VEGETATION EFFECTS MODELING FOR TERRESTRIAL BROADBAND RADIO ACCESS SYSTEMS OPERATING IN MILLIMETER WAVEBAND

Petr Lédl, Pavel Pechač, Miloš Mazánek
Czech Technical University in Prague, Department of Electromagnetic Field
Technická 2, 166 27, Praha 6, Czech Republic
E-mail: xledl@feld.cvut.cz

1. Introduction

Modern wireless distribution systems operating in millimeter waveband have become more and more popular in today's world; exact models evaluating signal attenuation are required. As overall signal attenuation is a result of signal interaction with different types of obstacles, more than one model is needed to predict signal attenuation with high accuracy. Moreover, because some obstacles are not static in a real environment, dynamic effects (especially in millimeter waveband) has to be considered as well. Modeling of dynamic vegetation effects on a received signal level for broadband radio access networks is a topic of this paper.

Since the blocking by trees can severely limit service availability in a given location, it is very important to evaluate the attenuation caused by the trees. This additional attenuation over the line-of-site free space loss has to be compensated by an increased power margin. In some cases, even if the sufficient mean power is obtained at the receiver, the desired quality of service is not obtained because of deep fades in the received signal [3]. The deep fades are caused by the movement of the tree in a windy environment. Since there is not enough power margin available in the millimeter waveband to protect the system (each even small power increase requires large investments into technology), it is desirable to evaluate all propagation effects as accurate as possible.

Various approaches and field tests results were previously published in the literature in order to evaluate path loss in vegetation environment [1] and [3], fades statistics [2], as well as dynamic effects [3] and [4]. In [3] a tree is modeled as a set of scattering components randomly positioned along a line tangential to the path. Time variability is obtained with sinusoidal movement of the scatterer. A new approach based on 3D-lattice is introduced in this paper. 3D-lattice could be of an arbitrary shape and density in order to sufficiently match behavior of different types of trees in different environments. Simulation results performed in 38 GHz band are presented.

2. New tree model

Tree, bush, or an arbitrary vegetation object is modeled as a 3D-lattice in our approach. Spherical and cylindrical shapes are presented in this paper (Fig. 1 and 2). Only randomly

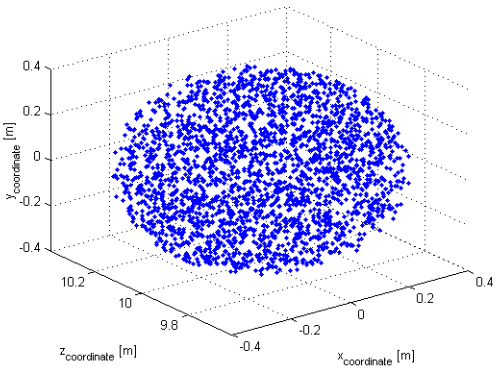

Fig. 1 Spherical 3-D lattice

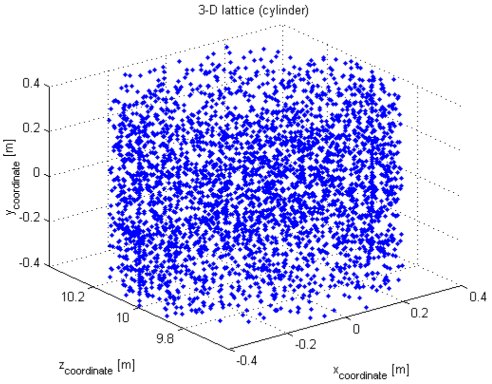

Fig. 2 Cylindrical 3-D lattice

selected nodes are displayed. Based on a decision algorithm each node of the 3-D lattice could become a secondary elementary source. The decision is a result of a random process directed by uniform probability density function. Other statistical distributions are under the investigation. The random decision process and the radiation pattern of each secondary elementary source could be arbitrary in order to follow the behavior of the vegetation object. In our simulations the radiation patterns were omnidirectional.

Primary source illuminating the 3-D lattice is located in such a way that the tree shadows a part of the receiving plane. Origin of the coordinate system is placed in the primary source location. The receiving plane is parallel to *xy* plane, and the receiver trajectory is located in *xz* plane. The situation is shown in Fig. 3.

