Simple Algorithm for Computation the Attenuation Correction Factor

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Abstract – **This paper presents novel algorithm for computation of the attenuation correction factor due to terrain irregularity. ITU-R statistic method uses this correction to improve its accuracy. Since the attenuation is given by diagram as a function terrain irregularity factor (Δh) and distance (r) the need for mathematic closed form of the attenuation is obvious.**

Keywords **– ITU-R method, attenuation factor, mathematic model**

I. Introduction

The staggering deployment and growth of wireless systems in recent decade has generated a great deal of interest in propagation prediction research. Any type of cellular or radio & TV system requires careful planning and prediction of signal coverage and interference. Unfortunately, this type of in-depth site planning requires tremendous amounts of measured data and trial-and error testing that can often be prohibitively expansive [1]. Therefore a huge demand already exists in the wireless industry for the development of accurate propagation prediction techniques. Site-specific prediction techniques tend to push aside empirically based prediction methods, but in cases where large area of coverage is in focus latter method seems to be dominant [2, 3, 4].

One of the most popular statistic methods for electric field strength prediction is described in ITU Recommendation 370-7. The ITU-R method for the determination of the field strength is based on measurements of the field strength conducted on a terrain with the *effective height of the transmitting antenna* as a parameter [5] and adjusted for half-wave dipole antenna, which radiates 1 kW e.r.p. Since ITU-R method suffers from inaccuracy in some zones there are three proposed correction, which improved accuracy of this method (terrain irregularity correction factor, clearance angle, and type of zone factor) [5].

The purpose of this work is to define an appropriate mathematical model of the attenuation due to terrain irregularity.

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II. Definition of the Problem

To gain a better accuracy it has been developed various corrections that take into account the degree of terrain irregularity of the nearby terrain (terrain factor – parameter Δh), the clearance angle correction and the height gain factor that takes into account type of zone (urban, suburban and rural) and frequency range for its calculating (see Table 1 in [4]). The parameter Δh is used to define the degree of terrain irregularity and for broadcasting services it is applied in the range 10 km to 50 km. The land path curves in [5] refer to a value of the $\Delta h = 50\,\text{m}$, which generally applies to the rolling terrain commonly found in Europe and North America. Clearance angle correction is given by formulas [5] that greatly simplify its calculation as compared to the terrain factor, which is read from the diagrams.

But attenuation correction factor is given by diagrams so there is problem to read it correctly since the patterns are given only for some specific values of Δh. Our goal is to find the appropriate mathematic model for calculation of the attenuation due to the terrain irregularity.

III. Finding the Approximation

Figure 1 defines the attenuation correction factor (in dB) as a function of the distance d and Δh, for frequency range 80-250 MHz [5].

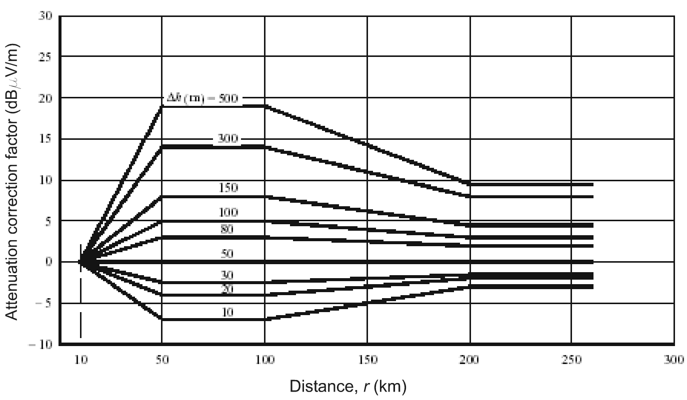

Fig. 1 Attenuation correction factor as a function of the distance d (km) and Δh

The other diagram for the frequency range 450-1000 MHz is similar to the above and the problem could be generally solved.

First we assume that function $\Delta E(r,\Delta h)$ could be represented in the following form:

$$\Delta E(r,\Delta h) = F(f(\Delta h), r) \tag{1}$$

Notice that the idea is the same as in [6].

