A MULTIPLE-BUILDING DIFFRACTION ATTENUATION FUNCTION EXPRESSED IN TERMS OF UTD COEFFICIENTS FOR MICROCELLULAR COMMUNICATIONS

José-Víctor Rodríguez, José-María Molina-García-Pardo, and Leandro Juan-Llácer
Departamento de Tecnologías de la Información y las Comunicaciones
Universidad Politécnica de Cartagena
Campus Muralla del Mar s/n
30202 Cartagena (Murcia), Spain

Received 18 July 2003

ABSTRACT: *This work presents an explicit formulation for multiple-edge diffraction for mobile radiowave propagation in terms of uniform theory of diffraction (UTD) coefficients when a spherical incident wave is considered. This solution can be used in an UTD context and sharply reduces the computing time over existing formulation. Results can be applied in the planning of microcellular systems.* © 2004 Wiley Periodicals, Inc. Microwave Opt Technol Lett 40: 298–300, 2004; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.11359

Key words: *microcellular mobile radio systems; radiowave propagation; UTD; multiple diffraction*

INTRODUCTION

The analysis of radiowave diffraction over multiple buildings has been used to propound theoretical models in order to predict the propagation of VHF/UHF signals in microcellular urban environ-

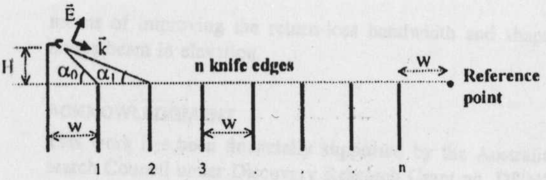

Figure 1 Idealized representation of an urban environment

ments, such that the results coincide accurately with the measurements [1].

For elevated antennas, plane-wave incidence approximations have been achieved to define theoretical models based on physical optics (PO) [2, 3] or on the uniform theory of diffraction (UTD) [4, 5], which forecast propagation path losses due to this multiple building diffraction.

For low antennas that may be near or below the rooftops of surrounding buildings, it has been shown in [1] that the PO-based solution for cylindrical wave incidence suggested in [6] is more appropriate than the plane-wave incidence approximation to develop theoretical models in this case. This solution expresses the attenuation function via Boersma's functions and, provided that the convergence of these series depends on the frequency, interbuilding spacing, source height, and number of buildings [6], a long computation time may be required to obtain it. For low antennas below or level with the rooftops, an approximation for the attenuation function is propounded in [7] that makes use of a larger number of computations and comparisons with existing formulations and defines a hybrid function which takes advantage of UTD and PO.

In this paper, a multiple building diffraction attenuation function for the low-antenna case (slightly above, level with, or below the average building height) expressed in terms of UTD-diffraction coefficients that consider spherical-wave incidence is presented. This new solution uses the summations of finite terms to satisfy a recursion relation, and its major advantage over that in [6] is the significant reduction in the computing time. In addition, the UTD approach outlined in this paper can be a step towards the analysis of multiple-wedge diffraction with different interior angles. Finally, results can be efficiently applied in a UTD context to both area coverage and interference predictions in the planning of cellular systems.

PROPAGATION ENVIRONMENT

A scheme of the propagation environment considered is shown in Figure 1, where buildings have been modeled as *n* parallel absorbing half-screens (knife edges) with the same height relative to the base station antenna height *H*, and separated by a constant distance *w*. The source point is at an arbitrary height (above, level with, or below the constant average edge height) and located at the same abovementioned distance *w* from the screens.

Propagation path loss consists of three factors: free-space loss, multiscreen diffraction loss, and the effect of diffraction of the rooftops fields down to ground level. In this work, a solution for multiscreen diffraction loss over a series of knife edges for spherical-wave incidence is presented.

THEORETICAL MODEL

Using a straightforward technique based on the final solution for the attenuation function for multiple knife edges given in [5], where an incident plane wave is considered, a new solution in terms of UTD coefficients considering spherical-wave incidence is

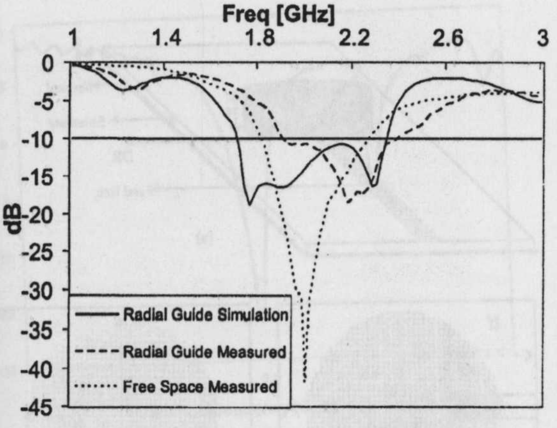

Figure 8 S_{11} parameters of the radial guide with dielectric taper

of supporting the upper ground plane, extensive investigations on it were abandoned.