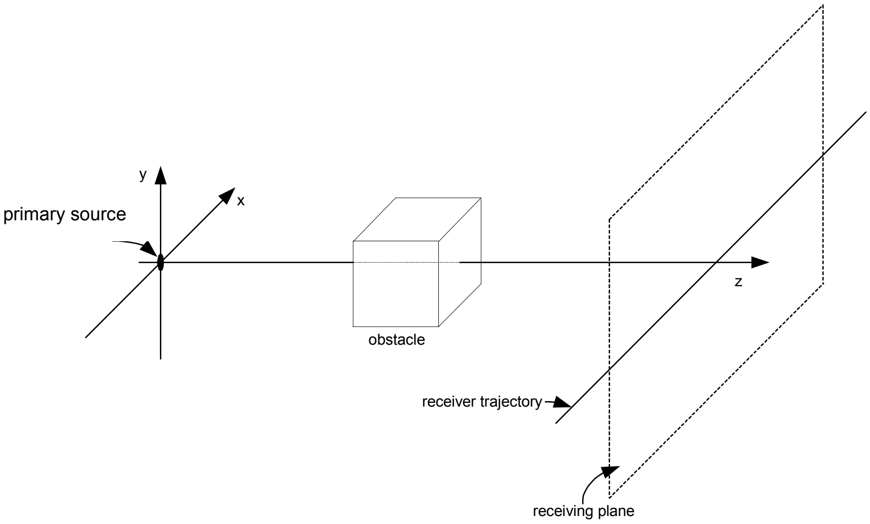

Fig. 3 Geometry of the simulation

Primary point source located in the origin of coordinate system is emitting a spherical wave towards the obstacle. At the receiving point the total received field is composed of contributions from all secondary elementary sources (scattered field) plus, in the not shadowed part of the receiving plane, a direct field from primary source. The total field at the point of the receiver is then obtained (considering a spherical wave) as

$$E_{total} = E_{dir} + E_{scattered} = \frac{E_{tx}}{r} e^{-jkr} + \sum_i \frac{E_i \alpha_i}{d_i} e^{-j(kd_i + \varphi_{0i} + \varphi_{ri})}, \tag{1}$$

where E_{tx} represents the amplitude of the transmitted field, r is the distance between the primary source and the receiver, E_i is the amplitude of the field transmitted from a secondary elementary source, α_l is a random attenuation factor, d_i is the distance between a secondary elementary source and the receiver, φ_{0i} is an initial phase, φ_{ri} is a random phase component, and k is the wave number.

The mean field modeling in the shadowed area is controlled by the parameters defining the generation of random attenuation factor. Dynamic effects of the obstacle are not modeled by movement of the scatterers as in [3], but by the combination of the movement of hypothetical receiver and changes in the random phase component in (1). The depth of fades is controlled by assigning significant amplitude to some of the secondary elementary sources. The speed of the receiver movement and an allowed range of changes of the random phase component then optimize the fading frequency and average duration of fades.

This simple model has enough flexibility to be able to simulate attenuation of different obstacles as well as their dynamic effects. The parameters defining the model (expressed in (1)) should be derived from a measurement of large number of different obstacles. After the definition of desired parameters, necessary power margins for different obstacles under different conditions can be evaluated. This is the task of the research study in the nearest future. Additionally, other shapes of 3-D lattice generated using fractal structures are also under the investigation.

3. Simulations

Using the presented model simple simulations in 38 GHz band were performed. The distance from the source to the receiver plane was chosen to be 20 m. The obstacle was situated in the middle of the transmitter and the receiver separation. The obstacle was of the cylindrical shape with the diameter of approximately 1 m. The signal received by the receiver moving along the receiver trajectory (Fig. 3) is displayed in Fig. 4. Relative field strength with respect to the LOS free space loss is shown.

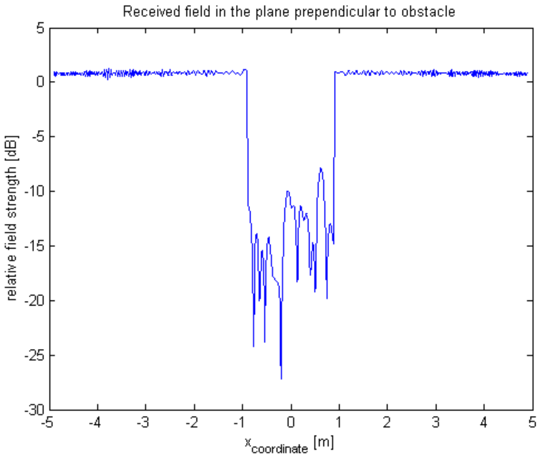

Fig. 4 Received field strength (38 GHz)

Dynamic effects of the obstacle were simulated as well. Results for different wind speeds are shown in Fig. 5, 6, 7, and 8. In Fig. 5 the signal received by the receiver located on *x* axis (Fig. 3) is plotted. High wind speed was assumed here. Statistical distribution of the received signal is shown in Fig. 6. The Rayleigh statistical distribution of the received signal was expected when the speed of the wind was high. Rayleigh probability plot of the received signal confirmed the expectations. When the wind speed is assumed to be low compared to the previous case, the result is in Fig. 7. Statistical distribution of the received signal is displayed in Fig. 8. One can see that the distribution is close to the Rician one in this case.