The shape of the curves are straight connected lines and it is easy to deduce that attenuation correction factor in function of distance (r) is simple linear function. Therefore we can simplify the model how attenuation varies with distance. This leads to explicit determination of $F(f(\Delta h), r)$.

Precise reading of values ΔE at the points of connection of the superimposed linear functions gives us next representation of attenuation:

$$\Delta E(r,\Delta h) = \begin{cases} 0, & r < 10 \\ E_I(\Delta h)\cdot\dfrac{r-10}{40}, & 10km \le r < 50 \\ E_I(\Delta h), & 50km \le r < 100 \\ E_I(\Delta h) + \left(\dfrac{r}{100} - 1\right)\cdot\left[\Delta E_{II}(\Delta h) - \Delta E_I(\Delta h)\right], & \\ & 100 \le r < 200 \\ E_{II}(\Delta h), & r \ge 200 \end{cases} \tag{2}$$

where Δh is in interval from 10 to 500 m. Both approximate functions, $E_I(\Delta h)$ and $E_{II}(\Delta h)$, will be determinated afterward. Note that $f(\Delta h)$ is split in two functions $E_I(\Delta h)$ and $E_{II}(\Delta h)$ which give a constant value of attenuation from 10km to 50 km, and for more then 200 km, respectively.

But the attenuation depends in quite complicated manner of Δh, *which* is the main problem to find. Analyzing the position of the values of $E_{II}(\Delta h)$ and $E_{II}(\Delta h)$ it can be showed that approximation function is linear combination of the following functions *Const*, $x^{1/4}$, $x^{1/3}$ and x. The form of the approximate function is:

$$E(\Delta h) = C_0 + C_1\Delta h^{1/4} + C_2\Delta h^{1/3} + C_3\Delta h \tag{3}$$

Finding least-squares fit to the list of values $E_{II}(\Delta h)$ and $E_{II}(\Delta h)$ of variable as a linear combination of the following elementary functions *Const*, $x^{1/4}$, $x^{1/3}$, yields to:

$$\begin{aligned} E_I(\Delta h) = {} & -12.8688 - 8.50214\Delta h^{1/4} + \\ & + 9.8629\Delta h^{1/3} + 0.01243\Delta h \end{aligned} \tag{4}$$

and

$$\begin{aligned} E_{II}(\Delta h) = {} & 9.6566 - 34.7648\Delta h^{1/4} + \\ & + 23.0012\,\Delta h^{1/3} - 0.0366\Delta h \end{aligned} \tag{5}$$

Thus we finally determined the function $F(f(\Delta h), r)$ that is the approximation of the results given on Figure 1.

IV. Algorithm for Computation of the Attenuation $\Delta E(r,\Delta h)$

Now we can define the algorithm for computation the attenuation in function of distance and terrain irregularity factor Δh :

1. Input variables are terrain irregularity factor Δh and distance *r.*
2. Using formulas (4) and (5) we compute $E_I(\Delta h)$ and $E_{II}(\Delta h)$.
3. Replacing the values for $E_I(\Delta h)$ and $E_{II}(\Delta h)$ into (2) we get $\Delta E(r)$.
4. For specific distance we easy compute the value of attenuation ΔE .

V. Analysis of the Obtained Results

Tables (1) and (2) contain the exact value of attenuation, the approximate value and the absolute error for a given Δh. The absolute error is less then 0.325 dBμV/m in both tables, which at first sight seems to be a rough approximation.

TABLE 1
APPROXIMATE FUNCTION $E(\Delta h)$-LINE AND EXACT VALUES –DOTS FOR r=50 KM

Terrain irregularity factor -Δh (m)	Exact value of $E(\Delta h)$ (dBμV/m)	Approximate value of $E(\Delta h)$ (dBμV/m)	Absolute error (dBμV/m)
10	-7	-6.863	0.137
20	-4	-4.325	0.325
30	-2.5	-2.493	0.007
50	0	0.236	0.236
80	3	3.207	0.207
100	5	4.782	0.218
150	8	7.917	0.083
300	14	14.044	0.44
500	19	18.995	0.005

On the other hand the error of the statistic method [5] caused by reading the diagram is up to ±1 dBμV/m, which tells us that error in computing the attenuation is acceptable. Therefore for practical work this algorithm gives quite precise results.