In order to achieve a radiation pattern with a good gain and return-loss bandwidth, a guide-to-free-space transition with a large enough T_l, $\theta > 0°$, and low dielectric permittivity was decided upon. Figure 7 shows the relative gain of the radiation pattern when the ground-plane radius is 100 mm, the transition parameters are $T_l = 60$ mm and $\theta = 10°$, and the platform width is $T_{pl} =$ 3 mm.

In Figure 7(a), the pattern in the azimuth is pointing at the expected direction and the simulated gain is 3 dB. Both the measured and simulation results are similar to each other, with the measured result showing a slightly higher side-lobe level. The elevation pattern, shown in Figure 7(b), contains both the measured and simulation results. From the simulation, a gain of around 8 dB is observed. This gain is slightly lower than that of the antenna array without the upper ground plane, which was 9.5 dB for the top-hat monopoles in a circular array. As in the azimuth pattern, the measured and simulation results are close to each other. One discrepancy between the two results is the maximum gain direction of the pattern. The simulation result's maximum gain is seen when the beam squint off the ground plane is around 75°. The measured maximum gain is at 45° beam squint off the ground plane.

The return-loss parameters of the array using the above parameters are shown in Figure 8. The observed 10-dB return-loss bandwidth of this array is 0.65 GHz for the simulation result and 0.5 GHz for the measured result. These results compare favorably with the 0.4-GHz bandwidth obtained for the same array without the upper ground plane.

The discrepancies observed between the simulated and measured results may be due to various reasons, such as manufacturing tolerances. Another source of the observed discrepancies may be due to the use of coaxial connectors in the experimental part. Using FEKO, an active monopole was simulated assuming an excitation of a segment adjacent to the ground plane.

5. CONCLUSION

It has been demonstrated that housing a switched-beam circular array of monopoles in a radial guide with a suitable guide-to-free-space transition offers more degrees of freedom in its design. By having the central element active and the remaining monopoles being open or short-circuited, the array is able to steer the beam in the azimuth. The use of a guide-to-free-space transition provides means of improving the return-loss bandwidth and shaping the arrays beam in elevation.

ACKNOWLEDGMENT

This work has been financially supported by the Australian Research Council under Discovery Research Grant no. DP0450118.

REFERENCES

1. R. Kronberger, H. Lindenmeier, L. Reiter, and J. Hopf, Design method for array antennas on cars with electronically short elements under incorporation of the radiation properties of the car body, IEEE Antennas Propagat Symp Dig 1 (1997), 418–421.
2. M. Daginnus, R. Kronberger, and A. Stephan, Ground plane effects on the performance of SDARS antennas, IEEE Antennas Propagat Symp Dig 4 (2002), 748–751.
3. K. Yang and T. Ohira, Single-port electronically steerable passive array radiator antenna based space-time adaptive filtering, IEEE Antennas Propagat Symp Dig 4 (2001), 14–17.
4. J. Lu et al., Multi-beam switched parasitic antenna embedded in dielectric for wireless communications systems, Electron Lett 37 (2001), 871–872.
5. N. Scott, M. Leonard-Taylor, and R. Vaughan, Diversity gain from a single-port adaptive antenna using switched parasitic elements illustrated with a wire and monopole prototype, IEEE Trans Antennas Propagat 47 (1999), 1066–1070.
6. R. Islam and R. Adve, Beam-forming by mutual coupling effects of parasitic elements in antenna arrays, IEEE Int Antennas Propagat Digest, San Antonio, TX 1 (2002), 126–129.
7. J. Janapsatya and M.E. Bialkowski, Analysis of an array of monopoles with the use of a radial waveguide approach, Microwave Opt Technol Lett 34 (2002), 235–240.
8. J. Janapsatya and M.E. Bialkowski, Fine beam steering for a monopole smart antenna system in a circular array configuration, IEEE Int Antennas Propagat Digest, Columbus, OH 3 (2003), 888–891.
9. FEKO: Comprehensive EM solutions, http://www.feko.co.za.