Effects of Diffraction and Ground Reflection on Ray-Tracing-Based Coverage Predictions in Urban Microcellular Environments

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Abstract—**Two-and-one-half dimensional ray tracing models, in combination with the uniform theory of diffraction and geometrical optics, are widely employed for propagation prediction in urban microcellular environments because of their high efficiency and reliable prediction accuracy. In this study, an improved ray tracing algorithm based on the "orientation face set" concept and on the improved 2D polar sweep algorithm is used. The aim of this paper is mainly to analyze the effects of different propagation mechanisms on ray-tracing-based coverage predictions in urban microcellular environments. In addition, the effects associated with the coverage prediction are visually represented.**

Keywords—coverage prediction; diffraction; reflection; ray tracing; urban microcellular environment[1]

I. INTRODUCTION

The growing demand for mobile communications, specially in urban areas, leads toward the adoption of the microcellular concept. It is then desirable to perform accurate coverage predictions in micro- and pico-cells to minimize on-site measurements [1]. The deterministic propagation models, which are principally based on numerical methods such as the ray tracing method and the finite-difference time-domain method [2], are developed and widely adopted. Ray tracing techniques as a site-specific prediction model can accurately predict the amplitude, delay, and direction of arrival of multipath echoes created by the propagation environment [3]. Ray tracing techniques are widely adopted, and their reliability and flexibility have been proven in urban environments [4–6]. Under urban microcellular environments, both transmitter and receiver are well below the rooftops [7]. In these environments propagation mechanisms may include direct, reflected, diffracted, and some combined rays. Therefore, it's very necessary to analyze the effects of different propagation mechanisms on ray-tracing-based coverage predictions. For this purpose, this study focused on analyzing the influence of diffraction and ground reflection on ray-tracing-based coverage predictions of path loss over a large area.

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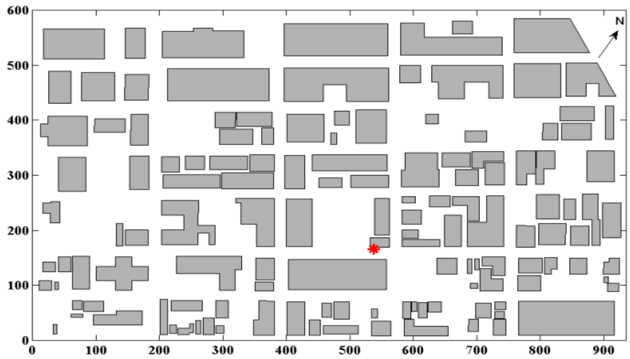

Fig. 1. Plan view of Ottawa city core with one transmitter (marked by asterisks).

II. RAY-TRACING-BASED MODEL

In this study, an improved ray tracing algorithm based on the "orientation face set" concept and on the improved 2D polar sweep algorithm is used. The used ray tracing model is proposed and validated in [8]. The model is a hybrid approach, wherein the object database is held in 2D, but 3D rays are produced by combining the results of the 2D ray tracers. This model considers the following ray paths: direct rays as line-of-sight, ray paths with an arbitrary number of reflections on vertical walls, ray paths with an arbitrary number of diffractions on vertical edges, all combinations of reflections on vertical walls and diffractions on vertical edges, and all ray paths mentioned above, including one additional reflection on the ground.

III. SIMULATION RESULTS AND ANALYSIS

To analyze the effects of diffraction and ground reflection on ray-tracing-based coverage predictions, a practical case study is investigated in this section. As illustrated in Fig. 1, the core of Ottawa, Canada [9], is represented. The transmitter has a carrier frequency of 910 MHz at a height of 8.5 m, while the receiver is 3.65 m high. Both the transmitter and receiver are half-wavelength vertically polarized dipoles. The locations of

