A Building-Transmission Model for Improved Propagation Prediction in Urban Microcells

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***Abstract*—This paper presents a model for the propagation of radiowaves through buildings. The model can be used as a seamless extension to ray-based propagation prediction models that only consider external reflection and diffraction, as do most current models. This involves the use of so-called transmitted rays, which are traced through building walls. Outdoor-to-indoor propagation (building penetration) is automatically taken into account as a "by-product." The transmission model requires no information about each building's interior other than a specific attenuation factor that describes the global behavior of the field inside the building. This coefficient can be determined for individual buildings by measuring the excess loss associated with the propagation path through the building. It is shown, however, that no large errors are to be expected if all buildings are characterized by the average of the empirical values obtained in this study, at 1.9 GHz. Path loss predictions generated with the aid of the new model are shown and compared with measured data to illustrate the considerable improvement in accuracy that can be achieved in realistic urban microcell scenarios by taking into account building penetration and transmission.**

***Index Terms*—Building penetration and transmission, mobile communication, radio propagation, urban microcells.**

I. INTRODUCTION

WITH the advent of microcellular radio networks likely to be employed in third-generation mobile communication systems, there is an increased interest in propagation models that are able to provide location-specific predictions of channel parameters such as local mean power and delay spread. Ray-based propagation prediction, in which the propagation of radiowaves is described in terms of straight trajectories in space called rays, has emerged as the most successful technique for this purpose. Quasi-two-dimensional ray-based models (often simply called two-dimensional or 2-D models) are quite adequate if transmit and receive heights are well below the average rooftop level [1], [2], as is normally the case in urban microcells. These models have been reported to provide excellent prediction results for a variety of urban scenarios. In many other cases, however, these models do not provide the same accuracy that can presently be achieved for macrocells.

Although currently available ray-tracing tools vary widely with regard to the implementation of the ray-tracing algorithm itself, they are generally based on models of the same propagation mechanisms: line-of-sight (LoS) propagation, reflection, and diffraction. In a number of frequently occurring scenarios, these mechanisms alone do not adequately explain the channel properties actually observed. In particular, scattering from trees located near street intersections can play an important role with regard to propagation around street corners [3], [4] and, as will be shown in this paper, transmission of radiowaves through buildings is often significant behind buildings obstructing the LoS to the base station antenna [5], [6].

Propagation research for mobile communications in urban microcells has hitherto been focused mainly on the modeling of reflection and diffraction from the exterior walls and corners of buildings. These buildings are usually treated as being opaque at frequencies used for terrestrial mobile communications. There does exist a limited amount of published material on outdoor-to-indoor propagation [7]–[12] and propagation through buildings [13], [14], but at present no building-transmission models are available that can be readily incorporated in ray-based propagation prediction tools.

Rigorous computation of the effects of propagation into, within, and through buildings, using, e.g., the method of moments [15], finite-difference time domain (FDTD) methods [16], [17], or indoor ray-tracing [18], [19] is generally much too complex in the context of cellular network planning. Also, it presumes the availability of detailed knowledge of the buildings' geometrical and dielectric properties, both external and internal. In the practice of cell planning, such information is not available. In fact, in order for a building-transmission model to be of practical value, it should be simple and require only a minimum of information about the buildings.

This paper presents a building-transmission model that requires each building's exterior coordinates and dielectric permittivity, as well as one additional coefficient that characterizes the attenuation in the building interior. This coefficient α_b can be determined for individual buildings by measuring the excess loss associated with the propagation path through the building. However, as will be shown later in this paper, no large errors are to be expected if all buildings are characterized by the same average value ($\alpha_b = 2.1\ \mathrm{dB/m}$ at 1.9 GHz). As the new model finds its application in propagation prediction for urban microcell environments, it is kept quasi-two-dimensional. This means that it will be assumed that the reception point and the source

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