RESULTS OF INDOOR PROPAGATION MEASUREMENT CAMPAIGN AT 1900 MHZ

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Abstract

For the design of indoor picocellular systems in the frequency band of 1800/2100 MHz, a signal propagation modelling is needed. Empirical and semi-empirical models represent an efficient approach to the coverage prediction. For these models, suitable empirical parameters must be provided. The indoor propagation measurement campaign in the frequency range of 1900 MHz was carried out in several multi-floored buildings in Prague and Brno. For the campaign a special portable measurement system was developed. Based on the measurement results, the model parameters were derived. Optimised parameters are presented for two basic models (empirical and semi-empirical) according to the indoor environment classification. The results are compared to standard models as well. Accuracy and validity of derived models are discussed.

Keywords

Measurement, indoor propagation prediction, electromagnetic waves, PCS

1. Introduction

For the design of indoor picocellular systems in the frequency band of 1800/2100 MHz (such as GSM1800, DECT, UMTS), a signal propagation modelling is demanded. Empirical models introduced in [1] and [2] represent an efficient approach to the signal coverage prediction in indoor picocells. For these models, suitable empirical parameters must be provided. There are many studies defining the models (e.g. [3], [4], [5]) but it should not be used for local architecture styles and used materials without any validation. That is why the indoor propagation measurement campaign in the frequency range of 1900 MHz was accomplished in several multi-floored buildings to cover various typical indoor environments. Six buildings were located in Prague and one in the city of Brno.

2. Measurement Campaign

2.1 Locations

For the needs of signal propagation modelling, indoor environments must be classified according to the wave propagation properties. Considering standards defined in [4] and [5] with respect to a practical implementation of the models, four classes were stated:

1. Dense (interiors with many walls and partitions, e.g. offices);
2. Large (halls or very large rooms);
3. Open (open or half-open spaces, e.g. atrium);
4. Corridor (with line-of-sight between transmitter and receiver).

Seven multi-floored buildings, mostly in Prague, were chosen to cover the selected environment classes. The measured data were treated separately according to the classification.

Fig. 1 Portable receiver controlled by PDA computer

2.2 Measurement System

The narrow-band system developed at the Dept. of electromagnetic field in CTU Prague consists of a transmitter, portable receiver and set of measurement antennas.

The receiver was designed as one conversion superhet for frequency band 1850 - 1950 MHz with dynamic range of 60 dB. Full computer control is assured through standard serial interface RS232. To enable mobile measurements, the built-in 12 V accumulator can be used as a power supply. For indoor measurements, the receiver can be carried on user's back using simple straps. Both hands are then free for handling an antenna probe and the PDA computer, which controls the receiver. The arrangement can be seen in Fig. 1.

PalmIIIx with PalmOS operating system was chosen as a control unit for the receiver. User-friendly software was developed under PalmOS operating system to control the receiver and collect the measured data using RS232 connection via short cable. Measured data are collected in a text form as a received power in dBm. After the measurement, the data are transferred to a desktop PC using standard PalmOS synchronisation. Then, another software tool automatically processes the text files. More information can be found in [6].

2.3 Data Processing

The measured data were treated separately for the four indoor environment classes. Measurements from different locations had to be divided so. To handle the data the I-Prop software [7] was used. It enables loading and exporting (after processing) of measured data as well as graphical analysis of signal coverage prediction by the models (Fig. 2) and its further comparisons.

The optimisation described in [1] and [2] was applied to obtain the model parameters for each case. The window averaging was performed to eliminate fast fading (Rayleigh fading).

The data subsets for the optimisation process were selected very carefully with respect to the particular environment of the measurement. The aim was to make the results as general as possible for each environment. The average values of resulting parameters from different locations were finally taken.

