COMPARISON OF PROPAGATION OVER IRREGULAR TERRAIN

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Abstract

Various cases of electromagnetic wave propagation have been solved such as two obstacles with the sharp edges or the spherical earth especially for low altitude propagation considering several combinations of antenna and observation point heights. Computation results and published solutions for individual special cases agree quite well. That demonstrates the usefulness of the method.

Keywords
propagation of electromagnetic waves, propagation over terrain, low altitudes propagation.

1. Introduction

Irregular terrain reflection computations can be found in [1] where the computer model and computation accuracy for propagation over irregular terrain are presented. Special attention is paid to computation for low altitude propagation and the finite distance between the antenna and the observation point (diffraction field zone) as the higher altitude propagation is considered in [2] where the propagation for flat surfaces, spherical earth and sharp edges is calculated and compared with the published solutions. Programs [2] allow to compute propagation over irregular terrain for both horizontal and vertical polarization considering the Fresnel reflection coefficient for terrain with random deviations and refraction (it is possible to enter the effective earth radius R_e). To compute reflections, the contributions from the irregular terrain are integrated. That cannot be used, if the difference between the incident and reflected rays is too small (less than one third of the wavelength).

This paper studies the electromagnetic wave propagation for low altitudes as well as for the transition zone between the low and higher altitudes. Various cases such as two obstacles with the sharp edges or the spherical earth considering several combinations of antenna and observation point heights are taken into account. Computation results and published solutions for individual special cases agree quite well. That demonstrates the usefulness of a given method.

2. Comparison of computation results and published solutions

If the surface change is stepped (such as the obstacle with the sharp edge on the plane surface), the attenuation of electric field is computed using the relationship for electric field calculation over infinite half-plane. The examples for this case were given in [2]. In this case, the difference is only small.

![Graph showing attenuation A(dB) for two obstacles with the knife-edges](image)

Fig. 1. The attenuation A(dB) for two obstacles with the knife-edges with \( p_1 = 228\text{m}, \ p_2 = 227.45\text{m}, \ d_1 = 5400\text{m}, \ d_2 = 10600\text{m} \), \( d = 10000\text{m} \) and the wavelength is 0.67m. The solid line is the calculation [1], dot and dash line is calculation using the program [2] and dash line is calculation according to [3].

According to [3], two obstacles with the sharp edges, located as shown in Fig. 1 are considered for illustration. Heights \( h_2 \), \( p_1 \) and \( p_2 \) are considered from the antenna height \( h_1 \) where \( p_1 = 228\text{m}, \ p_2 = 227.45\text{m}, \ d_1 = 5400\text{m}, \ d_2 = 10600\text{m} \), the observing point distance \( d = 10000\text{m} \)
and the wavelength is 0.67m. The solid line is the calculation [1], dash line is calculation according to [3] and dot and dash line is calculation using the program [2].

It can be seen that they are in very good agreement for greater heights but the second obstacle affects the electric field for smaller heights. It can be noted that the agreement between the measurement (38dB) and the calculation (37.18dB) for height $h_2 = h_1$ published in [3] is rather questionable due to the large distance between antennas.

Fig. 2 illustrates calculations for spherical earth according to expressions [4] by the solid line, [5] by the dash line and [6] by crosses for the wavelength of 0.04348m, antenna height $h_1 = 94.12$m, the distance between the antenna and the observation point $d = 80$kms and effective earth radius $R_e = 8500$km. It is evident that the approximation [5] and the „accurate solution“ [6] (of course, the accuracy of this solution is given by the used numerical method) are in a good agreement. The derivative of approximation [5] is not continuous at the point $v = 0$ ($h_2 = 94.12$m) and therefore there is the change of a slope. This change is not so important. Approximation [4] is rather worse. Similar conclusions are valid for various examples. Therefore the selection of approximation ([4] or [5]) is not unambiguous. For the program described in [1], the approximation [5] has been chosen.