TABLE 2
APPROXIMATE FUNCTION $E(\Delta h)$-LINE AND EXACT VALUES –DOTS FOR r=200 KM

Terrain irregularity factor -Δh (m)	Exact value of $E(\Delta h)$ (dBμV/m)	Approximate value of $E(\Delta h)$ (dBμV/m)	Absolute error (dBμV/m)
10	-3	-2.997	0.023
20	-2	-2.160	0.160
30	-1.5	-1.334	0.166
50	0	0.117	0.117
80	2	1.863	0.136
100	3	2.819	0.181
150	4.5	4.709	0.209
300	8	7.958	0.042
500	9.5	9.505	0.005

Figures (2) and (3) show exact values of the $E(\Delta h)$ (dots) and its approximate function (line). We can see that approximate function generates the values for attenuation even for the range out of Δh=500 m which corresponds to the extrapolation. In practice there are many cases when terrain irregularity factor is great then 500 m. ITU-R Recommendation suggests extrapolation of the values and the above algorithm also solves that problem.

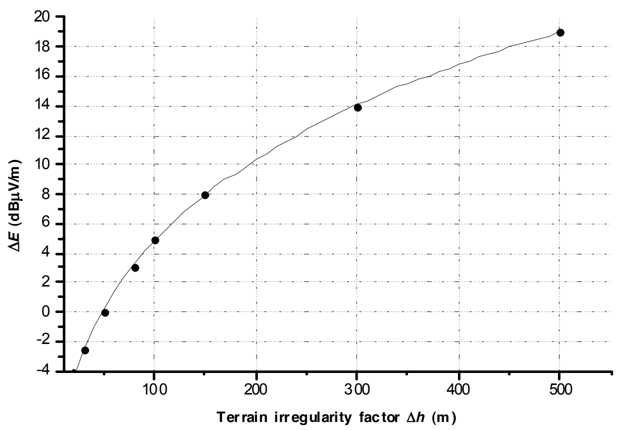

Fig. 2 Approximate function $E(\Delta h)$ (line) and exact values of $E(\Delta h)$ (dots), for r=50 km

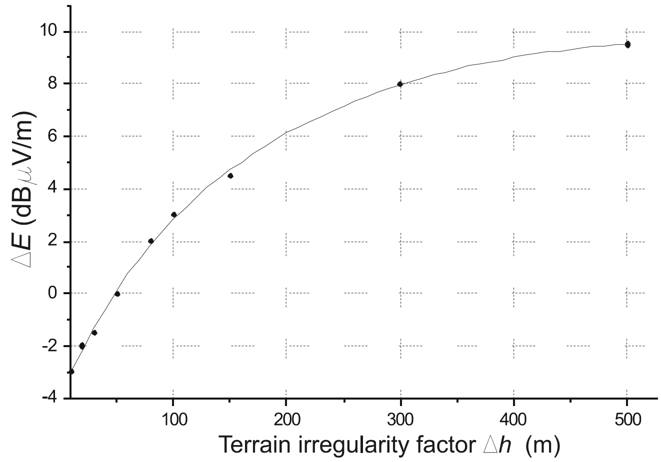

Fig. 3 Approximate function $E(\Delta h)$ (line) and exact values of $E(\Delta h)$ (dots), for r=200 km

The mean square error for the Figure 2 is σ_I=0.176 dBμV/m with maximum absolute error Δ^{I}_{max}=0.325 dBμV/m. The same parameters for the Figure 3 are σ_{II}=0.135 dBμV/m and Δ^{II}_{max}=0.209 dBμV/m

V. CONCLUSION

The proposed method for approximation of attenuation due to terrain irregularity gave results that could be defined as accurate and reliable when compared to the results determined graphically (standard method). Easy implementation of the derived results is the main contribution to the practical solution of the field strength prediction problem.

This algorithm generates continuously attenuation values for all terrain irregularity factors between 10 and 500 m. Also the algorithm gives the extrapolated values for Δh greater then 500m.

The idea for this work came from [6] and generally it could be apply to many empiric results to find approximate function.

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