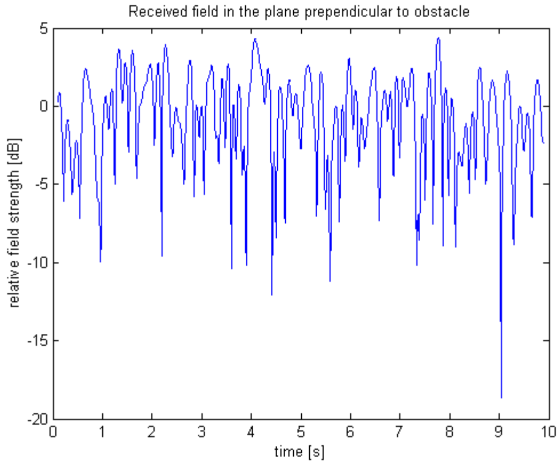

Fig. 5 Received signal strength (high wind speed)

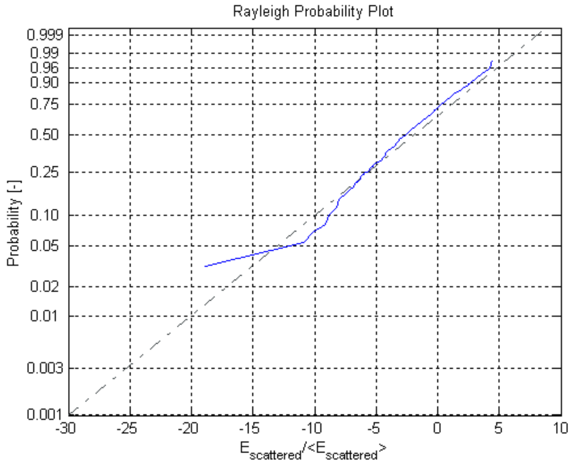

Fig. 6 Rayleigh probability plot of the received signal (high wind speed)

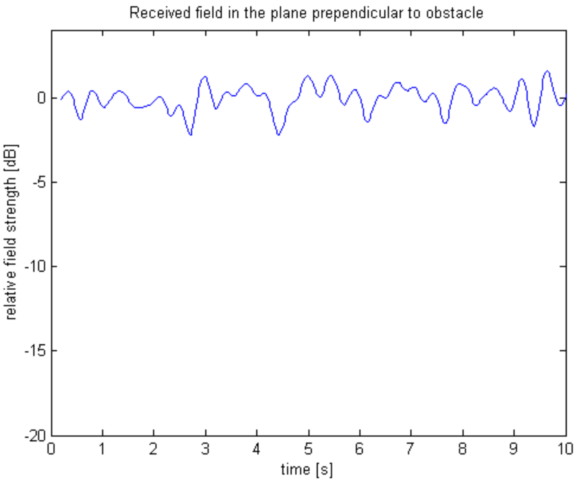

Fig. 7 Received signal strength (low wind speed)

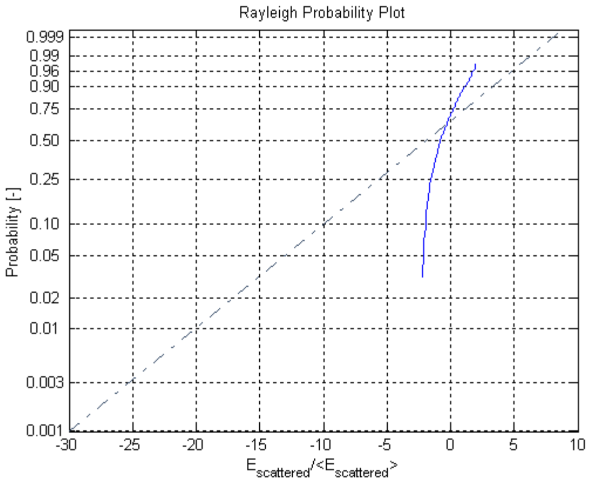

Fig. 8 Rayleigh probability plot of the received signal (low wind speed)

4. Conclusion

A new model based on a 3-D lattice to evaluate vegetation effects was introduced for broadband wireless distribution systems. The field strength of the received signal as well as dynamic effects caused by the tree could be easily modeled. Properties of the new model enable to predict the behavior of different types of obstacles under different conditions and in different environments. Dynamic effects were interpreted by defining the statistical distributions that describe the received signal. Evaluation of the model by measurement of different types of obstacles is the actual target of our research study as well as the investigation of fractal approach to the 3-D lattice generation.

5. References

[1] S. A. Torrico, H. L. Bertoni, R. H. Lang, *Modeling Tree Effects on Path Loss in a Residental Environment,* IEEE Transactions on Antennas and Propagation, vol. 46, No. 6, June 1998.

[2] J. Goldhirsh, W. J. Vogel, *Mobile Satelite System Fade Statistics for Shadowing and Multipath from Roadside Trees at UHF and L-Band,* IEEE Transactions on Antennas and Propagation, vol. 37, No. 4, April 1989.

[3] ITU-R P.1410 - *Propagation Data and Prediction Methods Required for Design of Terrestrial Broadband Millimetric Radio Access Systems Operating in a Frequency Range about 20-50 GHz,* ITU, Geneva, 2000.

[4] A. H. Lagrone, C. W. Chapman, *Some Propagation Characteristics of High UHF Signals in the Immediate Vicinty of Trees*, IEEE Transactions on Antennas and Propagation, vol. 9, pp. 487-491, September 1989.

[5] F. M. Cátedra, J. Peréz-Arriaga, *Cell Planning for Wireless Communications*, Artech House, 1999.

6. Acknowledgement

This work has been supported by the GAČR grant No. 102/01/0029 “Performance and Reliability of Advanced Telecommunication Systems Using Millimeter Wavelengths in the Czech Republic” and by the program “Research in the Area of Information Technologies and Communications” J04/98: 212300014.