Calculations of attenuation $A$ for spherical earth with the wavelength of 0.04348m, $d = 40$kms, $h_1 = 23.53$m and $R_e = 8500$km are shown in Fig. 3. The resulting attenuation $A[dB]$ calculated according to [1, Eq. (12)] is depicted by the solid line and calculations of $A_{IL}$ according to [5], see [1, Eq. (8)], are shown by circles. For the small antenna height $h_1$ and the observation point heights $h_2$, it is not possible to use [1, Eq. (8)]. In this case, the infinite series [6] can be approximated by the calculations of $A_{IL}$ according to [1, Eq. (9)]. The results are shown by the dash line for $h_2 < 20$m. For a transient zone between the lower and higher altitudes ($50$m $< h_2 < 65$m), the calculations of $A_s$ using [1, Eq. (12)] are shown by the dot and dash line. The infinite series calculations using the program [6] are given by crosses. It can be seen that the modification of solution in transient zone using expression (12) is a proper approximation. Similarly, the calculations of $A_{IL}$ according to [1, Eq. (8)] and the calculations of $A_{IL}$ according to [1, Eq. (9)] for small antenna heights agree quite well.

Fig. 3. Calculations of resulting attenuation $A$ according to [1, Eq.(12)] are shown by the solid line, calculations [5] are given by crosses, the dash line gives the calculations $A_{IL}$ according to [1, Eq. (9)], $A_{IL}$ according to [1, Eq. (8)] are shown by circles and $A_s$ using [1, Eq. (12)] are shown by the dot and dash line. The wavelength of $0.04348$m, $d = 40$kms, $h_1 = 23.53$m and $R_e = 8500$km.

Approximation [1, Eq. (9)] assumes that antenna height $h_1$ is very small. If this condition is not fulfilled and the expressions [5], see [1, Eq. (8)], cannot be used, the approximation according to [1, Eq. (10)] can be used. This case is analyzed in Fig. 4. The wavelength is 0.03162$m$, $h_1 = 70$m, $d = 42$kms and $R_e = 8500$km. Calculations of resulting attenuation $A$ according to [1, Eq. (12)] are shown by the solid line, calculations [6] are given by crosses, the dash line gives the calculations $A_{IL}$.
according to [1, Eq. (10)]. $A_{II}$ according to [1, Eq. (8)] are shown by circles and $A_I$ using [1, Eq. (12)] is shown by the dot and dash line.

It can be seen that the transition between [1, Eq. (8)] and the integration over irregular terrain (for $h_2 = 21$m) is continuous due to [1, Eq. (12)] but it is not smooth at all. This is caused by various calculation methods. Of course, it would be possible to smooth the transition but this problem cannot be solved generally. Fig. 3 illustrates the same problem even if that is not so important. The modification of the expression [1, (9)] by the relationship [1, (10)] is not optimum but that is rather exception. This modification is only used for great heights $h_1$ and small $h_2$ as for greater $h_2$ the expression [1, (8)] is used.

Calculations using reflections from infinity plane earth, given by

$$A[\text{dB}] = 20 \log(2 \pi h_1 \frac{\sin \theta}{\lambda})$$  \hspace{1cm} (1)

where $\theta$ is the elevation angle of the observation point $P$, are shown by the dash line for comparison. That can be used for greater heights because the reflection points approach the antenna for greater heights where the curvature can be neglected.

3. Conclusions

The computer model and computation accuracy for propagation over irregular terrain are presented in [1]. Special attention is paid to computation for low altitude propagation and the finite distance between an antenna and an observation point as the higher altitude propagation is considered in [2] where the propagation for flat surfaces, spherical earth and sharp edges is calculated and compared with the published solutions.

Computation results obtained by the described program agree quite well with the calculations of special cases such as two obstacles with the sharp edges or the spherical earth when the computations have been compared with calculations [6] or with calculations using reflections from the infinity plane earth. This demonstrates the usefulness of a given method.

Some problems arise for the transient zone. The transition between the integration over irregular terrain and low altitude propagation is continuous due to
expression [1, (12)] but it is not smooth. This is caused by various calculation methods. Of course, it would be possible to smooth the transition but this problem cannot be solved generally.

The modification of the expression [1, (9)] by the relationship [1, (10)] is not optimum but that is rather exception. This modification is only used for great heights $h_1$ and small $h_2$ as for greater $h_2$ the expression [1, (8)] is used.

References


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Vladimír SCHEJBAL was born in Hradec Králové, Czech Republic on January 1, 1941. He graduated in electrical engineering from Czech Technical University, Prague, in 1970. He received the Ph.D. degree in electrical engineering from the Slovak Academy of Science, Bratislava, in 1980. He was with Tesla UVR Opočin since 1969 until 1993. He is currently at University of Pardubice. His research interests include computational methods and measurement in control and electromagnetics, especially microwave antennas and propagation.

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