Chapter 12
A Generic Method for the Reliable Calculation of Large-Scale Fading in an Obstacle-Dense Propagation Environment

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ABSTRACT

The aim of this chapter is to summarize and present recent findings in the field of wireless channel modeling that provide a new method for the reliable calculation of the statistical parameters of large-scale variations of the average received signal (shadow fading). This algorithm is theoretically based on a path loss estimation model that incorporates losses due to walls and floors. This has been confirmed to be the most precise mathematical tool for average signal strength prediction for various frequencies of interest and propagation environments. The total path loss is estimated as a sum of two independent attenuation processes: free space loss and losses due to obstacles. This solution allows for a direct and reliable calculation of the deviation of the fluctuations of the average received signal in an obstacle-dense environment.

BACKGROUND

Information propagated over a wireless channel as an electromagnetic wave is subject to large-scale attenuation (path loss) due to free space loss and losses caused by interfering objects of various size, type and number. Large-scale attenuation can be calculated with path loss models (mostly logarithmic) which have been developed either theoretically (deterministic models) or based on experimental measurements (empirical models). In order to provide reliable predictions of the aver-

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age received power. The accuracy of the path loss models is of critical importance with regard to the design and implementation of wireless systems (Goldsmith, 2005).

When physical obstacles, whose dimensions are significantly larger than the wavelength of the transmitted signal, obstruct radio propagation, then the attenuation effect is known as shadowing (Rappaport, 1999). In such cases, the fluctuation of the average received signal strength can be approximated via statistical models (distributions). Shadowing occurs over a time period of minutes or hours, depending on the mobility of the obstacle and the transmitting and receiving antennas. Experimental work has confirmed that the fluctuations of the local mean strength of the received signal follow the *log-normal* distribution (Jakes, 1973).

Moreover, the transmitted Radio Frequency (RF) signal suffers small-scale attenuation (fading) over a period of milliseconds (ms) due to multipath propagation and, conditionally, Doppler spread (Parsons, 2000). Additional statistical models have been developed to describe fading phenomena (i.e. Rayleigh, Rice, Nakagami-m).

The adequate description and mathematical expression of all large-scale and small-scale variations of the received signal for a given propagation topology formulate the field of Wireless Channel Characterization.

WIRELESS CHANNEL CHARACTERIZATION: OPEN ISSUES

Many published works have raised the issue of path loss modeling in an outdoor propagation environment for the GSM/UMTS frequencies (Lee & Miller, 1998; Seybold, 2005). Various empirical and semi-empirical (deterministic) path loss models have been developed and validated in terms of mean error (%) in their predictions of average received power at any given distance from the transmitter throughout a propagation environment (Parsons, 2000; Rappaport, 1999). Intrinsic topology characteristics have been incorporated in the mathematical expressions of these models and various extensions of these models have been provided in terms of distance coverage and carrier frequency shifting (Iskander, Yun, & Zhang, 2001).

Over the years, many published works have dealt with finding the appropriate small-scale fading distribution to describe an indoor propagation topology (Cheung, Sau, & Murch, 1998; Henderson, Durkin, & Durkin, 2008; MacLeod, Loadman, & Chen, 2005; Walker, Zepernick, & Wysocki, 1998). However, there was not, until recently, a comparative validation of indoor path loss models for the estimation of the large-scale attenuation of an RF signal propagated in an indoor environment. Even more so, there had been no validation of path loss modeling for the 2.4 GHz frequency, which holds a dominant role in indoor wireless networks (802.11b/g/n) and will continue to be of importance as next-generation networks come into the forefront.

In addition, the log-normal shadowing distribution has been examined in terms of obtaining a closed-form expression for the statistical expression of the instantaneous received amplitude. The impact of shadow losses on the prediction reliability of path loss modeling, however, was not investigated any further. As a rule, the calculation of the shadowing deviation (in dB) requires an extensive set of on-site RF measurements that provide a pool of (logarithmic) local mean values out of which the mean value and the shadowing deviation (dB) are derived. In this chapter, however, a novel empirical method will be presented, allowing for the direct calculation of shadowing deviation and therefore the precise