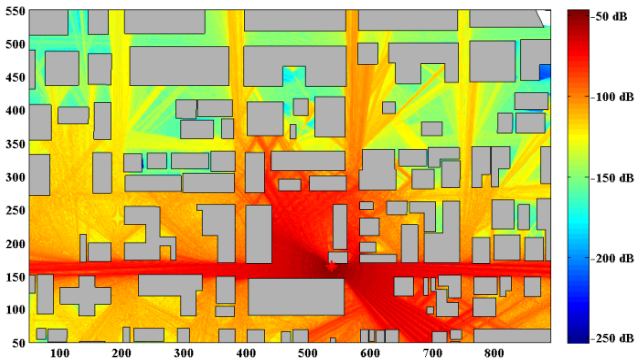

Fig.2. Path loss map

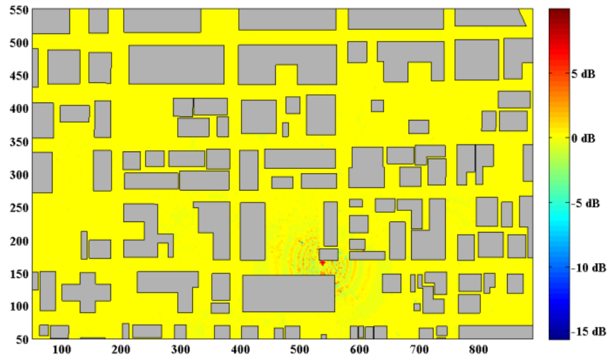

Fig. 3. Differences in path loss based on non-ground-reflection ray tracing model

receiver are uniformly distributed with a separation of 1 m between neighboring locations (243,695 test points). In our calculations, the values of relative permittivity and conductivity are 9, 0.1 S/m for buildings and 15, 7 S/m for the ground, respectively. These parameters can practically characterize the urban environment (Fig. 1) and are validated in [8].

When the limit number is 7, a satisfying prediction accuracy can be achieved for the ray tracing model [2] and, consequently, the corresponding prediction results (See Fig. 2) serve as the reference predictions below in this section. In the model, the following phenomena are taken into account: the direct line-of-sight ray when it exists, up to seven reflections, up to two diffractions or all possible combinations of up to six reflections, and a single diffraction per path. The aforementioned single reflection or multiple reflections may include one ground reflection or not.

In order to clarify the influence of ground reflection on ray-tracing-based predictions, the differences in path loss map are represented in Fig. 3. To obtain the differences, the path losses based on non-ground-reflection ray tracing model need to be minus by the reference predictions. The mean error and standard deviation of the differences are -0.0084 dB and 0.2498 dB, respectively. There is a obvious influence caused by ground reflection in a small area of a 100-meter radius around the location of transmitter. In other areas (especially in deep shadow region), the ground reflections can be neglected.

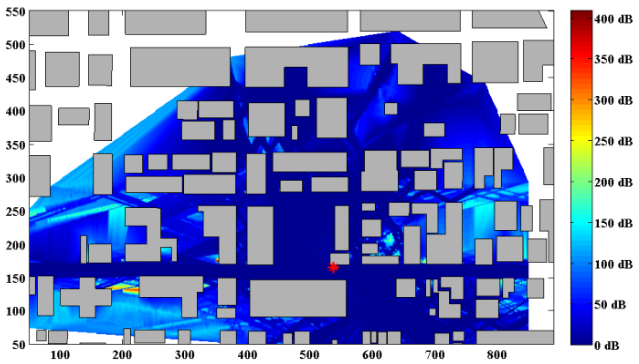

Fig.4. Differences in path loss based on non-diffraction ray tracing model.

The differences between path loss using non-diffraction ray tracing model and the reference predictions is shown in Fig. 4. The mean error and standard deviation of the differences are -21.52 dB and 38.58 dB, respectively. According to Fig. 4, the diffractions can be neglected in some areas where the direct rays and low-order reflected rays could arrive. However, the diffractions have to be considered in deep shadow region and some areas where the high-order reflected rays could arrive.

IV. Conclusion

In this study, an improved ray tracing model based on several acceleration techniques for point-to-area prediction is employed to analyze the laws associated with the coverage prediction. Simulation results can indicate the main radio propagation in urban microcellular environments. The diffractions can be neglected in some areas where the direct rays and low-order reflected rays could arrive. However, in deep shadow region diffraction is an essential propagation mechanism, and ground reflection should be neglected. Hence, the kinds of propagation mechanism should be distinguished in different radio propagation area. Future work will be concentrated on the further acceleration of ray-tracing-based microcellular coverage predictions.

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