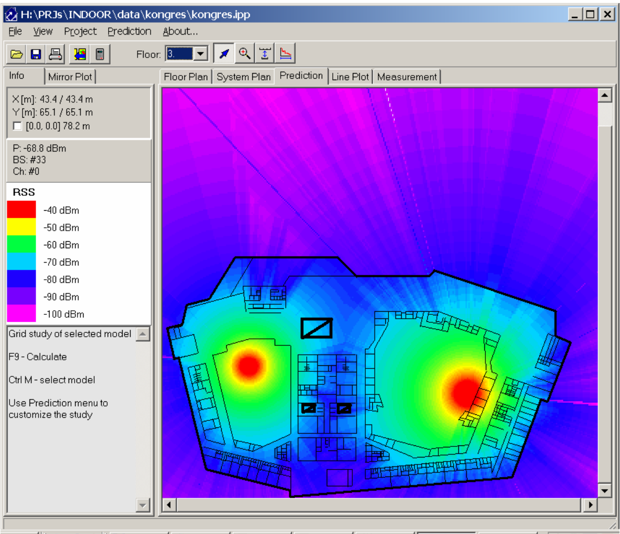

Fig. 2 Graphical analysis using the I-Prop software [7]

3. Results

3.1 Models

Two models from [1], empirical and semi-empirical, were used:

$$L(d) = L_0 + 10n\log d + kF_1 \tag{1}$$

$$L(d) = L_0 + 10n\log d + kF_1 + \sum_{i=1}^{M} A_i \tag{2}$$

where

$L(d)$ is the path loss in the distance d [m] from transmitter [dB];

L_0 is attenuation [dB] in the reference distance 1 m from the transmitter, usually calculated as the free space loss (FSL);

n denotes path-loss exponent;

k is number of floors between transmitter and receiver antennas;

F_1 denotes floor loss factor [dB];

M is number of walls between transmitter and receiver antennas;

A_i is attenuation factor for i-th wall [dB].

Two main types of walls were considered for (2):

1. Light wall;
2. Heavy wall.

3.2 Optimised Parameters

The resulting values of the model parameters for (1) and (2) are given in Tab. 1 and Tab. 2.

Model (1)	***n* [-]**	***F*$_1$ [dB]**
Dense	**4.0**	**7.0 - 13.0**
Large / Open	**2.1**	
Corridor	**1.3**	

Tab. 1 Optimised parameters for empirical model (1); *n*: path-loss exponent, *F*$_1$: floor loss factor.

Model (2)	***n* [-]**	***A*$_1$ [dB]**	***A*$_2$ [dB]**
Dense	**2.8**	**1.5**	**4.0**
Large / Open	**1.9**		
Corridor	**1.3**	**- - -**	

Tab. 2 Optimised parameters for semi-empirical model (2); *n*: path-loss exponent, *A*$_1$: attenuation factor for Light wall, *A*$_2$: Heavy wall, *A*$_3$:External wall.

3.3 Validity of the models

The results form Tab. 1 and Tab. 2 were compared to the One-Slope empirical model [4], the Multi-Wall semi-empirical model [4] and to the ITU-R indoor empirical model [5]. The comparative analysis of model parameters showed agreement within 5 dB for most of the cases. The differences in predictions remain within 12 dB according to particular location and building.

Some of the measurement arrangements pointed out impropriety of using empirical approach for considerable irregularities in building structure or furnishing. It is known disadvantage of empirical models, which is discussed in [2] as well. A typical example is a L-shape corridor. Due to waveguiding effect the signal propagates well around the corner while the empirical prediction strongly underestimate the field strength for non-line-of-sight cases.

In general, the mean error for average signal level value should be expected about 12 dB for prediction using empirical model (1) and about 9 dB using semi-empirical model (2). Naturally, the error can be much larger if there is any significant irregularity in the building structure. The prediction results should be always interpreted with care having the specific indoor environment on mind. Standard deviation for slow fading in order of 10 - 20 dB must be considered as well.

More information on the prediction precision by various models and other modelling approaches can be found in [3].

4. Conclusions

The empirical parameters for indoor propagation models obtained from extensive measurement campaign in the frequency band of 1900 MHz were presented. The derived models proved good efficiency for basic prediction of indoor coverage.

There is another project dealing with signal propagation prediction for wideband services in ISM band of 2.5 GHz (WLAN, Bluetooth). Measurement system for this frequency range is under development. Because empirical models are not suitable for wideband prediction a new semi-deterministic model is being developed [8] [9].

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