edge or not) should become a candidate to be considered as a knife-edge obstacle.
2.If that point is considered a knife-edge:
2.1 It will be labeled as main edge if the obstruction is higher than any other point of the profile
2.2 The process will continue finding out the secondary knife-edges recursively
3. If that point cannot be considered a knife-edge the following conditions are checked:
a) No knife-edges have been found near that point of the ground profile
b) The obstruction at that point is higher than the samples immediately after and before
c) No more than two knife-edges have already been considered in the whole profile analysis

If those three conditions are fulfilled the loss due to that profile point will be considered and calculated as if it was a knife-edge obstacle but no more knife-edge obstacles will be considered.

The Deygout method, as well as the modifications made by Meeks and Giovanelli to the original algorithm analyze each terrain profile to find the obstacles that obstruct the Fresnel ellipsoid and evaluate each obstacle to determine the main ones. Thus, the implementation of those three algorithm uses the same terrain analysis functions to identify main edges. As a consequence, any modification made on the terrain analysis function will affect all of them.

4. RESULTS

The proposed modification of the profile analysis functions was added to the field strength prediction algorithms and led to the results shown on table 2. The profiles shown on the table are only the ones having small rounded obstacles near the receiver (14 out of the 79 measurement locations).

Profile ID	Deygout		Giovanelli		Meeks	
	Original.	Modified.	Original.	Modified.	Original.	Modified.
607/08	-13.73	-0.25	-13.73	-3.48	-13.73	-13.73
607/16	-10.44	-8.39	-10.44	-8.39	-10.44	-8.39
707/08	-6.11	-2.09	-9.88	-2.09	-9.88	-2.09
707/11	-9.17	-6.35	-9.17	-6.35	-9.17	-6.35
807/10	-15.46	-9.57	-15.46	-10.75	-15.46	-10.75
807/11	-14.21	-8.32	-14.21	-9.5	-14.21	-9.5
907/05	-8.03	7.91	-8.03	-5.02	-8.03	-6.47
907/07	-8.04	5.18	-8.04	-2.69	-8.04	-5.96
907/08	-7.58	0.73	-7.58	-4.05	-7.58	-4.05
907/10	-18.37	2.36	-18.37	-3.88	-18.37	-12.19
907/11	-15.08	2.12	-15.08	2.12	-15.08	2.12
907/12	-16.76	-10.08	-16.76	-10.08	-16.76	-10.08
907/13	-17.13	-9.97	-17.13	-9.97	-17.13	-9.97
907/22	-0.019	3.32	-0.019	3.32	-0.019	3.32

Table 2. Error results comparison between original methods and modified ground profile analysis function.

The results of table 2 show the same values for the three methods if the proposed correction is not included. This behavior is due to the fact that most of those profiles have a single knife-edge obstructing the Fresnel first ellipsoid, so the diffraction loss calculation does not include the multiple edge algorithms. If the proposed modification is included the results are improved as expected in points where the profile is similar to the one shown in figure 1a.

Once the error value was improved in points like the one shown in figure 1a, the impact on the profiles like the one in figure 1b was studied. If the profile analysis modification is included, the number of knife-edges increased because some irregularities near any knife-edge were also considered as obstacles. Consequently, the inclusion of the modification affected the three methods in a different degree. The most affected one was the Deygout method because this method specifically presents a worse behavior when the profile shows relevant obstacles near from each other(eg. Profile ID 907/05 on Table 2).

The Giovanelli method is not affected by the modification because it was specifically designed to cope with profiles that have two or more relevant obstacles near from each other. In the same way, the Meeks method results are not affected because this algorithm takes into account the width of the obstacles. In general, the inclusion of the profile analysis algorithm leads to better results in points having small rounded obstacles near the receiver and it causes small variations in profiles where no special profile analysis was needed. Table 3 shows the overall mean error and standard deviation for the whole measurement locations after the profile analysis was included in Deygout, Meeks and Giovanelli simulations.

	Mean Error	Standard Deviation
DEYGOUT	-2,6762	4,9169
GIOVANELLI	-3,2572	5,6724
MEEKS	-3,5485	6,4295

Table 3. Mean and standard deviation of the difference between measurement and simulation values after the profile analysis modification was included

5. CONCLUSIONS

This paper suggests a profile analysis algorithm to be included in the multiple diffraction methods in order to consider the attenuation caused by small irregularities near the receiver. This algorithm has appeared to improve the results of multiple knife-edge diffraction loss estimation methods like Deygout, Meek and Giovanelli. This algorithm has been implemented to be included in a DVB-T planning software. The accuracy of the field strength prediction methods is essential for planning those networks because small variations on the received power lead to C/N values under the minimum required at points near the coverage threshold. More field trials are now under design in order to corroborate the efficiency of the proposed algorithm on different receiving environments

6. ACKNOWLEDGEMENT

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